THE FISHERIES OF CHINA

By Wei-Ching W. Yen

Second Secretary Imperial Chinese Legation, Washington, D. C.

Address before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

National Oceanic and Atmospheric Administration

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By WEI-CHING W. YEN,
Second Secretary Imperial Chinese Legation, Washington, D. C.

Mr. PRESIDENT, FELLOW-DELEGATES TO THE FOURTH INTERNATIONAL FISHERY CONGRESS: My colleagues and I deem it a great honor to participate in the proceedings of this assembly, and our only regret is that owing to unexpected circumstances two others were prevented from leaving Shanghai, thus reducing by one-third the strength of our delegation. Doctor Smith, the distinguished and learned secretary-general of this congress, has very courteously requested us to address you in a general way on the fisheries of our Empire—for various reasons so little known to the outside world. While it is true our principal object in attending this congress has been to avail ourselves of the opportunity of obtaining information from the distinguished assembly present on all questions pertaining to fisheries, it is also our object to inform the world of the efforts being made in our country to investigate the conditions of our fishing industry, to collect statistics, to study its needs and defects, to introduce new types of vessels and fishing apparatus and methods, and to initiate legislation and regulation—in short, to organize and develop the industry and to place the culture and propagation of fishes on a scientific basis.

The history of fisheries in our country, like that of many other things, is an old one. Our ancient classics refer to the times when our primitive ancestors tied ropes together to form fishing nets, and mention the appointment, several centuries before the Christian era, of special officials to rule over and protect our fishermen. The first statesman that recognized the importance of the fishing industry was Chiang Tzŭ-ya, who lived in the eleventh and twelfth centuries B. C., and who rose to eminence from an humble home on the coast. It is said that this wise and virtuous angler, then 80 years of age, was fishing with a straight piece of iron, upon which the fishes readily allowed themselves to be caught, when the Emperor Wên Wang discovered him, and for twenty years he served his imperial master faithfully and successfully. Through his ardent efforts and wise planning, fishing first became an important industry among our people, and with it also grew up its allied industry, the manufacture of salt, without which the former would have been seriously crippled for want of preservative facilities.

Our most ancient pisciculturist was Tao Chu Kung, who lived in the fifth century B. C. His method of fish culture combined both knowledge and ignorance. He dug a pond of the size of an acre, leaving nine small islands scattered about. In the pond he placed 20 female carps 3 feet in length and 4 male ones of similar size. This was done in the month of March. In March of the following year there were found 5,000 fishes one foot long, 10,000 two feet long, and 15,000 three feet long. In the third year the number had been multiplied ten or twenty times, while in the fourth year it was not possible to keep count. The nine islands were to deceive the fishes, who would believe that they were in the big ocean traveling around the nine continents.

Pisciculture in our country has been confined to fresh water kinds. The fry are fed with the yolk of eggs, with very fine bran, or with beans ground to a powder. When the fish reach the length of a foot or so, they are transferred to a pond, where they are fed with young grass. It is considered advisable not to have the ponds too deep for fear of the water getting too cold for the young fish, and certain plants and trees are grown around and over the pond for various purposes and with various objects. For instance, it is believed that the dew from the plaintain leaves has a medicinal effect on the fishes, the berries of a certain tree are relished by the young fishes as a food, the grape vines which cover the pond prevent birds from polluting the water, and the luxuriant growth of the hibiscus along the edges repels the invasion of beavers. Of course, all these beliefs and theories are not scientific, but are based on tradition and experience.

With the division of the people of the Empire into four distinct classes—scholars, agriculturists, artisans, and merchants—the men and women who followed the trade of fishing for a livelihood were placed in an anomalous position, in that they were not included in any of the four classes. Thus socially ostracised to a certain extent, they clung more and more to themselves, forming groups and colonies of their own along the coasts and on isolated and rocky islands. They lived in a world of their own, knowing nothing of the affairs of their country and caring less. To this day they do not come into direct contact with their countrymen on the mainland or in the interior, disposing of their catches of fish to fishmongers, who go out to them during the fishing season with silver or with the necessaries of life in exchange for the fishes.

Throughout our history the importance of the fishing industry has been dwarfed by its allied industry, the manufacture of salt, which, having been transformed into a government monopoly, has engrossed the attention of the official and merchant classes.

In discussing the fisheries of our country attention must be called to the difference in taste between our people and those of the West. In the first place, our epicures do not care much for deep-sea fishes, and a fish like the salmon would not at all appeal to our palates. We delight in eating those of the finny

tribes whose meat is soft and fine, and they are to be caught in rivers, brooks, lakes, ponds, and the surface of the ocean. Another factor which has checked the development of deep-sea fishing has been the lack of rapid transportation facilities and of refrigerative means, necessitating the preservation of deep-sea fishes in salt before they could be sent inland. On the other hand, there are products of the sea which are regarded by us as delicacies of the table, but which have little or no consumption in the West. Just to mention a few well-known ones, the fins of the shark, the bêche-de-mer, the cuttlefish, the jellyfish, the scallop, and the awabe form important articles of domestic commerce, but are not bought or sold to any extent in the West. Many people of the West poke fun at us for what may be termed our motley taste for fish food. They declare that we are omnivorous, as far as eating the products of the sea is concerned. It seems to us that if the standard of civilization is partly to be measured by the ability and ingenuity of the people to maintain life by utilizing the variety of foods placed at its disposal, then we have helped to solve one of the important problems of life. We have found so many of the finny tribes suitable for food and capable of being transformed into delicious dishes that it is possible for us to have a fresh species on our table every day during the year.

The more common of the edible fishes in our country are the perch, mackerel, sturgeon, goby, pomfret, eel, gudgeon, shad, sole, mullet, flounder, herring, carp, bream, etc.

With our dense population it is a matter of necessity that we seek our food from the waters as well as from the air and the land. As a writer has said, "All waters are vexed with our fisheries. Our nets and other contrivances for capturing fish display great ingenuity, and most of them are admirably adapted for the purpose (and no wonder, with our centuries of experience and experimentation). The right to fish in running streams and natural waters is open to all, with a few exceptional cases, while artificial reservoirs, as ponds, pools, tanks, tubs, etc., are brought into available use; rice fields near tide water are turned into fish ponds in winter. As to the modes of securing the inhabitants of the deep, they are killed with the spear, caught with the hook, scraped up by the dredge, ensnared by traps, and captured by nets; they are decoyed to jump into boats by painted boards, lifted by lifting nets, and dived for by birds—for the cormorant seizes what his owner could not reach." The last-named method is unique, I believe, in the world, and in our country is confined to one family, the Liu family. The fishes caught, however, are limited to those of creeks and small streams and of unpalatable kinds, bought and eaten only by very poor people.

With the spread and growth of new ideas through intercourse with western nations, the possibilities of the fishing industry have become more and more apparent to our leaders, and it is realized that for a proper development the whole industry must be thoroughly organized and all modern improvements in

the way of vessels, apparatus, and methods of fishing, aquiculture, etc., must be introduced. A bureau of fisheries, modeled much after the pattern of the West, with headquarters in Shanghai and branches in Mukden, Tientsin, Chefoo, Canton, and Foochow, has been established. The maritime provinces of Fêngtien, Shantung, Chêkiang, Kiangsu, Fukien, and Kuangtung have interested themselves in the work of this bureau. Investigation has been made of the different types of vessels, nets, and other apparatus employed in the industry, of the groups of fishermen and their methods of fishing, of the habits and rules and traditional usages obtaining among fishermen, with a view to governmental legislation and regulation, and also of the numerous islands and rocky coasts, which have for centuries been the resorts of our fishermen. The last-mentioned work has been carried out with the cooperation of instructors from our naval college at Nanking. This fisheries bureau, more commonly known as the Kiang-Chê Fishery Company, is authorized and recognized by our Ministry of Agriculture, Works, and Commerce, and has for commissioner-general the taotai of Shanghai.

Established only about four years ago, the fisheries bureau is of course only in an embryo state, but in a general way much has been accomplished. The industry has been encouraged and developed in that protection has been afforded to the fishermen from attacks of pirates, from clandestine fishing by foreign vessels in Chinese waters, and from illegal exactions by official underlings. By the construction of houses for the storing of natural ice, the sale of fresh fish has greatly increased. A fishing vessel propelled by steam power was purchased, but so far the vessel has proved to be a failure from the financial point, for the simple reason that deep-sea fishes can not fetch good prices in our country. Two years ago the bureau succeeded in sending a very complete exhibit of the fisheries of our Empire to the Milan Exposition, and those of you who were present will remember the numerous models of fishing boats and fishing nets and the hundreds of finny creatures caught in Chinese waters that were placed on view. We have with us this time models of 19 different kinds of fishing nets, which you may examine at your leisure.

It is proposed to establish a large fishery school at Woosung, the entrance to the city of Shanghai and the resort of numerous fishing boats, the funds being contributed by the governments of 11 provinces. The site has already been chosen and leveled, and construction of the building will begin in the immediate future. As a nucleus of this future college—for it is hoped the institution will grow into a college—we have already organized a school, with 100 pupils, mostly sons of fishermen. Connected with the school is a museum, and it is planned to construct an aquarium on a large scale.

One of the more important duties of the bureau has been the collection of statistics, a branch of knowledge much neglected by us in the past. The work is full of difficulties, but from a cursory examination it is found that the total

number of salt-water fishing vessels is in round numbers 200,000, one-fifth of which hover on the coast of Chêkiang Province.

The canning and preserving in other ways of fish after new and improved methods is growing gradually into importance. In Canton, in particular, it is becoming a valuable industry.

Such in brief is the state of the fisheries of our country. The activities of the bureau, you will notice, have been confined to the practical rather than the scientific side. There is a great deal more to be done, but at present its usefulness has been circumscribed by the lack of funds and of competent men. So many new measures are being introduced that necessarily the energies and resources of the Empire have been very much divided.

In attending this congress my colleagues and I have had it impressed on us to gather as much information as possible, to visit the various centers of fish culture, and to meet the leading scientists and experts engaged in the work, from whom we expect much assistance and with whom we hope to work together in the future.

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THE FISHERIES OF JAPAN CONSIDERED FROM A GEOGRAPHICAL STANDPOINT

By T. Kitahara, Ph. D.
Imperial Fisheries Bureau of Japan

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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THE FISHERIES OF JAPAN CONSIDERED FROM A GEOGRAPHICAL STANDPOINT.

By T. KITAHARA, Ph. D.,
Imperial Fisheries Bureau of Japan.

It is a well-known fact that the Japanese are among the most extensively fish-eating people of the world. The average annual consumption of fish in Japan, to my estimation, is nearly 50 pounds per head, a high average not surpassed by other nations, except the Norwegians and the Canadians. Although the preference for fish as an article of food is said to have originated from some religious belief in the old time, now the people of Japan are in the position of being forced to take it as the most important diet, because they have very small pasture for raising cattle, while there are seas to fish near at hand all around the country.

The Empire of Japan, as you know, stands off the northeast coast of Asia, stretching from southwest to northeast for nearly 3,000 miles, and from the tropical to nearly the frigid zone, washed by the warm as well as the cold currents. Thus it can be seen that Japan, so far as the maritime conditions are concerned, is much like the Eastern States of North America. The Gulf Stream may be compared with the Japan Current, the Labrador Current with the Kurile Current, the Gulf of St. Lawrence, probably, with the Japan Sea. The fishes which inhabit the waters of Japan are also like those of America to some extent, as regards both character and distribution.

But unfortunately we lack such great fishing banks as the Grand Banks off Newfoundland, the Georges Bank off Cape Cod, etc. On the contrary, Japan has the deep abysses along the east coast which are useless for the fishing industry, but give rise to the terrible earthquakes and awful tidal waves that at times destroy lives and property along the shore. This condition seriously affects the development of the fisheries in that part of the country. In fact, the Japanese islands, being as a whole steeply built, have but few submarine plateaus. The area within the 100-fathom line, i. e., the continental shelf, is only about 77,000 square miles, while that of the Chinese and the Korean seas comprises nearly 200,000 square miles, and that of North America about 1,000,000 square miles.

It naturally follows, therefore, that the fishermen cling to the shore for the bank fishing, and consequently their boats are very small and not ocean-rigged, being mostly shorter than 30 feet. Such small boats now number 400,000, and they are very densely distributed on the comparatively narrow shore fishing grounds, which are so actively fished over that the important shore fishes have been greatly decreased. I believe the shore fisheries of Japan are in the climax of development, and there seems to be very little room for further increase. The only hope for future progress rests upon the growth of the pelagic fisheries on the deep high seas.

Understanding these conditions in regard to the fisheries of Japan, we come to consider:

1. How to repopulate the depleted shore fishing grounds.
2. How to encourage the pelagic fisheries in general.

The first question is very difficult to solve, and when solved is not easy to practice, and we can not as yet report any good results, except in the artificial propagation of the salmon, on which I shall touch later. As to the second question, to make effective encouragement an act was passed by the Imperial Diet in 1897 by which fishing steamers of more than 50 tons and sailing vessels of more than 30 tons may receive certain subsidies from the Government. Since this act has been in force several vessels have equipped for the pelagic fisheries, but unfortunately the greater number of these vessels were for pelagic sealing, which is regarded with such disfavor by the American and Russian authorities. In my country, too, the increase of sealing vessels is not encouraged. Indeed, the profit from the fur seals is very limited, and it is not a wise policy to promote an industry which causes so much international difficulty.

The amendment to the act and the by-laws in 1905 were with the view that all important pelagic fisheries may receive subsidies. The lower limit of tonnage of sailing vessels was therefore reduced to 20 tons. Moreover, in case of vessels newly built under the instructed plan, they also may have a certain support from the Government. These amendments proved effective, and many fishing vessels were equipped for pelagic fisheries other than sealing. Among other vessels the *Fuji Maru*, of 25 tons, with an auxiliary gasoline motor, made a great catch in bonito fishing in 1906, which resounded throughout all the fishing communities, awakening the fishermen from a long sleep in the old methods of fishing. I believe Japan will have a great revolution in her fishing vessels within a few years, and will as a consequence increase the supply of the pelagic food fish.

It is a significant fact that the whale fishery on the high seas has sprung up with fullest vigor since 1905, almost regardless of the government encouragement. There are now 28 whaling steamers, while there were only 2 schooners in 1904. This wonderful development of whaling is, I think, partly because of the prohibition of whaling in the Norwegian seas and partly because of the

abundance of whales in the seas of Japan. Most of the gunners employed are from Norway.

Before closing I want to call your attention to some of the methods of fishing and fish culture introduced from America. The most important of these is the purse seine. It was first introduced into Japan by Mr. K. Sekigawa thirty years ago. After a good deal of encouragement, it was applied to the catching of sardines and herring; and now hundreds of such seines are being used on the southeast coast. It is not yet used for mackerel fishing, as in America. The artificial propagation of salmon and trout, which was introduced by the same man, is no less interesting; and Japan owes much to the kindness of the American authorities. There are now some 20 hatcheries in northern Japan, which annually yield about 35,000,000 fry. The fishermen are now in firm conviction that the beneficial results of artificial propagation of the salmon are beyond doubt. In fact, they have established by themselves several hatcheries at their fishing grounds. The rainbow trout, which was first introduced thirty years ago and new lots of which have been brought over several times since then, is thriving well in the lakes at Nikko and Aizu.

I have great pleasure in expressing thanks in behalf of my country for the ever kind aid that the American authorities have given for the promotion of Japanese fisheries and fish culture.

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GOLDFISH AND THEIR CULTURE IN JAPAN

By Shinnosuke Matsubara

Director of the Imperial Fisheries Institute, Tokyo

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

H 666

CONTENTS.

	Page.
Japanese varieties of goldfish	383
Goldfish culture in Tokyo	386
Ranchu	386
Ryukin	388
Wakin, demekin, and deme ranchu	391
Methods of culture in Koriyama	392
Collection and cultivation of fish food	392
Oranda shishigashira	393
Ranchu	395
Wakin	396
Artificial coloration	396
Interest and value of goldfish to the Japanese	396
Plates	facing 398

GOLDFISH AND THEIR CULTURE IN JAPAN.

By SHINNOSUKE MATSUBARA,
Director of the Imperial Fisheries Institute, Tokyo.

JAPANESE VARIETIES OF GOLDFISH.[a]

That the goldfish of Japan was originally introduced from China there is no doubt, but a long domestication of the fish has resulted in producing several Japanese varieties. The four known from remote times are as follows:

"*Wakin*" (Japanese goldfish).—This variety bears a close resemblance to the original *Carassius auratus* from which it came. Its body is slender and long, and the black pigment gives it when very young a color like that of steel, which gradually changes into vermilion red, often variegated with white. The caudal fin is either simply forked or split into three or four lobes. (Pl. XVIII.)

"*Ryukin*" (Loochoo goldfish).—This variety has a short rounded body with a protuberant or swelled-out abdomen. The caudal fin, pendulous when at rest and flowing when in motion, is as long as the body or sometimes still longer, all the other fins being also long. (Pl. XIX.)

"*Ranchu*," otherwise called "*Maruko*" (round fish).—The body of this variety is short and rounded, its tail and broad head being also short. It has no dorsal fin. The head, which is free from any abnormal features when the fish is quite young, in two or three years develops all over it a number of protuberances, like the achenia of a strawberry. In this state it is called "shishigashira (lion-headed) ranchu." Owing to the fact that this variety has a globular body, a short protuberant abdomen, and a short caudal fin, it can hardly swim, and is usually seen in an erect position with the head downward, which may be accounted for by the absence of the dorsal fin. (Pl. XX.)

"*Oranda shishigashira*" (rare lion-headed).—This resembles the ranchu in its bodily form with strawberry-like protuberances on the head. The body is big and longer than that of the ryukin and furnished with the dorsal fin; the caudal fin is long. (Pl. XXI.)

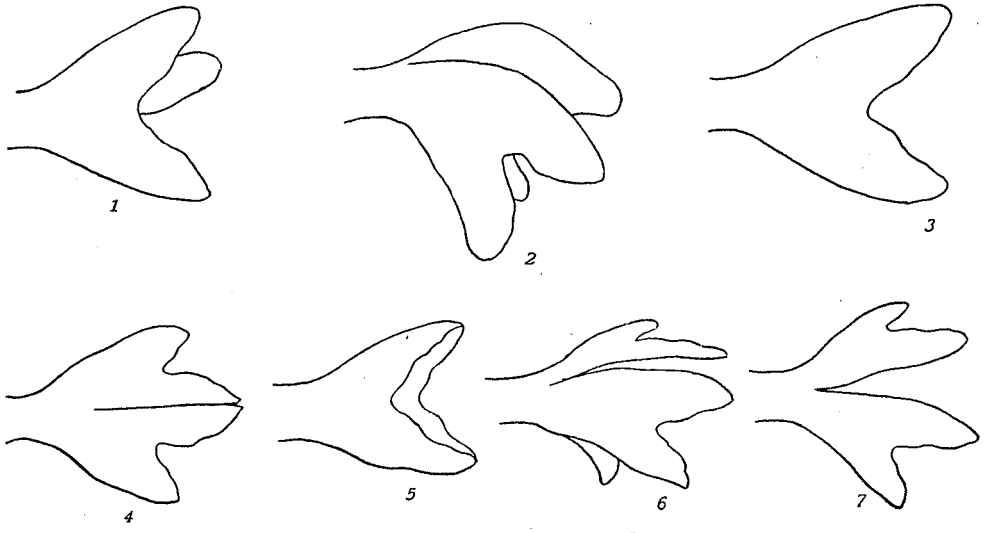
Among the older varieties are also the following:

"*Demekin*" (goldfish with protruding eyes) *and* "*deme ranchu*" (ranchu

[a] The ten colored plates accompanying this paper have been made from water-color drawings from life by J. Urata, and have been copyrighted by the author.

with protruding eyes). The former was first introduced from China toward the close of the Japan-China war (1894–95). It has protruding eyeballs, and the body and the caudal fin are short. It is not usually bright colored, being black all over the body or yellowish red variegated with black spots or irregular patches. The deme ranchu, first brought from China six or seven years ago, has a globular body and, like the ranchu, no dorsal fin. The eyes not only protrude, but also are turned upward 90 degrees. (Pl. XXII and XXIII.)

The foregoing are varieties for some time cultivated in Japan or recently introduced from China. New varieties, however, different from these, have lately come into existence, and I shall now describe how and in what order these have been produced.



TYPICAL FORMS OF GOLDFISH TAILS.

1. Arrow tail, lateral view.
2. Tassel tail, lateral view.
3. Forked tail, lateral view.
4. Three-lobed tail, dorsal view.
5. Bag tail, lateral view.
6. Rudder tail, lateral view.
7. Four-lobed tail, dorsal view.

"*Watonai.*"—When the Fisheries Exhibition was held in Tokyo in 1883, I saw there exhibited a highly interesting variety of goldfish, which was a wakin with a flowing caudal fin. Being struck with its extreme peculiarities, and inquiring how this variety came to be produced, I found that the exhibitor, who lived at Imaidani, Akasaka, Tokyo, had only one pond for breeding goldfish, and that there the said variety was produced. As in that pond all the different varieties just stated above were reared together, the strange new variety appeared to be a cross between the ryukin and the wakin; but I did not make at that time further investigation into the cause. That breed was called "watonai," which means "a variety hitherto found neither in Japan nor in China." (Pl. XXIV.)

As to the order in which the different varieties of goldfish have been produced in Japan, it is probable that the wakin stands first in priority, but in what order the others have come can not be definitely stated. The oranda shishigashira, however, is generally known to have been produced by crossing the ryukin with the ranchu at Koriyama, Yamato, in 1840. All the new varieties of recent times except the watonai, which comes first in order, were produced by Mr. Akiyama Kichigoro, a goldfish breeder in Tokyo. The latest produced varieties are the following three:

"*Shukin.*"—In 1897 a new variety, having its own peculiarities, was produced by the following means: Oranda shishigashira, ten in number and 3 years old, were crossed with ranchu equal in number and also of the same age. The cross thus made produced about 300 young fish, of which some were like the oranda shishigashira in form. There were 20 entirely without the dorsal fin; but in a large majority of the young there were some traces of the dorsal fin, one to three spines or something like knobs being discernible in its place. Those without any dorsal fin were then selected for breeding purposes, and in their offspring were still found some with traces of dorsal fin such as the spines and knobs mentioned above. This variety without the dorsal fin has been kept breeding up to the present; and being requested by the breeder to give it an appropriate name, I called it "shukin" (literally "autumn brocade"). The adjective "shu" takes its rise in the breeder's name, Akiyama (Chinese, Shu-zan, i. e., "autumn hill"), and the "kin" signifies "brocade," the epithet being given on account of the beautiful bright color. (Pl. XXV.)

"*Shubunkin.*"—The year 1900 first saw this new variety. The goldfish hitherto known in Japan having no such dapples as are found in the Chinese demekin, which is dappled in three or four colors, the breeder had wished to have a variety produced having the same dapples as the Chinese. Thus the males and females, each ten in number, of the demekin having the most attractive dapples were crossed with an equal number of the males and females of the wakin. The breeding fish selected were the demekin having black dapples on a vermilion red or purple ground and those speckled with red, white, black, and blue. Some of the offspring resembled the original *Carassius auratus* in form and had dapples like the demekin, while in some others the scales were not so conspicuous as is the case with the demekin. On the whole, however, those resembling the wakin were most numerous, while those similar to the demekin in form were very few; and the number of the cross the breeder had in view was only 100 out of a total of 500. This new variety, to which I gave the name of "shubunkin" ("vermilion red dappled with different hues"), has since been kept breeding. Among its descendants some were of a vermilion color, dappled with black, some of a purple color all over the body

without any dapples, and the others speckled with three or four colors. The entirely purple color above referred to was quite an unknown thing in the parent fish. (Pl. XXVI.)

"*Kinranshi.*"—With a view to obtaining a new variety without the dorsal fin, the ryukin was crossed with the ranchu. The number of parent fish, as well as the numerical ratio of the males to the females, was the same as in the preceding case. The offspring thus produced were of a bright attractive color. Some were provided with the dorsal fin or spines, others partially provided with the former, while in some others there were protuberances in place of the dorsal fin. Those entirely destitute of any dorsal fin numbered only one-third of the whole. This last-mentioned variety, which I called "kinranshi" (brocade-figures), has been kept breeding up to date. (Pl. XXVII.)

Of these three new varieties, the shukin is the most popular, but the shubunkin the most profitable one, only a few of the latter being eliminated on account of the caudal fin being crooked or irregular.

The goldfish is cultivated almost all over the Empire, but most extensively in Tokyo and Koriyama, Yamato, Nara Prefecture. Broadly speaking, the most popular varieties are those cultivated in these two localities, and the methods of rearing goldfish most in vogue are also those followed there. The northeastern half of the Empire follows Tokyo in things relative to the goldfish breeding, while Koriyama leads the southwestern half.

GOLDFISH CULTURE IN TOKYO.

The varieties of goldfish cultivated in Tokyo are the ranchu, the ryukin, the demekin, and the wakin. Attempt was once made in Tokyo to cultivate the oranda shishigashira by introducing the fish from Koriyama. This variety was not regarded with much favor, however, and has come to be scarcely ever cultivated in the capital. The most popular breed is the ranchu, which is highly prized by goldfish lovers and engrosses a great deal of the attention of breeders, who take pride in producing the best of this variety.

RANCHU.

This fish is chiefly cultivated in concrete ponds. When the culture is carried on upon a small scale, the usual number of parent fish is five, two of which are females and the others males, but when it is carried on upon a large scale, the number of parent fish is over fifty, one half of these being male and the other half female. The eggs are laid during the period between the beginning of April and the middle of May, and the utmost attention should be paid to the fish during the three months of September, October, and November of the preceding year, when the food should be given them in sufficient

quantity, without their being overfed. The males of the parent fish are separated from the spawners some time before the latter deposit their eggs. When the spawning season approaches, the water of the pond is not renewed, but the fish are kept amply fed with the larvæ of mosquitoes (*Culex pipiens*) or earthworms (*Limnodrilus* or *Tubifex*) for about ten days, at the end of which time the eggs are laid when the temperature of water in the pond rises or when it rains. As, by experience, this can be known beforehand, the water of the spawning pond is changed the day before and the parent fish are removed thither. The spawning bed is then made with "kingyomo" (*Myriophyllum verticellatum*), on which the eggs are deposited on the following morning.

When the number of parent fish is 5, the proper size of the pond is 4 by 3 shaku (1.2 meters by 91.0 centimeters) with a depth of 5 sun (15 centimeters). With 50 parent fish, the area of the pond should be 7 by 6 shaku (2.1 by 1.80 meters), the depth remaining the same as before. In a pond of the latter size, a circular concavity with a diameter of 8 sun (24 centimeters) to 1 shaku (30 centimeters) and with a depth of 1 sun 5 bu (4.5 centimeters) from the bottom of the pond, is made around the outlet for the water. This concavity is intended to prevent the fish from being driven, when the water is drained off, against the walls of the pond. When the spawning is over, either the parent fish or the eggs are removed to another pond to prevent the eggs from being devoured.

For a few days after the eggs are hatched, the fry do not move about, but stick to their bed or the bottom of the pond. During this time no food need be given, as every individual of the fry is provided with a yolk sac in its abdomen; if forcibly fed, their health would be impaired. In three days or so, they begin to swim about in the pond, and are then fed once every day in the morning with the yolk of hen's eggs boiled. This food is administered by straining the yolk, mixed with water in the proportion of 2 eggs to 5 sho (9.1 cubic centimeters) of water, through cotton or silk gauze, this mixture being then completely stirred up until it is yellow, when it is put into a watering pot and poured all over the pond as food. The belly of the fry becomes yellow by taking this food, and the shade of the abdominal yellowish color shows whether or not the fry have got sufficient food. After being thus fed for seven days, they are given the small crustacea, "mijinko" (*Daphnia*, *Moina* or *Cyclops*), which have been cultivated and kept in a separate pond, the crustacea being caught with a gauze bag and then sifted, in order that any injurious insect, etc., may not remain mixed in them. After fifteen days thus nourished with mijinko, the tender fish are fed with the larvæ of mosquitoes or earthworms cut in small pieces.

About twenty days after the fish are hatched, the first selection is made, for which purpose the fish are put into a white earthenware plate. As they are

still very small at this stage of development, it is difficult to select those which are satisfactory in every respect, and only those furnished with the better caudal fins, such as they are, are picked out. Ten days later the second selection takes place, when those having any irregularities on the back are thrown into a mud pond and put aside. Again, ten days later, the third selection is made and the fish are grouped together according to their size. And yet, about ten days after this, the fourth and last selection comes, when particular attention is paid to the form of the caudal fin. The fish are for the first time put up for sale when the third selection is over.

After the first selection the young are put into two concrete ponds, each of which is of the same size as the former one, and in the second selection they are distributed into three ponds of this same size. The area of these ponds would not be large enough for the original number of fish, but the number has been reduced as the inferior breeds were eliminated. To every twenty of the fish hatched in the beginning of May is given a space of one tsubo (3.3058 square meters), and when the cold weather comes they are removed either to a mud pond or to a hibernacle (i. e., wintering pond). The latter, which is made entirely of concrete and has a depth of 6 to 8 sun (18.2 to 24.2 centimeters), is provided with a lid, and the whole is again covered with an inclined roof opening toward the south, with one end coming down to the north edge of the pond. When the weather is warm, the lid is partially lifted up so as to admit the sun's rays into the pond from the south. The water sometimes becomes foul through the putrefaction of fish food and from other causes, in which case a basket having its lower part covered with gauze is immersed into the concavity of the pond and by means of a rubber siphon put into the basket the foul water is drawn out, to be replaced by fresh water. The fish in the second and third years should have a space of one tsubo at least for every twenty of them.

In the first year the fish attain in eight or nine months the size of 2 sun 5 bu (7.5 centimeters) from the snout to the extremity of the tail; in the second year they attain in the same length of time the size of 4 sun (14 centimeters); in the third year, 5 sun (15 centimeters); in the fourth year, 5 sun 5 bu (16.5 centimeters), and in the fifth year, 6 sun (18.2 centimeters). The fish that are kept four or five years are the only ones fetching a very high price in the market.

RYUKIN.

Being naturally very strong and healthy, the ryukin is much in demand abroad and is exported in large numbers. At home, also, this variety is a great favorite, and as such is kept in the ponds. Those having the longest caudal fin and called "ohiki," viz, "tail trailers," require at least four years for their full development. The superior kind has a head broad in front but not angu-

lar, and a short body. For instance, to be perfect in form, the body should be about 1 sun (3 centimeters) in length when it is 1 sun 5 bu (4.5 centimeters) in breadth. The body as long as broad comes next. As to the form of the caudal fin, it should be long and thin, at the same time the rays being fine and slender and the peduncle of the tail thick. To have the best coloration, it is essential that both the belly and the back should be well dappled and the tail vermilion colored. In former times when goldfish were kept in a china basin to be looked at from above only, those having the finest dapples on the back were most highly appreciated. Nowadays, however, the fish are kept in a glass tank to be viewed from the sides, hence the necessity of having fine dapples on the sides and downwards. The greatest desideratum for the ryukin is that it should have nothing abnormal in the caudal fin.

When the fish having a two-rudder tail are selected for breeding purposes, the tail becomes long in the offspring, but when the fish having a one-rudder tail are used for the same purposes, the tail becomes short in the offspring. Those having a long body and a short tail are regarded with the least favor. The second requisite for the ryukin is that the form of the body should be satisfactory, the shape of the head coming last.

A mud pond is used not only for rearing the ryukin but also for its spawning. Equal numbers of males and females of this variety are used as breeding fish, and 800 fish 3 years old are placed in a pond having an area of forty tsubo (132.2 square meters) with a depth of 2 shaku 5 sun (76 centimeters). An ample supply of food is given them in the preceding year. In order that sufficiently developed offspring may be put up for sale at the earliest possible date, the breeders vie with one another in causing the parent fish to deposit their eggs with little delay. Many of the offspring become striped like a tiger before their original steel color fades into white, and it is at this intermediate stage of their coloring that those inferior breeds destined to become white can be sold with the greatest profit. A full supply of fertilizer is required in the mud pond in which the breeding fish are kept, as it produces more plankton for them. About the end of March, when its temperature rises to 15° C., the water of the pond is renewed. In this season of the year, when the weather is very changeable, the fish require the utmost care. It is good for them if the temperature of water in the pond is higher than 15° C., but a lower temperature has a bad effect. A rising temperature accelerates the hatching of eggs, but a falling one retards it from two to three days, thereby producing a diversity of size in the offspring, an effect that should be avoided. When the eggs are deposited thereon, the bundles already referred to are removed to one or two ponds. In the case of its size being 4 tsubo (13.2 square meters), one pond may suffice to receive the eggs, but in the case of its being only 2 tsubo (6.6 square meters) the eggs are

distributed into two ponds. The more spacious the pond is, the better it is for breeding purposes.

The best food for the young is natural food, viz, plankton, which is on that account cultivated beforehand. About as much as one koku (5.2 bushels) of rice bran, soy lees or the excrement of man or horse is put into the pond, if it is 50 tsubo (165.3 square meters) in size and over 10 years old. But if the pond is only about 2 years old, a double quantity of the fertilizer is used. In each case, the pond is drained previous to putting in the fertilizer, after which its bottom is exposed to the sun's rays for about a week, and then the pond is filled with water. Another pond of 40 to 50 tsubo (132.2 or 165.3 square meters) in size is provided for receiving the fry just hatched. This pond already contains the plankton which was produced by feeding the pond with about 3 to 4 to (1.5 to 2.1 bushels) of the aforesaid fertilizer. Besides, if 1 go (0.005 bushel) of mijinko is put into the pond three days prior to removing the fry there, they increase to an immense number in that short interval.

When the young fish begin to swim about in the pond, the bundles on which the eggs were deposited are removed, and they are fed from the following morning with boiled eggs (5 in number), prepared as in the case of the ranchu. Three or four days later, when it is warm, the water in the pond is drained off by means of a rubber siphon, as stated before, and the young are put into a mud pond and fed with mijinko. Ten or fifteen days after, the fish, having outgrown the size of the pond, have to be removed to another pond. When a supply of mijinko falls short in that pond, the fish are again put into a new pond where plenty of such food can be had.

In order that the ryukin may be reared with any success, at least four ponds are required, two of which are intended for keeping the young and the other two for cultivating mijinko. In the middle of May the fish are grown so large that the larvæ of mosquitoes can be given them as food on earthenware plates slung by three strings from a bamboo pole. Given 800 parent fish, 200,000 offspring are produced, which is a proper number for the capacity (200 tsubo) of the four ponds just mentioned.

No selection of the fish is yet made at this stage of their development (the middle of May). After feeding them for about fifteen days from earthenware plates, the selection is first made in the following way: Food being put into a basket or a scoop net, the young are thereby enticed and caught, and are distributed into two ponds. The first pond is at the same time completely cleaned from everything pernicious and replenished with water. The selection is sometimes made while catching the fish with a basket or a scoop net from the new pond, when an earthenware plate is put for this purpose into the basket (or the scoop net), the inside of which is covered with gauze. The caudal fin is

the criterion by which selection or rejection is made. If there is any marked diversity in the size of the fish, the large ones are separated from the small. Those selected are put into the pond lately cleaned, when their number is roughly estimated by measuring them with a teacup or a lacquered bowl. Twenty or thirty days later another selection takes place, in which the fish are chiefly classified according to size. As at this stage those destined to be white can be distinguished from those to be dappled, the former are caught and sold off. Between this time and the following August all the fish are cleared off by selling, except 300 per tsubo of the ponds, it being possible to find buyers for the fish grown to one sun (3 centimeters) or over.

Toward the end of March the next year, 4,000 of the fish deemed best are retained and the rest sold off. From that time forward selection is made once a month during the following April, May, and June, and every time 1,000 fish are eliminated, commencing with the most inferior, until 1,000 are left at last for breeding purposes. Making allowance for loss from various causes and deducting 2 per cent from the above number, 800 fish may remain.

WAKIN, DEMEKIN, AND DEME RANCHU.

The wakin is never so much prized as the ryukin, but on account of its large size, besides being healthy and strong, it is kept in a garden pond. In this variety, the tail should be thick and widely spread, the rays invisible and the dapples not merged into one another, while the contrary is the case with the ryukin in this last respect. The method of its culture is the same as that of the ryukin.

Of the demekin those dappled with three of four colors are highly prized. Either the vermilion dapples or the black patches should be pronounced. In some the black pigment gives the color of ink, while others have the color of steel, like that of the crucian carp. In the former the color is permanent, but in the latter it fades into yellowish red in a year or two, and such a color as this last is worse than a uniform red. The caudal fin should be long and widely spread. The eyes, right and left, should protrude symmetrically. Those which protrude but little are not regarded with favor. Goldfish of this variety swim about, not in groups, but singly, which is not the case with the goldfish long known in Japan.

The deme ranchu is colored all over the body either with yellowish red or black pigment, or yet dappled with black and red. This variety remains most of the time at the bottom of the pond resting on the belly, and scarcely ever swims. It does not live in groups; even less so than the demekin, and it very seldom spawns. In cultivating this variety, the breeders follow the same method as with the ryukin.

Thus far as regards the culture of goldfish in Tokyo. I shall now describe the method of culture pursued at Koriyama.

METHODS OF CULTURE IN KORIYAMA.

There are but few trustworthy records giving information on goldfish breeding in remote times in Japan. Tradition has it that during the Hoyei era (1704–1710), a certain Sato Sanzaemon set up as a goldfish breeder at Koriyama and commenced to cultivate the fish in a mud pond. It is said that he pioneered the industry in that locality.

The principal varieties of goldfish cultivated at Koriyama are the oranda shishigashira, the wakin, and the ranchu. The ryukin was most extensively cultivated there until fifty years ago, but it has since been replaced by the oranda shishigashira and is not much reared at present. The demekin is not wholly uncultivated at Koriyama but no great attention is paid to it.

The dimensions of a pond at Koriyama do not vary with the different varieties of goldfish. It is usually oblong in form and measures 10 ken by 3 ken, i. e., 30 tsubo (99.2 square meters). This is a size most convenient for the purpose of efficient fertilization. Formerly a depth of 1 shaku 5 sun (45 centimeters) was given to the pond, but it is now increased to 2 shaku (60.5 centimeters) in order to protect the fish from the sun's heat or atmospheric changes. The only drawback in this increased depth is that injurious gases are thereby generated from the bottom, especially when a large quantity of fertilizer is put into the pond.

COLLECTION AND CULTIVATION OF FISH FOOD.

The most noteworthy thing in connection with goldfish breeding here is the attention paid to rearing as well as collecting mijinko. These small crustacea are caught in a bag 20 to 25 shaku (6.0 to 7.5 meters) long, with a diameter of 2 shaku (60.5 centimeters) and made of "tenjiku kanakin" (a kind of calico) with fine meshes, varnished with the astringent obtained from unripe persimmons, or with the extract of oak-tree bark. For two weeks after hatching the fish are fed with the smallest of mijinko, which have been sifted. For another fortnight a larger kind of the crustacea is also given. When mijinko can not be obtained recourse is had to the yolk of boiled eggs, well pulverized. But the latter compares unfavorably as a substitute.

Usually 40 days, but when it is warm, 30 days, prior to removing the newly hatched fish to another pond, soy lees packed in a straw bag are immersed in the bottom of the second pond with a view to producing mijinko. To determine properly what quantity of fertilizer is to be placed in the pond is very difficult. In the case of a newly made pond, 50 kamme (187 kilograms) of soy lees mixed with 4 or 5 ka (59.8 kilograms) of human excrement in liquid state

are poured over the bottom when it is not yet filled with water. When the bottom is sufficiently exposed to the sun, the pond is replenished with water, which in a few days presents a green color on account of the algæ produced there. Even after the young fish are put into the aforesaid pond it must be fertilized every other day. When they are fed with mijinko obtained elsewhere, one sho (0.4 gallon) of the crustacea is given every day in the case of a pond of 30 tsubo (99.2 square meters).

This is what should be done with the fish when removed to a new pond after forty days from the time of their hatching. During these forty days they are kept in a concrete pond and are given mijinko in such quantity as may be deemed proper. Afterwards the number of mijinko in that pond is ascertained by immersing something like a white earthenware plate in a corner of it, and a supply of food to the fish is kept daily increasing. Feeding the pond with fertilizer is intended for no other purpose than producing mijinko, with which the fish are to be provided without interruption.

The longer the fish are fed with mijinko the better it is for them. As there is, however, a limit to the supply of mijinko, that wholesome food when the young are grown to 4 or 5 bu (1.2 to 1.5 centimeters) gives way to the *Viviparus* (a kind of mollusk found generally in the rice fields) pulverized, or the dried chrysalides of silkworms pounded and mixed with starch. As it is during the three months of June, July, and August that the fish increase in size with great rapidity, the most abundant supply of food is given in this season of the year. The extent to which the fish are to be fed, indeed, is judged by the color of water in the pond. When the water is green and turbid, it shows that the supply of food is plentiful; when it is green and transparent, the supply is insufficient. The same is the case with all other colors.

ORANDA SHISHIGASHIRA.

A concrete pond is used for hatching the oranda shishigashira. It is 12 shaku (6.1 meters) long by 5 shaku (1.5 meters) broad with a depth of 7 to 8 sun (21.2 to 24.2 centimeters). The eggs having been deposited on bundles of willow-tree roots placed in a mud pond, about 50,000 or 60,000 are put into the above-mentioned concrete pond to be hatched. The water is removed without fail every four or five days, and is even changed every other day when the weather is warm. The first selection of the fish takes place after twenty-five days from the time of their hatching, when they are about 2 bu (0.6 centimeter) in length. About 20,000 of the then superior breeds are retained, the rest being eliminated, i. e., sold off. If the number of those first hatched suffices, it is most satisfactory, but if it does not, those hatched later are added. If sickness or other cause reduces this number, those hatched still later are used also. In that last case the fish are made to spawn even in midsummer. Forty days from the time of

their hatching they are put into a mud pond in the proportion of 300 fish per tsubo. The next selection is not made until the fish put on new colors at the end of July or the beginning of August, when those which are uniformly white or unsatisfactory in the form of the tail are sold at a nominal price. That the best kind of the variety may be obtained, however, two more selections are to be made, the character most highly prized being the form of the caudal fin. In Tokyo and Nagoya the four-lobed tail is regarded with preference, while Koriyama is content with the three-lobed tail, the four-lobed tail, or the bag tail, if only it is symmetrical in form. The head should be broad in front. The protuberances which are in three years developed on the head should be like a large well-proportioned flower of the tree peony and should not be small. In some localities, such as Kii, Hiroshima, Awa, and Sanuki, there is a variety called simply "shishi" (lion), which is brass colored and has a short tail. Not a few of this variety are found to be uniformly colored. Generally speaking, those which are satisfactory in the form of the head have the tail abbreviated; seldom are the fish perfect in both respects.

There was formerly neither oranda shishigashira nor ranchu having variegated figures on the back. Such varieties, however, have been occasionally produced since the twenty-second year of Meiji (1889), and their descendants have been studiously used for breeding purposes. Both varieties are now extensively produced and highly admired.

The young oranda shishigashira are first put into a mud pond in the proportion of 300 fish per tsubo, but those white in color and abnormal in form are eliminated, and from this and other causes the numbers are by autumn reduced to one-half of the number originally put into the present pond. These are left alone till the following spring, when they are put up for sale. They attain by that time the size of 1 sun 5 or 6 bu (4 to 5 centimeters) in length. When it is desired to produce fish of a greater size, the number of young first to be removed to a new pond after hatching is reduced from 300 to 100, and these attain the size of about 2 sun (6 centimeters) in the same length of time as before. In the third year they grow to 3 or 4 sun (9 to 12 centimeters), in the fourth year, to 6 sun (18 centimeters), in the fifth, to 8 sun (30 centimeters), and in the sixth, to 1 shaku (33.3 centimeters). In fact, it is known that in the last-mentioned year they sometimes attain to the minimum size of 1 shaku 2 sun (36.5 centimeters). Furthermore, for the purpose of producing breeds of a great size, the fish having a good natural constitution and a well-formed head are selected from the six year old stock as parent fish, and breeds are put into a pond in the proportion of 6 or 7 per tsubo. Selection is again made in the following year and the rate is further lessened to 2 per tsubo. The fish are fed with 2 kamme (7.5 kilograms) of *Viviparus* and 500 or 600 momme (1,875 to 2,250 grams) of the chrysalides of silkworms pounded and mixed with starch (of

wheat). All ponds are so made that they can be drained at any time to prevent the generation of poisonous gases. Usually twice a year, viz, in March or the beginning of April, when the young are about to be removed to another pond, and at the end of autumn when the fish are going to be put into a hibernacle, both these ponds, prior to receiving them, are drained and dredged and then exposed to the sun's rays for four or five days. Any place where the water gushes forth in the ponds should be exposed longer. It is usual for these steps to be taken twice a year as stated above, but the more this is done the better it is for the health of the fish; it would be best to do it even once a month. When the fish come up to the surface of the pond to breathe in warm weather before sunrise and go down afterwards into the water it shows that they are in good health.

RANCHU.

The ranchu is chiefly cultivated in a concrete pond, though in small numbers. The number of ranchu to be put into a pond after hatching is one-half the number of oranda shishigashira, and the amount of fertilizer used is also half the amount of that used in the case of the latter variety. When put into a mud pond, the method of culture of the ranchu does not differ from that for the oranda shishigashira, but when reared in a concrete pond it is essential that the fish should be constantly supplied with fresh water. Hence the necessity of entirely renewing the water once every day. An amateur breeder would be likely to partially change the water to prevent a sudden change of temperature in the pond; but nothing is better than entirely replenishing the pond with fresh water of the same temperature as before. The fish are fed only with the larvæ of mosquitoes.

In a concrete pond of the aforesaid size are generally placed 100 fish under 1 year, 30 under 2 years, 10 under 3 years, 4 under 4 years, or again 4 under 5 years, but if these numbers were reduced better results would be obtained. It is good for the fish to be constantly supplied with food. Earthenware plates are not used for this purpose as in Tokyo, except for the time being after the fish are first put into a mud pond. There is one advantage in this method of feeding them without earthenware plates: they are naturally made to thrust their snouts in quest of food into the bottom of the pond, with the result that the bottom remains free from gases. If the number of fish under 1 year to be put into a rearing pond is reduced below the normal quantity above referred to (i. e., 100), they can be made to attain the size of 2 sun 5 bu (7.5 centimeters) at the end of the year, while keeping to that quantity they attain in length only 1 sun 5 bu (4.6 centimeters) in the same length of time, 2 sun (6 centimeters) at the end of the second year, 3 sun (9 centimeters) at the end of the third year, 4 sun (12 centimeters) at the end of the fourth year, and 5 sun at the end of the fifth year.

WAKIN.

In the case of the wakin, twice as many as of the preceding variety are cultivated in a pond. When put into a miniature pond they are most lively, but do not live long.

ARTIFICIAL COLORATION.

Various designs are artificially produced on the back of goldfish at Koriyama. Dilute hydrochloric acid is applied to the part where certain figures are desired to be produced. But the scales along the margin of the intended figures (such as badges or flowery patterns) being but partially colored, the results are not very satisfactory. This artificial coloration is best attempted in August or September, in the early morning. When the fish are purely red, the discoloration makes them very unsightly; besides, the color of the head can not be changed. For the purpose of artificial coloring, the water of the pond in which the fish are kept should in the first place be completely renewed and then they should be abundantly supplied with food. When they grow plump and fleshy the figures are put on. This practice has been known from remote times.

INTEREST AND VALUE OF GOLDFISH TO THE JAPANESE.

On account of its beautiful form, its fine bright color, and graceful attractive motion when swimming, the goldfish has been for hundreds of years a great favorite with the people of Japan, and now different varieties are cultivated almost all over the Empire. In Hokkaido it is very difficult for the fish to survive the winter, owing to the intensely cold climate, and they are hardly ever hatched and cultivated there. Yet the favor with which they are regarded is extremely great and they are yearly brought there from Tokyo without number in the beginning of summer.

Such is the interest with which goldfish are regarded in Japan, and they are, moreover, admired by every class of the Japanese people. Some are kept in an artificial lake in a garden, some in tanks of various forms, others suspended in a glass globe from a ceiling, still others put into the pond of a miniature garden, and so forth. The kind and quality of the fish naturally vary with the class of people by whom they are kept. Those kept by persons of wealth and position are superior breeds specially selected, while people of limited means, holding in regard healthy and strong ones, prefer the wakin and the ryukin to others. Those enjoyed by children are mostly what are called "dregs" and often sold on fête days, which are many in Tokyo and other towns.

Although the goldfish is so extensively cultivated in Japan, as has been stated above, yet its value from a commercial standpoint can not be said to be

very great. The inferior breeds are sold at 1 sen (half a cent) a piece, while the superior ones fetch a price of only 50 yen ($25) a pair. On rare occasions, however, 200 or 300 yen are paid for a single pair. In costliness the ranchu ranks first, the superior breeds of the oranda shishigashira are also of great value, and the ryukin comes next. The number of the last variety yearly exported from Yokohama and Kobe is great.

As already mentioned, the ranchu is regarded with special favor in Tokyo. An exhibition of this variety is held there every year in autumn by lovers of the fish, for the purpose of having the merits of their exhibits determined, and a successful breeder to whom an award of merit is made prides himself upon it. The exhibition lasts two days, on the first of which are examined the grown-up breeds and on the second the young in the first year. Being developed in color and form, the former naturally attest the extent of skill in the breeders and their value can be known at a glance. The latter are those hatched only in the preceding spring and as yet little developed in every respect; but these, after all the care lavished upon them by breeders, are to appear again fully grown up for contest at a future show, and on that account are full of interest and promise. The examination of fish in an exhibition is made in a shallow tub containing a white earthenware plate in the center. Two ranchu being placed in the plate are examined by connoisseurs as to their shade, dapples, and the form of the tail and body. Those perfect in every respect are awarded the "first best," and a list of the exhibits made in the order of their merits is given to the public. Every time the classification is made amid a stormy debate by the examiners. No positive criteria exist to guide one in the examination of the ranchu. Nevertheless, those uniformly bright red are considered the best, so far as coloration is concerned. Those perfect in form, however uniformly white they may be, are counted tolerably good. The variegated ones are generally unpopular; but in Osaka and its vicinity, those having fine dapples are greatly appreciated, especially if the head is of a bright red color. A ranchu having either a white body and bright red fins and mouth, or a bright red in color in both cheeks, is also admired. Every one of the breeds exhibited has its own name, which is given in the aforesaid list with that of the owner. Those who participate in the show are mostly nobles, wealthy merchants, and others in comfortable circumstances. On such occasions the very best breed fetches a price of 200 or 300 yen, but not one in ten thousand commands such a high price. The exhibition takes place chiefly in Tokyo but it has recently come to be held in Osaka also. Not a few goldfish breeders with fish of their own culture now come from localities lying far beyond Hakone to take part in a Tokyo exhibition. The reason why the exhibition is held in autumn is that the goldfish puts on the most brilliant colors in that season.

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Plate XVIII.—WAKIN

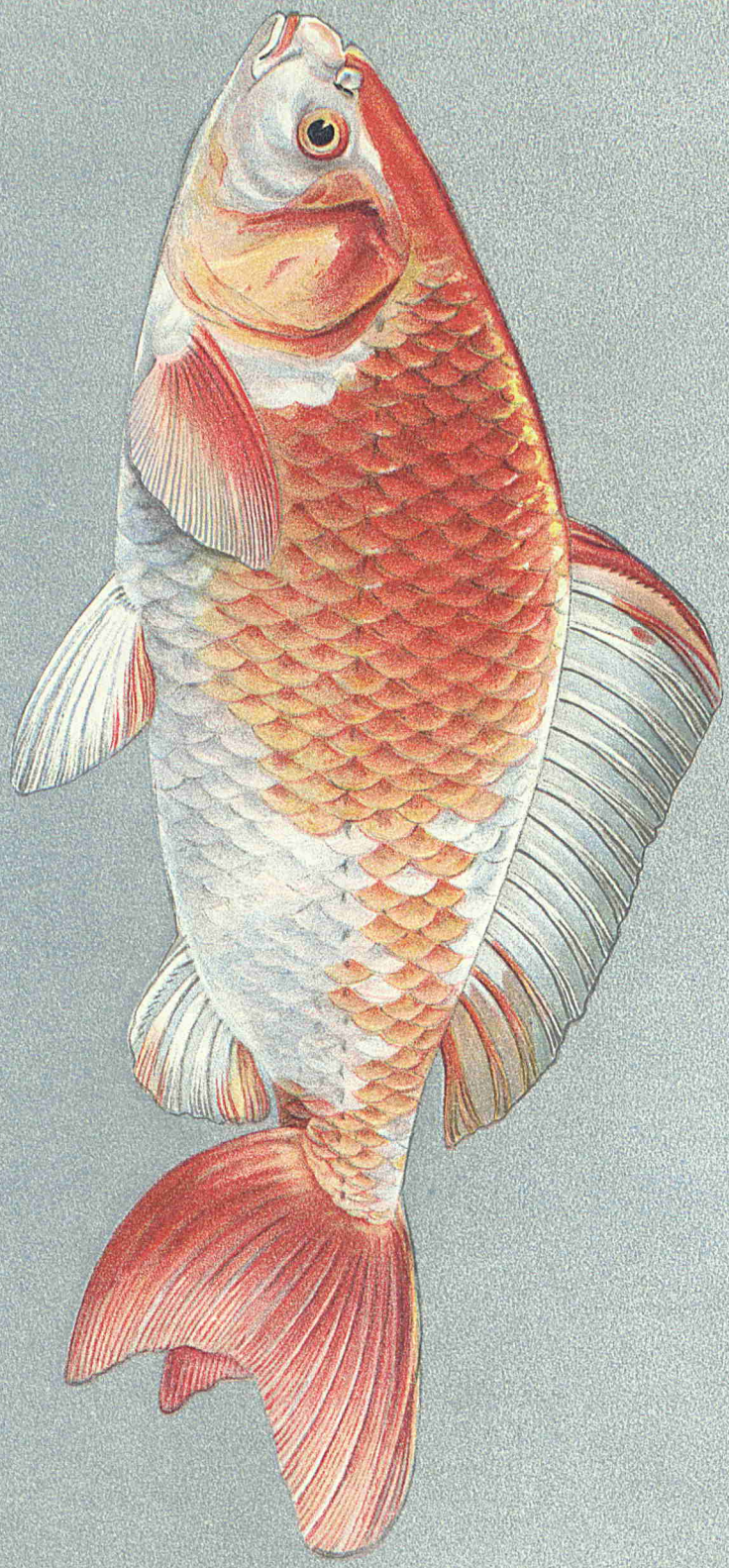


Plate XIX.—RYUKIN

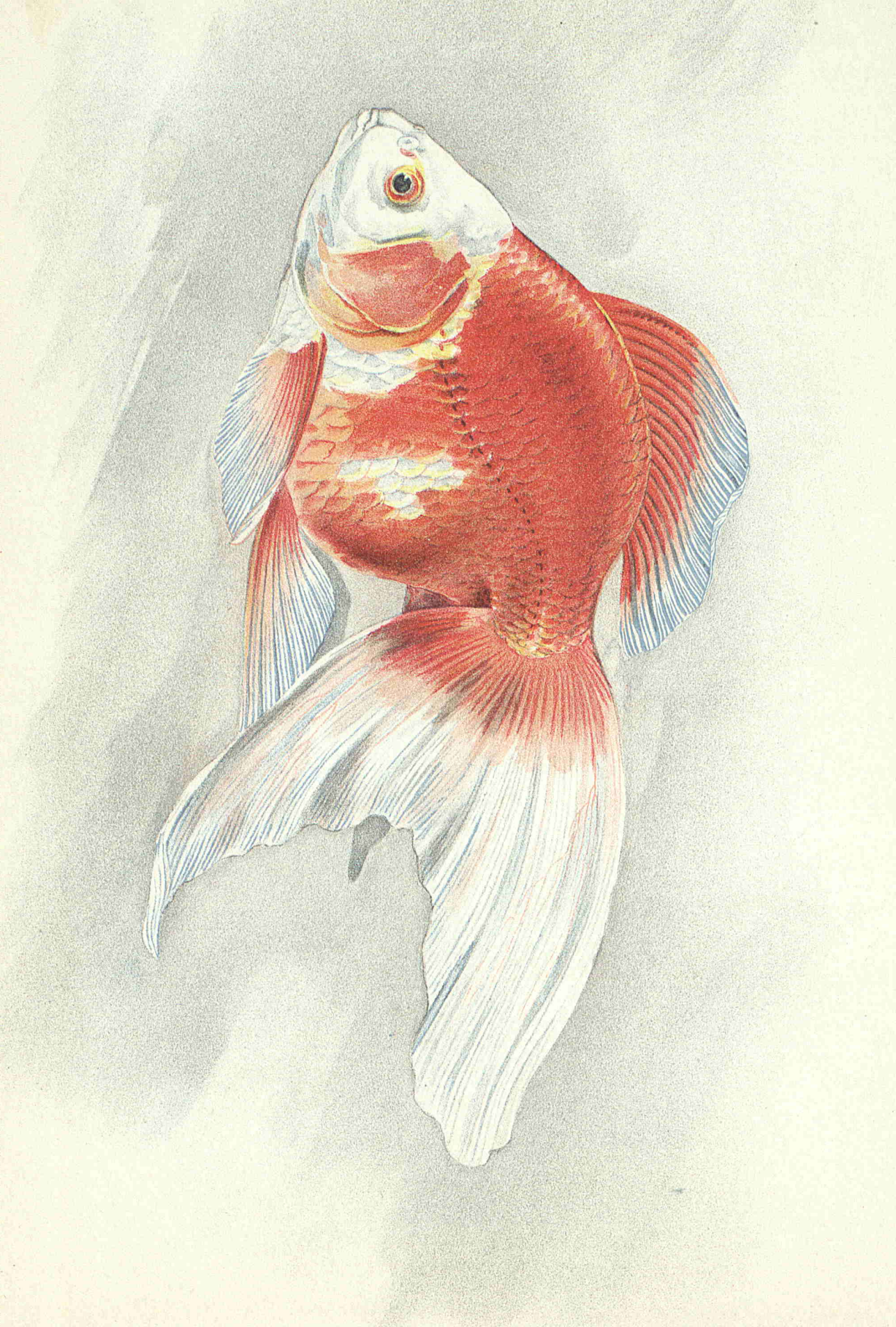


Plate XX.—RANCHU

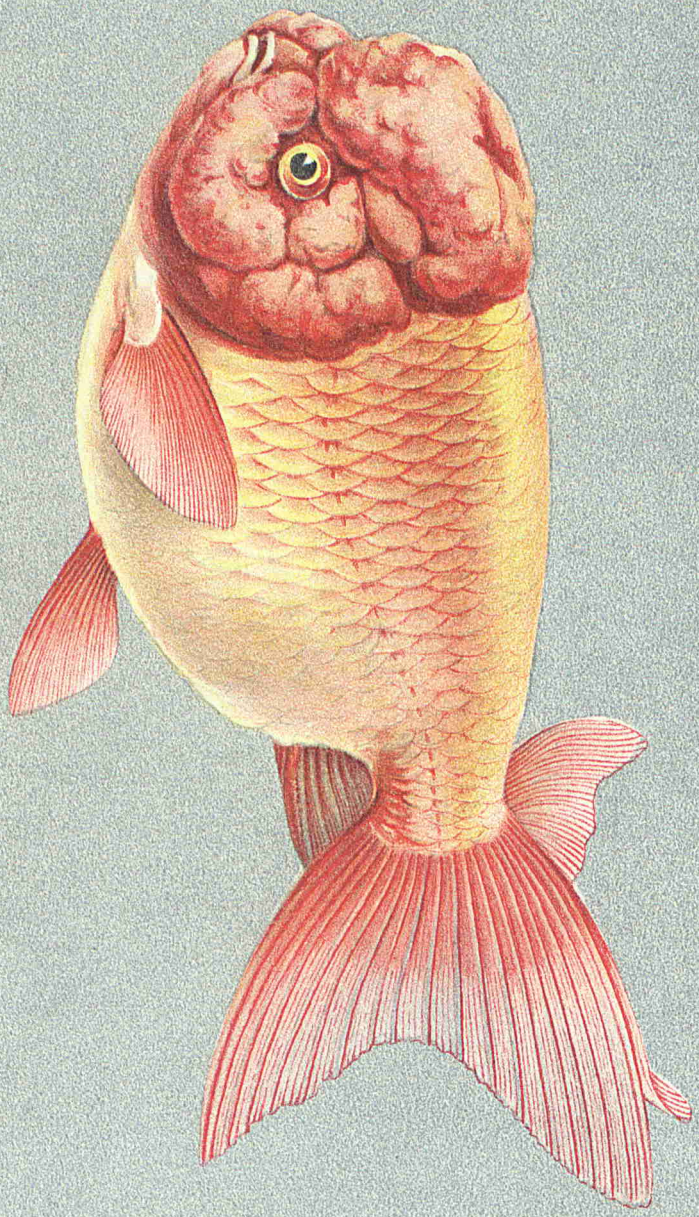


Plate XXI.—ORANDA SHISHIGASHIRA

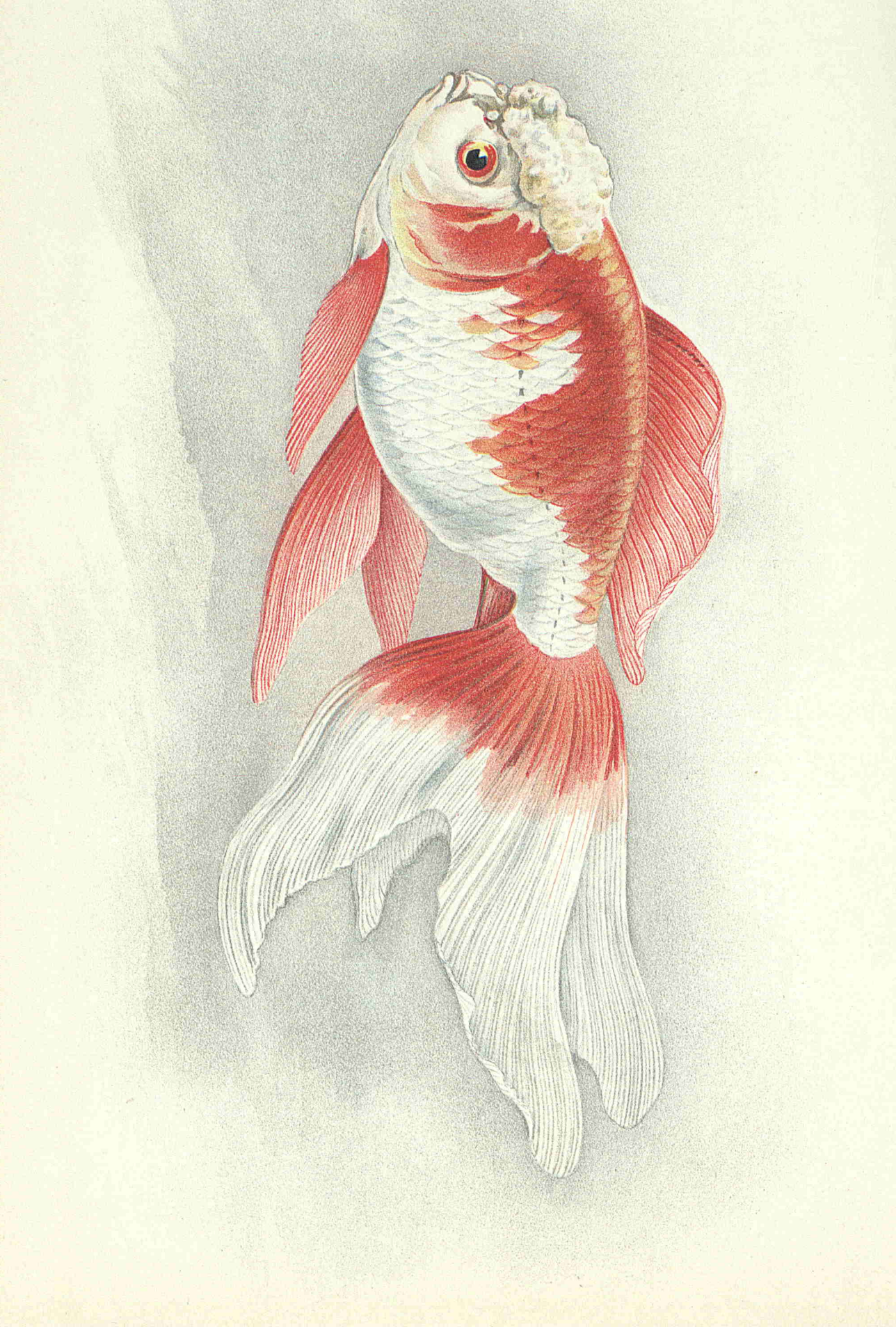


Plate XXII.—DEMEKIN

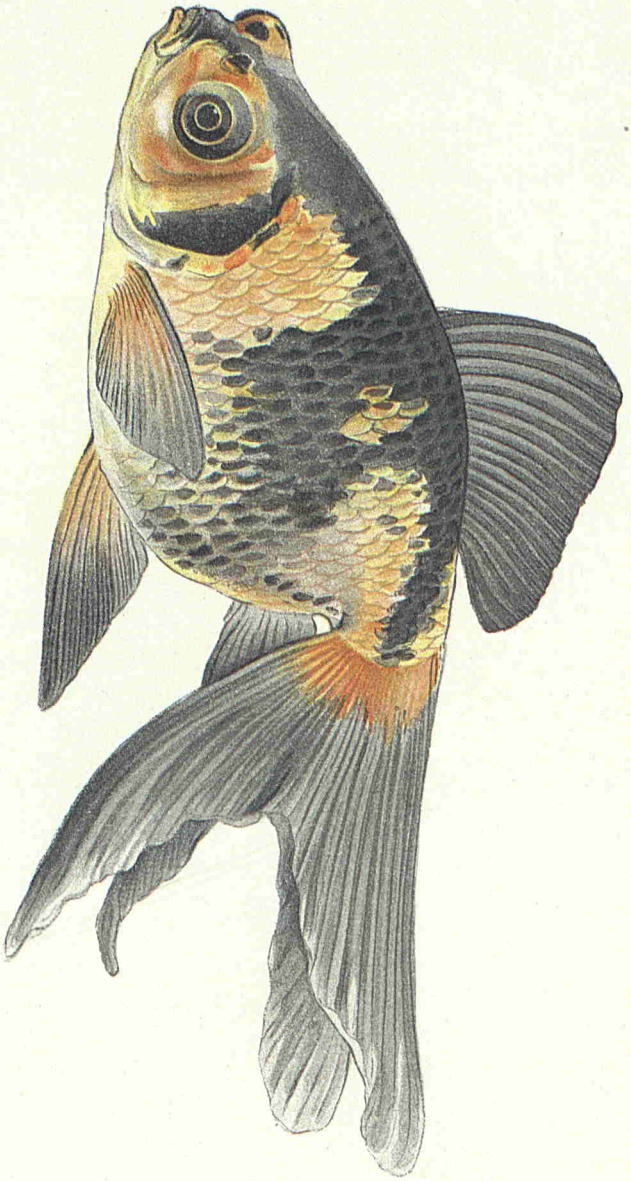


Plate XXIII.—DEME RANCHU

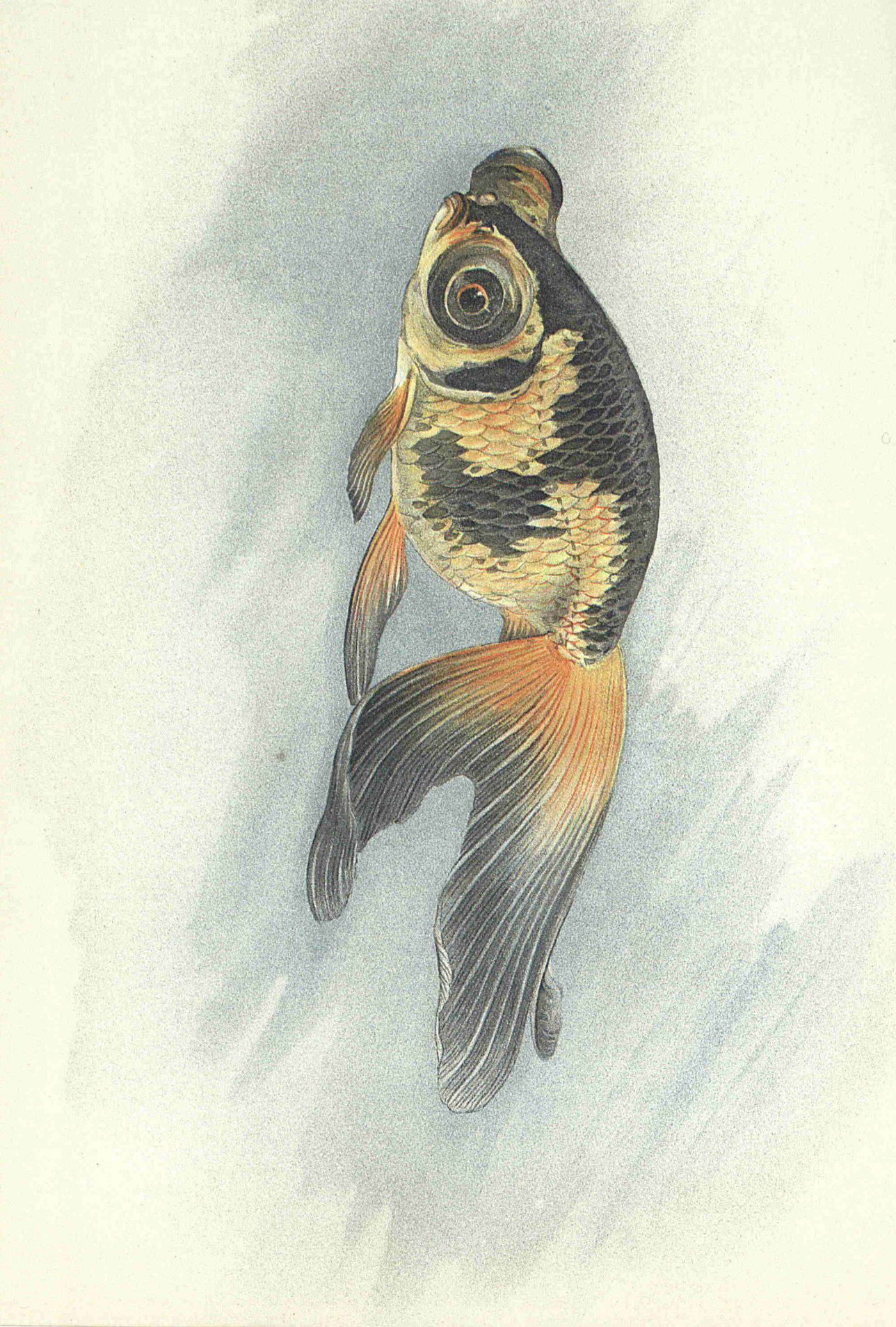


Plate XXIV.—WATONAI

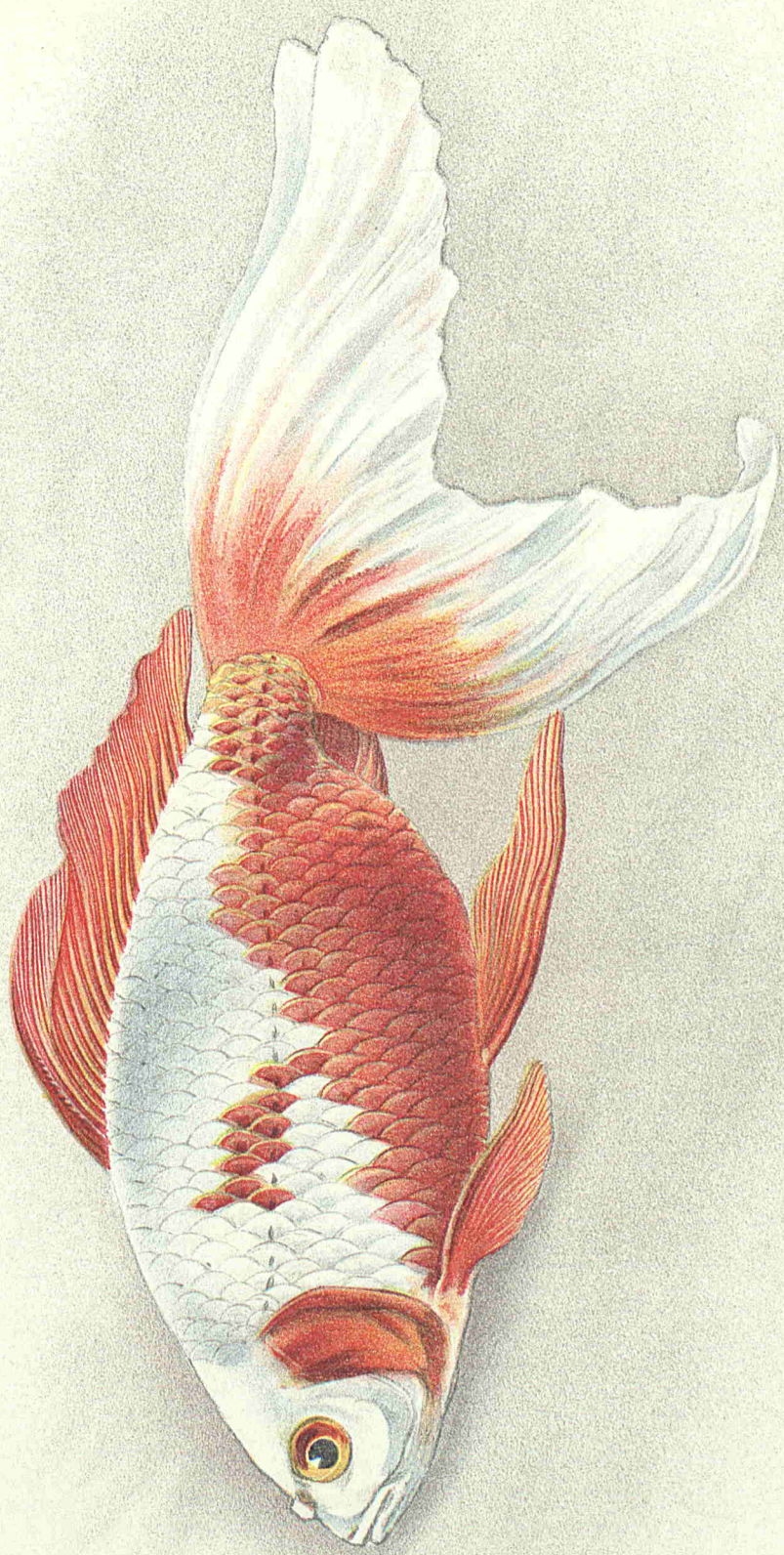


Plate XXV.—SHUKIN

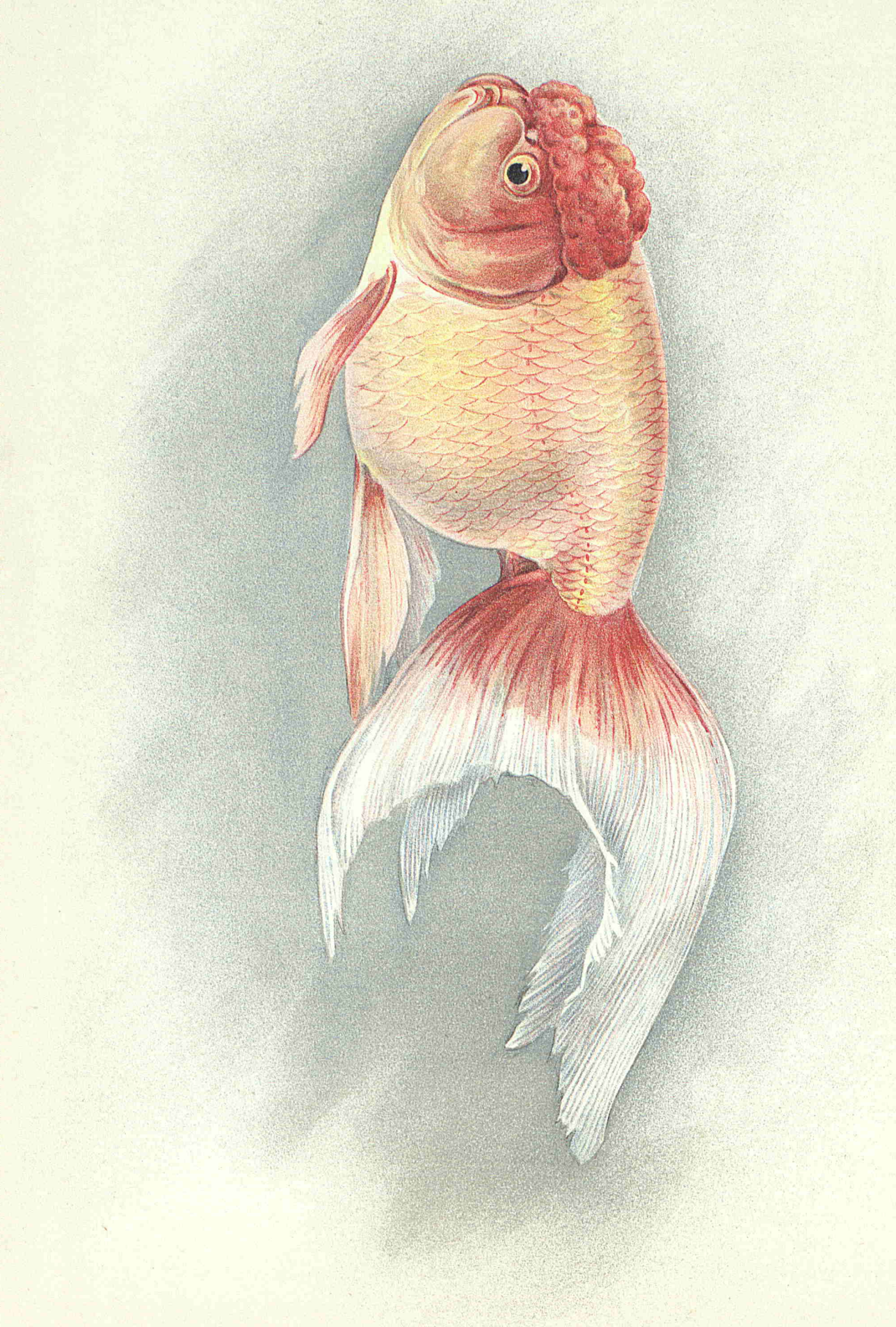


Plate XXVI.—SHUBUNKIN

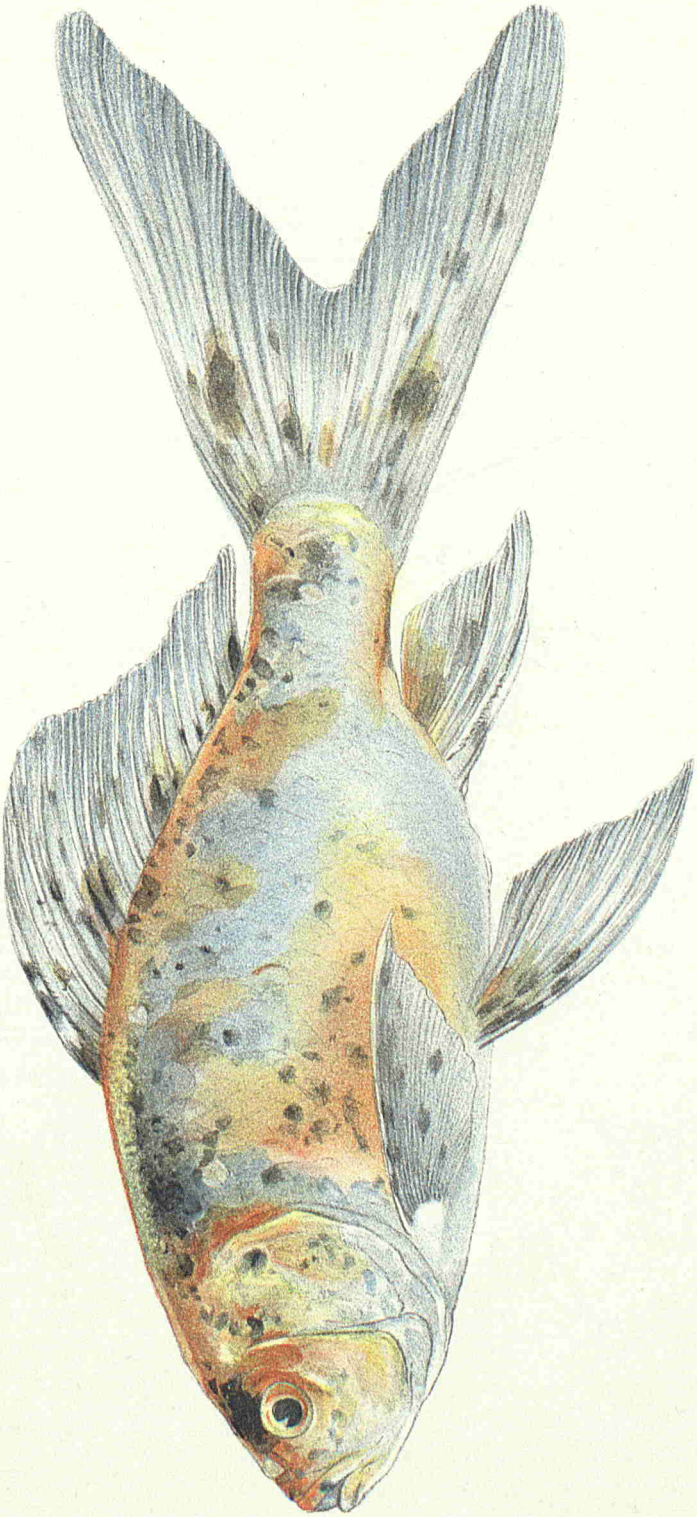
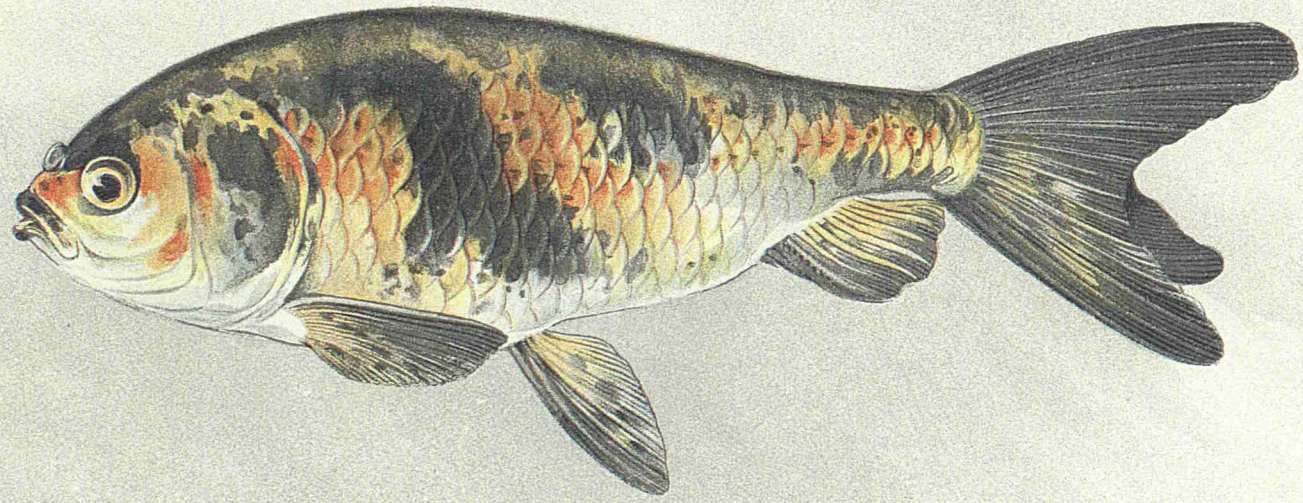


Plate XXVII.—KINRANSHI



THE COMMERCIAL SPONGES AND THE SPONGE FISHERIES

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Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded the prize of one hundred dollars in gold offered by John K. Cheyney for the best presentation treating of the methods of the sponge fisheries, the influence of such methods on the supply of sponges and the most effective means of conserving the sponge grounds

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CONTENTS.

		Page.
	Introduction	403
I.	The living sponge	404
II.	Requisites of a commercial sponge	407
	Color	407
	Size and shape	408
	Softness	408
	Fineness	409
	Toughness and durability	409
	Resiliency	409
	Absorptiveness	409
III.	The commercial varieties of sponges	410
	Common names in different languages	410
	Sheepswool sponges	411
	Yellow sponges	413
	Velvet sponges	415
	Grass sponges	416
	Glove sponges	419
	Reef sponges	419
	Hardhead sponges	420
	Wire sponges	421
	Turkey cup sponges	422
	Turkey toilet sponges	422
	Zimocca sponges	423
	Honeycomb sponges	423
	Elephant-ear sponges	424
IV.	The Florida sponge fisheries	425
	The sponging grounds	426
	Bay grounds	427
	Rock Island	429
	Pepperfish Key	430
	New ground	430
	Withlacoochee and St. Martins Reef	430
	Anclote	430
	Highlands	431
	Key grounds	431
	New grounds	433
	West of Key West	433
	Between Key West and Bahia Honda	433
	Money Key and Pigeon Key lakes	433
	Knights Key Channel and Rachel, Grassy, and Channel Key lakes	433
	Jewfish Bush lakes	434
	Lignum-Vitæ and Cotton Key lakes	434
	The Cowpens	434
	Biscayne Bay	434
	Hawk Channel	435
	Hooking	435
	Diving	442

IV. The Florida sponge fisheries—Continued. Page.
Killing and curing 451
The sponge trade 453
Sponge buying 453
Packing 454
Bleaching 456
Statistics 456
Foreign sponge trade of the United States 469
V. Other western Atlantic sponge fisheries 470
Bahama Islands 470
Cuba 472
Minor localities 474
Honduras 474
Nicaragua 475
Mexico 475
Colombia 475
Venezuela 475
Jamaica 475
Santo Domingo 475
VI. Sponge fisheries of the Mediterranean and contiguous waters 476
Spain and France 477
Adriatic Sea 477
Ægean Sea and Asia Minor 478
The Levant 480
Egypt 480
Tripoli 481
Tunis 482
Lampedusa and the Sicilian Sea 483
Algeria and Morocco 484
Methods of the fisheries 484
Wading 484
Nude diving 484
Harpooning 485
Dredging or trawling 486
Machine diving 489
Cleaning and curing 491
VII. Various minor localities 491
Philippine Islands 491
Australia and New Zealand 492
Other Pacific islands 493
Indian Ocean 493
Mid-Atlantic Ocean 493
VIII. Conditions and effects of the sponge fisheries 494
Depletion of the beds 494
Hooking and harpooning 497
Nude diving 498
Machine diving 498
Dredging or trawling 502
IX. Regulation and protection of the sponge fisheries, with particular reference to Florida 503
Measures in force 503
Measures proposed 505
X. Conclusions and recommendations as to the Florida sponge fishery 509
Bibliography 511

Plate XXVIII

Specimen of rock from the sponge beds off Anclote Key, Florida. This rock bears 13 species of commercial and noncommercial sponges, besides corals, sea-feathers, starfishes, crabs, and other animals characteristic of the fauna of the sponge beds. One-fifth natural size.

THE COMMERCIAL SPONGES AND THE SPONGE FISHERIES.

By H. F. MOORE,
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INTRODUCTION.

Sponges are known to the general public almost solely from their use in the toilet, one of their minor applications. They are vastly more valuable in the arts. In many trades they are practically indispensable, and despite long effort and the ingenuity of inventors no satisfactory substitute has ever been produced and it is doubtful whether one can be found. The properties that give a sponge its value are many, they are found in combination in no other natural or artificial product, and the perpetuation of the sponge supply is of no small moment to civilization.

The commercial sponges and their congeners are of wide distribution in the warmer waters, but the fisheries as at present developed are almost entirely restricted to the Mediterranean Sea, the Caribbean Sea, the Gulf of Mexico, and waters contiguous to these. Recently attempts have been made to establish a fishery in Australia, within the last year (1908) a few sponges have been shipped from the Philippines, and it is stated on rather vague authority that sponges resembling a poor quality of the Mediterranean toilet are now being fished on the coast of Madagascar. But the product of these regions is negligible in the markets of the world.

The Mediterranean fishery is of considerable antiquity, and it now produces over half in value of the world's supply, though it is impossible to obtain accurate statistics for all countries on its border. The newer fisheries of the American coast produce by far the largest quantity, but a predominance of lower-priced kinds reduces the value to about three-fourths of that of the Mediterranean fisheries. The following table gives approximately the world's annual yield at the present time:

Mediterranean and contiguous waters (partly estimated)	$2,039,000
Florida, 1903–1908 (average)	555,000
Cuba, 1903–1906 (average)	374,000
Bahamas, 1900–1905 (average)	520,000
Other localities (estimated)	10,000
Total	3,498,000

This paper, in conjunction with another on sponge culture,[a] is designed to furnish a brief, but fairly comprehensive, review of present knowledge of commercial sponges, the geographical distribution of the fisheries, the methods employed, the effects of those methods upon the natural beds, and the measures which appear to be necessary for the protection and conservation of the supply.

Concerning the qualities and the characteristics that distinguish sponges of different grades and values, the consumer is probably less informed than in respect to any other natural product in general use, and he is frequently imposed upon. In many cases it is difficult for even an expert to identify the different local varieties, though there is much difference between them in the qualities that fix their value for practical use. The distinctions by which the various grades can be recognized are, moreover, such as to be difficult or impossible of expression in words. For these reasons the illustrations of this paper have been prepared, with especial care, to supplement the descriptions. The sponges pictured are typical specimens of the numerous local varieties and without exception represent sponges now on the market.

As the purposes of the paper are mainly practical and economic, the discussion of the scientific status of the various kinds of commercial sponges, their general biology and morphology, has been reduced to the minimum necessary for a proper understanding of their nature and the problems which must be solved before the regulation of the beds can be placed on a rational and effective basis. The question of the scientific classification of the commercial varieties will be taken up some time in the future, when the accumulation of material and certain experimental data may offer some guarantee of better results than have been attained previously. The subject is one of extreme difficulty, and it is not believed that it can be successfully attacked without the assistance furnished by a well-equipped laboratory in the vicinity of the sponge grounds.

I. THE LIVING SPONGE.

To most persons familiar only with the sponges of the shops, the animal as it comes from the sea would be entirely unrecognizable. (Plate XXVIII.) It is a solid looking, rather slimy feeling, fleshy body, varying in color from light-greyish yellow through a considerable range of browns to black, and in form either cup-shaped, spheroidal, or cake-shaped, according to the species, its age, or the environment in which it grew. In general, in appearance and consistency and the manner in which it cuts with a knife, a living sheepswool sponge is not unlike a piece of beef liver, perforated with holes and canals.

[a] Moore, H. F.: A practical method of sponge culture, Proceedings International Fishery Congress, in Bulletin U. S. Bureau of Fisheries, vol. XXVIII, 1908, p. 545–585.

The sponge of the markets is merely the skeleton, the supporting framework, which gives strength and form to the soft gelatinous tissues of the living animal. It is composed of a substance similar in general chemical and physical properties to silk, horn, and chitin, the basic material which forms the shells of insects and crabs. This material is distributed in a fibrous network, usually in accordance with a definite general pattern in each species; the diameters of the fibers, the sizes of the meshes, and the relations existing between the several parts lying within more or less well-fixed limits. In addition, the main fibers always contain more or less foreign matter, sand grains, spicules, etc., embedded in their substance in the form of a core.

A casual examination of the living sponge will show it to be covered by a well-defined skin raised at more or less regular intervals into blunt little cones over the ends of the skeletal fibers, by which it is supported. Distributed over the surface, sometimes rather generally, sometimes locally, are sieve-like membranes, whose small pores lead into cavities lying just below the skin. From these cavities canals lead into the substance of the sponge, opening by numerous minute pores into as many small pear-shaped chambers, which from their opposite ends discharge through larger openings. If the canals leading from these could be followed, it would be found that, uniting with their fellows, they gradually increase in diameter until they open upon the surface of the sponge in one of the large conspicuous pores known as "oscula," or, as the spongers call them, "eyes." The oscula are sometimes more or less generally distributed, sometimes localized, according to the species, and each is surrounded by a smooth membrane capable of expanding or contracting in such manner as to vary the size of the opening.

This canal system is one of the most important organs, as well as the most characteristic feature of the sponge. It is the sole means of feeding and practically the sole means of respiration. Its method of functioning is as follows: The pear-shaped chambers described above are lined with cells of a peculiar character, collar cells, as they are called, each provided with a little lash or cilium projecting into the chamber and beating rhythmically in such manner as to set up a current in one direction. The mechanical effort of each is feeble, but the joint action of the untold numbers of such cells in a sponge sucks water through the small orifices in the surface, first described, into the ciliated chambers and in turn forces it into the successively larger canals until it finds vent through the oscula. The water, with its contained food and oxygen, therefore enters the sponge through the small superficial pores and leaves it by the large ones. Excluding from consideration the foreign bodies, shells, coral, etc., which the sponge often overgrows and surrounds, the whole interior, save the skeleton and spaces of the canal system, is occupied by tissues which are neither of many

varieties nor strongly differentiated. There are certain cells called "spongoblasts" which secrete the material of which the skeleton is composed. Collar cells and other epithelial elements line the ciliated chambers and the several canals with which they are in communication. The outer surface and the subsuperficial or subdermal surfaces are covered with a single layer of flat cells.

The main portion of the fleshy part of sponges is made up of what is known as ground substance, a jelly-like material, similar to that found in the umbrella of jelly fishes, without cellular structure, but containing connective tissue cells. Muscle cells are found in the skin, the canal walls, and the membranes around the peripheral pores, and nervous and sensory cells occur in association with them, an explanation of the limited sensitiveness and contractility which are noticed in handling live sponges.

Concerning the life histories of commercial sponges we know but little. In some species, at least, the sexes are separate, the females greatly preponderating, and the young are produced mainly if not solely from eggs. The young are, for a time, minute free-swimming organisms which may be carried considerable distances by the currents, and they are still very minute when they at last settle down for permanent attachment. At this stage, like oyster fry, they are liable to be covered and suffocated by comparatively thin deposits of sediment, and the object to which they can successfully attach must be hard and clean. It follows from this and from the fact that much of the sea bottom is more or less covered with soft deposits, however thin, that a vast majority of the young sponges fall on unsuitable bottom and are lost. This accounts in many cases for their irregular and sparse distribution on many rocky bottoms which superficial examination would indicate as favorable. The natural bars are undoubtedly capable of supporting a much heavier growth than they usually bear, and if partially grown sponges could be placed on them, as is proposed in the system of sponge culture elsewhere described, their productiveness could be enormously increased, as these deposits of sediment, fatal to the spat, would prove innocuous to larger individuals.

The rate of growth of sponges under undisturbed natural conditions is not definitely known, but the experiments recounted in another connection[a] indicate that it is slower than is generally supposed by the spongers. There is very good reason to believe that the average annual increase in diameter of sheepswool sponges in Florida waters is not greatly in excess of 1 to 1¼ inches. The rate varies somewhat in different localities and under different conditions. The average 6-inch sponge is probably not far short of four years old, though possibly the early growth may be more rapid than the experiments indicated for later stages.

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[a] Moore, H. F., op. cit.

Commercial sponges are very susceptible to the influences of environment, and when transplanted from one place to another speedily change in character. If grown in the midst of vegetation they become coarse and open in texture, of irregular shape, with long superficial processes and protruding oscular tubes. If raised high above the bottom the texture becomes more dense than that of neighboring bottom-grown specimens. Individuals suspended artificially on wires or growing naturally on gorgonians (sea feathers) tend to become spherical, and those torn loose to roll freely over the bottom assume the same shape, but develop harsh, very tough surfaces.

The commercial sponges of Florida, especially the sheepswool, yellow, and velvet sponges, can not live in water which falls for any considerable period much below oceanic salinity. Observations made in connection with sponge culture and on the natural beds indicate that the allowable minimum of salinity is reached when the water falls to a specific gravity of about 1.019 or 1.020. Exposure to the air is tolerated for considerable periods, especially during cool weather, and sponges grow naturally in situations where they are occasionally bared at low tide. From this extremely shallow water, the distribution of commercial sponges in Florida extends certainly to depths of 110 feet and probably to much deeper water, as in the Mediterranean, where they range to a depth of 500 to 600 feet. Of the food of sponges practically nothing is known. That it is taken in through the canal system and that it must be in a finely divided state is practically certain, but of what it consists and by what tissues it is absorbed is unknown. The so-called "roots" of sponges perform no other purpose than that of anchorage and are not special organs of nutrition like the roots of plants.

There appear to be few, if any, important natural enemies of commercial sponges, though perhaps they are subject to the attacks of microscopic organisms, producing certain epidemics which are ordinarily attributed to other causes. Crabs are ofter found in cavities burrowed in their substance, but despite popular belief to the contrary, I do not think that the chambers are actually excavated by the crabs. They probably find them ready-made and when they crawl in the pressure of their shells prevents filling up, or possibly expands the cavity.

II. REQUISITES OF A COMMERCIAL SPONGE.

The qualities of the skeleton affecting the commercial value of sponges are color, size and shape, softness, fineness, durability, resiliency, and absorptiveness.

Color.—The color is the consideration of least intrinsic importance, though for purely esthetic reasons it exerts a considerable influence on the price. The most desired color varies somewhat with different classes of sponges, but in general the lighter tones are preferred. For bath purposes a pale yellow appears to be most in demand, and this requirement is catered to by various processes

of artificial bleaching. Sponges of the same species will frequently differ in color in different localities. The sheepswool of the Florida Keys, for instance, has a deep reddish brown "root" and interior, while this is lacking in Rock Island specimens, and the latter are also more grayish externally. As these color characteristics are correlated with differences in other qualities, especially durability, they are of value in distinguishing the grades. In general the sponges of commerce, i. e., the skeletons, are yellow, light brown, or brownish gray.

Size and shape.—The most desirable size and to some extent the shape depend upon the purpose to which the sponges are to be put. For surgical purposes small ones are required, for toilet use a medium size, while for cleaning vehicles and cars a large sponge holding a considerable quantity of water is necessary. Sponges up to about 8 inches in diameter are commonly used entire and called "forms," but above that size they are usually cut into pieces and known commercially as "cuts." Most or all American sponges of a less diameter than 4½ to 5 inches are of comparatively little use and value, but the Mediterranean grades find a market in even the smallest sizes. Some species possessing all the other requisites are debarred from the markets solely by their shape.

Whatever the form of a sponge, to be of commercial value it must be regular, more or less massive, and free from long processes and digitations. Certain of the inferior Cuban sheepswool sponges are about the only exception to this rule, and in the case of these the long, teat-like projections which carry the oscula at their summits are usually cut off more or less close to the massive base from which they rise. Under normal conditions all commercial sponges are either spheroidal, cake shaped, conical, or cupped. The gradations between these shapes are infinite and each species presents great variety, due to age, environment, and perhaps individual tendency. The shapes assumed by the various species will be considered in the descriptions of the several commercial varieties.

For general purposes the most desirable forms are the spheroidal and cake shaped. In applying the glaze to pottery, however, and in other similar work, a smooth, flat surface is desired, and this is generally obtained either by cutting up the more massive forms or by taking pieces from a smooth-surfaced cup-shaped sponge like the Mediterranean elephant's ear. The American rough-surfaced conical and cup-shaped sponges, like the Anclote grass, are usually cut, invariably so when they are of large size.

Softness.—The more desirable grades of sponges, other things being equal, are those which are softest, the cheaper, inferior grades being generally, though not always, more or less harsh. This quality depends upon the thickness and arrangement of the fibers, the amount of foreign matter included in them, and

the openness of the canal system. Sponges with comparatively slender fibers, with the microscopic meshes rather open, with a small amount of foreign matter included in the spongin, and with an open canal system, are the softest. Those in which the fibers are heavily laden with sand are invariably harsh.

Fineness.—Fineness depends upon the macroscopic rather than on the microscopic arrangement of the skeleton, though the slenderness of the fibers is a factor. The Matecumbe sheepswool is one of the softest of sponges, but its open structure makes it appear coarse when compared with Mediterranean kinds. Fineness in the same species varies more or less with the environment under which the individual is produced.

Toughness and durability.—These qualities depend upon both the microscopic and the macroscopic characters of the sponge skeleton, and also apparently to some extent upon its chemical properties. These factors vary with the sort or species and in the same sort are subject to environmental differences. In any given species the looser the general structure and the larger and more numerous its canals and subdermal spaces, the more easily it is torn and the sooner it breaks down in use. The loose, open-textured sheepswool sponge of Biscayne Bay is much more quickly destroyed in a given service than is the denser Rock Island variety. That chemical factors also enter into the matter is apparently indicated by the greater tenderness of the red-rooted Key sheepswool as compared with equally open selected specimens from the Bay grounds not exhibiting this peculiar color.

Resiliency.—Upon this quality depends very largely the value of a sponge for economic purposes. Sponges are generally more elastic when dry and more compressible when wet, and if under the latter condition they return promptly to their original shape when the compression is removed they are more useful than if sluggish or "soggy" in their reaction. Resiliency depends upon the size of the fibers and the arrangement of the microscopic mesh work, and also upon the thoroughness and manner of cleaning. Specimens poorly cleaned and containing much "gurry" are sluggish in returning to shape after compression.

Absorptiveness.—This quality depends upon a combination of softness, fineness, and resiliency, and is the fundamental property upon which the usefulness of a sponge depends. A sponge that takes up little water or that absorbs it slowly or that drains quickly after it is removed from water is inferior for all purposes to one having the converse properties.

Water is absorbed by the capillarity of the mesh work, and the finer and closer this is the more water taken up and retained. The fibers themselves absorb a small amount of moisture, but this is not available for mechanical purposes, as it is released by evaporation only. Resiliency assists in absorption by promptly opening the meshes after compression, so that they act mechanically like so many minute pumps. The most copiously and quickly absorbent

sponges have fine meshes, slender fibers, and generally close texture. Large canals and cavities decrease the amount of water which can be absorbed in proportion to the size of the sponge, though they do not necessarily affect the rapidity with which it is imbibed.

III. THE COMMERCIAL VARIETIES OF SPONGES.

Both the scientific and commercial classifications of economic sponges are much confused and unsatisfactory and the two are mutually contradictory. Sponges considered by zoologists as of the same species or variety are separated into different commercial grades or species often differing widely in value, and, conversely, the trade often recognizes under the same name species that are undoubtedly zoologically distinct. These animals are so extremely plastic and susceptible to the influences of local environment, changing form, appearance, and character so completely under changing conditions, that it appears hopeless to expect a satisfactory scientific arrangement until present methods of research and nomenclature are completely departed from. In the present paper, designed as it is for economic purposes, the commercial classification is followed, the probable scientific names of the sponges described being indicated but incidentally.

In the following list are given the names commonly used in several languages, but the commercial classification is much more complex than is here indicated. All of the principal kinds are further subdivided in the markets according to geographical origin, quality, and even the methods by which they are taken. Among American sponges, in addition to the various geographical and local designations we have "forms," "cuts," and "seconds," while in the Mediterranean there are "fines," "commons," "seconds" (écarts), plongées, harpoonées, etc.

COMMON NAMES OF COMMERCIAL SPONGES IN DIFFERENT LANGUAGES.

English.	French.	Cuban.	German.
Sheepswool; wool	Indienne	Hembra.	
Yellow	Boulet	Macho fino.	
Velvet; boat	Havanne	Farao; aforrada.	
Grass	Afrique	Macho cueva.	
Silk grass		Macho peludo.	
Glove		Macho dulce; macho guante.	
Reef; "West India surgeon's"	Fine Antille	Macho dulce.	
Hardhead; American zimocca	Fine dure	Machito fino.	
Turkey cup; Turkey solid	Coupe turque; fine douce de Syrie; de Archipel.		Feiner Levantinerschwamm.
Toilet	Fine douce de Adriatic		Levantinerschwamm.
Zimocca	Chimousse; fine dure de Syrie; fine Grecque.		Zimokkaschwamm.
Bath; honeycomb; horse; Venetian, etc.	Fine de Syrie; fine blonde; commun de l'Archipel, etc.		Badeschwamm.
Elephant ear; wash rag; laparotomy; flat potter's.	Oreille d'elephant		Ohrenschwamm; Mundschwamm; Levantinerlappen.

Common names of commercial sponges in different languages—Continued.

English.	Italian.	Greek.	Various.
Turkey cup; Turkey solid		Melati; fina eklekta	Abiund (Syria).
Toilet	Spugne da bagno; Levantine.	Melati.	
Zimocca	Spugne zimocca	Tsimouka	Achmar (Syria); tsimouri (Turkey); hadjemi (Tunis).
Bath; honeycomb; horse; Venetian, etc.	Spugne da equine	Hondra (Hydra); kapadika (Calymnos).	Cabar (Syria).
Elephant ear; wash rag; laparotomy; flat potter's.		Psathouria; lafina (Hydra); lagofita (Kalymnos).	

SHEEPSWOOL OR WOOL SPONGES.

Hippospongia canaliculata gossypina.

The sheepswool sponges, which are found in the Gulf of Mexico, the Caribbean Sea, and the adjacent parts of the Atlantic Ocean, all appear to belong to this variety, with the possible exception of certain specimens from Cuba, concerning which I am uncertain. They exhibit wide local variation, are very sensitive to environment, and when transplanted from one locality to another undergo marked change in character. The whole surface of the skeleton is tufted with fascicles of fibers, which are longer and more fimbriated in the shoal-water specimens. The oscula are confined to the upper surface, are large and comparatively few in number. They are usually surrounded with a circle of tufts and are often slightly, sometimes enormously, elevated on cones or tubes. The color of the living sponge is black, becoming brownish at the base. These sponges grow to a large size, 18 inches or more in diameter, are soft, absorbent, very durable, and of good shape. They are unequaled for general bath purposes and for use in the arts. They are employed generally for cleaning carriages, cars, and other highly polished surfaces where size, softness, durability, and great capacity for holding water are required. The larger perfect forms are used as gun swabs in the army and navy, or are divided and sold as "cuts" for use by tile and brick layers, painters, potters, and other artisans. The market varieties are as follows:

Florida Rock Island (pl. XXX and XXXI).—These, the best and highest-priced sponges of North America, are found in the Gulf of Mexico, on the west coast of Florida between Johns Pass and St. Marks. They are generally rather flat and with a broad base, closely knit, soft and strong. The surface color is grayish brown and the root and interior are little tinged with red. Those from deeper water are superior to shallow-water specimens in texture, density, and durability.

Florida Key wool (pl. XXXII and XXXIII).—This variety comes from the Key grounds elsewhere described, and is next in value to the Rock Island, which it surpasses in softness, especially if from near Matecumbe Keys, but does not equal in

strength, durability, or capacity for holding water. The surface color is paler, and the interior and often the insides of the oscula and the surface channels are colored a rather bright red. The surface is generally well felted, but the interior is more open and the fibers weaker. It tends to grow proportionally higher than the Rock Island sponges, especially when young, and the base is narrower, an inverted pineapple shape being common.

Bahama wool (pl. XXXIV and XXXV).—This is generally inferior to either the Rock Island or the Key wool, being coarser and more open and less durable and absorbent. The softest and best specimens come from the vicinity of Abaco. The shape is generally rather flat and the upper surface much tufted. Those from the vicinity of Andros Island are generally rounder than from other parts of the archipelago and the lamellæ tend to become thicker and less tufted on their free edges, sometimes remotely resembling the velvet sponge.

The Bahama wool sponges are pale yellow superficially and those from some localities have pale vermilion roots, while from other places they are practically untinged with that color.

Cuba wool (pl. XXXVI).—The ordinary Cuba sheepswool sponge has the same general characteristics as the Bahama variety, though inferior to Abaco specimens. Another form which is not uncommon, and which rather insufficient material indicates may be zoologically distinct from the other sheepswool sponges, has a rather flat incrusting base from which arise as many as thirty oscular tubes, sometimes reaching a length of 8 inches and 2 inches in diameter. These tubes swell somewhat toward their middles and tend to anastomose. Certain specimens indicate that this anastomosis may become so complete as to form fluted columnar sponges, twice as high as thick, with long stout oscular tubes on the upper surface. Lendenfeld does not recognize this as a distinct zoological variety.

Mexican wool.—This is the poorest of the sheepswool sponges, being coarse, loose of texture, much more tender than those that have been mentioned, and lacking in resiliency. Its surface color is dark-brownish gray and the root and interior are dull rusty red. In shape it is rather high, growing from a narrow base, and the oscular pores on the upper surface are large, open, and ragged. These sponges grow in the shallow waters, but it is stated that a type much superior is found in deeper water on certain parts of the coast, especially about the island of Cozumel.

Honduras wool.—On the coast of British Honduras is found a wool sponge which resembles the Mexican but is of slightly better quality. It has in most cases the same dull red or brown root and interior and the ragged oscular openings on the top. It has a lighter superficial color than Mexican specimens and appears to be rather stronger and more resilient. The sponges are usually irregular in shape, but this quality will probably be found improved in deeper water, those now taken being from the shallows.

Other localities.—Sheepswool sponges are taken to a limited extent commercially, or are known zoologically, in Honduras, at the island of Gonaves, Haiti, and at other places in the Caribbean. In the Philippine Journal of Science Seal describes a wool sponge from the Philippine Islands. The specimen he exhibited to me had the appearance of a Bahama sheepswool, and had been used for bath purposes. It is not unlikely that it was imported and not indigenous.

YELLOW SPONGES.

Under this name are known sponges of several zoological species and varieties, some of which receive also other commercial names, according to quality, size, and locality. Though differing much in details and special qualities, the yellow sponges have these characters in common: They are highly elastic and resilient, more so than any other American sponges with the possible exception of the Anclote grass, but they are harder than the wool sponges, less absorbent, and drain more freely. They are regular in shape, attractive in appearance, and grow to a diameter of about 18 inches, though this size is not common. The color is a rich yellow or yellowish brown, in some localities tinged with rust red or chestnut. The surface is never furnished with the long fibrous filaments characteristic of the sheepswool, but is covered with a nap of short hairs of uniform length and lying in a uniform plane. Though less durable than either the sheepswool or the velvet sponges, the yellow sponges are excellent for many purposes in the arts, and when bleached make attractive and soft, cheap bath sponges.

In the living condition they have smoother surfaces than the sheepswool, and are very dark brown on top, becoming yellower on the sides. The pseudoscula, vents, or "eyes" are in some varieties situated on the summits of low, rounded cones and in others lie in the general level of the upper surface. They are never surrounded by circles of fimbriated tufts as in the sheepswool, or compounded as in the velvet sponge. They are generally large and conspicuous. The commercial varieties of yellow sponges are as follows:

Florida Key yellow (pl. XXXVII, XXXVIII, and XXXIX).—This is the finest grade of yellow sponge, being softer and more durable than the Anclote yellow or the foreign varieties. The best come from the vicinity of Matecumbe Keys, where the common species is *Hippospongia equina elastica* Lendenfeld. This species is massive, cake-shaped, or, commonly, in the form of truncated cones attached by a narrow base. The lamellæ form a network lying in a uniform surface, are usually more or less thickened at their free edges and inclose numerous more or less uniform polygonal, circular, or meandering orifices. The surface of the skeleton is more continuous than in most of the other American sponges. The vents or "eyes" usually lie in the general level of the upper surface, but are sometimes, especially

in the larger specimens, raised on soft rounded cones or craters, the rims of which are generally interrupted in one or two places.

Another variety of Key yellow sponge is *Euspongia irregularis pertusa*, the common form of the Anclote region and Cuba, but this is inferior and less numerous.

Anclote yellow (pl. XL and XLI).—These consist almost wholly of the zoological variety last mentioned. They are more massive than the common Key yellow and are almost invariably attached by a broad base, from which the sides and tops rise in a more or less regularly convex surface, bearing low, broad cones or lumps on the summits of which the oscula open. The latter occur more or less over both sides and top, and are not confined to the upper surface as in the preceding species. The surface of the skeleton is more uneven and lumpy than in *Hippospongia equina elastica* and the superficial villi of fibers are longer and more tufted and frequently connected with one another by an irregular loose network of fine fibers.

These sponges are harsher and less compressible than the Key yellow and less desirable for commercial purposes.

Bahama yellow (pl. XLII and XLIII).—There are two common species of Bahama yellow sponges. One is *Euspongia irregularis pertusa*, the common Anclote form, from which it differs mainly in the more numerous oscula and the brighter yellow color of the skeleton.

The other is Hyatt's *Spongia agaricina* subsp. *dura*, which Lendenfeld apparently erroneously includes with his *Hippospongia equina meandriformis*. This sponge is more open in texture and less strong than the foregoing, but softer and more quickly absorbent. It is spheroidal in shape, though often one-sided on account of lateral attachment to the rocks, and the free ends of the lamellæ lie in a common surface as in the velvet sponge, but the exterior faces, instead of being felted and compact, are covered with a nap of loose-ended fibers, giving the whole surface a villous appearance and a rougher feel. The lamellæ consist of radially arranged club-shaped bundles connected by tangential buttresses or lugs, making a weak structure easily torn into radial shreds. The color is light brown. The oscula are single, not compound as in the velvet sponges, and are scattered over the upper surface and occasionally on the sides. Hyatt says that this is the "hardhead," but so far as I have observed the spongers now class it as "yellow." It appears to be particularly common near Andros Island.

The common yellow sponge of the Florida Keys is also found in the Bahamas, but does not appear to be generally included among shipments of yellow sponges.

Cuba yellow (pl. XLIV).—The common Cuba yellow sponge is the same species as the Anclote yellow, *Euspongia irregularis pertusa*, from which it differs mainly

in its brighter color and more cavernous structure, the oscula being more numerous and the blunt cones in which they are situated being separated in the skeleton by clefts entering rather deeply into the body of the sponge.

A variety similar to the Key sponge is found on the north coast of Cuba.

Honduras yellow.—This commercial variety, which comes from British Honduras, is the same zoologically as the Key yellow. It resembles the latter in surface appearance, but is harsher, less compressible, more open in texture, weaker, and less durable. In color it is bright yellow and it lacks the red root and interior of the Key sponge, from which it further differs in its habit of flatter growth. It is less harsh than either the Cuban or the Bahama yellow.

Other localities.—*Hippospongia equina elastica* is also found in the Mediterranean, where it is known as the horse sponge and otherwise, from Haiti and other places in the Caribbean Sea, and from Australia and New Zealand. *Euspongia irregularis pertusa* is known zoologically from Ceylon, Australia, and the Ellice Islands in the Pacific Ocean.

VELVET SPONGES.

The velvet sponges found in the straits of Florida, the Caribbean Sea, and the Bahamas, with the possible exception of the Jamaica sort, appear to belong to Lendenfeld's *Hippospongia equina meandriformis*. They are generally cake-shaped or spheroidal in form, somewhat broader than high and usually attached by a moderately broad base from which the sides swell out. The surface lacks the pointed or the edged tufts of the sheepswool sponge and the lamellæ are thickened at their free edges to form rounded or flattened cushions lying in the same plane and imparting a smooth appearance to the sponge. These cushions form either meandering ridges or flat brush-shaped tufts, adjacent ridges being often united by a felting of fibers producing a flat surface.

There are usually two, sometimes one, or three, large pseudoscula or vents on the upper surface. These are subcircular ragged openings, unlike those of any other commercial sponge, divided internally into numerous circular openings by irregular torn-looking septa. The color of the skeleton is light brown or dull yellow.

The velvet sponges are very soft to the touch and well deserve their name, but they are rather less compressible than the sheepswool and absorb water less quickly. They are also less durable and on account of the large holes or vents in the upper surface tear more readily. They are next in value to the sheepswool, though not differing much from the yellow in price. Following are the commercial kinds or grades:

Florida velvet (pl. XLV).—Found only on the reefs between Key West and Cape Florida, where comparatively few are taken. They are generally rather harsh and more or less torn and irregular.

Bahama velvet (pl. XLVI).—These bring the highest price, and the best, from near Abaco, are excellent sponges, very soft, of good shape, and moderately strong.

Cuba velvet (pl. XLVII).—These somewhat resemble the Florida sponges and are about equal to them in quality, though softer and frequently with the pads less compact and more tufted or "frizzly."

Honduras velvet.—The velvet sponges are the best that have been produced, so far, in British Honduras. They resemble the Cuban sponges more closely than those from other localities and appear to be about equal to them in quality. The rollers are hard but attached specimens are usually soft, though not so strong as Bahama specimens.

Jamaica velvet.—This differs much from the other velvet sponges. Its surface is more villous, the lamellæ less swollen on their free edges, and the shape tends to uprightness rather than rotundity, the older specimens especially being decidedly columnar. The most marked difference, however, is in the character of the vents, which instead of lying in subcircular septate depressions are grouped in single or double rows on the summits of branching crests which cross the tops of the sponges. The crests are formed of laciniated tufts somewhat like those which surround the vents or "eyes" of sheepswool sponges, and the individual openings are incompletely separated by ragged partitions as in the other velvet sponges. This arrangement results in a gash or tear more or less completely across the top of the skeleton. These sponges are harsher and otherwise inferior to the other velvet sponges.

Other localities.—This species is also known zoologically from Fernando de Noronha and Mauritius. A few inferior velvet sponges are taken on the Mexican coast but are usually included with the equally inferior sheepswool from that country. The few sponges taken about the island of Gonaves, off the west coast of Haiti, are principally of this species.

GRASS SPONGES.

Grass sponges are known commercially from Florida, the Bahamas, Cuba, Mexico, and British Honduras. They exhibit great diversity of shape and texture, but are all inferior in quality, lacking in durability, usually harsh to the touch, or, if soft, exceedingly tender. Most of them appear to belong to Lendenfeld's *Hippospongia equina cerebriformis*, but it is by no means clear that they are all of this variety or that they can be assigned to Hyatt's several varieties of his *Spongia equina*. None of the descriptions is sufficiently clear and complete to enable one to assign satisfactorily any large proportion of a considerable series. Following are the commercial varieties:

Anclote grass (pl. XLVIII).—These are the best of the grass sponges, but their shape is such that they are generally used as cuts. They are almost always

shaped like waste-paper baskets, inverted truncated cones deeply hollowed on their upper faces. The attached base is one-third to one-half narrower than the upper rim, the sides are almost straight or slightly convex, and the interior is hollowed out almost to the base in the larger specimens. The sides are sometimes nearly smooth, but are generally furnished with interrupted vertical ridges tufted at their upper ends, and are perforated by numerous orifices about $\frac{1}{16}$ inch in diameter. There are no oscula on the outer surface, although there are often irregular openings penetrating to the interior or even to the central cavity. The walls are thin at the rim of the vase and thicken toward the base. The oscula or vents are numerous and cover the whole interior of the sponge, excepting the vicinity of the rim. They are about $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter and in the skeletons of older specimens are frequently converted into demicylindrical radiating furrows by the breaking down of the walls toward the cavity of the vase.

The skeletons are of a dirty brown color, harsh to the touch and highly elastic and resilient. These sponges are used by manufacturers of explosives, by masons, and for cleaning purposes about machine shops. They are especially useful where there is much oil, as greasy matter is more readily washed out of them than from any other sponge. For this reason, and on account of their harsh, stiff surface, they are useful for domestic purposes in washing pots and pans. They are found distributed over the entire Bay grounds.

Key grass (pl. XLIX, L, and LI).—These sponges are much more diverse in appearance than the corresponding grade from Anclote, are softer, more compressible, and much less durable. A typical form arises from a short narrow base or peduncle, spreading into a more or less hemispherical massive sponge with a flat or slightly concave top. The whole exterior is nearly covered by thin-walled oscular tubes about $\frac{3}{4}$ to 1 inch in length, the openings having a diameter of about $\frac{3}{16}$ inch. These tubes are directed variously, sometimes opening almost vertically downward, are sometimes deficient on one side, as in Lendenfeld's *Hippospongia canaliculata cylindrica*, and are not infrequently branched or Y-shaped. In some cases they extend more or less completely over the top of the sponge, but in the skeleton the latter is usually occupied by a great number of closely approximated orifices, about $\frac{1}{8}$ inch wide, separated by extremely thin walls, this feature being the principal reason for the great weakness of the sponge. In life this portion is covered by a membrane perforated by extremely minute pores, and even when the tubes extend over the top the space between is covered by a membrane of this character. In older specimens the oscular tubes on the outer surface become shorter and less prominent, though retaining the general characters just described.

In other cases the walls of the sponge become much folded and occasionally lobular, and the outer surface bears pencils, tufts, and vertical ridges of fiber,

which obscure the oscula and produce a cavernous interior. The walls in this type of sponge tend to become more vertical and the base of attachment broader, and as the top is often concave by the decay of the tissues, the sponge is more like the Anclote sponges, from which it is distinguished by its more irregular surface, its cavernous interior, thicker rim, and greater compressibility and tenderness of fiber, as well as by the presence of oscula on the outer surface. In other specimens the outer walls are smoother, with fewer and less conspicuous oscula, and the tufts of fibers are shorter and more uniform, exhibiting between them numerous small orifices. The whole top of these specimens, excepting a zone at the rim, is perforated by pores of uniform size, like those described in the first variety.

The Key sponges appear to be Hyatt's varieties *typica*, *plana*, *divisa*, and *caliciformis*, although his descriptions can not be recognized with certainty. The gradations are multifarious.

Bahama grass (pl. LII).—These differ strongly in general appearance from the Anclote and Key sponges and most of them probably, though by no means certainly, belong to Hyatt's variety *obscura*. They are generally round or cake-shaped and regular and are covered with fibrous tufts and pencils somewhat resembling those of the sheepswool sponge. The oscula are rather numerous, circular, and confined mainly, though not entirely, to the upper surface; but each has its own tube separated from that of its fellows, and there is nothing resembling the sieve-like upper surface of the Key sponges. The oscular tubes are thin-walled, of nearly uniform length in each individual, and the spaces between them are more or less completely filled with an irregular net or loose felt of fibers. In older specimens the soft superficial tufts often almost or quite disappear and the walls of the tubes break down, producing a rough, ragged exterior. The small specimens are light yellow, soft and compressible, the larger ones brown, harsh, elastic, stiff, and weaker in texture. Specimens from Andros Island, which grow principally on sea feathers, are nearly spherical, the oscula are less conspicuous, the surface tufts cushioned or palmate, and the texture weak.

Cuba grass (pl. LIII).—The Cuba grass sponges considered as a whole are intermediate between the Key and the Bahama sponges. In a given lot there are likely to be specimens resembling the *plana* type of Key sponges and others like the *obscura* type from the Bahamas with more or less intergradation. In old age the *obscura* type sometimes becomes cavernous and with a very irregular nodular surface. The quality on the whole is inferior to that of the same grade from the Bahamas.

Honduras grass.—The grass sponges from British Honduras appear to belong to the *obscura* type and resemble the coarser and harsher of the Bahaman

and Cuban sponges. There are occasional soft specimens, but in general they are so hard as to be of little commercial value.

GLOVE SPONGES.

This is the *Spongia graminea* of Hyatt, which Lendenfeld in his synonymy includes with certain Australian specimens in his *Hippospongia canaliculata*, var. *flabellum*, though the description which he furnishes does not apply, except perhaps as to the character of the fibers.

The shape is never "thickly flabellar," but almost invariably stoutly columnar, the sides being almost vertical and contracted at the top, which is usually flat. The base is almost as broad as the sponge. The appearance of this species is very characteristic, the sides being fluted with irregular vertical parallel ridges between which lie one or two rows of round holes from $\frac{1}{16}$ to $\frac{3}{16}$ inch in diameter. The ridges are frequently swollen on their free edges, which always bear long, ragged pencils of fibers. When the grooves are deep the ridges become plates, which viewed from above have a radial arrangement. They begin a short distance above the base and extend over the top of the sponge as far as the large open compound vents, which remotely resemble those of the velvet sponge.

Glove sponges are found on the Key and Bay grounds of Florida (pl. LIV) and in the Bahamas. Those from the Bay ground are very poor and are rarely brought in by the spongers, to whom they are known as "bread sponges," on account of their excessive tenderness. Glove sponges are very soft and elastic, but owing to the weakness of their fiber and their open texture they are almost worthless for commercial purposes. Hyatt states that "this is one of the grass sponges;" hence his name for it, but it is now generally known by the name used here.

The best glove sponges come from Biscayne Bay, where they grow stronger, less open, and with lower ridges than in other parts of the Keys.

REEF SPONGES.

The few reef sponges taken on the Key grounds in Florida are generally included with the yellow sponges and do not reach the market as a distinct sort. Those found in the trade come from the Bahamas, the north coast of Cuba, and British Honduras, the former two localities producing sponges of essentially the same character, while those from Honduras are inferior, more irregular and open, and with other indications of shoal water origin. Reef sponges are also taken on the west coast of Haiti.

Most reef sponges appear to belong to Lendenfeld's species *Euspongia officinalis rotunda*, embracing many of Hyatt's numerous varieties of *Spongia*

agaricina and *S. officinalis*. As might be expected from this statement, they are of varied shape, but comparatively uniform in quality and the appearance of the surface, which is a fairly even network inclosing numerous small round holes averaging about $\frac{1}{16}$ inch in diameter, the interlying ridges being covered with short, bristle-like bundles of fibers. In the general appearance of the surface these sponges resemble the finer grades of Mediterranean sponges much more closely than do any of the other American sponges, but the pores are somewhat larger and the projecting bundles of fibers are stouter and stiffer. In some specimens, particularly the helmet-shaped ones, which are apparently Hyatt's variety *disciformis*, the surface is softer than that of the zimocca, but not equal to that of the Mediterranean toilet sponge.

Most of the larger reef sponges from both the Bahamas and Cuba belong to Hyatt's *Spongia officinalis* subsp. *tubilifera* vars. *pertusa* and *mollis* (pl. LV), not Lendenfeld's *Euspongia irregularis pertusa*, and are massive lobular forms with the vents at the conical summits of the fistular lobes or the solid masses into which they fuse. In the furrows between the lobes and the depressions between the summits of those which have fused basally, the surface orifices are larger than elsewhere and the projecting bristles are much longer. The vents are generally arranged in more or less radiating rows extending down the sides of the sponge. Another common type is flattened in a vertical plane, with the oscula lying in a sharp crest extending longitudinally up the ends and across the top and surrounded by soft tufts of fiber longer than on the rest of the surface (pl. LVI). Between these two types there are intergradations tending to produce more or less massive forms, with the oscula in rows or scattered on rounded eminences. Others evidently belonging to Hyatt's *S. agaricina punctata* are considerably higher than broad, and have the oscula more or less radially arranged, those on the sides being slit in the direction of the base. These are often included among the "hardheads." The reef sponges are low priced and are used as desk sponges, for surgical purposes, for infant toilet sponges, especially when bleached, and for various purposes in the arts which require a soft sponge of no great durability.

HARDHEAD SPONGES.

The hardheads (pl. LVII), most of which come from the Bahamas, British Honduras, Haiti, and the north coast of Cuba, are another miscellaneous group, some of which are indifferently assigned to this or the preceding grade, as they are harder or softer to the touch. The hardheads are generally elastic and resilient, but somewhat less compressible than the preceding and harsher to the touch. They are also on the whole more regular in form.

A considerable number of them, especially among the Cuba specimens, belong to Lendenfeld's *Euspongia irregularis pertusa*, the larger and softer

specimens of which are classed as yellow sponges. Most of the others can be assigned to one or the other of Hyatt's varieties which Lendenfeld includes in his *Euspongia officinalis rotunda.* Common among these are conical or club-shaped forms sometimes bluntly branched (Hyatt's *agaricina corlosia* var. *elongata*) or rounded specimens attached by a narrow base (Hyatt's *officinalis tubilifera* var. *rotunda*). In both of these the surface is composed of narrow ridges separating small circular apertures and covered with short bristles. The larger of these sponges tend to become conical and somewhat flattened in a vertical plane, and they are also usually softer and more compressible than the smaller individuals. The oscula are large and conspicuous, they usually lie on more or less prominent rounded eminences and at the summits of the blunt branches, and tend to become slit-shape or elongate, especially on the sides. The hardhead sponges are used for applying shoe dressings, as desk sponges and for various purposes in the arts not requiring great softness. They are in general more durable than reef sponges.

WIRE SPONGES.

The wire sponge (pl. LVIII and LIX), sometimes called "bastard sheepswool," somewhat resembles the wool sponge in superficial appearance, though it more closely simulates the honeycomb sponge of the Mediterranean. In shape it is regular, rather broader than high, and attached by a broad base. The sides are perforated by numerous circular or polygonal orifices, separated by thin-edged partitions which, while sometimes ending in bristly tufts, are never prolonged into the long, soft, expanded processes characteristic of the sheepswool sponge, the surface of the wire sponge therefore lying in a more uniform plane. The oscula or "eyes" are confined to the upper surface, are smaller and more numerous than in the sheepswool sponge, and are rarely or never situated on the summits of cones rising above the general surface.

The wire sponge differs from the honeycomb sponge in its more open surface and general texture, its more bristly appearance, its much thicker fibers, and coarser, more open felt. If the fibers are examined under a lens they will be found heavily charged with sand granules, which impart to the sponge its characteristically harsh feel.

Until very recently wire sponges were rarely brought to market on account of their numerous bad qualities—their harshness, their lack of strength and absorptiveness, and the readiness with which they drain after being wet. Within the last year, however, a considerable demand has arisen, and they now yield the spongers a price per bunch about on a par with that of yellow sponges. They are all exported, and there is good reason to believe that they are bleached and sold as Mediterranean honeycomb. They come almost entirely from the west coast of Florida.

TURKEY CUP SPONGES.

These sponges (pl. LX and LXI, fig. 1), known also as fine Levant or fine Syrian, are the *Euspongia officinalis mollissima* of Schulze. They are sometimes massive, when they are known to the trade as "Turkey solids," but are frequently more or less cup-shaped, though perfect cups are comparatively rare, and as they are regarded as especially desirable bring high prices. The oscula are comparatively large and numerous and are grouped closely together on the upper surface of the solids or in the concavity of the cups, the skeletal partitions which separate them being often very thin. The outer surfaces are perforated by numerous round or polygonal pores, the narrow partitions between which are beset with long, slender, and very soft, fibrous pencils. The foreign bodies in the fibers are small in quantity, the main fibers themselves are comparatively few, and the microscopic network has rather large irregular and elongate meshes, this combination of characters making it the finest and softest sponge and one of the most elastic on the market.

The "Turkey cup" and "Turkey solid" are confined mainly to the eastern Mediterranean, though a closely related form comes from Zarzis, on the Tunisian coast. The very finest are obtained on the Syrian coast, but excellent qualities are found at Crete, Cyprus, and Mandruka in Egypt. It is stated that many of the best now come from caves and crevices, where they attain a finer and denser growth than elsewhere. This kind of sponge, like the Turkey toilet sponges, never attains a size comparable with that reached by most other commercial sponges, but the high price it brings compensates for its smallness. It is stated that a few of the very best sell for about $50 per pound. They are used mainly for the more exquisite purposes of the toilet.

TURKEY TOILET SPONGES.

These sponges (pl. LXI, fig. 2, and LXII) are mainly included in the zoological variety *Euspongia officinalis adriatica* of Schulze, though apparently some inferior specimens of the Turkey cup sponge are also embraced in this commercial species. Toilet sponges are flatter and more encrusting in their habit than are the cup sponges, and are generally broadly attached, though sometimes the base is constricted. The oscula are confined to the upper surface, being usually distributed over all parts excepting toward the edge, but in what appear to be compound individuals they are often arranged in groups. Each oscule is generally surrounded by a rampart of bristles. The surfaces other than those bearing the oscula are perforated by numerous fine pores. The ridges forming the network between these pores are rather sharp edged as compared with the cup sponges, while the fibrous processes which they bear are shorter, stouter, harsher, and more bristle-like. The sponge as a whole is less compressible than the cup sponges and not so soft and fine.

Toilet sponges are rather generally distributed in the Mediterranean from the Adriatic and the coast of Tunis eastward. They are used for toilet purposes, in surgery, and for leather dressing, pottery making, and various other purposes of the arts.

A somewhat similar sponge is found in great abundance at Sitanki, Philippine Islands. (Pl. LXIII.) Its general texture closely resembles the toilet sponge, but its upper surface bears longer tufts of fibers and numerous uniformly distributed oscula or pores about one-eighth inch in diameter, characters which cause it to resemble in that respect some of the grass sponges from the Florida Keys. It is very soft, but much weaker than the toilet sponge and about as strong as Key grass.[a]

ZIMOCCA SPONGES.

These sponges (*Euspongia zimocca*) are massive, more or less conical, broader than high, sometimes flat on top, sometimes concave, occasionally cup-shaped, and usually attached by a rather small base. (Pl. LXIV.) The oscula are scattered over the upper surface, occasionally arranged in irregular radial rows, and are frequently, though by no means always, surrounded by ramparts of bristly fibers. The whole outer surface consists of a reticulation of narrow ridges, inclosing numerous small pores and bearing short fibrous villosities which generally become longer and softer toward the upper surface. The surface texture of the skeleton resembles that of some of the Cuban and Nassau hardhead sponges, but the orifices are smaller, the intervening ridges are narrower, and the skeleton softer and more durable.

The zimocca sponge is found commercially in the Adriatic, the Dardanelles, on the west coast of Asia Minor, the coasts of Egypt, Tripoli, and Tunis, the islands of the Grecian Archipelago, Crete, Cyprus, Corsica, and Lampedusa. The zimocca sponges are the harshest of the Mediterranean grades, but in common with other kinds they become softer when bleached, though they are less durable. Both bleached and unbleached they are darker in color. They are used for toilet purposes, and by potters, leather dressers, and other artisans. They are generally too harsh for surgical purposes.

Seale describes a sponge which on the advice of a New York dealer he calls a "Philippine zimocca." The specimen shown to me was of excellent quality and commercially valuable, but was certainly not a zimocca sponge.

HONEYCOMB, BATH, OR HORSE SPONGES.

These are the *Hippospongia equina elastica* of Lendenfeld and are classed by zoologists with the yellow sponge of the Florida Keys, from which it differs

[a] I have recently seen one of these, in a good state of preservation, which has been in daily use for bath purposes for two years.

in shape, texture, strength, and softness. (Pl. LXV.) It is a massive, cake-shaped sponge, attached by a broad base, always broader than high and never "pineapple-shaped" as its American relative frequently is. The surface is fairly uniform, with the lamellæ superficially expanded and often forming narrow reticular bridges across subsurface cavities. The surface is covered with small rather blunt tufts or pencils of fiber, particularly around the edges of the numerous polygonal, circular, or meandering openings. The oscula are scattered over the upper part of the sponge, usually opening on the general surface, but occasionally surrounded by a rampart of fibers which produce a very short oscular tube. The general superficial aspect of this sponge is intermediate between the sheepswool and the velvet, being much less shaggy than the former and rougher and less meandriform than the latter. In surface appearance it somewhat resembles the Florida wire sponge. Certain sheepswool sponges which the author has artificially grown from cuttings in the Florida Keys reproduce quite accurately the surface texture of the honeycomb sponge.

The honeycomb sponge is quite generally distributed throughout the Mediterranean, being found from the Gulf of Lyons along the north, east, and south shores as far as the Algerian coast. It is known commercially from the vicinity of Marseilles, Corsica, the Adriatic, the Archipelago, the coasts of Asia Minor, Egypt, Tripoli and Tunis, Crete, Cyprus, Lampedusa, the Dardanelles and the Red Sea. The best are the Mandruka sponges, which are compact, soft, and fine, but those from Tunis, Crete and Asia Minor are little inferior and many of them enter the markets as Mandrukas. The Tripolitan honeycomb sponges are rough, coarse, and loose in texture, and those from the Archipelago are but little better.

As has been before stated, one of the yellow sponges of American waters is considered zoologically identical with the honeycomb, and the variety is also known from Australia and New Zealand, those I have seen from the former locality being harsh, open, coarse, and decidedly inferior to any known commercially.

As compared with American sponges, the Mandruka is softer than any except the Matecumbe sheepswool, but it is less durable than the Rock Island sheepswool, less resilient, and more quickly loses its elasticity in use. It is a popular bath sponge, for which its size and shape makes it excellent, but is being displaced in the American markets by the more generally superior sheepswool. These sponges are also used in the arts, by jewelers and silversmiths, leather manufacturers, and as desk sponges for bank tellers, etc.

ELEPHANT-EAR SPONGES.

These are the *Euspongia officinalis lamella* of Schulze and are either cup-shaped or cap-shaped with rather thin walls of uniform thickness or a more or

less rolled ear-shaped or fan-shaped plate from ½ to 1 inch thick. (Pl. LXVI.) The oscula are confined to the inside of the cupped forms or the concave faces of the lamellate specimens, and are arranged in groups of 4 to 6, surrounded by tufts of fibers longer than on the rest of the skeleton. These groups are generally in radial and concentric rows and the whole of the oscular surface of the skeleton often has more or less the appearance of being radially grooved, owing to the linear arrangement of the rows of fibrous tufts which cover it. The outer or convex surface of the sponge is more uniformly covered with soft fibrous tufts, though these tend to radial arrangement near the rim, and there are sometimes radial ridges or thickenings of irregular length extending from the base toward the margin. This sponge is very fine, soft, and durable, being equal in those respects to the Turkey toilet sponge. It is used for fine toilet purposes, for which its shape makes it desirable; for surgical purposes, and in the medical application of electricity, by potters, fine leather workers, jewelers, cane makers, hatters, and other artisans requiring a smooth, fine, soft, and durable sponge.

It is found commercially on the coasts of Provence and Dalmatia, in the Greek archipelago, on the coasts of Egypt, Tunis, and Algeria, and about the Balearic and Lampedosa islands, and the variety is known zoologically from the north coast of Australia.

A similar but much denser and harsher sponge is found near Jolo, Philippine Islands. In the few specimens that I have seen the fibers are heavily laden with sand grains, which makes them useless commercially, but it is possible that better grades may be found.

IV. THE FLORIDA SPONGE FISHERY.

The Florida Keys first received permanent settlement about the time that the present State was erected into a Territory upon its cession to the United States in 1821. Key West, the first and for many years the sole center of the sponge industry, was settled in 1822, and it is probable that the early inhabitants soon learned, from the specimens thrown up on the beaches of the keys, of the presence of several species of useful sponges in the surrounding waters. It is known that long before these became an article of commerce they were in limited domestic use among the inhabitants, but it was apparently not until 1849 that they were given a commercial value. In that year a cargo of sponges was sent to New York on a venture, probably as the result of knowledge of the recently discovered commercial value of the sponges in the Bahamas, which islands furnished the majority of the early settlers of Key West and have since maintained with it close social relations. Before this time the entire sponge supply of the United States was derived from the Mediterranean, though of later years a few sponges may have come from the Bahamas, which had begun to export seven or eight years

before, but that the supply from the latter source must at most have been small is shown by the fact that its total exports to all countries in the year mentioned were valued at but some $10,000. In any event, sponges other than those from the Mediterranean were but little known and the venturesome cargo from Key West narrowly escaped being thrown away as worthless. Its ultimate sale, however, established a market for this newly discovered product of the keys, and several merchants at Key West began to buy the better grades and to take them in trade. It is said that at first the price was but 10 cents per pound, presumably for sheepswool sponges, but as the quality of the domestic product became better known the price improved, there began to be a systematic investment of capital to take the place of the desultory fishery previously carried on, and a class of men developed whose principal or sole business and means of livelihood was gathering sponges.

THE SPONGING GROUNDS.

The sponging grounds as at present developed are broadly divided into two widely separated areas, the "Bay Grounds," lying in the open waters of the Gulf of Mexico, from about Johns Pass to St. Marks, and the "Key Grounds," stretching along and among the reefs and keys from Cape Florida to Boca Grande Key.

That there is sponge-bearing bottom between the New Ground off Cape Sable and the mouth of Tampa Bay admits of little doubt, but notwithstanding that the Key West fleet has traversed that region year after year in going to and from the Bay grounds, practically no sponges have been taken there, owing mainly to the depth and almost constant turbidity of the water. A few spongers have reported seeing sponges, but never in considerable quantities.

The grounds as exploited and worked by the hookers up to the time of the introduction of diving apparatus, in April, 1905, covered an area of 4,350 square miles, of which the Bay grounds contained about 3,400 and the Key grounds about 950 square miles. It must not be considered, however, that all of this area is productive, for on the contrary the actual sponge-producing bottom in any given field is far less than the barren areas with which it is mingled.

Sponges grow neither on sand nor mud, nor primarily on grassy areas, but must have some firm clean body to which to attach when the small free-swimming larva is ready to settle down and assume its final fixed condition and form. Among the Keys the bottom in the main consists of sand and more or less calcareous mud or marl, either naked or less frequently supporting a grassy growth, while on the Bay grounds it is generally sandy offshore with more or less grass in the shallow waters close to land. In the channels and other places among the keys where the currents run with sufficient velocity to scour the bottom or the waves prevent the excessive deposit of silt, the coral rock is exposed and furnishes

attachment for sponges and other sessile marine organisms. In the same way on the Bay grounds the bottom is denuded by currents in the channels, as at the north end of Hog Island, and on the Buoy grounds above Anclote Key, while offshore there are rugged outcroppings of rock rising above the surrounding sand. It is upon these "spots of bar," as the spongers call them, insignificant in area as compared with the adjoining stretches of sand and mud, that the sponges occur in greatest abundance, attached to the rocky floor of the sea.

Occasionally they grow on sea feathers, which in turn are anchored to the bottom, or on mangroves, and considerable numbers are often found in the grass or in saucer-shaped sandy depressions surrounded by grass. Their occurrence in the latter places apparently contradicts the statement that they do not grow on grass or sand, but the contradiction is apparent rather than real, as they have been in all cases originally attached, but either in the operation of sponging or by wave action have been torn loose, and rolling freely over the bottom at the mercy of the waves have finally been entrapped in the tangle of vegetable growth. Such sponges are generally almost spherical, have no "root," and the surface is uniformly smooth from friction on the bottom and harsh from the excessive inclusion of sand grains. They are known to the spongers as "rollers" or "rolling johnnies" and are often found in groups in sandy depressions in grassy bottom called "turtle sets" from the erroneous supposition that they are made by turtles.

BAY GROUNDS.

The Bay grounds, which formerly held a secondary place commercially, now yield practically the entire production of Florida sponges, the Key grounds furnishing hardly 9 per cent of the sheepswool sponges and less than 13 per cent of all kinds. The Bay grounds begin at or near Johns Pass, a few miles north of Tampa Bay, and extend without material interruption as far as St. Marks, a distance of 160 miles. As known at the time of the introduction of the diving machine, this ground extended from a depth of 10 or 15 feet to from 7 to 12 fathoms 20 to 40 miles from shore, but although sponges had been seen in the greater depths, no sponging had been done in more than 8 fathoms owing to the limitations imposed by the methods employed. Grass and a few sheepswool sponges were taken in less than 10 feet of water, especially in the early days of the fishery, but the bulk of the product was from between 20 and 35 to 40 feet, though in 1902, owing to unusually favorable conditions, a heavy catch of fine sponges was made in water as deep as 45 or 48 feet. Several persons had reported seeing sponges in 20 fathoms, and it is stated that on at least one occasion a sponge was brought up from 17 fathoms on a fish line.

In 1905 the area of the known sponge beds in the Bay grounds was about 3,400 square miles. Since then the operations of the divers, who in a few cases

have gone as deep as 110 feet, have slightly extended this area, and as that method of sponging becomes older and the shoaler waters more exhausted it can hardly be doubted that other productive grounds will be found in the greater depths. Should the Bay grounds be found to extend generally to a depth of 15 fathoms, about 3,700 square miles would be added to the area of sponge bottom, while if they prove productive to a depth of 20 fathoms there would be added to the area developed by the hookers no less than 5,900 square miles, making a total of about 9,300 square miles of sponge-producing bottom between Johns Pass and St. Marks inside of the 20-fathom curve.

It must of course be understood, as before intimated, that this area is not all productive. In general, the sponges are confined to the "barry bottom," which rises in patches like rocky islets above the sands that cover the general floor of the Gulf (pl. XXVIII). These bars are always more or less scattered, here isolated, there occurring in groups or series of ridges, and in the operations of sponging much time is consumed in looking for them. In the deeper waters they are found with the lead and in the shoaler waters by searching the bottom with the water glass or water telescope.

The bars, especially in the shoaler water, are sometimes moderately level expanses, but are generally rough and rugged, with fissures, clefts, crevices, miniature precipices and overhanging ledges, in all parts of which the sponges grow like lichens clinging to the rocks, sometimes exposed to view from above, often hidden in semidark recesses on the sides of upright walls or beneath projecting ledges. They are mingled with noncommercial sponges of many species, with gorgonians (sea feathers, etc.), polyzoa (sea moss), and corals, and surrounded by a wealth of life—fishes, mollusca, crabs, shrimps and other crustacea of bizarre shapes and brilliant hues, starfish and sea-urchins of varied form, sea cucumbers and worms, some permanently attached to the rocks and others free to wander, yet finding on the bars rich feeding grounds, oases in the vast desert of sand lying round about.

Compared with the total area of the sponge grounds the extent of these bars is small, nobody can say how small relatively, but it is from them and practically from them alone, that the supply of sponges must be drawn. Their distribution is irregular in different sections of the grounds and in different depths; sometimes there are great areas of white sandy bottom quite devoid of rocks and again the bars are comparatively closely approximated over a wide range.

The Bay grounds are broadly subdivided by the spongers into the Rock Island, Pepperfish, New, St. Martins Reef, Anclote, and Highland regions, each in itself of uncertain boundaries and more or less subdivided into indefinite sub-localities. The names used by the spongers are very contradictory, and the location of a fleet working in a given area may be described in five or six different

ways by hardly more than that number of masters. The reasons for this are twofold. In the first place the local distinctions between the grounds are purely artificial, as the sponge-bearing belt is practically continuous, bearing in mind the irregular distribution of the bars themselves, and in the second place the spongers when out of sight of land do not know exactly where they are, few if any being navigators. They usually refer their location to their last point of departure and it may thus happen that of two vessels working side by side one will declare itself off Rock Island and the other off Pepperfish Keys, the two locations being over 40 miles apart, the first vessel having sailed south and the other west from the last landfall.

Though the grounds as at present known to the spongers are indeterminate as to their boundaries, there were originally apparently natural distinctions between some of them. The shoal-water areas were first discovered and worked and there it was found that the sponge-bearing bottom was interrupted by large areas of smooth barren sand and grass. One of these, lying off Piney Point, separates the inshore parts of the Rock Island and Pepperfish grounds, and another and larger one, extending for 30 miles opposite Cedar Keys and the mouth of the Suwanee River, lies between the Pepperfish and St. Martins Reef beds. Each of these extends to a distance of 20 to 25 miles from shore and to a depth of 5 to 8 fathoms. Later discoveries developed bars outside of these "lakes" as they are called, so that in the deeper water the grounds are now continuous.

The most prolific beds extend from off Cedar Keys to the waters southwest of Anclote, including New, St. Martins Reef, and Anclote grounds. About 1895 the sponges on the Rock Island, Pepperfish, and New grounds were killed off by "poison water," which extended from the vicinity of St. Marks to the beds off the Suwanee River. Recuperation of the beds first began to make itself evident about 1901.

Rock Island region.—The region so designated takes its name from a small island about 22 miles to the eastward of St. Marks light. It extends from about Ocklockonee shoal to the smooth sandy bottom off Piney Point, which separates it in its shoaler parts from the Pepperfish Key beds. As developed by the hookers, it had an area of about 800 square miles, about 50 miles of which, forming a strip a few miles offshore, yields grass sponges in considerable numbers. Inside of the 5-fathom line the Rock Island beds produce sheepswool sponges in great abundance, though most of them are comparatively small. When first discovered, the sponges were larger; but owing to the intense fishery in the shoal waters they now have no opportunity to grow, if, indeed, their size has not become permanently impaired by the persistent and constant selection out of the larger ones, as appears to be the case at Sugar Loaf Key also.

The sheepswool sponges of this region are of fine quality, close and tough of fiber, rather flat or cake shaped, and somewhat darker in color than the Key sponges. They bring a higher price than any American sponges, though probably not superior to those from other sections of the Bay grounds, the product of all of which goes under the general designation of "Rock Island."

Pepperfish Key region.—These beds lie opposite Pepperfish Keys and extend from the sandy bottom off Piney Point and Grass Island to the similar, though larger, area off the Suwanee and Cedar Keys. In the deeper water they join the Rock Island beds on the one hand and the New ground beds on the other. They lie in a depth of from 6 to 7 feet to 10 or 11 fathoms, beginning about 3 or 5 miles from shore, and extend a distance of about 25 to 35 miles. Their total area in 1905 was about 550 square miles, of which about 75 square miles, lying in a depth of from 8 to 18 feet, was mainly productive of grass sponges.

New Ground region.—The New ground is so called because it was discovered at a later period than those on each side, Pepperfish and St. Martins Reef, between which it formed a connecting link in the deeper water outside of the sandy area, which separates them shoreward. Its extent northwest and southeast is about 30 miles, lying in sinuous outline in a depth of between 5 and 10 fathoms at the stage of development of 1905. Its width varies, but averages a little over 10 miles, and its area as exploited by the hookers is about 350 square miles. This is a prolific ground and, in the opinion of the hookers, marks the northern limit at which the sponges are at present most abundant.

Withlacoochee Bight and St. Martins Reef.—This includes the sponge beds between the mouth of the Waccasassa River and Sea Horse Reef on the north and St. Martins Reef on the south, covering an area of about 1,100 square miles. As developed by the hookers, the beds ranged from a depth of about 7 or 8 feet to 9 or 10 fathoms; but the divers have since found the productive bottom to extend in some places to 15 or 18 fathoms.

Withlacoochee Bight is prolific in sheepswool sponges, but owing, perhaps, to the discharge of the numerous small streams along shore the water is generally too cloudy for the hookers to work to advantage. In the shoaler water, from 1 to 3 fathoms deep, extending along the inner edge of these grounds for almost their entire length, there is an area on which grass sponges predominate, and some years ago many fine large ones were taken there; but it is stated that the growth now consists almost wholly of small specimens. In the deeper water sheepswool and yellow sponges predominate, with a considerable number of large grass sponges. This region and the grounds to the southward are those now principally resorted to by the divers.

Anclote region.—The Anclote region, practically continuous with the preceding and the following, extends from St. Martins Reef to about Big Pass,

and as known in 1905 covered an area of about 290 square miles. At that time the depth in which the sponges were found extended from about 4 or 5 fathoms to about 8 to 10 fathoms; but the divers have since then taken large quantities in from 10 to 15 fathoms, and a few boats are said to have worked as deep as 18 fathoms. There are a few small patches of bar in waters as shoal as 2 or 3 fathoms on the Buoy grounds, in the channel south of Anclote Key and near the north end of Hog Island. The Buoy grounds are noted for their rapid recuperation. The deeper waters produce a fine grade of sheepswool sponges, and both yellow and grass are also found in considerable quantities.

Highlands region.—This, the southern limit of the Bay grounds, stretches from Big Pass to Johns Pass, the known distribution of sponges in 1905 covering an area of about 300 square miles. Owing to the absence of streams discharging fresh water, the sponges extend much closer to shore than in the regions to the northward, but they range offshore to about the same depths as in the Anclote region, though, owing to the steeper slope of the bottom, the hookers never worked so far from shore.

KEY GROUNDS.

The Key grounds, though for many years the only source of supply of Florida sponges, are now comparatively exhausted and of reduced value. During the past few years they have produced about 30,000 pounds of sheepswool sponges per annum, while in 1900, an exceptionally good year for these grounds, the catch was 58,294 pounds. The production of all kinds averaged 79,487 pounds in the years 1906, 1907, and 1908, while in 1899 and 1900 the average was 139,458 pounds.

Between the keys and the mainland the grounds extend from Boca Grande Key and Cape Sable as far as the Cowpens, off Long Island, and from the lower end of Cards Sound to Cape Florida. In Hawk Channel there are patches of sponge-bearing bottom along the line of reefs forming its outer margin, and at intervals close to the keys which define it on the landward side, from near Key West as far as Hillsboro Inlet; but, though at one time fished throughout the entire distance, it is only between Knights Key Channel and Soldier Key that these patches now attract the attention of spongers.

The interruption in the distribution of sponges inside the line of keys from Long Island to Cards Sound, mentioned above, is due to the low salinity of the water. For nearly 30 miles Key Largo imposes an unbroken barrier against the interchange of waters between the inside bay and Hawk Channel, with the result that the drainage of the Everglades is impounded and the salinity reduced below the degree which inhibits sponge growth. On two occasions I have run a line of salinity observations through this barren area

and found the density gradually falling from about 1.0205 on the sponge grounds at either end to about 1.0135 approximately midway between. All other conditions for the maintenance of sponge life appear to be present, and certain species, like the loggerhead, more tolerant of fresh water, are found in abundance. In the construction of the new line of railroad to Key West many of the passes between the keys west of Key Largo have been completely or partially closed and it is not improbable that the salinity of the water will be so lowered as to affect adversely the sponge grounds near the Matecumbes.

The Key grounds produce sponges in greater variety than the Bay grounds. Not only are there more noncommercial species but there are more useful kinds, and of each of these there are a number of local varieties readily recognized by the spongers and dealers. All have, however, one well-marked characteristic that in general serves to distinguish them from corresponding species taken "up the bay," namely, a reddish or rusty appearance of the interior fibers, called "red root" on account of its being more readily seen on that portion of the sponge torn away from its attachment to the bottom. This color is not generally exhibited by the strictly peripheral fibers, but is readily observable in the oscula and at the bottoms of the channels or grooves which traverse the surface, and upon cutting the sponge it is found to permeate the whole interior. It is due to an oxide of iron and is popularly supposed among those engaged in the business to be caused in some manner by the coral rocks to which the key sponges are commonly attached. That it is due to the constituency of the water among the keys there can be no doubt, but that it is not absorbed directly from the rocks is shown by its presence in sponges growing above the bottom attached to sea feathers (gorgonians) or artificially grown from cuttings attached to suspended wires. Red-rooted sponges are almost invariably more tender, weaker in fiber, and less durable than those of generally similar texture not so colored, but whether the coloring material causes the weakness or whether the conditions producing the two are merely coincident can not be stated. The color is quite different from the paler yellow seen in some of the Bay sponges.

The "barry bottom" of the Key grounds is generally fairly level as to surface, though on the reefs and in places on the Key shore of the Hawk Channel there are bowlders and heads of coral rock, often rising from a depth of 2 or 3 fathoms almost or quite to the surface. The commercial species found on the Key grounds are sheepswool, yellow, velvet or boat, grass, and glove. The velvet or boat sponge is obtained principally from the reefs and owing to the difficulty of working in that exposed region is to be had in but comparatively small quantities. The other species are generally distributed.

The Key grounds are subdivided into innumerable more or less poorly defined areas, each of which has received from the spongers one or more local

names, sometimes fanciful, but frequently having some topographic, personal, or historic origin. It is impossible to describe within reasonable limits all of these various sublocalities, but a few of the more important will be mentioned.

The New grounds extend from Cape Sable and Middle Cape southwest to beyond Contents Keys and westerly from a depth of 11 feet to a depth of about 5 fathoms. The bottom consists of a series of more or less extensive bars separated by white sand, and the sponges produced are of excellent quality, generally pineapple-shaped and colored less brightly red than is usual in the keys. All classes of sponges are found, but the water is rarely clear and the grounds are therefore but occasionally productive. Southeast of this are "spots of bar" stretching to the so-called lakes along the line of keys as far as Lower Matecumbe.

West of Key West there is an area lying between Boca Grande, Man, Woman, and Mullet keys and the slope of Lavinia Bank, where most of the sponges are rollers. There are also beds along the sides of Northwest Channel, one of the entrances to Key West Harbor.

Between Key West and Bahia Honda.—In this region sponging has been carried on for many years in Wall Key Lake, Johnson Key Lake, Sugar Loaf Sounds, and in all of the long narrow channels leading between the keys. In the lakes and sounds schools of fish and in the channels the strong currents keep the water muddy a large part of the time. Sheepswool, yellow, grass, and glove sponges are found, but the quality of the first two is inferior.

Money Key and Pigeon Key lakes.—These areas are practically continuous and lie between Bahia Honda and Knights Key Channel, extending north and northwest to Teakettle and East Bahia Honda keys. The water has a maximum depth of about 9 or 10 feet in the former and 11 or 12 feet in the latter. Wool, yellow, grass, and glove sponges are found, the former being superior in quality to those found to the westward.

Knights Key Channel, Rachel Key Lake, Grassy Key Lake, and Channel Key Lake.—These form a practically continuous sponging ground between Knights Key and the sand banks and shoals running northwest from Long Key, and in the palmy days of the key fishery were much resorted to by the Key West fleet. During recent years, in common with the rest of the key grounds, this area was nearly exhausted and comparatively deserted by spongers, but in the spring of 1908 and the following winter excellent sheepswool sponges of good shape, size, and quality were being taken in the vicinity of Bamboo Key. They were described by dealers as being of the highest quality of Key sponges and unusually free from the objectionable red color before mentioned, and the spongers stated that there was an abundant young growth on the grounds. This appears to be an evidence of the natural recuperation of the

sponge beds when, either by legal prohibition or from commercial considerations, they are wholly or partially abandoned for a few years. On most parts of this area the barry bottom is scattered and the water, which has a maximum depth of about 10 feet, is frequently too muddy for work.

Jewfish Bush lakes.—These, known respectively as the upper and lower lakes, stretch from Jewfish Bush and Lower Matecumbe Key northwest to Schooner Bank, and produce limited quantities of excellent Key sheepswool. The bars are scattered and of comparatively small extent, and, particularly in the upper lake, the sponge growth is mingled with sea feathers and many kinds of noncommercial sponges. The water varies in depth between 6 and 10 feet, the deeper water being toward the northwest.

In the summer of 1908 the sponge beds in this region and to the eastward were destroyed by "poison water." It is probable that this was fresh water from the Everglades, impounded by the railroad embankments of the "Key West Extension." The closure or partial closure of the several channels between the keys must result in the westward extension of the same density conditions which formerly prevented the growth of sponges inside of Key Largo, to which reference has been made before.

Lignum-Vitæ and Cotton Key lakes.—These lie north of the Matecumbes and Lignum-Vitæ Key, are connected by Ironwood Channel, and almost surrounded by sand banks. The bottom of the former is almost all hard, and bears a scattered growth of sheepswool sponges and considerable quantities of other species. In Cotton Key Lake the rocky bottom is scattered and the growth consists mainly of grass sponges. In Lignum-Vitæ Lake the depth is generally between 6 and 8 feet, while in Cotton Key Lake it averages about a foot less. The sheepswool and yellow sponges from these and the two lakes previously mentioned are the softest produced in Florida, making them especially desirable for bath purposes; they are known to the trade as "Matecumbe," wool and yellow.

The Cowpens are at the eastern limit of sponge growth inside the keys west of Cards Sound. They produce few sponges, and those found are usually rollers on the soft bottom.

Biscayne Bay.—Cards Sound, which lies west of Biscayne Bay, contains a few yellow and grass sponges and an occasional sheepswool, but has never been of importance. There are also a few grass and yellow sponges scattered over Cutters Bank, which lies between the two bodies of water.

Billies Lake, which lies in the southern part of Biscayne Bay between Cutter and Featherbed banks, contains a scattered growth of sheepswool, yellow, grass, and glove sponges, and it is stated that in that portion nearest Sands Key, which is at present the most productive, the growth was at one time prolific. It is probably now restricted by the number of small boats which

for years have resorted to the locality. Featherbed Bank Lake lies in the deeper water between Featherbed Bank, Ragged Keys, and Black Ledge. Small patches of bar scattered over this area in from 7 to 12 feet of water produce limited quantities of sheepswool and yellow sponges and large numbers of grass.

Soldier Key Lake comprises all of the remaining sponge-producing area of Biscayne Bay lying between Ragged Keys, Black Ledge, and Cape Florida Channel. Most of the sponges are found in the eastern part, near the extensive banks which separate the bay from Hawk Channel, but the work of sponging is much interrupted, owing to the general muddiness of the water. Formerly large quantities of sheepswool and especially grass sponges were taken here, but owing to overfishing their numbers are much reduced, though there is no doubt that they still exist in considerable quantities in those places which least frequently clear. The sponges of Biscayne Bay are generally loose, "frizzly," and inferior, and are therefore not highly valued in the markets.

Hawk Channel.—The westernmost bed frequented by the spongers lies off Pigeon Key. Sponges in commercial quantities are found off the Sisters, at Duck Key, Long Key, Lower Matecumbe, from Upper Matecumbe to Tavernier Creek, between Tavernier and Rodriguez keys, off Key Largo, between Key Largo and Old Rhodes Bank, at Old Rhodes Key and at Ragged Keys. North of here they extend as far as Hillsboro Inlet, where the reefs cease, but are now never fished. Sheepswool, yellow, glove, and grass sponges are taken on all of these beds. Velvet or boat sponges are found along the inside of the reefs from the vicinity of American Shoal to Fowey Rocks, and they are not known to occur in commercial quantities at any other place in Florida. As they are not particularly abundant or valuable and as the water in their habitat is generally rough, few of them are taken.

HOOKING.

At first the fishery was carried on by wading in the shoal waters in the immediate vicinity of Key West, especially to the eastward, the sponges being pulled by hand. Later the sponge hook was introduced, originally a two-tined sharp hook attached to a pole of moderate length, but latterly the number of tines was increased to three, the type now universally employed (text fig. 1). With the introduction of this implement slightly deeper waters were explored, the fisher standing in the bow of his boat closely scanning the bottom for sponges and tearing them loose with his hook as discovered. To calm the ripples which interfered with their vision the spongers soon learned to make use of oil, and that extracted from the livers of nurse sharks was found to be the best, as it forms a tenacious film and at the same time spreads over a wide area of water. Thin, light oils are ineffective, as they are speedily dissipated and fail to quell the ripples in even a gentle breeze. The oil is usually carried in a wide-mouthed

bottle and is sprinkled on the water in small quantities by means of a stick or swab, the sponger drifting with the "slick," poling back and forth so as to cover its entire breadth.

This method of sponging is still followed in the vicinity of Key West and among the keys where the depth does not exceed 5 or 6 feet, two or three men, each with a dingey, cruising about on little sloops, cooking, sleeping, living, and to some extent curing their sponges in the most contracted of quarters. They usually build small, frail "crawls" of a temporary character, to which they return each night while in the vicinity, or else the whole product of the trip is carried back to Key West, often in a most unsavory condition, and "crawled" at that place. This fishery is now generally followed only during the winter months, when the more profitable deep-water fisheries can not be prosecuted on account of the weather, or at other seasons of the year by the less skilled spongers, by persons temporarily out of other employment, or by the local residents of the keys. It is prosecuted mainly on the Key grounds as far as the Cowpens and its product is small.

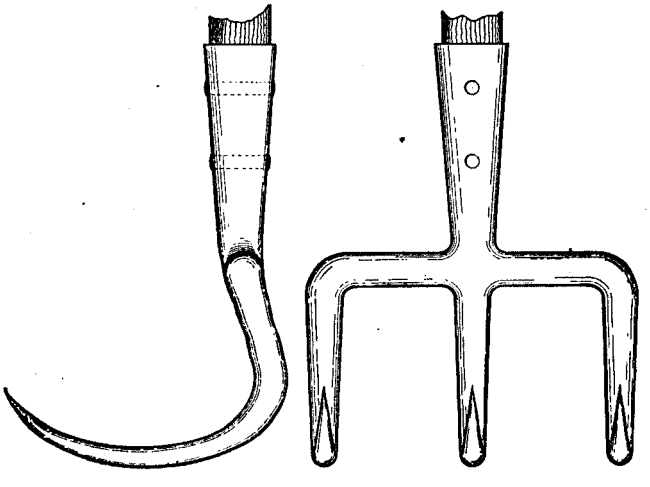

FIG. 1.—Hook used by the sponge fishermen of Florida.

With the growth of the demand for sponges and the depletion of the beds nearer Key West, the search for other grounds carried boats farther and farther away until the Matecumbes were reached. Here it was found that the sponge growth inside the keys came to a more or less abrupt limit, but along the northwest shore of Hawk Channel, between the keys and the reefs, the workable beds were found to extend as far as Norris Cut, a few miles north of Cape Florida. In 1879 this appears to have been the known extent of the Key grounds, as is shown by a chart of about that date prepared during the canvass for the Tenth Census. Few inhabitants then lived on the shores of Biscayne Bay and the beds in the waters within that bay and Cards Sound, if known, were rarely if ever worked, although soon after that time they were extensively resorted to by the Key West fleet, which found sheepswool sponges of rather inferior quality and especially grass sponges in large quantities. The sponge grounds were also found to extend along the reefs as far as Hillsboro Inlet, but owing to the prevalence of heavy seas on this part of the coast they were not extensively exploited.

With the extension of the fishery into the deeper waters of the channels and some of the "lakes," as the spongers term the broader expanses between and behind the keys, the old method of sponging became inadequate. Poling became laborious if not impossible, and, moreover, a man standing upright in the boat was unable to see the bottom with sufficient distinctness. To overcome this difficulty the "sponge glass" or "water telescope" was introduced, at first a square wooden box or tube with a pane of glass in one end, but afterwards an ordinary wooden pail with a glass bottom substituted for the wood. The device is said to have been employed first about 1870 or a little before, and correlated with its use came other changes. It was now necessary to have two men in the boat, one to propel it and the other to search for and take the sponges. The skiffs and miscellaneous small boats previously employed were displaced by the present type of dingeys, yawls about 14 or 15 feet long and about 4½ feet beam, light, strong, and handy, with a sculling notch at the stern. The latter is an oak board notched at the top, sometimes fixed but frequently sliding between guide pieces so as to be removable when the boats are hauled aboard the vessel.

Large vessels also came into use, especially after the development of the fishery on the Bay grounds, where the work is carried on often at a distance of 20 to 30 miles from shore. The smaller vessels, many of them under 5 tons, are employed among the keys where shelter in case of bad weather is usually close at hand. The registered vessels range from 5 to about 50 tons, most of them being under 15 tons measurement. The majority are rigged as schooners, but many of the smaller ones are sloops, as are practically all of the boats measuring less than 5 tons employed in the fishery among the Keys. Practically all of the boats and most of the vessels have been built at Key West, but some, especially the larger ones, have come from other places.

In the boat fishery from one to five men constitute the crew, the usual number being about three. A man working by himself must confine his operations to poling in shoal and smooth water, but two or more men, if occasion demands, may work in rougher and deeper water by using the water glass. The vessels carry crews of from 5 to 13 men, according to size, the usual number being about 7 or 9, the captains even of larger vessels objecting to crews of more than 11 on account of the difficulty of controlling the men. The number is usually odd on account of the distribution of duties as hereafter explained. As a rule the best men get together, as the proceeds of the trip go into a common fund from which each man receives his share according to his duties, and the presence of an unskilled or lazy man in the crew lessens the catch of the vessel and consequently reduces the profits of his fellows.

When a vessel reaches the sponging grounds, if the weather be favorable and the water sufficiently clear, a bar is located by means of the lead or by

"sighting" with the water glass, and the crew is sent out in the dingeys, two men in each, while the odd man, usually the cook, handles the vessel under shortened sail and picks up the boats at noon and night, or when signal is made by hoisting an oar blade up.

The men in a boat are called, respectively, the sculler and the hooker, the duty of the former being to propel the boat in obedience to the signals of the latter and to assist in handling the hooks when necessary. A proficient sculler has great command of the boat, stopping it almost on the instant, backing, going ahead, or making it spin as if on a pivot, as the exigencies of the work require. He will keep at work with easy grace all day long, and much of the success of the boat depends upon his skill and willingness. Upon the hooker devolves the work of finding and catching the sponges. His station is in the waist of the dingey, where he kneels, leaning over the side, watching the bottom through the water glass, the hook, with its pole, resting conveniently at hand across the gunwales, where it may be seized upon the instant. The position is a trying one physically, especially when the sea is choppy, and when the waves grow rough the work is impossible. The sponge glass, or bucket with its glass bottom below the surface of the water, operates by dispelling reflections, and to heighten its efficiency the hooker usually wears a large "conch" straw hat, which cuts off a large part of the direct light when his head is thrust well into the mouth of the bucket. By this means the bottom may be seen more or less plainly in clear water to depths of 50 feet.

When a sponge is sighted the sculler, at a word or signal, maneuvers the boat into position, the hooker seizes his hook, rests the pole on his shoulder as a fulcrum and with his right hand lowers it and inserts the tines into the base of the sponge, more or less plainly seen through the water glass held in position with the left hand. In pulling or tearing the sponges from their attachment considerable care and skill is required to prevent mutilation, which, of course, impairs their value in the markets. They sometimes adhere so tightly that it requires the united efforts of both men to loosen them, and in most cases more or less of the base of the sponge is left behind to grow anew under favorable conditions into a perfect specimen. From this cause, on bars which have been long worked, there are found many sponges of considerable diameter, but so low and flat that there is no room for the insertion of the hooks, and the hookers, much to their disgust, sometimes waste considerable time in futile efforts to detach them.

In deep water poles 50 feet long are sometimes employed, and as they bow and catch in the water if placed athwart the gunwales they are carried fore and aft, the hook over the bow and the other end trailing astern. In using these long, heavy poles the sculler always assists the hooker, placing the pole on the latter's shoulder and helping to handle it both in lowering and in

bringing it up. Even with this assistance the strain on the hooker is great, and in working in depths of 40 feet or more cases of hernia and similar injury are not infrequent even among strong men. The currents are often strong even when the sea appears calmest, and the slender, flexible poles bend and sway so that the greatest skill and strength are required to direct and insert the hooks. Should the current carry the hooks away from the sponge it is often impossible to force them back, and they have to be brought to the surface for a fresh effort.

Cloudy water brought from the swamps by the streams on adjacent shores, and milky water due to the stirring up of the sand and calcareous marls of the bottom, are the greatest impediments to this method of sponging, and the skill and experience of the hooker are largely exercised in seeing and recognizing the more valuable species under these adverse conditions. The tyro after very little practice can hook sponges in clear shallow water, but in depths of 15 feet when the water was somewhat roily I have seen one man catch eight times as many as another on the same bar, owing to his superior eyesight, the two men not differing greatly in the length of their experience as spongers.

In deep water—that is, in depths over 38 or 40 feet—probably not more than one-third of the hookers have sufficient strength, keenness of sight, and skill with the pole to work successfully. In consequence of this and the fact that only when the water is exceptionally clear can the sponges be seen at all in the greater depths, most of the hooking is carried on in less than 6 fathoms, and the inshore grounds have been the first, therefore, to become depleted. As a general rule the sheepswool sponge is now more abundant outside than inside the 6-fathom curve, and it is practically commercially extinct in the waters close to shore where it formerly abounded. Experienced captains, therefore, are in the habit of running offshore from time to time to "take a sight;" that is, to look for bottom with their water glasses, well knowing that if the water be clear and other conditions favorable, they can probably take more sponges in a day than they could in a week on the overworked inshore grounds. The spongers state that while the surface water may be clear the lower stratum is often turbid from the bottom materials stirred up by the swinging motion generally observed in the deeper waters of the Bay grounds.

If all the conditions be favorable, which is rare, the harvest is rich for those who can stand the arduous deep-water work. In the summer of 1903 an unusual condition prevailed in the deep water off the Rock Island region, where the water was clear and the weather favorable for a continuous period of many weeks. This gave the hookers access to bars in depths as great as 45 to 48 feet, which had rarely, if ever, been worked, and the result was a heavy catch of large, fine, perfect sponges of the best quality, which brought a good price in the markets. There has been no recurrence of this good fortune.

As is elsewhere described, sponges are not distributed uniformly over the bottom, but are found only on the scattered bars or rocky outcrops and coral growths. Sometimes a score or more will be found in an area of a few square feet, and again the same number may not grow on an acre of bottom apparently equally favorable for their attachment. Knowing this, the sponging boats will draw together when one is observed to be making a catch and it is not unusual to see dingeys so close to one another that the hookers can hardly wield their poles without collision.

In recent years, where the sponges are much scattered, or the bars small and irregularly distributed, the methods of hooking just described have been somewhat modified to meet the conditions. Instead of the sculling of the dingeys, these are towed by the vessel under shortened sail, sometimes as many as four, two astern and one on each side, from booms rigged well out forward. The hookers crouch in the sterns of the dingeys, scanning the bottom through their glasses, and when a sponge is seen a small buoy with a cord and anchor weight is dropped to mark the spot, the painter is cast off from the vessel, and the sponge is taken in the manner already described. Much larger areas can be systematically covered by this means than by sculling, and regions may be fished with some profit where the sponges have become too few and scattered for the usual methods to yield results.

In the Key grounds the vessels usually anchor at night close to the sponging grounds, and in fair weather some of the larger vessels do the same on the Bay grounds; but the greater number run inshore at night and out in the morning, thus losing much valuable time, especially when the morning winds are light and the conditions are best for work.

The crews are paid on shares, the distribution of the proceeds of a trip being usually as follows: The "vessel" furnishes boats, apparatus, and food, and in return receives one-half of the product of the trip. The other half is distributed so that the hookers get one and one-fourth share and the captain, scullers, and cook one share each. (The captain in addition draws 10 per cent of the vessel's portion and each member of the crew is usually assessed a small sum for the payment of the watchman at the crawls.)

The sponging industry of the United States was virtually introduced from the Bahamas, and so far as the spongers themselves are concerned, the fishery remained largely in the hands of the natives of those islands until the introduction of diving. In 1900, according to Cobb, of the 2,113 persons engaged in sponging, 1,268, or 60 per cent, were born in the British provinces, and of these 1,013 (80 per cent) were negroes. Of the 839 American-born spongers, 343 (41 per cent) were colored. Taken as a whole, of the persons engaged in hooking, about 65 per cent were negroes. Until 1906 neither the numbers

nor the proportions above stated underwent material change, but at the present time (1909) the number of persons engaged in hooking is considerably less on account of competition of the divers, though the proportional national and racial representation appears to be about the same. As a class, these men are industrious workers when actually on the grounds, but after their weekly trips to the crawls it is often difficult to get them promptly aboard the vessels again. The system of making advances against their shares of the catch also operated against their efficiency, as some crews, when a period of "bad luck" made it apparent that at best their earnings would hardly more than suffice to pay their indebtedness, would lose all interest in the work and spend their time largely in idleness or the most desultory labor. Some crews also frequently exchanged considerable parts of their stores for intoxicants brought by Cuban fishing smacks operating off the coast, either drinking the proceeds of the bargain or smuggling it ashore for consumption or sale. This practice has latterly been largely broken up by the customs officers, who have at various times seized vessels, boats, and persons engaged in it.

A very recent development in the hook fishery and one which promises to become important has been brought about by the legislation prohibiting diving during the summer. Certain Greek boats, in order not to be idle at that season, provided themselves with dingeys and hooks during the summer of 1908. They were so successful that several continued in the fishery during the following winter and others are preparing to follow their example. Difficulties with the divers and the expense of maintaining the diving boats appear to be operating to drive other vessel owners into the business, and as the Greeks have shown themselves to be superior to the Bahama and Florida hookers, it would not be surprising if the former eventually practically monopolized all methods of sponging on the Florida coast.

In January, 1909, it was possible to institute an interesting comparison between the Greek and "conch" hookers. The former were working in deeper water and were securing a better and more valuable grade of sponges, superior to the catch of their rivals in size, quality, appearance, and curing, factors which very materially increased the earnings of the vessel and crew. This is indicated by the following records of the catch of two vessels which marketed their cargoes on the same day. The schooner *Fillmore*, manned by 10 Greeks, out 60 days and fishing in a depth of 35 to 40 feet, marketed 293 bunches of wool sponges for $1,880 and 292 bunches of yellow for $300, a total of 585 bunches, selling for $2,180. Another schooner, under one of the best masters and manned by 13 of the most skilled negro hookers, sponging for 42 days in depths of less than 30 feet, marketed 400 bunches of wool sponges for $889 and 700 bunches of yellow for $291, a total of 1,100 bunches, selling for $1,180. This was a yield of $2.16 per

man-day, while the *Fillmore* averaged $3.63 per man-day, almost 50 per cent more. The Greeks not only worked in deeper water, but by curing their catch on the boat instead of running in to the crawls at the end of each week they lost less time.

DIVING.

Prior to 1905 the methods already described were the only ones employed in the Florida sponge fishery, although Messrs. E. J. Arapian, of Key West, and John K. Cheyney, of Tarpon Springs, had each experimented with diving apparatus without material results. In the spring of the year mentioned, John Cocoris, a Greek, who had been employed in a sponge house at Tarpon Springs, became convinced that the methods employed in the Mediterranean could be successfully employed on the Bay grounds, and with the financial assistance of Mr. Cheyney he began to get together at Tarpon Springs men and material for the experiment. He secured from New York a number of his countrymen who had had experience in the sponge fisheries of the Mediterranean, remodeled a small sloop to suit the purpose of a machine boat, and in April of that year made his first trip and took a large quantity of fine sponges.

The success attending this venture produced considerable excitement among those engaged in the industry. Those interested in vessels engaged in hooking soon recognized a serious competitor in their business and raised various objections to the use of the scaphander, some of which were well founded and others baseless. In many instances the real objection was not so much the actual or alleged injurious effects upon the beds, but a belief that the divers would lower the price of sponges by vastly increasing the supply, and that, moreover, they could work with profit under market and weather conditions which would make hooking commercially impossible.

During the following winter the opposition crystallized and certain bills were introduced in Congress aiming to prohibit or curtail the use of the scaphander. The conflicting interests appeared before the Committee on Merchant Marine and Fisheries of the House of Representatives and eventually there were passed two bills partaking of the nature of a compromise. On the other hand, sponge dealers, buyers, and some vessel owners, together with a number of persons not previously connected with the industry, saw apparent opportunity for profitable investment, and during the following summer and winter great activity prevailed at Tarpon Springs, and to a minor extent at Key West, in getting together diving outfits. Diving boats were built in New York, New Orleans, and other distant places, some were even brought from Greece, and small schooners were in much demand for deposit or living boats. By May, 1906, a little over a year after the first successful experiment, there were 50 diving boats at work and 55 more awaiting crews, which could not be supplied despite a great influx of Greek

divers and boatmen. In the beginning the crews were paid wages, which under the competition for competent skilled men that developed, rose rapidly until the divers were receiving as high as $300 per month. The old system of advances or bounties, which had been the bane of the vessel owners during the preeminence of the hookers, was introduced on the diving vessels, and the owners competed against one another for the best men and even for those of little experience and ability.

These facts were soon noised abroad among the Greeks and there was a heavy influx from New York and a considerable immigration from Greece, until within a year there was a Greek colony of not less than 700 to 800 located at Tarpon Springs and more were coming on every train. A few Americans also engaged in diving, but as a rule they were less successful than the experienced men from the Mediterranean and they gradually dropped out of the business.

Cocoris's experiment was made at a particularly favorable time. The great crop of 1903, made under unusual conditions on practically virgin deep-water grounds, had been consumed, and the comparatively poor crops gathered by the hookers in the succeeding year had left the market largely depleted of high-grade goods. To allay to some extent the animosity of the users of the established method, the first diving boats went well offshore in depths of 7 to 10 fathoms, where they found sponges of large size and excellent quality for which the buyers were ready to give high prices. Each dealer was anxious to secure his full share of the product, and being uncertain as to the possible yield and the period during which it would be maintained, prices continued high throughout the year, reaching their culmination in February, 1906, when one particularly excellent cargo sold for $11 per bunch, the highest price ever paid, the usual price for divers' sponges at that time being $8 to $10 per bunch.

Between January 1 and February 15, 1906, a season when under the old methods very little was marketed, over $60,000 was produced by diving. By the middle of April about 40 outfits were at work and this number had increased to 50 by the middle of May, at which time the yield from January 1 had been no less than $250,000 and about $20,000 worth was coming in weekly. The boats properly manned were averaging about 500 to 600 bunches per month and one got 500 bunches in five days without moving much over a mile. Under this heavy supply the price broke sharply and sponges which would have brought $8 to $10 per bunch in February were selling for $2.75 to $3 in May.

Under these conditions the exorbitant wages of the earlier trips became prohibitive and the divers were placed on shares, their pay then being more dependent upon their own skill and industry. In some cases the other members of the crew were on shares, but about May 1, 1906, when wages were paid, the managers or overseers, stern oarsmen, and life-line men, received $75 to $80 per month, and the pumpers and bow oarsmen from $50 to $60. Under the

discouragement of low prices for sponges and the demoralized condition of the labor problem, some of the diving outfits were withdrawn from service and tied up, while others recently built or acquired never went into commission. Other owners, unable to deal efficiently with crews speaking an alien tongue, gave up the attempt to operate directly and chartered their boats and outfits to Greeks, who have thus gradually assumed a practical monopoly of the diving operations, though under the navigation laws it is necessary for them to employ citizens of the United States as nominal masters of the living or deposit boats.

There was also about this time a change in the quality of the product. Previously there had been but few small sponges and the large ones were perfect forms, but in May, 1906, there were many small ones in the cargoes and many of the large ones were old, ragged, and inferior, about 30 per cent of the whole being packed as cuts and seconds. One typical cargo packed as follows:

Sizes.[a]	Weight.	Per cent.
	Pounds.	
Large	41	2.44 +
Ones to twos	139	8.27 +
Twos to threes	140	8.33 +
Threes to fours	160	9.52 +
Fours to sixes		
Sixes to eights	500	29.76 +
Eights to tens		
Tens to twenties	180	10.71 +
Cuts and seconds	520	30.95 +
Total	1,680	100.00 −

[a] The sizes are based on the number of sponges or pieces per pound.

The depreciation in quality was apparently due, in some degree at least, to a change in the locality of the fishery. The Greeks, feeling that they were, in a measure, interlopers, at first treated the prejudices of the hookers with considerable respect and carried on their work far offshore, on virgin or little worked beds, where the run of sponges was large and the quality good. It was stated that some cargoes came from a depth of 14 fathoms and there were reports, never properly authenticated, of diving in still greater depths, but there is no doubt that the major portion of the catch came from depths of between 40 and 60 feet. As it became more apparent that the divers were not to be seriously molested, despite the loud threats of some of the hookers, they became more confident and encroached more and more on the beds in shoaler water, where, of course, they took the same class of sponges brought in by the hookers. The arduousness of diving and its physical perils increase with the depth of water, and the divers will not work in deep water if they can get sponges in the shoaler.

The first diving or machine boats used in Florida were small sponging sloops from which the cabins were removed and which were otherwise remodeled to suit the requirements. The pump was installed in the hold, from which the hatch was removed, the sides were built up and pins or crutches, two on each side at a considerable height above the deck, were provided for the sweeps. A shorter mast was introduced and rigged with a spritsail.

It was soon found that these boats were heavy and clumsy for the work, and boats of the Greek type (pl. XXIX) were speedily introduced and are now almost universally employed. They are "double-enders" with high bows and sterns and considerable shear, making them good, dry sea boats in any weather, either under way or at anchor, and they are spritsail rigged. More recently gasoline engines have been placed on many of the boats, the propellers being guarded by cages to prevent fouling of the hose or life line, an accident which might readily prove fatal to the diver at work. The machine boats are also provided with two pairs of stout crutches, to which the sweeps are slung by rope loops or grommets, and on each side amidships is a rail about 18 inches high, with a sailcloth curtain or screen stretching to the gunwhales. When not in use the oars or sweeps rest fore and aft on the crutches. On the starboard side forward is a heavy ladder, hinged so that it can be swung outboard or stowed inboard as required, and of sufficient length to extend 2 to 2½ feet below the surface of the water. This is an essential feature of the machine boat, as without it the diver in his heavy cumbersome armor could be brought aboard only with extreme difficulty. The Greek boats have each a circular hatch forward, in which stands the man using the water glass. The machine boats of the Greek type are about 32 feet long and about 11 feet beam on deck, and, fully equipped with a good pump and gasoline engine for propulsion, cost about $2,000.

The pump is of the usual type employed in diving operations, is placed amidships in the boat and when not in use is covered by a hatch to protect it from the weather. The diving dress consists of a helmet, breastplate, shoes, and weights. The suits, which are made of several sizes to suit the physical proportions of the divers, are of double waterproof cotton cloth with rubber between and completely cover the body with the exception of the hands, a close-fitting rubber cuff being provided at the wrists, and a heavy rubber yoke or collar extending across the breast, back, and shoulders. The helmet is of tinned copper with three heavy glass windows at the front and sides and one obliquely above in front. At its back are two valves, one with a connection for the hose and the other for the discharge of vitiated air. In some helmets the latter valve is automatic, but few of the Greek divers will use this, preferring those in which the escape of air from the helmet is regulated by the diver, the valve being held in place by a spring and released by pressing against it with the

back of the head. The fresh air is conducted in flat tubes from the intake toward the front side of the helmet, serving the double purpose of supplying unvitiated air for respiration and preventing condensation on the window. The hose is of the best quality, covered with a canvas jacket to protect it from abrasion and with tight screw couplings between the sections, the weight of the unions being compensated for in the water by cork floats. The rest of the hose is of itself sufficiently buoyant when full of air.

In preparing to descend, the diver dresses in heavy woolen underclothing and stockings, and thoroughly soaps his hands and wrists to permit pulling on of the rubber cuffs and to secure closer contact at the wrists. With assistance he then crawls into his suit; the breastplate, covering the upper part of the breast, back, and shoulders, is inserted inside of the rubber yoke, which is provided with eyes fitting over corresponding screw lugs on the breastplate and the two are clamped to a water-tight joint with thumb screws and brass straps. Stout weighted leather shoes, brass soled and tipped, are then securely strapped on the feet. In the meantime the interior of the helmet has been washed and the air supply tested by placing water in the helmet to determine whether the air bubbles freely through the intake valve when the pump is operated. The pump is then started slowly and the helmet secured to the breastplate by an interrupted screw, the joint being made water-tight by means of a rubber gasket. The helmet is then lashed to the breastplate, the front and back weights of lead are lashed on, the hose brought under the left arm and lashed to the waist and the life line is fastened tightly around the body under the arms.

The diver is then ready to descend, and with his burden of about 200 pounds is assisted to the side, where he either jumps, or rather falls overboard, or else climbs down the ladder, the pump being run more rapidly as needed to supply the air pressure commensurate with the depth in which the diver is working.

The crew of a machine boat with their stations when at work is as follows: Two divers, who alternate on account of the arduousness of their duties, one resting while the other is at work; these men are always particularly abstemious as to food and drink, no alcohol being used and the daily meals consisting of a cup of coffee in the morning and a hearty dinner at night when the day's work is over. Three oarsmen; the bow oars are pulled each by one man sitting down, but the stern oarsman stands facing forward and pushes two sweeps, which are balanced by heavy weights near the handles so as to reduce the fatigue of rowing. Two pump men and one relief who manages the hose when not pumping. One life-line man, whose important duty it is to see that the life line is kept clear and that the signals of the diver are promptly regarded; experienced and careful men are required for this station, as the

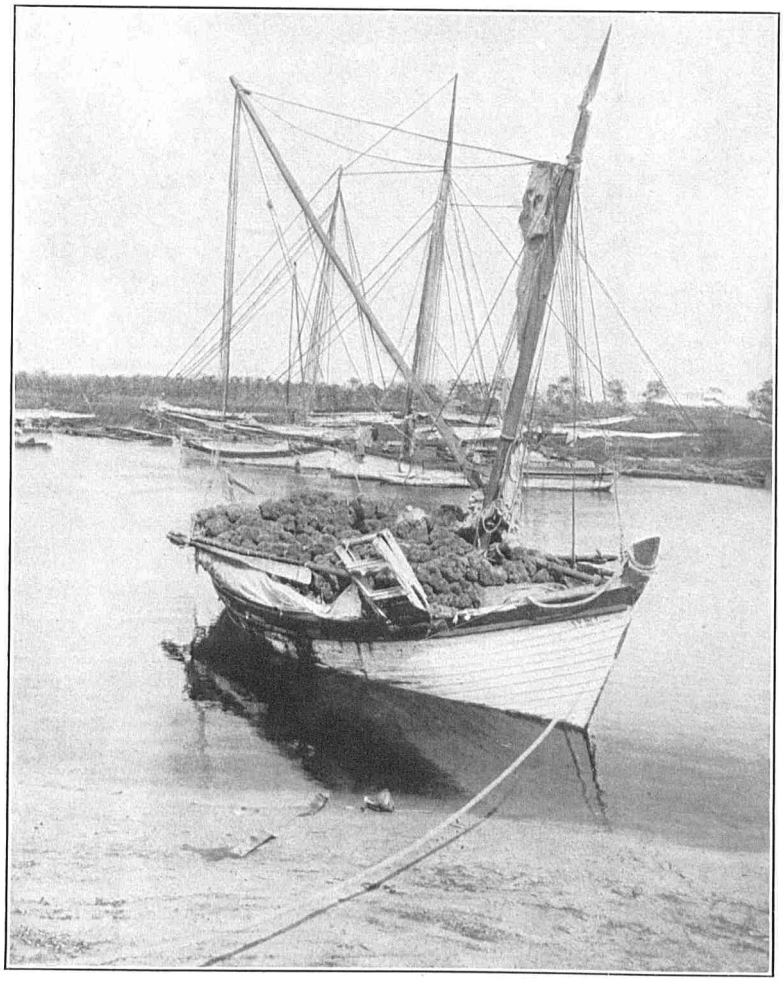

FIG. 1.—Diving boat, with cured catch. Shows diver's ladder triced up.

FIG. 2.—Diving boat hauled out.

efficiency of the diver's work and not infrequently his life depend upon intelligent communication between him and the boat, while delays and misinterpretation of signals are always annoying and in case of the emergencies likely to arise in this class of work are exceedingly dangerous. One hoseman, the relief from the pump, who pays out or takes in hose as the diver moves away from or approaches the boat; a surplus of hose trailing out in strong currents impedes the diver in his progress over the bottom, and should the hose become fouled, pinched, or kinked the supply of air may be cut off with possibly serious results. When moving from place to place the hose tender relieves the stern oarsman, and the bow oarsmen and pump men alternate at their respective duties, thus obtaining some rest. On boats provided with gasoline engines there is sometimes in addition a man to run the engine.

At the present time[a] the rates of pay are based on shares as follows: The operator furnishes the boats, outfits, and provisions and receives one-half of the gross proceeds of the trip, the remainder being divided into shares, of which the divers receive 2½ or 3, the life-line tender and stern oarsman 1½, and the others of the crew 1 each.

The deposit or living boats are usually schooners, such as are commonly employed in the hook fishery, most of them between 10 and 20 tons register. They furnish the living quarters for the crew and a place of deposit for the sponges, most of which at present are cured aboard, as is done in the Mediterranean. They carry in addition to the diving crews a master, one deck hand, and a cook, the former being a citizen of the United States, as required by the navigation laws. To each deposit boat, according to its size, there are attached one or two machine boats with their crews. During the first year of the fishery one schooner was fitted for three diving crews, but it has never gone into commission, on account of the depression of the price of sponges and the lessened profit of operation. Most of the boats carry but one diving crew.

The method of carrying on the fishery is as follows: When the vessel arrives in approximately the region where she wishes to work, the bars are located by sounding with the lead or by towing a small grapnel lashed in such manner as to trip when it fouls. When a bed of suitable size is found, it is marked with a buoy and the machine boats are sent away. Since the latter have been equipped with engines, they themselves frequently search for the bars. The diver then dresses as before described and descends, taking with him a netting bag about 2 feet deep and 18 inches or more in diameter, with a hinged hoop at the top closing like the frame of an old-fashioned carpet bag. The boat, propelled either by the oars or by means of the engine, follows him in his progress over the bottom, which is marked by a stream of fine bubbles escaping from

[a] This statement applies January, 1909.

the wristbands of the suit and by sudden eruptions of large ones discharged from the relief valve, which he opens from time to time by throwing his head back against the helmet.

He regulates the air supply with two purposes in view—respiration and a proper degree of buoyancy in his suit. If all is working properly the suit is always more or less inflated, and in spite of the great weight of the man and his armor, 350 to 400 pounds as weighed in air, he treads the bottom with a pressure of but a few pounds. Should insufficient air be liberated the suit becomes still more inflated and its buoyancy will carry him to the surface, a method frequently employed in making ascent from moderate depths, but liable to produce serious hygienic consequences if practiced under greater pressures. If the pump be working too rapidly or too slowly he gives the proper signal by jerking on the life line, and the supply of air is modified accordingly.

In moving over the bottom the divers do not walk as do persons on land, a thing impossible owing to their levity and the resistance of the water. Their movements are rather a series of headlong springs or dives upward and forward with the body strongly inclined.

As the diver finds the sponges, which in the region in which the work is carried on are of but four kinds—sheepswool, yellow, wire, and grass—he tears them loose and places them in the bag, which when full he signals to have pulled up on the life line and an empty one sent down. When he wishes to come up, he gives the signal and walks toward the side of the boat, the direction of which he can determine by the trend of the life line, or else he buoys himself to the surface and is hauled in hand over hand, rotating and rolling like some monstrous form of the deep, with the air whistling and gasping at intervals from the relief valve. Reaching the ladder, he laboriously ascends with the assistance of one or two members of the crew, his helmet is taken off, and, unburdened of his chest and back weights, he comes aboard to be relieved by his diving mate.

The length of time that a diver can safely stay submerged depends upon his physical strength and endurance, but especially upon the depths in which he works. On the Florida coast, where sponging is generally carried on in less than 60 feet, the usual shift is about two hours down and two resting, but fairly good divers can stand longer shifts.

The maximum depth at which divers can work has been a matter of dispute among the spongers, but there is no doubt that they can go much deeper than they have ever yet gone on the Florida coast (about 110 feet), though at the greater depths their efficiency decreases and they become subject to serious maladies, which will be discussed later. The laws of Greece, for humanitarian reasons, prohibit diving at greater depths than 38 meters (125 feet), but it is said that the Mediterranean sponge divers sometimes work in 40 fathoms (240

feet). Siebe, a recognized authority, states that 150 feet is the maximum limit for safe diving by physically sound men, and that the greatest diving feat known is a stay of forty-two minutes in a depth of 201 feet.

The proceeds of a sponge diver's work depend upon a number of conditions—his own skill and industry, the condition of the water, and the abundance, size, and distribution of the sponges on the bottom. During the spring and summer of 1906, when the boats were working in from 40 to 60 feet of water, with good average weather conditions and sponges relatively abundant, two divers working alternately were taking on an average about 20 bunches a day, or, making allowance for time lost from various reasons, between 25 and 30 bunches per working day. One of the most successful trips averaged 50 bunches per day for each diver, or about 500 bunches in five days for the boat. For single days this average has been considerably exceeded.

During the season for diving, which under act of Congress began October 1, 1907, and closed April 30, 1908, the conditions were far from favorable, the weather especially during the winter and spring being unusually turbulent and the water almost constantly turbid. In consequence of this the divers were working closer to shore, in water of much less depth than the minimum prescribed by law, and in April I saw two boats operating even within state jurisdiction. The sponges brought in were ragged and inferior in size and quality, and many of them were, moreover, poorly cleaned. The proportion of small sponges was large, the limit prescribed by law being almost wholly disregarded, as was also the case during the season preceding. I saw large quantities of small sponges in some of the packing houses, and it is a matter of common notoriety in Tarpon Springs that many small sponges packed in bags are shipped by the Greek spongers without ever being exposed to sale at the Sponge Exchange.

Owing to the unfavorable weather the product per outfit during the season from October 1, 1907, to May 1, 1908, was much below that stated above, averaging about 300 bunches per boat per month. The total yield was $392,399, as compared with $638,766 the year before, but this was due in part to the restriction of the diving season to seven months during the period least favorable for work. The character of the catch during the season is indicated by the fact that 50 per cent of the sponges were larger than twelves, about 12 per cent were twelves or smaller, and 38 per cent were packed as cuts and seconds. The yield was inferior in quality to that of the first year of the fishery, but was about the same as in 1906, excepting that the proportion of cuts and seconds was higher.

During the winter of 1908–9 the yield of sponges on days when the weather was favorable was from 10 to 15 bunches per diving boat. The following actual

returns will illustrate the average catches during the months of December and the early part of January:

Diving boat *Amphitrite*, out two months:

172 bunches sheepswool, selling for	$1,292.05
60 bunches small sheepswool, selling for	116.00
253 bunches yellow, selling for	289.50
84 bunches grass, selling for	47.00
569 bunches all kinds, selling for	1,744.55

Diving boat *Harikila*, out two months:

160 bunches sheepswool, selling for	$1,353.00
59 bunches small sheepswool, selling for	117.18
205 bunches yellow, selling for	259.00
70 bunches small yellow, selling for	34.00
94 bunches grass, selling for	55.00
588 bunches all kinds, selling for	1,818.18

Schooner *Edna Louise*, with two diving boats, out seventeen days:

250 bunches sheepswool, selling for	$1,398.00
75 bunches small sheepswool, selling for	101.00
444 bunches yellow, bid refused	248.00
115 bunches wire, bid refused	83.00
884 bunches all kinds, bid	1,830.00

These figures give an average per boat day of about 13 bunches of sponges of all kinds, selling for $35.

As compared with hooking, diving requires a more expensive equipment. The smaller vessels of the old fleet are not suitable for living boats, for the crews are necessarily large and require the same accommodations needed for an equal number of hookers, especially as the sponges are now cured on the vessels. In addition, the diving or machine boat, with its pumps, suits, and gear, is much more costly than the sponge hooks, glasses, and five or six dingeys which constitute the secondary equipment of the hooker. The expense of operation and maintenance is also greater, and to pay expenses the yield per man must be considerably larger.

To compensate for this, diving has several advantages: It can be carried on in rougher and more turbid water and at greater depths, and, moreover, the diver can get sponges inaccessible to the hooker working on the same beds. In practice, too, the diving crews can be kept more persistently at their work, and the Greeks are less prone to lose time running inshore at night unless under stress of weather. When diving was first introduced on the Florida coast it was claimed that but rarely would the sea be so turbulent as to stop operations. Experience, especially that of the last season, has shown that this fishery also is more or less at the mercy of the weather and that while it can be prosecuted

when hooking would be absolutely impossible the frequent gales and strong northers which sweep the Gulf of Mexico in winter and early spring are factors that have to be reckoned with, and the proportion of days of enforced idleness is considerable.

The turbidity of the water is also a factor, and while it is rarely absolutely prohibitive, as with the hookers, it at times more or less seriously interferes with the efficiency of operations. When the water is clear and the light good, the diver can see plainly at a distance of some yards, but on cloudy days in turbid water sponges more than a few feet away will escape notice, especially if the bottom be covered with gorgonians and similar growths. It will be readily understood that under such conditions the efficiency of the diver is much reduced, so that he must necessarily miss many sponges that would be readily found under more favorable circumstances, and that while moderately clear water is not essential, as in the earlier methods of sponging, its relative prevalence is reflected in the balance sheet at the end of a trip.

The ability of the diver to penetrate to a depth beyond that accessible to the hooker is of value only if sponges extend into the deeper water. That this is the case to some extent has already been demonstrated, but there is as yet no indication that the beds extend to depths equal to those attained in the Mediterranean. The advantage in the efficiency of the two methods at depths of 40 feet or more, where the hooker is approaching his limit, is vastly in favor of the diver, who can work there in average weather, while the hooker can operate only under very rare combinations of favorable conditions.

Finally, the diver is able to gather sponges which, while within the limits of the hooks, are so situated as to be invisible or inaccessible from above. As has been stated elsewhere, the bottom on the beds is rough and irregular, and many sponges grow in crevices, on overhanging ledges, or hidden by masses of coral, and can not be gathered by the hooker. The diver walking over the bottom can find and secure almost everything, stripping the bottom almost bare if he wishes.

KILLING AND CURING.

When a sponge is brought to the surface a certain amount of air immediately enters its pores and replaces the water in some of the canals and chambers. In this condition it will float, and the spongers, taking this as a sign of death, believe that the sponge is killed immediately upon exposure. If the floating sponge be left to itself, however, most of the entrapped air is soon expelled by the pressure of the water and it will then sink and become a "roller." The air can also be expelled without injury to the sponge by gently squeezing it under water. The hookers have always killed their catch by prolonged exposure on the decks of the vessels, the sponges being carefully placed "root" down, so as to facilitate the escape of the "gurry," or liquefied organic matter which

results from decomposition. In hot sunny weather death comes rather quickly and the internal tissues begin to slough in a day or two, but when it is cold and cloudy a week of exposure is sometimes insufficient to kill the tissues throughout, the result often being the retention of more or less hardened matter in the substance of the cured sponge, to the detriment of its value and very difficult to remove by subsequent treatment. The spongers recognize this fact, but being imbued with the idea that the sponge is dead as soon as removed from the water they ascribe it not to retained vitality but to what they call "chilling," a physical change in the fleshy substance of the sponge which causes it to resist decay. During the process of killing some care has to be exercised to prevent the skin from drying and adhering to the skeleton.

Each hooking vessel has located somewhere along shore at a point accessible to the sponge grounds an inclosure called a "crawl" or "kraal," about 10 feet square, constructed of stakes driven close together and nailed to horizontal pieces to keep them from spreading. Among the keys the crawls are usually isolated, small, and of a temporary character, but on the Bay grounds they are more substantial and grouped under the care of a common watchman to prevent the depredations liable to occur during the distant absences of the owners. The Bay fleet has groups of crawls near Cedar Keys Light and at Baileys Bluff, Sawyers, and Union Crawl, just north of the mouth of Anclote River, and at various times they have been established at other localities. In these inclosures the dead sponges are placed to macerate, the organic matter undergoing rapid decomposition and liquefaction. This method appears to have originated in the Bahamas, the first sponges produced in Florida being rather poorly cured, principally because they were not thoroughly beaten and squeezed. It is stated that for similar reasons the first product of the Bay grounds was regarded as inferior to the Key sponges and sold at a lower price.

Usually on Friday night the vessels run in to the crawls, and Saturday is spent in "crawling" the dead sponges of the recent catch and cleaning those deposited on the Saturday previous. During the week most of the fleshy matter has macerated and washed out and the remainder is removed by beating the partly submerged sponge with a short heavy stick and by repeated squeezing under water. If particles of skin adhere they are scraped off with a dull knife. The crawls are always located in salt or brackish water, as maceration in fresh water darkens the fiber of the sponge. By means of a long needle the cleaned sponges are then strung on rope yarns 6 feet long, the ends of which are tied together to form wreaths, technically known as "bunches," which are partly dried and stowed in the hold of the vessel pending the end of the trip. The approved method is to string together sponges of approximately the same size, "eye and root"—that is, with the top of one sponge against the bottom of its neighbor—but some captains will have their catch

strung so as to make the largest possible number of bunches by placing the minimum number of sponges on each, a subterfuge which rarely deceives the watchful buyer, who reduces his bid accordingly.

The diving boats at first followed the same methods, but afterwards to obviate the loss of time involved in making the weekly trips to the crawls and to save the expense of employing watchmen they recurred to the method of cleaning on the vessels, to which they had been accustomed in the Mediterranean. The sponges as taken are placed on deck and thoroughly trod under the bare feet of the crew, so as to hasten death by crushing the soft tissues. They are then hung over the side to macerate, after which they are washed out on deck in tubs of sea water. The results of this method of cleaning were at first regarded as less satisfactory than of that practiced by the hookers. Occasionally more or less solid matter is retained through imperfect killing and maceration, and in addition the water in the tubs is sometimes allowed to become thick and gelatinous with partially dissolved animal matter, which, adhering to the fiber, makes the sponge hard when dry and sticky when moist. When sponges so treated are thrown on the beach, sand and dust adhere to the surface, injuring the color and making pure goods look as if "loaded." When properly performed, however, the results are good. Less sand is picked up by the sponges than when they are rolled about in the crawls, and as the animal matter is more quickly removed there is less injury to the fiber of the sponge than if the maceration be more prolonged. The sponges are also lighter in color and cleaner in appearance, while the soluble animal matter left in the sponge by the washing in tubs is appreciated by the buyers as adding to the weight.

THE SPONGE TRADE.

Buying.—The first sponges produced in Florida were sold to one or two merchants at Key West or exchanged for goods at a fixed price of 10 cents a pound, but as the demand increased competition for the product grew also an the method of selling at auction developed.

At Key West, which held an absolute monopoly of the trade until about 1891, a wharf is set apart as a sponge market, the buyers each paying for its use a fee proportional to the amount of their purchases. Here the spongers bring their catch and spread them, sorted according to kinds, in piles arranged to show them to best advantage, the sponges being wet to swell them to their largest proportions. At appointed times the buyers assemble, and, proceeding from pile to pile, bid for each separately, basing their offers upon the number of bunches and the size and quality of the sponges. Each buyer writes his bid upon a slip of paper and hands it to the person appointed for the purpose, who when all bids are in reads them off, the highest taking the lot, though the owner may elect not to sell at the price offered. Intending buyers usually examine the

several cargoes offered before the sale begins, and the bids usually run pretty close, though I have seen a bidder, through some miscalculation and his anxiety to buy, offer 40 per cent more than his nearest competitor.

At Tarpon Springs until recently the sponges were sold at the several crawls at such times as the spongers chose to offer them. As the crawls were several miles from the town and separated from one another by considerable distances, much time was often lost in the disposal of relatively small quantities. To obviate this a sponge exchange has been organized by the buyers, who have bought a suitable site on the river near town and have erected houses and bins suitable for the storage of their purchases. The expenses of construction and operation are borne jointly by the buyers, or the houses which they represent. The actual sales follow the system already described. Tarpon Springs first became a sponge mart on a small scale about 1891, and at the end of ten years it had passed Key West in importance. With the waning of the catch on the Key grounds, and especially with the development of diving, it has now secured a practical monopoly of the business and Key West has become an almost negligible factor.

Packing.—As purchased from the fishermen the sponges are cleaned of animal matter, but they are more or less irregular where they have been torn from the bottom, and they frequently contain shells or fragments of coral and rock. After they are received at the packing house these foreign particles are removed and the irregularities and torn parts clipped off with sheep shears, the "clippers" requiring some skill to reduce the sponge to a regular shape with a minimum of waste, the work being done to best advantage while the sponges are wet. Large specimens, for which there is a limited demand, and especially those which are torn or contain crab holes, are cut into pieces with a sharp knife, the edge of which has been serrated with a file. Nearly all Anclote or Bay grass sponges, which are usually large and cup-shaped or conical, are so treated, as are at times considerable quantities of sheepwool and yellow sponges. There is always more or less loss in cutting up large sponges owing to the waste of trimming off the sharp edges left by the knife. After being trimmed the sponges are sorted according to size and quality, the whole perfect specimens being known as "forms," those with holes and similar imperfections as "seconds," while cut pieces are known as "cuts." The sizes are named from the number of "pieces" required to make a pound, the usual sizes being "ones, twos," "twos to threes," "threes to fours," "fours to sixes," sixes to eights," "eights to tens," "tens to twelves," "twelves to sixteens," and "sixteens to twenties." The "sizing" is usually made by eye, but in some cases, for greater accuracy, the sponges are passed through holes or rings.

The first sponges shipped from Key West were packed in cylindrical bales about 6 or 7 feet long and compressed by hand or treading with the feet, but within

a few years a dealer versed in the methods of the Bahama fishery introduced the present type of square bales. These vary in size according to the demands of the trade, the standard weights being 15, 30, 50, and 60 pounds. But one size, kind, and grade of sponges is placed in a bale, the pieces being packed in layers and rows, due care being exercised that when the head of the bale is opened the contents shall present the best possible appearance. A simple screw press is used for compression of the bale to about 40 per cent of its hand-packed thickness. The bales while still under pressure are sewed up in burlap and corded with jute rope ¼ or ⅜ inch in diameter. They are then weighed and marked with a card giving the date, the kind and grade, the weight, and the number of pieces. The sponges are packed almost dry, so that the pieces when relieved from pressure remain compressed until moistened. Owing to the hygroscopic character of sponges, the weight of the bales fluctuates in accordance with atmospheric conditions, moisture being absorbed in wet weather and discharged in dry, and dealers and jobbers selling sponges by the bale frequently keep their stocks in damp places for the sake of the gain in weight. When reasonably dry, baled sponges will keep for years without deterioration, but if allowed to become wet, especially with fresh water and in warm weather, they sometimes "heat" and turn yellow or orange in color, with more or less loss of strength of fiber.

During ten years or so preceding the inception of diving, owing to the limited supply of sponges and their high price, there grew up a practice of "loading" by which the weight was increased by the addition of foreign matter of various kinds. In later years this practice became so extravagant that practically all Florida sheepswool sponges were loaded to double their natural weight and in some cases the increase was 150 per cent. The fact of loading was well known in the trade and what was originally a deception became in the end a sort of legitimate fraud which deceived nobody, though the degree to which it should be practiced was a source of constant controversy between the packers and the jobbers. The process was originally fraudulent, but eventually absurd, the same amount of actual sponge being obtainable at about the same price, whether loaded or pure. In fact, a pound of pure sponge could usually be obtained at a slightly lower cost than double the quantity of goods loaded 100 per cent, the packer having to reimburse himself for the labor and materials consumed in loading. In addition, the quality of the loaded sponge was injured by reason of the gritty materials employed, which detracted from its usefulness for the finer purposes in the arts.

The methods of loading were supposedly kept more or less secret by the various packers, but, as a matter of fact, they differed only in minor details. The clipped sponges were placed in tanks containing a "dope" composed of water, glucose, glycerine, dextrin, salt, litharge, sand, and similar materials, the

whole being thoroughly stirred or tramped under foot to keep the heavier materials in suspension and incorporate them in the texture of the sponge. At first the excess of moisture was squeezed out by hand or with a clothes wringer, but later, when the desire for heavier loading became strong, the sponges were merely drained on a rack and then placed in the sun to dry.

When the supply of sponges was temporarily increased through the introduction of the diving machine and the price fell, loading was almost abandoned and most of the goods were shipped pure. But during 1908 the practice again developed, though the loading did not exceed about 25 per cent. At the beginning of 1909, with an increase in the price, there was a tendency to increase the percentage. The sand, salt, and glucose which formed the bulk of the old loading have been replaced by barytes, epsom salts, and dextrin, which are less gritty, not so hygroscopic, and more readily worked out. The present desire to increase the loading will probably induce the use of sand, as it is difficult to get the added weight without it.

Bleaching.—The sponges used in the arts are usually in their natural condition so far as color is concerned, but for bath purposes many persons prefer them bleached.

A fine whitish bleach which does not greatly injure the quality of the sponges may be imparted by repeatedly impregnating them with dense soapsuds and exposing them to the action of sun and air.

A bright yellow color, such as is generally seen in the bath sponges of the shops, may be produced as follows: Soak the sponges for about ten minutes in 5 per cent hydrochloric or sulphuric acid; then thoroughly wash in water and place in 5 per cent potassium permanganate solution until they have assumed a very dark brown, almost black, color; thoroughly wash again in fresh water and place, until almost decolorized, in a 10 per cent solution of oxalic acid. After another very thorough washing place them in a 10 per cent solution of sodium carbonate (washing soda) until they assume a bright yellow color. A very thorough washing completes the process. The fiber of all chemically bleached sponges is more or less injured by the treatment, and though softer they are inferior to the natural sponges in durability and resiliency and soon become soggy in use.

STATISTICS.

No statistics of the Florida sponge fishery are available for years prior to 1880, and no complete canvass, separate from the general fisheries of the state, was made until 1900. The following tables[a] exhibit in some detail the extent of the fishery in the years 1903 to 1908, inclusive, embracing the transition period during which hooking was largely supplanted by diving.

[a] Compiled from a canvass made by Mr. John N. Cobb, Bureau of Fisheries.

The difficulties in dealing statistically with this period have been considerable, as persons, and especially vessels, have been engaged, in many cases, part of the year in hooking and part in diving. In each such case, however, effort has been made to accredit the vessel to that method in which its activities predominated during each year.

The tables are interesting as showing not only the changes in the methods of the fishery, but also as exhibiting the shifting of the location of investment incident upon these changes. Until the inauguration of diving the investments at Key West (Monroe County) were paramount, but in 1906 Tarpon Springs (Hillsboro County) passed Key West as a center of investment, as it had done some years previously as the principal sponge market. In 1908 the capital employed in the fishery at Tarpon Springs exceeded that at Key West by about 85 per cent.

In the tables of the product for the years 1903 to 1908, inclusive, the weight is based upon the number of bunches purchased. In previous years it was determined from the pack, a method highly defective on account of the practice of "loading."

PERSONS EMPLOYED IN THE SPONGE FISHERY OF FLORIDA IN 1903–1908, BY COUNTIES.

	Monroe.	Hillsboro.	Pasco.	Levy.	Franklin.	Total.
1903.						
Vessel	1,033	84	13	16	52	1,198
Boat	700	164	----------	----------	23	887
Total	1,733	248	13	16	75	2,085
1904.						
Vessel	885	64	----------	16	50	1,015
Boat	630	112	----------	----------	20	762
Total	1,515	176	----------	16	70	1,777
1905.						
Vessel	816	177	----------	21	32	1,046
Boat	721	117	----------	----------	25	863
Total	1,537	294	----------	21	57	1,909
1906.						
Vessel	681	613	13	30	48	1,385
Boat	595	221	----------	----------	13	829
Total	1,276	834	13	30	61	2,214
1907.						
Vessel	495	570	----------	27	34	1,126
Boat	490	462	----------	----------	10	962
Total	985	1,032	----------	27	44	2,088
1908.						
Vessel	583	910	----------	----------	20	1,513
Boat	392	397	----------	----------	18	807
Total	975	1,307	----------	----------	38	2,320

INVESTMENT IN THE SPONGE FISHERY OF FLORIDA IN 1903–1908, BY COUNTIES.

Item.	Monroe.		Hillsboro.		Pasco.		Levy.		Franklin.		Total.	
	No.	Value.	No.	Value.	No.	Value.	No.	Value.	No.	Value.	No.	Value.
1903.												
Vessels	121	$195,385	10	$11,650	1	$1,250	2	$1,750	6	$5,150	140	$215,185
Tonnage	1,521		100		12		16		50		1,699	
Outfit		64,490		4,000		300		850		2,050		71,690
Boats	200	90,300	38	13,550					5	1,900	243	105,750
Outfit		90,000		6,635						1,900		98,535
Apparatus, vessel fisheries:												
Hooks, etc		2,544		209		34		45		116		2,948
Apparatus, boat fisheries:												
Hooks, etc		2,300		318						43		2,661
Shore and accessory property		4,500		1,400								5,900
Total for year		449,519		37,762		1,584		2,645		11,159		502,699
1904.												
Vessels	107	163,065	8	9,000			2	1,750	6	4,950	123	178,765
Tonnage	1,234		79				16		49		1,378	
Outfit		55,280		3,400				750		1,875		61,305
Boats	180	77,400	24	9,300					4	1,700	208	88,400
Outfit		72,000		5,405						540		77,945
Apparatus, vessel fisheries:												
Hooks, etc		2,163		153				45		124		2,485
Apparatus, boat fisheries:												
Hooks, etc		2,340		215						36		2,591
Shore and accessory property		4,800		1,300								6,100
Total for year		377,048		28,773				2,545		9,225		417,591
1905.												
Vessels	91	153,980	[a] 17	25,600			3	2,600	4	3,400	115	185,580
Tonnage	1,158		224				22		31		1,435	
Outfit		51,540		13,995				1,450		1,375		68,360
Boats	206	88,580	23	9,400					5	2,000	234	99,980
Outfit		82,400		4,400						1,075		87,875
Apparatus, vessel fisheries:												
Diving			11	6,600							11	6,600
Hooking		1,998		217				59		79		2,353
Apparatus, boat fisheries:												
Diving			1	600							1	600
Hooking		2,678		200						45		2,923
Shore and accessory property		4,300		1,300								5,600
Total for year		385,476		62,312				4,109		7,974		459,871
1906.												
Vessels	40	40,360	[b] 47	104,450	1	1,250	4	4,800	6	4,400	98	155,260
Tonnage	345		1,083		12		36		41		1,517	
Outfit		18,480		45,815		600		1,950		1,650		68,495
Boats	170	73,100	34	16,660					3	1,250	207	91,010
Outfit		68,000		13,328						800		82,128
Apparatus, vessel fisheries:												
Diving			55	32,400							55	32,400
Hooking		681		207		34		87		124		1,133
Apparatus, shore fisheries:												
Diving			14	8,262						25	14	8,262
Hooking		2,210		310								2,545
Shore and accessory property		4,600		1,200								5,800
Total for year		207,431		222,632		1,884		6,837		8,249		447,033
1907.												
Vessels	62	62,455	[c] 47	95,780			3	3,250	4	3,350	116	164,835
Tonnage	568		1,050				32		32		1,682	
Outfit		22,328		66,195				900		1,450		90,873
Boats	140	60,200	74	36,200					2	900	216	97,300
Outfit		42,000		29,000						500		71,500
Apparatus, vessel fisheries:												
Diving			48	27,600							48	27,600
Hooking		1,016		478				84		90		1,668
Apparatus, boat fisheries:												
Diving			30	18,000							30	18,000
Hooking		1,820		450						18		2,288
Shore and accessory property		4,000		1,000								5,000
Total for year		193,819		274,703				4,234		6,308		479,064
1908.												
Vessels	[d] 72	85,705	[e] 71	145,770					2	1,950	145	233,425
Tonnage	709		1,477						19		2,205	
Outfit		26,278		74,125						740		101,143
Boats	130	65,000	56	33,850					4	1,600	190	100,450
Outfit		8,000		30,240						400		38,640
Apparatus, vessel fisheries:												
Diving	3	1,800	86	51,600							89	53,400
Hooking		1,188		469						56		1,713
Apparatus, boat fisheries:												
Diving			34	20,400							34	20,400
Hooking		910		558						28		1,496
Shore and accessory property		4,100		500								4,600
Total for year		192,981		357,512						4,774		555,267

[a] There were 11 diving boats, valued at $3,500, working with these vessels; their value, but not number, has been included with vessels.
[b] There were 55 diving boats, valued at $18,850, working with these vessels; their value, but not number, has been included with vessels.
[c] There were 48 diving boats, valued at $16,100, working with these vessels; their value, but not number, has been included with vessels.
[d] There were 3 diving boats, valued at $900, working with these vessels; their value, but not number, has been included with vessels.
[e] There were 86 diving boats, valued at $28,850, working with these vessels; their value, but not number, has been included with vessels.

CATCH BY VESSELS AND BOATS IN THE SPONGE FISHERY OF FLORIDA IN 1903–1908, BY COUNTIES, KINDS, AND GROUNDS.

Kinds and grounds.	Monroe.		Hillsboro.		Pasco.		Levy.		Franklin.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1903.												
Hook catch by vessels on Bay grounds:												
Sheepswool	141,255	$287,014	12,836	$25,520	86	$136	1,168	$2,013	3,339	$6,057	158,684	$320,740
Yellow	38,571	11,119	3,836	912	20	4	302	75	1,374	308	44,103	12,418
Grass	33,790	6,047	8,434	1,301	52	11	438	84	588	94	43,302	7,537
Total	213,616	304,180	25,106	27,733	158	151	1,908	2,172	5,301	6,459	246,089	340,695
Hook catch by vessels on Key grounds:												
Sheepswool	10,534	16,749									10,534	16,749
Yellow	3,924	1,894									3,924	1,894
Grass	10,000	2,200									10,000	2,200
Glove	3,828	579									3,828	579
Velvet or boat	571	287									571	287
Total	28,857	21,709									28,857	21,709
Hook catch by boats on Bay grounds:												
Sheepswool	10,834	13,654	16,251	24,931					2,496	2,605	29,581	41,190
Yellow	3,156	661	5,460	1,249					1,434	274	10,050	2,184
Grass	8,626	1,033	7,012	941					1,332	210	16,970	2,184
Total	22,616	15,348	28,723	27,121					5,262	3,089	56,601	45,558
Hook catch by boats on Key grounds:												
Sheepswool	20,535	32,883									20,535	32,883
Yellow	3,924	1,894									3,924	1,894
Grass	13,109	2,873									13,109	2,873
Glove	7,656	1,159									7,656	1,159
Velvet or boat	1,144	575									1,144	575
Total	46,368	39,384									46,368	39,384
Total for year	311,457	380,621	53,829	54,854	158	151	1,908	2,172	10,563	9,548	377,915	447,346
1904.												
Hook catch by vessels on Bay grounds:												
Sheepswool	121,672	235,212	9,091	11,111			1,653	3,426	3,793	5,068	136,209	254,817
Yellow	26,980	8,063	2,544	574			384	120	1,620	393	31,528	9,150
Grass	17,292	3,084	7,536	1,005			356	38	1,058	231	26,242	4,358
Wire	76	13									76	13
Total	166,020	246,372	19,171	12,690			2,393	3,584	6,471	5,692	194,055	268,338
Hook catch by vessels on Key grounds:												
Sheepswool	13,294	20,256										20,256
Yellow	4,459	2,118										2,118
Grass	9,295	1,450										1,450
Glove	2,927	388										388
Velvet or boat	879	499										499
Total	30,854	24,711									30,854	24,711
Hook catch by boats on Bay grounds:												
Sheepswool	7,972	11,863	10,029	18,037					846	1,300	18,847	31,200
Yellow	2,684	644	3,698	938					384	95	6,766	1,677
Grass	3,942	447	2,718	327					484	59	7,144	833
Total	14,598	12,954	16,445	19,302					1,714	1,454	32,757	33,710
Hook catch by boats on Key grounds:												
Sheepswool	26,589	40,511									26,589	40,511
Yellow	8,919	4,238									8,919	4,238
Grass	18,591	2,900									18,591	2,900
Glove	5,856	776									5,856	776
Wire	22	3									22	3
Velvet or boat	1,758	998									1,758	998
Total	61,735	49,426									61,735	49,426
Total for year	273,207	333,463	35,616	31,992			2,393	3,584	8,185	7,146	319,401	376,185
1905.												
Hook catch by vessels on Bay grounds:												
Sheepswool	123,343	274,412	12,867	31,713			1,858	8,063	5,757	9,703	143,825	323,891
Yellow	20,642	8,725	2,442	813			328	147	1,472	547	24,884	10,232
Grass	10,561	2,067	8,408	1,321			50	11	704	130	19,723	3,529
Wire	1,142	164									1,142	164
Total	155,688	285,368	23,717	33,847			2,236	8,221	7,933	10,380	189,574	337,816
Diving catch by vessels on Bay grounds:												
Sheepswool			9,250	47,506							9,250	47,506
Yellow			572	225							572	225
Grass			172	30							172	30
Total			9,994	47,761							9,994	47,761
Hook catch by vessels on Key grounds:												
Sheepswool	20,613	25,040									20,613	25,040
Yellow	4,586	2,345									4,586	2,345
Grass	13,510	3,983									13,510	3,983
Glove	4,387	737									4,387	737
Velvet or boat	792	450									792	450
Total	43,888	32,555									43,888	32,555
Hook catch by boats on Bay grounds:												
Sheepswool	8,233	15,427	10,387	18,574					2,026	2,924	20,646	36,925
Yellow	2,268	736	2,944	897					644	109	5,856	1,742
Grass	2,878	408	3,924	490					214	28	7,016	926
Total	13,379	16,571	17,255	19,961					2,884	3,061	33,518	39,593
Hook catch by boats on Key grounds:												
Sheepswool	41,227	50,082									41,227	50,082
Yellow	9,172	4,690									9,172	4,690
Grass	27,020	7,968									27,020	7,968
Glove	8,774	1,473									8,774	1,473
Wire	350	88									350	88
Velvet or boat	1,585	900									1,585	900
Total	88,128	65,201									88,128	65,201
Total for year	301,083	399,695	50,966	101,569			2,236	8,221	10,817	13,441	365,102	522,926

CATCH BY VESSELS AND BOATS IN THE SPONGE FISHERY OF FLORIDA IN 1903–1908, BY COUNTIES, KINDS, AND GROUNDS—Continued.

Kinds and grounds.	Monroe.		Hillsboro.		Pasco.		Levy.		Franklin.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1906.												
Hook catch by vessels on Bay grounds:												
Sheepswool	42,202	$73,799	14,964	$29,663	1,934	$4,054	8,100	$12,420	1,978	$2,613	69,178	$122,549
Yellow	7,206	2,844	2,878	796	8	2	506	190	1,890	628	12,488	4,460
Grass	2,562	708	494	110	6	1	32	7	500	101	3,594	927
Total	51,970	77,351	18,336	30,569	1,948	4,057	8,638	12,617	4,368	3,342	85,260	127,936
Diving catch by vessels on Bay grounds:												
Sheepswool			254,870	498,921							254,870	498,921
Yellow			59,022	20,525							59,022	20,525
Grass			3,412	645							3,412	645
Total			317,304	520,091							317,304	520,091
Hook catch by vessels on Key grounds:												
Sheepswool	6,283	9,284									6,283	9,284
Yellow	3,442	2,080									3,442	2,080
Grass	11,798	3,354									11,798	3,354
Glove	2,218	364									2,218	364
Velvet or boat	440	163									440	163
Total	24,181	15,245									24,181	15,245
Hook catch by boats on Bay grounds:												
Sheepswool	3,460	5,647	16,387	27,723					4,611	6,678	24,458	40,048
Yellow	352	120	4,114	1,287					596	206	5,062	1,613
Grass	98	23	2,876	412					160	45	3,134	480
Total	3,910	5,790	23,377	29,422					5,367	6,929	32,654	42,141
Diving catch by boats on Bay grounds:												
Sheepswool			63,858	112,065							63,858	112,065
Yellow			18,038	6,316							18,038	6,316
Grass			1,230	294							1,230	294
Total			83,126	118,675							83,126	118,675
Hook catch by boats on Key grounds:												
Sheepswool	12,567	18,570									12,567	18,570
Yellow	6,886	4,160									6,886	4,160
Grass	23,597	6,709									23,597	6,709
Glove	4,437	730									4,437	730
Velvet or boat	882	326									882	326
Total	48,369	30,495									48,369	30,495
Total for year	128,430	128,881	442,143	698,757	1,948	4,057	8,638	12,617	9,735	10,271	590,894	854,583
1907.												
Hook catch by vessels on Bay grounds:												
Sheepswool	38,122	61,120	11,506	14,343			2,710	3,291	3,522	6,168	55,860	84,922
Yellow	19,673	5,902	6,558	1,974			2,482	997	3,396	1,066	32,109	9,939
Grass	31,462	6,131	11,176	1,674			572	103	3,296	594	46,506	8,502
Total	89,257	73,153	29,240	17,991			5,764	4,391	10,214	7,828	134,475	103,363
Diving catch by vessels on Bay grounds:												
Sheepswool			135,598	248,617							135,598	248,617
Yellow			137,648	41,285							137,648	41,285
Grass			23,750	5,518							23,750	5,518
Total			296,996	295,420							296,996	295,420
Hook catch by vessels on Key grounds:												
Sheepswool	7,707	11,556									7,707	11,556
Yellow	4,717	1,998									4,717	1,998
Grass	13,497	3,635									13,497	3,635
Glove	490	102									490	102
Total	26,411	17,291									26,411	17,291
Hook catch by boats on Bay grounds:												
Sheepswool	849	811	13,146	16,611					925	1,910	14,920	19,332
Yellow	128	33	11,410	2,255					1,434	362	12,972	2,650
Grass	1,022	117	13,282	1,772					992	141	15,296	2,030
Total	1,999	961	37,838	20,638					3,351	2,413	43,188	24,012
Diving catch by boats on Bay grounds:												
Sheepswool			48,834	82,529							48,834	82,529
Yellow			47,410	13,395							47,410	13,395
Grass			5,594	1,055							5,594	1,055
Total			101,838	96,979							101,838	96,979
Hook catch by boats on Key grounds:												
Sheepswool	15,415	23,113									15,415	23,113
Yellow	9,436	3,996									9,436	3,996
Grass	26,995	7,271									26,995	7,271
Glove	982	206									982	206
Wire	13	2									13	2
Velvet or boat	221	98									221	98
Total	53,062	34,686									53,062	34,686
Total for year	170,729	126,091	465,912	431,028			5,764	4,391	13,565	10,241	655,970	571,751
1908.												
Hook catch by vessels on Bay grounds:												
Sheepswool	43,148	58,175	14,139	13,472					1,769	1,723	59,056	73,370
Yellow	13,614	2,389	7,716	1,039					2,040	264	23,370	3,692
Grass	12,664	1,368	13,384	1,285					528	47	26,576	2,700
Total	69,426	61,932	35,239	15,796					4,337	2,034	109,002	79,762

CATCH BY VESSELS AND BOATS IN THE SPONGE FISHERY OF FLORIDA IN 1903-1908, BY COUNTIES, KINDS, AND GROUNDS—Continued.

Kinds and grounds.	Monroe.		Hillsboro.		Pasco.		Levy.		Franklin.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1908—Continued.												
Diving catch by vessels on Bay grounds:												
Sheepswool	1,356	$1,561	151,658	$284,014							153,014	$285,575
Yellow	1,072	196	128,924	29,444							129,996	29,640
Grass	320	52	49,780	7,557							50,100	7,609
Wire	56	3	8,240	1,314							8,296	1,317
Total	2,804	1,812	338,602	322,329							341,406	324,141
Hook catch by vessels on Key grounds:												
Sheepswool	23,879	30,926									23,879	30,926
Yellow	4,879	2,180									4,879	2,180
Grass	6,402	1,861									6,402	1,861
Glove	327	134									327	134
Velvet or boat	671	511									671	511
Total	36,158	35,612									36,158	35,612
Hook catch by boats on Bay grounds:												
Sheepswool	159	81	23,807	22,697					1,543	$2,497	25,509	25,275
Yellow			8,936	1,432					1,148	230	10,084	1,662
Grass			10,390	1,064					260	36	10,650	1,100
Total	159	81	43,133	25,193					2,951	2,763	46,243	28,037
Diving catch by boats on Bay grounds:												
Sheepswool			24,344	38,480							24,344	38,480
Yellow			17,506	3,774							17,506	3,774
Wire			118	58							118	58
Grass			5,844	946							5,844	946
Total			47,812	43,258							47,812	43,258
Hook catch by boats on Key grounds:												
Sheepswool	23,879	30,927									23,879	30,927
Yellow	4,879	2,181									4,879	2,181
Grass	10,045	3,014									10,045	3,014
Glove	975	402									975	402
Wire	80	10									80	10
Velvet or boat	2,010	1,532									2,010	1,532
Total	41,868	38,066									41,868	38,066
Total for year	150,415	137,503	464,786	406,576					7,288	4,797	622,489	548,876

For purposes of comparison and to illustrate the statistical history of the Florida sponge fisheries, another series tables have been prepared. They embrace all years for which accurate returns are available. The data for 1903 to 1908, inclusive, are summaries of the preceding tables here first published, and for the years prior to 1903 are obtained from previous publications of the Bureau of Fisheries.

The returns of the investments in the sponge fisheries prior to 1900 are incomplete or inseparable from those in other fisheries, and the same statement applies to the personnel. The yield of the fisheries is known for a longer series of years, though the earlier returns are not so fully itemized as are those for the years beginning with 1900. It will be observed that all of the tables indicate a general shrinkage in the fishery until 1905, when the success of the experiment with diving apparatus administered a stimulus and largely revolutionized the methods. Since that time there has been an increase in the total investment, the number of vessels employed, the personnel of the fishery, and especially in the volume and value of the catch, though the latter reached its maximum, so far as the sheepswool sponges are concerned, in 1906. In that year the quantity of sheepswool sponges alone far exceeded that of all kinds in any previous year in the history of the fishery, and the value was greater than that of the entire yield of the fishery in any year before or since.

In 1907 and 1908 the production of sheepswool sponges fell between 35 and 40 per cent, and to an even greater extent in value. This retrogression in the production of the highest grade of sponges was due to legal restrictions placed on diving, which became operative in 1907.

Accompanying this decrease there has been an enormous increase in the production of the cheaper sponges, especially yellow and grass, and the entrance of the previously neglected wire sponge into the markets as a valuable product. The production of yellow sponges in 1908 was about fourfold that of 1905, and about 50 per cent more grass sponges were put on the market, while 8,494 pounds of wire sponges, valued at $1,385, were marketed in 1908, and the product of 1909 will much exceed this in quantity, with a value relatively much greater than in 1908.

Diving apparatus has undergone a rapid increase, but it is probable that its maximum has now been nearly reached, and its future development will be slower. There was a steady decrease in the number of vessels and men employed in the hook fishery between 1900 and 1905, and since that year the decrease has been rapid. Between 1900 and 1908 the number of vessels and men employed in hooking each fell about 54 per cent, and the product decreased about 45 per cent. At the present time there are indications of an increase in this method of sponging, certain of the diving vessels manned by Greeks outfitting with hooks and dingeys for work during the summer, when diving is prohibited.

INVESTMENT IN THE SPONGE FISHERY OF FLORIDA, EXCLUDING SPONGE BUYING, FOR A SERIES OF YEARS.

Item.	1880.		1900.		1903.		1904.	
	No.	Value.	No.	Value.	No.	Value.	No.	Value.
Vessels	102	$162,050	156	$182,151	140	$215,185	123	$178,765
Tonnage	1,260		1,750		1,699		1,378	
Outfit				115,499		71,690		61,305
Boats			228	178,465	243	105,750	208	88,400
Outfit						98,535		77,945
Apparatus, vessel fishery:								
Diving								
Hooking				3,153		2,948		2,485
Apparatus, boat fishery:								
Diving								
Hooking				3,223		2,661		2,591
Shore and accessory property				12,375		5,900		6,100
Total				494,866		502,669		417,591

Item.	1905.		1906.		1907.		1908.	
	No.	Value.	No.	Value.	No.	Value.	No.	Value.
Vessels	115	$185,580	98(?)	$155,260	116	$164,835	145	$233,425
Tonnage	1,435		1,571		1,682		2,205	
Outfit		68,360		68,495		90,873		101,143
Boats	234	99,980	207	91,010	216	97,300	190	100,450
Outfit		87,875		82,128		71,500		38,640
Apparatus, vessel fishery:								
Diving		6,600		32,400		27,600		53,400
Hooking		2,353		1,133		1,668		1,713
Apparatus, boat fishery:								
Diving		600		8,262		18,000		20,400
Hooking		2,923		2,545		2,288		1,496
Shore and accessory property		5,600		5,800		5,000		4,600
Total		459,871		447,033		479,064		555,267

CRAFT ENGAGED IN HOOKING AND DIVING, RESPECTIVELY.

Craft.	1880.	1900.	1903.	1904.	1905.	1906.	1907.	1908.
Hooking: Vessels	102	156	140	123	104	51(?)	69	72
Boats		228	243	208	233	193	186	156
Diving, machine boats					12	69	78	123
Diving, living or deposit vessels					11	47	47	73

PERSONS EMPLOYED IN HOOKING AND DIVING, RESPECTIVELY.

Craft.	1880.	1900	1903.	1904.	1905.	1906.	1907.	1908.
Hooking: Vessels	828	1,239	1,198	1,015	893	639	457	568
Boats		874	887	762	850	633	542	410
Total		2,113	2,085	1,777	1,743	1,272	999	978
Diving: Vessels					153	746	669	945
Boats					13	196	420	397
Total					166	942	1,089	1,342
Grand total		2,113	2,085	1,777	1,909	2,214	2,088	2,320

PRODUCTS OF THE FLORIDA SPONGE FISHERY, BY KIND AND GROUNDS.

Kind and grounds.	1880.		1889.		1890.		1895.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Sheepswool: Bay								
Key								
Total							231,272	$363,107
Yellow: Bay								
Key								
Total							29,509	11,798
Grass: Bay								
Key								
Total							21,387	5,464
Glove: Bay							23,952	6,502
Key								
Total							23,952	6,502
Total: Bay grounds								
Key grounds								
Grand total	207,000	$200,750	$316,559	$381,087	366,772	438,682	306,120	386,871

Kind and grounds.	1896.		1897.		1899.		1900.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Sheepswool: Bay					126,700	$278,390	123,017	$356,045
Key					27,000	54,000	58,294	127,218
Total	149,724	$248,196	157,476	$240,599	153,700	332,390	181,311	483,263
Yellow: Bay					28,000	7,205	32,433	18,097
Key					27,000	9,000	42,033	25,948
Total	23,655	9,318	32,362	13,082	55,000	16,205	74,466	44,045
Grass: Bay					59,400	11,819	71,686	15,516
Key					17,500	2,500	71,426	17,747
Total	44,617	11,508	128 622	29,188	76,900	14,319	143,112	33,263
Velvet: Bay							386	64
Key					8,000	4,000	6,422	5,256
Total					8,000	4,000	6,808	5,320
Glove: Bay	18,315	3,990	13,086	3,171			1,185	168
Key					10,000	1,000	11,243	1,626
Total	18,315	3,990	13,086	3,171	10,000	1,000	12,428	1,794
Wire: Bay								
Key								
Total								
Total: Bay grounds					214,100	297,414	228,707	389,890
Key grounds					89,500	70,500	189,418	177,795
Grand total	236,311	273,012	331,546	286,040	303,600	367,914	418,125	567,685

PRODUCTS OF THE FLORIDA SPONGE FISHERY, BY KIND AND GROUNDS—Continued.

Kind and grounds.	1901.		1902.		1903.		1904.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Sheepswool: Bay					188,265	$361,930	155,056	$286,017
Key					31,069	49,632	39,883	60,767
Total	202,673	$422,561	133,518	$297,727	219,334	411,562	194,939	346,784
Yellow: Bay					54,153	14,602	38,294	10,827
Key					7,848	3,788	13,378	6,356
Total	62,512	39,290	56,787	31,113	62,001	18,390	51,672	17,183
Grass: Bay					60,272	9,721	33,386	5,191
Key					23,109	5,073	27,886	4,350
Total	108,748	24,210	140,682	29,765	83,381	14,794	61,272	9,541
Velvet: Bay								
Key					1,715	862	2,637	1,497
Total			8,307	4,660	1,715	862	2,637	1,497
Glove: Bay	21,627	6,679						
Key					11,484	1,738	8,783	1,164
Total	21,627	6,679	7,365	1,111	11,484	1,738	8,783	1,164
Wire: Bay								
Key							98	16
Total			230	46			98	16
Total: Bay grounds					302,690	386,253	226,736	302,035
Key grounds					75,225	61,093	92,665	74,150
Grand total	395,560	492,740	346,889	364,422	377,915	447,346	319,401	376,185

Kind and grounds.	1905.		1906.		1907.		1908.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Sheepswool: Bay	173,721	$408,322	412,364	$773,583	255,212	$435,400	261,923	$422,700
Key	61,840	75,122	18,850	27,854	23,122	34,669	47,758	61,853
Total	235,561	483,444	431,214	801,437	278,334	470,069	309,681	484,553
Yellow: Bay	31,312	12,199	94,610	32,914	230,139	67,269	180,956	38,768
Key	13,758	7,035	10,328	6,240	14,153	5,994	9,758	4,361
Total	45,070	19,234	104,938	39,154	244,292	73,263	190,714	43,129
Grass: Bay	26,911	4,485	11,370	2,346	91,146	17,105	93,170	12,355
Key	40,530	11,951	35,395	10,063	40,492	10,906	16,447	4,875
Total	67,441	16,436	46,765	12,409	131,638	28,011	109,617	17,230
Velvet: Bay								
Key	2,377	1,350	1,322	489	221	98	2,681	2,043
Total	2,377	1,350	1,322	489	221	98	2,681	2,043
Glove: Bay								
Key	13,161	2,210	6,655	1,094	1,472	308	1,302	536
Total	13,161	2,210	6,655	1,094	1,472	308	1,302	536
Wire: Bay	1,142	164					8,414	1,375
Key	350	88			13	2	80	10
Total	1,492	252			13	2	8,494	1,385
Total: Bay grounds	233,086	425,170	518,344	808,843	576,497	519,774	536,049	473,823
Key grounds	132,016	97,756	72,550	45,740	79,473	51,977	86,440	75,053
Grand total	365,102	522,926	590,894	854,583	655,970	571,751	622,489	548,876

CATCH ON BAY GROUNDS, BY APPARATUS.

	1905.		1906.		1907.		1908.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Sheepswool: Diving	9,250	$47,506	318,728	$610,986	184,432	$331,146	177,354	$324,055
Hooking	164,471	360,816	93,636	162,597	70,780	104,254	84,565	98,645
Yellow: Diving	572	225	77,060	26,841	185,058	54,680	147,496	33,414
Hooking	30,740	11,974	17,550	6,073	45,081	12,589	33,454	5,354
Grass: Diving	172	30	4,642	939	29,344	6,573	55,944	8,555
Hooking	26,739	4,455	6,728	1,407	61,802	10,532	37,226	3,800
Wire: Diving							8,414	1,375
Hooking	1,142	164						
Total: Diving	9,994	47,761	400,430	638,766	398,834	392,399	389,208	367,399
Hooking	223,092	377,409	117,914	170,077	177,663	127,375	155,245	107,799
Grand total	233,086	425,170	518,344	808,843	576,497	519,774	544,453	475,198

NOTE.—All sponges from the Bay prior to 1905 and all from the Keys to date were taken by hookers.

FOREIGN SPONGE TRADE OF THE UNITED STATES.

The foreign sponge trade of the United States has attained considerable proportions, amounting to $735,571 during the year ended June 30, 1907. The growth in the imports of sponges and the sources from which they are derived are shown in the following table:

IMPORTS OF FOREIGN SPONGES INTO THE UNITED STATES.

Year.	North America.	Europe.	Asia.	Oceania.	Africa.	Total.
1875						$118,229
1880						197,431
1885						333,774
1890						416,718
1895						350,008
1900						536,303
1905	$454,070	$88,444	$181	$17		542,712
1906	453,137	107,877	3,051	2		564,098
1907	374,418	113,830	178		$31	488,426

The decrease in 1907 was in the imports from Cuba and the Bahamas and was due largely to the heavy crop of domestic sponges in the preceding year. The imports of Mediterranean sponges, with which our own product does not so sharply compete, exhibited an increase.

During the past five years the exports of domestic sponges have been as follows:

EXPORTS OF SPONGES FROM THE UNITED STATES.

Year.	Europe.	North America.	South America.	Asia.	Oceania.	Africa.	Total.	
							Pounds.	*Value.*
1903	$42,545	$6,553	$652	$311	$245		95,159	$50,306
1904	23,472	9,700	653	1,728	1,033		64,214	36,646
1905	11,645	4,773	550	1,386	26	$10	31,700	18,390
1906	27,481	14,321	544	1,359	221		50,953	43,926
1907	99,686	11,217	506	2,413	532		136,301	114,354

The heavy increase in the exports for 1907 was also due to the large crop in the preceding year, which for the time being glutted the American market and materially reduced the price of the better grades of sponges. Ordinarily it is the lower grades only that are exported.

In addition to the foregoing sponges of domestic origin there were exported foreign sponges, principally Bahaman and Cuban, to the value of $153,452 in 1905, $152,675 in 1906, and $132,791 in 1907, most of them going to France, Great Britain, Germany, and other countries of Europe and to Canada. About 90 per cent of the export trade is in New York, and practically all of the rest in various ports on the Canadian border.

V. OTHER WESTERN ATLANTIC FISHERIES.

BAHAMA ISLANDS.

The sponge fisheries of the Bahamas date from 1841, when, it is related, the value of the native product was recognized by a French sponge dealer who had been wrecked in the archipelago, and who shipped a sample lot to Paris.

Sponge grounds.—The principal beds lie on Great and Little Bahama banks, Exuma Bank, and the shoals about Eleuthera, and differ considerably in their product. The sheepswool and velvet sponges from Little Bahama Bank, especially in the vicinity of Abaco Island, are known as Abaco wool and velvet, as distinguished from "Nassau" or "Cay" sponges, coming from other parts of the Bahamas. They are soft and fine, the velvet being the best of that variety known to commerce, are packed separately, and bring a higher price in the market. It is stated that owing to the demand for these sponges and the consequent overfishing, the beds have been more or less exhausted and many of the sponges now sold as Abaco wool and velvet are in reality selected specimens from other grounds.

The Great Bahama Banks, which extend north, west, and south of Andros Island and along the Old Bahama Channel, produce large quantities of wool, velvet, yellow, and grass sponges, but these are generally open in texture, coarse, and weak, especially those from the southern and southeastern parts of the bank. Many of them grow on gorgonians (sea feathers) or corals and are frequently pierced by large holes, which mar an otherwise spherical shape. In this region all of the four varieties named generally have the lamellæ more or less thickened to form cushions or flat-ended brushes, so that they all have surfaces more or less remotely resembling that of velvet sponges. The region from which these sponges come is known to the spongers as "The Muds."

The banks about Eleuthera, which were discovered about 1883, produce a somewhat better quality of sheepswool, but not equal to those of Little Bahama Bank.

The best of the grass sponges come from Long, Acklin, and Turks islands in the southeastern part of the Bahamas, but as a rule they are packed with those from other localities. Though the larger part of the banks lie far beyond the marine league, the Bahama government assumes jurisdiction for purposes of protection and prohibits the operation of foreign sponging vessels. In 1902 or 1903, several vessels from Key West were seized on Great Bahama Bank and the masters and several members of the crews were imprisoned at Nassau, but were ultimately released. The men were well satisfied to secure their own release and escape the confiscation of their vessels, and no test was made of the legality of the procedure.

From the view point of the perpetuation of the sponge beds it is not improbable that the Bahama govenment is justified in adopting these measures and others with like purpose, for as long ago as 1875 it was claimed that the beds were becoming exhausted by overfishing. The same claim is made to-day, especially with regard to the more desirable kinds, and in view of the increased demands on the beds in recent years it is probably warranted, notwithstanding that the product has steadily grown in quantity and value.

In 1849 the total exports of sponges were valued at $10,752, and between 1850 and 1853 the average annual exportation was valued at $50,052. The averages at other periods have been as follows: 1855 to 1858, 255,300 pounds, valued at $54,097; 1866 and 1869, 625,850 pounds, valued at $164,900; and from 1873 to 1875, inclusive, 313,733 pounds, valued at $103,673.

The exports in more recent years are shown in the table below:

EXPORTS OF SPONGES FROM THE BAHAMA ISLANDS, 1880–1905.

Year.	Pounds.	Value.	Year.	Pounds.	Value.
1880	429,400	$168,125	1893	844,300	$284,282
1881	379,700	147,207	1894	893,600	286,901
1882	612,500	286,310	1895	965,200	327,690
1883	541,600	244,216	1896	1,365,900	393,291
1884	1,274,000	220,932	1897	1,228,047	437,038
1885	808,200	254,498	1898	1,207,683	472,933
1886	676,500	215,918	1899	1,124,585	407,414
1887	622,300	229,118	1900	1,165,406	505,462
1888	789,044	238,198	1901	1,517,597	[a] 665,890
1889	703,163	251,598	1903	1,515,626	506,310
1890	917,784	306,195	1904	1,407,958	512,732
1891	987,400	284,607	1905	1,486,128	551,702
1892	1,011,200	317,888			

[a] 15 months, January 1, 1901, to March 31, 1902.

It will be observed from the foregoing that the exports have shown a steady increase during the past twenty-five years, and as practically the entire catch is shipped abroad the statistics cited can be regarded as an index of the yield of the fisheries. During the decade ending with 1889 the average annual product was 683,640 pounds; in that ending with 1899 it was 1,054,569 pounds, while for five years ending with 1905 it was 1,350,993 pounds.

There is here no intrinsic evidence that the beds are being depleted, but in the absence of data showing the intensity of the fishery no conclusions of value can be reached. There are no details available which would permit a comparison of the catch per man, though there is unofficial authority for the statement that "about 3,000 men and boys" were employed in the fishery about 1880, while official returns show that more than twice that many were employed in 1902.

Methods of the fishery.—The methods of fishing for sponges in the Bahamas are essentially those which have been described as in use in Florida prior to the introduction of the diving machine in 1905, and the history of the development of the industry is parallel. Practically all of the sponges are taken by means of hooks, by poling and sculling, though a few are secured by wading and naked diving. The methods of curing and packing are the same as those employed in Florida and the entire product passes through the sponge exchange at Nassau.

In 1902 there were employed in the fishery 265 schooners of from 5 to 43 tons and 322 sloops of from 1 to 16 tons, in all 587 vessels with an aggregate tonnage of 5,952. Attached to these vessels were 2,517 dingeys and crews numbering 5,517 men and boys. In addition there were engaged in the shore fisheries 291 boats and 445 men and boys, while the packing houses employed 258 persons.

The sponge fishery is the most important industry of the islands and over half of the product is shipped to the United States. The following statement shows the exports for 1905:

EXPORTS OF SPONGES FROM THE BAHAMA ISLANDS IN 1905.

	Pounds.		Pounds.
United States	864,658	Russia	10,441
Germany	254,494	Canada	1,457
Holland	158,488	Italy	4,396
France	95,715		
United Kingdom	95,499	Total	1,485,148

CUBA.

Sponge grounds.—The sponge beds of Cuba are found on both the north and south coasts, the latter supporting the more important and productive fishery. There are a few inferior sponges, principally a hard quality of velvet, on the north coast of Pinar del Rio, but the productive beds of the north coast are all among the numerous keys between Cardenas and Nuevitas. These beds were known before the discovery of the Batabano grounds and were resorted to by the Bahama spongers under license from the Spanish authorities. They lie in shallow water within and about the line of keys which skirts the Nicholas and Old Bahama channels, opposite the important beds of the Great Bahama Bank. It is stated that these beds have become greatly depleted by overfishing and

they now produce but about 20 per cent of the total product of the Cuban fishery. This region is the source of practically all of the Cuban reef, hardhead, and silk grass sponges. Sheepswool and velvet are now comparatively scarce, but the former are stronger and better than the product of the south coast. Certain vessels from Key West which visited this region in 1898 or 1899 reported comparatively few sponges and returned with practically none. Caibarien is the principal center of this fishery, but some of the product is sold in Cardenas and Nuevitas. There are one or two buyers located on the coast, but it is also periodically visited by buyers from Batabano.

The most important beds of the south coast lie in the vicinity of Batabano, between the main island and the Isle of Pines, from Cayos de Felipe to Cabeza del Este. This region is dotted with numerous small islands, keys, and rocks, and over most of the bottom the depth is less than 3 fathoms and in very few places does it reach a maximum of 6 fathoms. Outside of the banks in the Caribbean Sea, however, the bottom slopes rapidly to profound depths. Sponges are also found among the keys and shoals off Santa Clara Province, but no commercial fishery has been developed in that locality.

The grounds off Batabano were discovered in 1884 and an attempt was made to secure a concession monopolizing the exploitation of the beds. Fortunately this was frustrated and the beds were reserved as a common fishery. In 1891 there were upward of 180 spongers at Batabano alone, and the yield of the fisheries in that region was valued at about $110,000 per year. Since then there has been a heavy increase in the yield and the annual product is valued at about $275,000 to $350,000, as based on the declarations for export. As a general rule, however, the imports into the United States are subjected to revaluation, and it is difficult to arrive at a definite estimate of the first value of the fishery to the spongers.

The exports, which represent the entire catch for both coasts, for the fiscal years ending June 30, 1903–1906, have been as follows:

EXPORTS OF SPONGES FROM CUBA, 1903–1906.

Exported to—	1903.		1904.		1905.		1906.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
United States	381,462	$146,076	332,534	$155,099	366,388	$200,296	325,872	$161,622
France	357,410	210,589	384,478	231,140	185,427	114,438	195,683	133,062
United Kingdom	47,934	13,470	38,612	12,242	19,897	7,764	23,008	8,818
Spain	48,726	13,819	35,607	9,398	18,301	8,319	26,514	13,400
Germany	20,288	7,500	57,449	23,581	11,730	6,028	19,883	9,629
British West Indies					13,900	2,952	110	40
Canada	1,243	1,800			2,055	840		
Holland	2,200	1,000			2,013	750		
Belgium	3,148	850	2,285	1,200				
Italy			1,712	368				
Mexico			392	280				
Total	862,411	395,104	853,069	433,308	619,711	341,387	591,070	326,571

I have not been able to obtain reliable data showing the quantity of sponges shipped in preceding years, but for 1900 to 1902, inclusive, the average annual value of the exports was about $460,000. It will be seen, therefore, that during the past four or five years there has been a steady shrinkage in the value of the catch and a still greater falling off in its quantity. Between 1903 and 1906 the quantity of sponges exported, and presumably the quantity fished, shrunk over 30 per cent.

Methods of the fishery.—After experiment with the scaphander and naked diving, both of which proved expensive or inefficient, and with a species of grapnel dragged over the bottom, the method of hooking, essentially similar to that practiced in Florida and the Bahamas, finally became established as the most satisfactory and effective and is now generally employed, though a few sponges are taken in the shoaler waters by wading.

The first spongers were former Spanish sailors from the Balearic Islands, but there are now a number of Greeks and Cubans engaged in the fishery. The sponges are cleaned as in the United States and are then strung on cords, each holding a dozen sponges of uniform size or half that number of larger individuals.

They are sold at auction by the merchant owning or outfitting the vessel instead of by the master, as in Florida, being hung up in festoons for inspection for some time before the sale. There is no regular sponge exchange, as at Nassau and more recently at Tarpon Springs, the sales being conducted in some convenient coffee house, where the buyers congregate and hand in the bids on slips of paper, the highest bidder securing the lot. The method of stringing the sponges by sizes and count which is established by law is more systematic than that followed in Florida, and the buyer can more readily determine the value of the cargoes offered for sale.

MINOR FISHERIES.

Honduras.—Sponges are found along the entire coast of British Honduras, in the shallow waters about the numerous islands, rocks, and banks, but they are inferior in quality and not many are placed on the markets. The varieties found are sheepswool, velvet, and grass, the latter almost worthless. Many of the sheepswool, velvet, and grass sponges grow attached to staghorn corals and gorgonians, the removal of which leaves large holes penetrating the cured sponge and detracting from its value. Others are irregular from growing among marine growths or on the sides of rocks. The characteristics of some specimens, however, lead to the expectation that better grades will be found in deeper water. The velvet sponge in particular has some good qualities.

The value of the exports of sponges to the United States during recent years has been as follows: 1903, $1,218; 1904, $50; 1905, $915; 1906, $1,949, and 1907, $2,331.

Nicaragua.—A very few sponges are produced on the coast of Nicaragua and other Central American countries. In 1905, the exports to the United States were valued at $50.

Mexico.—The sponge beds of Mexico lie on the north and east coast of Yucatan, on Campeche Banks and about Cozumel Island. The beds which have been exploited lie in very shallow water and the sponges are very inferior, but it is said that there are better grades in the deeper water toward the southern end of the east coast. The exportation from Mexico is very small, in 1906 amounting to but $218 on shipments to the United States and $250 on shipments to France. During the five years from 1903 to 1907, inclusive, the total exports to the United States were valued at but $1,214. A very few American vessels have sponged off the Mexican coast in recent years, but the value of their catch is not definitely known. Several years ago a vessel with two diving boats operated for three seasons off Cozumel. Large yellow sponges were found in abundance, but the few sheepswool sponges taken were so much inferior to those of Florida that the venture never paid.

Colombia.—The United States consul at Cartagena says, in 1907:

> The bay of Cartagena is rich in sponge beds, and the local fishers for sponges find some fine in quality and large in size. These are handled in a crude way by the "bumboat" men only, and sold alongside vessels in the harbor, no effort being made to export them in a business-like manner.

The Consular Reports for 1903 noted the granting of concessions on both the Atlantic and Pacific coasts which included the sponge fisheries, but nothing is known of the value of the beds. The only Colombian sponge of which the author has definite knowledge is a hardhead closely resembling that from Honduras. This is said to be very abundant. The writer ventures to predict that the sponge fauna will be eventually found to embrace all of the principal kinds of American commercial sponges, though it is doubtful whether they will prove of very high quality.

Venezuela.—Weil states that there are sponges on the coast of Venezuela, but that they are hard, incompressible, not very porous, and practically worthless.

Jamaica.—A few velvet sponges, elsewhere described in this paper, are taken from the waters of Jamaica, but the fishery is of comparatively little importance.

Santo Domingo.—The principal sponge beds are about the Island of Gonaves, in the Republic of Haiti. They produce velvet and reef sponges which are both inferior in quality and generally poorly prepared for the market. The spongers are Greeks, 5 or 6 in number, and fishing but occasionally produce sponges with a value of but $600 or $800 per year.

Commercial sponges similar in general to those of other parts of the Caribbean are known zoologically from Porto Rico, the Danish West Indies, and other of the Lesser Antilles.

VI. SPONGE FISHERIES OF THE MEDITERRANEAN AND CONTIGUOUS WATERS.

The Mediterranean produces the finest and most valuable sponges known to commerce, but they differ greatly in quality in different regions. Broadly speaking, the commercial varieties are five in number—the Turkey cup, toilet, zimocca, elephant ear, and honeycomb; but these are subdivided in the sponge trade into numerous sorts in accordance with the localities from which they come and the means by which they are taken, and then are still further distinguished by grades of quality and even by the nationality of the fishermen who take them. Sponges are found along the European, Asiatic, and African shores from Gibraltar to Port Said, but it is in certain places only that they exist in such numbers as to support a fishery. These regions will be taken up for consideration in more detail hereafter.

West of Sicily and Cape Bon, in Africa, the fishery is unimportant and almost negligible, and the finer varieties, the toilet and cup sponges, are practically absent. To the eastward of a line between the places mentioned the fishery is highly important and one of the most valuable in the Mediterranean. Owing to long-continued overfishing the supply from the Adriatic, the Ægean, and the Levant is smaller than formerly, and to meet the increased demand of the markets there has been in the last twenty-five to thirty years a most important development of the fisheries of the African Coast from Alexandria to the western frontier of Tunis.

The very finest grades come from the Levant, and the quality falls toward the westward along both the north and south shores. In the waters contiguous with the Mediterranean Sea, commercial sponges are known from the Dardanelles, the Sea of Marmora, the Bosphorus, and the adjacent parts of the Black Sea, but the quality appears to become progressively lower and the quantity less in the order named. In the Red Sea there are said to be vast quantities of sponges, but their quality is inferior and their value small.

It is difficult to form more than an estimate of the value of the Mediterranean sponge fisheries, owing to the nomadic habits of most of the fishermen. The Greeks, both national and Turkish, carry on their operations not only at home but in almost every part of the sea which promises anything like a lucrative return. The Italians, while not quite so wandering, extend their operations across the Mediterranean to the Tunisian coast, and both they and the Greeks vary somewhat in their practice of marketing their catch, sometimes selling it in the native markets but often carrying it to their home ports, where its identity is lost by mixing it with the products of other localities.

In the following pages an endeavor has been made to present such statistical information as is available relating to the number of men and boats engaged and

the value of the product. The transshipments between the various markets make it difficult, if not impossible, to state the value as a whole, and while the available figures, official and otherwise, have been used, the following must be regarded as an estimate:

Spain and France (estimated)		$9,000
Adriatic:		
Istria and Dalmatia (estimated)	$10,000	
Gulf of Taranto (1902)	22,000	
		32,000
Ægean Sea, including Crete and sponges brought from the African coast and Lampedusa (1901)		1,090,000
The Levant		113,000
Tripoli (1904–1905 average)		237,000
Tunis (1904)		435,000
Lampedusa, etc. (1904)		123,000
		2,039,000

This does not include the sponges sold at Benghazi nor the Egyptian catch, but as there are undoubtedly some duplications, it may be assumed with some assurance that the annual product of the Mediterranean fisheries is valued at not far from $2,000,000. The various fisheries, considered more in detail, are as follows:

SPAIN AND FRANCE.

For years sponges have been known to exist on the Spanish coast, but until recently practically no attempt was made to develop a fishery. Explorations during the past few years have developed the existence of workable beds about the Balearic Islands and on the adjacent coasts of Catalonia and Valencia, particularly on the banks in the vicinity of the Columbretes Islands between Majorca and the Spanish Peninsula, and a small quantity of elephant-ear, zimocca, and honeycomb sponges have been taken there with scaphanders. The Spanish Government has taken steps to encourage the industry, and in 1903 there were 10 Greek diving vessels at work, but in 1904 these had dwindled to 2, and since then there have been none. Sponges are also found on the coast of France east of Marseilles, but they are scattered and few in number and have not been commercially exploited. Zimocca, elephant-ear, and honeycomb sponges are also found off the southern coast of Corsica and of recent years have been taken in small quantities by means of the diving machine.

ADRIATIC SEA.

The sponge beds of the Adriatic appear to have been always less prolific than those of many other parts of the Mediterranean, and they have suffered so severely from the fishery that they are now of comparatively little importance.

They occur about the shores of the numerous islands of the Istrian and Dalmatian coasts south of Trieste in a depth of water not exceeding 10 fathoms.

According to Faber, the toilet sponge comes from the vicinity of the islands of Incoronata and Zara Vecchia, the zimocca sponge is confined mostly to the coast of Istria, while the honeycomb sponge is generally distributed along the coast. The honeycomb or horse sponges of the Adriatic are rather brittle and inferior to those from other localities. The fishery employs from about 150 to 200 men, who fish from small boats by means of harpoons and tongs during the good weather between March and October. . The average catch per boat manned by two men is said by Faber to be about 300 to 400 pounds per year, the total yield being about 32,000 pounds, worth about $10,000.

In 1902 about 11,000 pounds of sponges of good quality, valued at from $1.80 to $2.30 per pound, were taken in the Gulf of Taranto. This small fishery is carried on mainly by Italians, but in 1901 seven Greek boats, manned by 28 men, took about 1,500 pounds of sponges, which were marketed in Greece at about $1.30 per pound.

ÆGEAN SEA AND ASIA MINOR.

The sponge beds about the Greek and Turkish islands of the Archipelago and along the coast of Asia Minor have been important from ancient times and have produced a race of bold and hardy fishermen, who have gradually extended their operations into all parts of the Mediterranean and within the last few years to the waters of the Gulf of Mexico and the Caribbean Sea.

The beds are scattered generally over the Ægean, in the Gulf of Salonica, the Dardanelles, the Sea of Marmora, and the Bosphorus, but the principal centers of the fishery are in the Cyclades and Sporades, about the islands of Rhodes, Cos, Symi, Calymnos, Samos, Patmos, Hydra, Kharki, Kramihdi, Ægina, and Crete.

In these waters the sponges are taken by naked diving, the harpoon, the dredge, and the scaphander. The first two methods are the older, the last two having been adopted at a comparatively recent date. The fishery with the scaphander is now prohibited in the waters of Samos and Crete, and the advisability of expelling it from the waters of the Cyclades has been the subject of animated though futile debate in the Greek Parliament.

The sponge beds of this entire region are much less prolific than formerly, and much of the blame is ascribed to the diving machine. Many of the best sponges are now found in crevices, caves, and under overhanging rocks which abound along the shores of the islands of the Ægean, and being inaccessible to harpoons and dredges are taken only by the divers, especially those not using the diving dress. These sponges are generally denser and finer than those more directly exposed to the light.

All varieties of Mediterranean sponges are found in these waters. The honeycomb sponge of the Cyclades is rather coarse and open in texture, but in Crete and many of the other islands it is of excellent quality. The other varieties are generally excellent, but not equal to the Syrian sponges, though those from the vicinity of Smyrna are coarse and open in texture and inferior in quality.

The sponge fishery is the most important and profitable of the fisheries of the Ægean and it ordinarily employs between 4,000 and 5,000 men, accurate statistics being difficult to obtain, owing to the nomadic habits of many of the spongers who, as it has been stated, travel to all parts of the Mediterranean.

During the summer of 1903, 318 vessels under the Greek flag alone employed 2,494 men in the sponge fisheries. There were 134 vessels, using 158 diving outfits, upon which there were employed 599 divers and 1,255 others. Thirty-six vessels with gangavas (dredges) employed 173, while 122 craft engaged in harpooning were manned by 443 persons. The operations of these vessels appear to have extended over a considerable part of the Mediterranean, and two crafts were used solely in the transportation of supplies to the African coast.

In 1900 sponge fishers of the Sporades produced about $900,000 worth of sponges and in 1901 about $810,000 worth, and in the same years there were exported from Piræus $171,791 and $280,048 worth, respectively, but undoubtedly a considerable proportion of these were taken on the African coast and the banks of Lampedusa.

The commander of the Greek hospital ship *Kreta* estimated that the Greek spongers took, in various parts of the Mediterranean in 1902, about 350,000 pounds of sponges, valued at about $1,000,000. In 1902 the exports from Piræus were valued at $214,180. In 1901 toilet sponges from the Sporades averaged from $8 to $13 per pound and honeycomb sponges from $2.75 to $4. The United States consul at Smyrna writes that during more recent years the price was from $4.65 to $15.60 per pound.

The sponge fisheries of Crete are important, but the island has neither a local market nor native fishermen. The spongers are all Greeks from the Grecian and Turkish islands, who arrive on the grounds in the spring and in the fall return to their native places with their catch. From 150 to 200 vessels and boats, manned by from 800 to 1,000 men, engage in the fishery, which produces an annual product valued at about $160,000 to $200,000. This revenue is included in that before given for the Grecian and Turkish isles. The fishery is carried on by harpoons, naked divers, and dredges, the first paying an annual license fee of $18 and the last two $46 for each boat. The revenue of the government is from $4,000 to $5,000 per year. The use of the scaphander is now prohibited, mainly for humanitarian reasons, but also on account of the depletion of the beds, which were formerly much more productive.

THE LEVANT.

In this region the sponge beds surround the island of Cyprus and skirt the Syrian coast from the Gulf of Alexandretta to the vicinity of Latakia and from Jaffa to the Suez Canal. It is stated that about May, 1907, a new bed was discovered, stretching off Port Said toward the north and northeast for a distance of about 50 miles.

The same methods are followed as in the Ægean, and a very large proportion of the spongers come from that region. The scaphander was recently prohibited both at Cyprus and on the Syrian coast, though it is reported that several diving boats have been quite recently at work in the latter locality despite the prohibition. Cyprus has lately rescinded the prohibition of the diving machine, but the regulation excluding the gangava or dredge is still in force.

The American consul at Beirut estimated in 1902 that the annual export of Syrian sponges for several years preceding had averaged about $85,000 in value and that the product was gradually decreasing, owing to the depletion of the beds. According to Simmonds, the average yield about thirty years ago was from $100,000 to $125,000 per annum. From Cyprus the exports were valued at $19,425 in 1898 and $28,835 in 1899, but it would appear that this may not represent the entire product of the island. The principal markets are Tripoli in Syria and Latakia. The sponges produced in both Cyprus and Syria are the very finest quality of cup and toilet sponges, although it is said that those on the south side of Cyprus are inferior. The very finest are sold by the piece and may bring $50 to $100 per pound, but the usual price is between $15 and $35 for the fine levants.

EGYPT.

The sponge beds off the Egyptian coast extend from the vicinity of Alexandria to the Tripolitan frontier, and are practically continuous with the sponge grounds which reach along the Tripolitan coast to and beyond Benghazi. The sponges, especially those of Mandruka, are of excellent quality, but on the whole are not equal to those of the Ægean and the Syrian coast. The spongers are principally Greeks from the Archipelago, who were colonized at Marsa Matruh by the Egyptian government in 1902. The fishery appears to be prosperous and is carried on without the use of the scaphander, which apparatus has been interdicted for hygienic and humanitarian reasons, vessels using it being subject to confiscation. The dredge is restricted to depths greater than 80 meters (262 feet), and is subject to an annual license impost of $50 per boat, the tax for harpooning and naked diving being $25 per boat. There has recently developed some difficulty in the enforcement of the regulations, owing apparently to the beds being beyond territorial jurisdiction and the spongers beyond the authority of the Egyptian government.

TRIPOLI.

The sponge beds of Tripoli extend between the Gulf of Bomba and the region about Benghazi and from Misrata to the frontier of Tunis. In the western region some of the banks are as much as 20 miles from shore and produce a better quality of sponge than in the waters nearer the coast.

Most of the fishery is carried on during the warmer season from April to October, but a few of the more hardy crews of divers work at other times. The fisheries on the banks between Tunis and Misrata, which are known especially as the "Tripoli grounds," from Tripoli-in-Barbary, their headquarters and market place, appear to have been exploited first about 1889. In 1890 they produced a value of $58,398, and their average annual product during the next nine or ten years was valued at about $165,000 per annum. The exports in 1904 were $337,750; in 1905, $226,196; in 1906, 232,565; in 1907, $213,300, and in 1908 were estimated at $175,800. In 1898 there were engaged in this fishery 53 scaphander vessels with crews of 963 men, and 25 dredges with 150 men. The former are mostly Greek, but there are a number of vessels flying the Turkish flag and manned by Greeks from the Sporades. The trawlers, or dredgers, are principally Italian. During the active fishery the Greek Government maintains at Tripoli a shore hospital and a hospital ship, to care for the divers and sailors meeting with accident or injured by the reckless use of the diving apparatus. Four methods of fishing are practiced; naked diving, harpooning or hooking, dredging, and diving with the scaphander. The latter method predominates, and of late years harpooning and dredging are said to be falling into disuse. The fishery appears to have reached its maximum development, despite efforts that have been made for its increase. The Turkish Government imposes a license tax upon the vessels, graduated from $147 per annum for scaphanders to $18 for boats employed in harpooning. Boats engaged in naked diving are taxed about $45 each, and trawlers pay about $13 if measuring 5 tons or under and $26 if above 5 tons.

The sponges from these grounds are darker in color and inferior to those from the Ægean Sea and the Levant. The first quality of bath sponges, which comes from the rocky bottoms, formerly brought from $1.50 to $1.90 per pound and the second quality, from the grassy bottoms of the channels, from $1.15 to $1.50 per pound. Recently prices appear to have appreciated, the American consul at Tripoli in Barbary stating in 1908 that sponges from rocky bottom sold for $2.73 to $3.64 per pound, those from shingle bottom for $2.05 to $3.07, and those from grassy areas for $1.91 to $2.39. He states further that an average catch for a machine boat with 12 to 14 divers is $6,000 to $7,000 a season, and that a boat with 4 or 5 naked divers will average about $1,200. About one-fourth of the product is marketed in Tripoli, the remainder being carried home by the foreign fishermen and mixed with inferior or medium grades coming from other localities.

The sponges from the Bay of Bomba and neighboring parts of the Tripolitan coast, which are generally known in the markets as Benghazi sponges, are much superior to those above described and will sell for from two to four times the price of Tripoli goods. In 1908 bath sponges sold for $6.20 per pound, toilet sponges for $8.22, and cup sponges for $13.65. The bath or honeycomb sponge of Benghazi is hardly inferior to that of Mandruka and most of the better ones are sold as such. The annual product of this region is about $75,000 to $90,000.

All types of Mediterranean sponges are found on the coast of Tripoli, but zimoccas and honeycombs are more common, especially on the Tripoli grounds.

TUNIS.

The Tunisian sponge beds lie between Bibau and Sarsis near the Tripolitan frontier, about the island of Gherbis, in the Gulf of Gabes, in front of Sfax between Mahares and Mehedia, about the Kerkennah Isles, and along the coast in front of Monastir and Susa.

Sponges are taken on these coasts by wading, naked diving, harpooning, dredging, and diving with the scaphander. The seasons vary with the method. Naked diving and harpooning are carried on in general from October to January, at the time when the bottoms are cleaned of vegetation and the sponges can be plainly seen, but the use of the scaphander and the dredge is physically possible throughout the year.

Wading is practiced by natives only, especially those of Kerkennah and Gherbis; the harpoon is employed by natives, Sicilians, Maltese, and Greeks; the dredge is used by Sicilians and Greeks, while the latter alone employ the scaphander. The Tunisian government has recently interdicted the use of the scaphander during November and December and has restricted the number of licenses to be issued. In 1904–5 the maximum was 22.

In 1904 the fishery gave employment to 1,368 vessels and boats, of which 522 were Italian, 79 Greek, and 767 Tunisian, upon which were employed 1,688 Italians, 444 Greeks, and 2,299 natives, a total of 4,431 men. Gourret says that in 1896, an average year, there were engaged in the fishery 1,089 vessels, measuring 2,371 tons and manned by 3,201 men, in addition to which there were 169 persons taking sponges afoot (wading). In 1854 there were but 102 boats, and in 1882, according to Henneque, 572 boats and vessels—Sicilian, Greek, and native.

Following is a table of the product for various periods since 1854:

Year.	Pounds.	Value.	Year.	Pounds.	Value.
1854	26,400	$12,000	1894	254,000	----------
1884–85	206,000	----------	1896	222,000	$224,000
1885–86	197,000	----------	1900	211,200	----------
1890	245,000	----------	1904	234,000	434,900
1892	200,000	237,700			

Judging from the statistics alone, the fishery seems to have been well maintained during the past twenty years.

The sponges of Tunis are inferior to those of Tripoli and average from 10 to 20 per cent less in price for corresponding kinds. Those taken by the gangava or dredge bring a lower price than the product of either the harpoon or scaphander, probably on account of their miscellaneous character as to both size and quality. Many of the native spongers sell their catch in its natural or uncleaned condition (pêche noire), but the foreign fishermen all clean their product (pêche blanche) before selling it.

The Tunisian Government has followed a vacillating policy in regard to licenses for the fishery, especially as to the scaphander; but in 1903 the annual fees were fixed at $20 for harpoons, $75 for dredges, and $200 for scaphanders. For the "pêche noire" the tax is $8 per boat, all sponges to be landed and sold in the uncured state.

Sfax and Gherbis are the principal markets, whence a large part of the product is shipped to Marseilles. Owing to the imposition of an import duty in France there is a growing tendency to ship to London.

LAMPEDUSA AND THE SICILIAN SEA.

The sponge fishery in these waters is carried on from March until about the middle of November, principally on the banks stretching south and southwest from Lampedusa almost to the coasts of Tripoli and Tunis, but also to some extent north of Pantellaria and off the west coast of Sicily. The fishery is almost solely in the hands of Italians and Greeks, although a few Turkish and Tripolitan vessels are occasionally engaged in it. In 1904 there were 63 Italian vessels of 1,302 tons carrying 309 men and 37 Greek vessels of a total tonnage of 716 and carrying 406 men. The vessels range between 10 and 40 tons.

Three methods are employed in the fishery—harpooning or hooking, dredging, and diving with the scaphander. The native fishermen use the first two methods solely, while about half of the Greeks employ the diving dress. The Italian fishermen are practically all Sicilians, though a few come from Naples.

In 1904 the product was about 81,000 pounds, valued at $123,000, as compared with 98,000 pounds, valued at $150,000, in 1903 and 68,000 pounds, valued at $85,000, in 1902. Both the product and the number of persons engaged in the fishery have decreased since 1899.

The Italian spongers sell most of their catch at Lampedusa, whence it is shipped to Palermo, Leghorn, Milan, Ancona, Venice, Trieste, Paris, Marseilles, and Barcelona. Those taken by the Greek divers are carried to Piræus, where those of the best grade, which come from the bank of Mezogiorno, bring about 20 per cent more than in Lampedusa. In 1904 the sponges taken with the gan-

gava brought about $1.80, and those caught by the divers from $1.80 to $2.90 per pound, the product of the scaphander being superior in quality as well as larger.

The sponges taken on the banks of Lampedusa and the Sicilian Sea are Turkey cup and toilet, elephant ear, zimocca, and honeycomb. They vary in quality on the different beds.

ALGERIA AND MOROCCO.

There are sponges on the coast of Algeria, but beds extensive and rich enough to warrant a fishery are unknown. The elephant ear was recorded from Bona many years ago, and a toilet sponge similar to that of the Adriatic has been found at LaCalle, Philippeville, and other places on the coast. Within a few years the Spaniards have explored the coast of Morocco and have found beds capable of commercial development.

METHODS OF THE FISHERIES.

The methods followed in fishing for sponges in the Mediterranean, though differing somewhat in details, are essentially the same as those employed on the coast of Florida, with the addition of nude diving (which though occasionally practiced on the American coasts has never been of any importance commercially) and dredging.

Wading.—This was probably the primitive method of sponging in the Mediterranean, as it was in Florida, but with the extermination of the sponges in shoal water it has long disappeared as a factor in the fishery, excepting on the coast of Tunis. The natives of Gherbis and the Kerkennahs take a few sponges in this manner, wading in the water to their necks when the sea is smooth, detaching them with their toes and kicking them within reach of the hands, and occasionally diving into the holes where the water is slightly deeper. The sponges taken by this method are inferior.

Nude diving.—This is another ancient method and a logical sequence of the preceding. It is practiced principally by the Greeks of the Archipelago, the Syrians, and natives of the Tripolitan and Tunisian littorals. It is said that the most skilled naked or "common" divers are from the islands of Calymnos and Symi, and that some of them can descend to the enormous depth of 240 to 250 feet. If this be true it is far in excess of the depths reached by ordinary divers, which usually do not exceed 150 feet. They ordinarily remain under water about two minutes, resting about thirty minutes between dives, but experts sometimes stay down four minutes, and it is stated on good authority that two extraordinary divers of Calymnos remained under water over five minutes, though the depth is not stated.

To aid their descent the divers hold in their hands a flat stone (scandli) attached to a cord, the other end of which is held by a man in the boat. When

the bottom is reached the stone is dropped, the diver retaining hold of the cord to prevent floating, while he gathers the sponges within reach, which are deposited in a net bag attached to his waist. His desire to come up is signaled by jerking on the cord.

The nude divers are not attacked by the serious maladies to which the machine divers are subject, and despite the arduousness of their calling are able to follow it for years, but owing to the brevity of their stay beneath the water and the length of the intervening rests their actual working time is short.

This method of sponging is followed to best advantage on uneven bottom too rough for the dredge, where the sponges are in crevices or under overhanging ledges which make them invisible to the harpooners or where the rocks are so sharp as to make the use of the scaphander dangerous, owing to the liability of injury to the suit and hose. Most of the finest "cave" sponges of the Ægean are taken by this means.

Nude diving is carried on from small boats, the crews of which are generally paid wages, while the diver works on shares. On the African coast this fishery is carried on during the fall and early winter, when the bottom is comparatively free from marine vegetation, but in the Ægean and the Levant it is conducted during the warmer months of the year.

Harpooning.—This, historically the third method of sponging, has been used in the Mediterranean for many years and is still employed on practically all of the sponging grounds where the water is not too deep. It is practically the same in its general features as the hooking on the Florida coast, and the conditions of wind and weather necessary for its success are the same. The instrument employed is essentially a trident, though it may have other than three barbed points or tines. The Tunisian fouchga has two barbed points, the Sicilian fuscina, fuscia, or fiocino has three points, the Greek kamaki has four, while the Dalmatians use a five-pointed instrument. These all differ from the hooks of Florida and the Bahamas in having the tines straight instead of recurved.

The water telescope, practically similar to that used in Florida and the Bahamas, is now generally employed in all parts of the Mediterranean, but it was not used on the African coast until introduced by the Greeks about 1875.

The boats employed are various, each nationality having its preference, those of the Sicilians resembling New England dories; but they are all small, and are manned by two or sometimes three men, one of whom is the harpooner. The boats used by the Greek harpooners are similar in shape to the diving boats elsewhere described. The harpooner stands in a small circular hatch forward and, with a cushion placed beneath his chest, leans over the bow to scan the bottom through his water glass. The nomadic Greeks and Sicilians use large living and deposit boats, while the native spongers of the various regions have

smaller, less seaworthy vessels, or dispense with them entirely when working near home. The working boats, corresponding to the dingeys of the Florida coast, are propelled usually by one, occasionally by two, pairs of oars, and are not sculled with a single oar as in our own waters. When a sponge is sighted the harpoon is driven into it, preferably on the side near the root, and it is detached by a double motion of rotation and rocking.

This fishery is practicable in deeper waters than those in which hooking is carried on in Florida. Depths of even 70 to 80 feet are reached, and off Benghazi sponges are harpooned in as much as 90 feet. In fishing in such deep water three persons are assigned to a boat, the third usually a boy handing the harpoons to the harpooner and assisting in attaching and detaching the additional shafts.

The poles are about 20 feet long, and to the top of each is lashed a short stick, about 6 or 8 inches long, the end of the pole being slightly cut away to create a space between it and the stick. Into this gap the end of the next harpoon is thrust and held in place by a ring, just above the iron, which is slipped over the stick. A third, or as many harpoons as are necessary, are added to reach the desired depth. After the sponge is impaled and torn loose from the bottom the poles are successively detached as they are brought up. The sponges are less firmly attached to the bottom than are those of Florida.

Owing to the rents likely to be made by the harpoon, the finer grades of sponges are less valuable when taken by this method than when procured by diving, and are known in the markets as "harpoonées," as distinguished from "plongées." On the Tunisian coast there appears to be but little difference between the two in price. In Dalmatia tongs are employed, one leg of which is attached to a pole and the other operated by a cord.

Dredging or trawling.—The dredge or trawl (Greek gangava, Italian gagova or cava, French drague), shown in text figures 2 to 4, is of special type and large size, and has been used for many years by Greeks in the Levant and by Greeks, Sicilians, Neapolitans, and Maltese on the coasts of Africa and the banks of Lampedusa. It consists, essentially, of a rectangular frame from 15 to 40 feet long and from 20 to 30 inches high, to which is attached a bag about 6 to 10 feet deep, made of large-mesh webbing of light rope (fig. 2, p. 487).

That part of the frame which scrapes the bottom is a round iron bar about 2½ to 3 inches in diameter, the ends being bent at right angles for a distance equal to the desired height of the frame and connected by a stout wooden bar to form the top. Frequently the ends of the frame are short wooden bars fitted into sockets in the upturned ends of the iron bar (fig. 3, p. 488).

In the larger frames the parallel iron and wooden bars forming the bottom and the top of the frame, respectively, are connected and stiffened by one or two transverse struts (fig. 4, p. 488), but in the smaller dredges these are omitted.

The bridle is composed of a rope running from the middle of the wooden top bar and two, three, or four chains connected near the ends and at one or two intermediate places on the bottom bar, all being united in an eye or ring to which the towrope is attached. The several parts of the bridle are of such comparative length that the frame stands upright when towing. The net bag is laced to the wooden top bar and to rings welded to the iron part of the frame. The tow rope or cable varies in length from 300 to 600 feet, and passing through a chuck or snatch block near the bow is led aft to a hand wind-

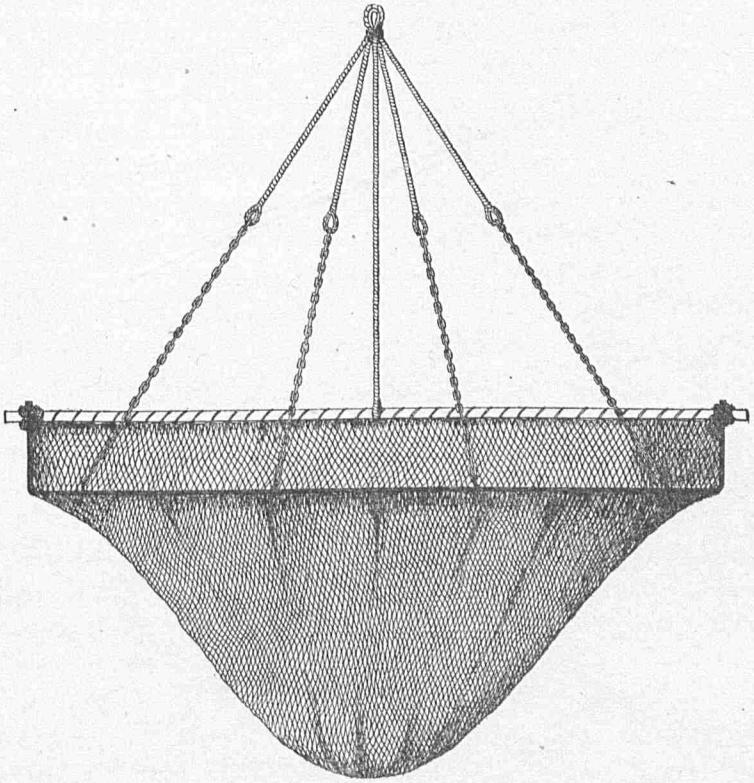

FIG. 2.—Dredge, or gangava, used in Mediterranean sponge fisheries.

lass. A guy line bent to the cable with a rolling hitch at some distance from the vessel is led directly to a cleat or bit near the stern, and is used in controlling the drift of the vessel. A similar line is carried under the jibboom and attached to the opposite side, to be used when the vessel comes about.

The method of using the dredge is essentially as follows: By means of masthead tackles or davit tackles attached to the wooden bar of the frame it is lowered bag first until the frame reaches the level of the rail. The towline is then bent to the bridle cringle and carried through a snatch block forward. The tackles are cast loose and the net lowered by slowly paying out the tow line

until the bottom is reached, when paying out ceases for a moment to allow the bag to straighten out without fouling the frame or bridles. The weight of the chains and the lower part of the frame and the buoyancy of the wooden upper bar makes it easy to land the apparatus right side up. The towline is then paid out with a scope commensurate with the strength of the wind, less being required in light and more in strong breezes, and the guy lines are bent on at such distance from the ship as to give proper facility in handling.

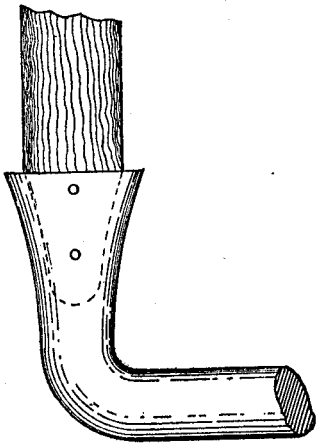

FIG. 3.—Section of dredge, frame showing bend of iron bar at ends.

The apparatus is always paid out on the windward side, the vessel drifting to leeward with comparatively slight headway, so as to drag the dredge at a speed of about one mile per hour. The guy line is used to govern the boat's position with respect to the dredge and the wind so as to secure the proper direction and speed of drift. Slacking the line puts the boat closer to the wind, decreasing both speed and headway, while hauling it in puts her off the wind, thereby increasing both headway and drift.

Should the direction of drift carry the dredge off the edge of the sponge bed, the weather guy line is slacked, the vessel comes into the wind, the lee guy is hauled in, the towline is passed under the bowsprit and made fast on the other bow, while the vessel pays off on the opposite tack across the bed.

When the dredge is full, the fact is indicated by the heavy drag of the apparatus. The headsails are then lowered and the guy line is paid out until the vessel is head to the wind. The towline is passed to a snatch block forward and is hove in until the bridles come home to the block. Two rather long flying bridle lines, not shown in the drawing, are then hooked to masthead tackles, or usually to a pair of davits, and are hove in by small hand windlasses until the iron bar is brought level with the rail, where it is secured by a couple of chain stops. The contents of the bag are then overhauled, the rubbish thrown overboard, and the sponges on deck. Three men can handle the vessel and dredge, but as the work is carried on day and night the crew generally consists of 5 or 6.

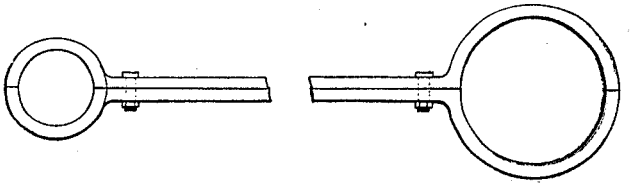

FIG. 4.—Transverse struts sometimes used between bars of dredge frame.

This apparatus can be employed on smooth bottom only, as the frame is liable to foul and the net to be torn on rough rocks, but it can be used at all seasons of the year and in all ordinary weather. It is much complained of for its destruc-

tiveness, the charge being made, apparently with justice, that it tears loose or crushes all sponges in its path, both large and small, and that not only is a considerable portion of the catch inferior on account of the small size, but that many sponges are torn loose and not brought up at all, being left to die on the bottom or to become rollers. In some localities the gangava is prohibited in depths less than a prescribed minimum. In Egypt the limit is fixed at 80 meters (262 feet), and in Cyprus the instrument is entirely prohibited. It is used principally on the African coast and on the banks of Lampedusa.

There are probably between 400 and 500 dredges or gangavas employed in the sponge fisheries of the Mediterranean, of which the great majority come from the Sporades and Cyclades.

Machine diving.—This method of diving and the apparatus employed is sufficiently described in that part of this paper treating of the Florida fisheries. The scaphander was introduced into the Ægean and the Levant about 1866, and at once came into such general use among the Greeks that ten years later about 110 machines were in active service. In 1907 it was reported that there were from 100 to 120 diving machines for sponge fishing owned in Greece alone. In 1903 there were 158 diving outfits employed in sponging under the Greek flag, the reduction in 1907 being probably due, at least in part, to the export of apparatus to the United States for use in Florida.

From the time of its introduction the diving dress has met with active and sometimes violent opposition from the spongers using the older methods, who charged it with being destructive to the sponge beds. Recently it has been opposed on hygienic grounds, and, mainly through the efforts of Mr. Charles Flegel, since 1892 its use has been prohibited in Austria-Hungary, Egypt, Crete, and Samos. Turkey also passed prohibitive laws, but they were not enforced and have been repealed, and the interdiction formerly existing in Cyprus has been removed. Italy and Greece have placed restrictions on the depth to which the divers may go, and both have vessels to enforce the law, which, however, is more or less generally ignored. The Greek regulations prohibit all diving at greater depths than 127 feet, and at least until recently regulated the period for which the diver could remain submerged at various depths. During the sponging season the Greek Government maintains a hospital and hospital ship on the African coast to provide medical attention and succor to the divers.

Some divers are injured or killed by accidents to the diving dress or hose, but the chief danger to which they are exposed is caisson disease, which is a frequent consequence of working in depths of over 60 feet. This malady is caused by the absorption of gases from the compressed air and their release as bubbles in the blood vessels and tissues upon decompression, especially if the latter be rapid, as in the quick ascent of a diver from the bottom. In caisson

work rapid decompression is guarded against by gradual transition from higher to lower compressions in the air locks, or in carefully regulated diving with the scaphander by slow ascents, but in sponge diving these precautions are ignored, with the result that many of the divers become paralyzed and a considerable number of them are killed. Flegel states that the average yearly mortality among the Mediterranean divers reaches the almost incredible proportion of nearly 20 per cent, and the cases of more or less serious illness about 25 per cent. He states, further, that during thirty-nine years upward of 5,100 sponge divers were killed by their work and 2,100 were so paralyzed as to be incapacitated.

That the results of sponge diving are so serious is not surprising in view of the practices obtaining. I am informed by various authorities that the machine divers in the Mediterranean go to a depth of 250 feet, remaining on the bottom three or four minutes at each descent. Boats working in these depths carry 12 or 13 divers, each of whom has a rest of about two hours between plunges. Though the pressures are so great that the heavy woolen stockings worn by the divers are pressed deeply into the flesh, no measures are taken to ascend gradually, the claim being made that the more quickly the person is removed the less the liability to injury. Sponge divers have informed me that serious cases of "bends" occur more frequently in depths less than 25 fathoms than in those greater, owing to the shorter time to which the diver is subjected to the pressure in the latter case.

On the other hand the highest scientific authorities on diving place the safe limit for physically sound men at 150 feet, and they all prescribe a slow ascent and a gradual release from pressure as an essential element of safety. In caisson operations, where the conditions under which the men are working are essentially the same as those in a diving dress, the compulsory use of air locks for gradually reducing the pressure on workers making the exit has been found absolutely necessary to preserve the health of the workmen. It appears that the incentive to deep diving is imposed largely by the financial conditions under which the fishery is conducted. The masters of the vessels, having little capital, are obliged to borrow at rates as high as 25 per cent, and feel obliged to force their divers in order to make their ventures pay.

In many parts of the Mediterranean the sponges grow on bottoms covered with vegetation, the location being often indicated by a mere hiatus in the tops of the growth. In working on such bottom the diver lies almost horizontally above the vegetation, looking for the telltale spots and locating the sponges by feeling with his hands.

About the islands of the Ægean many sponges are attached to the faces of submarine cliffs 50 or 60 feet high, and to reach them the diver floats himself by regulating the air pressure in his suit and propels himself from place to place by a swimming motion of the hands.

The scaphander fishery is mainly in the hands of Greeks from both the Grecian and Turkish islands, and there were recently between 250 and 300 diving outfits in use in the sponge fisheries of the Mediterranean.

Cleaning and curing.—The native fishermen of Tunis sell their product in the natural state, but all of the other spongers of the Mediterranean cure their catch before selling it. The process of curing is essentially that followed by the Greek divers in Florida which has already been described. The sponges sold by weight are loaded with sand, marble dust, and other materials. They are packed under foot in cylindrical bales weighing from 40 to 75 pounds, or in boxes. A considerable proportion of the Mediterranean sponges are bleached before entering the final markets, the process being essentially that employed in the United States and elsewhere described.

VII. VARIOUS MINOR LOCALITIES.

Sponges of some economic value are found at various places which have not yet developed fisheries of commercial importance. In other localities sponges closely allied to economic species or zoologically identical with them have been recorded by naturalists, though but little is known of their abundance, accessibility, and characteristics as measured by commercial standards. Certain of these places geographically adjacent to the important sponge fisheries of North American and the Mediterranean have been discussed, but the isolated localities can be considered most conveniently in a separate chapter. Certain of them are quite likely to develop, eventually, fisheries of more or less importance, especially with the growth of a demand for sponges incident to the extension of modern civilization and manufactures.

PHILIPPINE ISLANDS.

When this archipelago has been more thoroughly explored and its marine resources are more generally known it is probable that it will support a sponge fishery of some importance. The recent work of the Bureau of Fisheries steamer *Albatross*, not yet concluded, has brought to light several sponges of commercial utility, though of rather poor quality.

The Tawi-tawi group appears to be particularly rich in horny sponges, some of which are of value commercially, and the *Albatross* obtained specimens at Siminor, Tataan, and other localities. Small grass sponges were found in extraordinary abundance on the tide flats of Tataan Island, attached to the coralline and shelly bottom in a depth of 1 to 1½ feet at low water. Several other kinds of possible value are reported from the same locality.

Similar sponges are found at Siassi in the Tapul group and several Americans have recently gone into the business of gathering them for the market. Inexperience in curing and packing lessened the value of the product, but it is under-

stood that instructions given by the *Albatross* party have resulted in improvement in this respect.

About the island of Sitanki or Sibutu there are considerable beds of sponges resembling somewhat the toilet sponge of the Mediterranean, though with the upper surface more fibrous and with numerous closely ranged pores. The sponge is very soft, but much weaker in fiber than its Mediterranean congener. Thirty or forty thousand of these have been marketed in Singapore and shipped to New York and London, where they brought a low price.

On the south side of Jolo the *Albatross* obtained a single beach-worn specimen closely resembling the reef sponge of North American waters. From the north side of the same island there was collected, in a depth of 20 fathoms, a specimen resembling the elephant-ear sponge, very strong but harsh and rather incompressible. The texture is closer and more dense than in the Mediterranean sponge and the primary fibers of the skeleton are so heavily laden with sand granules as to render it of but little commercial value. It is possible that superior qualities may be found in other localities. The specimen collected is about 15 inches in diameter, almost flat, with several flaps or lamellæ on the upper surface, and was attached by a short stalk or peduncle.

Small sponges said to resemble the Key grass of Florida are sold in the shops of Cebú and are reported to come from nearby reefs. Others of excellent quality resembling wool and yellow sponges are sold in native shops in various places but are believed to be imported. I have been shown a specimen, said to be indigenous, which very closely resembled the Bahama sheepswool. It had apparently been in use for bath purposes and I am convinced that it was exotic. Another specimen from an unknown locality was of excellent shape and quality, somewhat resembling the honeycomb sponge of the Mediterranean but differing from it sufficiently to remove suspicion that it was not of native origin. It was soft, strong, firm, and elastic, rather flat and attached by a narrow base. If it can be obtained in quantities, it should prove of considerable commercial value.

AUSTRALIA AND NEW ZEALAND.

The sponge fauna of Australia is exceedingly rich, and according to Lendenfeld the zoological species which include the elephant ear, honeycomb, zimocca, glove, and reef sponges are found on its coasts, in addition to several others which he regards as of possible commercial value. The rather poor specimens of Australian sponges which I have examined, comprising 10 or 15 species of supposed commercial value, were nearly all of inferior quality, open in texture, irregular, hard, and harsh. The specimens had the appearance of being beach worn, and the defects of some of them were due in part to imperfect curing. One or two kinds could probably find a limited market at a low price. Attempts have recently been made to find a market for these sponges with a

view to establishing a fishery, but it is understood that the results have not been encouraging. Honeycomb and reef sponges are reported to occur in New Zealand.

OTHER PACIFIC OCEAN LOCALITIES.

The horny sponges of the Pacific islands are known practically from the *Challenger* collections only, those of the various expeditions of the *Albatross* not having been studied.

In the Sandwich Islands there occurs a sponge which somewhat resembles the sheepswool in appearance, but the single specimen upon which the report is based was hard, very weak of texture, and of little, if any, commercial value. A reef sponge from the Fiji Islands and a grass sponge from the Gilberts, both of doubtful value, practically complete the record for this region, although the Carolines are stated to produce a soft, fine sponge, probably not unlike the Sitanki sponges of the Philippines.

INDIAN OCEAN.

I have recently received inquiries in regard to a toilet sponge from the coast of Madagascar. It is stated to "look like the Mandruka toilet sponge," but to have a poor texture and to be lacking in durability. This is possibly the sponge which Cotte says is taken at the southern end of the island about Cape St. Marie. The American consul at Tamatave in response to inquiries reports that sponges occur on the west of the island from Cape St. Marie to Ambohibe, a distance of 340 miles. About 1902 5 Greek divers were employed by 2 merchants and in 1907 some Ceylonese were employed by another concessionaire, but both experiments proved failures and excepting a few sponges taken by natives there is at present no fishery. The price received by native fishermen is about $1.15 per hundred pieces, the sponges being very badly cured. None were exported in 1908.

Lendenfeld records several varieties of the common toilet sponge, the velvet, and several other species of horny sponges from Mauritius, but nothing is known of their economic value.

Sponges also occur in the Seychelles, and the government of those islands has recently taken steps to determine their commercial value.

In Ceylon a variety of the toilet sponge is found in abundance, and Hornell believes it to be of commercial value. *Euspongia irregularis pertusa*, which includes the yellow sponge of the Gulf of Mexico, is also recorded from the island, but nothing is known as to its commercial characteristics and value.

MID-ATLANTIC OCEAN.

Weil states that there are beds of excellent sponges lying in deep water about the Cape Verde Islands and the Azores, and that in quality and general characteristics they are intermediate between those of the Mediterranean and

western Atlantic. He believes that in those places a profitable fishery merely awaits the time when the exhaustion of the older fisheries will force their exploitation.

I have been informed by a Greek of wide experience on both sides of the Atlantic that in the shallow waters about the Canary Islands there is a sponge closely resembling the coarser qualities of the yellow sponge, though the shape is flatter.

Several sponges are reported from the Madeiras and the Bermudas, those of the latter islands resembling those of the North American coast and including the grass, sheepswool, and possibly the velvet. The velvet sponge is also recorded from Fernando de Noronha, off the Brazilian coast, indicating the probable extension of the American commercial sponges along the mainland south of the equator.

VIII. CONDITIONS AND EFFECTS OF THE SPONGE FISHERIES.

DEPLETION OF THE BEDS.

Wherever the sponge fisheries have been prosecuted with vigor for a long period, there has resulted a more or less definite depletion of the beds, or a well-grounded fear of the approach of that condition. The commercial sponges can never be actually exterminated by the agency of man. It is an impossibility to denude the grounds so completely as to leave none for reproduction, and, moreover, as soon as the beds become so depleted as to reduce the earnings of the spongers to a bare living wage, the economic result is a reduction in the number of fishers and the establishment of an approximate equilibrium between productiveness and catch. The point at which this equilibrium is established will vary with economic conditions, becoming lower with an increase in the value of the product and higher with an increase in the cost of living of the fishermen. More men, gathering in the aggregate a somewhat larger quantity of sponges, though the catch of each individual may be less, can be supported when the price is high than when it is low, and this results in increasing the fishery, in a further reduction in the productiveness of the beds, in profits, and eventually in the number of fishermen, the equilibrium being again established on a somewhat lower plane of productiveness. Thus, while the sponges are never actually exterminated there results an approximate commercial extermination, never quite complete for the reason that were the fishery entirely abandoned the beds would soon recuperate and again become commercially productive.

This is well illustrated in a number of cases. In the Adriatic, sponges were formerly much more abundant, but the fishery has been nearly stationary for a number of years. In the Ægean and on the Syrian coast there is said to have been a material decrease during the past thirty years, but the conditions of the

fishery are such that it is difficult to obtain statistics which will show the actual product of the beds in those waters.

On the African coast the yield of the beds during the past fifteen or twenty years has been fairly maintained, though most writers on the subject have expressed the opinion that the productiveness of the beds is waning, and that the average size of the sponges is growing smaller. Such statistics as I have been able to obtain show a rather remarkable uniformity in the total catch. In the fishery tributary to the Benghazi market the only material variation in the catch between 1889 and 1895 can be traced to a difference in the intensity of the fishery, especially in the number of scaphanders employed. In Tunis during the twenty years between 1885 and 1904 the maximum yield has exceeded the minimum by about 25 per cent, and the catch of 1904 was greater than for any year previously recorded, excepting 1890 and 1894. The average catch of three years prior to 1892 was 216,000 pounds and for five years since that date 224,000 pounds. In this connection it must be noted, however, that between 1890 and 1892, principally in the latter year, there was a rapid increase in the number of fishermen from about 3,000 to about 4,500 with a corresponding increase in the number of boats employed. In other words, if the statistics be reliable, an increase of 4 per cent in the average yield of the fishery has been produced by an increase of about 50 per cent in the number of fishermen. This, possibly, may be accounted for to some extent by changes in regulations or methods of which I am ignorant, but the facts substantiate the statement that the dealers of Sfax and the spongers themselves are of the opinion that the fishery is being depleted, as indicated by the smaller catch per man employed and the increasing proportion of small sponges.

The total product of the banks of Lampedusa has decreased materially since 1888–1899, when the fishery reached a maximum in both yield and intensity. Considered by five-year periods, the available statistics appear to indicate some depletion of the beds during recent years. During five years from 1890 to 1894, inclusive, the average catch per sponger was about 151 pounds, the average of five years from 1895 to 1899, inclusive, was the same, while the average of the four years from 1901 to 1904, inclusive, was but 120 pounds, a decrease of 20 per cent. Owing to the fluctuating proportions of scaphanders and dredges from year to year and other variations in the fishery, it may be that this decrease has no great significance, but those familiar with the beds are of the opinion that their productiveness has decreased. It is noteworthy also that the smallest catches made since 1889 were in the years immediately following the intense fisheries between 1895 and 1900, when the largest number of men and boats were employed and the beds most thoroughly scoured. In the Mediterranean the dredge and the scaphander are both blamed for the depletion of the beds, the former because it tears everything from the bottom and the latter because

of the number of small sponges taken. The harpoon and naked diving are regarded as harmless, and it is generally held that the beds could not be seriously injured by those methods alone.

On the western side of the Atlantic the case is different. In Cuba and the Bahamas, and until recently in the United States, the diving machine has not been used and the dredge is unknown. Hooks, the equivalent of the Mediterranean harpoon, were the only implements employed, yet the complaints of waning productiveness of the sponge grounds are quite as loud and, in some cases at least, as well grounded.

The earlier statistics of the Florida fishery are nearly valueless for the determination of the productiveness of the beds. The sponges are bought by bunches which vary in weight with the size and character of the sponges and the manner in which they are strung, and the only comparative weights or quantities which are available are those of the packed goods. Unfortunately these weights are not those of the pure sponges but of sponges plus salt, sand, glucose, and other materials used in loading. Were this loading uniform the statistics would still be of some value for the purpose of the present inquiry, but the amount of foreign matter introduced has gradually increased since the practice was recommenced, about 1895, after an interval of comparatively honest packing, until in 1903–4 I found it to range between 100 and 150 per cent of the true weight of the sponges. At that time, and until the heavy influx of sponges from diving operations, practically all sheepswool sponges and some of the cheaper grades were heavily loaded, and even much of the small quantity sold as "pure" was more or less "doped" with salt, glucose, glycerin, and a little litharge. Since 1903 the statistical weight of the catch has been based upon an assumed approximate average weight of the bunches and the result is probably more accurate.

Considering the total yield of both Bay and Key grounds, the average catch of sheepswool sponges between 1895 and 1899, inclusive, was 173,043 pounds, while between 1900 and 1904, inclusive, it was 186,155 pounds. In the latter period, however, there were two years, 1901 and 1903, when clear water on certain grounds rarely fished gave the spongers access to practically virgin bottom. It should be stated, however, that in the latter part of this term the number of men and vessels employed exhibited some decrease.

In the period from 1905 to 1908, inclusive, there occurred a great increase in the production, the average product of sheepswool sponges being 313,697 pounds. This was due to the introduction of diving.

Considering the production in its relation to effort expended in the fishery, we find that each man engaged in hooking from 1900 to 1904, inclusive, produced an average of 100 pounds of sheepswool sponges per year as compared with an average of 81 pounds for the years 1905 to 1908, inclusive. The

average production per diving boat per month of actual operation, as nearly as can be ascertained, has been 385 pounds in 1905, 437 pounds in 1906, 338 pounds in 1907, and 206 pounds in 1908. The latter part of 1907 and the entire spring of 1908 was characterized by boisterous weather, and part of the decrease may be due to these conditions.

So far as we can judge from the statistics, however, and making due allowance for the uncertainties of the fishery, there appears to have been a considerable decrease in the productiveness of the beds, especially in the Gulf of Mexico, since 1900, a statement which is strongly supported by the observations of those engaged in the fishery.

HOOKING AND HARPOONING.

Hooking and harpooning are essentially the same and are limited by the same conditions. They can be carried on only when the weather is moderate and the water clear, and as the latter essential may occur on some beds only at intervals of several years, as, for instance, on the New grounds off Cape Sable and in the deeper water on the Bay grounds, there is imposed on these methods of fishery certain natural and irrefrangible close seasons which operate to effectually protect certain beds by restraining the fishery for sufficient periods to permit of recuperation. In most places, however, clear water is the rule rather than the rare exception; and in such cases hooking, while temporarily inhibited, may be carried on for a greater or less part of each year. When this is the case the effects on the beds are dependent upon the intensity of the fishery and the degree to which the fishers rob the grounds of young sponges. As a rule, wherever the beds are sufficiently productive to make it profitable they are worked beyond reasonable limits until more or less gradually the yield is reduced below the economic minimum and most of the spongers withdraw to other fields, leaving, however, enough of their less enterprising fellows to prevent the possibility of effective recuperation. This has been the case on the Key grounds of Florida, where the fishery continues to produce a small crop, though abandoned as unprofitable by most of the vessels and some of the boats. The New grounds, where the water is found clear only at intervals of several years, still produce sponges under favorable conditions, while several other places—for instance, the vicinity of Bamboo Key, which were almost abandoned for a while—have again become moderately productive.

In connection with the hook fishery there are two factors which assist in the recuperation of the beds. One is the presence of sponges in adjoining waters too deep to be reached with the hooks, and the other is the retention on the beds actually fished of sponges which are out of sight from the surface. This is more fully discussed in connection with diving. Another factor assisting in the recuperation of the beds reserved to hookers is the regenerative growth of fragments

remaining attached to the bottom after the main portion of the sponge is torn loose. It often happens that the hooks are inserted above the base, and more or less of the root is left to grow into a new sponge. On overworked beds the spongers frequently find apparently large sponges which are so flat that the hooks can not be inserted at all, and a bed which has been fished continuously for a series of years produces more flat sponges than when first discovered. It is probably because the beds are only worked at intervals of several years that the New ground sponges have a greater height than those from other Key grounds, and the sponges now being taken from the rested Bamboo Key grounds are higher than those formerly obtained. It is not at all unlikely that this regeneration of attached "roots" is a more important factor in the rejuvenation of the beds than is generally supposed.

The greatest abuse connected with hooking is the capture of small sponges, though the proportion of those below the legal limit of 4 inches is smaller than in the catch of the divers. This abuse is always greater on partially depleted grounds, which are less able to stand the drain, than on newer and more productive beds. A gradual reduction of the average size of the individual sponges taken is always a serious symptom of depletion already accomplished and a potent cause of greater depletion to come.

NUDE DIVING.

Nude diving is not practiced to any extent in the fisheries of the western Atlantic, and though it appears less objectionable than almost any other method it is prohibited by the laws of Florida. The natural limitations imposed upon this fishery are stringent and are such as to prevent the depletion of most beds by this method alone. The sea must be moderate and the water fairly clear, while the brevity of the period of submergence and the length of the intervening rests, together with the small proportion of men who will develop into first-class divers, makes the devastation of the beds by such means a remote contingency. Although sponges unattainable by other means can be taken by this, the history of the Mediterranean beds leads to the conclusion that nude diving is comparatively harmless to the sponge grounds.

MACHINE DIVING.

The objections which have been urged against the use of the diving machine are resolvable into essentially two: (1) That the divers with their heavy-mailed shoes crush innumerable young sponges in walking over the bottom, and (2) that they take everything, large and small, leaving the bottom denuded of the growth essential for reproduction.

The first objection appears ridiculous to anyone familiar, either theoretically or practically, with the principles of diving. It is true that the diver as he appears

on the deck of the vessel is burdened until he is hardly able to walk, partly by the essentials of his dress, but largely by weights which he deliberately adds for the express purpose of enabling him to keep on the bottom when submerged. After his descent, when his dress becomes inflated, it is necessary to release air from time to time, not only for purposes of respiration, but to prevent the buoyancy of his inflated suit from raising him to the surface, and should he lose a weight on a shoe he will immediately lose control of himself and float. It is one of the well-known restrictions of working in the diving dress that while a strong upward pull can be exerted a vigorous lateral push can be put forth only when the diver can place his foot or some part of his body against a fixed object, while even a moderately effective downward push or blow can not be delivered unless the operator can anchor himself by holding with his hand or other means. These restrictions in the employment of his full strength all result from the lightness with which the diver rests on the bottom, the ponderous and grotesque object which can barely stagger on the deck of the boat treading gently with but a few pounds pressure as he travels over the bottom. As the weight with which the diver actually treads could seriously injure none but the very smallest sponges, and as his footprints can not possibly cover more than a very small proportion of the ground over which he works, this objection to the diving machine can well be totally disregarded.

The second objection stated above is more serious. It has been claimed by some opponents of diving that the diver is unable to distinguish accurately the size of the sponges, owing to the optical conditions under which he works, while the advocates of the method claim that he is in much better position to do so than is the hooker, looking through a deep stratum of water of variable transparency. There is but little doubt that experienced divers, depending not only on eyesight but upon touch, can distinguish with sufficient nicety to avoid flagrant breach of the law and common prudence, but so long as undersized sponges have a market and infractions of the law are not punished they will not hesitate to pluck most of the young sponges which come in their way. Whether they do the damage knowingly or unwittingly is of no material moment, however, in the face of the fact that the damage is done, and there is no doubt that immense numbers of small sponges are brought in by the divers, many of them being sold in the exchange at Tarpon Springs, while undoubtedly a much larger number are shipped for sale in other markets. The proportion of these sponges to the total catch appears to be much larger than among the product of the hookers.

Another phase of this matter is concerned not so much with the taking of the young sponges as with the thoroughness with which the bottom is denuded of all sizes. In working over rough bottom especially, the hookers and harpooners always leave a considerable proportion of the sponges, not from choice but because they are overlooked, hidden from view from above or inaccessible

owing to their situation in crevices or under ledges. These the divers are able to find and obtain and in consequence they leave fewer sponges to furnish the young necessary for the recuperation of the beds. Where the divers are working on grounds already partially depleted by other methods of sponging, as was the case during the first two years of the fishery in the Gulf of Mexico and in many places in the Mediterranean, there can be no doubt that the method is exhausting to the beds, even if it be conducted without the abuse of gathering undersized sponges. When the beds are already worked to or beyond their limits of productiveness any method which increases the draft upon them must be injurious.

This was one of the contentions of the opponents of diving in Florida and was the reason for the restriction of the divers to depths greater than 50 feet. It was hoped by this means to preserve the inshore grounds inviolate for the hookers, while permitting the taking of sponges in the deeper waters unattainable by the methods previously in use. Concerning the productiveness of these offshore grounds we are not yet in possession of data which would warrant an opinion of value, but the little that we do know does not indicate that they are more productive mile for mile than were the shoaler waters when first discovered. In fact, the bars appear to be fewer and more scattered, and though sponges occur on some of them in great numbers, this abundance is due to the fact that they are virgin beds and have never before sustained a fishery. There is no doubt that in time some, at least, of these will be depleted and the proximity of that time will be proportional in some measure to the intensity of the fishery and conversely to the area of new grounds developed.

Assuming that the fishery can be carried on to the 20-fathom curve and that the productiveness of this region is proportionately equal to that covered by the hookers, an increase of from 250 per cent to 275 per cent in the annual product, making no allowance for the consideration about to be presented, would result in approximately the same degree of over-fishing which had gradually decreased the catch of the hookers prior to 1905–6. This allowable increase was nearly attained in the year ending May 1, 1907, when the value of the sheepswool product was over twice the normal of the years immediately preceding. Owing to the sudden increase in the supply the price dropped far below that of previous years.

In discussing the effects of the fishery upon the rate of depletion of the inshore beds, consideration must be given to the effect upon their recuperative powers of the sponges lying in the deeper water, beyond the reach of the hookers but now being taken by diving. Undoubtedly a considerable proportion of the young sponges on any bed are the offspring of breeding adults in the immediate vicinity, either overlooked by the hookers, concealed from sight under ledges, or protected from capture by the prevailing turbidity of the water, all factors

less operative with the divers; but it is equally beyond doubt that no inconsiderable proportion are derived from sponges in deeper water, at a distance from the beds on which the young finally settle.

We have evidence that this must be true in the phenomena of the recuperation of large areas after the practically complete extermination of the sponges from so-called "poison water." This has recurred at irregular intervals about ten years apart. In 1878, for instance, practically all sponges accessible to the hookers between Johns Pass and Cedar Keys were destroyed and the fishery was abandoned for several years, the first sign of recuperation being observed about 1882. About 1895 a similar occurrence in the northern part of the Bay grounds killed the sponges between St. Marks and the mouth of the Suwanee River from about the 5-fathom curve to the greatest depth explored by the hookers, and in 1901 I was informed that the first sponges taken since then from the depleted bed had been obtained recently.

The evidence all indicates that over the large areas involved few if any sponges escaped the disaster, and as the repopulation of the beds was apparent practically simultaneously over the whole area and did not appear first merely at its edges, it is evident that the young must have been derived from grounds more or less remote. The very young sponge is a free-swimming organism which is probably often carried far by currents before it reaches the stage at which it settles down and becomes fixed. It is evident that the rate or probability of recuperation of any exhausted area depends not only on the number of resident breeding sponges, but also upon the presence and number of such sponges on surrounding areas. An exhausted area adjacent to virgin beds will have a more abundant set of young than if the surrounding areas are equally exhausted. In the history of the sponge grounds of the Gulf of Mexico prior to 1905 there were always untouched bars offshore just beyond reach of the hooks, and these must have supplied untold millions of fry to the workable beds, retarding their commercial exhaustion. This condition is now changing, for the offshore beds themselves are yielding up their sponges in large numbers, and even if they exist in still deeper water than has been explored the virgin beds are becoming more and more remote from inshore waters. It would appear, then, though the basis of the conclusion is purely a priori, that, in view of the increasing exploitation of the deeper beds, the grounds now reserved to the hookers will probably not have the same powers of recuperation in the future as in the past, and that with the same expenditure of effort in the fishery the product of these beds will tend to fall at an increasing rate. The consequence of this will be that the principal seat of the sponge fishery will gradually move into deeper and deeper water until the limit is reached, either by the depth in which it proves practicable to work or by the attainment of the limits of sponge production, which may be fixed by either the depth of water or the absence of suitable bottom.

The introduction of diving came at a time when the older method of sponging had finally demonstrated its inadequacy to supply the demand for sponges, and by developing new beds it has deferred the time when the Florida sponge beds will no longer be able to sustain the demands of the markets. On the other hand, it will undoubtedly operate to retard the recuperation of beds already or about to become exhausted, and will, of itself, tend to depopulate the beds on which it is carried on and, indirectly, the hooking grounds adjacent to such beds. From the comparative facility with which it can be conducted, irrespective of the condition of the water, the thoroughness with which the bottom can be scoured and the reckless disregard of the future with which the divers gather small sponges, diving is undoubtedly more dangerous in the denudation of the beds than is hooking. The recent legal restriction of the fishery to the deeper waters and to the more boisterous season of the year, when many days are lost on account of stormy weather, will operate to curtail the catch and the profits and restrict the number of persons engaging in it, and to this extent the conservation of the beds will be accomplished. What may be the ultimate result of the introduction of the diving machine will depend largely upon the area and productiveness of the beds outside of the 8-fathom curve. If they be four or five times as great as those of the beds within that limit, the Bay grounds can support a profitable fishery for some years to come, but if they are no greater than there is now reason to suppose, the effects of the fishery will become apparent within the next five years.

DREDGING OR TRAWLING.

The dredge or gangava is not used in Florida or the West Indies, but the testimony of European authorities and an appreciation of the effects of the dredge and beam trawl used by naturalists indicate that without regulation its effects must be disastrous. If used in profound depths to take sponges wholly beyond the reach of other methods of the fishery it has some justification, but even then it would probably retard the recuperation of the adjoining beds in more shallow water in the same manner as denudation by the scaphander would curtail the supply of young sponges on still shallower beds.

There can be no doubt that the gangava is a destructive engine. With it there can be not even such imperfect selection as is exercised by the hooker and the diver, and the proportion of young sponges brought up is correspondingly greater. On the banks of Lampedusa, where the gangava and the scaphander work practically side by side, it is stated on the authority of Lucifero that the refuse sponges brought up by the former constitute 25 per cent of the total catch, while but 6 per cent of the diver's catch is composed of refuse, small, and seconds. It is stated, also, by the same authority, that owing to the damage done to small sponges it requires five years for banks to recover from the effects of dredging, and even then the crop is limited, while two years suffices for the

recuperation of beds exhausted by diving, and the crop then produced is comparatively abundant. While the hardships and personal risks of the dredgers are negligible as compared with those attending diving, the effects on the beds are far more disastrous.

Owing to the comparatively small expense for equipment and operation, and the fact that dredging can be carried on in all depths and in weather which would inhibit other methods of fishing, it is possible by this means to conduct a fishery of great intensity and to exploit grounds so depleted as to be unprofitable for diving. It is by no means certain that the offshore grounds of Florida are not too rough for the gangava, but to prevent the introduction of this method of fishing in shallow water and to forestall the establishment of a "vested interest" which might be difficult to deal with in the future, it is desirable that legislation be passed restricting the use of the dredge to depths far beyond those which it is possible to exploit by other means.

IX. THE REGULATION AND PROTECTION OF THE SPONGE FISHERIES, WITH PARTICULAR REFERENCE TO FLORIDA.

MEASURES IN FORCE.

Until recently the regulation of the sponge fisheries of the Mediterranean has been, with few exceptions, concerned chiefly with the production of a revenue for the governments concerned, but during the past fifteen years, owing chiefly to the efforts of Mr. Charles Flegel, another element has been introduced, the protection of the spongers themselves from the physical effects of their calling.

It is true that in a few places measures are in force which tend to protect and conserve the sponge beds. In Dalmatia recent attempts to introduce the scaphander and the dredge have met with opposition and interdiction, and the sponge banks are opened to the other spongers only during alternating periods of two years. A somewhat similar regulation is proposed for the Bay of Taranto. In Cyprus the dredge is entirely prohibited, and in Egypt its use is authorized only in depths greater than 262 feet, where it is impossible to take sponges by any other means. In Greece, Tripoli, Tunis, and on the banks of Lampedusa all forms of apparatus are permitted under varying conditions as to taxes and licenses; but in Turkey, Egypt, Crete, and the principality of Samos the scaphander is prohibited on broad economic and humanitarian grounds rather than for the narrower consideration of the protection of the sponge beds, and for the same reason Greece has attempted to regulate the maximum depth to which this apparatus may be used without restricting in any way its employment in shoaler waters, in which it might be supposed to do greater damage to the beds. The attitude of the Greeks in this matter is readily understood, for they are dominant in the fishery and most of their diving is carried on in waters away from home.

In Florida, the Bahamas, and Cuba, while the matter of revenue has been by no means overlooked, more consideration has been given to questions of conservation of the fisheries, the measures adopted being the prohibition or restriction of the use of supposedly destructive forms of apparatus, the establishment of close seasons, and a minimum size of sponges which it is permissible to take.

In the Bahamas, Cuba, and the territorial waters of Florida both the scaphander and the dredge are absolutely prohibited, Florida also including in the interdiction all methods of diving, either with or without apparatus. In Cuba the sponge beds are all in territorial waters, and as the Bahama government without challenge assumes jurisdiction over the entire area of the banks, neither of these countries has much difficulty in making the legislation effective. In Florida, however, a difficulty confronts those interested in the conservation of the industry.

On the Bay grounds in the Gulf of Mexico practically the entire sponge-bearing bottom is outside of territorial jurisdiction, beyond the 3-mile limit, and therefore in neutral waters not subject to direct regulation of either state or national government. So far as this region is concerned, therefore, the laws of Florida are from the nature of the case inoperative, and to obviate the difficulty the Congress of the United States has recently enacted laws prohibiting the landing of sponges taken by diving between May 1 and October 1, those taken by diving at any time in water less than 50 feet in depth, and all sponges of less than 4 inches in their largest diameter taken by whatever means.

The effect of the federal laws, taken in conjunction with those of the state, is, therefore, to prohibit the landing or sale of sponges having a maximum diameter of less than 4 inches; to prohibit naked or skin diving and the use of the scaphander by American vessels fishing for the American market in depths less than 50 feet, and in any depth during the seven months from May 1 to October 1; and to prohibit the use of dredges on the Bay grounds within 3 miles of shore, where there are no sponges, while permitting their use outside of that limit, where the sponges actually exist. No legal restriction is imposed on hooking excepting that applying to the minimum size of sponges which may be caught, landed, or offered for sale. There is no prohibition, nor from the nature of the case does such prohibition appear possible, against either American or foreign vessels using the scaphander at any time anywhere outside of the 3-mile limit, provided that the product of such operations be not landed in an American port except by regular entry and payment of duty as a foreign product.

On the Key grounds these difficulties are not encountered. The waters are shoal. The sponge beds are within territorial limits and under state control, and the federal statutes therefore do not apply and are not necessary.

MEASURES PROPOSED.

The possible measures for the regulation and conservation of the sponge fisheries resolve themselves into (1) the prohibition of taking sponges below a given minimum size, (2) the establishment of close seasons, (3) the restriction of the character, amount, and location of the apparatus employed, and (4) sponge culture. As has been previously indicated, the taking of young sponges is one of the great abuses of all sponge fisheries, and that one most fatal to the perpetuation of the beds; and young sponges are taken by all present methods of fishing, though to varying degrees. A few of them are thrown away by the fishermen, but the vast majority are placed on the market. I have seen 30,000 small sheepswool sponges in the house of one dealer at Tarpon Springs, who paid but $500 or $600 for the lot, an average of less than 2 cents apiece. This was probably the largest quantity bought by any one man at that place, but the other dealers also had large numbers, and it is notorious that the divers ship many away for sale in other places. It is impossible to state the total number of young Florida sponges annually placed on the market, but there must be at least between 150,000 to 200,000 pieces. Accepting the lower estimate, these are worth to the spongers not over $3,000, but if left to grow for another year they would more than double in weight and increase about ten times in value at the present prices. Not only is there this direct monetary loss to the fishery, but there is an indirect loss to the beds resulting from the unprofitable removal of this large number of breeding individuals capable of furnishing fry for the regeneration of the sponging grounds.

The present minimum limit placed on sponges by both the federal and state statutes applicable to Florida waters is 4 inches in the longest diameter when wet, but most persons do not realize the small size of such sponges. The dealer mentioned above was of the belief that all of his 30,000 small sponges were under the legal limit, but a careful measurement showed that probably 50 per cent of them could be construed as complying with the conditions of law, the largest diameter reaching 4 inches, though the other dimensions were usually considerably less. The average weight of such sponges when pure and perfectly dry is less than one-half ounce and they are of little value in the markets. To sell most of them at all it is necessary to bleach them and place the price so low as to leave little profit. If the law is to be made really effective for the protection of the beds and to prevent the taking of economically unremunerative sizes the minimum limit must be raised to 5 inches and the law must be rigorously enforced against spongers, buyers, dealers, and others who are concerned in its infraction. It is believed that most of the buyers and vessel owners at least would welcome more rigorous measures, which would work no hardship to any-

body if enforced on all without prejudice or favor. The difficulty now is that each man feels that the law will be broken with impunity by some of his competitors and that he may as well get his share of such profits as may accrue from disregard of the regulations.

The amendment and enforcement of the law as suggested will not restore the depleted beds to their pristine productiveness nor prevent the partial depletion of beds at present more or less unimpaired, but it will prevent the ultimate commercial extinction of the sponges and will insure for all years to come at least a partial crop from all beds now known or which may be hereafter discovered. As to the foregoing there can be no room for discussion among fair-minded and disinterested persons, but in regard to close seasons the various suggestions that have been made from time to time are open to more or less difference of opinion. The following propositions all have their advocates: (1) The closure of all beds during the spawning season, (2) the closure of all beds for a part of each year irrespective of the spawning season, and (3) the alternating or rotative closure of some of the beds for a longer period while all other grounds are open to more or less unrestricted fishing.

The first suggestion appears to me to be futile and ineffective. In the first place a difficulty presents itself from the circumstance that the sponge, at least in the warmer waters, spawns more or less generally throughout the year, though the greater number of embryos are emitted during spring and early summer. This, however, would be a minor consideration if much were to be gained, for the period selected for closure could be made to correspond with the time of maximum discharge of young, but nothing more would be accomplished than by closing the beds for an equal period at any other season of the year. Whether a breeding sponge is taken before or during the spawning season the loss is the same so far as its potential powers of reproduction are concerned.

The close season embracing a part of each year, similar to that established for the scaphander in Florida from May 1 to October 1, or the Tunisian regulations of like import, is of value chiefly in restricting the catch and leaving a larger number of sponges on the beds. If by an increase in the intensity of the fishery as many sponges are taken in the shorter period as would otherwise be caught in the entire year, practically nothing is gained, for the duration of closure is too short to permit the protected sponges to increase very materially in size and, as stated above, the protection of spawning as distinguished from nonspawning mature individuals is immaterial. Where, as in Florida, the open period is made to coincide with the season under which the fishery is most subject to difficulty and interruption, the regulation is made more effective in protecting the beds by a reduction in the profitableness of the operations and the consequent discouragement of increases in apparatus, personnel, and intensity of the fishery.

A somewhat different aspect is presented by the proposition to close the grounds in rotation for periods of a year or upward. This would tend to intensify the fishery on the open grounds but would compensate for this by providing periods of rest, recuperation, and growth. By periodically closing a portion of the grounds for terms of say two years, there would be given to many of the small sponges already set an opportunity to grow to marketable size, the sponges already marketable would increase very materially in size, weight, and value, and these two would in turn result in the production of a larger number of embryos and a heavier set of young. Notwithstanding that many of the spongers and others interested in the business believe to the contrary, a period of two years is not sufficient to produce a merchantable sponge from the egg, and the earlier set of the closed period would not be ready to market until a year or two after the area was again opened to fishing. Even upon the impossible assumption that all marketable sponges were removed during the first open year, if the young were properly protected in accordance with previous suggestions the good effects of the closure would be apparent over a term of several years.

The practical impediments to the application of this system of protection to the waters of Florida lie mainly in the necessity for making the required subdivisions of the grounds rather small and generally distributed, and the consequent difficulty in securing its enforcement. It would not be feasible, for instance, to close the Bay grounds north of Cedar Keys and open them south of that place for the reason that the water might be turbid in the latter area while clear in the former, to the utter prostration of the fishery and the ruin of those engaged in it. To guard against such contingency it would be necessary to divide the whole area into transverse strips, say 10 miles wide, closing alternate zones or every third zone, as the case might require, leaving the others open. It would be necessary to mark these areas adequately with buoys and to establish a patrol to enforce respect for the regulations. Moreover, as most of these waters are outside of marine jurisdiction, it would appear possible to make the regulations effective to our own fishermen only, though the distance from foreign ports would probably act as a geographical deterrent to the depredations of foreign vessels. In any event the regulations would be difficult to enforce even with the assistance of several guard boats. This is probably the best and most effective type of close season, though presenting practical difficulties of enforcement; but it also is in essence a restriction on the intensity of the fishery and consequently on the yield, and whether it would add materially to the productiveness of the long-used hooking grounds is a matter of grave doubt; however, it might operate as insurance against ultimate depletion. It is practically the method which nature already enforces in places by prolonged periods

of turbid water, the effectiveness of which we can determine by a comparison of the present condition of the grounds with their past.

Restrictions upon the character, amount, and location of apparatus and methods are designed either to suppress destructive or wasteful fisheries or to curtail the use of efficient methods which are not inherently destructive or wasteful, though they may become so in the employ of the reckless or unprincipled. Examples of the first type of legislation are seen in the prohibition of the use of the dredge in Florida, the Bahamas, Cuba, and Cyprus and its restriction to great depths off the Egyptian coast. There is no doubt that such regulation is in the interests of the fisheries. The dredge has no place in a well-regulated fishery in depths approaching those that can be exploited by other means. It may be effective, but it is also inordinately destructive, and the sponge fisheries of this day are in no condition to support unnecessary and preventable waste.

The federal and state legislation restricting the use of the diving machine to depths of not less than 50 feet is an example of the second type of restriction of apparatus. Properly conducted diving is inherently neither destructive nor wasteful. Its chief menace to the beds, if the taking of young sponges be prevented, lies in its efficiency and the thoroughness with which it operates to denude them. It is intense in its effect, and the legislation directed at it is intended to confine and limit it and to preserve both the inshore and offshore beds by practically restricting its efficiency and the volume of its catch. The restriction of the scaphander to water deeper than 50 feet is absolutely necessary for the conservation of the beds already shrinking under the operations of the hookers. Later it may be necessary to protect the divers from themselves and fix a maximum depth beyond which they may not go.

The three general means of regulating and conserving the sponge fisheries above discussed are applicable to the public beds, limiting the intensity of the fishery, aiming to secure and maintain what we have rather than hoping to add to it. They are restrictive and conservative rather than constructive, and without the discovery of new grounds offer little hope of maintaining the supply in equilibrium with the constantly growing demand.

The fourth method, sponge culture, is on the contrary concerned with the sponge industry rather than the sponge beds. It is constructive, aiming to add to the sponge supply of the future without particular regard to the source of supply of the present. It apparently offers the only hope of permanently maintaining the sponge fisheries in those countries in which they are now established, though the discovery of extensive beds in other parts of the world may make it not absolutely necessary for the prevention of an ultimate sponge famine. As it is at present not applicable to the public beds, but even more than oyster culture susceptible of development by private enterprise only, discussion of it is reserved for another paper.

X. CONCLUSIONS AND RECOMMENDATIONS AS TO THE FLORIDA SPONGE FISHERY.

All known and exploited sponge beds, in whatever part of the world, are showing more or less marked indications of depletion, and in some places, notably the Key grounds and to a less extent the Bay grounds of Florida, there has been under average conditions a conspicuous falling off in the product. By the introduction of improved methods of fishing the yield has been temporarily increased in some places, but there is no reason for believing that these increases can be indefinitely maintained or materially augmented.

Such depletion as has occurred is in part due to the taking or destruction of small sponges, but is attributable principally to the intensity of the fishery rather than to preventable abuses. The demand for sponges, especially for those which are employed in the arts and industries, is constantly growing. Countries which formerly used practically no sponges develop a demand with the growth of manufactures, and countries which for years have used sponges now require many more than they did a decade or two ago. In 1880 the United States used about $394,000 worth of sponges and in 1900 about $987,689 worth. In the fiscal year 1907, with a domestic crop of $854,583, imports of $488,426, and exports of $247,145, the apparent consumption was $1,095,864, but of these a considerable quantity were in the warehouses of the dealers at the end of the year. The increase noted is due in part to higher prices but largely to greater consumption. The demand is outrunning the supply and to satisfy it the beds are being scoured as never before. New and more efficient methods are being introduced, while the fishermen using the old methods on old grounds are taking fewer sponges individually but still find the fishery more or less profitable owing to the higher prices which they are able to obtain.

The outcome of these conditions is inevitably the ultimate depletion of the beds or the economic limitation of their product. The world can produce annually by natural processes alone only a certain more or less definite quantity of sponges. It is obvious from the facts which have been set forth in preceding pages that many beds have reached their limits of productiveness, and that were it not for the higher prices of to-day they could not be fished with profit by the methods which proved lucrative in former years. A bed from which a fraction of the sponges has been removed has not the reproductive and recuperative possibilities which it possessed in its virgin state. Worked as intensely as they are to-day the sponge grounds can not improve; they are almost certain to retrograde, but by wise regulation some of them may be maintained in approximately their present condition of productiveness.

The discovery of great sponge fields in places in which they are not now known or developed, in Australia and the Philippines, for instance, may provide for the future growth of the world's demands, but that will be of no value to

fisheries already established, however desirable it may be from the standpoint of the consumer. Exhausted or partly exhausted fisheries must suffer if brought into competition with those whose productiveness is unimpaired and whose product may be put on the market at a lower price. Those countries which have with forethought provided for the contingencies of the future are those whose fisheries will be best fitted to survive competition, or, should that not come, be in a position to reap the greatest profit from the increased demand for their product.

To secure to the people of Florida the conservation of the natural beds, for the maintenance of the fisheries already established, to regulate those which may be introduced in the future, and to provide for an increase in the sponge supply to meet the growing demands of civilization, changes in the federal and state statutes are suggested to meet the following requirements in addition or amendment to those already provided for:

1. The minimum size of sponges allowed to be taken, landed, or sold should be increased from 4 inches to 5 inches in their maximum diameter. This would prevent the present wasteful destruction of sponges commercially almost worthless, would conserve the beds, and after one year would increase the income of the fishermen without materially decreasing it in the meantime.

2. In addition to the restrictions now in force, the use of the scaphander should be prohibited in water deeper than 20 fathoms. This is intended primarily as a hygienic measure, to protect the divers from the evil results attending work in deep water, but it will also indirectly protect the workable beds by maintaining outside of them a possible reserve of spawning sponges to supply them with young.

3. Gangavas, dredges, trawls, and similar instruments for scraping the bottom should be prohibited in depths of less than 30 fathoms. This regulation, while not required by any present development of the fishery, will prevent the sudden unregulated development of a method which would undoubtedly be destructive to the inshore grounds.

4. State and federal laws should be enacted for the encouragement of sponge culture in both territorial and extraterritorial waters, securing to private individuals or corporations the sole use, under proper restrictions, of suitable areas of the bottom for the purpose of raising sponges by artificial means. In case of further depletion of the natural beds, or with the growth of demand and the failure to discover new and more productive grounds, sponge culture offers the only possible means of prevention of a practical sponge famine. With the development of sponge fields in other parts of the world which would be serious competitors with the depleted beds of Florida, the practice of an economic system of sponge culture is the only means which would prevent the extermination of the lucrative sponge business of the state.

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Plate XXX

Rock Island sheepswool sponge. Natural size.

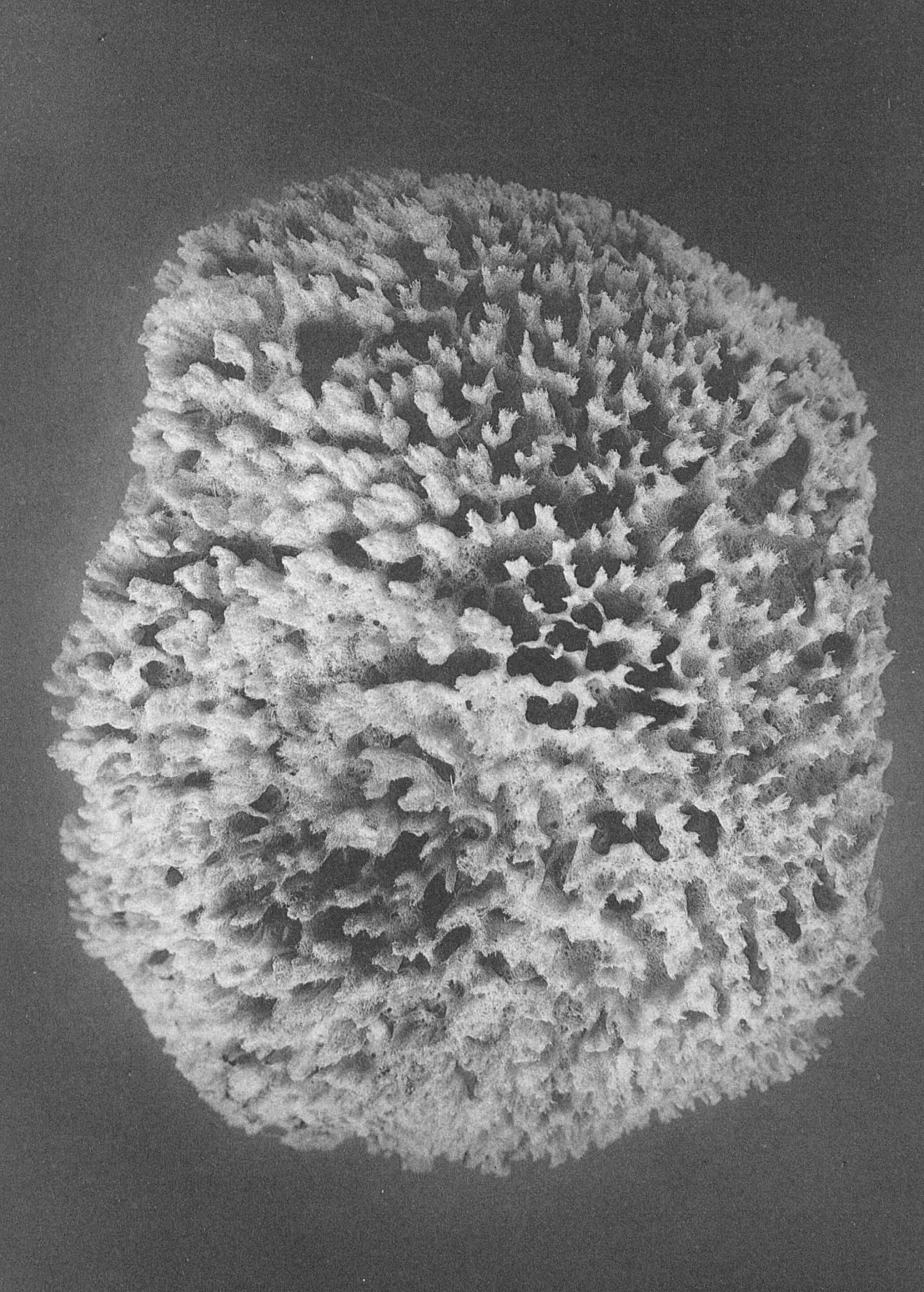


Plate XXXI

Rock Island sheepswool sponge, top view. Three-fourths natural size.

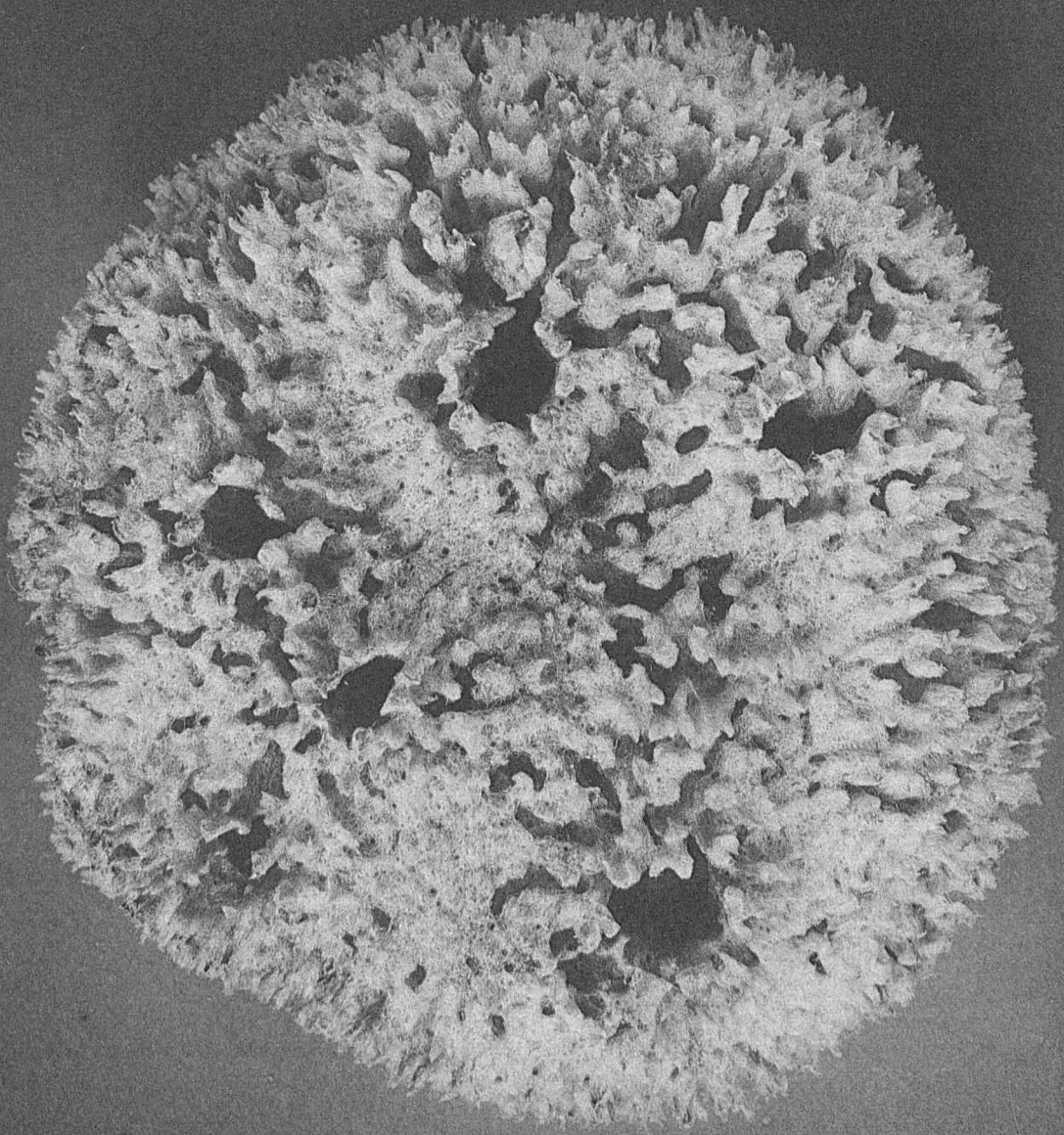


Plate XXXII

Florida Key sheepswool sponge. Natural size.

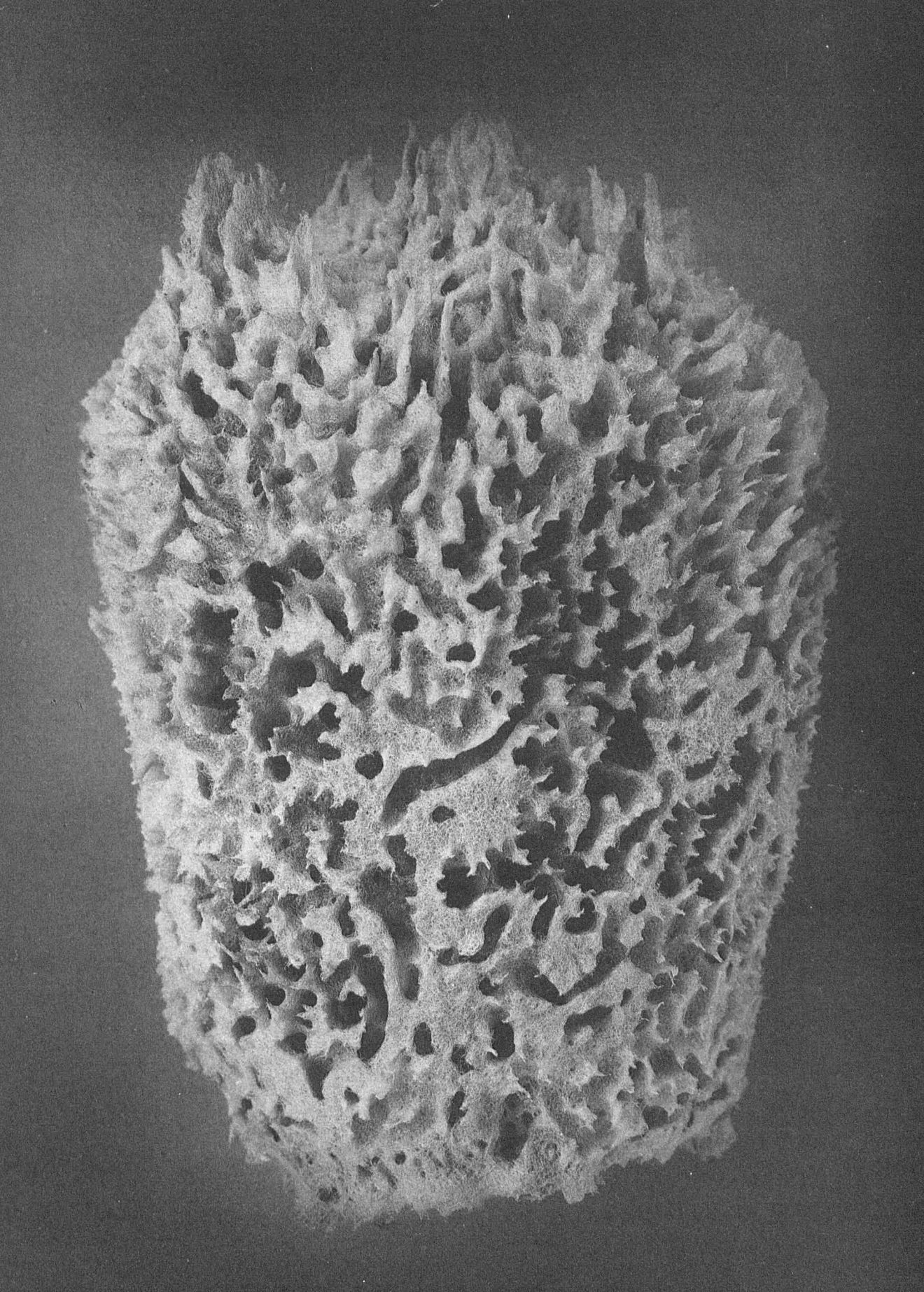


Plate XXXIII

Matecumbe Key sheepswool sponge. Natural size.

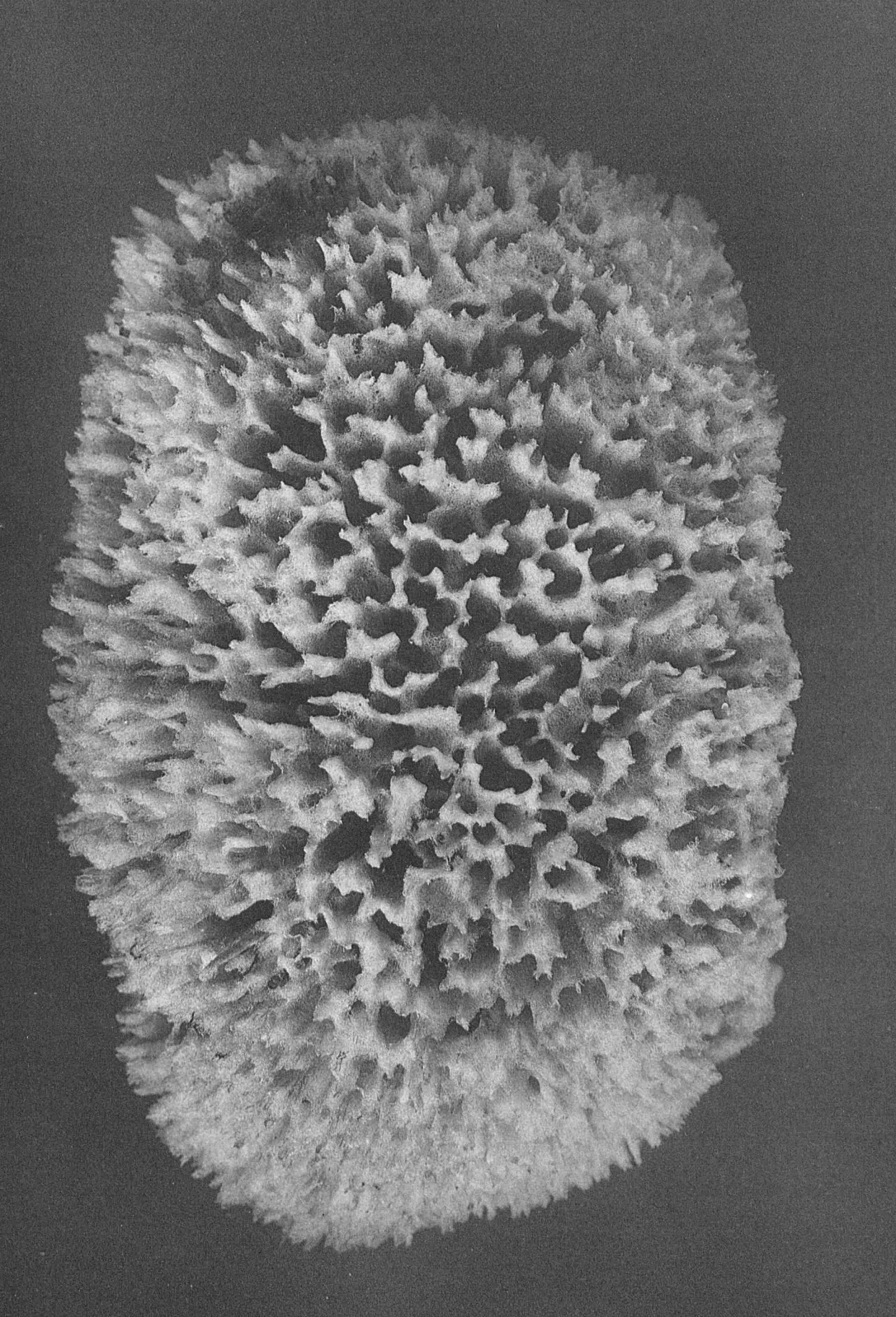


Plate XXXIV

Nassau sheepswool sponge, Bahama Islands. Natural size.

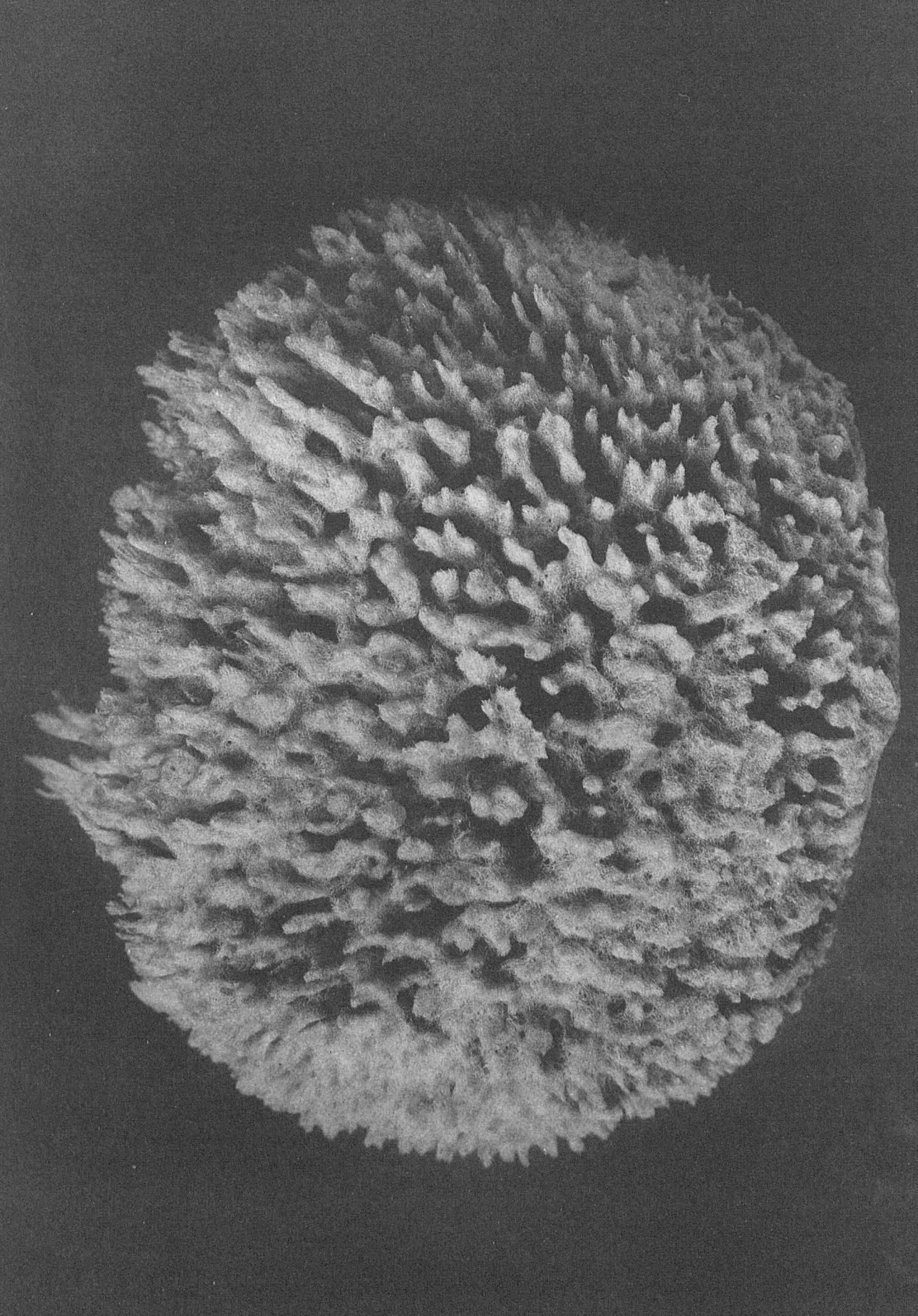


Plate XXXV

Abaco sheepswool sponge, Bahama Islands. Natural size.

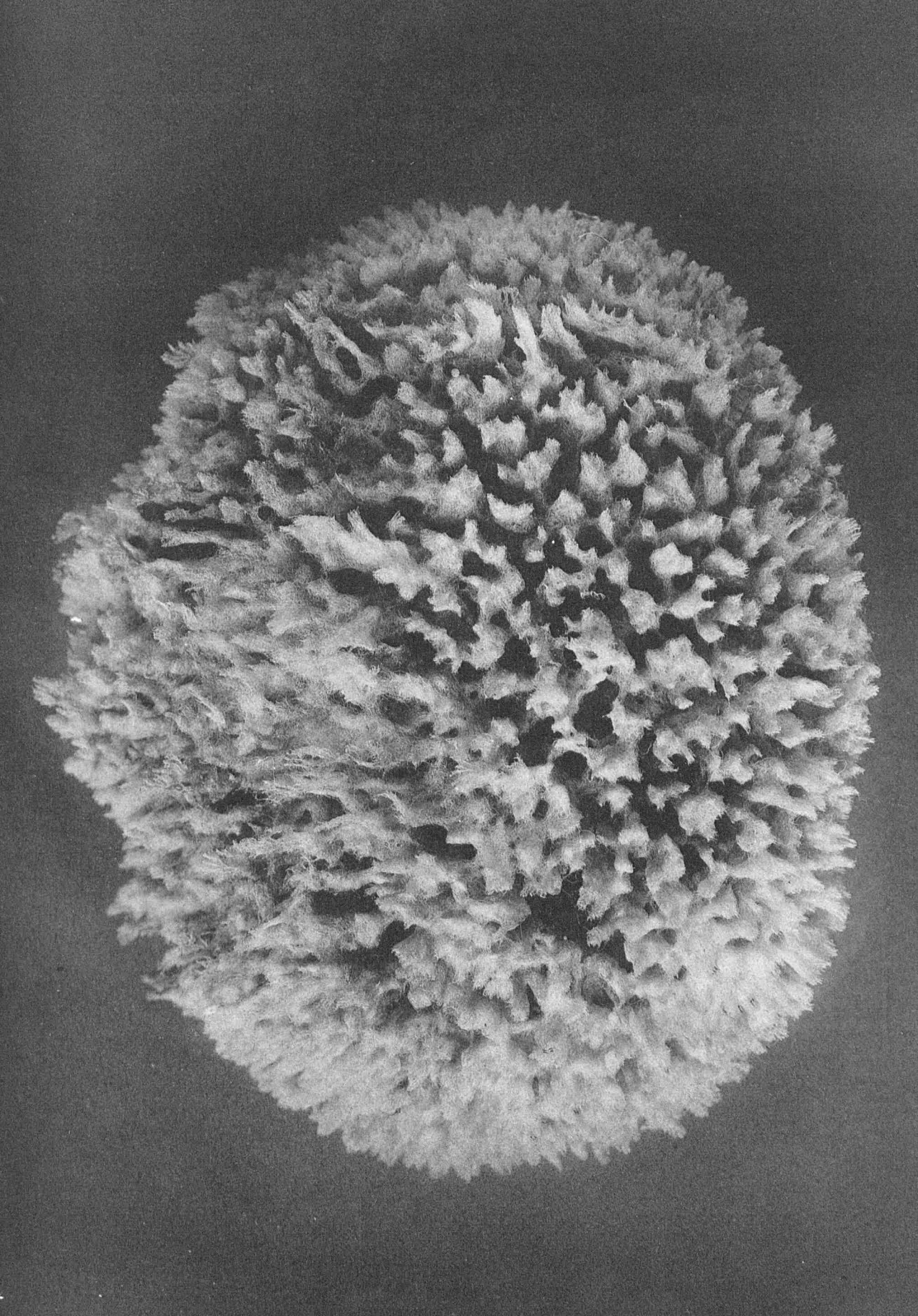


Plate XXXVI

Cuba sheepswool sponge. Natural size.

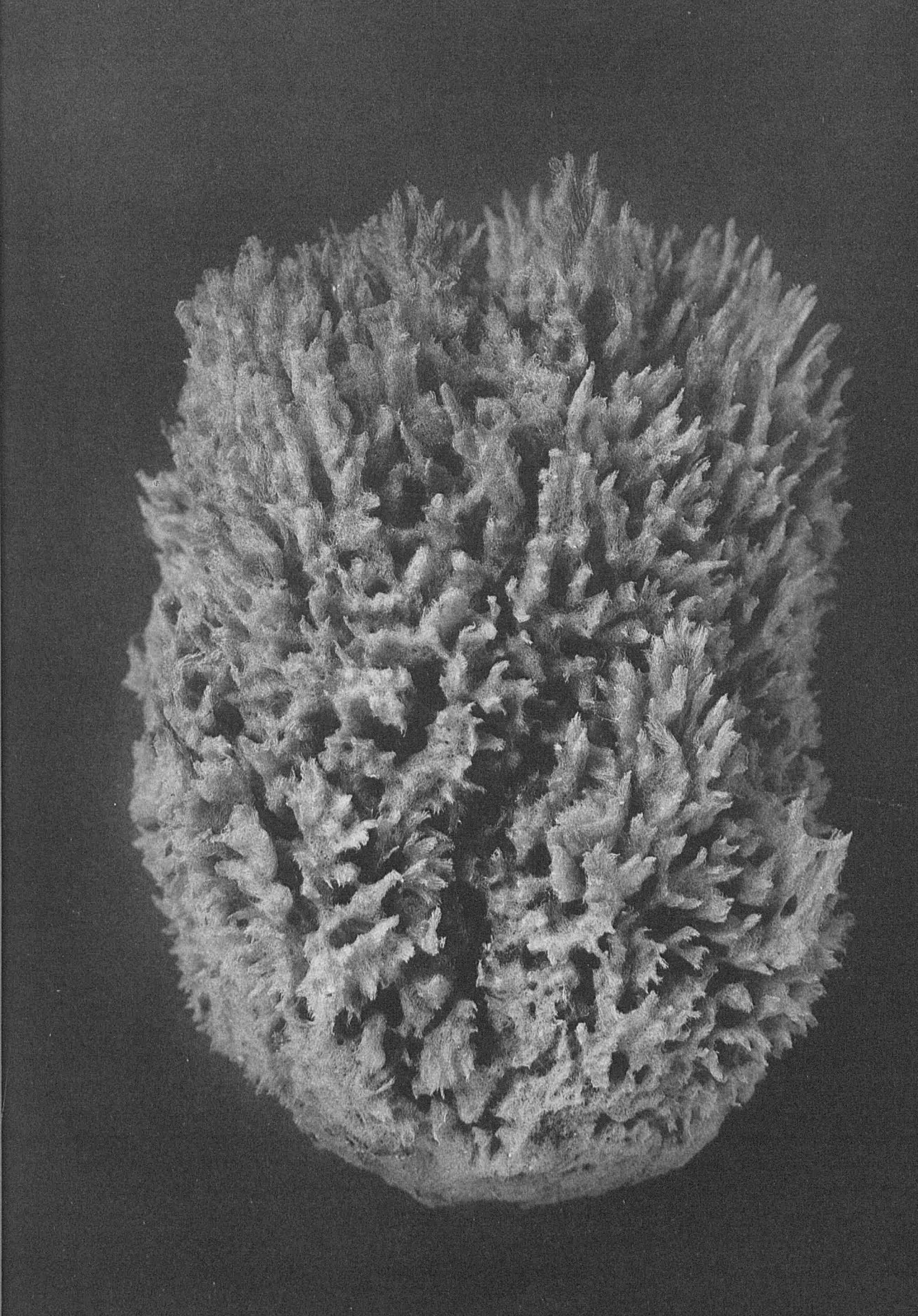


Plate XXXVII

Florida Key yellow sponge. Natural size.

Plate XXXVIII

Florida Key yellow sponge, top view. Natural size.

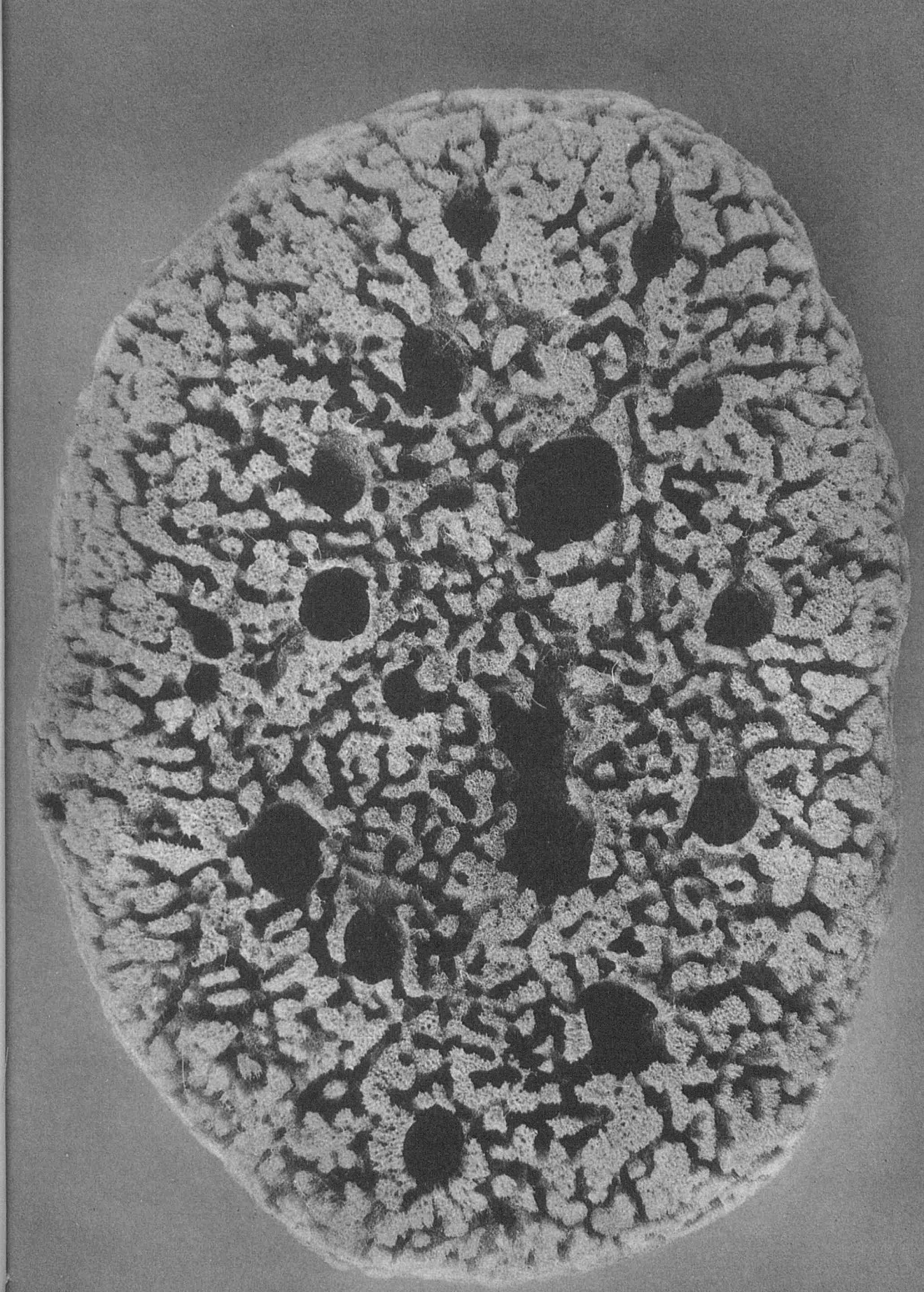


Plate XXXIX

Florida Key yellow sponge. Natural size.

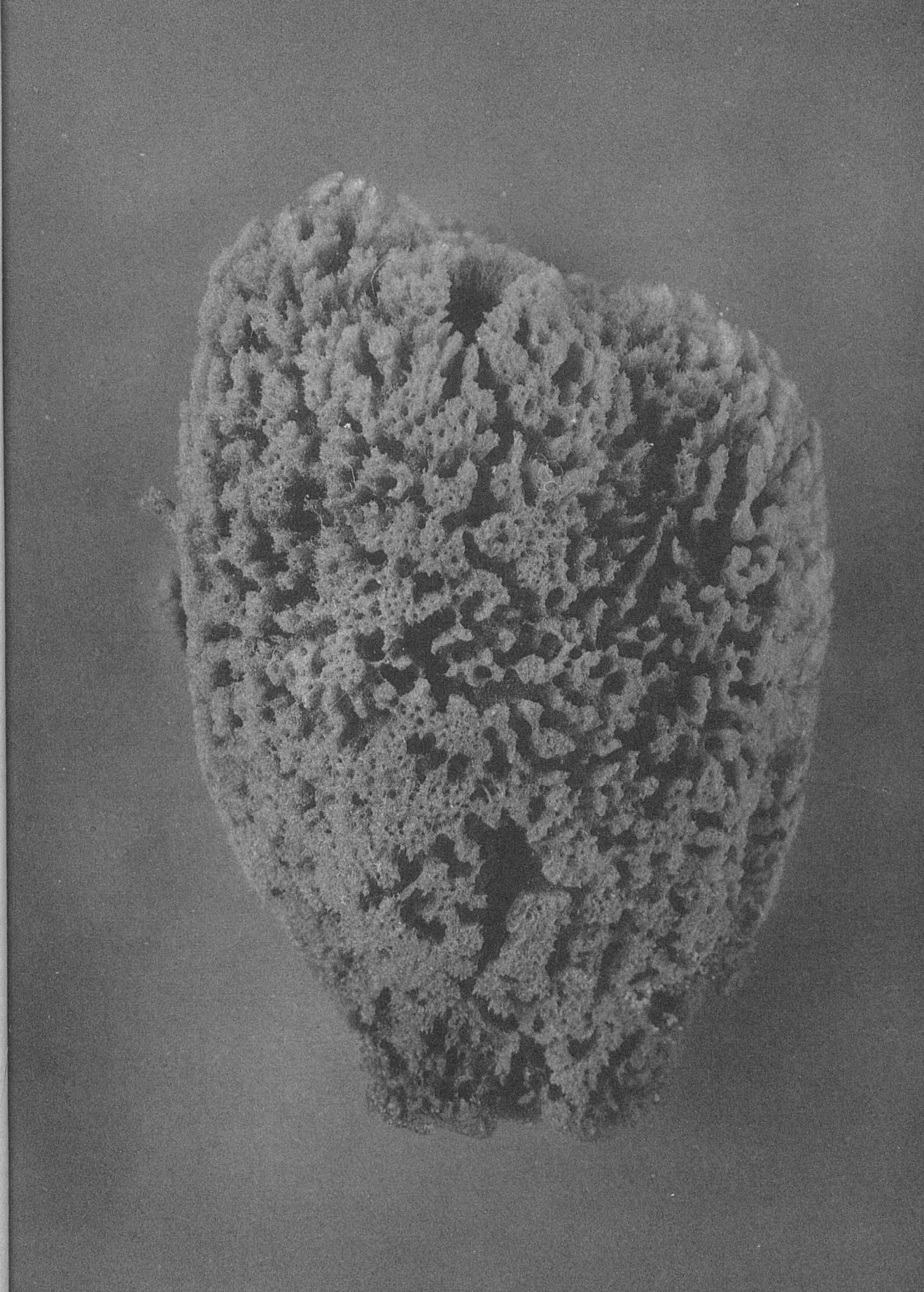


Plate XL

Anclote yellow sponge. Natural size.

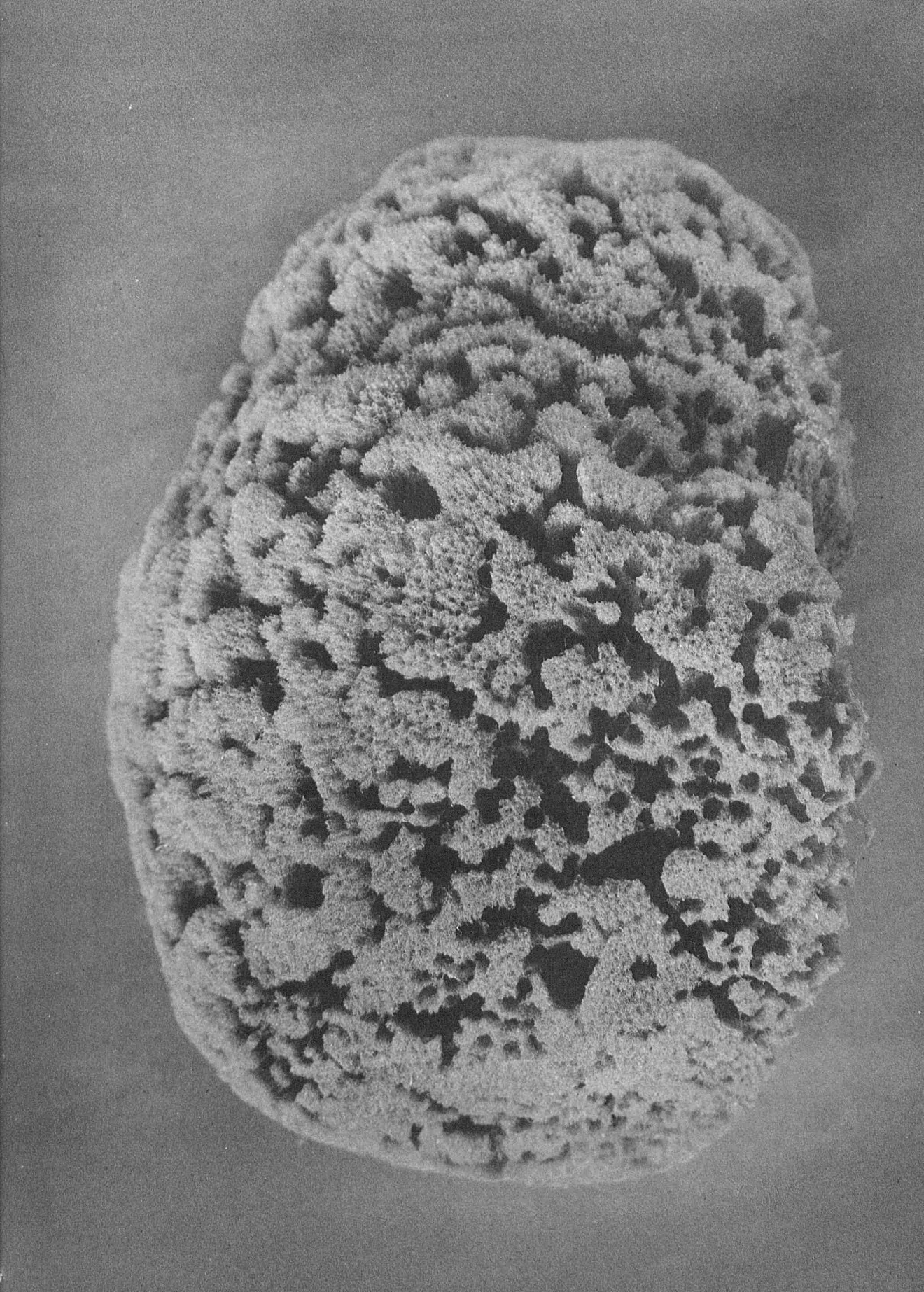


Plate XLI

Anclote yellow sponge. Natural size.

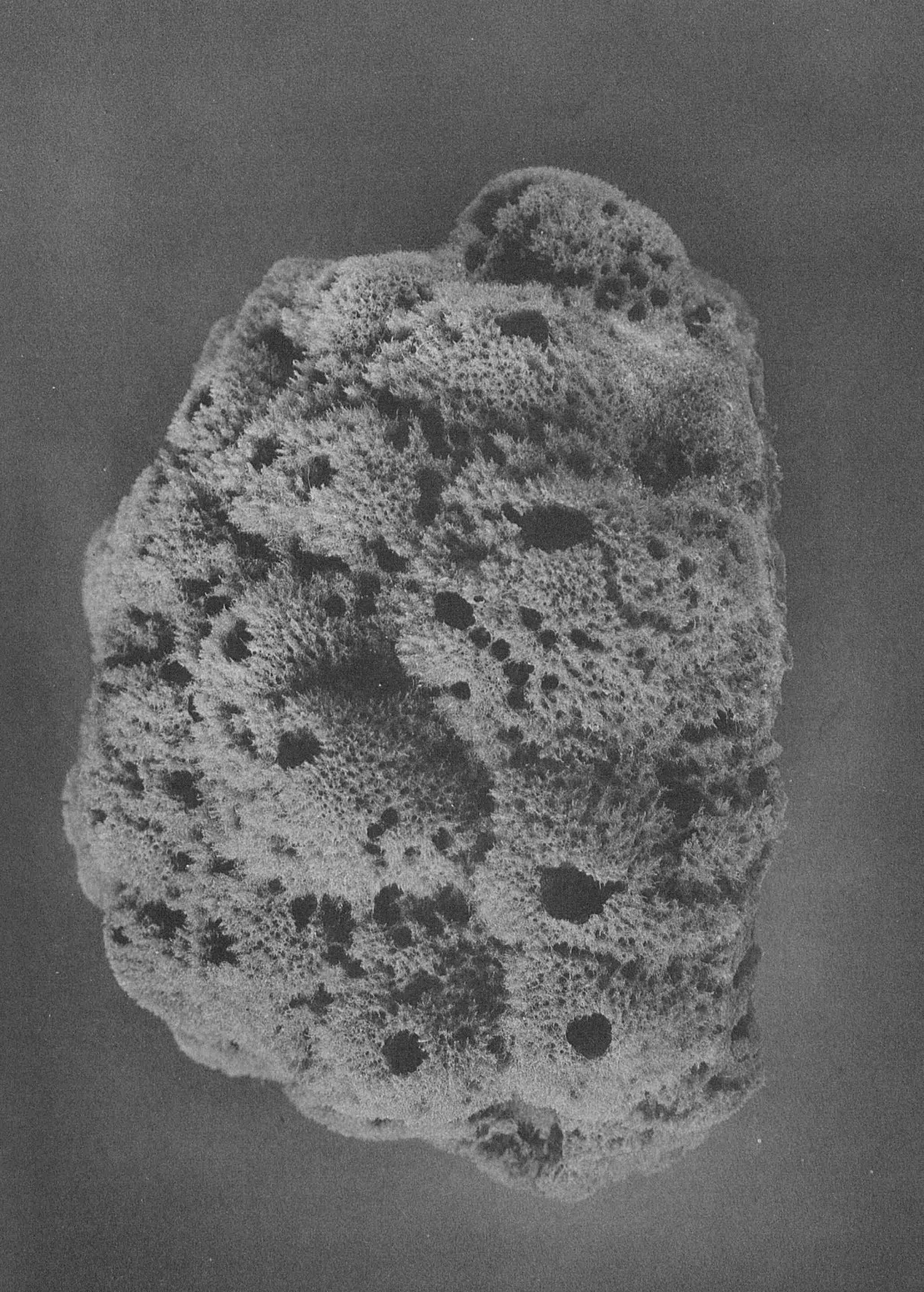


Plate XLII

Bahama yellow sponge. Natural size.

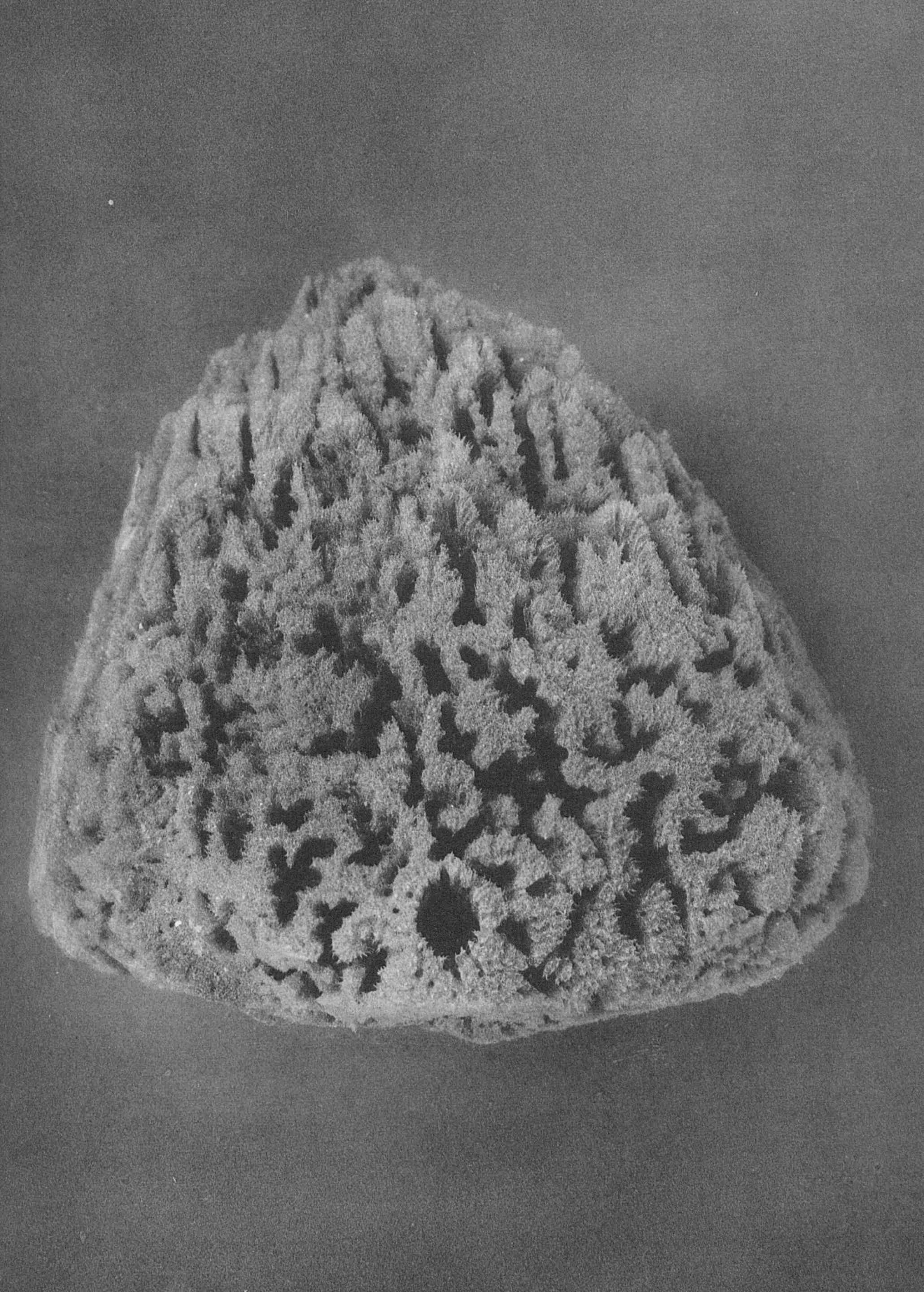


Plate XLIII

Bahama yellow sponge. Natural size.

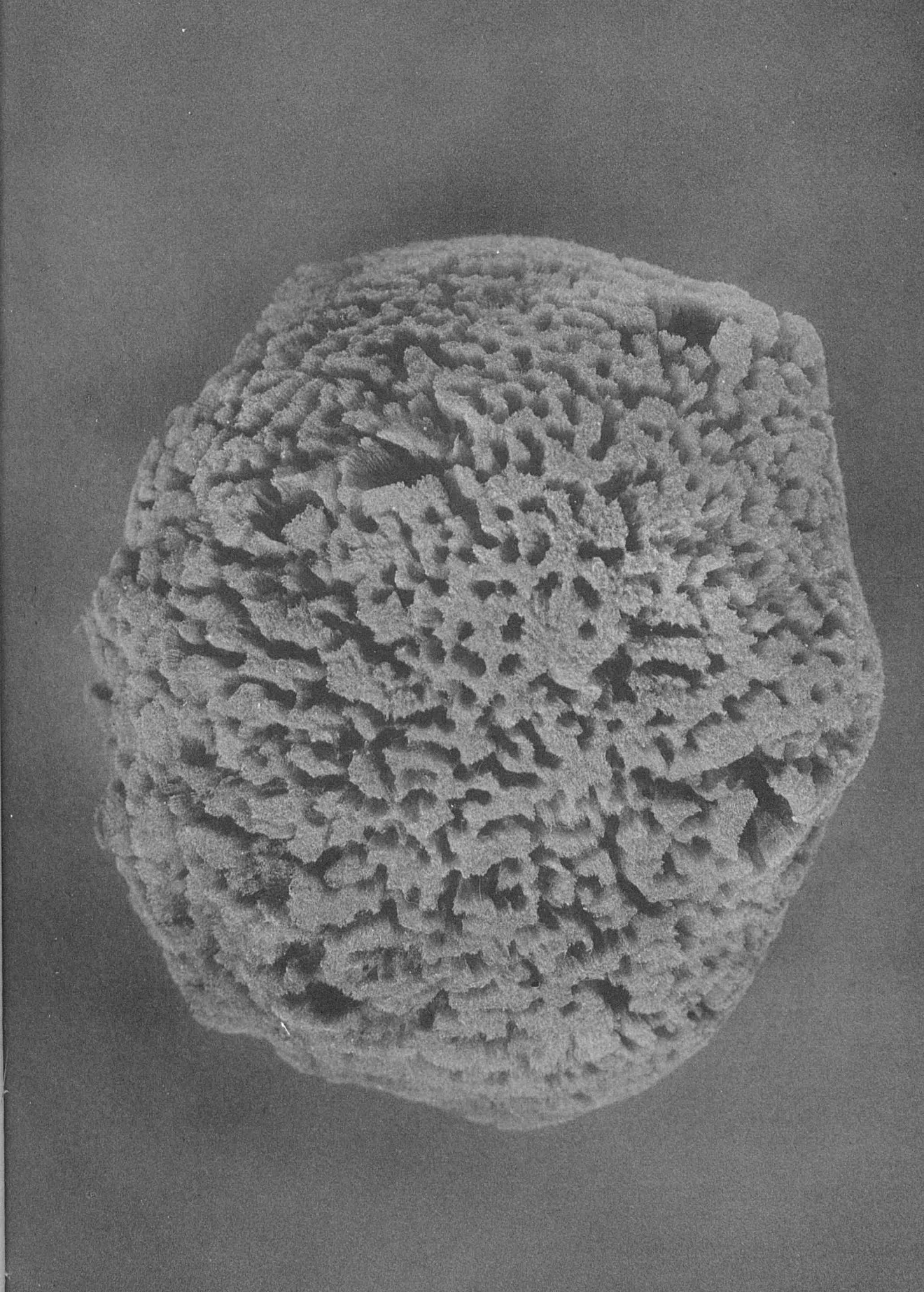


Plate XLIV

Cuba yellow sponge. Natural size.

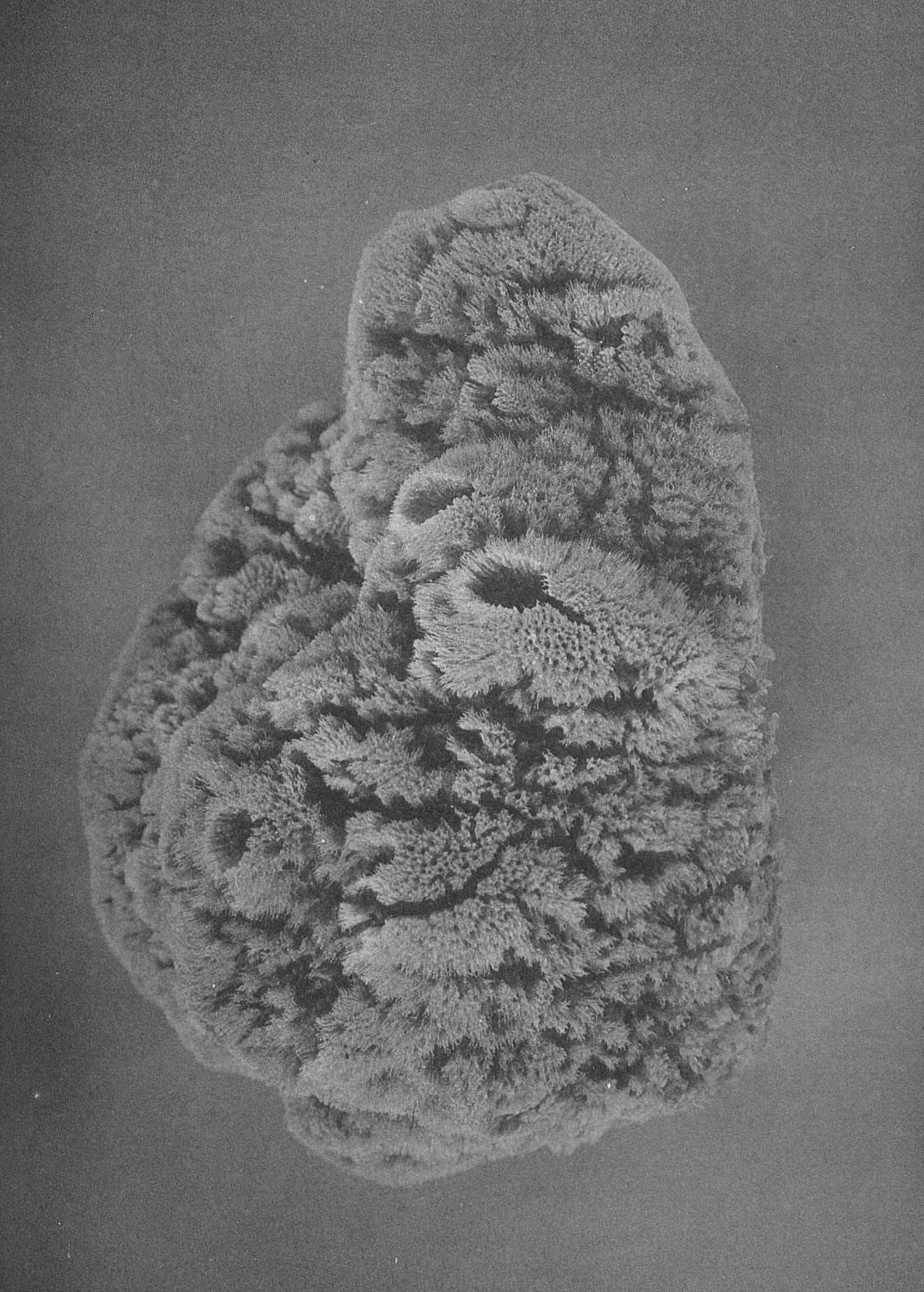


Plate XLV

Florida velvet sponge, top view. Natural size.

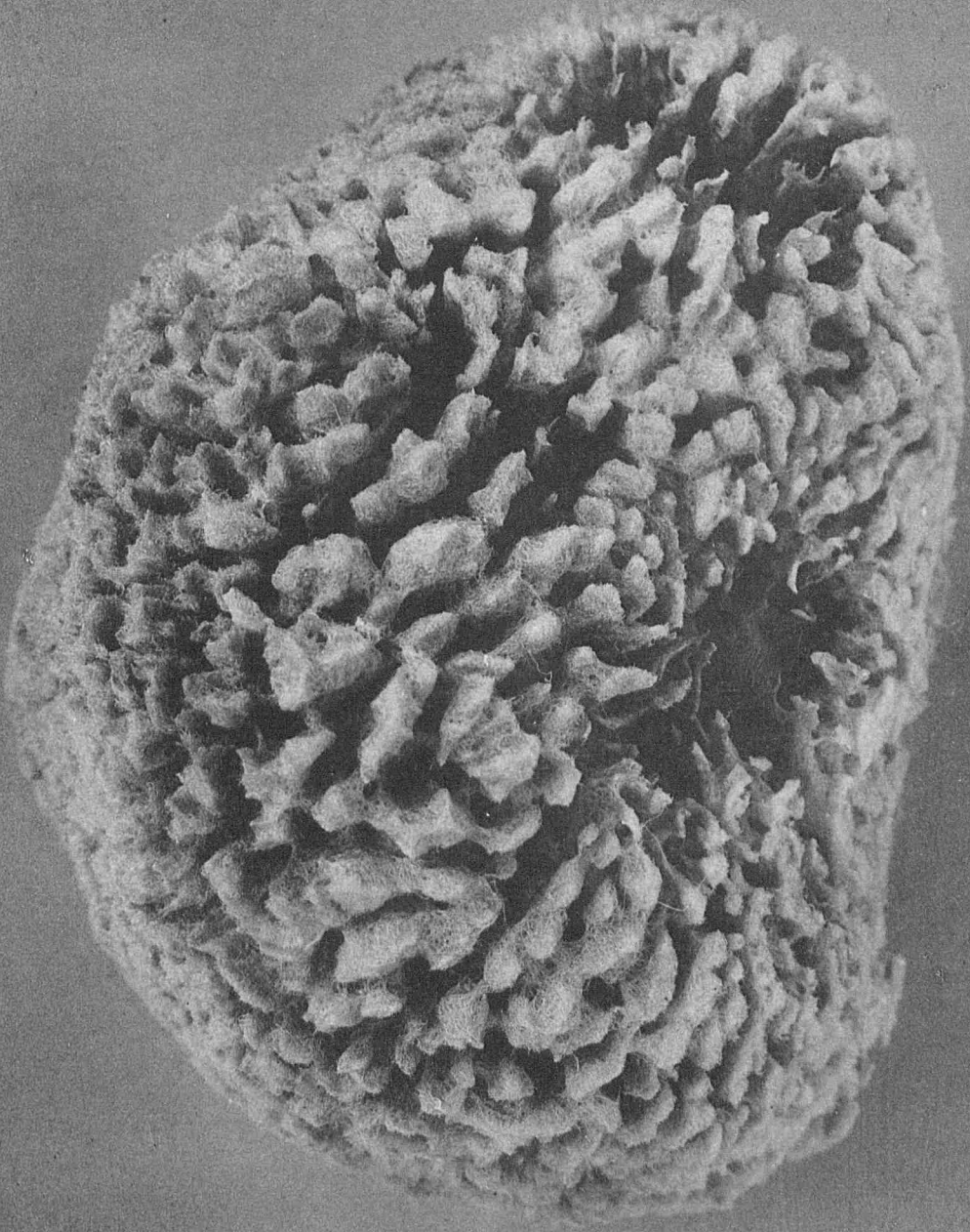


Plate XLVI

Bahama velvet sponge. Natural size.

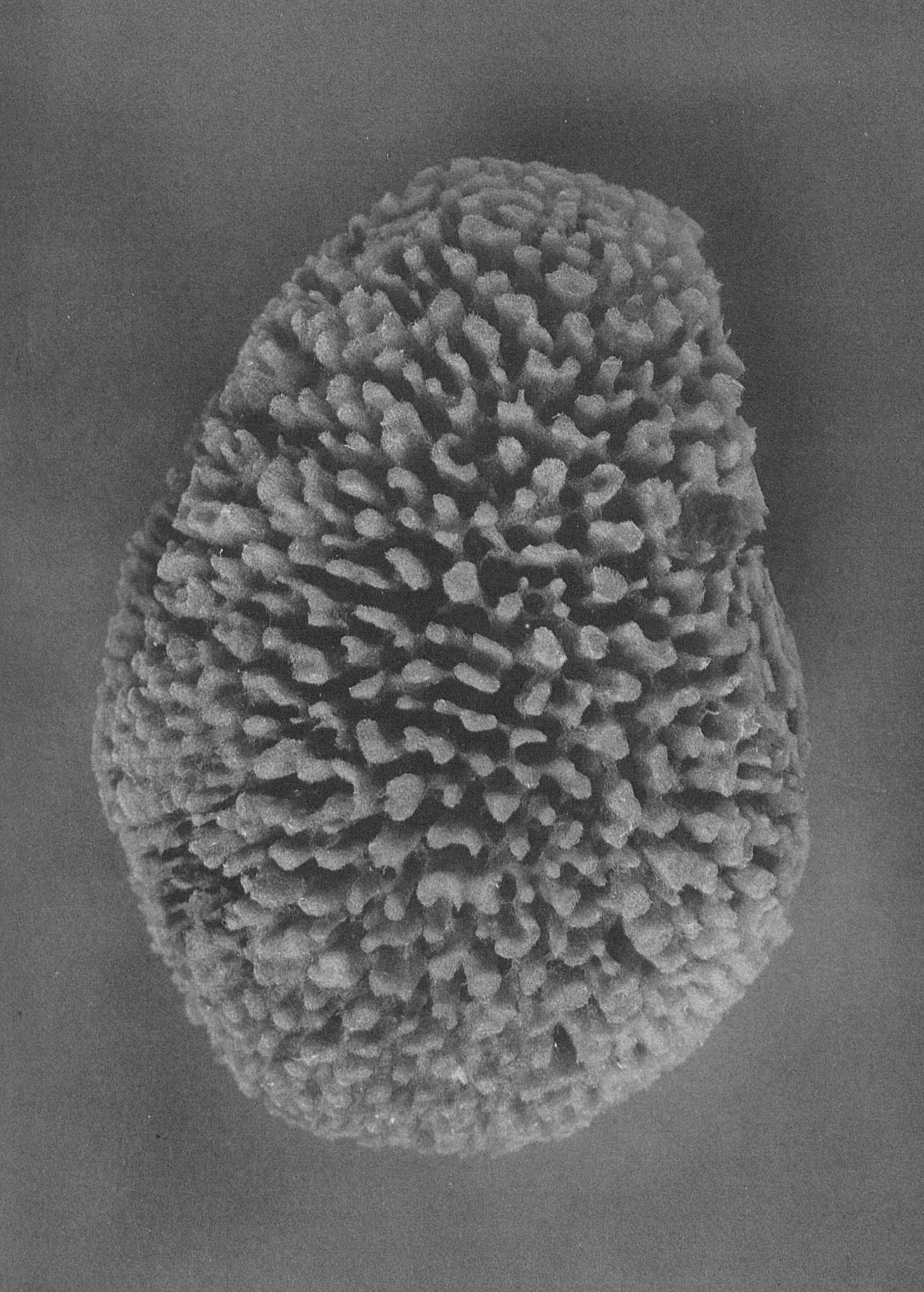


Plate XLVII

Cuba velvet sponge. Natural size.

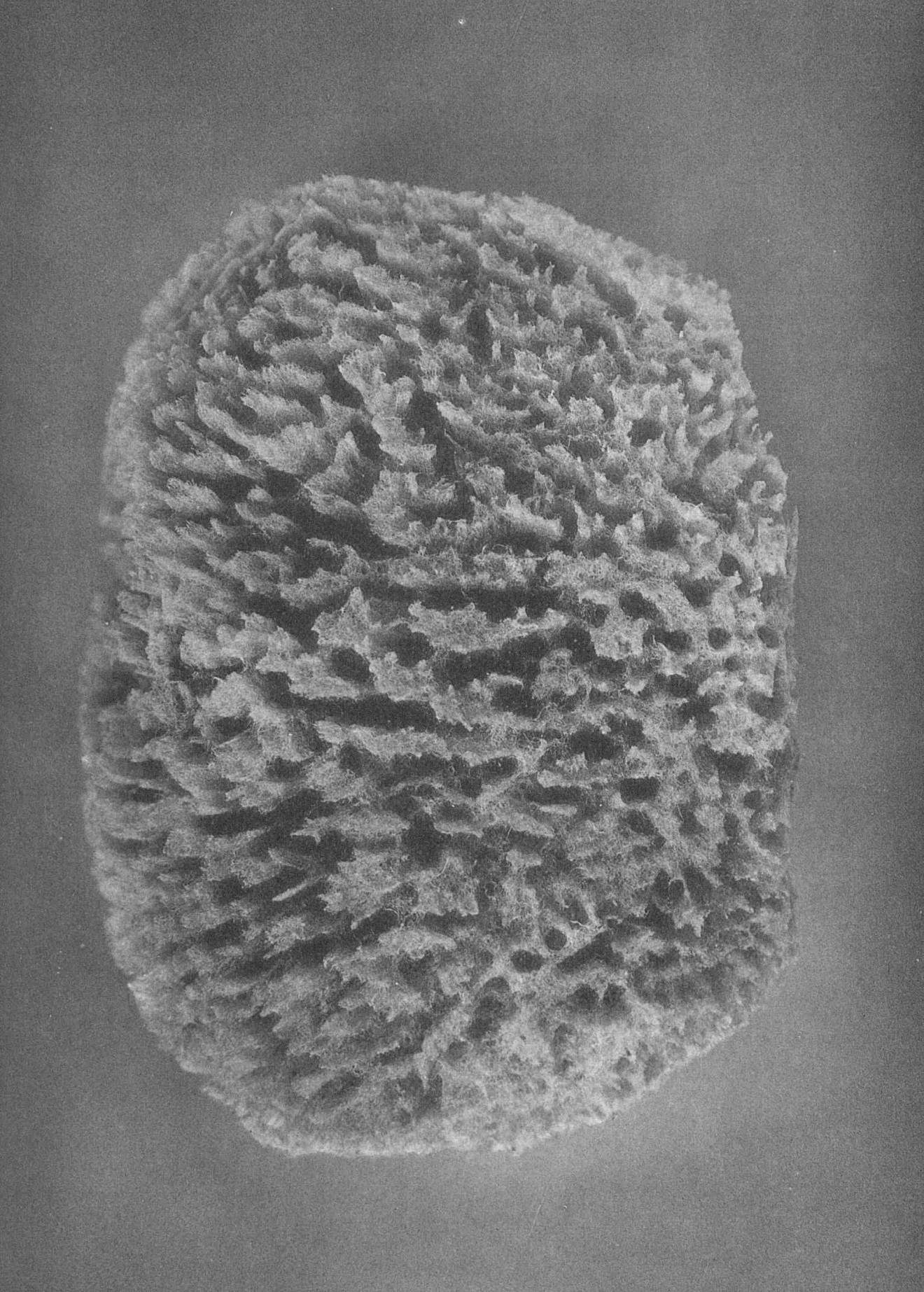


Plate XLVIII

Anclote grass sponge. Natural size.

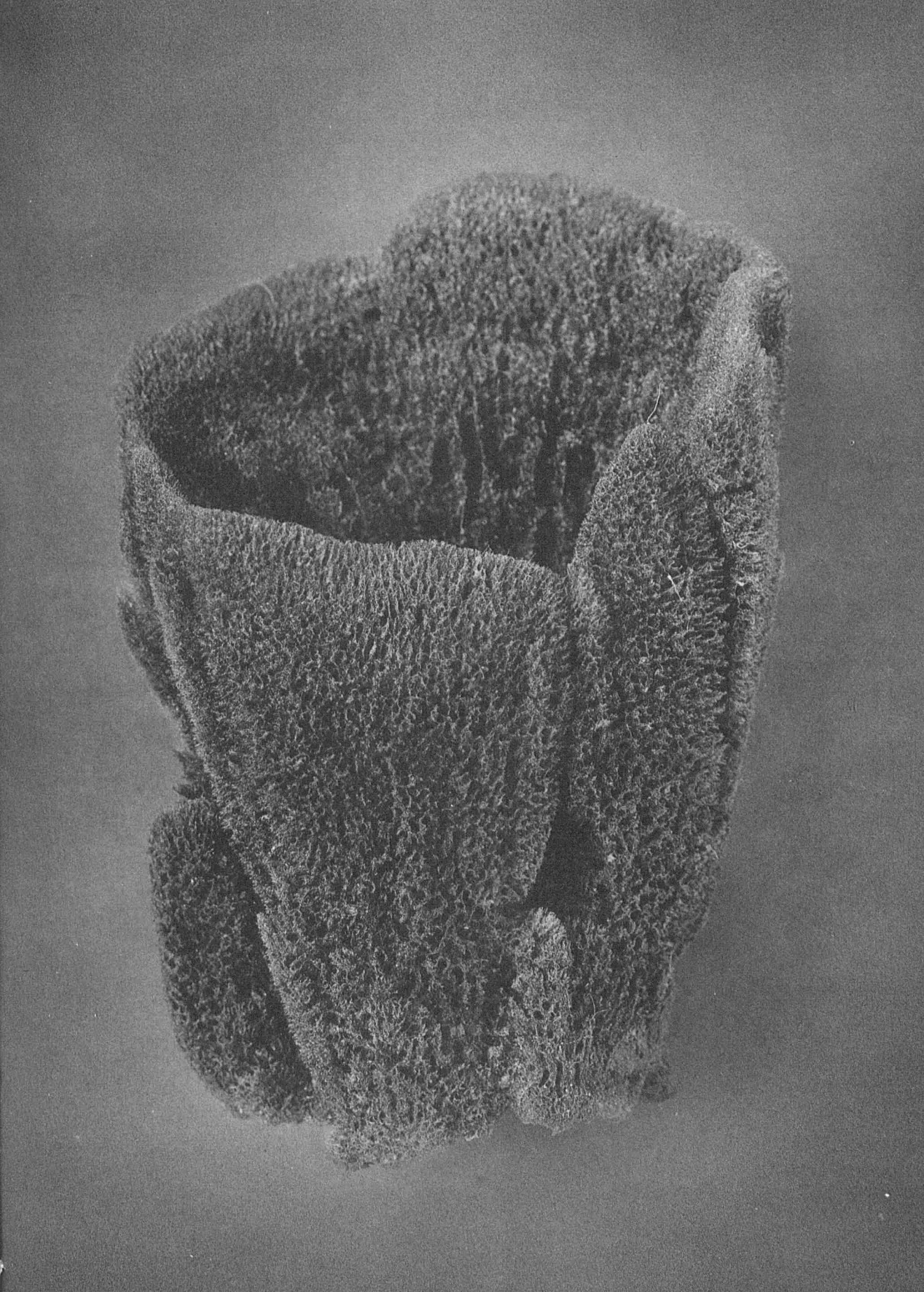


Plate XLIX

Florida Key grass sponge. Natural size.

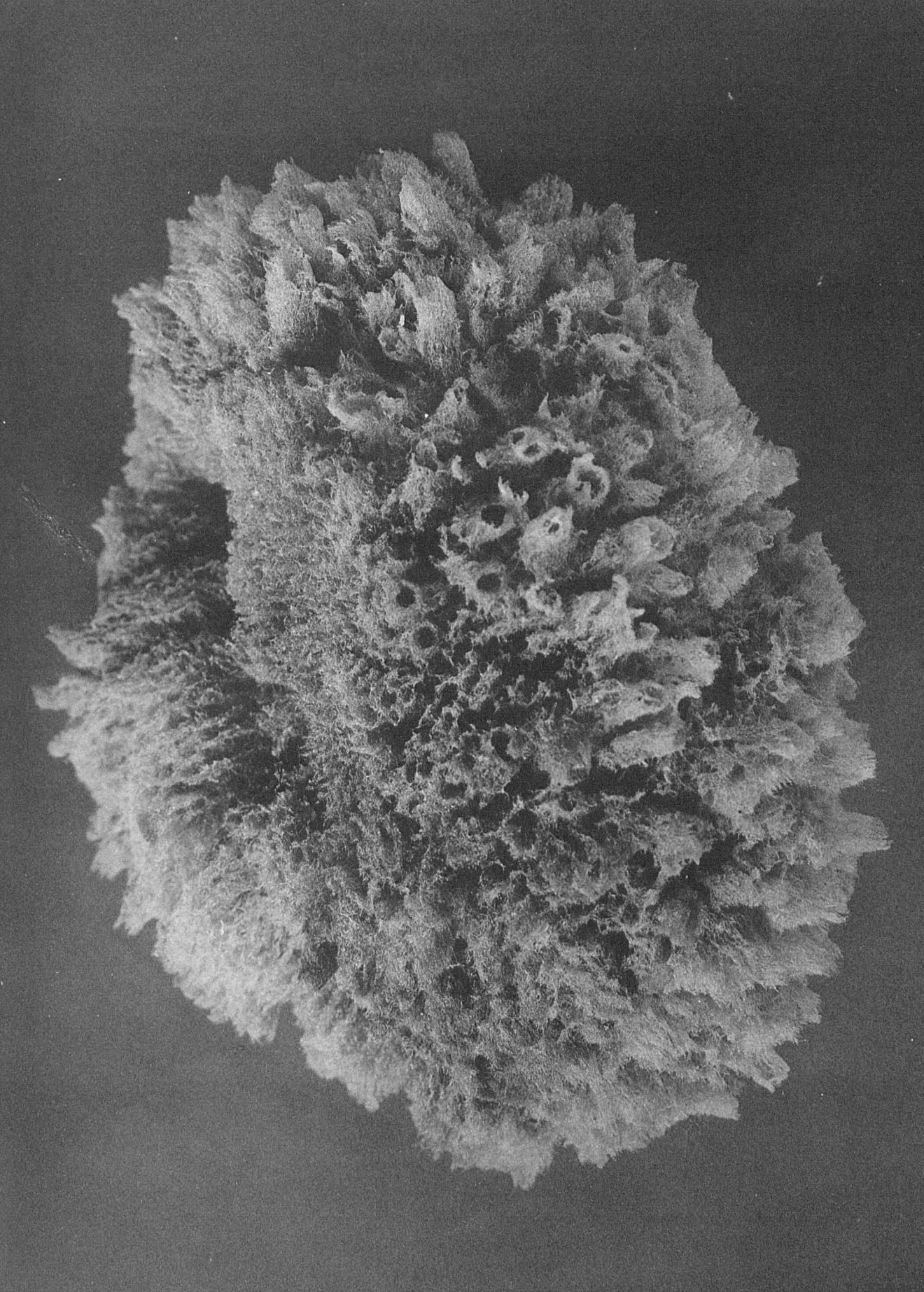


Plate L

Florida Key grass sponge. Natural size.

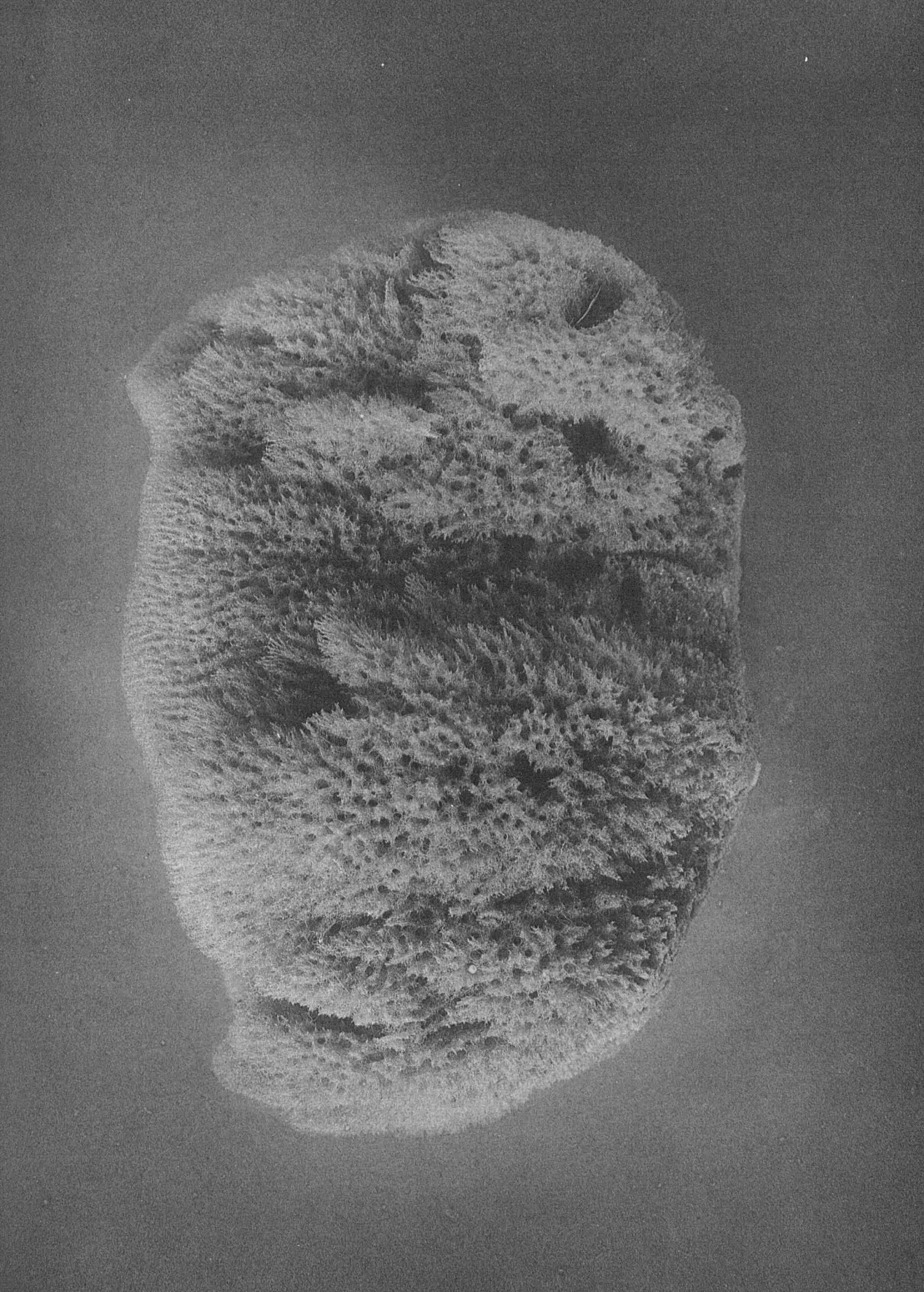


Plate LI

Florida Key grass sponge, top view. Natural size.

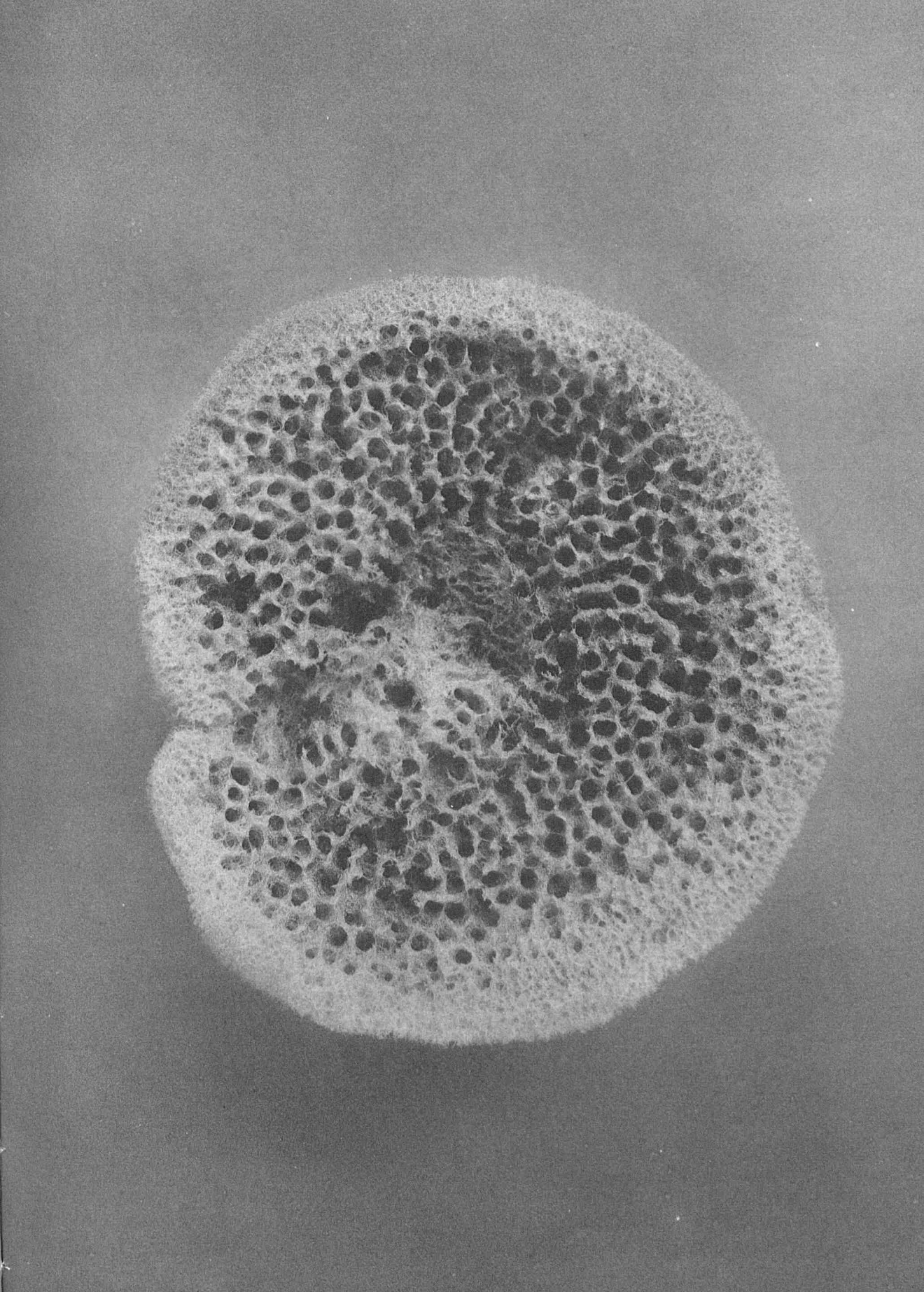


Plate LII

Bahama grass sponges. Natural size.

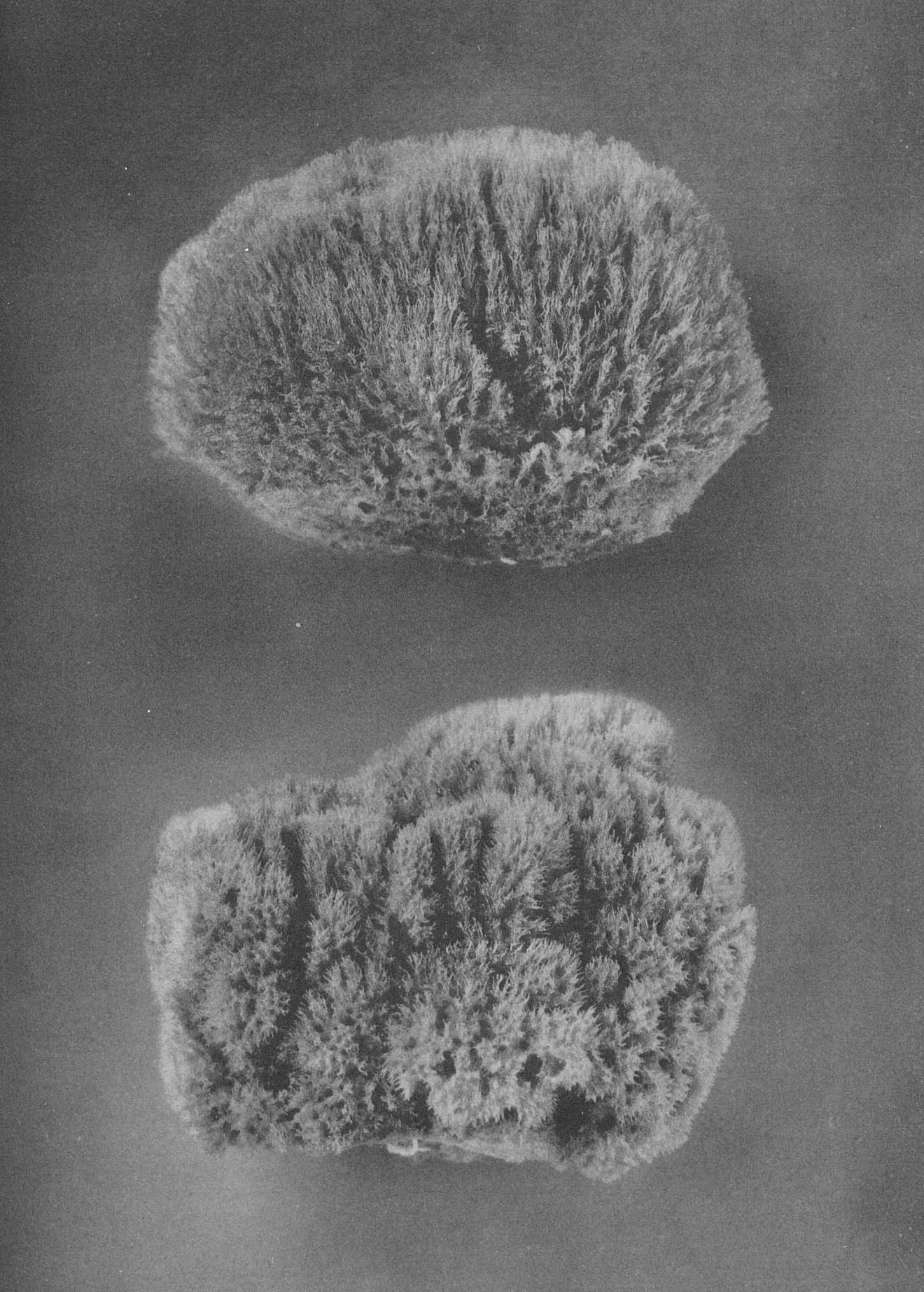


Plate LIII

Cuba grass sponges. Natural size.

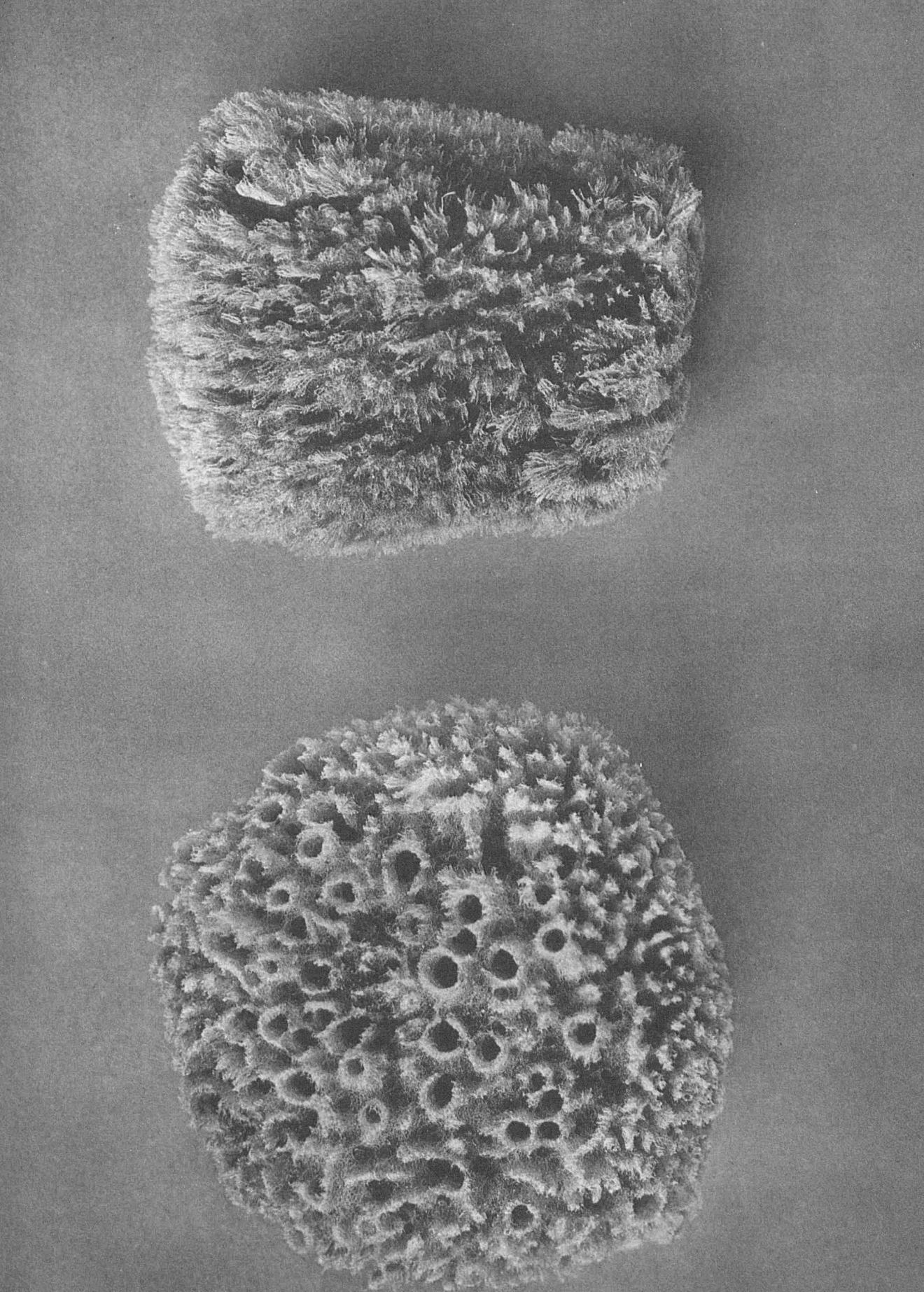


Plate LIV

Florida glove sponge. Natural size.

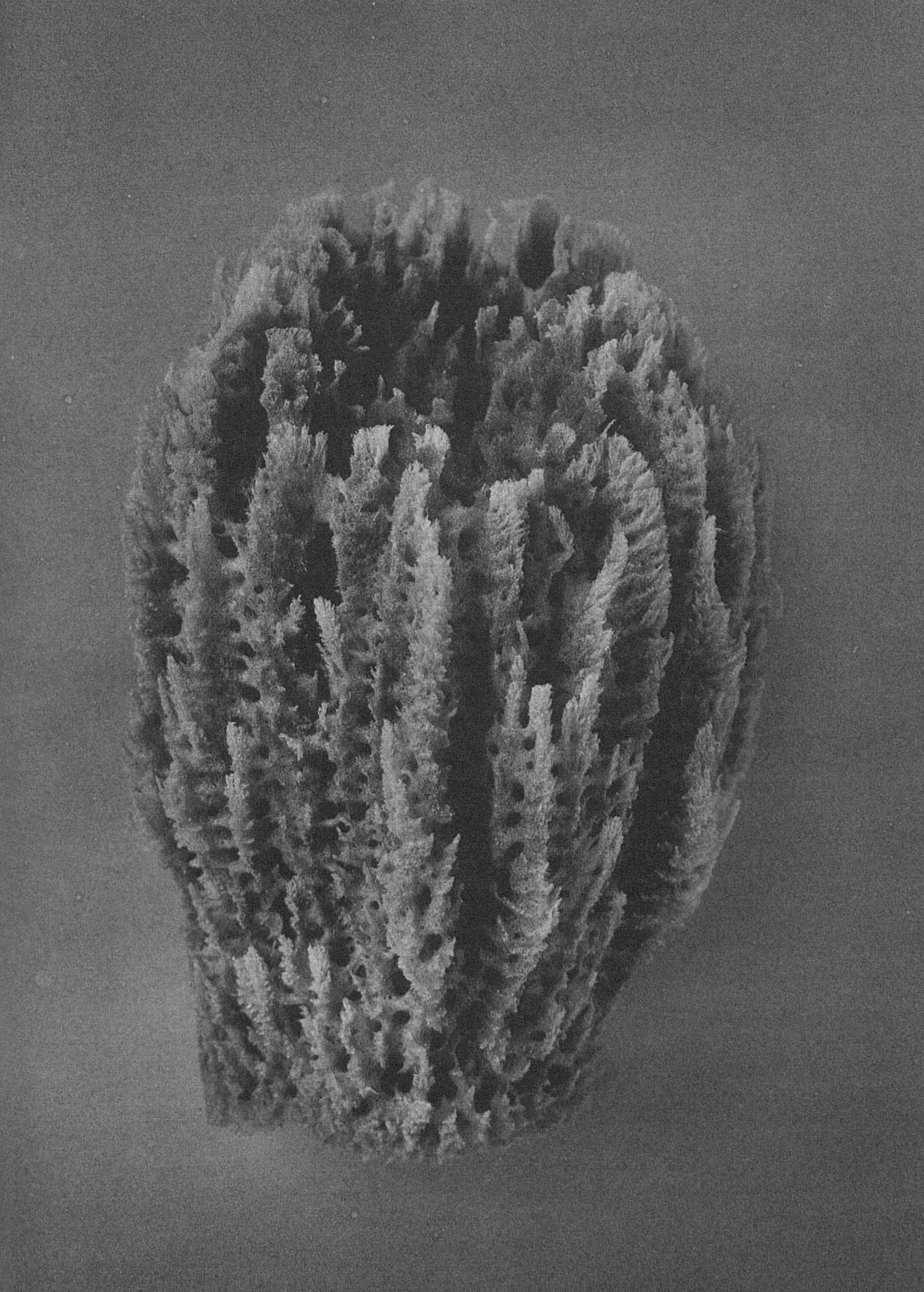


Plate LV

Cuba reef sponge. Natural size.

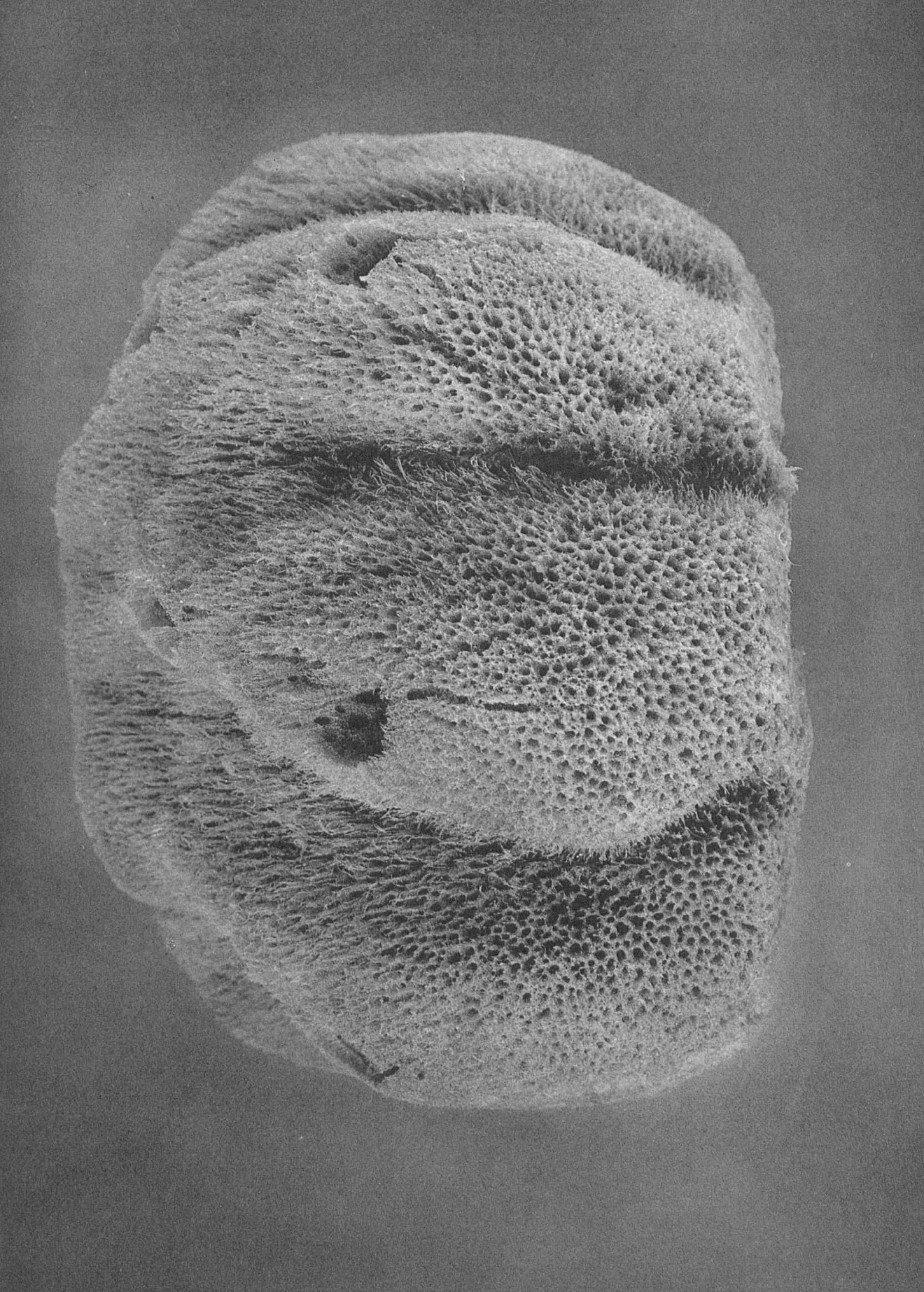


Plate LVI

Fig. 1.—Bahama reef sponge, side view. Natural size.

Fig. 2.—Bahama reef sponge, top view. Natural size.

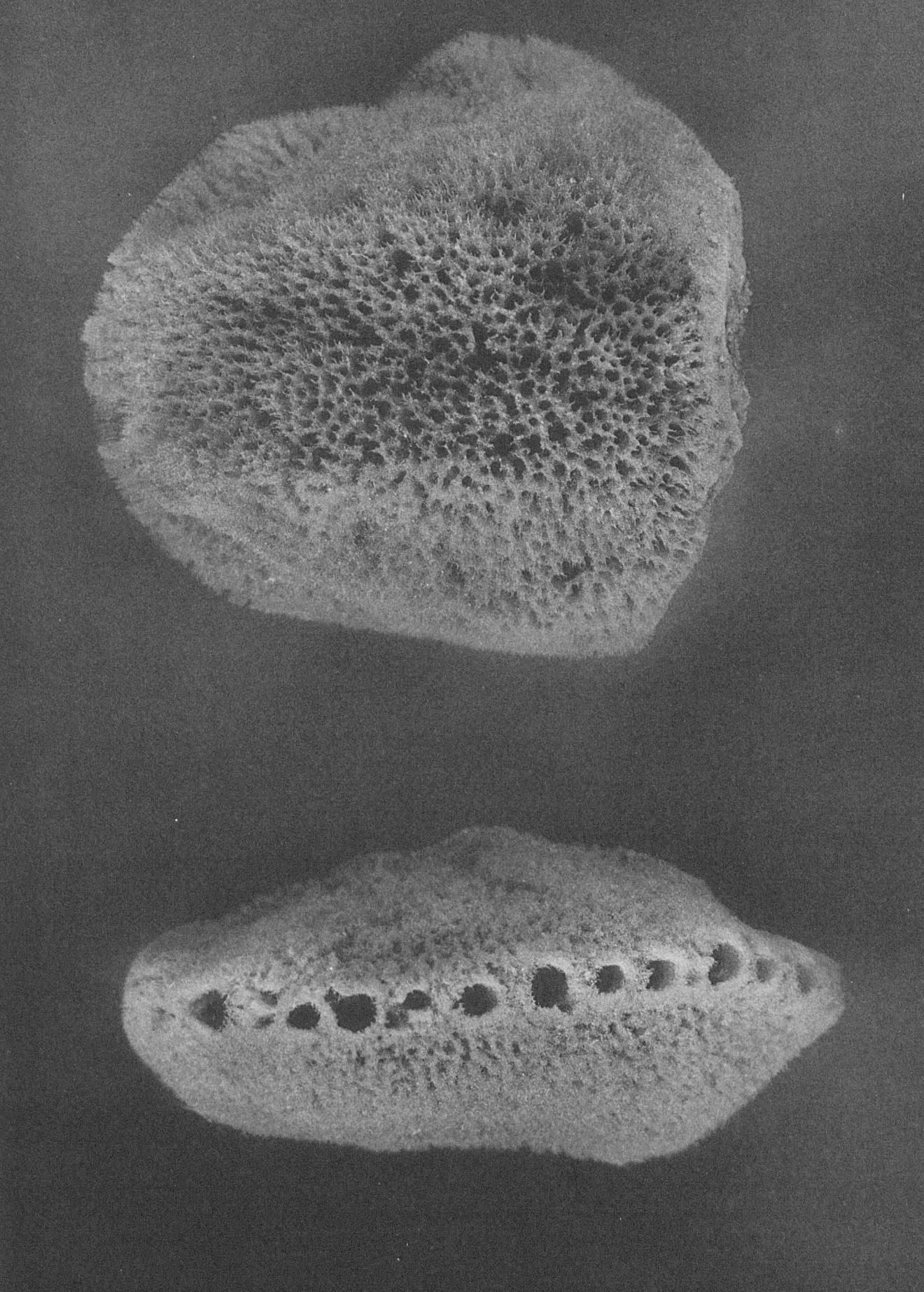


Plate LVII

Cuba hardhead sponges. Natural size.

Plate LVIII

Florida wire sponge. Natural size.

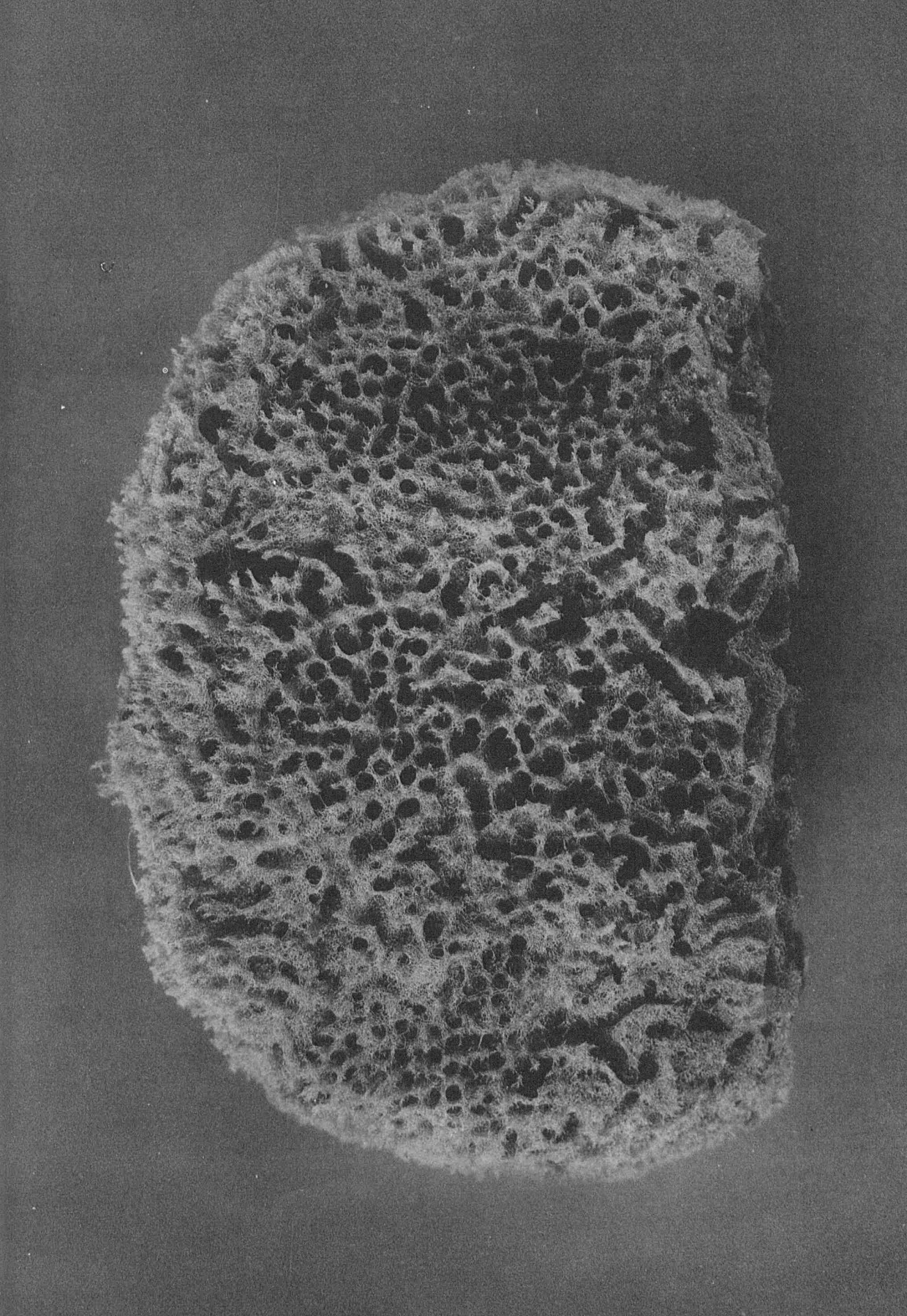


Plate LIX

Florida wire sponge, top view. Natural size.

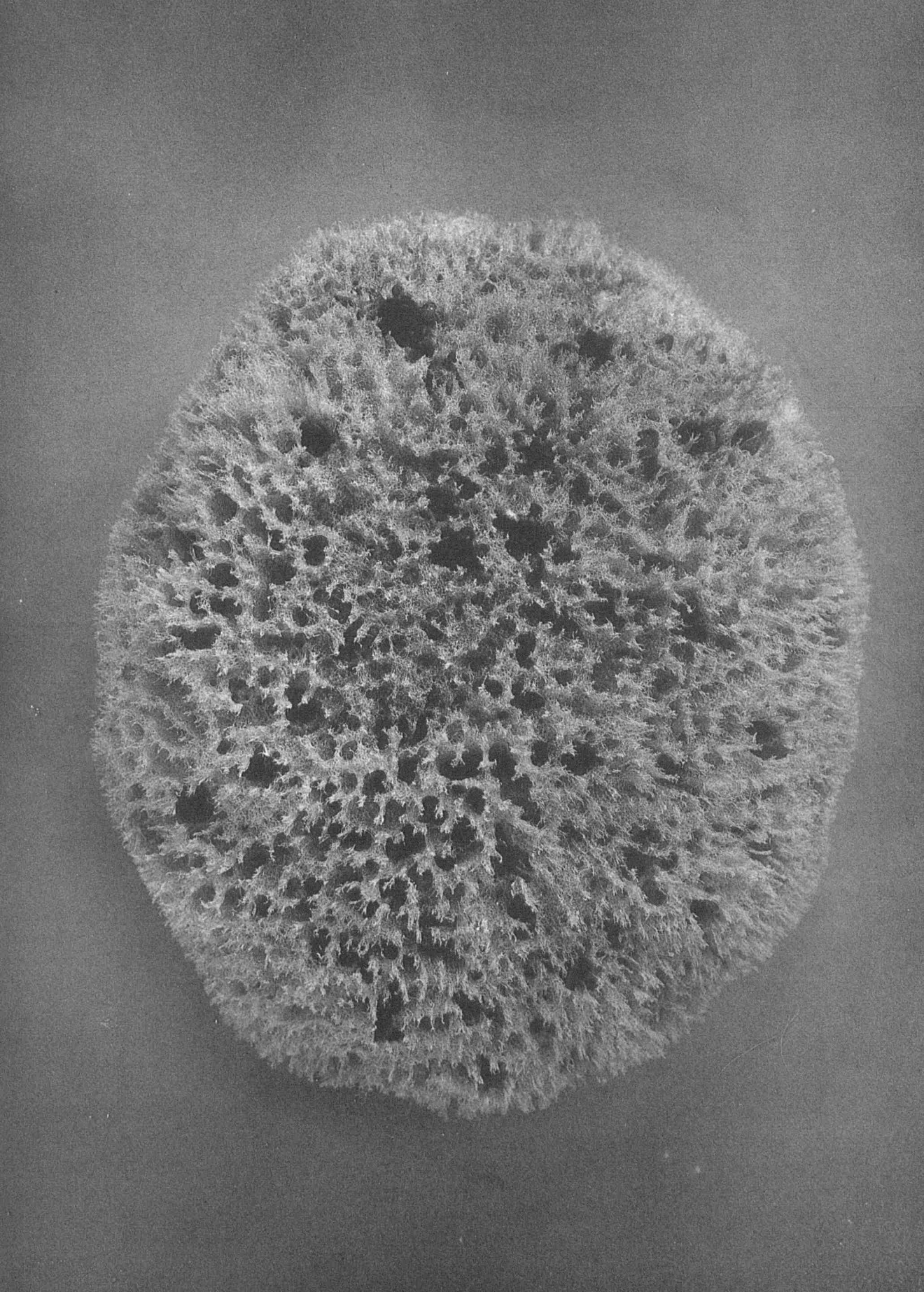


Plate LX

Turkey cup sponges, Mediterranean Sea. Natural size.

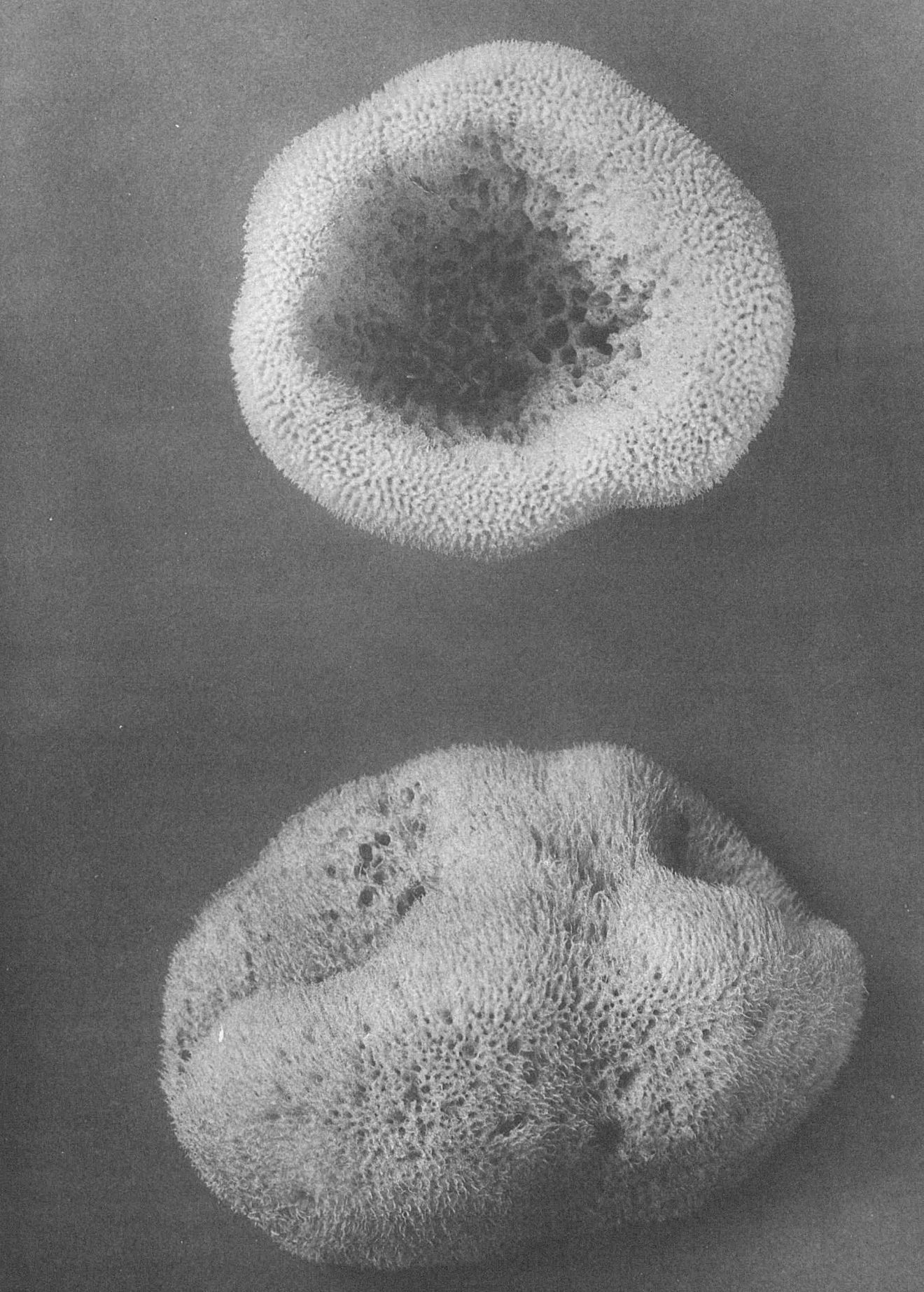


Plate LXI

Fig. 1.—Turkey solid sponge, Mediterranean Sea. Natural size.

Fig. 2.—Toilet sponge, Mediterranean Sea. Natural size.

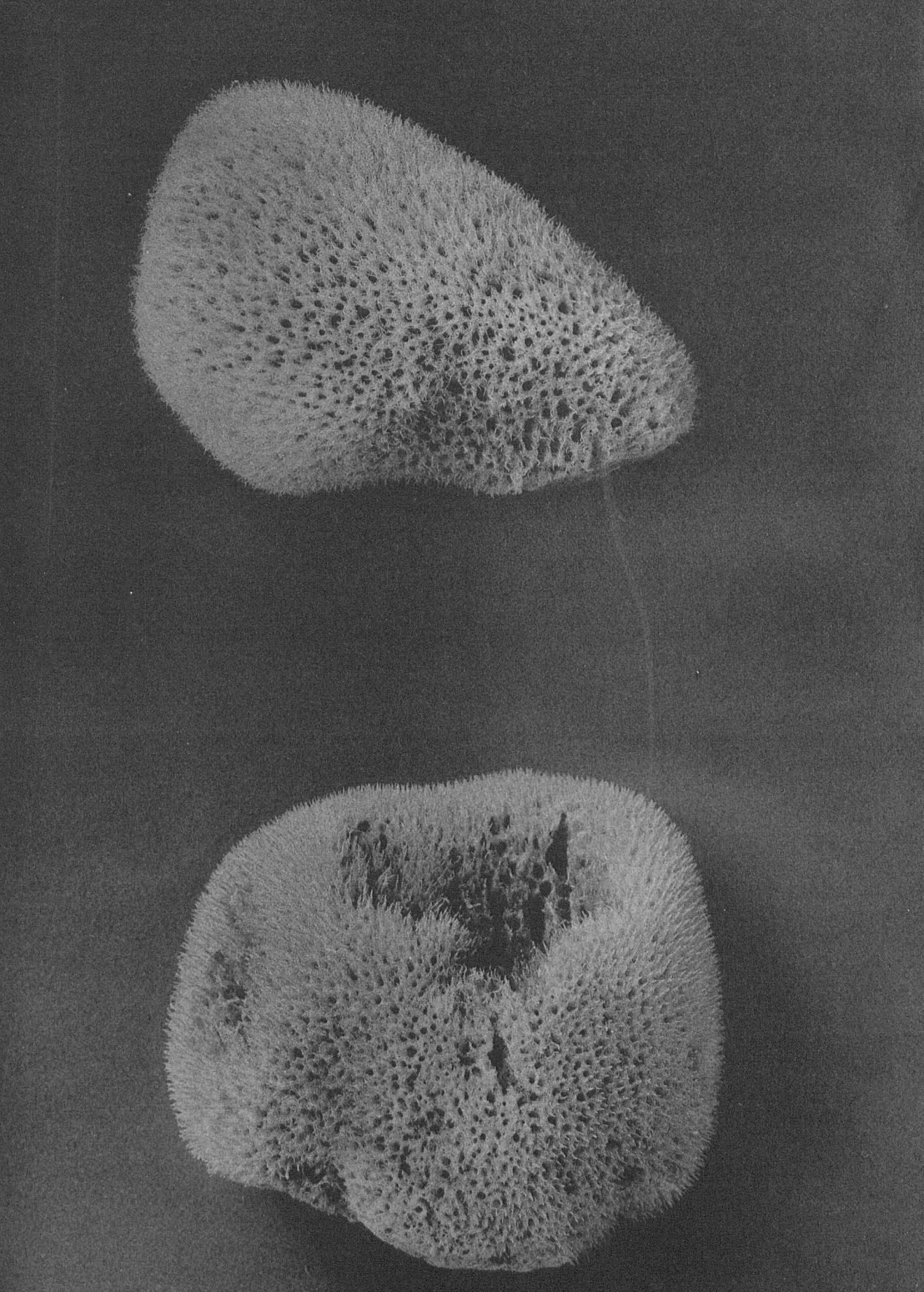


Plate LXII

Toilet sponge, Mediterranean Sea. Natural size.

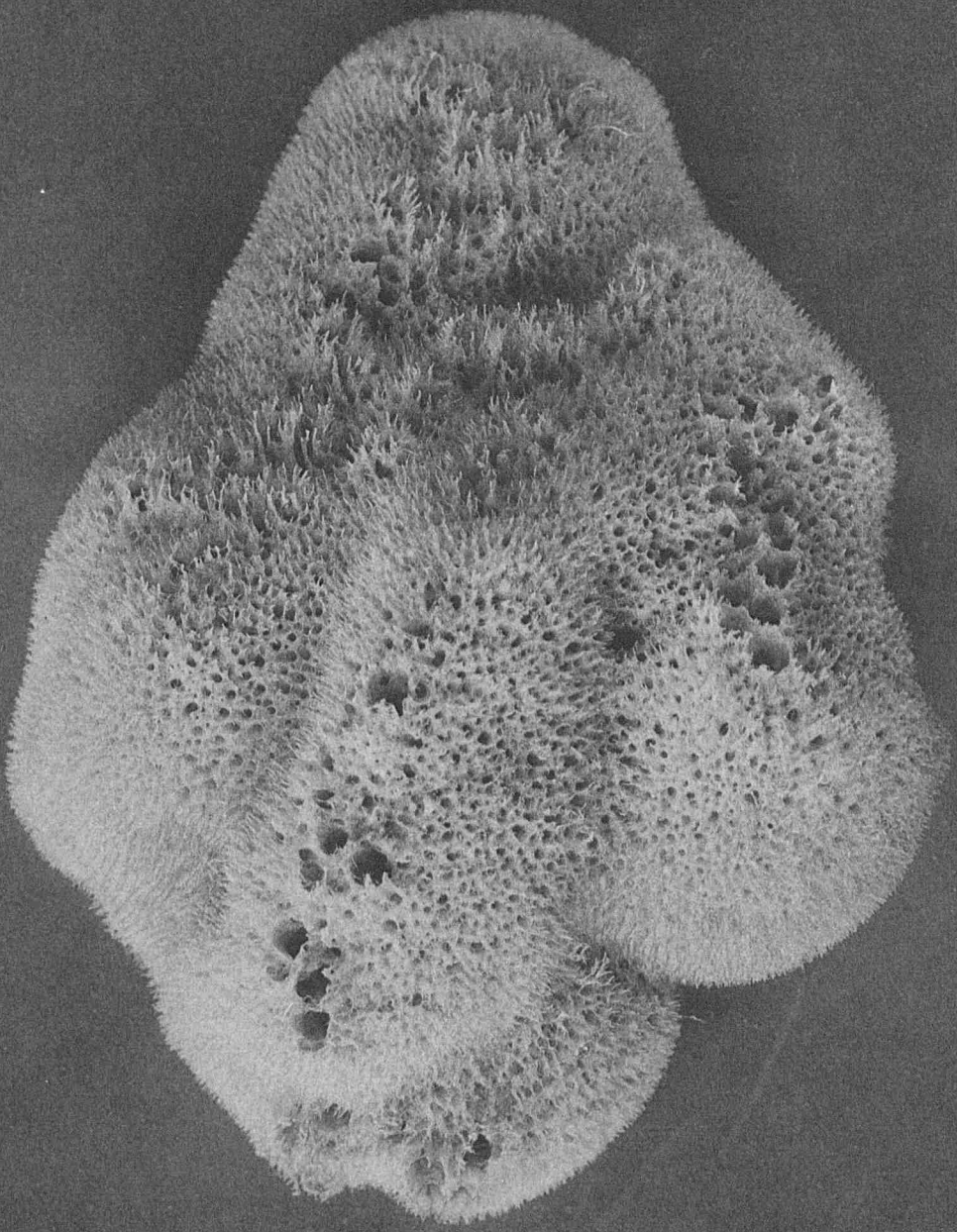


Plate LXIII

Fig. 1.—Philippine toilet sponge, Sitanki, P. I. Side view, natural size.

Fig. 2.—Philippine toilet sponge, Sitanki, P. I. Top view, natural size.

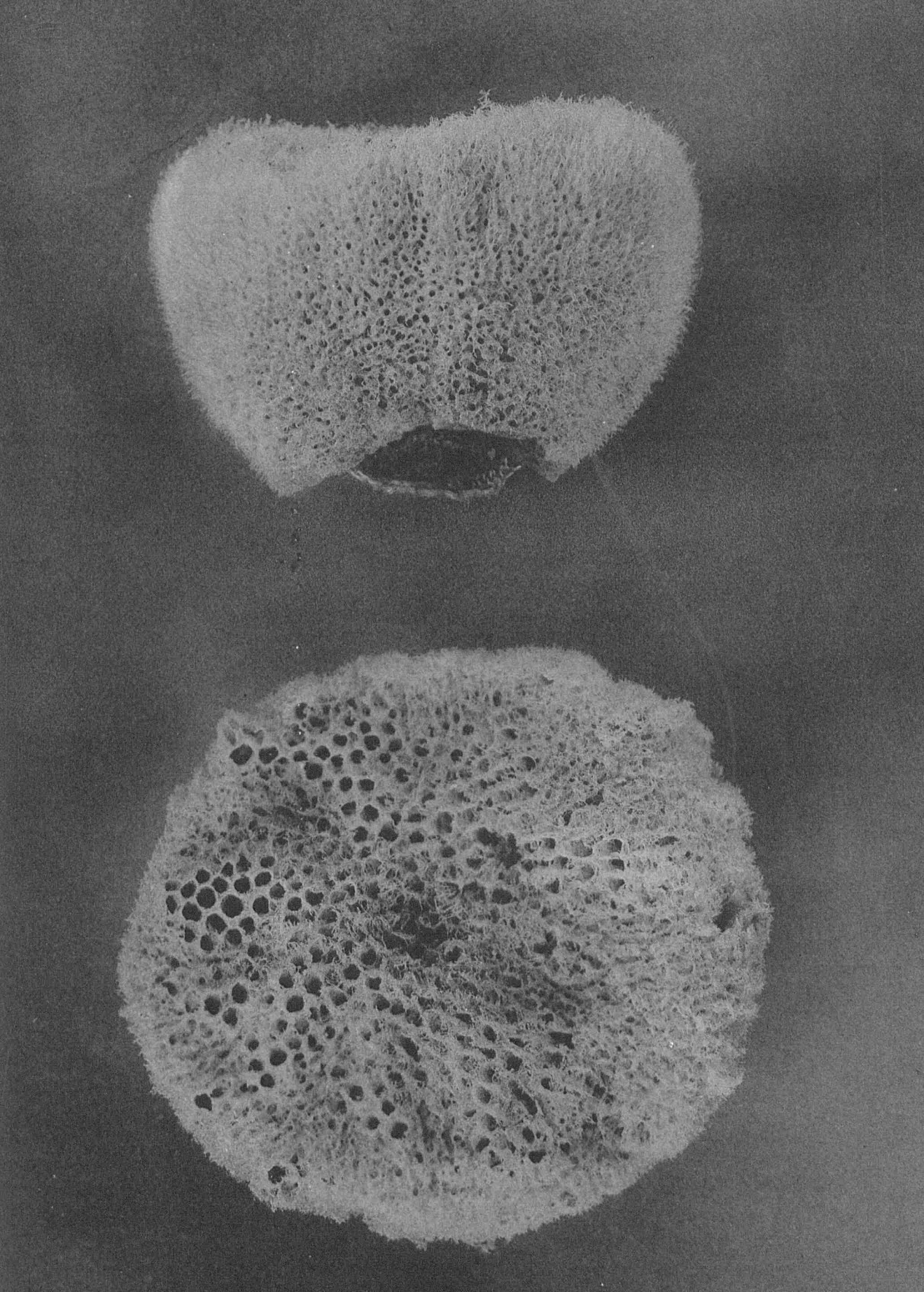


Plate LXIV

Fig. 1.—Zimocca sponge, Mediterranean Sea. Side view, natural size.

Fig. 2.—Zimocca sponge, Mediterranean Sea. Top view, natural size.

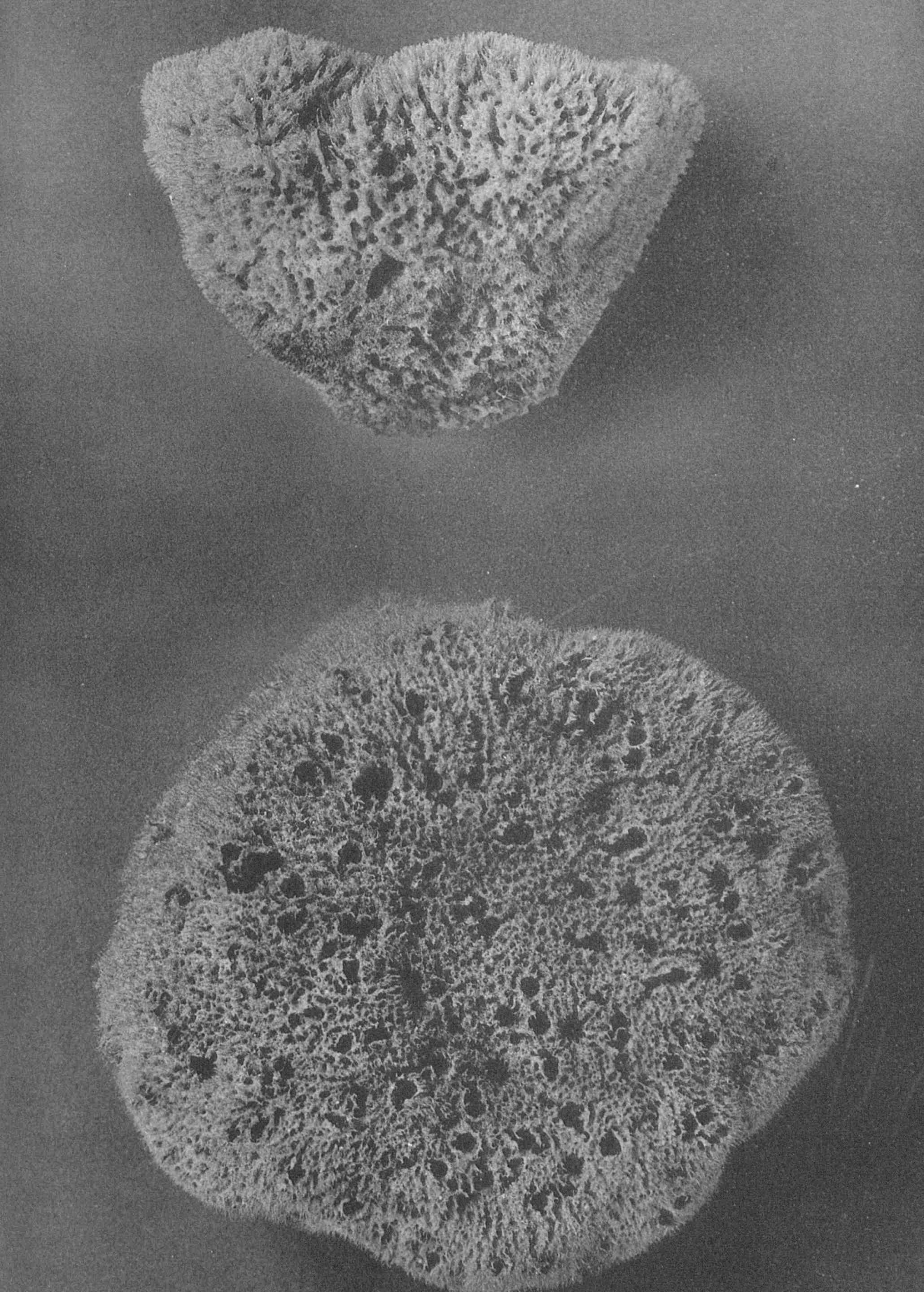


Plate LXV

Honeycomb sponge, Mediterranean Sea. Natural size.

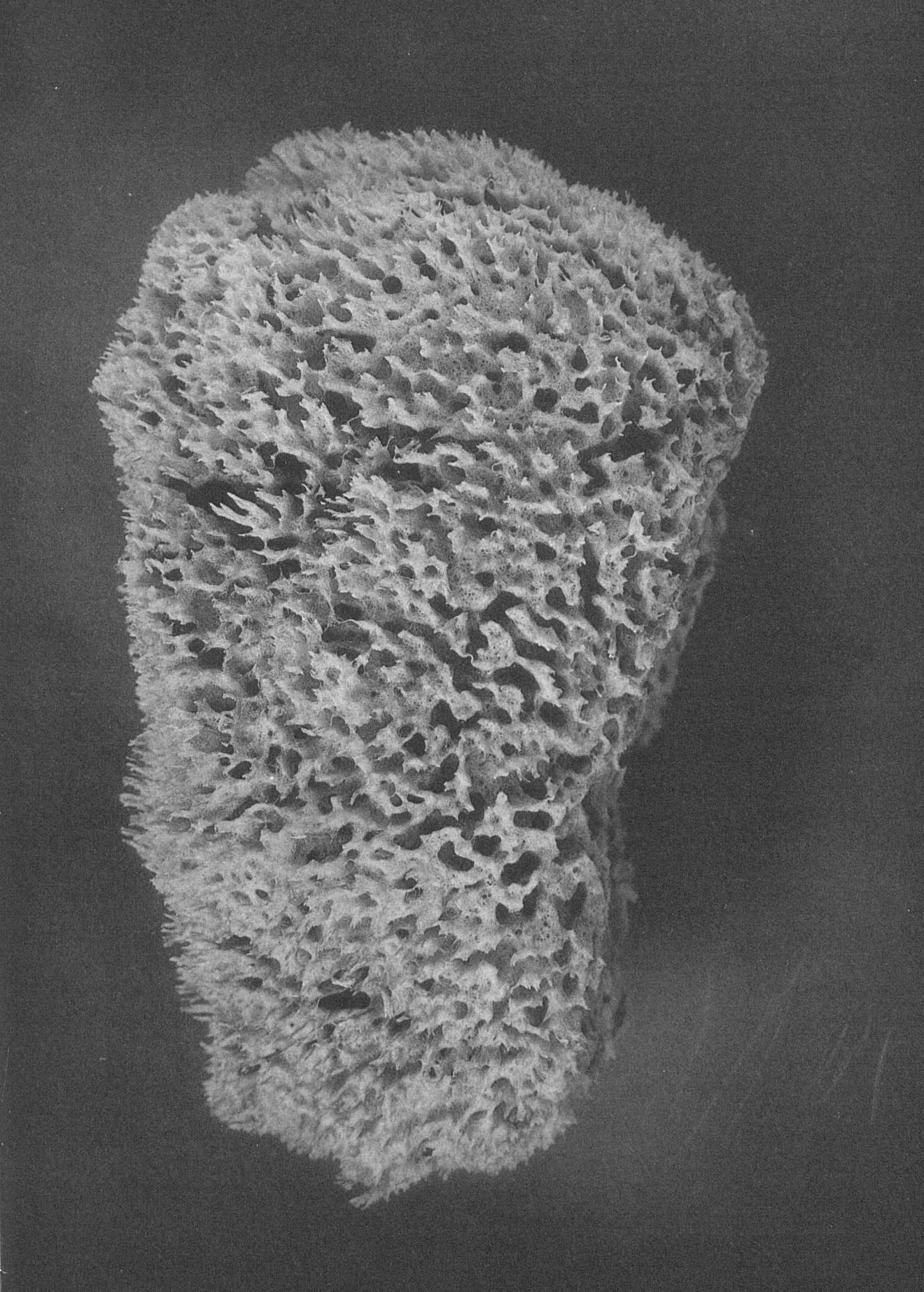
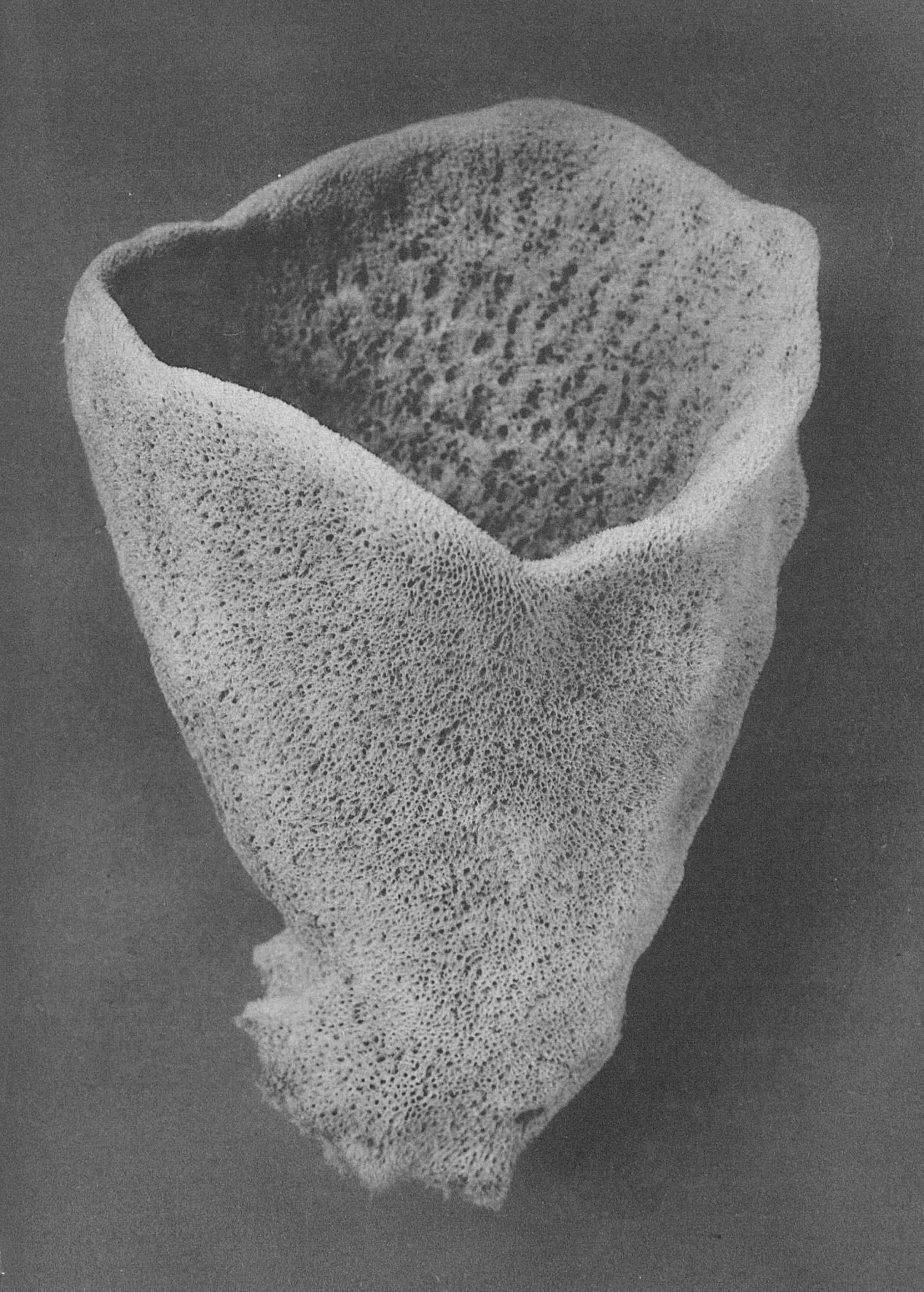


Plate LXVI

Elephant-ear sponge, Mediterranean Sea. Natural size.



THE ABUSE OF THE SCAPHANDER IN THE SPONGE FISHERIES

By Ch. Flégel

Member of the Austrian Fishery Society, Vienna

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 28, 1908

CONTENTS.

	Page.
Methods of sponge fishing	516
Evils of the scaphander	518
Attitude of the governments	522
Greece	522
Kalymnos	530
Samos	530
Crete	530
Cyprus	532
Tunis	532
Turkey	532
Egypt	533
Spain, Algeria, and Morocco	534
Italy	534
Austria-Hungary	538
United States	538
Résumé	540
Appeal to the International Fishery Congress	542

THE ABUSE OF THE SCAPHANDER IN THE SPONGE FISHERIES.

By CH. FLÉGEL,
Member of the Austrian Fishery Society, Vienna.

[Translated from the German.]

I have the honor to report to the Fourth International Fishery Congress in Washington the unfortunate condition of the sponge divers of the Mediterranean Sea and the Gulf of Mexico. I do this with the well-founded hope that I shall meet here the active sympathy these sufferers so badly need.

A condition of this sort, of course, never arises without a precedent abuse or evil, and this rule is borne out in the sponge fisheries. The evil in this case lay and lies in inordinate greed of gain, uncontrolled by law, unchecked by any national regard for the general weal. Filled with this greed, which stops at nothing, men found it good forty-two years ago to adopt for the fishing of sponges the diving apparatus invented for quite other purposes. Although death and illness have ensued, these people continue this abuse at the present time so far as they are permitted. It is true that they did not succeed in winning the whole world over to their method; they met rather with strong resistance from their own compatriots, and thus a hot struggle began which has not yet ended, though fortunately the evil has lost ground before the good.

While in the island of Kalymnos in 1892, I accidentally learned of the sufferings of the sponge divers by asking a cripple the cause of his condition. The evils and abuses disclosed by his reply and confirmed by subsequent investigations of the subject led me to dedicate myself to the cause without in the least realizing that it would absorb years of my life.

The sponge fishermen everywhere lived in health and happiness so long as they gathered sponges by means of the three time-honored methods, hygienic and consistent with the public welfare; i. e., by means of diving naked, and by fishing with the hook and the dragnet. Since the scaphander was introduced in Greece and Turkey in 1866 numerous evils have befallen these formerly well-conditioned fishing people. There have been frequent cases of sudden and premature death, as well as of chronic diseases, worse than death, of youths

and men; a correspondingly large number of widows and orphans without means of livelihood, with the worst of consequences to the high morality of former times; fading girls on account of lack of marrying men; lack of work for many on account of the scarcity of sponges due to the destructive fishing; pauperism and emigration on account of the general misery—in short, a social disintegration of the worst kind. The suffering people sought relief in vain for twenty-six years, unable to make their protest heard or to obtain assistance in their struggle. The various governments in whose power it lay to remedy the evil were slow to recognize it, and it has been only by unremitting effort that action has been secured. Most of the Mediterranean countries, and also the United States, have within the past decade taken measures of prohibition or relief, but there still remains in many localities much to be desired.

METHODS OF SPONGE FISHING.

Sponge fishing by the three good methods had been an industry for centuries, especially in the eastern basin of the Mediterranean Sea. Sponges were found in great abundance before, both in shallow and deep waters, the fishermen, especially the naked divers, obtaining a good profit. The rowers were taken from neighboring localities, and youths and men, up to advanced age, were engaged for naked diving or the manipulation of the five-pronged hook and the dragnet. Whole fleets of small, excellent sailing vessels with naked divers departed to the East every spring after Easter, to the harbors of Syria, to the islands of Kalymnos, Syme, Chalke, and Kastelloriso; and other sailing fleets, with the five-pronged hook and the dragnet, left Tschesmé, Halikarnass, Hydra, Kranidion, Hermione, and Salamis, the village of Crappano in Dalmatia, the harbors of Italy, Tunis, Florida, Cuba, and the Bahama Islands. Healthy and jolly crews returned in September, from the coasts and the banks of the Mediterranean Sea and the Gulf of Mexico, with a rich harvest of sponges to sell to the local merchants for exportation.

The inhabitants of some of the islands and coasts of the Ægean Sea have from early generations been excellent divers, and were skillful also with hook and dragnet. The divers of Delos were famous in antiquity; those of Kalymnos and Syme are so to-day.[a]

The naked divers descend to the considerable depth of 75 meters and remain under water from 1½ to 2 minutes, a few even 2½ to 2¾ minutes. In a quest by the commander of a Russian gunboat in the harbor of Suda on August 10, 1907, one of several divers proved to be the best of them by remaining under water 2 minutes and 5 seconds at a depth of 17 meters, moving about hurriedly. In

[a] Herodotus mentions in Urania (chap. 8) the celebrated diver Skyllias of Skione. The sponge is mentioned by Homer in the Odessey (song 22, verse 455) and by Æschylus in Agamemnon (verse 1,329).

order to reach bottom the more rapidly, the diver grasps in both hands a flat block of white marble weighing from 14 to 16 kilograms, holds it in front of him, and jumps from the side of the vessel head downward into the spray, while a rope, passing through a hole in the stone and fastened also by means of a cord to the right wrist of the diver, follows him into the sea. Scarce touching the ground with his toes, the diver places the stone under his left arm, tears off the large sponges, and places these in a net fastened to his neck and waist. The crew of a sailing vessel with naked divers consists of 5 to 7 divers and 2 rowers. The only danger threatening the naked diver is the attack of a shark, but he does not consider this eventuality, as it is a very rare one.

The second mode of gathering sponges is by means of a five-pronged hook of iron, weighing from 2 to 2½ kilograms and fixed to a handle 9 meters long. Each bark of the Ægean Sea carries 4 to 6 hooks, 3 of which are bound together and braced end to end by 2 smaller handles of 2 meters each, making a combined length of 27 meters. For still greater depths, up to 45 meters, the sponge fishermen of the Ægean Sea use a five-pronged hook 1 meter long and weighing 12 to 15 kilograms, which is let down on a rope. The handles of the hooks of the Italian fishermen and the fishermen of Crappano in Dalmatia reach a length of 18 meters, while those of the Italians were, some sixteen years ago, only from 4 to 5 meters, according to the "Condizioni della Marina Mercantile Italiana," 1892. The crews of hooking vessels number from 2 to 5 men, one manipulating the hooks, the others rowing and assisting. Two men per bark are found only among the crews of Crappano, the crews in Italy, Tunis, Greece, and Turkey numbering 3 to 5 men. The sponge fishermen of Crappano, in order to be able to see the bottom of the sea more easily, pour oil on the surface of the water to render it smoother. A more practical and cheaper method is that of the fishermen of the Ægean Sea, who use for this purpose a special apparatus consisting of a tin cylinder with a glass bottom. The smoothing of the surface by a slight pressure of the glass bottom of the cylinder allows the eye to examine the bottom of the sea better than does the use of oil.

The third method of gathering sponges is by means of the dragnet, which is fastened to a rectangular frame 4 to 7 meters long and 0.35 to 0.45 meter high, and is dragged by means of three ropes joined to a heavier rope. The part of the frame lying on the ground is of iron and weighs 20 to 30 kilograms; the three other parts are of wood. The net has a depth of about 3½ meters and its meshes are 8 centimeters square. A sailing vessel equipped with a net is of 4 to 40 tons, and has a crew of 3 to 6 men, though the larger sailing vessels from Torre del Greco have more. The dragnet takes sponges at a depth of 120 meters, although not frequently. As it needs, for one thing, a flat sea bottom, and for another wind for the sails and room for maneuvering, it is evident that this work takes

place far from the coast in deeper water—taking up, it is true, all that lies in its path, but this is what would otherwise be left to die off, as no other means can reach the depths at which the dragnet works. The clamor against this apparatus on the ground that it harms schooling fishes is an exaggeration, but some countries, as the United States of America and Cyprus, have forbidden the use of it. This is regrettable, for thousands of people live by this mode of sponge fishing, without harm to themselves or others.

The fourth mode of sponge fishing is by means of the scaphander, or diver's suit, in which the sponge fisherman may descend to greater depths than the naked diver, and may secure great numbers of sponges not otherwise obtainable. The sailing vessel equipped with such an apparatus takes on board 4 to 10 divers and 8 to 12 sailors, and is always accompanied on long expeditions by a second sailing vessel, to carry provisions and to receive the sponges. The equipment of such an expedition for a summer's cruise of seven to eight months along the coasts of Africa costs 30,000 francs, that of a sailing vessel with naked divers 3,000 francs, that of a bark with the five-pronged hook 2,000, and of a sailing vessel with the dragnet 1,500, with the exception of the big vessels of Torre del Greco, the equipment of which is always more expensive.

EVILS OF THE SCAPHANDER.

The scaphander is in itself a splendid invention and very important and useful in submarine work at small depths, but its abuse in sponge fishing is equally harmful to the divers, the sponge grounds, and the economic welfare of the state. The diver in the apparatus may work without risk at a depth up to 16 meters, although accidents happen at smaller depths, as demonstrated by practice and as stated by Professor Katsarâs.[a] But at the greater depths of 16 to 75 meters, to which the unhappy diver is often forced to descend, the air, which is being driven down to him by two strong men by means of a pump, is correspondingly compressed in order to withstand the pressure of the water, which increases with every inch. This pressure hermetically fastens the rubber garment to the lower extremities of the diver, driving the blood continously toward the heart and head. The air breathed by the diver in the apparatus, saturated with carbon, penetrates into the blood through the lungs, renders it frothy and clogs the small vessels with bubbles, causing local obstruction and impediment of the circulation.

The degree of harm depends upon the depth to which the diver descends and the time he passes under water, then on secondary conditions, as colds, a heavy meal before diving, and fatigue. The disease of the divers, which is of

[a] In his excellent work "Recherches cliniques et expérimentales sur les accidents survenant par l'emploi des scaphandres," Paris, 1890, p. 292–293.

but one nature, is protean in its manifestations. It affects mostly the spinal marrow and the brain, the most important life centers, but appears in the most varied forms, as hemorrhages, stomach troubles, articular rheumatism, complete or partial lameness, lameness of separate limbs, fainting, vertigo, vomiting, dumbness, deafness, madness, brain stroke, heart stroke, hemorrhages of the brain, gangrene, loss of the finger nails, and frequently death, which is relief to these unfortunates. It should also be observed that the offspring of these divers have a weak constitution, especially of the nervous system. It is only if the diver is slightly attacked by the disease and immediately discontinues his work and subjects himself to treatment that it is possible for him to regain his health. Otherwise he is doomed to die prematurely, or he limps through life on crutches, or spends long years in bed covered with wounds. If the air-supply tube of the apparatus is punctured the unfortunate diver is immediately squeezed to death by the pressure of the terrible mass of water, which had received until that moment the necessary counter pressure from the air laboriously pumped down. His head grows black and swells so that it can not be pulled out of the metal helmet. It must, consequently, be detached from the body and cut to pieces before being removed. The body is lowered to the bottom of the sea in a sack weighted with stones, or it is buried on the coast. Soon after another diver assumes the helmet which but shortly was covered with the blood of his comrade, and goes to meet the same danger, like a gladiator of ancient Rome.

Since the dreadful consequences of the abuse of the diving apparatus are so evident, it is astounding that this business has spread and lasted so long, and in spite of the protests of the population and of individual philanthropists. Five conditions, however, explain partly the extraordinary duration of so great an evil: (1) The abuse is practiced on the high seas and concerns poor fishermen of distant, isolated localities, from which, moreover, they are absent the greater part of the year. (2) The evil is not confined to one country, but appears in all the sponge-bearing countries of the Mediterranean Sea and some of the Gulf of Mexico; the sponge fishermen do not live in compact settlements but dispersed on islands, peninsulas, and coastal strips of these two great basins. Thus the question is an international one. (3) The owners and partisans of diving apparatus endeavor to influence the governments, the press, and public opinion by such means as concealing the terrible consequences of this abuse or by excusing them. (4) There is a lack of official or private statistics on the mortality and diseases of divers using the diving apparatus and on the harm done by the apparatus to the sponges in respect to their reproduction. (5) There is a lack of responsibility on the part of harbor masters or captains for the death or illness of a diver; nor is there in

the countries where these divers live, i. e., in Greece and Turkey, any insurance on their lives, or in case of illness due to the diving apparatus.

The diver is circumscribed by an evil circle from which he can be released only by a beneficent law prohibiting this mode of sponge fishing. Greed, bravado, and necessity sent the first divers into the scaphander at the instigation of the harbor masters and captains. Now, with premature or sudden death or chronic disease before him, the "machinist" (μηχανικός, the sponge diver working in the machine, μηχανή, is named by the Greek people) sells his health and life as dearly as possible. He is paid for a summer season of seven to eight months 2,000 to 3,500 francs. This, however, he soon spends, as he is tortured by a craving for enjoyment, as a man condemned to death or with thoughts of suicide. The high wages of the divers, moreover, are often accompanied by rough treatment. They desert, and the harbor masters and captains punish them for it as long as they can by the exaction of high percentage, of extraordinary returns in sponges, of inordinately high prices for the provisions delivered to their families, or by pitilessly requiring them to dive to too great depths, where they meet death or disease as a result.

The sponge-fishing population of the Ægean Sea, Greeks and Albanians, was a religious one without being fanatic or superstitious. They maintained faithfully the ancient simple rites and customs, and their mode of life was honorable and patriarchic. But what a change has come in all this since the abuse of the diving apparatus shook to the depths the moral and material life of these brave fishermen! Both those who use and those who do not use the diving apparatus have fallen into misery, but the worse fate and the responsibility for the evil has befallen the users. A victim of premature death, or of chronic diseases worse than death, the unfortunate diver seeks in his affliction to forget his terrible fate in amusement and profligacy to-day, for to-morrow leaving his aged parents or his young wife and small children in misery; or still worse, he is left to share this misery with them as a cripple; or, by the height of misfortune, he limps through his native place or a foreign land as a beggar, if he is not so crippled as to have to be carried in a cart. The harbor masters and captains, as already stated, bear no responsibility for the frequent accidents, and with no provisions of insurance for cases of disease and death, the entire burden of the misfortune falls upon the family and the nearest relatives of the victim. The sponge trade likewise has for years suffered from the high prices of the sponges, a natural consequence of the destruction and scarcity caused by the diving apparatus and by the expensive hire of the divers.

Specialists have for some time been studying and publishing the results of their observations on the frequent and varied diseases and the numerous cases of death from working in compressed air, and more recently especially among

the sponge fishermen working in diving apparatus. Paul Bert, Guérard, Febvre, Feltz, Bouchard, Petit, Couty, Chabaud, Vivenot, Schultze, Saeger, Leyden, Pierre Marie, Rameaux, Bucquoy, Hermann von Schrötter, Kononoff, and others have written on the general subject, and Paul Bert, Leroy do Méricourt, Gal, Lampadarios, Kotsonopoulos, Parissis, Tetsis, Charpentier, Katsarâs, Savvas, Livadâs, and the Greek naval officer Melâs have treated it with especial reference to the divers. It will be to the purpose to cite some of these writings.

Michael Katsarâs, professor of nervous diseases at the University of Athens, published in 1890 the already mentioned work on diseases of divers,[a] which were not sufficiently considered by the governments of the interested countries.

Katsarâs observed and described 62 cases of diseases of divers, and made experiments with the diving apparatus on dogs. I refer to his book all those who desire better acquaintance with the subject. The celebrated scientist lives in Syme, one of the principal seats of abuse of the diving apparatus, and is, consequently, well acquainted with this evil.

Katsarâs limits himself to purely scientific demonstrations without uttering any cry of horror. After having described all the forms of the diseases, he indicates the means of curing the slighter ones. These treatments, however, demand so much time that only persons in prosperous circumstances can take them, and not divers weighted down by debts. Katsarâs gives the following advice as to what the diver must do to avoid disease:

(1) Regulate the duration of the sojourn under water according to the depth, as one hour at depths of 10 to 15 fathoms, one-quarter of an hour for depths of 15 to 20 fathoms, ten minutes in depths of 20 to 25 fathoms, five minutes in depths of 25 to 28 fathoms, 3 minutes in depths of 28 to 30 fathoms, and one minute in depths of 30 to 32 fathoms.

(2) Rise very slowly, stopping for one minute after each 2 fathoms.

(3) Avoid consecutive diving by the same person.

(4) Do not dive too deep.

(5) Do not dive while afflicted with a cold.

(6) Have the intestines empty before diving, and eat only in the evening after the completion of the work.

(7) Avoid fatigue.

What would become of pecuniary profit, which is the most important consideration in each trade, if the seven prescriptions of Katsarâs were followed? Of these the most important is the fourth, and this according to his own words it is not possible to follow. Katsarâs himself says:

Of these the fourth precaution can not be considered; to forbid the divers to descend too deep would be to forbid them their trade, for a sufficient quantity of sponges can not be found at small depths.

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[a] "Recherches cliniques et expérimentales sur les accidents survenant par l'emploi des scaphandres," Paris, 1890.

This is the only passage, but a very important one, in Katsarâs's work, which indicates that the diving apparatus is likewise very harmful to the reproduction of sponges.

Katsarâs gives other specific advice:

> I advise the affected divers to dive daily for two or three months to a depth of 8, 10, and 12 fathoms, staying under water from fifteen to thirty minutes; and to vary the treatment by compressed air for one month by first cautiously eliminating the pressure, and then resuming it again, etc. * * * The authorities of these sponge-fishing islands should therefore establish small hospitals on the seacoast in order to introduce the systematic treatment with compressed air by means of the diving apparatus. Each small hospital ought to possess 2 or 3 apparatuses for this purpose, and other treatment should be included.

Can anything be more obnoxious and futile than this system? Rendering men ill in order to cure them, and recommending to them a trade with such precautions that it must cost more than it would yield? Katsarâs has likewise failed to give statistics of deaths; he contents himself with far too mild a statement when he says on page 2 "No year goes by without at least 10 dead."

Katsarâs wrote as a clever physician, leaving others to apply his results. These others are in the first place the authorities of the localities and countries in which the sponge divers live, and in the second place the authorities of the countries in which the abuse is practiced, and unfortunately they pay no attention to the work of the great scientist. It has therefore brought scarcely any aid to the unfortunates to whose weal it is dedicated. Only by enforcing the important logical deduction from the excellent work of Katsarâs can the solution of this question and the salvation of these unfortunates be brought about. The diving apparatus in sponge fishing must be prohibited, a thing which has now taken place in some countries, thanks to the pains we have taken.

ATTITUDE OF THE GOVERNMENTS.

As already stated, my work in behalf of the sponge divers began with my visit to Kalymnos in 1892. My plan was to appeal to the governments of each of the sponge-producing countries of the Mediterranean Sea, beginning with the smaller and nearer ones and going to the larger and more distant, and including countries without sponge fisheries, but with sponge beds, as well as those with sponge fisheries with and without machine diving. According to this programme, after Kalymnos came Samos, Crete, Cyprus, Egypt, Tunis, Italy, Austria-Hungary, Greece, and Turkey, all of which except Tunis I visited in person. It will be best to discuss first the conditions in Greece.

GREECE.

The sponge fishermen of Greece live at Kranidion, of 8,000 inhabitants, and Hermione, of 2,000 inhabitants, on the Argolic Peninsula, at Hydra with

7,000, Spetzæ with 6,000, Ægina with 8,000, and Salamis with 3,000 inhabitants; with the exception of the Æginetes, they are all Albanese. There are no naked divers in Greece; the sponge fishermen of Kranidion, Hermione, and Salamis use the hook and the dragnet; those of Hydra use the diving apparatus, which was introduced in Greece in 1866 by several men from Nauplia for the sponge fishermen of the neighboring localities of Kranidion and Hermione. After these machines had brought death to several men and had crippled others, also had cost a great deal of money, they were voluntarily relinquished in the two latter places. A new attempt to introduce them in Greece was made in 1882, however, after they had been operating without interruption in Turkey. This occurred at Syme and was more successful financially, since it was in direct communication with the world market of London and especially because much less heed was taken to spare the human victims which must be sacrificed if financial success is to be obtained in this deadly trade.

The evil made thus great progress notwithstanding the protests of the people from time to time, the terrible abuse growing at last into a recognized industry. The fearful consequences were excused by citing that in other industries, as in mining, accidents happened likewise. It was not taken into account that in the mines it is the natural conditions that bring about accidents, while in sponge fishing with the diving apparatus men make deliberate choice of this over the three safe modes of fishing, because by this means they can gain money more rapidly, the sacrificing of human lives, the misery of their neighbors, as well as the future of the sponge fishery being unheeded, and nobody held responsible for the evil.

The Greek Government, however, does not ignore the cause of the sponge divers. On the contrary, as appears from various official reports, the evils of the business are well recognized.

The ministry of war published on April 12–24, 1896, a circular on the precautions to be taken by machine divers, and sends out every summer the dispatch boat *Kreta*, sometimes also a second war ship, to the coasts of Africa from Derna to Sfax for the purpose of supervising the sponge fisheries, of supplying the fishermen with drinking water, and of lending the necessary assistance in cases of illness. This ministry also founded in April, 1904, at the recommendation of Her Majesty Queen Olga of Greece, a hospital for seriously diseased divers at Tripoli, the lighter affections to be treated on board the *Kreta;* and it published in March, 1904, the very noteworthy report of Constantine Savvas, member of the board of health, professor of hygiene at the University of Athens, and physician to His Majesty King George of Greece, on the diseases of the divers and remedy for the evils existing.

According to the data furnished by the Greek Naval Office and by private individuals (Savvas, p. 10), Hydra sent out, during the summer season of 1903,

171 vessels with 1,370 sponge fishermen, of which craft 36 were sailing vessels equipped with diving apparatus, 342 divers, and 667 sailors; 15 were sailing vessels with the dragnet and 80 fishermen, and 70 were barks equipped with hooks and 281 fishermen. Ægina sent out 40 sailing vessels with the diving apparatus, of which 24 were accompanied by another sailing vessel, with 214 divers and 508 sailors. According to the harbor master of Spetzæ this island put out in that year 8 sailing vessels with the diving apparatus, 43 divers, and 80 sailors. Kranidion sent out 52 barks carrying hooks, with 162 fishermen, and 21 sailing vessels with the dragnet and 93 fishermen, moreover 2 vessels with 24 sailors carrying supplies to the fishermen on the coast of Africa. The number of 12 sailors on each of these vessels is extraordinarily large, and Hermione is not mentioned by Savvas. The total of the above figures is 318 vessels with 2,494 men, of which 134 carried 599 divers and 1,173 sailors, 122 carried hooks and 443 fishermen, 36 carried the dragnet and 173 fishermen, 24 were escort of the diving vessels and had 82 sailors, and 2 were packet boats with 24 sailors. According to the commander of the *Kreta*, Stamatios Vuduris, the fishermen flying the Greek flag gathered in 1902 120,000 to 130,000 oka, or 153,600 to 166,400 kilograms, of sponges, valued at 5 to 5½ million drachmas.

From the data furnished by the Greek naval physician, George Sphinis, who served on the *Kreta* from 1900 to 1903, Savvas gives the following statistics:

> Under the eyes of the officers of the *Kreta* in 1900, 12 divers died, 228 fell slightly ill, 34 fell seriously ill. In 1901, 396 fell ill, 34 were treated on the *Kreta*, and 5 of these died. In 1902, 3 died on the *Kreta*, 232 fell slightly ill, and 23 gravely ill. In 1903, 56 sick were treated on the *Kreta*, of which 9 were completely cured, 17 improved to such an extent that they could do some work, while 27 improved, but needed after treatment. Three died.

Savvas observes:

> The number of divers treated on the *Kreta* seems small in comparison with the cases of illness in previous years. This is due to the fact that the captains of the sponge vessels are distrustful toward the war-ship on account of its rigorous supervision and would not report their sick, going only so far as to ask for remedies.

But do not the men asking for remedies avow that there is at least one sick on board, and has not the commander of a war-ship the power to seek out the sick on board the small vessel should he earnestly desire it?

Savvas says further that Paul Bert had found that about 30 Greek sponge divers died every year. Katsarâs reduces this already inadequate figure to "at least 10," while Sphinis states that the number seen by him and the officers of the *Kreta* were 12 in 1900, 4 in 1901, 3 in 1902, and 2 in 1904. Savvas, however, observes, quoting official witnesses for corroboration, that "the number of deaths among the sponge divers is much larger." And the commander of the *Kreta*, Stamatios Vuduris, says that 60 divers had died at Bengazi and Derna in 1901. In the Great Desert there was found a sack containing the bodies of two divers.

The commander of the *Kreta* in 1903, Petros Zotos, obtained under oath names of 24 divers deceased in that year. This commander learned, moreover, from a reliable source, that 40 other divers, whose names he could not get, had died. He is of the opinion that of the 900 divers who work under the Greek flag in 140 scaphanders more than 100 died within the period of one summer cruise (from March to October), that the others all but a few "are either crippled already or will soon be so and absolutely incapable of any other work." My experience of many years confirms the opinion of Captain Zotos.

Savvas republishes in his report the already mentioned circular of the Greek Naval Office of April 12–24, 1896, on the precautions to be taken by the divers. This had never been enforced, a fact which has made the Greek Government since 1900 detail a war-ship each summer for the protection and assistance of the sponge fishermen. Savvas finds even this measure insufficient, however, without a special law, observing that—

> The measures of the rapidly succeeding governments have unfortunately but a very small effect upon the sponge fishing conducted with diving machines. It is absolutely necessary to take more effective and thorough measures, and such ought to be inaugurated by a special law for the purpose of limiting the evil.

The measures recommended by Savvas are divided into three classes, (I) financial, (II) administrative, and (III) sanitary.

I. The captains of sponge-fishing vessels borrow, at very high interest, a considerable sum which is to be paid back to the lender at the end of six months. In order to obtain sufficient sponges to be able to pay back the borrowed sum with the interest and, moreover, to support themselves and their families, they employ a comparatively small number of divers, who must work very hard and risk every danger. The captains exhibit a change of attitude as the fishing season advances. Until their indebtedness has been covered by the number of sponges obtained, they spare the divers, but after this the latter are driven to extremest effort for the captain's personal gain before the end of the season shall have come. Savvas proposes, accordingly, to decrease as much as possible the borrowed sum and the interest, which amounts each year to from 24 to 36 per cent. The prices of provisions for the crew and for the vessel's supplies are exorbitant, but the captain is obliged to accept; otherwise he does not obtain the necessary loan. Savvas would, therefore, as a first financial measure, decrease the interest to 10 per cent and 12 per cent, and allow the captains to purchase the provisions and other necessaries where most advantageous to them. Savvas does not discuss the question of source of the capital for the enterprise, whether to be supplied by banks or otherwise; but he deplores the advancing of money by the captains to the divers, since the latter spend it in orgies which are harmful, not only because the money is uselessly spent, but also because the physique of the divers, weakened by dissipation, is much more readily the prey

of disease. By this advance, moreover, the diver is placed in complete subjugation to the captain, who makes him work even when he is ill. As a second financial measure, Savvas would change the advance pay into a monthly salary. As a third, he proposes the founding of a relief fund for the divers, to which all captains and divers ought to contribute. From this fund assistance would be given to the widows and orphans and to the sick and disabled divers. The school for divers and the hospitals for the latter would likewise be maintained from the proceeds of this fund.

II. The first administrative measure proposed by Savvas is the founding of a diving school at Toros, Hydra, or at the navy-yard of Salamis. A diploma from this school would be demanded for permission to follow the calling of diver or to be a captain of a sponge-fishing vessel. Only when all the men are trained will it be possible, according to Savvas, to place upon the captain the responsibility for violating precautionary measures and not now when he acts in ignorance. The school would be under the direction of a naval officer, after the latter, if possible, has visited the diving school of the Russian fleet in Cronstadt, which is considered a model. A naval physician would likewise be detailed to this school, after having undergone a course of special studies on this subject in order to learn the elementary anatomical and sanitary knowledge in this domain. He would be present at the practical exercises of the students, to give immediate assistance in case of accident and to subject divers suffering from a chronic disease to a regular treatment, and if possible a hospital would be erected in the vicinity of the school. A course of one month should be sufficient training for the divers.

Savvas's second administrative measure is to subject the sponge-fishing vessels to a thorough examination before their departure, not only to ascertain the condition of the divers, but also to inspect the diving apparatus, the air pump, the rubber tube, the clothes of the diver, the manometer. Men suffering from lung and heart diseases should not be allowed to work as divers, nor should neurasthenic, weak, or anæmic persons, those suffering from chronic diseases of the ear and nose, those who are very lame, nor men under 20 and over 40 years of age. This inspection ought to be held by a commission consisting of a naval officer as president of the board, a naval physician, and a naval engineer, who should go in person to the point from which the fleet of sponge-fishing vessels is to take its departure. The board of inspectors should be authorized by a special law to issue permit and ship's papers to each vessel fulfilling the above-mentioned conditions, which permit and papers are at present issued by the authorities of the port; also to prohibit, by force if necessary, the departure of a vessel not fulfilling the conditions, or of a diver who does not possess the qualifications demanded.

The third administrative measure proposed by Savvas is to insure the correctness of the ship's papers, which heretofore have been supervised very carelessly by the port authorities. The captain should be compelled to keep his records with the greatest exactitude and to report each change in his crew to the nearest port authorities or to the commander of the cruising war ship. Upon returning to his native port, he must render account of the health of each of his crew individually, as well as of deserters and deceased. The harbor master must then make to the Naval Office a detailed report on the cruise.

Savvas recommends as a fourth administrative measure the supervision of sponge fishing along the coast of Africa by one or two men-of-war, which has been done since 1900. Savvas urges, further, that the naval commanders be empowered to take more active measures, to impose small fines for the violation of regulations, and even to deprive the captains of their permits.

As a fifth administrative measure Savvas recommends an exact regulation of the duties of the captain and the master of the divers in regard to the latter, as well as of the mode and duration of the work and an express definition of the responsibility of the captain and the master for each violation of regulative measures, thus to prevent all excuses based on ignorance.

The sixth administrative measure is the imposition of heavy punishment on the captain and the master for the violation of any regulation, and Savvas cites articles 300, 301, and 310 of the Greek penal code and articles 222 and 230 of the German, in force in the diving service of the German fleet. He does not deem the articles of the Greek penal code sufficient, however, and expresses the opinion that they ought to be made more rigorous by new legislation applying especially to the diving business, for only then could a limit be put to the requirements of the captains. The harbor masters and the commanders of the supervising war vessels should have authority to impose punishments upon the guilty, for too much time would be necessary for action in such cases by the court or by the Naval Office, and the effect of the punishment would be weakened.

III. The following are the sanitary measures recommended by Savvas:

(1) Perfect health of the diver when entering upon his work.

(2) Slow descent to the depths of the sea.

(3) Regulation of the duration of the sojourn of the diver under water by the depth, according to Katsarâs.

(4) Slow ascent from the depth, according to Katsarâs, Silberstein, Méricourt, and Kononoff.

(5) Prohibition of continued diving by the same person, quoting the opinion of the inventor of the most popular diving apparatus, Denayrouze, that the duration of work for a diver in this apparatus should never exceed

2½ hours daily and, according to others, that the diver should dive but once a day.

(6) Avoidance of diving during a cold or with a full stomach.

(7) Avoidance of fatigue, of use of liquor, of fasting.

(8) Presence of remedies and means for first aid on each vessel, as (*a*) compressed-air treatment when the diver falls ill, a thing which Savvas himself admits is impossible, since there is room for only one diving apparatus on each vessel, and the latter serves for the work and not for curative purposes; (*b*) breathing of compressed air; (*c*) establishment of hospitals on the African coast and in Greece; such a hospital was founded in Tripoli in April, 1904.

Savvas says in chapter 8, under the heading "The result," that about 2,600 men are engaged in sponge fishing in Greece alone, that among these there are 636 machine divers on 134 vessels with 1,218 sailors, that according to the reports of the commanders of the *Kreta* at least 60 to 100 divers die each year, and that so many fall ill that four-fifths of them are more or less severely crippled, a fact that renders their work much more arduous or often completely incapacitates them. The remaining sponge fishermen, of whom those using the dragnet form the minority in Greece, while the naked divers form the majority in Turkey and are the only ones in the other countries—these, Savvas observes, suffer no harm. Why, then, does not Savvas state the conclusion to which every impartial person must come, that the harmless modes of sponge fishing should be encouraged and the harmful prohibited? He does imply this conclusion in the following statement:

> If the execution of these measures is for one reason or another impossible (and it is impossible, for the profits, which are the principal incentive of every trade, would be lost), then should the prohibition of machine diving be considered, not only for the salvation of a large number of persons from death and disease, but also for the honor and good name of the country.

Regard for the life and health of the divers and for the good name not only of Greece but of all countries interested in the sponge fisheries, I share fully with Savvas; but I am amazed at the time required by most theoreticians, of whom Savvas is one, for recognition of the fact that no advance can be made by the execution of even a part of his measures—that their enforcement imposes the prohibition of machine diving. It is the same end at last, after all is said and done, i. e., the actual prohibition of the scaphander.

While Professor Savvas was writing his report, the Naval Office detailed in January, 1904, a board, consisting of 12 members, to which belonged Savvas and deputies from Parliament from the sponge-fishing districts as well as naval officers, for the purpose of working out a project of law to govern sponge fishing with diving machines. The board finished its work within a month. The drafted law contains all that Savvas demands in his report, but has not been

once brought up in the Chamber of Deputies during the four years that have elapsed since then. It may be gathered hence that the partisans of the diving machine, wishing not to be molested, know how to hinder the presentation of the question before the Chamber, and without the vote of the Chamber the execution of the measures is of course impossible. Thus, then, the well-meant regulations are absolutely unimportant because they are impossible of execution; and they are worthless and impossible of execution also because they cost more than the industry yields—and this is the worst to be said about an industry. This wretched business is profitable now because all responsibility, all burdens, all the suffering of it, can be shifted and because the two countries where it exists, Greece and Turkey, have indorsed it for forty-two years.

In January, 1907, the Greek Naval Office in Athens published the "Guide for Divers" by the naval physician, Dr. Spiridon Livadâs, and the naval lieutenant, Constantine Melâs. By the wish of Her Majesty the Queen of Greece, Livadâs and Melâs were detailed for a few weeks to the diving school of the Russian fleet at Cronstadt, in order to familiarize themselves with the innovations and improvements brought about in this work. Their "Guide" does not give any statistics of death in the sponge fisheries, but it reiterates the advice already given by Katsarâs and Savvas; and it has a highly suggestive title-page depicting a naked sponge fisherman lying on a bed in the hospital of Tripoli, his body covered with wounds, himself one of the numerous victims of the diving apparatus who died from gangrene after an illness of six weeks. This title-page, the short description of the sufferings of this victim, and the great number of precautions to be observed by the diver in order to avoid the grave danger threatening his life and health, are likely to frighten him, and thus this book renders a great service to the sponge fisheries. Not otherwise, however, can it prove of great benefit to Greek divers, for there is an enormous difference between the work of the divers in the navy, which is of great usefulness and harms nobody, and that of the sponge divers, who have to consider pecuniary remuneration and engage in work which causes the greatest harm to men and sponge resources.

Thus, as shown by the official reports quoted; by the fact that the Greek Government maintains the hospital ship *Kreta* in the interests of the sponge divers; by the fact that a hospital has been established at Tripoli at the instigation of Her Majesty the Queen; by the issuance of circulars and regulations from the Greek Ministry of War—by all these various actions the evils of machine diving are acknowledged in Greece. I have obtained the favorable consideration of the King and the cordial sympathy and aid of the Queen in the cause of these suffering subjects. The people themselves have given evidence of their need and of their appreciation of efforts for their relief. But the logical and

hoped-for result, the suppression of the evil by entire prohibition of the diving apparatus, is not yet accomplished.

KALYMNOS.

In Kalymnos results were at last obtained by the promulgation, in 1902, of an irade from the Sultan, which in the extent of its prohibitions exceeded the expectations of both factions interested. In execution the irade has, however, been defective. Provision was not made for the confiscation of diving machines nor for their exclusion from Turkish import and export. And in spite of the prohibition, a considerable number of Greek and Turkish sponge divers worked until lately in Turkish and Cretan waters without being prosecuted. They contended that they worked in neutral waters, since they fished at a distance of 3 maritime miles from the coast, where, according to them, everything was free to everybody. This interpretation of the neutrality of waters is absolutely arbitrary and sophistical, since it is the sponges that are here in question and not the waters, and since the sponges, with the banks on which they grow, even if 20, 30, and even more maritime miles from the coast, belong to particular states, generally to the one whose coast is the nearest. But even if the owner does not wish to protect his sponge banks or if he can not do it, as happened with Crete, on account of the lack of a revenue cutter, the wrongdoers need by no means be allowed to carry on illegal operations, even in neutral waters. Civilized nations are solidary in this respect and do not overlook such criminality, as was shown in 1905, by the four protecting powers of Crete, Great Britain, France, Italy, and Russia, and lately again by France in Cretan waters. The sponge fishermen following the three older methods of fishing are naturally displeased at the disregard of the prohibition, and there have been some disorders on this account in Kalymnos and Syme.

SAMOS.

The Duchy of Samos possesses good sponge grounds, but no native sponge fishermen, and by reason of its small size would be of slight importance in the sponge fisheries had it not been the first autonomic country to prohibit diving machines. This prohibition took place in 1898, and in 1902 was revoked, but in 1904 the law was again changed, prohibiting the diving machine and repermitting the dragnet, which in the meantime had been prohibited for an interval.

CRETE.

There are no sponge fishermen in Crete, with the exception of a few who allow themselves to be tempted to work on foreign sailing vessels in diving apparatus. But there are excellent sponges there, especially on the coast of

the eastern prefecture (Lasithi) and the islands belonging to it. Since 1898, the revenues obtained from licenses for sponge fishing fluctuated between 7,833 francs 40 centimes in 1903, and 26,360 francs in 1902. The naked divers and those using the dragnet paid in 1907, up to November of that year, 230 francs for each sailing vessel and since that date 250 francs, while the hook fishermen paid 90 francs, now 100 francs, for each bark. The working season in sponge fishing is considered on Crete from March 1 until February 28. The Cretan statistical data do not give, unfortunately, any information as to how many, whence, or on how many vessels sponge fishermen arrive, how many of them use the three proper modes of fishing, nor the quantity and value of the catch of each.

The first action against machine diving on the sponge banks of Crete was obtained in 1899, and consisted of a law of complete prohibition. The sponge beds flourished in consequence, and soon became a great temptation to the greedy machine divers of Greece and Turkey, who sought repeatedly, from 1901 to 1907, to have the law repealed. Failing in this they circumvented it by fishing secretly on the coasts of Crete on their return from the African banks, and in 1905 enlisted even a few Cretans in this illegal enterprise. I at once took steps in the matter, and had the satisfaction of seeing the four protecting powers—Great Britain, France, Italy, and Russia—send their war ships to seize the culprits. Unfortunately, however, proper punishment was not inflicted, and the situation became an open scandal. In government circles it was claimed that enforcement of the law was impossible because Crete owned no revenue cutter. But there were guilty Cretans who could have been apprehended without any revenue cutter, and the license fees from the sponge fisheries would have built a revenue cutter long since. The contention between the friends and opponents of the diving machines kept the question embarrassingly alive to the Government and Parliament of Crete, and finally brought about action in the fall of 1907, whereby a limited number (10) of diving machines were permitted for ten years to a syndicate under certain specified conditions. These conditions, however, were purposely made so difficult that no such syndicate could be found, nor ever can. Another provision of the law was for the payment of damages to the families of divers who died as a consequence of the use of the scaphander. Thus the law has been saved; but the lack of a revenue cutter in Crete is a disadvantage that calls for prompt remedy.

The cause of the sponge divers in Crete received a further signal support in 1908, when the French Government, at the request of the Cretan Government, ordered its war ship *Faucon*, stationed at Suda, to apprehend the sponge divers fishing illegally in the waters of Hierapetra, which are under French control. The *Faucon* captured 7 boats, with 80 men, from Kalymnos and Syme. The remainder escaped in a heavy gale, and three were wrecked, with

a loss of 25 men. The decisive action on this occasion of the Cretan Government has greatly encouraged the opponents of the diving machine, and has led to similar requests in regard to the sponge grounds of Turkey, Italy, Tunis, Cyprus, and the Gulf of Mexico. In any event, the governments of Greece and Turkey have before them the important duty, whether or not they forbid the diving machine in their own territory, to prevent their own subjects from violation of the laws of other countries. And such violation when it does occur should be punished by confiscation of the ship's papers for a year or more, and forever in case of repeated offense.

It will be noted from the foregoing that the position of Crete in regard to the sponge fisheries and her attitude in the present question is most important and worthy of admiration.

CYPRUS.

Cyprus likewise has rich sponge banks but no native fishermen. The harmless dragnet was long ago prohibited, but the diving machine was permitted until 1901, when, the authorities having been enlisted against this abuse, a law was obtained which remained in force for three years. In 1904 the partisans of the apparatus succeeded in obtaining authority for a limited number of diving machines, under pretext of work to be done in the harbor of Famagusta. The naked divers and hookers were driven away by the conditions operating to their hardship; and a plan for a colony of sponge fishermen, as in Egypt, likewise came to nothing, naturally, since it of necessity involved the discontinuance of machine diving. At the present time the Government of Cyprus leases to the highest bidder the privilege of using six diving machines in one and the other half of the waters alternately, a misstep which is the more astonishing in the face of the wholesome example of near-by Egypt.

TUNIS.

The Regency of Tunis has extensive sponge banks, and numerous sponge fishermen, about 1,500, on 400 barks equipped with hooks. A great number besides come yearly from Italy, Greece, and Turkey. I lack statistics for Tunis, however. At my solicitation the scaphander was prohibited in 1901, but unfortunately, notwithstanding the apparatus is termed "engin destructeur" in the language of the decree, enforcement of the prohibition has failed, through intrigues of the opposing forces.

TURKEY.

Turkey has the most and the best sponge fishermen, but unfortunately official statistics of the sponge fisheries are entirely lacking. The chief localities are Kalymnos with 18,000 inhabitants, Syme with 20,000, Chalke with 6,000,

Kastelloriso with 6,000, Halikarnass with 3,000, Tschesmé with 3,500, Aivali with 20,000, Moschonisia with 3,000, and Marmara with 2,000, also villages and cities of Syria. Before the introduction of the diving apparatus there were some sponge fishermen also in the islands of Patmos, Leros, and Telos. In Kalymnos, Syme, Chalke, and Kastelloriso all four kinds of fishing methods are represented, in Halikarnass and Tschesmé, only the dragnet; in Aivali, Moschonisia, and Marmora, only the diving apparatus, though in limited numbers; in Syria there are only naked divers. The first six places and the villages of Syria have always depended entirely upon sponge fishing for a livelihood. Since the introduction of the diving machine there has been a marked emigration, especially to Russia and the United States of America. The famous naked divers, who have inherited this skill from many generations of forefathers and have perfected it by practice, live at Kalymnos, Syme, Chalke, Kastelloriso, and on the coast of Syria.

A law prohibiting the scaphander was promulgated in 1902, but is not effectively enforced.

EGYPT.

I went to Egypt in 1901, after successful visits to Samos, Crete, Cyprus, and Tunis. I encountered considerable opposition, but a beneficent law was at length promulgated in the spring of 1902, to be followed in the autumn by a similar decree for the whole Ottoman Empire. The Egyptian Government has always shown great interest and care for its sponge fishermen, having founded a colony for them near the excellent harbor of Marsa Matruh, 160 kilometers west of Alexandria, and having also rigorously enforced the law by means of the coast guard.

In 1906 a rich new bank, extending 110 miles from Abukir and having a width of 1 to 3 miles in a depth of 20 to 60 meters, was discovered by some Italian fishermen, who found sponges in their nets. This El Dorado, known as the bank of Port Said, after a most successful cruise thither by a vessel from Syme, attracted sponge fishermen from everywhere. The sponges were of the finest quality, and conditions were most favorable, for the diving apparatus was entirely excluded.

In 1908, however, word began to be circulated that the Egyptian Government could not enforce its law outside the 3-mile limit. The sponge fishermen following the three good methods had meantime begun to assemble near Marsa Matruh, in Alexandria, where a fleet of 350 vessels with 3,000 men waited two weeks for decision from the Egyptian Government. Requests and petitions with thousands of signatures were of no avail. The advocates of the diving machine proved the more powerful, although they possess legal rights only in Greece. The Egyptian Government refused to assert control of the banks out-

side of the 3-mile limit, and the waiting sponge fishermen found themselves at once in competition with vessels equipped with diving machines and armed with rifles, revolvers, and sabers. A crew of naked divers from Kalymnos were fired upon, and in response to complaint of the captain the Egyptian Government apprehended 110 men with 9 diving machines 26 miles off the coast and brought them to Port Said. Instead of prosecuting them, however, and inflicting the punishment that was deserved; notwithstanding that arms and ammunition were found on board their boat; notwithstanding also that they were Turkish subjects and therefore liable to the laws of Turkey and Egypt against diving machines, they were allowed to depart, after twenty-four hours, in full possession of diving equipment, arms, and ammunition.

The hardship upon the original occupants of the sponge grounds was great. After paying their fees of 8 to 4 Egyptian pounds (200 to 100 francs) for permission to fish, they were driven away, and in Syria, whither they resorted, they must pay an equal fee. The banks of Port Said are thus, moreover, left at the mercy of the machine divers. I have appealed to the International Life Saving Congress, held at Frankfort on the Main, and now urge the International Fishery Congress at Washington to give support and sympathy to the unfortunate sponge fishermen who have undergone such loss this season at Port Said.

SPAIN, ALGERIA, AND MOROCCO.

Sponge fishing is not remunerative in Spain, Algeria, and Morocco on account of lack of good sponges. Those to be found there are mostly funnel-shaped, called elephant's ears and simply ears by the Greek fishermen. Ten sailing vessels worked in Spain in 1903 with diving apparatus, coming from Kalymnos, Syme, and Ægina; in 1904 there were only two sailing vessels from Kalymnos and none since then.

ITALY.

Official statistics of the sponge fisheries were attempted in Rome earlier than in Athens, and the Italian Naval Office has for twenty years detailed a small war vessel each summer for the supervision of sponge fishing in Italian waters. The commanders of these vessels see to the maintenance of order, give medical assistance and remedies to the diseased sponge fishermen, supply them with drinking water, and send in reports to the Naval Office. Articles based on these reports are there prepared for publication in the "Condizioni della Marina Mercantile Italiana," published each year by the Ministry of Merchant Marine, in a section devoted to the sponge fisheries. We find in these "Condizioni" abundant material on the sponge trade as carried on in Italy by natives and foreigners, and this material contains naturally some

statistical data. The majority of the foreigners are machine divers on sailing vessels flying the Greek and Ottoman flags, and the "Condizioni" report regularly cases of death, disease, and desertion among them. Since, however, the Greek divers conceal their accidents and misdeeds from the Italian authorities, the statistics are not very complete. In the summer of 1902 the Naval Office promulgated a partial prohibition of the diving machines, regulating the depth in order to prevent disease and death; but the enforcing of such partial prohibition is very difficult, and thus this measure is quite insufficient in practice, as shown by the report of the "Condizioni" for the year 1907 for the cruise of 1905, which mentions four new cases of illness of Greek sponge divers.

According to the "Condizioni" for 1906, there were in the Italian waters in the year 1904, 309 Italian fishermen on 63 sailing vessels of 1,302 tons. The total number of Italian sponge fishers for that year may, however, be computed at 1,270 men on 200 sailing vessels. The official statistics do not mention the 137 sailing vessels which departed for Tunis, nor the quantity and value of the sponges gathered by them. According to the same source, there were in the Italian waters 406 Greek fishermen on 37 sailing vessels, of which 110 on 22 sailing vessels from Kranidion were equipped with dragnet and 296 on 15 sailing vessels from Ægina carried diving apparatus. The fishing grounds were the extensive banks of Lampedusa and Pantellaria, where 36,864 kilograms of sponges, valued at 615,781 francs, were gathered as follows: For the 309 Italians, 247,184 francs; for the Greeks, 368,597 francs, or for each Italian 800 and for each Greek about 908 francs. If we consider, however, that the expenses of the fishery are far greater for the diving apparatus than for the other modes of fishing, we see that the profit of the Italians and of the minority of the Greeks without these machines was in no way smaller than that of the majority of the Greeks using the diving apparatus, with the great difference that all the Italians and the minority of the Greeks fished with harmless means, while the majority of the Greeks used apparatus injurious to their health and to the prosperity of the Italian sponge grounds. The Italian Government hoped to be able to protect these divers by its partial prohibition of 1902, but the desired results were not attained.

The Italian sponge fishers live at Terra del Greco, Porto Empedocle, Trapani, Naples, Palermo, and Catania, using mostly the dragnet and more rarely the hook, and fishing on the banks of Lampedusa, Linosa, Pantellaria, Ustica, the Æolian and Ægadian islands, along the coasts of Apulia and Calabria, Sicily, and Sardinia, and especially the coast of Tunis. In 1887 Captain Leonardo Angugliaro, from Trapani, discovered the extensive sponge banks of Lampedusa, and in the following year Greek fishermen with diving apparatus, under the Greek and Turkish flags, appeared there, to continue in Italy what they had

so thoroughly begun in their native country, i. e., the gradual but sure destruction of the sponge fishery. It was thus that the question of diving machines was introduced in Italy.

We must render the Italian Government the justice to acknowledge that it took and takes pains to obtain information. This is proved by the fact that as early as May 22, 1890, the Italian Naval Office sent a circular to the consuls at Tunis, Tripoli, Korphu, Canea, Piræus, Thessalonica, Smyrna, and Larnaka, containing questions as to the sponge fishing, but the result of this action was not published. In June of the same year the Italian Government detailed to the *Mark Antonio Colonna*, commanded by Eugenio de Gætani, Prof. Enrico Giglioli, of France, a scientist, now director of the Zoological Museum in that city. We owe to the joint work of these men several good maps of the sponge banks of Lampedusa, an unsuccessful attempt to raise sponges artificially, and a few partly correct and partly incorrect observations on the value of the diving apparatus for sponge fishing, which may be found in the report of the "Condizioni." Giglioli, a scientist of great ability, unfortunately favored the diving apparatus in this practical question, having not the least perception of the miseries it brought about. The evils of the method were thus not appreciated by the Naval Ministry and the Ministry of Agriculture, Industry and Commerce and the use of the diving apparatus was recommended to the Italian sponge fishermen often and warmly in the "Condizioni" until 1901.

These frequent official recommendations in the "Condizioni," based upon the reports of the commanders of war ships supervising the sponge fishing, and the success of the Greeks, who concealed carefully their dead and cripples from the Italians, showing only the advantages of the method, induced a few Italians in 1893 to make a few experiments with the diving apparatus. These attempts were without the desired success, however, because in order to obtain the most modest results the life and health of human beings must be sacrificed without pity and no one could or would understand this in Italy, neither the officials of the ports nor the divers who serve in the Italian navy. The experiment to obtain sponges by means of the diving apparatus was tried once and no more, as may be ascertained by the report published in 1894 in the "Condizioni." The observation of the necessary precautions for the divers being followed in Italy, sufficient pecuniary results were precluded. The Naval Office continued to recommend the use of the machines until 1901, however, though fortunately without any success, as may be seen from the reports of 1895, 1897, 1899, and elsewhere.

The following incident, mentioned in the report of the "Condizioni" of 1898 for the cruise of 1897, is very characteristic:

The naval authorities of Lampedusa learned that several Greek divers who met with accidents during their work were secretly buried on a neighboring island. The dispatch

boat *Rapido* brought the proper authorities to the above-mentioned point, and three bodies of Greek divers were found. Microscopic examination, made by the ship's surgeon, showed that the divers were suffocated, and it was found they were afterwards buried by their comrades without notice to the authorities of Lampedusa. Thanks to the presence of the dispatch boat *Rapido*, these regrettable facts were found out and it was shown that the Greek captains of sponge vessels do not observe all the necessary precautionary measures demanded by humanity in this work.

In the interest of justice and humanity the Italian Ministry of the Navy requested the Greek Government to take measures in order that such incidents should not occur again, and the Greek Ministry published on the 3/15 of February, 1898, a circular to the harbor masters and the consular authorities, enjoining them to see that the captains of the sponge-fishing craft observed rigorously all requirements, including the circular issued by the Ministry of the Navy on April 21/24, 1896, on precautions for divers. But all these measures remained without result, because the Greek Government does not fix the responsibility for cases of death and sickness, as we have already mentioned. The Ottoman Government likewise holds no one responsible for the abuse of the diving apparatus in spite of the prohibition of August, 1902.

Fortunately a change has taken place since 1901 in the attitude of the Italian Ministry of the Navy in regard to the diving apparatus. In addition to the partial prohibition of 1902 in regard to the depth, we find in the "Condizioni" during the later years reports almost similar to that of 1906 for the cruise of 1904, which I transcribe here:

> The use of diving apparatus, which was fortunately not adopted by our sponge fishermen, is, although preferred for the selection of the product, always harmful and often deadly to those using it.

This sentence and especially the word "fortunately," as well as the partial prohibition of 1902, is a declaration of the Ministry of the Navy of conviction that the diving apparatus is harmful, a conviction which ought to be substantiated by an entire prohibition. The limited questionable merit for selection of the product is of very small practical value and is easily changed into an evil if we think that after the selection of the large sponges soon the smaller and smallest are taken and the young growth is being crushed by the heavy and broad soles of the divers. The use of diving apparatus in sponge fishing is thus wholly condemned and ought to be prohibited by every wise government.

The other official body in Rome concerned with the fisheries, the Commissione Consultiva per la Pesca, which has been for more than twenty years a part of the Ministry of Agriculture, has as yet taken no action further than to recognize the question as deserving of study, action being deferred pending fuller information. Such delay is most dangerous to the interests at stake, since much evil may be done during the time consumed in further study of the subject.

AUSTRIA-HUNGARY.

The sponge fisheries in Austria-Hungary are located in the village of Crappano, district of Sebenico, in Dalmatia. There were, in 1904, 140 sponge fishermen on 70 barks. Each bark carries a rower and a fisherman, with a five-pronged hook which has a handle 18 meters long. The men smooth the surface of the sea by pouring oil over it, instead of using the tin cylinder with the glass bottom. The annual harvest of sponges per man varies from 225 to 500 crowns in value; a few earned 800 crowns in 1897. The two former figures are below and the latter is above the sum mentioned by the "Condizioni" for the Italian sponge fishers in 1904, i. e., 800 francs.

The Oesterreichische Gesellschaft für Seefischerei und Fischzucht, in Trieste, from whose reports I have taken the data for sponge fishing in Austria-Hungary, have recommended the diving machine to the sponge fishermen of Crappano since 1892, the Imperial and Royal authorities of Trieste prescribing that on the coast of Istria and in the vicinity of the islands of Quarnero the apparatus should not be used at a depth of less than 12 meters and in the Dalmatian waters at a depth of 20 meters; but the enforcement of this requirement is very difficult. Experiments with the diving apparatus failed, however, as in all cases in which an enlightened government provided for personal safety of the divers and the future of the sponge beds. Observation of the necessary precautions precluded all profit. These efforts were met likewise with an obstinate resistance on the part of the majority of the sponge fishermen of Crappano, who recognized a great danger in the diving apparatus. Their own experience as well as the resolutions of the International Fishery Congress at St. Petersburg in 1902, at which the Oesterreichische Gesellschaft was represented, caused the latter to desist from further encouragement of the diving apparatus.

The same society resolved in 1904 to make experiments with the dragnet at depths over 40 meters, having in mind the considerable results obtained by this mode of fishing in the waters of Lampedusa. Such an apparatus was made for the society by a Greek sponge fisherman in Trieste. I have not yet, however, obtained a report of the results it yielded. The Austro-Hungarian waters are divided into zones for sponge fishing, in order to allow time for the sponges to grow to their full size and propagate, and it is forbidden to take sponges of less than 6 centimeters in diameter.

UNITED STATES.

There are numerous sponge banks in the waters of the Gulf of Mexico, especially south and west of Florida, Cuba, Haiti, the Bahama Islands, which are situated outside the Gulf, and in other places. Sponge fishing in the state of Florida has its centers at Key West, Tarpon Springs, and Apalachicola. In 1900

this industry was followed in the first locality by 1,827 persons, in the second by 354 persons, and in the third by 64, making a total of 2,245. Among these, 1,239 men were working on small vessels, 874 on barks, and 132 on shore. There were 1,356 colored and 75 white men among the sponge fishermen, and among the workmen on shore there were 119 white and 13 colored men. According to nationalities, 1,268 were British subjects, mostly from the Bahama Islands, of which 1,013 were colored; 839 were citizens of the United States, of which 343 were colored, 5 Portuguese, and 1 Norwegian. Among the men working on shore 114 were citizens of the United States, all white, and 1 Greek. Up to 1905 the sponges were gathered in Florida exclusively by means of the hook. It is to be regretted that the dragnet is prohibited for the greater depths where the hook can not reach.

In 1900 there were used in sponge fishing 156 small vessels of 1,750 tons in all, valued at $182,151, and 228 barks valued at $176,465. The trade in native sponges was concentrated at Key West and Tarpon Springs, and was carried on by representatives of firms in New York, Philadelphia, and St. Louis, with the exception of one independent firm in each of the two above-named Florida localities. These firms had in this year 17 buyers and 124 other employees and workmen, the annual salary of whom amounted to a total of $43,947. In 1900 there were obtained in Florida 418,125 pounds of sponges, valued at $567,685, while in 1880 there were gathered 207,000 pounds of sponges, valued at $200,750. (These data are taken from official reports of the United States Bureau of Fisheries.)

In February, 1905, the question of sponge diving arose in America. In the course of a few months 70 diving machines from Greece and Turkey, increasing to 100 in the following year, appeared in Florida, and, so far as I could ascertain at such a distance, operated without loss of life, since the work was done in shallow waters. It did so much the more harm to the future of the sponge beds, however, and the practical Americans did not need much time, fortunately, to see the danger threatening from these reckless foreigners. Thus the question arose in the United States, and those concerned were divided into two large groups with diverging interests for and against the diving apparatus, exactly as previously in other countries. All who could obtain a temporary profit declared themselves in favor of the diving apparatus, while all those who had regard for the future were opposed. Both parties had influence and sought justice and protection from the Government, and the matter came before the Houses of Congress in Washington, there to be very promptly investigated and acted upon.

On June 20, 1908, was passed the beneficent law by which the diving dress in sponge fishing was absolutely prohibited in depths of 50 feet and less, and

at depths greater than 50 feet it could be used only from October 1 to May 1. Moreover, the taking of the sponges of a diameter less than 4 inches was prohibited, under penalty of a fine of $100 to $500 or confiscation of the vessel and the diving dress. The important action of the Government of the United States was undoubtedly influenced by the resolutions of the International Fishery Congresses held in St. Petersburg in 1902 and in Vienna in 1905, as well as by the beneficent legislation of so many countries of the Mediterranean Sea, for these were frequently mentioned in the debates upon the subject, as were also the reports of American consuls in countries of this vast sea basin, who have given and still give this important question the consideration it merits, as may be seen from the report of Consul G. B. Ravndal in Beirut. The practical spirit of quick resolution in the Americans deserves high commendation and imitation, and it is to be hoped that this recent excellent example of forethought will influence the slower governments to early action in this important matter.

RÉSUMÉ.

Most of the sponge-bearing countries—Samos, Crete, Egypt, Tunis, and Turkey—exact only a moderate payment of dues from each vessel. Cyprus did the same until 1904; since that date the government of this island has exacted a very high percentage of the harvest of sponges, which is unjust and, moreover, unpractical, as it demands the continuous supervision of each sponge-fishing vessel. The United States, Austria-Hungary, Italy, and Greece exact no fees. I lack the necessary information in this regard as to Cuba and the Bahama Islands.

In fact, as I have stated, there is a lack of complete and general statistics on sponge fishing, especially as to injuries to health and life of the sponge fishermen and the condition of sponge beds arising from the use of the diving apparatus. I obtained the following approximate figures, which vary, however, from year to year, by long years of observations and investigations. The number of diving machines in use by part of the sponge fishermen of Hydra and exclusively by those of Spetzæ and Ægina in Greece; by part of the sponge fishermen of Kalymnos, Syme, Chalke, and Kastelloriso, and exclusively by those of Aivali, Moschonisia, and Marmora in Turkey, has varied according to the year from a few in 1866 to 225 with 1,200 divers and 1,500 sailors in 1898. The adherents of the three good methods may be computed at 10,000 in round numbers, fishermen and sailors, from Syria to Florida. Yet even this figure varies, though somewhat less, according to the years. With their families and the families of the classes closely united with them as priests, teachers, merchants, and artisans, the sponge fishermen form a population of more than 100,000 heads. The yearly mortality of sponge fishermen in the diving apparatus is

about 20 per cent and the seriously and slightly diseased reach annually 25 per cent. The health of the sponge fishermen working with the hook and the dragnet is not exposed to the slightest injury. Only the naked divers run at times the danger of being attacked by a shark, but accidents of this kind are so rare that the fishermen do not consider them at all. The number of victims of the diving apparatus during the entire time of the abuse, i. e., during forty-two years, may be computed at 5,300 dead and 2,300 seriously disabled, while cases of slight diseases, transformed into serious ones with time and ending in death or chronic ailment, attack all divers after a longer or shorter period of work in the machines.

For the future of the fishery as well as the welfare of the fisherman the diving machine is most harmful. It has been contended that the diver fishes without disturbing the bottom. This is not true. The heavy apparatus breaks and crunches the embryo sponges that lie in the path of the diver, and he searches over the entire sponge-bearing area. He takes, moreover, not only the largest and best sponges but also the small ones, arguing that what he does not take to-day will be taken by some one else to-morrow, and he fears also the cruel captain. The naked divers, on the other hand, are unable to take so many sponges or to harvest so closely, since their stay under water must be brief. Their season is from April to September. The hookers and the dragnet fishermen work throughout the year, but it is to be noted that the dragnet can not be used either in total calm or in gale or storm, while calm or light breezes are necessary for the naked diver or the hooker. Thus it will be seen that each of these methods is subject to frequent and sometimes long-continued interruption. Their harmlessness as compared with the scaphander is obvious.

Experiments in artificial raising of sponges, although undertaken frequently, have never been successful and probably never will be on account of the very nature of things. When the sponges are torn from their roots a milky fluid flows from their elastic tissues, and it is this fluid that contains the germs of new sponges, which are carried along by the currents as the seeds of some plants are carried by the wind, until they attach themselves and grow. A sponge needs four to five years to reach maturity, after which it begins to die, having discharged its fluid with the germs. The sea currents, which the sponge needs for its growth, are an obstacle to artificial raising of sponges, for while they allow the microscopic embryo to fasten itself to a suitable spot, they do not permit cuttings selected for culture purposes to do so, and the equipment necessary to overcome this is easily destroyed by storms. Moreover, if it were possible for science to succeed in effecting this miracle, on a small scale and at a large expense, the result would be of no commercial value, as all the most effective conservation of the sponge beds would be accomplished by prohibition

of the diving apparatus. This would cost neither money nor labor, and under it the sponges would propagate abundantly, while hundreds of lives would be saved or benefited thereby.

APPEAL TO THE INTERNATIONAL FISHERY CONGRESS.

My work in the cause of the sponge divers at first consisted of efforts to arouse public interest in their behalf, by written communications and petitions, by publications in the press, and by lectures on the subject. I at length, however, resorted to direct appeal to the authorities of the different countries concerned, presenting my cause in person. I have likewise organized societies or enlisted the efforts of existing organizations wherever possible, and have brought the matter before various official and unofficial bodies. As recounted in the preceding pages, all of the sponge-bearing countries of the Mediterranean, and also the United States of America, have passed prohibitory or restrictive laws. For the most part, however, the laws have been ineffective, by reason of intrigues on the part of advocates of the scaphander and indifference on the part of the governments. The various international congresses before whom the question has been brought, while in one or two instances slow to act, have for the most part given prompt and full indorsement of my plea. I am now addressing the International Life-Saving Congress at Frankfort on the Main, and at the same time making a fervent appeal to the International Fishery Congress at Washington. The measures for which I solicit the support of these congresses are the following:

(1) Prohibition of the diving apparatus and protection of the three good modes of fishing brought down from antiquity.

(2) Inauguration of an international supervision of the execution of international measures against the illegal sponge fishing with diving apparatus in neutral waters where the national supervision is not sufficient.

(3) Establishment of life and accident insurance as well as of savings banks for the sponge fishermen.

(4) Care of the surviving victims of the diving apparatus.

(5) Levying of dues for the permission to take sponges, and the utilization of part of this revenue in behalf of the sponge fishermen.

(6) Rigid supervision of the execution of these measures on land and on water.

Since parts of this programme have already become law in various interested countries and have operated with the best of success, there is reason to hope that they will soon meet with recognition and execution in countries where little has as yet been done for the suffering sponge fishermen.

The question of maritime jurisdiction is a further problem of importance in the sponge fisheries. Greece, Turkey, Tunis, the United States, and lately

Egypt, have accepted the 3-mile limit in the dispute as to the use of the scaphander—an old formula not applicable in scientific administration of the sponge fisheries, since the sponge grounds often lie beyond that distance from the coast. It is to be hoped that all enlightened governments will give due recognition to this fact and in regard to the sponge fishermen will assume jurisdiction over a zone of 60 miles to seaward, abolishing the abuse of the scaphander within that territory. I earnestly solicit the International Fishery Congress to recommend such action.

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A PRACTICAL METHOD OF SPONGE CULTURE

By H. F. Moore

Scientific Assistant, United States Bureau of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded the prize of $100 in gold offered by Hayes Bigelow for the best demonstration, based on original investigations and experiments, of the commercial possibilities of growing sponges from eggs or cuttings

CONTENTS.

	Page.
Conditions and needs of the sponge fisheries	547
Previous experiments in sponge culture	550
Possible lines of experiment:	
Grafting	553
Growing from eggs	554
Growing from degenerative bodies and dissociated tissues	555
Growing from cuttings	555
Propagation of sponges from cuttings:	
Seed sponges	555
Cuttings	557
Attachments	559
Planting	566
Rate of growth	569
Mortality	576
Shape and quality	578
Harvesting	579
Transportation and acclimatization	580
Economic application of the method:	
Essential considerations	581
Financial aspects	583

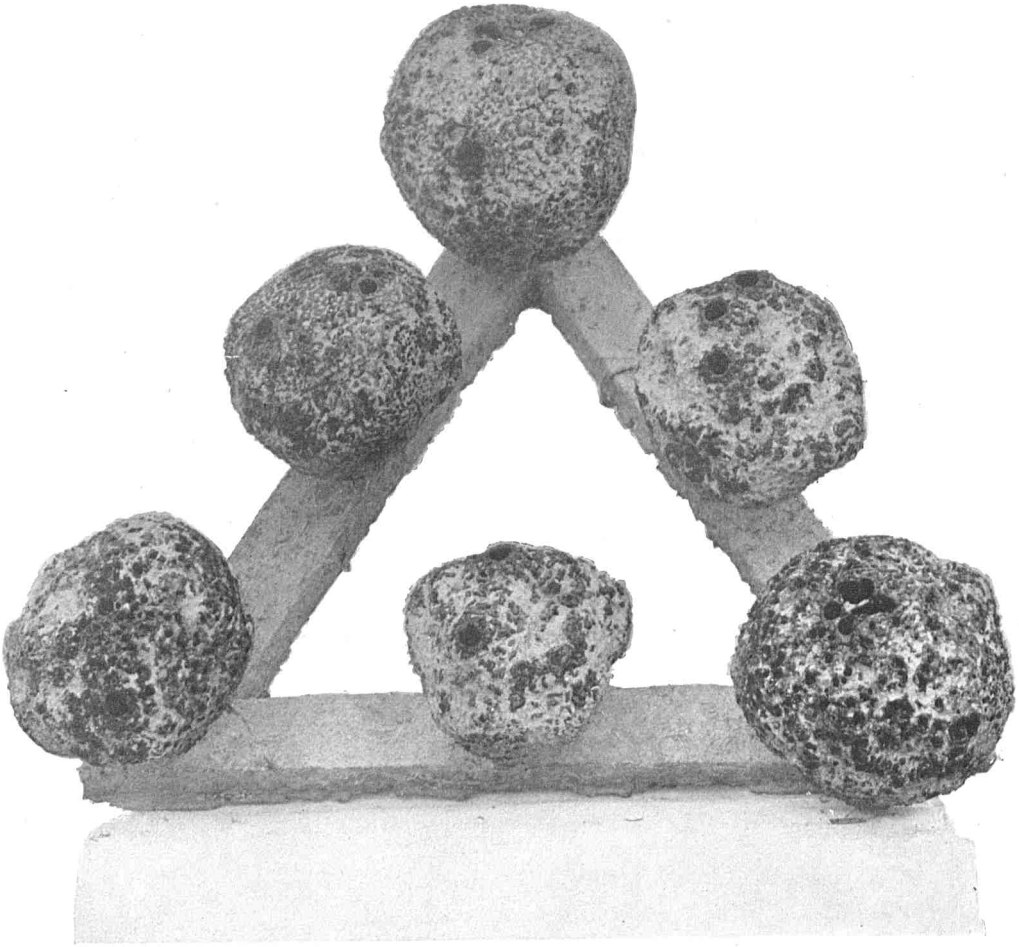

FIG. 1.

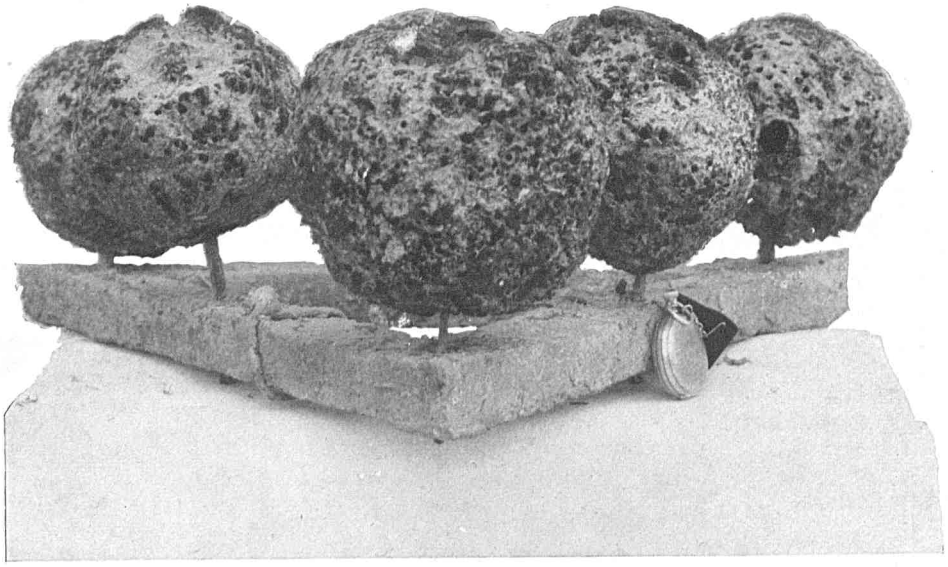

FIG. 2.

SPONGES GROWING ON CEMENT TRIANGLES USED IN EXPERIMENTAL PLANTS OF CUTTINGS.

A PRACTICAL METHOD OF SPONGE CULTURE.

By H. F. MOORE,
Scientific Assistant, United States Bureau of Fisheries.

CONDITIONS AND NEEDS OF THE SPONGE FISHERIES.

As has been shown elsewhere,[a] all or most of the important sponge beds of the world are being fished in such manner as to give more or less grave concern as to their depletion. In the Mediterranean, the Bahamas, Cuba, and Florida the danger of commercial extinction is exciting discussion among the thoughtful, though often denied by the more shortsighted of those who are most intimately concerned, the persons who as fishermen and dealers are dependent upon the sponge fishery for a livelihood. The reasons for the imminence of this danger the writer has elsewhere discussed and the condition is here taken for granted.

Statesmen, men of science, and men of affairs have all taken part in the discussion of the measures necessary to perpetuate the supply of this commercially valuable and almost essential product, viewing the situation not only from the standpoint of the sponge fisherman and the dealer, but from the more important view of the consumer, who can find no satisfactory substitute for the sponge in many of its applications to the arts and domestic uses. It is indubitable that the threatened extinction of many of the beds is due to the employment of methods of fishing which are in themselves destructive, and that, especially in Florida, the Bahamas, and Cuba, a still greater danger lies in the improper use of methods which, properly controlled, would be open to no reasonable objection.

The illegitimate taking of small sponges on the Florida coast by both divers and hookers is, for instance, an almost wanton destruction of natural wealth. Many of these small sponges, of little practical use and worth but a few cents apiece, if given two years' additional growth would increase in value a score, and in addition would furnish myriads of larval sponges to replenish the bottoms bared by more legitimate operations. Every young sponge has

[a] Moore, H. F.: Commercial sponges and the sponge fisheries, Bulletin Bureau of Fisheries, vol. XXVIII, 1908, p. 399–511.

commercial potentiality both as an individual and as a parent, and in both respects its utility is vastly curtailed by premature destruction.

Legal measures for the prohibition of especially destructive methods, and the regulation of abuses connected with the more legitimate means of taking sponges, would undoubtedly, if properly enforced, do much to make more remote the depletion of the beds. But aside from the difficulties encountered in enforcing such legislation, as is witnessed in the failure of the considerable navies maintained by some of the states to enforce the oyster laws, such regulation could but retard the approach and not prevent the arrival of the day when the product of the natural beds will be inadequate to the demands of the markets. Even a legitimate fishery prosecuted under the spur of an increasing demand is eventually able to exterminate for all practical commercial purposes any sedentary organism toward which it may be directed.

When the demand is light and prices consequently low, as they were for many years after the discovery of the Florida beds, the more populous grounds only may be worked with profit. When the sponges become so few and scattered that the time spent in looking for them greatly exceeds that expended in actually taking them from the bottom, profits are reduced to a degree when a closed season is automatically established by the removal of the spongers to other and denser grounds, and an opportunity is given for the replenishment of the beds by natural means. As the demand increases and the product becomes more valuable, more persons are attracted to the fishery, the methods become more efficient, and the degree of depletion of the beds, serving as a deterrent to further operations, more nearly approaches the limit of actual extinction. The beds are scoured year after year for the few remaining sponges, the decreasing supply and the increasing demand operating together to make profitable a closeness of search before unthought of and giving a value to small and otherwise undesirable sponges which in the earlier days of the fishery would have been allowed to lie unmolested on the bottom for want of a market. The consequence of this is that when a ground is finally even partially abandoned as a profitable fishery so few sponges are left, and these are so small in average size, that the reproductive capacity of the area is most seriously reduced and a long time must elapse before the bottom can be reseeded by nature's unaided operations.

Some assistance could be rendered by the establishment of closed seasons, not so much those which prohibit fishing for a more or less restricted period each year, but such as would deny the right to fish on given depleted areas for terms of sufficient duration to permit the remaining young sponges to grow to reasonable marketable size and become of greater potential value in reseeding the area with a fresh crop of young. If such regulation could be rigorously and intelligently enforced, and if it were supplemented by measures preventing the taking

of sponges of a less diameter than at least 4½ or preferably 5 inches, the danger of extinction of our American beds would be eliminated; but there are certain serious objections which may be urged against this solution of the difficulty, which at best can be but a partial solution. Aside from the difficulties and expense of enforcing such regulations and the hardship which they may at times work upon the spongers, the most serious objection is that they would from their very nature restrict the output of the fishery, or, at best, would not permit its development commensurately with the increasing demands of the markets. The writer has discussed the question at length in the paper above referred to, but for present purposes it appears to be advisable briefly to consider again the force of the last and major objection just mentioned, particularly with reference to the waters of the United States, although the application is general.

That the demand for sponges is growing rapidly can not admit of dispute. Prior to the discovery of the beds of Florida the imports of sponges into the United States were insignificant, and of course none was produced at home. There was practically no demand, except for domestic purposes. Thirty years later, in 1879, the imports had increased to an average value of $100,000 to $120,000, while the average annual importation for the three years from 1905 to 1907 was valued at no less than $531,745. The domestic production grew from nothing in 1849 to $200,000 in 1880 and an average of $658,403 per year from 1906 to 1908, most of which was consumed at home. In certain other countries also, notably Russia, Turkey, Spain, and the various states of South America, where very few or no sponges were formerly used, the past two decades have developed an important consumption. With the development of civilization and modern methods of industry the countries of Asia, too, are sure to make important demands for this practically indispensable product of the seas.

No doubt new beds will be discovered from time to time and new regions will come into productiveness, but it is not believed possible, in view of what is known of the resources of the sea in most localities in which sponges may be expected to occur, that any vast areas producing the more desirable grades will be brought to light. If regulations governing the fisheries will merely preserve what we now have and will not materially augment production, there is forced upon us consideration of the necessity and possibility of increasing the supply by artificial means analogous to those employed in oyster culture or some other type of aquiculture. From a study of the breeding and life history of the commercial sponges two broad avenues of experiment open themselves. Research has shown that sponges may be propagated either in the natural sexual way by means of eggs, or artificially by cuttings or their equivalent. The following is a brief history of various observations, experiments, and suggestions in these directions:

PREVIOUS EXPERIMENTS IN SPONGE CULTURE.

The basis of sponge culture by means of cuttings is in an observation made by F. Cavolini[a] in 1785, that sponges cut into pieces would attach to foreign bodies and grow.

In 1862 Oscar Schmidt[b] repeated and confirmed this observation and was apparently the first to make the practical suggestion that the regenerative phenomena might be utilized in the development of a system of sponge culture. This suggestion bore fruit in the following year when the Austrian Government and certain merchants of Trieste established a station on the island of Lesina, which in 1867 was placed in charge of Gregor Buccich. Of the experiences of the first four years of this work there appears to be no record, but Buccich submitted a report which was made the basis of a paper by Dr. Emil von Marenzeller[c] in 1878.

Buccich appears to have discovered most of the salient facts relating to the growth of sponges from cuttings. He found that sponges can be removed from the water and cut in the air without injury; that in cool, damp weather they can be exposed to the air for eight hours without suffering material injury; that they can be cut and handled with less liability to injury during the winter; and that the cut surfaces will grow together or to certain foreign bodies with which they may be placed in contact. He observed also that apparently similar cuttings were sometimes dissimilar in their rates of growth, and that some cuttings would heal and live for years without material increase in size. Concerning the rate of growth, the information is indefinite. The cuttings were small (about 1(?) inch cube) and they are stated to have doubled or trebled in size (bulk?) during the first year, and to have grown to a "considerable size" in five years, but that seven years would be required to produce a commercial product. There is no statement of the actual mortality among the cuttings experimented with, but it is estimated, upon what basis does not appear, that it would not be over 10 per cent during the seven years.

The methods employed by Buccich were various. He pegged the cuttings to stones, to the inside of wooden boxes, and to various other contrivances. In perforating the cuttings to admit the pegs, which latterly were of bamboo, he used "a trepan 6 millimeters wide, fastened to a vertical turning table, which was kept in rapid motion by a fly wheel." The experiments were ultimately abandoned after nine years, mainly on account of the hostile attitude of the inhabitants. The somewhat elaborate methods of handling and planting

[a] Cavolini, F.: Memorie per servire alla storia de' polipi marini. Naples, 1785.

[b] Schmidt, O.: Die Spongien des Adriatischen Meeres. Leipzig, 1862.

[c] Von Marenzeller, E.: Die Aufzucht des Badeschwammes aus Theilstücken. Vienna, 1878. Translated in Report U. S. Fish Commission, 1879, p. 771–777.

the sponge and the character of the materials employed appear to have been unfit for commercial application. Marenzeller observes: "As far as our present knowledge goes, it is certain that sponge culture will not be profitable for poor men, but can be only carried on successfully on a very large scale either by wealthy individuals or by joint stock companies."

The failure of Buccich's work to yield commercial results appears to have ended experiments in Europe, but about 1879 Mr. Fogarty, a sponge buyer of Key West, Fla., planted 216 cuttings in a depth of about 2½ feet of water. The pieces were about 2½ inches long; they were attached to the bottom by sticks and wires, and it is stated that it required four months to repair the injuries and reestablish growth. Four specimens, said to be six months old, sent to the National Museum are stated to have grown from four to six times the bulk of the original cuttings. This experiment was never pushed to a conclusion, and the fate of the cuttings, other than those mentioned, is unknown. A few years later Mr. R. M. Munroe, of Cocoanut Grove, Fla., began work in Biscayne Bay, where for several years he experimented in fastening cuttings to stones and various arrangements of stakes forming hurdles and frames. A large proportion of the pieces survived and grew to some extent, but none reached a greater bulk than 3 or 4 cubic inches, and practically all were eventually destroyed or lost. The bottom selected and the materials employed were in some cases unsuitable and in others the antagonism of some of the spongers prompted them to destroy the plants. At this time the first sponge-culture law was presented to the legislature of Florida, but it was subsequently so amended as to be highly objectionable and unjust to the spongers and it consequently failed of passage.

About 1897–98 several thousand cuttings were planted at Sugar Loaf Key by Dr. J. V. Harris, of Key West. They were attached to galvanized iron wire laid on the bottom, but the wire soon corroded and broke into short pieces, the sponges became detached, and the mortality was very high. From time to time I have picked up a considerable quantity of this wire with a few attached sponges. Growth appears to have been slow or, after a while, almost entirely arrested, and the largest specimens seen by me have been under 4 inches in diameter at an age of from 3 to 5 years, the exact age of any given specimen being indeterminate. The quality of the sponges in the vicinity of their attachment was also injured by iron rust. In addition to the sponges planted as described, Doctor Harris planted many thousand cuttings by sowing them broadcast over the bottom. It is not improbable that some of these may have attached to rocky patches of bottom and grown, but if so they became indistinguishable from the natural growth, and their history is lost.

In January, 1898, Dr. H. V. Wilson presented before the National Fisheries Congress, held at Tampa, Fla., a paper[a] making some suggestions on rearing sponges from the egg and on improving their quality by grafting. In June, 1907, he published[b] some results of his experiments with certain noncommercial sponges at the United States Fisheries Laboratory, Beaufort, N. C., demonstrating that they could be raised by regeneration from degenerate masses to which the sponge is reduced under certain artificial conditions of confinement. Doctor Wilson suggested that this phenomenon would probably be presented by the sponges of commerce and might be utilized in a system of sponge culture for economic purposes. The same investigator has since discovered that practically the same effect can be produced by squeezing the soft parts of the sponge through bolting cloth into vessels of sea water, the expressed tissue substances, aggregating themselves into little heaps on the bottom, eventually regenerating the skeletal tissues and developing into complete sponges. None of these experiments has been performed on commercial species and the growth of the new individuals has not been kept long under observation, but I believe that there is no good reason to doubt that it would be possible to apply the methods successfully to any of the economic sponges of Florida.

With the exception of my own investigations and the related and parallel experiments of Messrs. Cheyney and Bigelow recounted in the main part of this paper, I believe the foregoing to cover all actual experiments in sponge culture, save one or two cases in which a very few cuttings or small sponges have been planted on the bottom by persons engaged in the industry; but in 1895 Bidder[c] considered the question from a purely academic standpoint and raised certain questions as to the utility of the whole project. Mr. Bidder on a priori grounds reached the provisional conclusions, inter alia (1) that the total volume of the new sponges grown from cuttings would not exceed the volume of the original sponge if it were permitted to attain its natural growth under the same conditions for an equal time; (2) that sponges or cuttings raised above the bottom, as in Buccich's experiments, would probably grow more rapidly than the same or similar individuals on the bottom; and (3) that the sponge-bearing area, naturally confined practically to the bottom, might be extended by using a suspension system of culture in which several strata between the surface and the bottom might be utilized by appropriately constructed supports for the growing sponges. How far some of these questions are answered by my own experience will be seen in the following pages.

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[a] Wilson, H. V.: On the feasibility of raising sponges from the egg. Bulletin U. S. Fish Commission, vol. XVII, 1897, p. 241–245. 1898.

[b] Wilson, H. V.: A new method by which sponges may be artificially reared. Science, n. s., vol. XXV, no. 649, p. 912–915. 1907.

[c] Bidder, George: Notes on projects for the improvement of sponge fisheries. Journal of the Marine Biological Association of the United Kingdom, vol. IV (n. s.) p. 195–202.

POSSIBLE LINES OF EXPERIMENT.

Under instructions from the Commissioner of Fish and Fisheries, experiments in sponge culture were inaugurated in January, 1901, at Sugar Loaf Key and at divers places in Biscayne Bay. From the beginning the aim has been not to demonstrate purely scientific possibilities, but to develop, if possible, a system of sponge culture having present economic application, the condition of the fishery being such that there may arise at any time an exigency demanding immediate measures of relief to the overtaxed natural beds.

As has been seen from the preceding historical résumé, a number of theoretical considerations have been offered by various persons and several attempts have been made toward a solution of the problem. It has been proposed to multiply and improve sponges by growing them from cuttings, from the egg, and from the peculiar degenerative masses described by Wilson, and by grafting superior varieties upon those less desirable. Each of these, except the third, which has been but recently discovered, was considered when the present experiments were begun.

GRAFTING.

It does not appear that there is much of value in the suggestion as to grafting, which is based upon an imperfect analogy between certain aspects of the process of growth in sponges and in the higher plants. Cut surfaces of related varieties of sponges, as of related varieties of plants, will fuse and heal if brought into proper apposition, but there the analogy ends. In grafted plants each member of the union (stock and scion) furnishes essential parts of the compound, the stock supplying the roots and trunk of a tree, while the scion develops the branches, foliage, and fruit. Without foliage the stock would die, and without roots the scion would not survive. In plants, too, each member of the graft produces a definite influence on the resultant whole, making it more or less unlike either of the pure varieties of which it is compounded. The fruit produced on the scion will differ from that which is produced by the ungrafted stock, while the influence of the latter may be seen in greater hardiness, a different size and general habit, or in other respects. With sponges the case is quite different. The two members of the union will have the same organs and be essentially similar even though they may differ in quality and texture. One piece may be attached or rooted, but that is immaterial and in a measure accidental, for the so-called root is merely a part of the surface adherent to some foreign body and performs no particular function other than that of anchorage. If the sponge be torn loose, some other part of the surface may with equal facility become the root, or more likely the sponge will continue to live and grow as an unattached individual or "roller." As has been shown by experiment, if a graft be made, each piece will continue to grow independently without influence upon its fellow except in limiting

the direction of its growth, although the character of one or both may be affected by any change in environment. A cutting from a sponge transplanted and grafted on another growing in a different environment will tend to approach the latter in character, not as the result of the graft, but on account of the physical surroundings, precisely as it will do if transplanted to the same locality without grafting. In other words, nothing can be done by grafting that can not be more readily done by propagation from cuttings which attach themselves, and the former process results in a waste of time and effort without compensating advantages. Neither cutting is improved by the amalgamation. Sponges of the same species will unite if grafted. Sheepswool sponges from different localities readily fuse, but they will not unite to either yellow or grass sponges, and probably not to any species other than their own.

GROWING FROM EGGS.

That sponges can be grown from eggs to a marketable size under the control which is essential to any system of sponge culture appears probable, but it has not yet been demonstrated. Although experiments made with the noncommercial sponges show that they can be kept alive for a considerable time after development from the egg, I know of no cases in which they have been artificially raised to maturity or to any considerable size, and experiments with the commercial sponges are still less conclusive. Raising sponges from the egg must probably always remain a delicate operation, practicable only to skilled investigators provided with special facilities and entirely beyond the reach of the practical man engaged in a commercial enterprise. For that reason the method appeared to be ill-adapted to the present needs of the sponge fishery and was therefore discarded in the experimental work described in the present paper. As has been pointed out, however, in an academic discussion of the proposition by H. V. Wilson, it may be that this method will have a distinct place in the sponge culture of the future, though its development and practice must probably necessarily be in the hands of a few skilled operators. It may be possible to breed sponges from selected parents, thus improving their quality and supplying better seed sponges from which to make cuttings. Possibly some system of hybridization may be developed along lines analogous to those which have produced such astounding results in the hands of experimental horticulturists.

The plasticity of sponges and their extreme susceptibility to environmental influence, as well as the technical difficulties which the experimenter must overcome in his attempts at breeding and hybridization, will probably long postpone, if they do not entirely defeat, successful efforts in this direction. The problem is one which may well be taken up and studied when the Bureau of Fisheries comes into possession of a properly equipped laboratory in the sponge region of Florida.

GROWING FROM DEGENERATIVE BODIES AND TEASED OR DISSOCIATED TISSUES.

Wilson's extremely interesting and scientifically important studies in this field open, as he points out, a new means by which sponges may be propagated. The experiments so far have been confined to noncommercial species, but there appears to be no reason for believing that they can not be applied to horny sponges. In fact, in certain "sick" sheepswool sponges in my experimental plants I have observed in the dead skeletal remains certain degenerative masses resembling, at least superficially, those described by Wilson in silicious sponges.

Wilson's methods are to induce the partial death of the sponge and the production of small degenerate bodies in the remaining living tissue, or to tease up the soft tissue, or finely divide it by squeezing it through bolting cloth bags. The resulting small masses speedily attach and regenerate into little sponges.

Leaving out of consideration the morphological significance of these processes, and viewing them solely from the practical standpoint of sponge culture, these methods of rearing sponges appear to be essentially similar to rearing from cuttings made with a knife, the main difference being that the tissue aggregates, or pieces, are obtained by an elaborate method instead of a simple one.

GROWING FROM CUTTINGS.

This method was adopted as that giving greatest promise of success, and it is discussed in detail in the following chapters.

PROPAGATION OF SPONGES FROM CUTTINGS.

Growing sponges from cuttings has to recommend it, as a practical method, its simplicity and the certainty with which the excised pieces will attach and regenerate when placed under suitable conditions. The ease with which suitable seed sponges may be obtained at any season, their immunity from the effects of more or less rough handling, the facility and rapidity with which they can be attached to such materials as may be selected, the promptness with which they will grow fast to suitable foreign bodies, and the certainty with which they heal and grow into perfect sponges make this an immediately feasible method of sponge culture, provided the proper means of attachment and methods of handling can be developed. How far the present experiments have solved the problems will be seen in the following account.

SEED SPONGES.

For seed any healthy sponge may be used, whatever its shape or size. Torn and irregular specimens, or those so filled with sand and other foreign matter as to make them of little value in the markets, may be utilized equally with well-shaped ones, though they often do not cut so economically in respect to either material or time. When the seed sponge is heavily loaded with shells, corals,

and similar material, there is always considerable waste and much time is lost through the dulling of knives and the necessity of avoiding obstacles too stout to cut. For this reason it is economy to select the cleaner specimens for seed when they can be readily obtained. The sponges as fast as detached from the bottom should be placed in a gunny sack or net attached to the side of the boat or, if taken by diving, carried by the diver, the sack when full being emptied into a live car. During cool or moderately warm weather, treated thus, they will remain alive and uninjured for several weeks, though if the sea be rough their surfaces are likely to become more or less abraded by rubbing against the sides of the car. They must not be brought into water at all brackish, however, or they will be speedily killed. In warm weather if long confined even in salt water some will sicken and die, and the resulting foul water will soon produce a general epidemic.

In carrying live sponges from the beds to the planting grounds a boat-shaped or spindle-shaped live car will be found most convenient, as either can be towed rapidly and for long distances without injuring the contents. The car should be provided with several "thwart-ship" bulkheads or partitions dividing it into compartments, and the slits or perforations in the forward end should be small or narrow so as to reduce the violence of the currents set up by its rapid passage through the water. If these openings be large, the sponges will churn violently or be massed under pressure at the after ends of the compartments and are certain to be more or less injured. The car preferably should be constructed entirely of wooden slats and boards, as wire netting tends to abrade and injure the surfaces of the sponges. Where a boat with a small "well" is available, sponges can be transported in that, or when the distance is short they may be carried in tubs of water protected from the sun by cloths or sacks, but they should be removed from the tubs and placed in open water as soon as opportunity occurs. In cool weather they can be readily carried for many hours without water if they are protected from the sun and rain and kept moist with sea water. At the planting grounds the sponges may be kept best and most conveniently by stringing them on rope yarns about 5 or 6 feet long, the two ends of which are then tied to stout lines or wires stretched between stakes so that the sponges are suspended just clear of the bottom. In a situation where the water is sufficiently salt and pure they will readily live longer than the lines will last, and at the same time they will be easily accessible, those required from time to time being conveniently detached without disturbing the remainder.

There is some reason to believe, as is discussed later, that in regions which have been for years subject to an intense fishery, especially where the water is shallow and generally clear, a race of slow-growing small sponges may be developed by constantly selecting out the larger more rapidly growing specimens,

and that cuttings made from such seed will not grow as rapidly as those from more virile stock. When there is reason to suspect this, seed should be brought from other localities.

CUTTINGS.

In the beginning of the present experiments the cuttings used were small, about 1 by 1 by 1½ inches, the purpose being to secure as many plants as possible from a given quantity of seed sponges. This size gives from 100 to 120 plants from a 6-inch sponge. Theoretically the use of small cuttings was correct for securing the greatest ultimate product from a given amount of material. As is shown hereafter, the average growth in diameter is fairly constant for the first four years at least, and the relative increase in volume or weight is therefore greatest when the cuttings are small. Growing at the average rate of 1 inch per year, 120 cuttings made from a 6-inch sponge would in four years reach a volume of about 75 times that of the original sponge, provided there was no mortality, whereas the same sponge cut into 20 pieces, in the same time and under the same conditions, would increase about 20 times, while if the seed sponge were planted entire it would increase but 4 or 5 times, provided it grew at the average rate established for specimens up to 8 inches in diameter. This is illustrated in principle, though not in detail, in figure 6, page 575. The solid line shows graphically the growth of an entire sponge, the middle dotted line the aggregate increase in a sponge of the same size cut into 20 pieces and the upper line the increase when cut into 50 pieces, in each of the latter two allowance being made for a mortality of 5 per cent of the cuttings per annum.

It was found, however, that the smaller pieces were placed at considerable disadvantage by reason of the greater readjustments required to perfect again the canal system, and moreover when they were injured, as frequently happens, a proportionately larger part of their substance was affected and the regeneration required to convert the fragments into functionally and anatomically perfect sponges was more drastic. These two factors operated to produce a somewhat higher mortality in the small cuttings than in larger ones, and moreover tended to retard materially the growth of the first six months, though after that there was little difference between the diametric increase of large and small pieces. The smaller cuttings also require a longer time to reach a marketable size, the planter has to wait longer for his returns, and in the meantime the sponges are subject to such risk of disaster as may exist. In properly selected localities the last consideration is not very grave. It was necessary, therefore, to effect a compromise between the theoretically economic advantage of employing small cuttings and the practical biological superiority of large ones, and it was finally established that pieces about 1½ by 2½ by 3 inches

(pl. LXIX) or of approximately the same volume, were the best, all things considered. The shape of the cuttings will, of course, vary with the size and shape of the seed sponge, but the more nearly equilateral they can be made, the more generally satisfactory they will prove. Thin edges or ragged parts are likely to die and slough off.

In making the cuttings it is generally better first to cut away the roots of the seed sponges if they contain fragments of rock or coral or shells. Otherwise much time is lost through the dulling of the knives. For this rough work it is well to use a heavy knife with its edge serrated by vertically grooving the flat face of the blade with a three-cornered file, converting it into practically a sharp-edged saw. For making the actual cuttings large butcher knives of good quality should be employed, and they should be kept sharp by frequent whetting with a coarse stone, such as is used for sharpening scythes. A rather rough ragged edge is preferable to a smooth one. If the knife be in proper condition the sponges will cut as readily as beef liver, but if it be dull the operation is slower and the cuttings are liable to injury by the compression of their tissues under the knife.

The direction of the cuts will depend upon the size and shape of the seed sponge, but in the majority of cases the latter should be placed on a wet board, root down, and cut into slices from 1¼ to 1¾ inches thick, each of these being subdivided to best advantage as dictated by the judgment of the operator. It is desirable, but not essential, to leave on each cutting one surface covered by the uninjured skin of the original sponge. I have successfully grown cuttings taken from the interior of the sponge, but while the mortality is no higher and a new skin is soon formed over the entire surface, growth appears to be somewhat more slowly initiated than in the case of normal cuttings.

Neither the seed sponge nor the cuttings are injured by moderate exposure to the air, but it is safer, especially in hot weather, to throw the pieces into a tub of fresh sea water as soon as cut. Care should be exercised to change the water at intervals of about one hour, as the cuttings will be injured and probably die if left for any length of time in foul water and a few fragments of dead sponge will speedily contaminate a tubful. Neither the entire sponge nor the cuttings should ever be brought into water much below oceanic saltness and care should always be taken to protect the tubs from rainfall, which appears to have an effect disastrously out of proportion to its volume. If it is necessary to keep cuttings over night they should be placed in netting bags and hung in the open water, but they should never be so left more than a day or two, as they will soon grow together and be separable without injury only by the knife. Specimens left in contact for three or four days have grown into conglomerate masses difficult to handle.

ATTACHMENTS.

The chief problem confronting the experimenter in sponge culture is to find some ready and economical means of attaching the cuttings to a durable support which shall be capable of resisting the chemical action of sea water and the ravages of the teredo and other animals having similar destructive habits, and which at the same time is without injurious effect upon the sponges. During the course of the present experiments numerous materials and methods were employed, most of which sooner or later demonstrated their unfitness to fill the requirements. It was found that the cuttings would speedily attach to any firm, clean, innocuous material, and many methods of attachment appeared satisfactory for a year or two, but then developed some defect due to corrosion, tensile weakness, or the lack of sufficient attaching surface. It was necessary to await developments before the direction of further experiments was indicated, and much time was expended on materials which afterwards developed unexpected defects.

During the first season the cuttings were attached to stakes and rectangular frames laid on the bottom, to vertical stakes, and to pieces of coral rock and small copper wires laid on the bottom. Some of the sponges were threaded on the supporting copper wires and others were bound to them by means of short pieces of lighter wire, with the expectation that the sponge would eventually encompass its support. About six weeks after the plants were made it was found that 95 per cent had healed and were living under apparently healthy conditions, but seven or eight months later most of them had died. It was expected that the action of the sea water on the copper wires would produce poisonous salts, but in quantities so small as to have merely a local effect. It was found, however, that wires one-sixteenth inch in diameter were completely corroded away in places, especially where the cuttings were attached, and the latter were either killed, or lost by the breaking of the wires. The effects were especially pronounced when the wires were lying on the bottom. The cuttings placed on the bottom on rocks and stakes soon became covered with silt and vegetable growths and were either killed or lost, and it was evident that the choice of both materials and localities had been unfortunate.

During the winter of 1901–2 advantage was taken of the experience gained during the preceding year, and in addition to Biscayne Bay and Sugar Loaf Key, where the first year's experiments were made, Anclote Key was selected as an additional locality. Instead of using naked copper wires, various types of insulation were tried, other metals, including lead and heavily galvanized iron, and various cordage materials were experimented with, and molded forms of terra cotta, plaster, and cement were used in place of the rocks and stakes placed on the bottom. The more or less expensive insulations composed of

various patented compounds of rubber, etc., which have been found to possess superior properties for electrical purposes, soon developed their worthlessness for sponge culture, the insulation being affected by salt water and stripping from the wires. Underwriters' insulation, so called, a cheap covering of cotton and white lead, proved to be more durable and lasted for upward of two years, but it, too, eventually stripped or crumbled from the wire. Ordinary telegraph wire electrolytically galvanized rusts very quickly and breaks into pieces. Iron wire galvanized by the "hot process" will last for a number of years if kept fully immersed in sea water, but when it is periodically partly exposed at low water it rusts more quickly, and moreover the zinc coating kills that part of the cuttings brought into contact with it. Iron wire coated with lead is also quickly destroyed, and copper wire coated in the same way kills the sponges. Plain or "black" iron rusts quickly and breaks, and the iron salts are injurious to the fiber of the sponges. Aluminum wire is innocuous as to its salts in sea water, but is rather expensive when of sufficient diameter, and is subject to rapid corrosion in spots, causing it to break into pieces.

Asbestos cord was found to be practically indestructible chemically, but when wet the fibers become loose and frayed and so slippery that the tensile strength is seriously reduced. This difficulty was overcome by treating the cord with rubber solutions, white lead, a mixture of paraffin and asphaltum and other waterproofing and cementing substances. This treatment very greatly increases the strength of the cord, especially in the water, but the rubber is somewhat expensive and the asphaltum, despite its mixture with paraffin, has an abrasive effect on the cuttings and wears large holes where the cord passes through the growing sponge.

Jute, sisal, manila, cotton, and hemp lines were employed, but as expected, they were all quickly destroyed in salt water. Coir (cocoanut fiber) rope was not experimented with, as there was some difficulty in obtaining it, and moreover, experiments with the fiber showed that it, too, is more or less quickly rotted in the water.

Stakes and other wooden structures placed on the bottom are quickly riddled by the teredo and other boring organisms. If planted green with the bark on they will last longer, but the bark of the most durable, the mangrove, has a bad effect on the sponges, while that of other trees tends to scale off after a while, the sponges becoming detached with it. If there were no better method available, black mangrove and white wood stakes stripped of bark would probably hold together for four years, but to prevent rotation and capsizing they must be nailed together in frames.

To none of these materials, excepting the barked stakes, did the cuttings make organic attachment. When the artificial attachments loosened, the cuttings were free to rotate and drift on the wire, and when the latter was at

all rough, holes of considerable size were eroded in the sponge. Asbestos cord treated with rubber solution was least objectionable in this respect, owing to the softness of its surface and the firmness with which it could be gripped by the binding wires, the method of applying which is explained later.

It was found that this difficulty of the corroding wires was obviated by the use of lead wire, to which the cuttings speedily form organic attachment and cling independently of artificial aid. The tensile strength of this metal is so low, however, that in spans it will not support itself, to say nothing of the weight of the sponges and the pressures exerted by waves and currents. To secure the virtues of lead, its freedom from corrosion, its chemically inert and innocuous qualities, and the facility with which the cuttings grow fast to it, while at the same time eliminating its defect of tensile weakness, the device was adopted of employing a strong fiber or wire core encased in a thin coating of lead.

Several types of this construction have been employed with varying success. One of the earliest was ordinary tarred marline encased in lead about one thirty-second inch thick. This was light and when new quite strong enough for the purpose, but eventually the marline rotted and the lines broke, though some lasted for two years. Asbestos cord covered in the same way was also experimented with and found unsatisfactory.

Several forms of lead-covered insulated wires have been used, but the ordinary commercial sorts have been unsatisfactory, being either too heavy and expensive, or, if sufficiently light and cheap, lacking in durability. Commercial underwriters' wire with a copper core and specially encased in lead was superior to the higher priced insulations, and a still better wire was of the same type with the copper core replaced by galvanized iron. This had to be made to order, as there are no such insulated iron wires on the market.

All of these wires and lines were used in the same general way, stakes being driven in the bottom in parallel rows at intervals of about 25 feet and the wires suspended between to form squares. At first the wires were attached merely by tying or winding them about the stakes, but it was found that this rigid attachment caused them to break under the repeated flexure to which they were subjected by swaying in the waves. Later galvanized rings were placed over the stakes, four wires radiating at right angles from each toward the adjacent stakes, the whole being supported at a proper height above the bottom by means of a short wire attached to the stake and ring, respectively.

When lead-covered lines began to be employed they could not be attached directly to the rings on account of electrolysis, which would cause the iron to rust, and the rings were then wrapped with insulating tape to keep the two metals from coming in contact. Here another difficulty was encountered, the lead coating wearing through when loosely attached to the ring, or breaking near

the ring under repeated flexure when rigidly attached. In the latter case the insulation was abraded by the rubbing of the rough edges of the broken lead casing, and the exposed core broke by the concentration of flexure at the weakened point, or else, coming into contact with the lead, was destroyed by electrolysis.

To overcome this, horseshoe-shaped porcelain pieces were interposed between the rings and the wires, as shown in figures 1 and 2. By this means the electrically antagonistic metals were kept apart and at the same time there

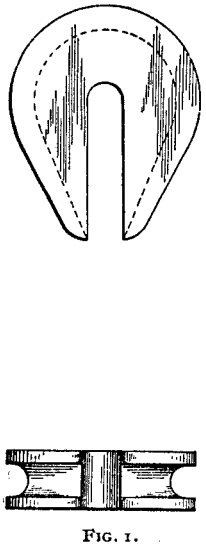

FIG. 1.

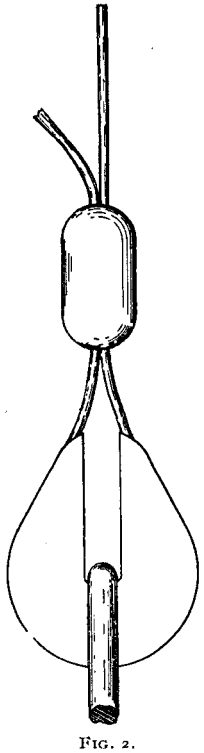

FIG. 2.

FIG. 1 AND 2.—Showing insulated attachment for lead-covered lines supporting sponge cuttings.

was formed a rocking attachment without wear on the lead, the flexure of the wire being distributed throughout its length instead of being concentrated near the stakes.

With galvanized iron wire with underwriters' insulation and incased in lead, this device served very well so long as the sponges were not much over 4 inches in diameter, but when they grew larger there was a contingency which had not been anticipated, the sponges being torn loose and rotating on the wire. Practically all of the wires used were less than one-fourth inch in diameter, a larger size being objectionable on account of its weight and the hole produced in the

sponge. This gave a small surface of attachment which, while sufficient at first, became proportionally smaller as the sponge grew. The attached area, and consequently the strength of the attachment, grew proportionately to the diameter of the sponge, while the forces acting to loosen it grew in proportion to the surface exposed to the impact of the waves. The consequence was that in rough water sponges 5 inches in diameter were generally torn loose, and, once started to rotate or oscillate, a large hole was soon worn about the wire to the detriment of the quality of the sponge and the retardation of its growth. In sheltered places sponges were successfully grown on wires until they reached a diameter of 7 inches, but eventually they also must have become loose.

To correct this tendency to loosen, the shape of the wire was modified to assist the strength of the attachment by mechanical resistance to the rotation of the sponge, longitudinal slipping on the wire being negligible after the attachment of the cutting is once established. A galvanized iron ribbon three-eighths inch wide and one-sixteenth inch thick was incased in a tight-fitting lead jacket one thirty-second inch thick, the whole making a flat band one-eighth inch thick and not quite one-half inch in breadth. This appears satisfactorily to prevent rotation in sponges as large as 8 inches in diameter.

This lead-incased ribbon is durable so long as the casing is not mechanically broken or punctured. At the cut ends the iron rusts away slowly, but the contact between the iron and the lead is so intimate that the water at a depth of 10 or 12 feet penetrates but an inch or two at most, and electrolysis is, therefore, strictly localized to the open ends. It has to be handled with care, however, as the thin lead is easily punctured and the slightest hole becomes the seat of electrolytic action to the speedy destruction of the iron and the consequent breakage of the ribbon. When carefully put out this material has lasted for three years with no other sign of impairment than the rusting away of about one-half inch of the iron where exposed at the ends. Its strength is great, as was demonstrated at Biscayne Bay during the great hurricane of 1906 when a piece of wreckage fouled some of it, pulling up deeply embedded stakes and flattening a ¼-inch wrought-iron ring without injuring the ribbon. It is heavy and difficult to handle when planting from a small boat and there is also some difficulty in attaching it at the stakes. It, of course, can be bent in but one plane, and it can not be attached directly to the rings owing both to the electrolytic effect upon the latter and to the abrasion of the lead casing of the ribbon.

In the experimental work porcelain insulators were attached to the rings by means of galvanized wire, the ribbon being bent over them, with a piece of thin sheet lead interposed, and secured by means of a flattened seine lead or piece of lead piping as shown in figure 2. In a commercial application a special insulator similar in general shape to that shown in figure 1 could be employed. In any case it is necessary to place a piece of sheet lead or asbestos

cloth between the porcelain and the ribbon to prevent wear and tear on the lead covering of the latter.

All of the foregoing experiments were made with a view to the utilization of soft muddy or grassy bottom upon which sponges will not grow naturally and in depths not exceeding 10 or 12 feet. This would have made possible the utilization of considerable areas among the keys and close to shore along the Gulf coast, in localities where the plantations could be readily protected. The results of the work, however, have failed to disclose a material which is satisfactory in all respects. The lead-covered iron ribbon if carefully handled and planted with its casing uninjured has sufficient durability and prevents the loosening of the sponges as they reach commercial size, but it is not a commercial product and has to be made to order, which militates against its use by small planters, while its weight makes it somewhat difficult to handle in lengths of more than 15 feet, this, in its turn, increasing the cost of stakes, rings, and attachments. The rings and insulators will last indefinitely, the stakes will have to be renewed once during the growth of the sponges, and the indications are that the ribbon, or at least most of it, will not be useful for a second planting. Lead-incased galvanized-iron underwriters' wire about one-fourth inch in external diameter with no. 12 Brown & Sharp gauge core is durable, costs about one-half as much as the ribbon, is easily handled, and much of it can be used for a second planting, but on account of its circular cross section the sponges as they grow will loosen and rotate in any but the most sheltered places.

The value of a method which would permit of the utilization of otherwise useless and barren bottom in shoal water is great and warrants further experiment, but the results so far obtained are not such as would justify the recommendation of any of the methods or materials experimented with. The experimental results of the work with wires are valuable on account of the facility with which the sponges could be examined and the data which it has been possible to obtain as to the rate of growth, the mortality, and the general behavior of the cuttings.

As has been mentioned, in the very beginning of the work experiments were made with various bottom attachments. The use of stakes or poles has already been discussed and the objections stated. They never offered much encouragement for further trial. The plaster, cement, and pottery forms first employed were about 5 inches in diameter on the bottom, 4 inches on top, and about 1½ inches thick. The larger face was slightly convex, and the smaller, to which the cutting was attached by means of a V-shaped wire running through a central hole, was flat. They were found to be too small, tending to capsize as the sponges grew and offering greater surface to the impact of waves and currents, and there was also some difficulty with silt and vegetable growths which

interfered with the welfare of the cuttings so that they were also difficult to keep under observation for experimental purposes.

Owing to the encouraging early results and the apparent advantages of the wire suspension methods previously described, provided a suitable material could be obtained, work with bottom planting was suspended for several years but was taken up again in 1905 when it became apparent that none of the lines and wires previously experimented with was likely to prove satisfactory. About the same time a sudden disaster, due to the presence of drainage water near the surface on the plantation at Anclote key, made it necessary to transplant hurriedly the remaining sponges to the bottom in another locality. Not only the plantation of the Bureau of Fisheries was affected, but also that of Messrs. Cheyney and Bigelow, who on an adjoining site had been, for two years preceding, conducting a similar experiment on a commercial scale.

Bricks, rocks, and anything available were first used in the hurry to remove the sponges from untoward influences, but in the meantime there were being made a number of cement disks larger and heavier than those used during the first two years of the experiment. These disks (pl. LXVIII) are about 10 inches in diameter and 1¼ inches thick, and are composed of a mixture of 1 part cement to 3 or 4 parts sand. They are molded in iron rings of the required dimensions laid on the sand, and two holes about 4 inches apart are made in each by thrusting through the cement before it hardens an iron bar three-eighths inch in diameter. The molds are removed as soon as the cement has set and before it hardens, the operation being facilitated by running a thin-bladed knife around the inside of the rings to break their adhesion to the disk. The disks can be made by this method for less than 2 cents each, including material and labor.

For experimental work hollow triangles (pl. LXVII) were substituted for the disks, six sponges being planted on each. As each triangle was marked or numbered, record could be kept of the growth and behavior of the cuttings, and as the large triangles were less easily overlooked than the smaller disks and as each was planted with a definite uniform number of cuttings, the rate of mortality could be readily determined from time to time.

These disks and triangles are satisfactory on rocky bottom, but tend to bury on sand, marl, or soft mud. They may, however, be used on bottom with a sparse growth of grass. When the grass is long and dense it tends to fall over the sponges, causing death or irregular growth. Where shifting sands and silt are carried by the currents these materials tend to deposit in the eddies on the lee side of the disks and triangles, and eventually pile up around the base of the sponges and kill them. To obviate this difficulty spindles were placed in some of the triangles (pl. LXVII) and disks, six in each of the former and one in the latter, the cuttings being attached near their tops so as to prevent free flow of the currents beneath. These spindles project about 8 inches and various materials were tried,

the most satisfactory being short lengths of the lead-covered iron ribbon before described. They serve the purpose perfectly, they are sufficiently durable, the sponges soon permanently attach, and no suffocation occurs in places where cuttings on the disks would be buried in mud or sand. The spindles are, however, about double the cost of the disks, and although the indications are that if carefully handled they will last long enough to mature two crops of sponges, they eventually will be destroyed while the disks are practically indestructible. The spindles also prevent close packing of the disks and are more troublesome to handle, but on the other hand they facilitate the attachment of the cutting, as will be hereafter explained.

PLANTING.

The method of applying the cutting to the support has undergone gradual modification. In the early experiments with various insulated wires, when the sponge did not form organic attachment, the pieces were bound against the supporting line with short pieces of aluminum wire thrust through the sponge and twisted around the support. It was found that the cuttings were often slow in growing around the support and should the binding wires become loose were likely to be detached and lost. To obviate this difficulty the expedient was adopted of slitting the cutting, placing the two legs of the slit astride of the supporting wire and binding the several faces in close apposition by means of rubber bands or short aluminum wires traversing the two flaps of the cutting and at their ends twisted around the supporting wire. Under such conditions the slit speedily fused and the cutting became organically intact about the wire. Aluminum was employed for binding because its salts in sea water are neither rapidly produced nor injurious.

With the use of lead-covered materials, to which the sponges grow fast, it became possible to "thread" the cuttings on the wire, the use of binding wires being unnecessary to hold them in position. To facilitate this operation needles (text fig. 3) were made of clock-spring steel, one end being shaped to a sharp stiletto point, and the other rolled or folded over to form a socket fitting the end of the wire on which the sponges were to be planted. In planting, the needle was fitted to the wire and the cutting pierced by the sharp end of the needle and pushed onto the wire as one would use an ordinary needle and thread in stringing beads. After attaching the ends of the wires to the stakes the cuttings were distributed at regular intervals by sliding them along with the hand, their friction against the lead usually holding them in place until organic attachment occurred. Several mechanical distributers were devised and experimented with, but none was very satisfactory.

In planting on plain disks the cuttings are pierced by short aluminum wires, the ends of which are carried through the two holes already described and twisted

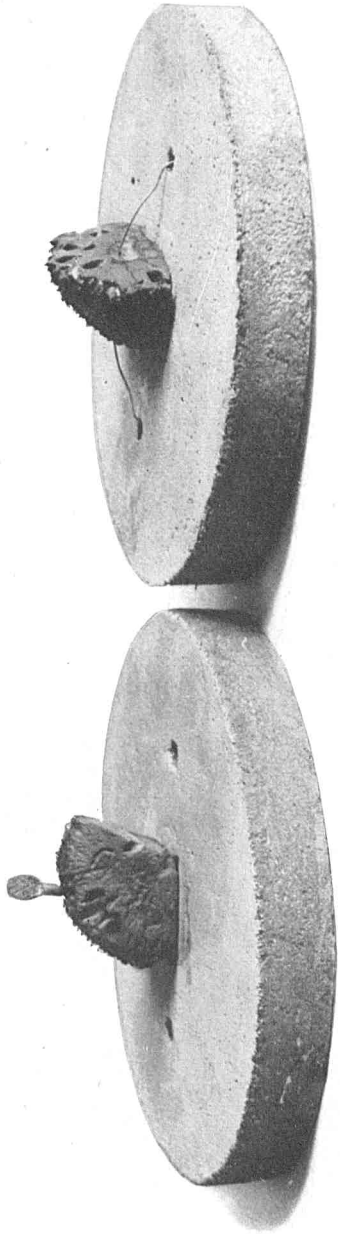

FIG. 1. FIG. 2.

CEMENT DISKS WITH CUTTINGS MOUNTED. FIGURE 1 SHOWS SPINDLE ATTACHMENT; FIGURE 2 SHOWS CUTTING SECURED BY WIRE.

on the under side (pl. LXVIII, fig. 2). This is a rather slow process, and it is not possible for two men to cut, attach, and plant more than about 100 cuttings per hour. To accelerate the speed of planting I have placed in the center of each disk a short spindle of ¼-inch lead wire, slightly flattened at the top by a blow from a hammer and projecting to a length of about 2½ inches (pl. LXVIII, fig. 1). About 8 or 10 cuttings are placed on a long needle (fig. 3) of the required shape, the socket of which is placed upon spindle after spindle in succession and the cuttings pushed into place in contact with the cement base, each with a single motion of the left hand. Friction of the slightly stretched tissues against the spindle and the burr at the top of the latter prevent the detachment of the cutting, which in a few days grows fast to both the spindle and the disk. With this device two men can plant from 250 to 300 cuttings per hour, and this gain in speed over the other method is highly important in places where rough weather is prevalent, as it makes possible the fullest utilization of such opportunities as present themselves. The spindles add about 25 per cent to the cost of the plain disks, but as they will survive a number of plantings this cost is compensated for by the decreased cost of labor.

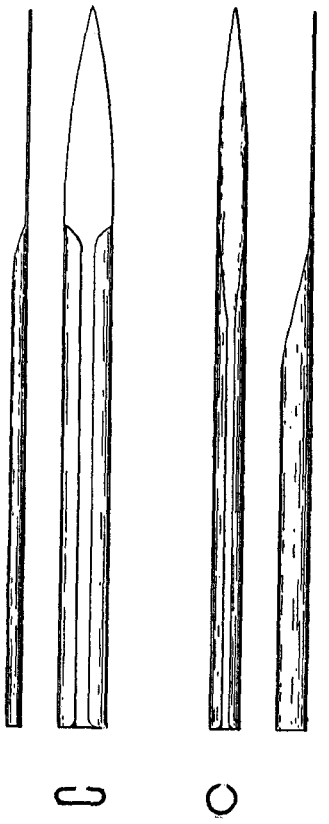

FIG. 3.—Needles used for threading cuttings on supporting wires.

This system also facilitates replanting with cuttings at the time of harvesting of the first crop, as the grown sponges can be quickly detached and new cuttings substituted. In shoal water where the sponges can be taken with hooks, two additional men in the boat should be ample to detach the sponges and replant the disks as rapidly as they are brought up. In deep water where a diver has to be employed for harvesting the crop, the cuttings can be taken down by the diver and planted as the matured sponges are removed, avoiding the labor and inconvenience of bringing the disks to the surface, and reducing the cost of operation very much more than sufficient to cover the increased first cost of the disks.

The expense of labor in deep-water planting is of such importance that the strictest economy of operation, especially in taking up the sponges, must be given careful consideration. The diver's time must be economized, as the time of the entire crew of the diving boat is dependent upon the rapidity and

efficiency with which he works. The attachment of sponges to the disks by means of wires is slow under the best conditions and must be much slower under water where work is done at a disadvantage, but the cuttings can be slipped on to the spindles as readily under water as in the air.

The same considerations apply to cuttings planted on long spindles (pl. LXVII) which will hold them above the bottom and in deep water. Especially in a locality requiring the transport of the disks or triangles for considerable distances, the second planting can be carried on more economically than the first. Holes should be punched in the disks, however, even when spindles are used, so that a wire attachment can be employed should the spindle eventually be broken off.

The density with which sponges can be planted on the bottom in any given locality is a subject which will require actual experiment on a commercial scale for its elucidation. That ordinary waters will support a dense growth of miscellaneous sponges is well known, and among the Florida keys I have observed an average of several to a square yard over considerable areas.

Though nothing is known of the actual facts concerning the food of sponges, it can hardly be doubted that all horny sponges feed on essentially similar material. If this be true, it is fair to assume that an area which will support a large number of useless horny sponges should support and produce an equal volume of the commercial kinds. Unfortunately the shoal-water beds of our coast are now so depleted that present day observations are useless and the distribution of the valuable kinds on the deep water grounds is so unequal, owing to the irregular and sporadic occurrence of suitable bottom, that nothing definite can be learned. I am informed by Dr. H. M. Smith, however, that in very shoal waters in the Philippine Islands he has seen commercial sponges somewhat similar to the Florida grass sponge averaging one to every square foot of the bottom over areas many acres in extent. The commercial experiment carried on at Anclote Key by Messrs. Cheyney and Bigelow showed that, even in an unfortunately selected locality, cuttings would grow rapidly when planted with a density of about one per square yard over an area of about 15 acres, and that the growth was no less satisfactory than upon the government's neighboring plantation covering but a few acres. In no case, on any of the plantations under observation, did the density of planting, up to a maximum of a little over one sponge per square yard, have any apparent effect upon the rate of growth. In bottom planting on a small scale sponges have been planted in some cases as densely as 5 or 6 per square yard without apparent bad effect, but with extensive areas so thickly planted it is possible that there might be an insufficiency of food. Experiments in Biscayne Bay appear to indicate that sponges grow more rapidly in strong currents, and presumably the same condition would permit denser planting than where the currents are weak.

RATE OF GROWTH.

(Plates LXIX to LXXVI.)

The rate of growth of cuttings is a matter of paramount practical importance to the prospective sponge culturist, and it has been the subject of considerable discussion and difference of opinion. The fishermen variously claim that on the natural beds sponges grow to a "marketable size," presumably 6 or 7 inches in diameter, in from six months to a year, basing their statements on the fact that grounds supposedly denuded one year are found to bear salable sponges the next. They fail to consider the certainty that they have overlooked a number of large specimens and numerous small ones already well on their way to merchantable size. Smith, in his paper, "The Florida Commercial Sponges," basing his statement upon the reports of others, says that the claims of the spongers are borne out by experiments, and that "in as short a time as one year, under favorable conditions, the cuttings will attain a marketable size, and certainly within sixteen or eighteen months the harvesting of relatively large sponges may be depended on." To substantiate the statement he furnishes a photograph, a careful inspection of which creates the impression that the photographer has somewhat assisted nature in establishing the apparent rate of growth. I have reason to believe that both Dr. Harris, the grower of the sponges in question, and Dr. Smith were deceived as to both the age and the origin of the larger specimen, and that it came from a mangrove root and not from a wire, as supposed. As photographed it is about 5½ inches in diameter and is said to be not over eight months old, but I have seen a number of other sponges planted at the same time and place and under the same conditions which had attained a size of not over 4 inches when between three and five years old. They were all planted under unfavorable conditions, and the best result that I have been able to attain in the same locality and under better conditions of growth was an equal diameter in about two years from cuttings between 2 and 2½ inches cube.

The experiments by Fogarty at Key West about 1880 have not been accurately or definitely reported, but it is said that cuttings about 2½ inches in diameter in some cases increased from four to six times in bulk within a period of six months. This is more in accord with my own experience, though, as will be shown later, the relative increase in volume is greater with small cuttings than with larger ones.

The results obtained by Buccich are also out of accord with the popular view of the rate of growth of sponges under natural conditions, although the reports of his work are lacking in definiteness. His cuttings, about 1 inch cube, increased to two or three times their original bulk in one year and did not reach full marketable size, the exact dimensions not being stated, until the lapse of seven years, a much slower rate of growth than in Florida.

My own experiments show that the raw surfaces of cuttings become pigmented within a few days and that at the end of a month they have completely healed and have begun to grow and project little papillæ or cones. Sharp angles and edges generally die and slough off slightly, and the central portions of the plane faces become swollen so that at the end of three months in small cuttings and somewhat later in larger ones there is evident a distinct tendency to rotundity. At the end of six months in many specimens the cut faces can not be distinguished from the original surface of the sponge and in practically none can they be determined except by the shape. In all cases there is a constant tendency toward a spheroidal or ellipsoidal shape, cubical cuttings approaching the former and irregular ones the latter form if suspended above the bottom, but all becoming cake-shaped if grown from basal attachments. (Compare plates LXXIV and LXXV.)

Growth takes place in all directions with approximate equality when the cuttings are suspended freely in the water, but is generally more rapid in the horizontal plane when the sponge is attached to a basal support. If the cutting be attached to a small horizontal surface it will grow downward over the edges, and if the surface be uneven it will project itself into all the irregularities and holes. For this reason, if basal attachments are used, it is desirable to have them with smooth surfaces and of a horizontal expanse greater than that of the sponges which it is desired to grow, otherwise considerable weight, and also time, is lost in trimming the marketable specimens to a desirable and uniform shape.

Buccich observed considerable variation in the rate of growth and my own experiments confirm his statements. Cuttings which, so far as could be determined, were similar in size, shape, and character, diverged widely from one another in this respect and some of them, while healing completely and remaining in an apparently healthy state, had grown hardly at all in the course of several years. In some cases cuttings made from the same sponge exhibited this diversity. Different lots of cuttings of the same average size and planted in the same locality exhibited a remarkably uniform average rate of growth year after year. In Sugar Loaf Sound the average annual increase in diameter was about 0.8 inch, while at Anclote Keys and Cape Florida it was from 1 to 1.2 inches. In Sugar Loaf Sound this average was maintained to the end of three years, when the experiment was abandoned for reasons already explained, while at the other two places it continued until the end of four years, when accurate records were lost as the result of disasters due to meteorological causes.

Recent developments in Biscayne Bay indicate that the average growth of sponges planted on the bottom in Cape Florida Channel is slightly in excess of the rate stated above, while at Soldier Key, about 7 miles away, it is much less. At the first locality the currents are strong, the bottom muddy, and the neighboring

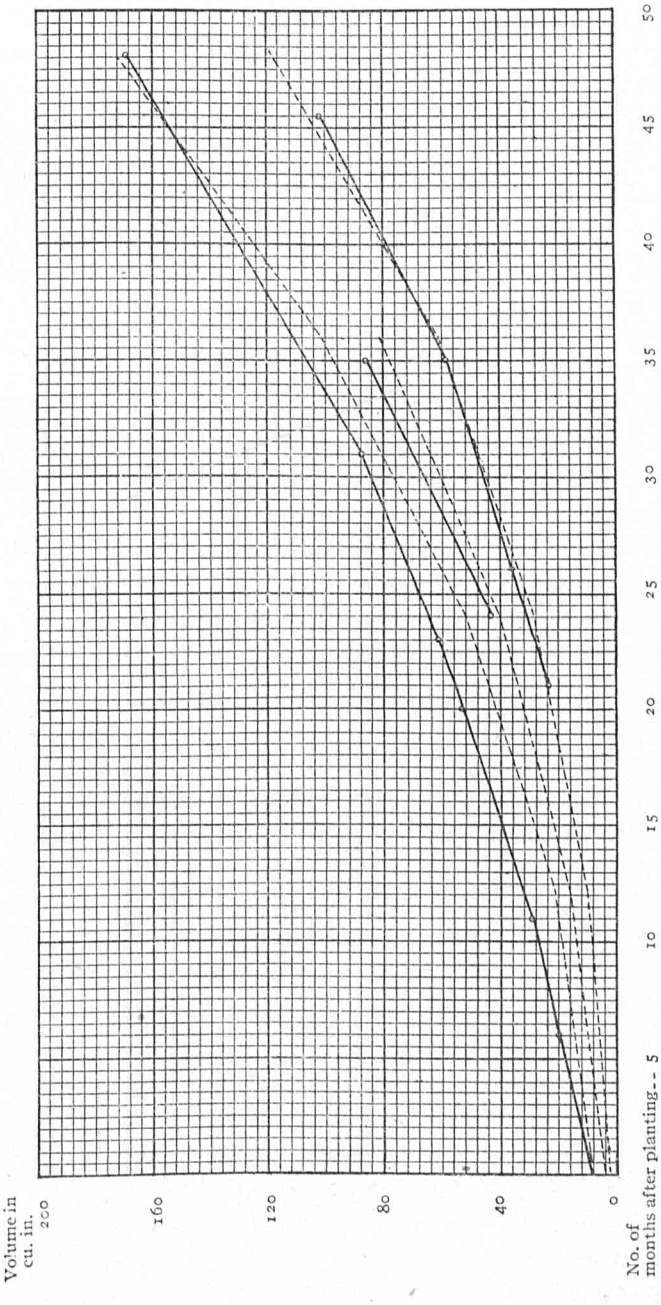

FIG. 4.—Average rate of growth of sponges from cuttings of several sizes. Anclote Key.

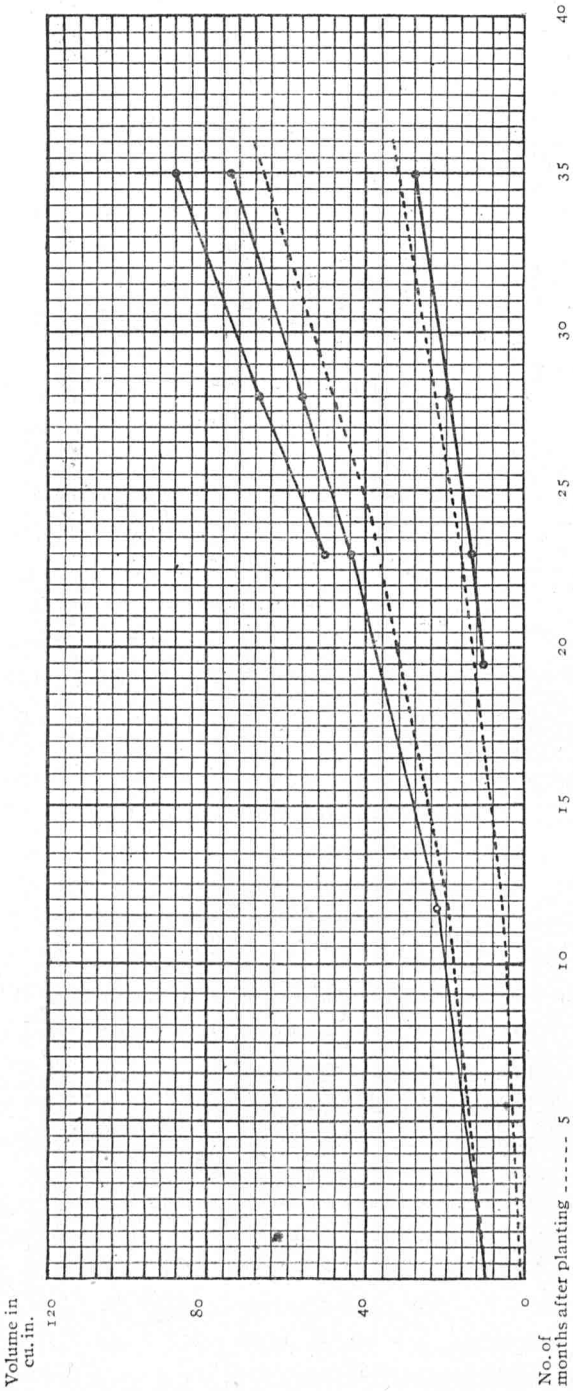

FIG. 5.—Average rate of growth of sponges from cuttings of several sizes. Sugar Loaf Key.

banks covered with vegetation, while at Soldier Key the bottom consists of clean rock, the adjoining banks are sandy, and the current is probably less rapid, though of the latter I am not certain. The difference in the rate of growth may be due to the strength of the current or to the larger amount of food in the waters adjacent to marine vegetation. That the latter is the probable reason is indicated by recent observations that sponges planted on bottom covered by short grass at Soldier Key exhibit a more rapid rate of growth than those planted on bare rock.

The slower rate of growth in the warmer waters of Sugar Loaf Sound was a surprise, and it may possibly be accounted for by the general absence of strong currents or by the character of the seed sponges. These were all small specimens rarely over 5 inches in diameter, obtained from the waters of the sound, which while formerly producing large ones now rarely do, possibly as a result of overfishing in former years. In these shallow waters the spongers have been able rigidly to select out all marketable sponges, a process which would logically tend to eliminate those which grew rapidly and had an inherited tendency to reach larger dimensions, while leaving a preponderance of those of slower or stunted growth to perpetuate their kind. The inevitable tendency of an intensive fishery of this character would be to breed a race of more or less dwarfed sponges of slow growth, an assumption which is in a measure confirmed by the fact that Sugar Loaf Sound formerly produced a much greater proportion of large sponges than it does at present. This could not be due to the intensity of the fishery during the period within which I have been familiar with it, as the sound was then closed to promiscuous fishing and the sponges had ample opportunity to grow to larger size than the average attained.

In Biscayne Bay and at Anclote Key the seed sponges were obtained from partially depleted beds, but owing to the greater depth and the more frequent prevalence of turbid water these have never been so thoroughly scoured of marketable sponges. The specimens from which cuttings were made were larger, and presumably more virile, and in any event the cuttings grew more rapidly. At Sugar Loaf and Anclote Keys the planted sponges were measured at intervals after the first year by means of calipers, and occasionally specimens of average size were taken and cleaned. In Biscayne Bay local conditions prevented the systematic measurement of the sponges while growing.

Text figures 4 and 5 exhibit graphically the rates of growth in volume of the cuttings at Anclote Key and Sugar Loaf Sound, respectively. The dotted lines indicate the theoretical increase in volume, assuming a uniform annual increase in diameter of 0.8 inch at Sugar Loaf and 1 inch at Anclote Key, while the heavy lines show the average growth of a number of measured specimens of the ages indicated by the position of the small circles. It will be observed that the

growth is fairly uniform up to the end of the fourth year, when there is a tendency to drop, but whether or not this late decrease in the rate is normal can not be stated, as the specimens measured had been injured by an influx of fresh water on the plantation.

The experiments with wires appeared to show that sponges suspended above the bottom grow more rapidly than those on or near the bottom, but more recent results with disks and triangles appear to throw some doubt on this. It is probable that dense vegetation among which the sponges lay had an inimical effect and that sponges planted on bottom where they would not be covered by vegetation would grow as rapidly, or nearly so, as those suspended above it. With bottom planting it is difficult to make accurate and systematic observations on a large scale, but such observations as have been made at Biscayne Bay and Anclote indicate that the rate of growth of cuttings planted on disks and spindles is at least equal to that of sponges planted on wires.

The question has been raised in regard to sponge culture whether if a sponge be cut into pieces the total growth of the pieces will be greater than the increase of the same sponge would have been if it had remained intact, the environment being identical in the two cases. It has been argued with some plausibility that the reply to this question is in the negative, but experiments at Sugar Loaf Key do not bear out this assumption, and it was determined that entire sponges from 2½ to 4½ inches in diameter grow at approximately the same rate as healed cuttings of the same volume each. They both increased in diameter at the average rate of about 0.8 inch per year, some individuals in each exceeding and some falling short of the average. The greater aggregate increase in volume, therefore, is obtained by cutting the sponges into pieces, and the smaller the cuttings, provided the minimum heretofore stated is not passed, the greater the advantage of subdivision. This is expressed graphically in figure 6, where the solid line represents the growth of an entire sponge 6 inches in diameter, and the broken line the aggregate growth of a sponge of the same diameter cut into 20 and 50 pieces, respectively, making an allowance of 5 per cent per year for mortality. The same data are shown in the following table.

COMPARATIVE INCREASE IN VOLUME OF AN ENTIRE SPONGE AND THE AGGREGATE OF CUTTINGS FROM SPONGES OF EQUAL VOLUME.

	Volume when planted.	1 year.	2 years.	3 years.	4 years.
	Cu. in.	*Cu. in.*	*Cu. in.*	*Cu. in.*	*Cu. in.*
Entire sponge	168	244	343	464	629
20 cuttings	168	399	738	1,287	1,952
50 cuttings	168	446	1,035	1,932	3,200

It will be seen that at the end of four years the volume of 20 cuttings made from a 6-inch sponge will be over three times that which the same sponge entire would have attained under the same conditions, while 50 cuttings made

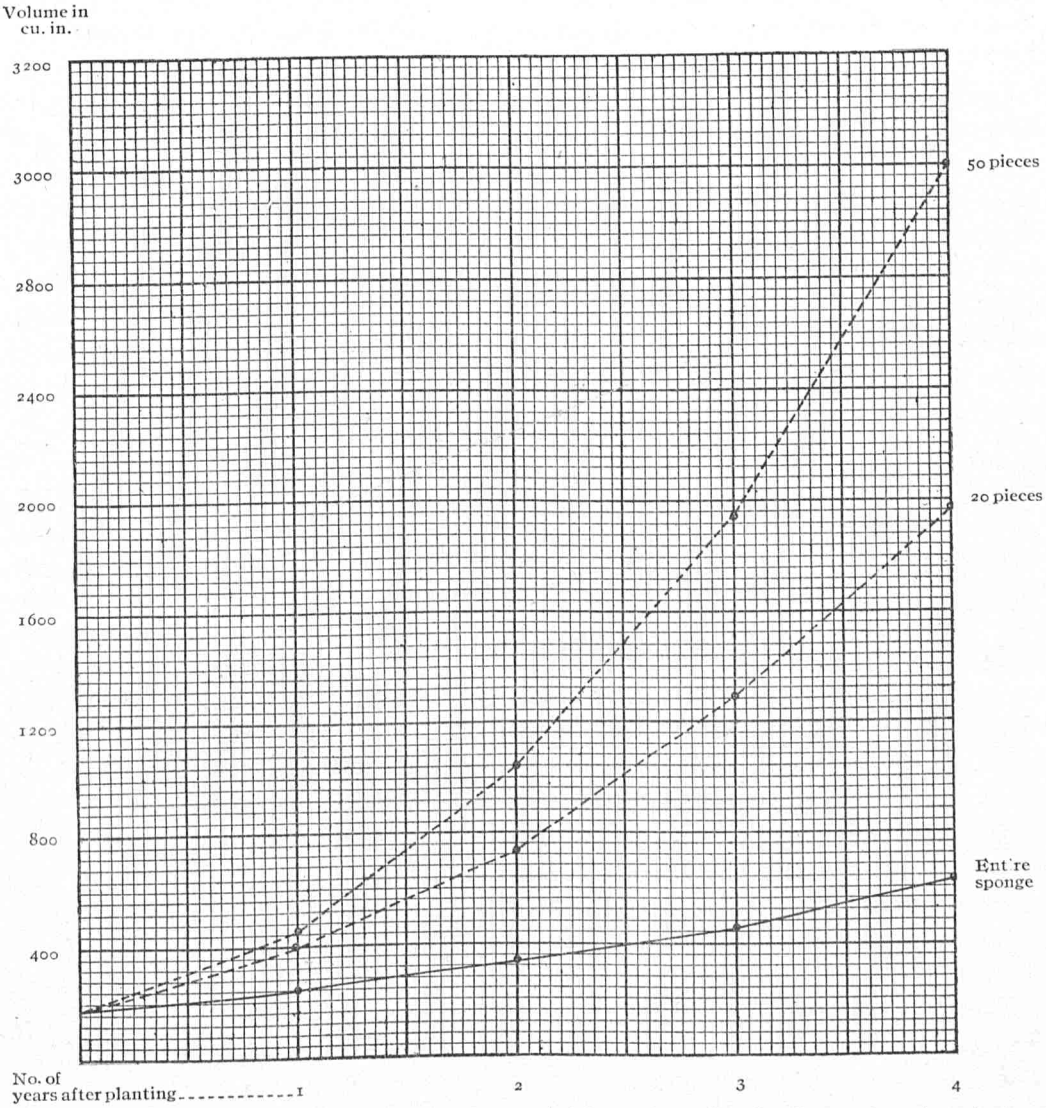

FIG. 6.—Comparative increase in volume of an entire sponge and of the aggregate of cuttings from sponges of equal volume.

from a sponge of the same size will have a volume nearly 5 times as great. It should be explained, however, that these data do not represent a concrete case, but are based on observed rates of growth of cuttings and entire sponges under the same environment. The experiment begun to demonstrate these facts was interrupted by theft and vandalism.

It should be stated also that 50 cuttings made from a 6-inch sponge would be smaller than has been found advisable and the rate of increase in diameter during the first year would be somewhat smaller than has been assumed, though thereafter it would be fully equal to that of the larger cuttings.

MORTALITY.

The data upon the highly important question of the death rate among sponges grown from cuttings are not satisfactory. Buccich estimated it at about 10 per cent in seven years, but my results indicate a somewhat higher rate.

Owing to the unsatisfactory character of the supports which were employed during the early years of the experiment, it was necessary to shift the sponges from time to time, each handling resulting in some loss, and moreover the breakage of the lines often allowed the plants to fall to the bottom, where they were much injured by adverse conditions. The mortality was highest at Anclote Key, where the plantation was exposed to the full force of the waves and the parting of the lines was frequent, and it was least at Sugar Loaf Key, where the greatest shelter was afforded. At Anclote there also was always more or less fall in the salinity during the heavy rainfall of summer, and the greatest mortality on the lines which remained intact was invariably coincident with this. Cuttings planted in the fall frequently reached the late spring months with a mortality of but 1 or 2 per cent, a rate increased to 8 or 10 per cent by fall. The observations made at that place are of value only as indicating the necessity for establishing the plantations in places not subject to the influence of freshets in neighboring streams. At Cape Florida, in Biscayne Bay, the plantation was more sheltered from boisterous seas, but the surface water was liable to fall in salinity during summer with a coincident increase in the death rate, though here the results were not so uniform. At this place various lots of sponges planted at different times and all subject to more or less of the vicissitudes of experimental work mentioned above, exhibited mortalities of 32 per cent at the end of fifty-three months, 29 per cent at the end of forty months, and 15 per cent at the end of twenty-six months, respectively. The first two lots were subject to damage from the breaking of the wires, but the last did not have this condition to contend with and the mortality during the last twenty-one months was equal to but 4 per cent of the original number planted. The heavy death rate of the first five months was due to the sagging of the wire so that the cuttings lay among the dense vegetation, none of those raised above the top of the grass dying during that period.

At Sugar Loaf Sound no difficulty was experienced with fresh water, and the death rate was correspondingly decreased. The lot of 400 cuttings having the longest period of growth at that place—thirty-five months—exhibited at the end of that time a mortality of 14 per cent. All of these were transplanted at

least once after having lain for an unknown time on the bottom vegetation under conditions which other experiments have shown to be inimical, and a considerable proportion of the deaths occurred at those times. Had the wires remained intact and the cuttings been kept always suspended above the vegetation the death rate at the end of three years would undoubtedly have been

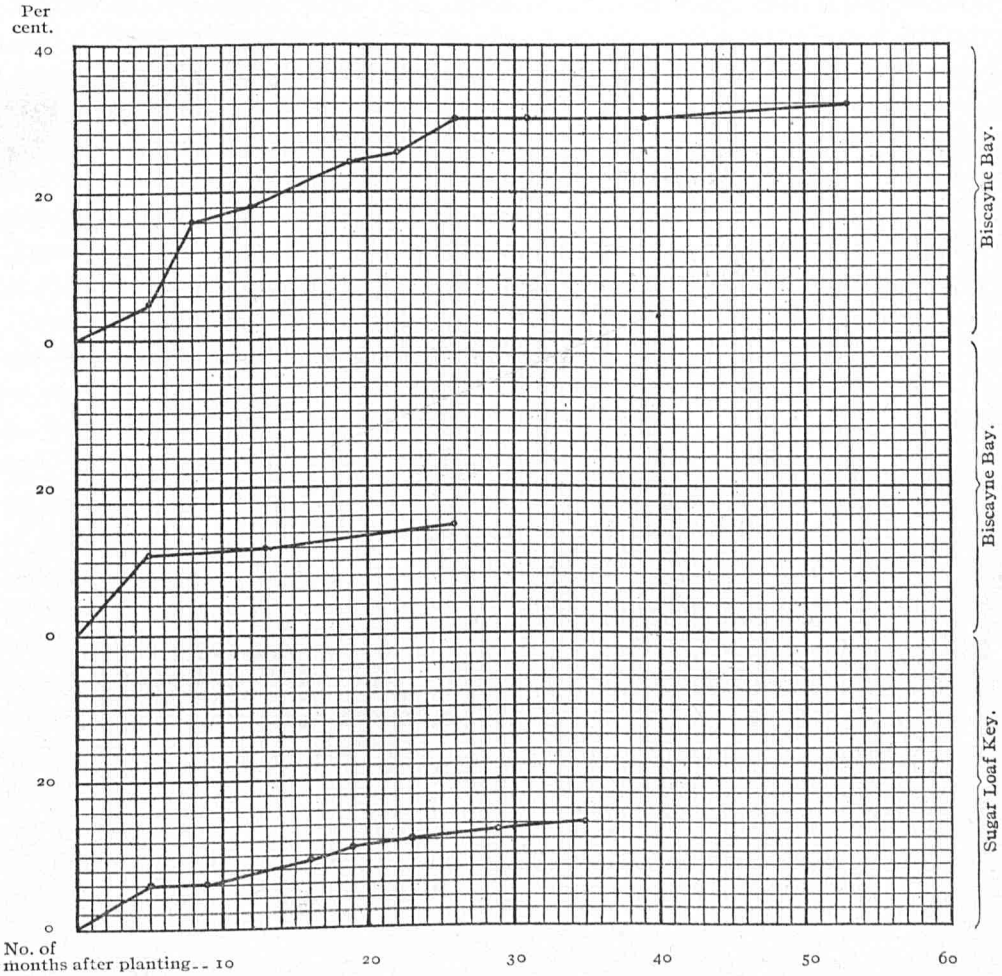

FIG. 7.—Percentages of mortality among different lots of sponges grown from cuttings at Sugar Loaf Key and Biscayne Bay.

under 10 per cent. Curves showing the percentage of mortality among different lots of sponges at Sugar Loaf Key and Biscayne Bay are shown in figure 7. These sponges were all on wires suspended above the bottom.

At Anclote Key, owing to the almost constant turbidity of the water, it has been found impossible to determine the mortality among sponges planted on the bottom. At Cape Florida, in order to obtain data on this point and to

avoid the error due to the liability to overlook disks from which the sponges may have become detached, practically all sponges planted on the bottom were attached to triangles either with or without spindles, each holding six cuttings. At that place the mortality at the end of six months was less than 3 per cent, and at the end of nineteen months a little less than 6 per cent, the latter including a few sponges in shoal water evidently detached by being fouled by the center-board of a boat, and at thirty months 9 per cent. At Soldier Key, also in Biscayne Bay, the death rate among sponges planted on triangles on smooth rock bottom was about 3 per cent at the end of ten months. Data relating to bottom planting for longer periods are not available, the first extensive experiment in this direction having been destroyed by the great hurricane of 1906.

From the results recounted it is believed safe to assume that in localities free from influx of fresh water and the extensive deposit of silt or sand, with sponges planted on disks or triangles on rocky bottom, or on other bottom free from vegetation and stable enough to prevent the gradual sinking of the attachments, the mortality will be well below 5 per cent per annum.

SHAPE AND QUALITY.

Under artificial culture the shapes of sponges may be modified more or less to suit the special requirements of the arts. Sponges grown on wires or spindles assume a spheroidal shape with a uniform texture of surface and devoid of any semblance of a "root," such as is found in all natural sponges excepting rollers. This form is very attractive and durable.

Cuttings grown on disks tend to assume a flatter shape and the surface attached to the cement is plane, in that respect resembling the root of natural sponges, but instead of being "raw" and exposing the canals it is covered with a close soft felt of great strength and durability, and forms the strongest instead of the weakest part of the sponge (pl. LXXVI).

In certain arts and trades sponges with flat surfaces are required and to obtain these it is customary to cut the entire "forms" into pieces. The raw surfaces exposed in this way lack the durability of the natural surface and to obtain the latter, while at the same time retaining the several flat faces and sharp angles of the "cuts," a modified form of disk was employed. In this there were two partitions raised to a height of 4 inches, crossing one another at right angles on the upper surface of the disk. This left at the center of the disk four angular compartments, and in each of these a cutting was planted, which, being limited on three sides by the disk and two partitions, respectively, grew into a form having three plane surfaces at right angles to one another and one convex surface. The latter is similar in texture to the outside of an ordinary sponge, but the plane faces form contact with the disk and partitions and

develop a smooth, soft, and very durable felt-like surface. These sponges cost more to grow than those of ordinary shape, but experiments recently inaugurated will probably make the additional cost of production trifling. The superior durability of sponges grown in this manner should make it possible to market them at a price considerably above that brought by the natural product.

It has been found that the sponges grown suspended above the bottom are superior in density and closeness of fiber to the natural sponges from the same locality. The same superiority is not apparent in those grown on disks, but the absence of the torn surface or root which characterizes the natural product makes them much more durable than the latter, the close felting of the attached surface making it the softest and strongest part of the sponge. In other words, the place of greatest weakness is converted into that of greatest strength, while the other parts remain normal. The artificially grown specimens are always superior to the natural product of the same immediate locality.

At Anclote Key a considerable proportion of the sponges grown on the bottom are affected with so-called crab holes, cavities which commonly contain small crabs. The general opinion of the spongers is that the crustaceans produce the holes, but of this I am by no means assured. As has been explained heretofore in this paper, practically all of the sponges planted on the bottom in this locality were previously injured by fresh water and already bore patches of dead tissue when planted on the bottom. As these dead areas sloughed away they left cavities, and I believe that these invited the crabs, which thus did not actually excavate their hiding places. In the many hundreds of these crab holes which I have examined in both artificially and naturally grown sponges I have never seen the slightest indication of a raw surface which looked as if the crab had torn away the tissues of the sponge. The presence of the crab, however, undoubtedly prevents the hole from filling up as it would tend to do under other conditions. In none of the healthy sponges planted on the bottom in Biscayne Bay do these holes occur, though they are found in the usual proportion in the natural sponges of the vicinity.

HARVESTING.

With the wire method of suspension from stakes, if such can be commercially developed, the problem of gathering the crop is simplified, for all that is necessary is to detach the wire at one end and slide the sponges off. As has been shown in the foregoing, however, this method has not yet been perfected and can hardly be commercially considered as yet.

With bottom planting on disks or spindles the method of harvesting will vary with the depth of water. In comparatively shallow water the crop can be taken up when matured by means of hooks, and the conditions essential are

the same as for ordinary sponging—the weather must be moderate and the water clear. In deep water, beyond the reach of the hooks, it will be necessary to employ divers to gather the sponges, which will materially increase the capital required and the expense of operation. As has been explained previously, the operations of harvesting and replanting can be economically combined.

TRANSPORTATION AND ACCLIMATIZATION.

The transportation of seed sponges by water has been dealt with in another connection, but experiments indicate that they can also be carried considerable distances overland if proper precautions be observed. With the air temperature ranging between 70° and 80°, specimens have been easily kept without injury by merely packing them in wet seaweed in tubs. Others have been shipped by express, closely packed with wet eel grass and gulf weed (sargassum) in orange crates, over distances requiring three days between the time of removal from the water and the time of replanting. Although carried in heated express cars they were absolutely uninjured and started growth immediately after transplanting. Of another lot shipped on a six days' journey under the same conditions nearly all were killed.

If kept cool, the sponges will live much longer, and there is reason to believe that if carried in moist packing in refrigerator cars there would be little doubt of their surviving a trip extending over one week. Thus, with proper arrangements Florida sponges could be carried alive to the California coast. With similar arrangements and with the facilities which would be afforded for giving the sponges occasional refreshing baths in sea water it is believed that little difficulty would be experienced in carrying specimens from the Mediterranean to Florida. The water used in moistening the sponges and the packing material must be of full oceanic salinity, an experiment having shown a mortality of 50 per cent among sponges sent on a three-day journey when a portion of the packing material was inadvertently moistened with nearly fresh water from Anclote River.

But while there may be little difficulty in transporting sponges to distant places and acclimating them in suitable waters, there is grave doubt if they will retain the characteristics which they exhibit in their original habitats. Sponges from the vicinity of Anclote Key transplanted to Biscayne Bay undoubtedly gradually developed some of the characters of indigenous specimens, but unfortunately the experiment to determine this point conclusively was seriously interfered with by a hurricane which intermingled the various lots. All of the transplanted specimens which could be definitely identified, about 15 in number, had completely lost their original characteristics at the end of two

years, and it is probable that one not knowing their history would be unable to distinguish them from those grown from indigenous seed. The close-set bristles which cover the surface of wire-grown sponges at Anclote have been replaced by flat brushes of fiber, the oscula, formerly inconspicuous, have become larger and resident on the summits of short tubular processes, the general texture of the sponge is more open, and, finally, the fibers have become thoroughly charged with the characteristic red color of the Key sponges. In some specimens the red coloration is more pronounced than is normal in the locality to which the sponges have been transplanted.

At Anclote, also, it was observed that whatever the source of the seed there was a strong tendency of the plants to advert to a common type, though there appeared to be a tendency to compromise between the influences of heredity and environment. Deep-water sponges a year after the cuttings were planted assumed the bristly appearance above referred to, but the processes were shorter and blunter than in sponges grown from shoal-water seed. The texture of the skeleton was also closer and more dense than in the cuttings of shoal-water origin, but neither resembled very closely the sponges from which they were derived. With these facts in view, it is almost certain that Florida sponges transplanted to the California coast, or Mediterranean specimens carried to the waters of Florida, will not retain their original characters, but it does not follow that they will be inferior. It is even possible that with judicious selection localities may be found where the transplanted products may prove superior to their fellows at home, though it is true that one can hardly expect to improve on the quality of the fine sponges of the Mediterranean.

ECONOMIC APPLICATION OF THE METHOD.

ESSENTIAL CONSIDERATIONS.

The choice of a locality for commercial sponge culture is a highly important consideration. In the first place, it must be one that can be guarded, for whatever the law may be it can not enforce itself, as has been amply demonstrated by the history of the oyster industry and some of my own experience in sponge culture. For this reason the small planter will have to select his location near shore, where he can live and himself guard his property, and this practically restricts the choice for such persons to the region of the keys. The large planter, employing a number of persons, can afford to station a guard boat on his plantation, and can therefore carry on his operations farther from shore and on the high seas.

Selection also must be made of a locality not subject to the effects of freshets and heavy rainfall on the adjacent mainland, and for this reason the

vicinity of the mouths of rivers must be avoided. The water should at all times be of a saltness not much below that of the open sea, and no locality where it frequently falls below a specific gravity of 1.019 or 1.020, reduced to a standard temperature of 60° F., can be regarded as safe. Disastrous experience on the plantations of the Bureau and of Messrs. Cheyney and Bigelow at Anclote Key, where the density, especially near the surface, fell below 1.018 for a considerable period and killed the majority of the sponges, emphasizes this consideration. Along the keys below Lower Matecumbe or between the upper end of Key Largo and Cape Florida this trouble is not likely to be experienced, but there are few places near the mainland opposite the keys or in the Gulf of Mexico, where localities close to shore can be occupied without apprehension from this cause. Several years may intervene between successive periods of fresh water, and the fact that it does not occur for one or two years does not guarantee that a plantation will not experience its effects just when the planter is beginning to hope to reap the results of his labor. With this consideration firmly in view, there is no great difficulty in avoiding most of the disasters which have affected the experimental work.

The experiments with wires and lines for the suspension of the cuttings above the bottoms having not reached favorable termination, the use of soft muddy or densely grassy bottom can not be recommended, and the sponge grower is, therefore, practically restricted in his choice to such bottom as is more or less capable of supporting a natural growth of sponges. Disks and triangles tend to sink on mud marl or shifting sand, or are overgrown when deposited among dense marine vegetation, in any of which contingencies the cuttings are either killed or injured. Even when the sponge is but partially buried in sand the basal portion will die from suffocation, and the still living upper parts will eventually lose attachment and be carried away. But a sparse growth of grass may prove highly beneficial in stimulating a more rapid growth of the sponges. This appears to be indicated by very recent experiments, and if it should prove true a large area of virgin bottom will be opened to productiveness. Otherwise, the selection of a sponge farm is practically limited to rocky bottom, though there are occasional localities where a mud bottom comparatively free from vegetation is sufficiently firm to support disks or triangles.

Care must be exercised also to avoid places where there is much sand carried in suspension in the water, as this will be deposited in eddies created by the sponges and their supports, and will gradually build up around the plants. This difficulty can be avoided on otherwise suitable bottom by raising the cuttings on spindles, so as to allow the currents to have a scouring action below the growing sponges. For attachments it is recommended that the disks described in a previous section of this paper be employed. The plain disk perforated by two holes is the simplest and cheapest form of attachment, but its

use involves more labor than when the form with a short lead wire spindle is used. The cuttings should be bound to the disk by short pieces of no. 14 or no. 16 Brown & Sharp gauge aluminum wire, passed through the substance of the cutting, and thence through the holes in the disk, the ends twisted together below.

The cuttings should be made as already described, and should have preferably a volume of 8 to 10 cubic inches, measuring, say, 1½ by 2½ by 3, or a little less. They should be made as regular as is convenient without the expenditure of additional labor. They can be handled and exposed to the air without special precautions, but should not be allowed to remain in foul water.

If the disks with short spindles are used, the cuttings may be merely threaded on to the spindle by means of a needle, as has been already described, the cuttings being pushed down into contact with the cement disk, to which, as well as to the spindle, they soon grow fast. The process is much more rapid and less laborious than wiring the cuttings to the plain disks, which fact almost compensates for the increased cost of material.

The triangles are not recommended excepting when it is necessary to use long spindles to raise the sponges above possible sand deposit, in which event they are less liable than the disks to capsize under the impact of the waves against the larger sponges. They are more difficult to handle and transport than are the disks, and more easily broken. When fitted with 8-inch spindles of lead-covered iron ribbon, they cost about twice as much per sponge as do the disks, and the greater labor of transporting to any considerable distance will add to the difference in cost.

In shoal water the disks or triangles with the cuttings attached may be dropped overboard right side up. They will in the great majority of cases sink to an upright position on the bottom, though occasionally, in strong currents, one will capsize in its descent. Advantage should be taken of the first opportunity to inspect the planting, to right the capsized disks, and to shift any that may have fallen on those already planted. In deep water there is greater liability that the disks will capsize; the danger is less with triangles. Though the experiment has not been tried, it is probable that an inclined chute, one end resting on the bottom and the other coming to the side of the boat, down which the disks could slide, would not only insure an upright position of the disks, but would generally facilitate planting. As the boat was hauled ahead the disks would be distributed over the bottom in rows.

FINANCIAL ASPECTS.

The cost of planting will vary somewhat with the locality, but the following figures, based on actual experience at Anclote Key, are fairly representative of what may be regarded as average conditions. The computation is based on

the requirements for planting 1 acre with a sponge on each square yard of bottom.

For plain disks:	
4,840 disks, at 2 cents	$96.80
4,840 cuttings, at 2 cents	96.80
Labor, planting, fifteen days, at $2	30.00
	223.60
For disks with short lead spindles:	
4,840 disks, at 2½ cents	121.00
4,840 cuttings, at 2 cents	96.80
Labor, six days, at $2	12.00
	229.80

The first cost is slightly in favor of the plain disks, the expense for aluminum binding wire being so small as to be negligible, but when it is remembered that both kinds of disks are available for subsequent plantings when recovered, this advantage disappears. Assuming that during four years of growth 20 per cent of the original cuttings die and that the disks to which they were attached are lost on account of their inconspicuousness, each of the above accounts would have to be credited with the value of the disks recovered, 80 per cent, amounting to $77.44 in the first case and $96.80 in the second, making the actual cost of planting in the two cases $146.16 and $133, respectively.

In subsequent use of the disks for replanting, especially in deep water where a diver is employed, the advantage is strongly in favor of the disks with spindles for reasons that have been already explained. The cost of harvesting the sponges can not be stated, as there are no adequate data available. In shoal water, where the sponges could be taken by hooks and the replanting with fresh cuttings be carried on simultaneously, the cost would be slight. Where a diver would have to be employed the expense would be heavier, but by using the spindles this could also be reduced by planting fresh cuttings as fast as the mature sponges are taken, without removing the disks from the bottom. In most localities in deep water there would also be a compensatory greater return on account of the superior quality of the sponges.

Assuming that there is no expense in guarding the beds, but that this service is incidentally performed by the men making the disks and planting the sponges, the apparent profits to be derived from sponge planting are as follows:

Net cost of planting 1 acre with 4,840 cuttings	$133
Value of 3,872 sponges (80 per cent of 4,840), at 25 cents	968

Thus, at the end of four years from the date of planting, the net value of the sponges on the bottom would be $835, assuming that they had grown at the rate demonstrated at Anclote Key and had attained an average weight of 1¼ ounces, dry, that the mortality during their growth was 20 per cent, and that

the value of pure sponges is $4 per pound, which is less than the average of recent years. These assumptions are all regarded as very conservative.

From this must be deducted the cost of harvesting, which, in shallow water such as is to be found among the keys, should not exceed about $25 if proper conditions of weather and water be availed of. The net return, therefore, from an original investment of about $225 per acre would be an average of about $200 per year. In deeper water the cost of harvesting the crop would be somewhat greater, but as the operations would be carried on on a larger scale economies could be practiced which would reduce the expense.

In conclusion it should be plainly stated that the above calculation, though based on the actual results of experiment, is largely theoretical and that definite data can not be attained until the work is actually undertaken on a commercial scale. It is confidently believed, however, that if directions are followed in a suitable locality the actual net returns per acre will be considerably greater than those stated.

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Plate LXIX

Fig. 1.—Sheepswool cutting of about the size recommended for planting.

Fig. 2.—Sheepswool sponge 11 months old, grown on wire at Anclote Key from a cutting about one-half size of figure 1. Natural size.

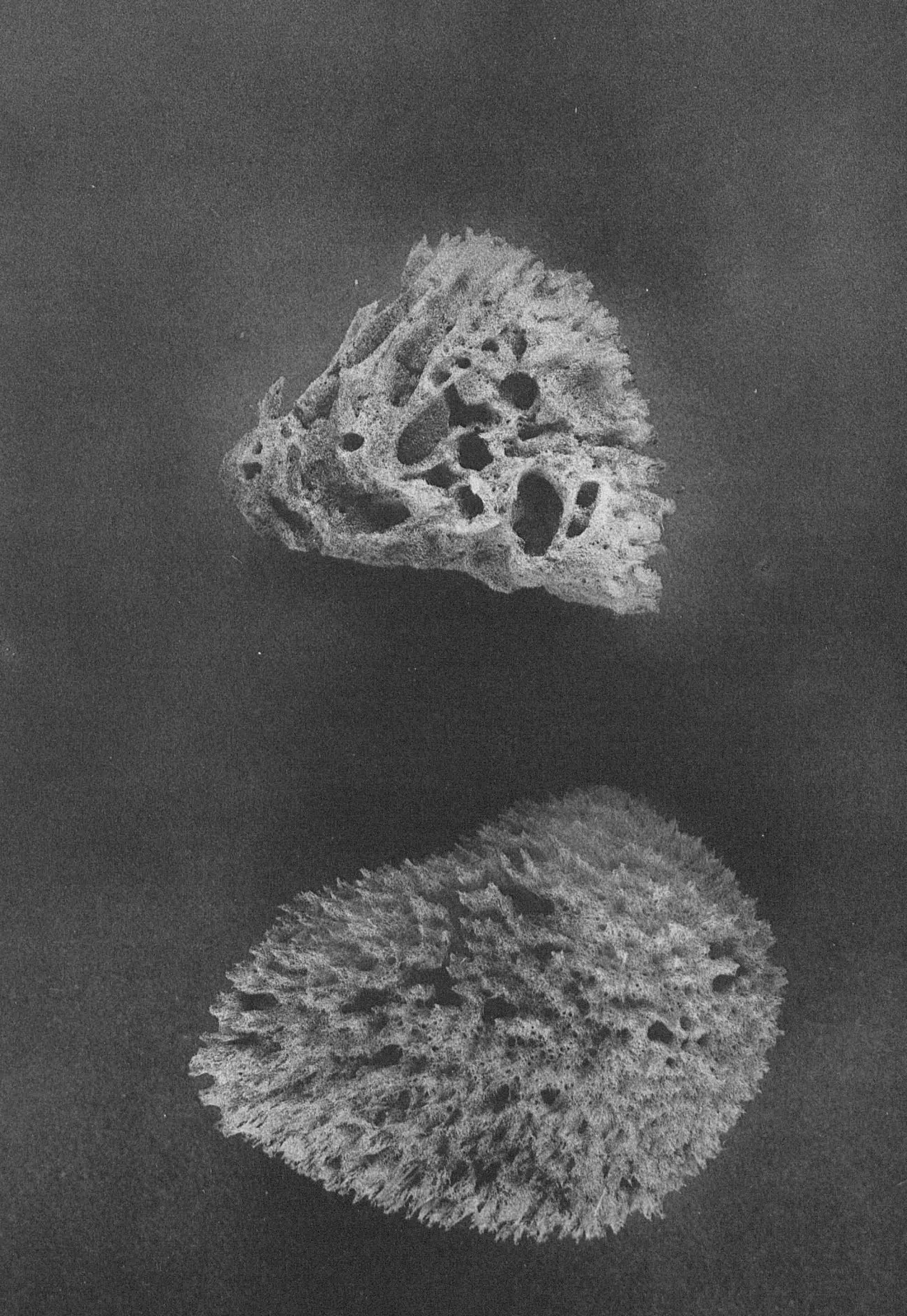


Plate LXX

Fig. 1.—Sheepswool sponge 20 months old, grown on wire at Anclote Key from a cutting about one-half the volume shown in figure 1, plate lxix.

Fig. 2.—Yellow sponge 21 months old, grown on wire at Sugar Loaf Key from a cutting about the size shown in figure 1, plate lxix. Natural size.

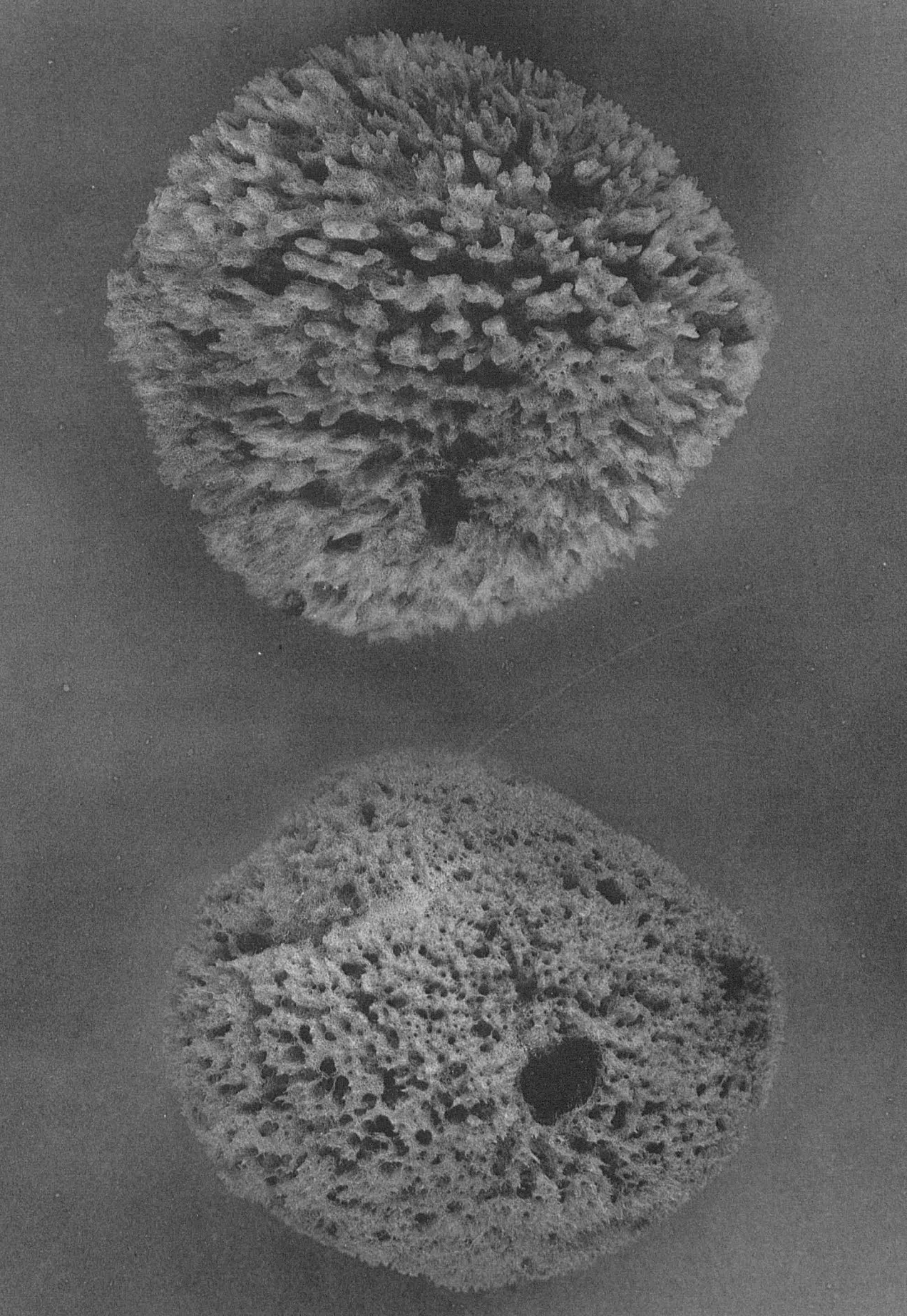


Plate LXXI

Sheepswool sponge 31 months old, grown on wire at Anclote Key from a cutting about one-half the volume shown in figure 1, plate lxix. Nine-tenths natural size.

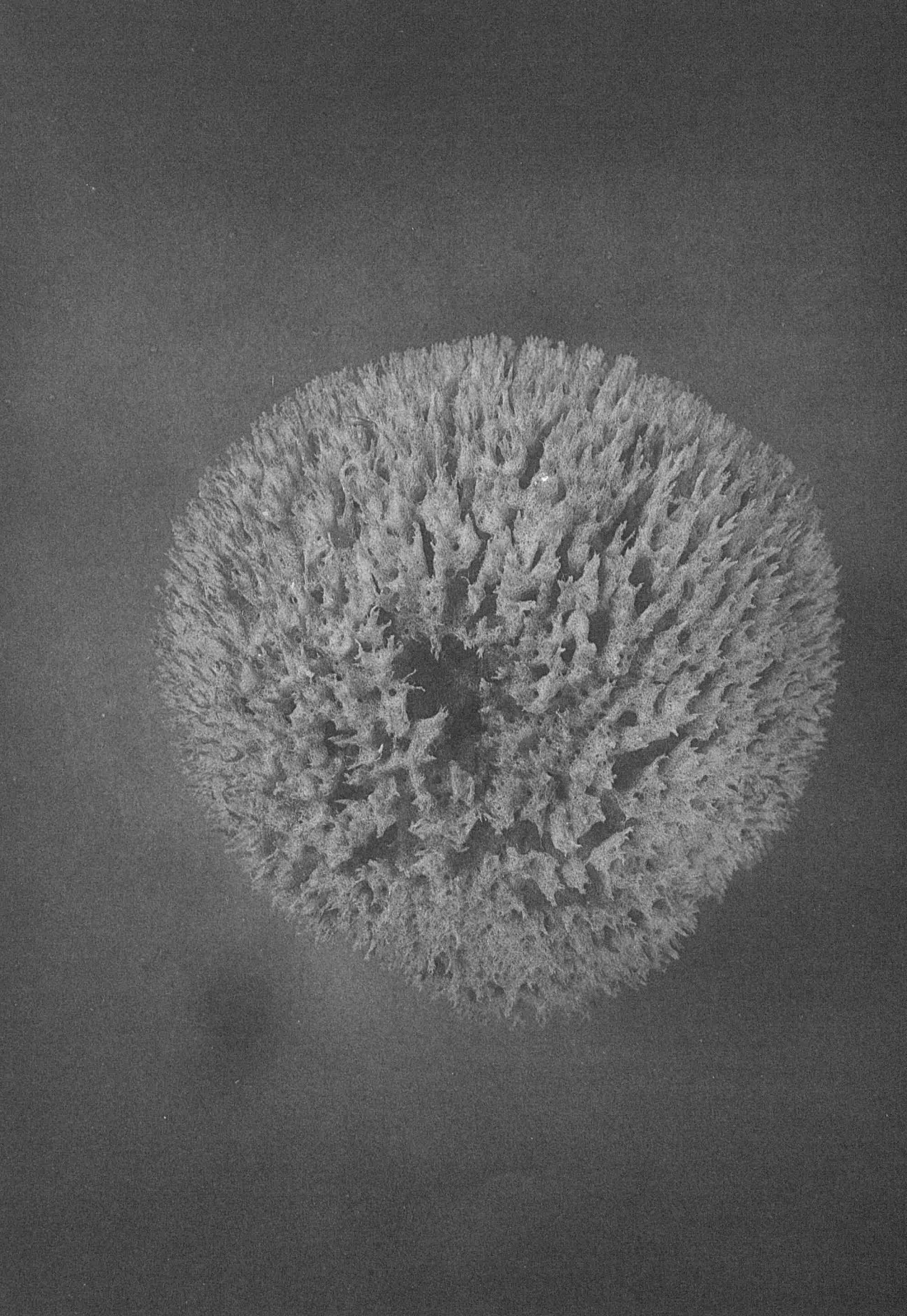


Plate LXXII

Sheepswool sponge 35 months old, grown on wire at Sugar Loaf Key from a cutting about the size shown in figure 1, plate lxix. Nine-tenths natural size.

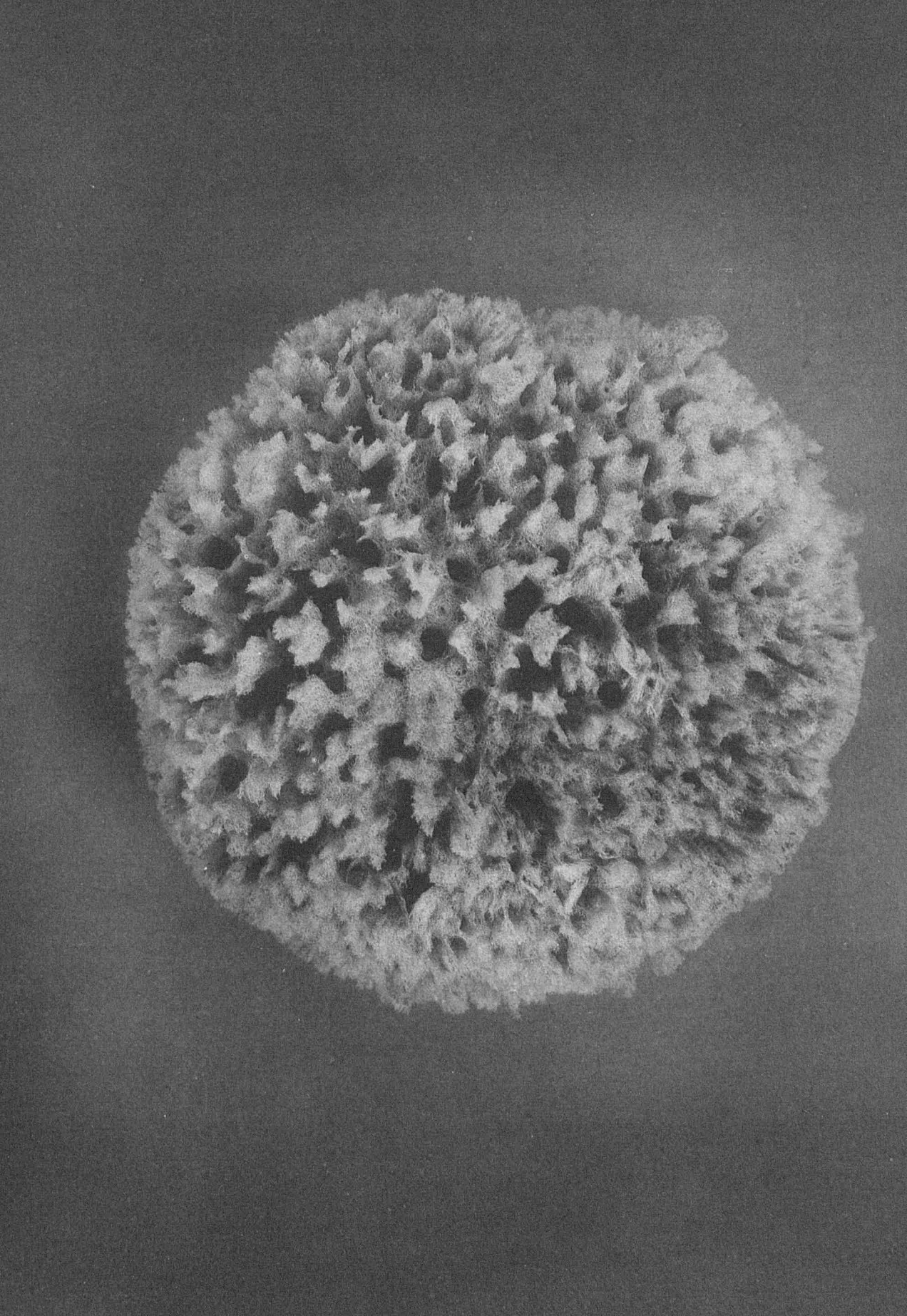


Plate LXXIII

Sheepswool sponge 52 months old, grown on wire at Cape Florida from a cutting about one-half the volume shown in figure 1, plate lxix. Weight, dry and thoroughly cleaned, 1 ⅓ ounces. Nine-tenths natural size.

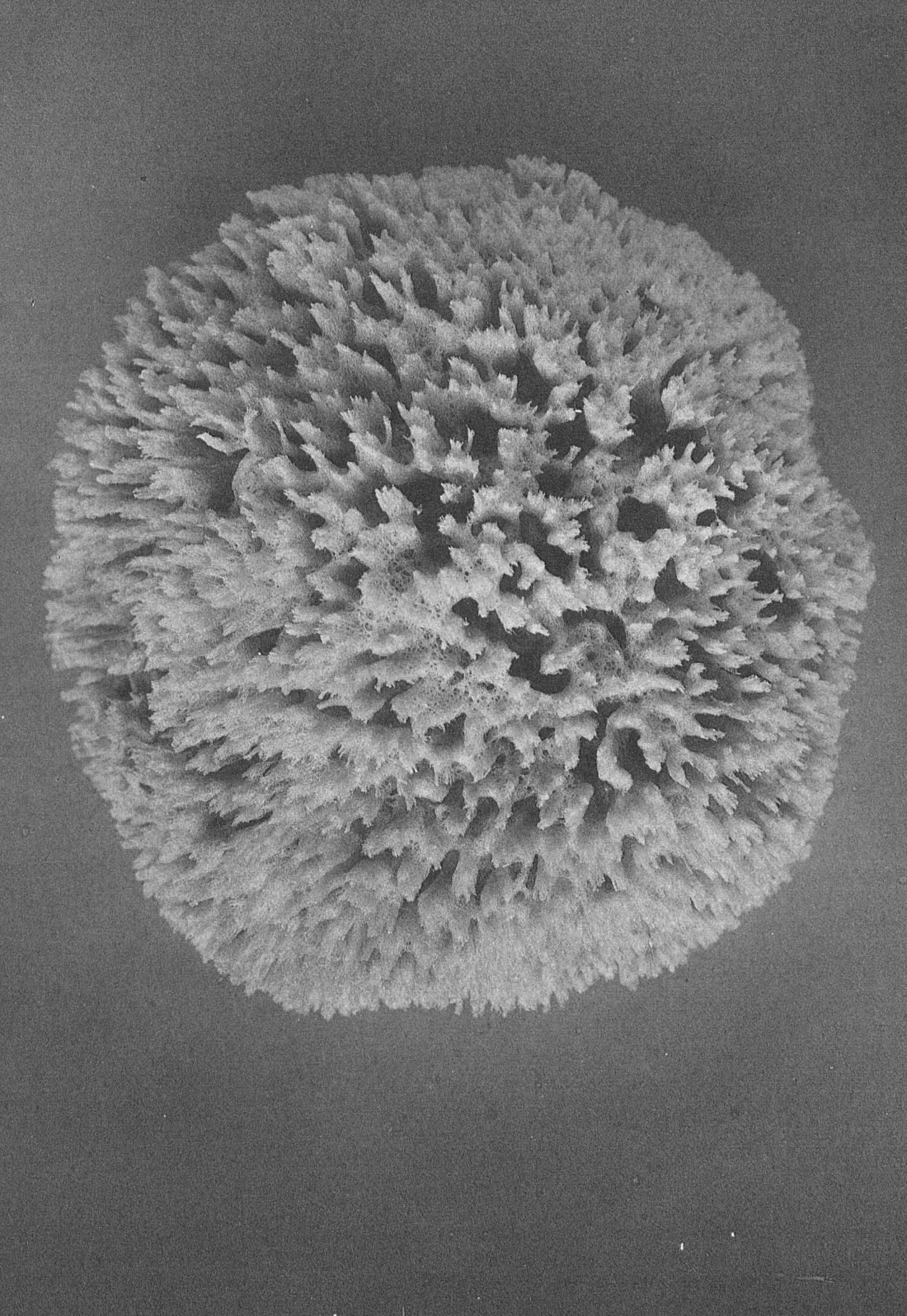


Plate LXXIV

Sheepswool sponge 35 months old, grown on spindles (plate lxvii) in Cape Florida Channel from a cutting about the size shown in figure 1, plate lxix. Weight, dry and thoroughly cleaned, 1 1/3 ounces. Nine-tenths natural size.

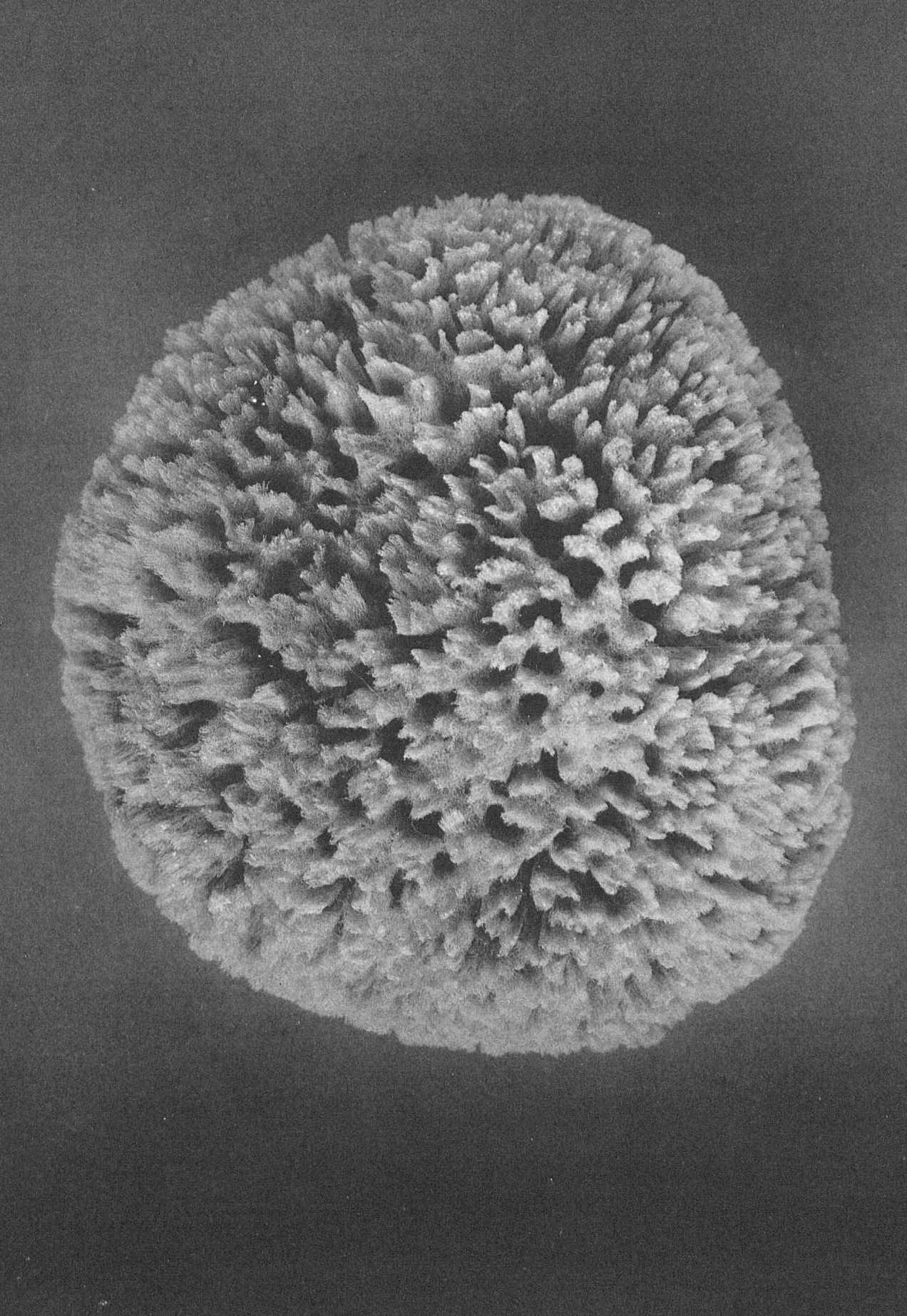


Plate LXXV

Sheepswool sponge not over 48 months old, grown on a cement disk at Anclote Key from a cutting about the size shown in figure 1, plate lxix. Weight, dry and thoroughly cleaned, 2½ ounces. Nine-tenths natural size.

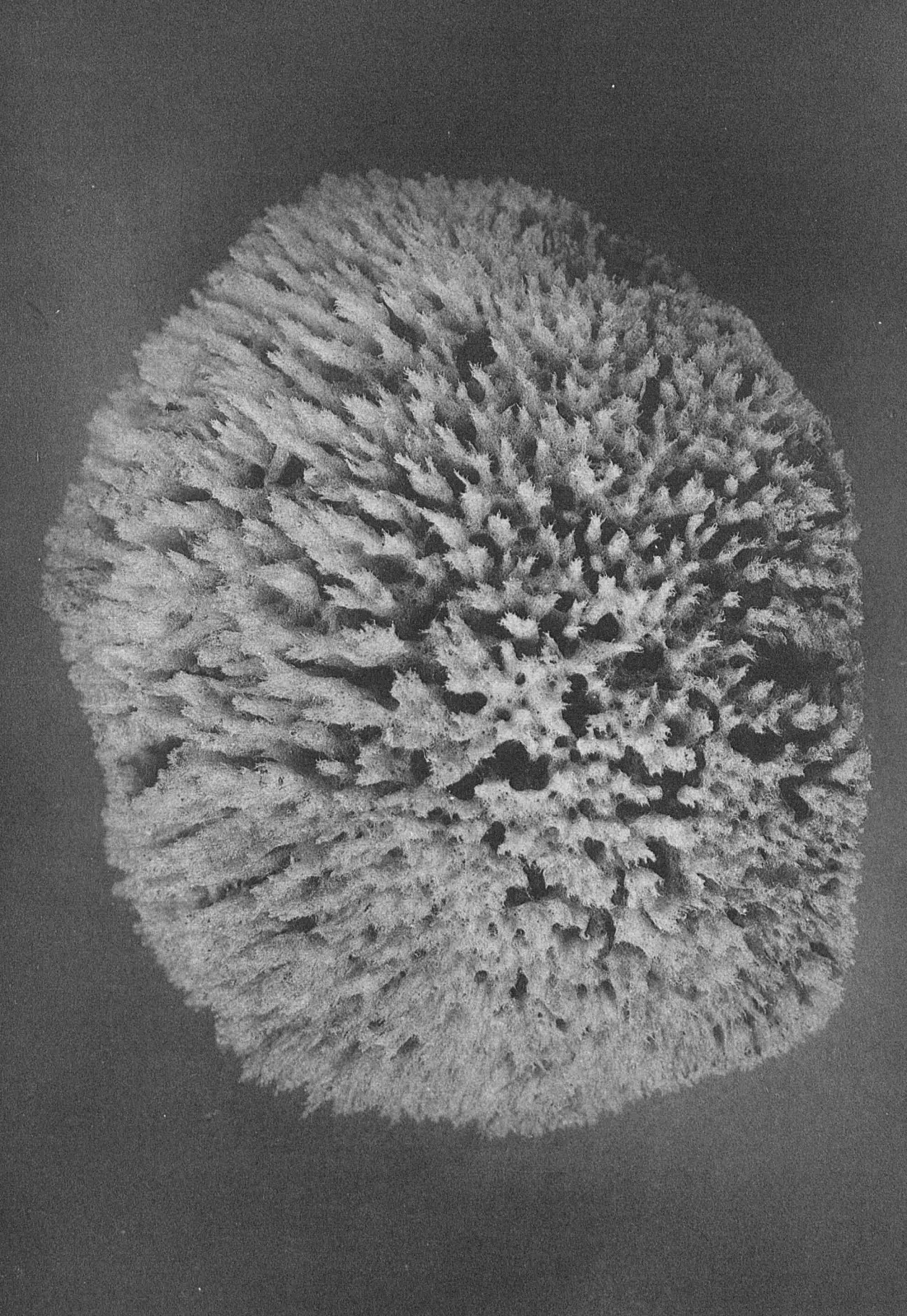
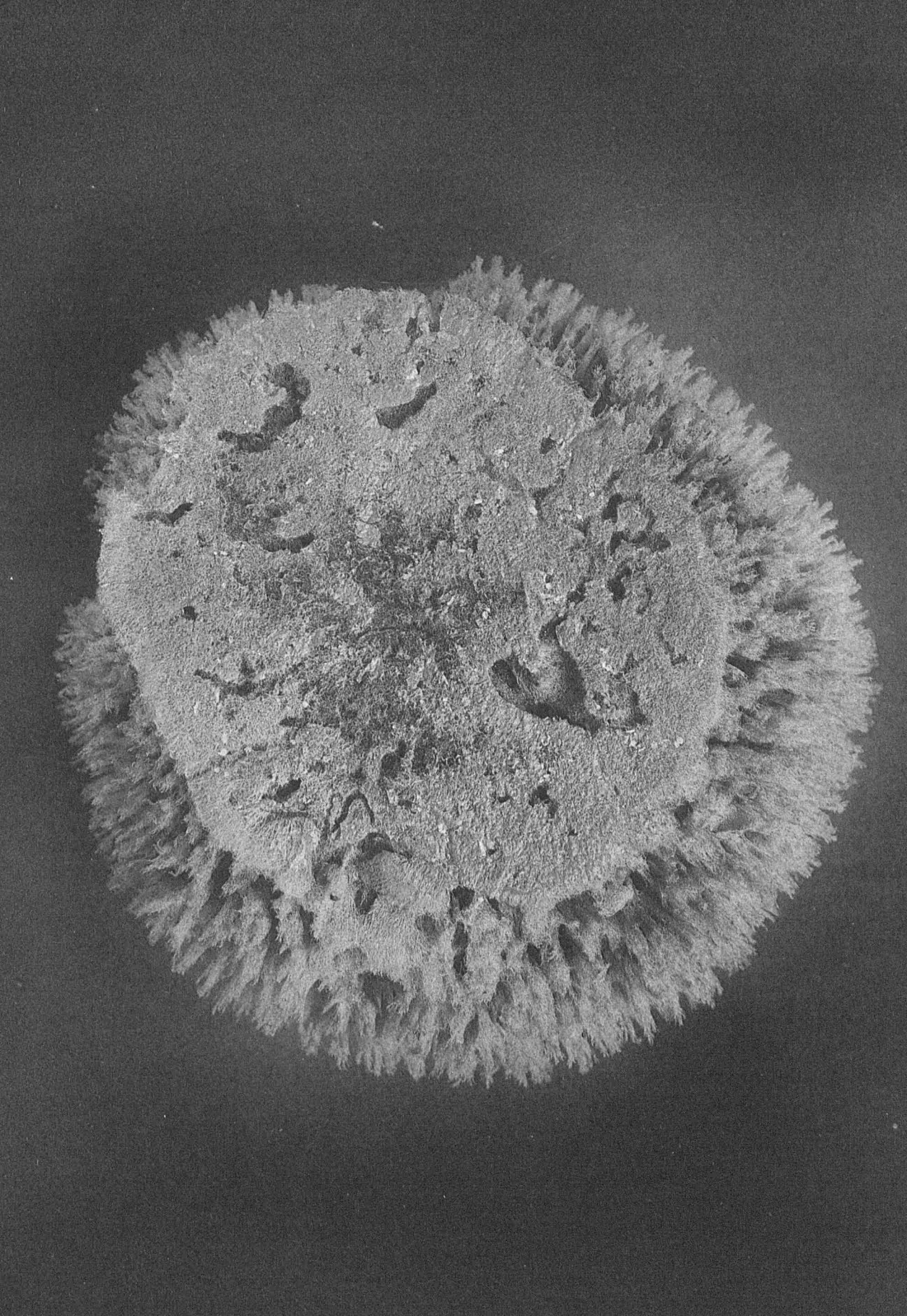


Plate LXXVI

Sheepswool sponge not over 48 months old, grown on a cement disk at Anclote Key from a cutting about the size shown in figure 1, plate lxix. Weight, dry and thoroughly cleaned, 1½ ounces. Nine-tenths natural size. This illustration shows the closely felted soft surface in contact with the disk. The corresponding surface of a natural sponge is open, like the interior, and therefore weaker and less durable.



SPONGE CULTURE

By Jules Cotte

Adjunct Professor at the School of Medicine and Pharmacy, Marseille, France

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
Definition of sponge culture	589
General considerations	590
Culture of sponges by planting	594
Sponge culture by parcage	598
Sponge culture by means of collectors for larvæ	599
Sponge culture by means of cuttings	604
Conclusion	613
Bibliography	613

SPONGE CULTURE.

By JULES COTTE,
Adjunct Professor at the School of Medicine and Pharmacy, Marseille, France.

[Translated from the French.]

One of the greatest glories of the nineteenth century undoubtedly will be its patient, persevering, and methodical exploitation of nature's resources. It must be acknowledged, however, that not everything has as yet been obtained from the sea that may well be expected. Great progress may be looked for in the propagation of useful species inhabiting its depths, although in this field of work, by its excessive mobility, the limits of exploited areas must be determined in a very arbitrary way.

Great anxiety has prevailed for a long time among those interested in the sponge fishing and sponge trade because of the improvidence with which the sponge grounds were being worked. It has been the most productive methods of fishing that were being sought, without any thought of the morrow. It is important to combat these unfortunate tendencies, and several procedures, of which each has many partisans, have been presented: One is the regulation of the number of fishing appliances (for example, the limitation of the number of divers, as in Tunis); another, the complete prohibition of certain means (the prohibition of divers, as temporarily promulgated in Tunis and elsewhere); another, the fixing of a minimum size for the sponges taken; another, applying to the fishing of sponges the principle of regulated cutting, with alternation of rest and fishing for each of the banks visited by the fishermen; the temporary prohibition of fishing (several months a year) in order to allow the larvæ to leave the sponges and to take root; and, lastly, the propagation of sponges by methods of culture.

DEFINITION OF SPONGE CULTURE.

The term "sponge culture" must be understood in the widest sense possible. It comprises all the methods which man may adopt in order to obtain under his direct supervision or by his intervention an increase in the output of commercial sponges from any given locality. It would be sponge culture to carry sponges

from one locality to another, either to increase the number of individuals in an already sponge-bearing region, to improve their production, or to make a barren region yield. It would be sponge culture to take young sponges from a natural bed and transplant them to a given area of the sea, a parc, where they might acquire a good commercial size under the supervision of a caretaker. It would be sponge culture to gather sponge larvæ on appropriate collectors and rear them in a suitable place. It would be sponge culture to break a sponge in several pieces and develop separately the individual cuttings.

It is thus possible for us to conceive various methods of sponge culture, each of which merits individual study, for we feel more or less strongly the lack of knowledge concerning the physiology of the sponge species when we take up the different methods. We shall call the first method sponge culture by sowing, the second sponge culture by parcage, then sponge culture by means of collectors, and lastly sponge culture by cuttings.

GENERAL CONSIDERATIONS.

The first question to be considered, as it belongs to all the methods, concerns the choice of the locality in which sponge culture is to be attempted. As a general rule, it is necessary to provide surroundings identical with those in which sponges naturally live as regards the depth and the quality of the water. It is, consequently, unnecessary to insist on the fact that the salinity of the water must be similar to that in which the sponges prefer to propagate; for example, care should be taken not to repeat the error of Lamiral, who attempted to introduce sponges from the Levant into the brackish ponds of the Mediterranean Sea.

Delage said that the sponges of commerce require somewhat rough water, which keeps in suspension the grains of sand, the remnants of *Foraminifera*, and the spicules of sponges which accumulate in the primary fibers of their skeletons. This, however, is an exact theoretical consideration which may be entirely overlooked in practice. The entire volume of mineral débris which a toilet sponge keeps inclosed in its spongeous sheath is never very large; it does not exist near the coasts where sponge culture is possible; there are probably few localities far from the coast where the purity of water is so great that sponges might suffer from a want of material for the formation of their skeletons.

The authors reporting experiments in sponge culture almost all agree on one point, i. e., that the results of these experiments are always remarkable when made in waters where there exists a certain current. Buccich and O. Schmidt [a] advise localities but little exposed to waves coming in from the open sea, the bottom lined with highly colored algæ, and a certain current present.

[a] In Marenzeller.

Fogarty[a] has observed that the presence of a moderate current is most useful. These results are evidently explained by the simple fact, known to all, that the waters of a current are better aerated and contain a richer fauna. In such places, consequently, a more abundant supply of nourishment is available and from it the bottom animals, like the sponges, profit more or less directly. It may be easily understood that the presence of a certain current improves the conditions of the surroundings in which the sponges grow and facilitates thus the success of experiments in sponge culture. However, too swift currents should be avoided. The aim of sponge culture is the furnishing of skeletons of sponges easy to sell, hence we must not forget that the sponges grown in very agitated waters have a coarse skeleton and that this diminishes their commercial value. This observation was made a long time ago; Aristotle says that sponges differ according to their place of growth, "the ones by their softness and the others by their coarseness," and he thus explains this fact: "The softest sponges are those which come from deep, always quiet, waters." Similar observations have been made by modern fishers of sponges,[b] and the reason is easily found. We meet here one of the applications of the principle of Lamarck concerning adaptation to surroundings. The rôle of the spongeous skeleton of a *Euspongia* or a *Hippospongia* is to insure a relative rigidity to the body of the animal; it is quite natural that there should be established a certain automatic balance between the firmness of the skeleton and the shocks or pressure which the sponge has to bear. This is a hypothesis which Keller[c] has very well elucidated. It might not be quite wise to accept all the deductions he made from it, but the primary idea of his work seems to me perfectly correct. We can not as yet properly orient the phylogenic tree of the spongeous species. In certain kinds the spongeous matter is doubtless in part an ancestral persistence; in others it may have been acquired more recently, and we have no means of distinguishing between these two species. Hence, the ideas of Keller should not be discredited, because species generally inhabiting relatively deep and calm waters are provided with rather firm spongeous skeletons.

It would be interesting to know, also, without departing from this question, whether the individuals developed in agitated waters owe the firmness of their skeleton to a difference in the nature of their spongeous matter (greater impregnation of salts, for example, different physical condition, etc.) to a greater quantity of solid particles in their primary fibers, to a greater thickness of these fibers, or to a lesser flexibility of secondary fibers. We know that Len-

[a] In Rathbun.

[b] See observations of M. Crozat, made on the coasts of Provence, in: L'Industrie des pêches aux Colonies, by Darboux, Stephan, Cotte, and Van Gaver, p. 220, vol. I.

[c] Zeitschrift für die wissenschaftliche Zoologie, vol. LII, and Festschrift der Universität Zürich, Nägeli and Kölliker, 1890–91.

denfled has shown us the rôle played in the suppleness of sponges by the flexibility of their secondary fibers; it would be necessary to determine whether this flexibility is closely dependent upon the conditions of the surroundings and whether it is immediately modified by the latter, beginning with the first generation of cultivated sponges.

A detail which the cultivators of sponges must not lose sight of is the very great care with which the sponges should be manipulated. They thrive well only in running water, and the aquarium of a laboratory is not a favorable place for their development, unless the water be constantly renewed. Moreover, they very quickly die out of water, especially in summer. We do not find any commercial sponges in shallow areas not covered by water at low tide, which is a fact to be taken into account. Preference should be given, consequently, as far as possible, to methods of work in which the sponges shall not be taken out of their natural element, or in which they shall be taken out for the shortest period possible. We find in bibliography some information on the duration of sojourn in the air compatible with the submerged life and the normal development of individuals experimented with. Allemand has made numerous experiments on this point. He has found that sponges left ten hours in the shade (at 12° to 14° C.) may revive and continue to grow.

It might be said that, on the whole, experiments in the culture of sponges so far have not been conducted by the method which ought to characterize scientific work; they have been mostly empirical and lacking the substratum of knowledge which preliminary research and observations would have furnished. It seems hardly credible that the partisans for and against sponge culture should have spent so much time in discussion, debating whether sponges propagated from cuttings develop more or less rapidly than those derived from larvæ, without any research to ascertain the period of growth of a normal sponge. This is, nevertheless, the fundamental information, the key to all undertakings in sponge culture, which requires a fixed capital in order to withstand the fluctuations in market prices. If a sponge needs ten years to acquire an adequate size, or if ten months are sufficient for this, sponge culture has to be abandoned a priori, or deserves to be studied. Investigation as to the rapidity of growth of sponges derived from larvæ is the first thing to be done before sponge culture can be considered, and this research ought to be conducted methodically in each sponge-bearing country and for each of the species utilized. It is not possible to maintain that *Hippospongia equina elastica* develops in various countries with exactly equal rapidity, nor can it be said any more justly that the rate of its growth may be compared to that of the American sheepswool. Each variety may have its particular rate of development; we have already seen that in regions where there is a certain current the cuttings

of sponges grow more rapidly. It is consequently impossible to establish any general rule, and definite conclusions may be arrived at only after numerous observations. Yet, scientific observations in this line are not numerous and can not be superposed; infrequent endeavors have been made to throw some light on the legends current in this question.

We know nothing precise in regard to the most highly prized variety, *Euspongia officinalis mollissima*. Masse says that at Rhodes it reaches an average size within three to four years. As to *Hippospongia equina elastica*, Servonnet and Laffitte fix upon a few months, according to the statements of fishermen, as being the time necessary for this sponge to obtain commercial size in the Gulf of Gabesa. This idea continues to be applied to the Sfaxian region, where Servonnet and Laffitte have gleaned part of their information. The fishermen and the merchants of sponges determine the age of individuals (one, two, three years) by the dimensions. Bouchon-Brandely and Berthoule report that in the month of June a diver had observed carefully on a rock in the environs of Benghazi the existence of 57 very young sponges, lately out of their larval stage; the following year he dived at the same place and found the same sponges still alive, their number being almost the same, but their diameter about 10 centimeters. This observation deserves attention, as it has been confirmed by researches made by Allemand. This author has noticed that for *Hippospongia equina elastica* about two years, beginning with the time when the larvæ gets fixed, were required for the circumference to reach 30 to 40 centimeters.

The researches made in the laboratory of Sfax were more successful than those made by the Administration des Travaux Publics of Tunis. The latter had three parcs constructed in March, 1897, at Sfax, at Kerkennah, and at Djerba, and sponges were carried there with all desirable precautions. The sponges had not increased in size by September, and they were invaded by algæ, which shows to what an extent their vitality had been weakened. Experiments were made with still less success, as may be easily understood, with sponges brought to Tunis in August, 1898, and held in glass jars. At Kerkennah eight living sponges were isolated under water by means of metallic gratings; development in size was noticed throughout the months of October, November, and December, but ceased later on.

The American species grow very rapidly, if we are to believe the accounts. The velvet acquires a commercial size in one year, and the sheepswool and the glove are said to grow faster still. Sawyer fixes [a] at ten months the time necessary for a sheepswool to weigh 45 grains. At Nassau the time is fixed at four months,

[a] In Brice.

and even three months[a] (Nye) is given for the same variety; for Arapian[b] this period varies according to localities, from four to six months. If this information is correct, which even Bidder doubts, it is easy to understand the optimism of the fishermen who do not fear any serious decrease of wealth of growth; it would seem, however, that if the impoverishment does not take place so rapidly in all sponge-bearing countries it yet threatens them all, for in none of the commercial species is development so extremely rapid as might be expected from some of the opinions I have mentioned here.

CULTURE OF SPONGES BY PLANTING.

It was by planting that the culture of sponges was first undertaken by Lamiral. Being one of the members of the Société d'Acclimatation, he prevailed upon the latter to intrust him with the mission of transplanting to the western coast of the Mediterranean Sea *Euspongia officinalis mollissima*, which inhabits the eastern region of this sea. The knowledge of Lamiral concerning the biology of sponges was elementary, and among the localities in which he proposed to introduce them were, as I have already mentioned, brackish ponds along the shores of the Mediterranean Sea. The Société d'Acclimatation had intrusted the study of the propositions of Lamiral to a commission, the reporter of which was Loubeiran. The report was very sensible and contained excellent advice as to the conduct of such work. The brackish ponds were to be abandoned, and advice was given in favor of localities along the shores of Africa. Lamiral had been given a sum of 5,000 francs, of which 1,000 francs were donated by the governor-general of Algeria, Marshal Pélissier.

Lamiral neglected one of the most important precautions indicated in the report of Loubeiran. Instead of keeping the boxes containing sponges submerged in the sea, he disposed them on the deck of the steamer. The water was changed, it is true. The period of transportation was likewise badly selected—in June the temperature is much too high. Attempts were made with ice to cool the water flowing on the sponges, but the effect of these adverse conditions did not fail to show. Tank water is alive with bacteria; Lamiral thinks that they are sexual products:

> The water flows out of the tanks, leaving on deck a fatty and white substance which must be the substance of the larvæ * * *. The difference in temperature of the water in the tanks has advanced the period of swarming of the sponges. They are ill from the parturition excited before its time.

Arrived on the coast of France the sponges were placed in cement boxes and deposited in the roadstead of Toulon, at Bandol, at Pomegues, and at Port-

[a] Cited by Thomas Lee in Report on the work of the U. S. Fish Commission steamer *Albatross*, by Z. L. Tanner. Report U. S. Commission of Fish and Fisheries, 1886 (1889).

[b] In Brice.

Cros. Those placed at the latter point had traveled a whole month; it may be easily understood in what condition they were. At the end of the same year, the sponges in the roadstead of Toulon were said to be still living and even to have increased in number (?). But at the close of the following year nothing remained of them anywhere. Such was the end of the enterprise. The transplantation of these 123 sponges from Syria cost 4,993.20 francs.

Lamiral later organized at Marseille a committee of aquiculture, which had only a few meetings and did not have the time to produce any useful work. The culture of sponges was on its program, but no attempt in this direction was made.

General Garibaldi[a] had thought at Caprera to make an experiment similar to that of Lamiral. In vain have I endeavored to obtain information as to whether Garibaldi's project was put into execution. It is more than probable that no attempt was made.

The projects of Espina, French consul at Sousse,[b] who wished to attempt dissemination of sponges on the coasts of Algeria, were not brought into effect, neither were those of Salse and Deel,[c] members of the Société d'Acclimatation of Nice, who proposed to transplant sponges from Syria to the shores of the island of Ste. Marguerite.

In 1896, at the request of the Colonial Office of Great Britain, Bidder indicated his opinion as to the mode of proceeding in experiments of this kind. He advised placing stones bearing the sponges in wooden cars with lateral apertures and having pointed extremities; these cars were to be towed in the rear of steamers, barely floating and letting the water flow through, which would be useful in case of an accident. But Bidder did not deem this experiment advisable; it would be "an experiment in the dark." He concurred in the opinion of Hyatt that the American sponges were simply varieties of the European species, produced under the action of a higher temperature and of coral sands; sponges introduced from the Mediterranean Sea to the Bahamas would probably undergo the same adaptations, and would thus become identical with the native varieties.

Lendenfeld does not admit, and not without reason, such plasticity in the sponge family, but he does not believe any more than Bidder in the success of attempts to transplant sponges long distances; he holds as a principle that transplanted sponges are less suited to their surroundings than the native ones and consequently not so well fitted for the struggle, a fact which will cause them to disappear in time. Expressed in such a form, this conclusion is some-

[a] Bulletin de la Société d'Acclimatation, vol. VIII, 1861.
[b] Ibid., vol. X, 1863.
[c] Ibid., 2d s., vol. I, 1864.

what too arbitrary. The density of the population of sponges on the banks is not so great that new individuals might not live in unoccupied spaces. It seems that the deterioration and degeneration of imported species is more to be feared than their entire disappearance, if the choice of the varieties and of the localities destined to receive them be made with sufficient care.

All this obviously pertains to transportation at long distances. There should be no hesitation whatever where short distances are concerned. All naturalists know that such transplantation is possible and, taken all in all, quite easy. All those who have attempted it have succeeded, no matter what species of the sponge family was experimented with, and experiments have several times been made with the commercial varieties. As to the *Hippospongia equina elastica*, Allemand transported in April and May, 1906, 67 sponges obtained at Sfax, which he immersed and made to live in the Lake of Tunis; on June 15 of the same year 44 remained alive, some of them, however, in a rather bad condition.

There is a reason for asking whether the culture of sponges from seed is worth the effort. It may answer two purposes—that of introducing sponges and establishing fishing grounds in regions naturally without this industry, or that of improving the production of a region having sponges of inferior quality by renewing the varieties existing there. Whatever the object in view, it is necessary to make the attempt with the greatest possible number of individuals and to be content to wait for results in a distant future. For the dissemination of the introduced varieties, we must depend upon the swarming of the larvæ around the centers of dispersion formed by the transplanted individuals, and it is only after a sufficiently long time that a group of these individuals may be seen to form an oily spot around the place where they were deposited. It is, consequently, an undertaking demanding much time and much money; we can not expect private persons to risk the undertaking for the purpose of profit; only powerful organizations can afford to take the initiative in this matter.

The rapidity with which the diffusion of the acclimated colony occurs depends upon a large number of factors. Account should be taken of the strength of the current at the given point to carry the larvæ along and, moreover, of the active movement of the larvæ themselves. We know very little concerning this latter question, however. I do not think that much has been learned as to the rapidity of movement of larvæ of the utilized species. I have, however, demonstrated that in the monaxid *Reniera simulans* the larvæ move at an average rapidity of 0.10 meter per minute. Under the combined action of the beatings of their lashes and the force of the current, the larvæ of sponges may make quite long distances, though these distances in actuality

seem to be rather limited. On the one hand, the movement of larvæ does not occur constantly in a clearly determined direction, but in a most irregular zigzag. On the other hand, the larvæ pass but a short time in a free condition, not over a few hours; hence they generally are fixed near their parent. Consequently the extension of transplanted colonies takes place very slowly. On the exploited points off the coast of Tunis observation showed that the maximum density of groups of sponges varies each year in a direction determined by the currents and the tide, but that the area of these displacements is not extensive.

If it is desired to sow sponges in an almost barren region or in a region situated a short distance from cultivable banks, it is necessary to ascertain that there are no special conditions adverse to a spontaneous growth on these bottoms which might interfere with the success of the proposed attempt. Let us take as an example the coast of Provence[a]: There may be found the *Hippospongia equina elastica* and the *Euspongia officinalis lamella*, but the individuals are not numerous in general, so few in fact that their presence was for a long time unperceived. Shall these be considered as the scarce descendants of former colonies which have disappeared almost entirely? It is certain that these sponges have a difficult struggle against unfavorable external conditions, and it would not be logical at the present stage of our knowledge to bring here at large expense the same varieties of sponges as the native ones in an attempt to disseminate them where sponges a long time acclimated show so little vitality.

Allemand noticed that the bottoms of the cantonment in the vicinity of the laboratory of Sfax are not everywhere favorable to the life of the sponges. In one part of the bottom "invaded by light yellow algæ, which probably harmed the sponges," all the individuals planted there perished. This is one more proof of what I assert, i. e., that the biological study of sponges is as yet not sufficiently advanced for the success of an undertaking in sponge culture to be determined in advance.

In short, sponge culture by seed may be compared to the replanting of forests on mountains by setting out a certain number of adult trees, the fate of the enterprise resting solely on the spontaneous dissemination of seeds from the latter. The results obtained might be excellent in some cases, while in others only failures would be registered. The seeds of the transplanted specimens might be inferior in the struggle for existence as compared to the neighboring specimens of vegetation; herds of cattle, if they were allowed, might destroy a quantity of young plants, and, similarly, the larvæ of sponges might in certain places be pursued by active enemies. Lastly, imagine the

[a] See J. Cotte: La pêche des éponges en Provence, Comptes rendus des Sociétés savantes de Provence. Marseille, 1906.

disappointment awaiting the sylviculturist who should attempt to grow chestnut trees on soil permeated with lime. Compared to our knowledge of sylviculture, our knowledge of sponge culture is most uncertain, and it is therefore difficult to foresee the future of sponge culture from seed. There arises in this instance the question of species; each individual case ought to be studied separately and only one general rule may here be given—that recommending the greatest prudence.

SPONGE CULTURE BY PARCAGE.

This method might give more immediate results than the former. Undertaken by a private individual in a limited and well-defined area of the sea, it would consist in preserving sponges of small dimensions, brought up in fishing, by placing them in favorable localities, whence they would be taken out at the desired time to be prepared and sold. The fisherman would not neglect the small specimens, the skeleton of which can be sold only at a loss. If the legislation of his country is wisely protective, if it forbids the fishing, sale, and exportation of small sponges, the fisherman will preserve them in parcs, awaiting the time when they will be sufficiently developed.

Such an enterprise is theoretically possible, but this does not mean that it would be remunerative. Sponges which it is desired to preserve must be gathered and transported with the greatest precautions, for which there are no facilities in practical fishing and which would render the latter quite expensive. In spite of the greatest care individual sponges would suffer fatally; the death of some would be unavoidable and the survival of the others would demand a certain period of time to recuperate and regain their former health before growing. "A fixed fragment, or an entire sponge transplanted and fixed like a fragment, will exhibit a rapidity of development much inferior to sponges coming up spontaneously." Such is the opinion of a convinced sponge culturist, Allemand.

The installation of a parc would probably be subjected to an annual tax which we might suppose to be quite negligible; but expenditures of maintenance would not be at all negligible. Sponges are a commodity which it is very easy to steal, and it would be necessary not only to supervise the parc but even to inclose it. It has been observed that sponges do not develop so rapidly when they are subjected to too much thinning. This was noticed by O. Schmidt and Buccich in regard to *Euspongia officinalis adriatica*, and it was likewise observed by Allemand in regard to *Hippospongia equina elastica*. Sponges can not, consequently, be kept in very shallow water; the inclosing of the parc would then be very expensive if it were done with a wall; it would be necessary to content one's self with determining the boundaries by means of floating beams.

However it might be effected, this expense would have to be added to that involved in taking up the sponges with which to stock the parcs. It remains to be seen whether these expenditures would be covered or exceeded by the profit from this enterprise.

Everything depends upon the rapidity of growth of the sponges. We have already noticed the data obtained. In Tunis, for example, we may expect from what we have learned that specimens of *Hippospongia equina elastica*, too small to be sold immediately, may be placed in parcs and would be ready for preparation beginning with the following year. Profit would be rapidly obtained from the difference in price for small sponges, which must be sold at a loss, and that of sponges of commercial size. It is difficult to calculate, however, whether this difference in price would counterbalance the expenditures involved. This is a question to be solved by experience alone. So far, we have the right to have a limited confidence in the future of this method of culture, but not to believe in its importance, since it seems that it can never be adopted on a very large scale.

SPONGE CULTURE BY MEANS OF COLLECTORS FOR LARVÆ.

This method, which might be considered as the most perfect theoretically, consists of parcage, not of the small sponges obtained by difficult and very expensive fishing, but very young sponges, fixed on adequate collectors. This method was neglected by most of the experimentors in spite of the advantages which it presents theoretically; this comes from the fact that the authors hesitated to undertake observations on larvæ of sponges, the average length of which is of about half a millimeter.

Ralph M. Monroe,[a] after having stated the results obtained by sponge culture by cuttings, says:

> It is quite possible that with state protection to the planters, and better methods to be determined upon by further experiments, sponge culture might be quite profitable. My belief is, gained in oyster culture from spawn, that a similar method with sponges will eventually prove the correct one, but until more is known of sponge biology it would be useless to suggest methods, notwithstanding the fact that several points in connection with it have been to my mind quite clearly demonstrated.[b]

In "L'Industrie des Pêches aux Colonies" we read:

> The desired aim might be more easily reached, perhaps, in operating on methods similar to oyster culture and clam culture, by receiving on suitable collectors the larvæ given out by sexually mature sponges in closed spaces. * * * It should not be forgotten, however, that it would be a very difficult attempt.

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[a] H. V. Wilson has studied the reproduction of sponges "by means of eggs, by means of the gemmules, and by cuttings." (Report Commission of Fish and Fisheries 1889–91 (1893).) Wilson's works have been published, but he is not engaged in sponge culture.

[b] In Allen. 1896a.

Allemand announces practical experiments in this matter. The information published by him on this subject is, however, quite elementary:

> A larva, fixed to a support which we afterwards immersed in flowing water in May, 1905, has developed this summer, but gave in September only a large spot with an oscule, not a completely formed sponge; this fact ought to be ascribed to the manipulations necessary in the transportation of the larva.

Evidently we can not deduce anything from this solitary failure.

In view of the absence of positively established facts, we are forced to study this method in a purely theoretical manner. The choice of the collectors deserves first consideration. Breeding effected in aquaria shows that collectors of various kinds may be utilized for the larvæ of sponges, and we know that such is the case in nature, the larvæ of commercial species attaching themselves to plants (branches of *Posidonias*) as well as to shells and stones. It should not be forgotten, on the other hand, that these collectors must be easy to manipulate and very inexpensive. We need not expect such a number of sponges to attach to these collectors as might be observed on oyster collectors. Are there not found in Arcachon over 300 young ones on one tile? After the young sponges are attached they should be preserved, and we know that they must adhere to a support. If small stones or shells have been utilized as collectors this support will not be of a sufficient size to be considered permanent, and it will have, in its turn, to be attached to another support. Should tiles be used? Tiles would be durable, as there could be no question of disintegration, but the use of tiles would be expensive. It seems that a good collector might consist of wooden branches tied in fagots and immersed in the vicinity of sponges that have attained their sexual maturity. The branches possess great resistance to sea water, and by using them, as is being done in Italy in deep-water oyster culture, it would be possible to divide them and to tie them to ropes or to apparatus similar to that used for sponge culture by means of cuttings.

The use of fagots presents another advantage. It is generally admitted that the larvæ of sponges possess a marked negative phototropism. My observations, made on *Reniera simulans*, do not concur with those of other authors in this respect, and I found, on the whole, that the larvæ of this species are quite indifferent to light. Allemand has stated that the larvæ of a commercial species, *Hippospongia equina elastica*, seek a feeble light. It is certain that a negative tropism theoretically may be very useful to the species by impeding the larvæ from rising to the surface and by making them descend to less lighted regions, i. e., to the bottom, where they may find supports in great numbers; the opinion of a sponge diver would be quite useful, and it would be wise to ask him whether young sponges are not often attached above their mother to vertical walls of rocks. Should there really exist a negative phototropism the fagots would present the advantage of offering in their lower

region a zone of lesser light, where a greater number of larvæ would attach themselves; these would be attracted at this point less imperiously by the darkness of the bottom.

Supports for young sponges would be attached with advantage to bodies which the waves might put in motion—ropes treated so as to resist putrefaction, etc. Bidder luckily demonstrated the advantage derived by sponges living on mobile supports. Thanks to the renewing of food and aerated water, a consequence of their oscillations, the rapidity of growth of young sponges is increased. It should not be lost from view that in such cases the skeleton is coarser, as stated by several authors; the advantage gained on the one hand is decreased by the diminution in value of the product obtained.

The sponge cutting should be immersed at a certain depth, and it seems rational from this point of view to choose the depth preferred by the spontaneously grown sponges of the species it is desired to cultivate. Experimenters have noticed that sponge cuttings seem to fear too intense a light; this is a thing to be remembered and may find its application.

Sponge culture appears to us then as an operation fraught with difficulties, which can be attempted, without involving too high expenditure, only in localities offering an exceptional combination of favorable conditions. It should not be forgotten that if the sponges are to be immersed at a sufficient depth they must be attached so firmly that a wave shock can not detach them. They should also be protected against marauders, and the question of guarding the parcs and inclosing these arises again in connection with the expenditure involved.

It is possible to attempt the combination of this method of sponge culture with that undertaken in parcs by placing the collectors in the parcs themselves where the adult sponges are kept. There would thus be no interruption in the future gathering of sponges, since those maintained in the parcs would furnish the larvæ before being garnered, and the young sponges attached to the collectors would be taken care of until the time when, in their turn, they would emit larvæ and reach the necessary size.

It is to be regretted that this method has not been the object of serious study and has been neglected by the cultivators of sponges.[a] In the meanwhile we are reduced to simple hypotheses where it is concerned, and it is impossible to know whether it is indeed a practical method for purposes of profit. It might be possible that, at the present state of our knowledge, such an operation would not pay nor cover not only the expenditures involved by

[a] It will shortly be attempted along the French coast of the Mediterranean. I have been asked for information on this subject. Without concealing my skepticism from my interviewer, I told him that sponge culture by collectors alone or combined with parcage was the only method worth attempting.

the concession, the construction of parcs, the guarding mentioned above, but even the cost of manipulation of collectors and larvæ attached to these. Experience shows, in fact, that even on the richest of banks sponges grow at considerable distances the one from the other; this fact shows us that a great number of larvæ are lost to reproduction, as the sponges emit larvæ in considerable numbers, and if the majority of these came out victorious from their struggle for existence we might see among the sponges themselves intense vital competition. Such is not the case. Are the larvæ destroyed because only few of them find a favorable spot to which they may attach themselves; are few of them capable of living; or is their greater number the prey of their enemies? Let us study these three hypotheses separately.

In regard to the first, it must be observed that the larvæ possess very imperfect means for the seeking of a support; they have no organ of direction. When sponge larvæ are kept in a glass jar their fixing is retarded because glass is not a very suitable support; it is accelerated by placing in the jar solid objects to which the larvæ attach themselves readily, as fragments of shells, or even by covering the interior of the jar with a coating of collodion.[a] At the moment of the physiological crisis, which acts so radically on their anatomical structure, it seems that each larva which does not meet a solid body to which it might cling is destined to perish; it must attach itself or die. Do we not see at times, in our laboratories, sponge larvæ spread useless on the surface of the water of the jars against the upper layer as they would do against a solid body? If our hypothesis is well founded it seems to us that collectors with a large surface, disposed around the sponges, would save a great number of larvæ which in their normal course would not meet any bodies to which they could attach.

We know nothing at all of any of the enemies of the sponge larvæ. Among animals widely utilized by man the sponges are perhaps those the ethology of whose larvæ is least known. We know that adult sponges are respected, ordinarily, by almost all marine animals; I saw accidentally, in an aquarium, blennies attack *Suberites domuncula* and serranids come and bite the parts wounded by the blennies. But these are exceptional cases. The immunity may be due to the great amount of organic ammonia contained by the sponges. How far are their larvæ left unmolested by other animals? This we do not know at all. We see that on bottoms of geological structure and flora identical in appearance there are banks rich in sponges separated by zones almost completely barren. We have every reason to seek to know why the distribution of these sedentary animals is so unequal, and we must observe that the interrelations of animals have not been sufficiently studied from this point of view.

[a] I have made this observation quite frequently. This question of the nature of supports offered to the larvæ is of the greatest importance to sponge culture.

This is a question of the greatest importance; if we knew that some animal species were greedy for sponge larvæ the presence of these species at given points would be a warning against the choice of such localities for sponge culture. Such a series of experiments, easily conducted and absolutely necessary, should be made as a preliminary by those who wish to encourage capital to take an interest in sponge culture. I intend to publish in the near future the results of research of this character.

We are completely ignorant of the reasons why in nature the number of larvæ that survive transformation is so very greatly limited. It is probable that there is a frequent combination of the two reasons on which I have insisted and that a certain number of larvæ after having escaped the attacks of active enemies succumb later because they fail to find suitable support at the moment when the transformation must occur.

We are obliged to consider these questions and to revert to them insistently, for experiments in sponge culture by cuttings the results of which are known to us seem to discourage us entirely from attempting sponge culture by means of collectors. The authors who made them mention but very superficially the attachment of sponges derived from larvæ on their apparatus. It seems, however, that a maximum of favorable conditions was combined there. A considerable number of sponges was assembled at a given point constituting a kind of parc; the apparatus of sponge culture consisted of collectors, and yet these collectors gathered almost nothing. Shall it be assumed that the sponges held in the parcs to be divided into sections had scarcely ever any mature larvæ or larvæ capable of living? This might be possible, although somewhat strange. Do cuttings habitually fail to reach sexual maturity under cultivation? Such a conclusion would annihilate certain hopes of sponge culture which shall be mentioned later. Shall it be admitted that the larvæ were emitted and that they died in the parcs? This would be a very grave deduction for the future of sponge culture by means of collectors if we did not observe that sponge cultivators have generally made their experiments by immersing the cuttings at a very slight depth.

However this may be, it will be noticed that there remain many obscure points by the solution of which alone can we foresee the chances of success of sponge culture by means of collectors. We may appraise the amount of capital needed for a venture of this kind, but it is absolutely impossible to know how many sponges may be garnered and, consequently, to what extent the capital engaged might be remunerated. From a purely theoretical point of view, sponge culture by means of collectors seems to us the ideal method, as being the most rational of all; but, on the other hand, it is the one which possesses the least number of scientific data. It would be lack of conscience to advise at pres-

ent the owners of capital to take a rush into the unknown by embarking on a venture of this kind before patient investigations had thrown some scientific light on the principal obscure points.

SPONGE CULTURE BY MEANS OF CUTTINGS.

This is the only method of sponge culture on which we possess any precise information, as this is the only one which has been seriously experimented with. In early antiquity observations were made on the facility with which sponges could regenerate. Aristotle affirms that "when a sponge is torn off it may be regenerated from the fragment left and become complete." The fishermen of the Mediterranean Sea continue to believe this. Hennique says that four years are necessary for a torn-off sponge to regain a good size. Masse likewise believes that the root of torn-off sponges grows up again, and he supposes also that the skeleton of the new sponge is less fine than that which it succeeds. This latter opinion can not be accepted without being tested, for it seems that if it were true the commercial varieties of sponges would have degenerated long since.

The first really scientific observations on the regeneration of sponges are due to Cavolini. This author demonstrated that a sponge which was detached from its support could adhere to a new support and continue to grow. Vaillant remarked that after isolating the cortex and the central part of *Tethya lyncurium* these two regions were susceptible of reproducing a complete individual; he also succeeded in grafting, the one on the other, two individuals of the same species.

But O. Schmidt had already undertaken research in this line on *Euspongia officinalis adriatica*, the soft fine sponge of the Adriatic Sea. In "Die Spongien des Adriatischen Meeres" he announces his first attempts and complains of lack of capital. He was soon assisted as to the financial difficulty by the Deputation de la Bourse of Trieste; he met likewise in Buccich a valuable collaborator, thanks to whom he could continue at Socolizza, northeast of Lesina, a long series of experiments (1863–1872). The results obtained by Schmidt and Buccich were studied and commented upon in an excellent report by Marenzeller.

O. Schmidt and Buccich observed that the best season for operation was winter, as during this time it was possible to manipulate the sponges in the open air and thus cause a minimum of injury to them; they may be kept several hours in the open air in winter, whereas their exposure in summer would be fatal after a few minutes' time. It was possible to secure the survival and development of fragments of sponges that had remained eight hours in the shade in February with a temperature of 7° Réaumur. On the other hand, the growth of the cuttings is slower in winter.

The sponges should be gathered by experienced men by means of the drag net rather than the hook. As soon as they are taken they are rid of their impaired parts, then fastened by wooden pegs, and, kept in water, towed astern of a boat. They are cut by means of a very fine saw into fragments measuring 26 millimeters longitudinally, and care is taken that each of the fragments retain as much as possible of the ectotome. It was observed in the experiments made at Lesina that if the sea remained calm for twenty-four hours fragments placed directly on the rocks adhered and were susceptible of further development. In practice it would be better to attach these fragments to suitable supports. Attempts of this character with wooden or metal pegs in cavities dug in flat stones or on the walls of wooden boxes did not give any favorable results. The greatest difficulty presented by metal pegs comes from their oxidation. Moreover, these first attempts were greatly interfered with because the supports became covered with sand and ooze. It may likewise be that the too intense action of light impeded the growth of the cuttings.

The apparatus constructed by Buccich gave far better results. The fragments of sponges, 72 in number for each apparatus, were perforated with a trepanning instrument, then threaded on bamboo sticks between two parallel horizontal boards. The apparatus was weighted down with stones and could be raised for examination by means of a handle attached to the upper board. The fragments were thus disposed beyond all risk of being covered with ooze and without any impediment to the free circulation of water, while the upper board of the apparatus served as a screen against the rays of light. The silicate varnish of the bamboo also protected the sticks most effectually against the action of boring insects, but the latter entirely destroyed the boards in a number of installations.

The place chosen for these experiments was a bay in which a certain current was felt, but which was well sheltered against the waves, and where the algæ at the bottom were highly colored. The operation may be considered as having succeeded when at the end of three to four weeks it is possible to ascertain that the cuttings have adhered to their supports. Beginning from this moment the growth is quite rapid; the cuttings reach a double or treble size during the first year; the growth is more marked during the first and fourth (?) years than during the second and third. This result can but surprise, and it seems to show that the observations were made on a limited number of cuttings for the whole, and that the influence of some untoward accidents has falsified the results. But however this may be, the cuttings had reached quite a considerable size at the end of five years, and the experimenters were able to conclude that a commercial size could be attained within seven years, showing the method to be a practical one.

A certain number of cuttings die, while others continue to live indefinitely without increasing in size; the materials of attachment deteriorate; but Schmidt and Buccich admit that in the hands of a careful operator not more than 10 per cent of loss need be expected. Applying these results, we see that 5,000 cuttings, the cost of which is 735 francs, would give at the end of seven years 4,500 sponges, valued at 2,205 francs, and thus an average increase in value of 210 francs. In a regular enterprise in which 5,000 cuttings were put out every year a lump sum of 5,880 francs would have been expended at the end of seven years, and from this on a profit of 1,470 francs would be obtained annually. Marenzeller deems the estimate of the price of sponges exaggerated, observing that the sale of such planted sponges would be difficult on account of the central perforation left by the bamboo sticks. The valuation would be correct if each sponge weighed 25 grams and could be sold at 20 francs per kilogram.

In the Bulletin de la Société d'Acclimatation (1879, p. 372) it is said that Schmidt and Buccich advise not to allow the cuttings to reach the current size; the cuttings might be allowed to develop only for three years, at the end of which period sponges would be gathered at a smaller size but would be sold at 0.10 franc. Four thousand sponges would cost 225 francs, including the interest of the capital for three years (which would be far from the valuation given above); the sale price being 400 francs (without deduction of the 10 per cent), we would have a profit of 175 francs. We must observe that the sale price of small sponges might fall below 0.10 franc if sponge culture, understood as above, became a current practice and flooded the market with small sponges.

In spite of the optimism of O. Schmidt and Buccich, they were obliged to interrupt their work. The Dalmatian fishermen crossed themselves as in the presence of a miracle when they saw the cuttings growing on the devices of sponge culture; later on, becoming more bold, they continually disturbed the apparatus with their nets and more than once they even stole it. In short, these classical researches had to be abandoned entirely on account of lack of protection against the fishermen.

Fogarty, agent of the firm of MacKesson & Robbins, has made similar experiments at Key West. The localities where the sponges were placed were not very happily chosen and the growth of the cuttings was not as rapid at it might have been. The cuttings of sheepswool were about 2½ inches thick; they were maintained at the bottom under about 2½ feet of water by means of wire or sticks put through them. Four months were required by the sponges to complete the healing of their wounds, and they did not grow during this time. One cutting was placed in a creek where there was no current, or very little, and its growth was very slow; the others developed very rapidly, and four months after they had been placed they had grown to four and six times their size. A total

of 216 specimens were planted; lack of protection against the fishermen here obliged Fogarty also to abandon his attempts. The result of his observations, however, was found sufficiently conclusive for Rathbun to demand that special laws be promulgated by Florida for the protection of future undertakings in sponge culture.

In 1896 there appeared a report by Allen, director of the Laboratory of Plymouth. This report was made at the request of the colonial office of Great Britain with the desire of introducing sponge culture in the Bahamas. We find in this report, in addition to accounts of the experiments of Schmidt and Buccich, and of Fogarty, information, though not detailed, on experiments made in Florida by Benedict. The latter divided the sponges under water; he wanted simply to prove that cuttings attached to favorable localities grew rapidly. The fishermen were greatly opposed to these experiments, fearing that they might be conducive to the creation of monopolies which would deprive them of their means of livelihood.

In 1889–90 Ralph Monroe likewise experimented in Biscayne Bay at a point where the most varied conditions existed. He used for supports trunks of white wood, about 12 feet in length, provided with a cross-piece at one end so as to hinder them from rolling. The cuttings were affixed to these in various manner; the method most quickly executed, but far from the best, consisted in making use of small pieces of double copper wire which were pushed into the wood by means of a special instrument. Galvanized iron can not be used in any form whatever, as it corrodes too rapidly; brass wire must likewise be eliminated on account of the deleterious action on the sponges of the salts formed by the chemical action induced. The sponges with which Monroe operated, solely sheeps-wool, readily endure being in the open air for several hours, though they die very quickly in stagnant water. They were cut on a cutting board with a very thin and sharp knife, the pieces being about 1 inch in length. Each whole sponge gave an average of 25 cuttings. The cuttings were immersed to depths varying from 8 feet to less than 1 foot at a distance of 12 inches apart. It would be easy to plant, with the aid of two assistants and a good boat, from 600 to 800 cuttings per day. The sponges, with a few exceptions, survived the operation and began to grow well. Later, they were destroyed or lost in various ways; nevertheless a lot, planted at Elliott's Key under 4 feet of water, gave at the end of six months 75 per cent of living cuttings which had doubled their size. In some of the other lots individual sponges were brought to maturity, but the average loss was considerable on account of insufficient adherence to the supports, or from other causes. The author concludes by saying that satisfactory means of attaching the cuttings is still to be found; the localities selected should be in bays and lagoons sheltered from the high sea, the too rapid currents, and too agitated

water; the cuttings should be immersed at a moderate depth in order that it may be easy to manipulate and observe them. The growth is more rapid when the current is strong, but the shape is then more frequently bad and the skeleton hard. This point, however, is not quite elucidated by the author. Under favorable conditions the cuttings double their size in six months, consequently eighteen months to two years would suffice to produce a sponge of commercial size. "It is quite possible that with state protection to the planters and better methods to be determined upon by further experiment, sponge culture might be profitable." Nevertheless, the author comes finally to the conclusion, mentioned above, that the most rational method in his opinion is the one closest to oyster culture. Let us observe that the estimates of Monroe as to the time necessary for a sponge to attain a commercial size are based on the results of one single experiment which was especially lucky and extended over only six months.

At the request of sponge merchants of Sfax, the Direction Générale des Travaux Publics (of Tunis) undertook researches on the biology of commercial sponges, and erected for this purpose a laboratory on piles in the open in the harbor of Sfax. This laboratory was intrusted to the supervision of Raphael Dubois. Allemand was appointed assistant director and made a series of experiments in sponge culture by cuttings, which he continued for two years and the results of which he published in 1906. He tells us that the sponges to be divided should be gathered with great care and utilized as quickly as possible after being taken, or they should be allowed to heal entirely in running water before cutting them up. He divided them with a very sharp blade previously immersed in boiling water for each cutting. The operation is successful when it takes place at a temperature of about 15°. If made at this temperature the healing of the cuttings rarely took more than three months, while in winter it is very slow, as is also the growth of the cuttings in this season.[a] On the other hand, the vivid light was, as in the experiments of Schmidt, detrimental to the healing as well as to the development of the cuttings. It is, consequently, of great advantage to shelter them.

In some ten months the cuttings grow to three times their original size. "In proportion to the growth observed, a fragment can form a sponge of commercial size (0.30 meter in circumference) only in four or five years." In short, the *Hippospongia equina elastica* developed somewhat more rapidly than the *Euspongia officinalis adriatica* of Schmidt. The author remarks that the apparatus of sponge culture must be very resistant and especially well sheltered. It is necessary to discontinue wooden materials, which suffered from the boring in-

[a] This concurs entirely with the results obtained by Schmidt and Buccich. The healing and growth of the cuttings is more rapid when they are not kept at the bottom of the water. Bidder, as we have seen, called attention to this fact.

sects, as did those of Lesina, and select "durable bodies of clay (pyramids, cones, or perforated amphoras)" or reenforced cement. Allemand forgets, however, to tell us how these clay attachments may be sheltered from light, for all the experimenters will not have the advantage of suspending their apparatus under a laboratory, as was done in Sfax. The author advised, a few pages earlier, the use of baskets or boxes to preserve the sponges precisely for the purpose of shielding them from too strong a light.

Allemand, agreeing on this subject with his predecessors, concludes from these researches that sponge culture has a real industrial and commercial value. But what he published, no more than what was published by the others, is of a nature to lead to this conviction. There is a great distance between laboratory experiments and the founding of an industrial enterprise. It should not be forgotten that the experimenters unconsciously pass very lightly over their failures and insist only on the encouraging facts, forgetting that industry must take everything in account, success as well as failure. Schmidt and Buccich discount 10 per cent of loss for undertakings in sponge culture; nevertheless, during the course of researches made by them during ten years they were unable to follow their most promising cultures for a longer period than five years; after this they became discouraged. In their hands, skillful by long practice, the final loss came near to 100 per cent. Monroe admits that the average loss in his researches was quite considerable. Allemand, evidently alluding to his own experiments, says that an undertaking in sponge culture, if well conducted, will suffer but a very small loss. We must, unfortunately, ask how he computed the mortality of his cuttings. It seems that he took into account only the mortality which occurred during the first weeks after the cutting of the sponges. We find information like the following in his table of experiments:

Mortality, 7 per cent; at the end of February there remained two sponges. Mortality, 5 per cent; at the end of February almost all the fragments were dead. Mortality, 20 per cent; on June 29, 1906, the apparatus was entirely dislodged.

On the whole, the mortality in the work at Sfax seems to have been quite considerable; it must also be remembered that the experiments were carried on during a maximum period of two or three years, and it is impossible for us to foresee what supplementary losses might have taken place during the two or three years that would have to elapse before the sponges could have been garnered. This is information which a merchant ought necessarily to have.

With the exception of Schmidt, the sponge cultivators do not give the cost of their cuttings. "The cost of the installation will not be high," says Allemand. On the contrary, the cost would be considerable. Shall I repeat what I have already said about the other methods of sponge culture? The

fishing of sponges destined to be divided into cuttings must be effected with greatest care, thus the cost of fishing would be considerably greater than that of sponges destined for the trade. The transportation, the care of the sponges, the division into cuttings, the purchase and manipulation of the apparatus of sponge culture will involve supplementary expenditures, as will also the installation and the concession of the parc where the plants are to be made. It should not be forgotten that this parc must be established in deep water as far as this is possible, so that the cuttings shall not be kept too close to the surface, where the light would be too intense for them. It is necessary to inclose this parc and to guard it carefully; it was the theft of apparatus and in general the lack of protection which forced Schmidt, Fogarty, and Benedict to abandon their researches, and it would have been the same with the experiments at Sfax if the Direction des Travaux Publics of Tunis had not provided most efficient guard. A private individual could not count on so vigilant an assistance as that of the fishing guards and the custodian of the laboratory of Sfax, and would himself have to insure, in a permanent manner, both day and night, the guarding of his installations. Schmidt and Buccich seem to have neglected these various factors of expense in sponge culture in the estimate of the cost of their cuttings. The other sponge cultivators keep silent on this subject as if it were a secondary one. This may be so from a scientific point of view, but from an industrial one it is of vital importance.

In spite of all that has been published on this subject, it is as yet impossible for us to foresee at the present time what is to be gained from an undertaking in sponge culture. It is even to be admitted that the result of the enterprise would be a considerable loss. I do not mean Buccich's diminution of value of the sponges on account of the central perforation left by the bamboo stick; these are small details easily corrected by improvements in technique. We must notice that the time needed for healing was always considerable for the species with which experiments were made. This loss of time is not a negligible quantity. Moreover, the growth of the cuttings is slow. Allemand says that they would have to grow four to five years to attain the size reached in two years by sponges coming from larvæ. It is, consequently, not possible to see how the products of sponges, obtained at a great cost and bred at a great cost likewise, can compete economically with the sponges at present brought to market. As long as sponge banks are sufficiently supplied to permit normal fishing, until the value of sponge skeletons has increased considerably, it will be impossible to adopt any other conclusion than the one here expressed.

Such could be the case, however, if the yearly increase in size of the cuttings were far in excess of the size that would have been attained by the original sponge had it not been divided. Schmidt thinks that this is so, without, however,

having verified this statement. Allemand is far more convinced, for he has observed that "the whole of the cuttings taken from a small sponge gave a greater volume than that obtained from an identical sponge placed whole at the same time and under the same conditions." It is rather difficult to have this statement agree with another of the same author, i. e., "the growth of a fragment or of a sponge derived from a fragment is much slower than that of a sponge growing spontaneously and not coming from a fragment." We might conclude, perhaps, that the sponge "placed under the same conditions," the term of the comparison, had not a normal subsequent development. An accident in experimentation can not serve as a basis for generalization. It is, moreover, to be regretted that the most of the authors who have given us information on the culture of sponges do not give any precise definition of what they mean by size and volume; it seems to me that what they mean by doubling or trebling the size is the diameter, and not the size or volume.

Marenzeller, taking into consideration the results reported by Schmidt and Buccich, seemed to be skeptical as to the future of sponge culture. He finally raised the question whether this method of culture ought not to be applied only to the cutting up of flat and worthless sponges, the pieces of which would give sponges of rounded shape, or to the grafting together of badly shaped and consequently cheap sponges. Such application would be of very small importance. The fishermen garner sponges haphazard, without taking pains to give the care and minute precautions demanded for the manipulation of individuals destined for cuttings. When the sponge brought up by the harpoon is of little worth it is not reasonable to expect the fisherman to lose time in manipulating and preserving this worthless piece, which might be utilized in a more advantageous manner if he continued his fishing. Supposing that the fisherman followed scrupulously the directions given him, the worthless sponges thus gathered would cost the breeder of sponges much more than the sponges to be had on the market. He would then have to continue with them a series of procedures involving expenditures the history of which has been given here. And all this to bring about what results? To obtain at the end of several years sponges which also might be worthless, fit only to be thrown aside, like their parent.

The project of fusing badly shaped sponges into one does not deserve to be considered. It is only a pastime for the naturalist, not a procedure for daily practice, and only the virtuosi of sponge culture might attempt it with some hope of a modest remuneration for their day's work. But we have not yet gone so far, and there is no dean in sponge culture. Moreover, there is nothing to prove that the final result of these operations would always be perfect. Should I judge by what I obtained from attempts of grafting halves of different

individuals of *Tethya lyncurium*, ultimate disappointment may be frequently met, arising after premature cicatrizations.

Buccich questioned, on the other hand, whether no senile degeneration took place on cuttings obtained from senile sponges; the growth of these would be slower than that of a sponge of the same dimensions but developed spontaneously. This last proposition was entirely confirmed by facts, as we have already seen; but it should not be deduced thence that the opinion of Bidder on the senility of sponges has been verified. It is impossible to compare experiments made on intact sponges with cuttings attached to apparatus. Let us observe, however, as an accessory consideration, that Allemand thinks to have observed that cuttings taken from large sponges do not develop as well as those from small-sized sponges; but his information on this subject is quite meager. As far as the senility of sponges is concerned, our knowledge, I believe, is limited as yet to some measurements which Allemand made at Sfax. He noticed that in some fifteen months the circumference of certain sponges increased from 40 to 45 centimeters and of others from 50 to 54 centimeters, while some increased from 60 to 63 centimeters, which means an increase in volume of 455 cubic centimeters in the first case, of 544 in the second, and 580 in the third. It can not be said that these observations constitute a definite demonstration of the fact that the sponges had their vitality weakened as they advanced in age.

These are questions, moreover, the importance of which is purely theoretical, since sponge culture by cuttings can not be the subject of practical application. The methodical study which I have given here leads us inevitablv to the conclusion which sponge culturists themselves were obliged to accept. We see that Monroe says doubtfully: "It is quite possible that * * * sponge culture might be profitable;" yet, after all, he thinks that the most rational method is sponge culture by means of collectors. The last experimenter who took up this question could not answer against the argument arising from these observations. After having said that sponge culture by cuttings possesses real industrial value, which I expressly deny, he ends, nevertheless, by preferring to it a mixed method in which, unfortunately, he has no personal experience. He considers as being "the true method of culture in the future" a combination of sponge culture by cuttings and sponge culture by planting; the cuttings would produce larvæ which would stock the parc. There would thus be every four or five years a harvest from the cuttings which had grown and every two years another from the sponges spawned in the parc. This mode of operating does not seem at all justified. It is difficult to understand why the author does not advise sponge culture by means of collectors as previously studied; why he insists upon utilizing, in spite of everything, the method proposed by Schmidt. Since the cuttings require five years to reach the size which the sponges reach normally in two years, it is very probable that the emission of

larvæ would be retarded or diminished in such individuals in similar proportion. It would then be quite illogical to use sponge cuttings even for this purpose. What opinion should we have of a horse breeder who would use only sick, crippled, or deformed stallions with which to increase his stock?

From whatever standpoint it be considered, sponge culture by cuttings seems to us only a scientific amusement which can not have any practical application.

CONCLUSION.

We see from the preceding that experiments in sponge culture so far made forbid all hope of ever seeing in current practice methods like the above, and command us most imperiously to warn those desiring to undertake this industry against imprudent advice which they might receive on this subject. There remain, however, other methods which have not been attempted or which were not tried seriously enough and on which our opinion must remain provisionally pending. Let us wait before expressing it definitely; let us await carefully conducted experiments to enlighten us. It would be unfortunate for the fame of applied natural science if industrial attempts at sponge culture, after having been lauded by naturalists, brought about failure from a financial point of view or ended in insignificant results, as when the mountain gave birth to a mouse.

Thorough consideration ought to be given to the matter before engaging capital in an enterprise that might be dangerous. Since the gradual exhaustion of the banks threatens all sponge-bearing countries, however, those interested in this question should be reminded that more important and more easily solved problems urgently claim their attention. There should be as uniform legislation as possible, promulgated after international agreement, regulating in various countries (1) the period for sponge fishing, so as to allow the swarming of the mature larvæ; (2) the minimum size of individual sponges fished and offered for sale; (3) the fishing apparatus, either in regard to character or number; and (4) the security of banks situated in neutral waters.

This is the first programme to be considered. When this is done, let us hope that precise researches during the interval shall have carried the question of sponge culture a few steps further, and that we shall have then a new basis for appreciation in thorough knowledge.

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EXPERIMENTS IN THE ARTIFICIAL PROPAGATION OF FRESH-WATER MUSSELS

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CONTENTS.

	Page.
Object and scope of the undertaking	617
Some facts in the reproduction and life history of mussels	618
Breeding seasons	620
The larva, or glochidium	621
Implantation of the glochidia	622
Experimental infections	622
Method	622
Behavior of the fishes—Their susceptibility and resistance	623
Duration of the parasitic period	624
Post-larval growth of mussels	625
Infection of large numbers of fish	626

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OBJECT AND SCOPE OF THE UNDERTAKING.

The threatened extinction in the Mississippi River and its more important tributaries of those species of mussels whose shells have been taken in enormous numbers during the past fifteen years for the manufacture of pearl buttons has led the United States Bureau of Fisheries to undertake an extensive investigation to determine the possibility of artificial propagation of these mollusks, and to devise such means as may be practicable for restocking depleted waters which present favorable conditions. The general direction of the investigation has been placed in the hands of the writers, who for the past three years have devoted to the work as much time as their professional duties would allow. In certain phases of the work, however, many others have collaborated.

It was recognized at the outset that if the investigation was to have real practical value it would have to be wide in scope and extend over a period of at least several years. At that time little was known with accuracy of the breeding habits and seasons of the commercial species, of the biological and physical conditions under which they live, of their distribution, and of many other essential matters, while it yet remained to be discovered whether artificial propagation could be successfully accomplished. At the very inception of the work, therefore, a comprehensive plan was outlined which was designed to include every subject that might bear even remotely upon the central problem, and, although many parts of this programme have not yet been touched, much progress has been made in some of the more important lines.

The plan of work contemplated, besides a thorough investigation of artificial propagation, a detailed study of the life history and ecology of the Unionidæ, emphasizing especially the geographical distribution of the group throughout the Mississippi Valley, the breeding habits and seasons, the physical conditions of the waters in which the different species thrive, food, enemies, and diseases,

rate of growth, post-embryonic development, and the mutual behavior of glochidia, or larvæ, and fishes as parasites and hosts.

The results that have already been obtained, although far from being complete, will serve as a basis for future investigations, while the lines of attack in the main problems have been definitely indicated. We have proceeded far enough to make it clear that the ultimate end of the investigation is assured, and with proper facilities for the infection and care of large numbers of fish the final success of the work is no longer in doubt. The essential facts in the life history of the Unionidæ are known; the general conditions of infection have been determined; the entire feasibility of artificially infecting large numbers of fish has been established; while the requisite conditions for placing artificial propagation on a practical basis are clearly understood. Furthermore, during the summers of 1907 and 1908 several parties, working under the direction of the Bureau of Fisheries, have made extensive observations on a number of different rivers in the upper Mississippi Valley, with a view to determining the distribution of all of the species of mussels occurring in these waters. The rivers that have been explored in this manner are the upper Mississippi, Illinois, Iowa, Minnesota, Wabash, Ohio, and Tippecanoe, as well as several smaller streams in Indiana. When the results obtained by these parties have been brought together, we should be in possession of detailed information regarding the distribution and relative abundance of at least all of the important commercial species throughout this region. In addition, the breeding seasons of almost all of the important commercial species have been determined, and a large mass of miscellaneous data relating to a great variety of subjects has been accumulated.

Some of the more important results that have thus far been obtained in the investigations are briefly presented here.

SOME FACTS IN THE REPRODUCTION AND LIFE HISTORY OF MUSSELS.

As is well known, the Unionidæ carry their young in the gills, which act as a marsupium or brood chamber until the completion of the embryonic development. The eggs are passed from the ovaries into the suprabranchial chambers, where they are fertilized by spermatozoa brought in by the inhalent current of water. In many species the eggs are bound together in masses by a gelatinous or glutinous matrix which is secreted by the gills and which may be very tenacious. This, however, in most cases gradually dissolves away as development proceeds, until at the close of the embryonic period the larvæ or glochidia are no longer agglutinated. These masses assume in different species many forms of flat plates or cylindrical cords which fill the water tubes of the gills. The latter may be greatly distended or modified in various ways to receive the egg-masses. In some species, on the other hand, the condition

just described is absent and the eggs are either not agglutinated at all or are only loosely held together in a slightly viscid substance.

The extent to which the gills are modified as a marsupium varies greatly in different genera. In many, as in *Anodonta*, *Pleurobema*, *Strophitus*, *Symphynota*, and *Unio*, the entire outer gill of each side is thus utilized and when filled with embryos or glochidia, presents a much swollen, padlike appearance. In others, for example, *Lampsilis*, *Obovaria*, *Plagiola*, only the posterior portion, varying from one-third to two-thirds of the entire outer gill, is used as a receptacle for the eggs, a sharp demarcation existing between the marsupial region and the anterior respiratory part. The former is highly modified in structure and may be readily recognized, even when empty. In *Obliquaria reflexa* a varying number of enlarged and distended water tubes contain the dense, glutinous cords in which the embryos are embedded. Finally, there are at least two genera, namely, *Quadrula* and *Tritigonia*, in which all four gills are utilized as brood chambers. This condition would seem to be the most primitive one, as the gills show but little structural modification and when empty are indistinguishable from those of the male mussel.

In all of the species of the genus *Lampsilis* which we have examined the posterior margin of the valves in the female is less pointed than in the male, and by reason of this difference in the shape of the shells the sexes may be readily distinguished externally. In most of the other genera that have come under our observation, however, the shells of the two sexes are identical, and an internal examination is necessary in order to determine the sex of an individual.

The entire embryonic development takes place within the marsupium, and at the end of this period the glochidium, which has become liberated from the egg membrane within the gill, is fully formed. In those species which are known as "summer breeders," the glochidia are discharged at once, while in many others, the so-called "winter breeders," they are carried in the gills for several months before being set free in the water.

The glochidia, as has long been known, do not complete their development unless they become attached to fishes, and the metamorphosis occurs while they are living parasitically in a cyst formed by the epidermis of the host. After discharge from the marsupium, the glochidia under natural conditions lie quiescent on the bottom, their valves gaping widely apart, and unless chance brings them in contact with a fish they will die. Once attached to the gills or external parts of a fish, however, the rest of the development, if conditions are favorable, is assured.

This unique peculiarity in the life history of fresh-water mussels has been taken advantage of in artificial propagation, as it has been found that a single fish, even though small, may successfully carry to the close of metamorphosis several hundred glochidia. One fish may, therefore, be made to do the work

of a large number in a state of nature, for under ordinary conditions it is extremely improbable that more than a very few glochidia would succeed in attaching themselves to a single fish.

After a parasitic life of variable length, during which the metamorphosis is completed, the cyst breaks down, and the young mussel, thus liberated, falls to the bottom and leads thereafter an independent life.

BREEDING SEASONS.

We have confirmed the conclusion, first reached by Sterki (Nautilus, vol. IX, 1895), that the Unionidæ, with respect to their breeding seasons, fall into two classes, the so-called "summer breeders" and "winter breeders." The latter designation, however, is not strictly appropriate, for in the species which belong to this group the eggs are fertilized during the latter part of the summer, usually in August, and the glochidia, which are carried in the brood chambers over the winter, are not discharged until the following spring and summer. In fact, in some cases the close of one breeding period may overlap on the beginning of the next, as one may still find in late July some females gravid with glochidia, while in others the eggs are passing into the gills for the next season. In the case of the summer breeders the eggs are fertilized during the late spring and summer, and the glochidia are in all probability discharged before the end of August, or certainly not later than the middle of September. In the species of this class of which we have the completest records, ovulation begins in May and early June and may last well into August, but after the end of August gravid females have not been found.

In view of the above facts, it would seem in better accord with actual conditions to separate the species with respect to the length of time that the glochidia remain in the gills, designating them as those which have a "short period" of gravidity and those having a "long period," rather than to distinguish them as "summer breeders" and "winter breeders," respectively, for in the case of the latter neither ovulation nor discharge of the glochidia takes place in winter. The breeding season is undoubtedly a generic character, for, so far as our observations go, all species of a given genus belong to the same class.

The following list shows the distribution, with respect to the period of gravidity, of the genera we have had under observation:

Long period:	Short period:
Alasmidonta.	Obliquaria.
Anodonta.	Pleurobema.
Lampsilis.	Quadrula.
Obovaria.	Tritigonia.
Plagiola.	Unio.
Strophitus.	
Symphynota.	

As there are important commercial species in each class, the futility of any law which would prohibit the taking of mussels during their breeding season becomes at once apparent, for there is no month in the year when some species are not carrying either embryos or glochidia.

THE LARVA, OR GLOCHIDIUM.

Two well-marked types of glochidia occur in the Unionidæ, one provided with stout hooks on the ventral margin of the valves and the other entirely hookless. The former are characteristically parasitic on the fins and other external parts of the fish, the latter on the gills. We have given special attention to a study of the physiological peculiarities correlated with these two types of structure, including their differences in behavior in attachment.

The occurrence of the two types of glochidia in the genera which we have examined is shown below.

Hookless glochidia:	Hooked glochidia:
Lampsilis (except *L. lævissimus*).	Anodonta.
Obliquaria.	Lampsilis lævissimus.
Obovaria.	Strophitus.
Plagiola.	Symphynota.
Pleurobema.	
Quadrula.	
Tritigonia.	
Unio.	

It is thus seen that the hookless type is by far the commoner one, and furthermore, practically all of the commercial species of mussels belong to the genera included in this class.

The type of glochidium is constant for the genus, so far as our observations have gone, except in the genus *Lampsilis*, one species of which, *L. lævissimus*, produces glochidia having hooks, while all of the remaining species that we have examined have the hookless forms. The glochidia of *L. lævissimus*, moreover, are of quite a different form from those of any other species we have encountered, being shaped like an axe head when seen in side view.

The hookless glochidia are usually much smaller than those having hooks, and also differ characteristically from the latter in shape.

We have repeatedly determined the fact that the hooked glochidia form permanent attachment as a rule only to external parts of the fish, as the margins of the fins, operculum, anus, and mouth, the barbules, or even to scales and along the fin rays occasionally. Wherever a free border is presented that may be grasped between the valves of the glochidium, attachment is possible, the hooks holding securely as soon as the valves have closed. Hooked glochidia, furthermore, are not infrequently found on the gill arches and rakers, as these places furnish the requisite conditions for a firm grasp. Glochidia of this type,

however, do not as a rule acquire a permanent lodgment on the delicate gill filaments, as their hooks usually tear through these when grasping. Their greater size would also seem to render it difficult for the hooked glochidia to become properly embedded under the epidermis of the slender filament.

Hookless glochidia, on the other hand, are only rarely found on the external parts of the fish, and although they become attached readily to such places, in the absence of hooks their grasp is insecure, and the usual consequence is that they are all soon brushed off. Being hookless and quite small, they are admirably adapted to lodgment on the gill filaments, among which they may become entangled in great numbers.

Interesting differences of a physiological nature also are correlated with the two structural types, apparently in adaptation to their different parasitic habits.

IMPLANTATION OF THE GLOCHIDIA.

Contact with any part of the fish affords the stimulus which causes the adductor muscle of the glochidium to contract and close the valves. This stimulus is purely a mechanical one, as the same result may be produced by touching with any object. In this way they may be caused to snap shut on a bristle or hair, or on the edge of a piece of paper. Once attached to the fish, however, the glochidium exerts a stimulus upon the epidermal cells of the host which causes them to undergo a rapid proliferation. The stimulus in this case is undoubtedly a chemical one, and its immediate effect is to throw the cells of the epidermis into active mitotic division. The epidermis now grows rapidly over the glochidium, which may become completely embedded in three hours after attachment in the case of the gill parasites. The proliferation of the epidermis of the fins occurs more slowly and in this situation twelve to twenty-four hours are usually required before the glochidia are covered.

After the process of implantation is completed, the glochidia are entirely inclosed within the cellular cyst, where they are nourished by the host until liberated by the rupture of the cyst at the end of the parasitic period. It is during this stage of the development that the metamorphosis occurs and the structure of the glochidium is replaced by that of the mussel.

EXPERIMENTAL INFECTIONS.

METHOD.

A very large number of experimental infections have been made, and the conditions determining infection have been investigated as far as the material at our disposal has allowed. This study has included not only the behavior of both types of glochidia, their manner and place of attachment, but the reactions of the fish as well.

Twenty different species of mussels, yielding both hooked and hookless glochidia, have been used for the infections. The majority of these have been species showing the long period of gravidity, although several of the summer breeding species have also been employed. Eighteen species of fishes have been used, and their reactions have been carefully observed, but, as all are not equally favorable for receiving and carrying the parasites, the greater number of infections have been made upon five or six species.

When only a few fishes are to be used at a time, the method which has been employed is quite simple. The brood chambers are excised from the gravid mussels, split open lengthwise, and the ripe glochidia washed and scraped out into dishes of water. The fishes are then placed together with the glochidia in small aquaria, and, if the infection is to be made with gill parasites, the water is agitated by mechanical means, in order to keep the glochidia suspended and thus insure their being taken into the mouth of the fish. When using hooked glochidia for external attachment, however, it is better not to stir them up, as the fishes usually settle down to the bottom of the vessel and, by rubbing their fins among the glochidia, quickly become infected to any desired degree.

When making gill infections, the fishes must be examined at intervals of one or two minutes for the purpose of observing the rapidity with which the glochidia are attaching, and when the degree is reached which experience has shown to be the optimum for the species of fish in question, the exposure is at once discontinued. Usually the gill infections take place very quickly, and in four or five minutes the fishes will have received as many glochidia as they can safely carry, although of course the duration of exposure depends upon the abundance of glochidia in the water. Other things being equal, the fewer glochidia present the more prolonged the exposure must be. Experience has shown that the best results are obtained when the glochidia are used in very "dilute mixtures," for it is difficult to avoid overinfection, if they are at all concentrated. Some species of fishes, however, are less susceptible than others, and a longer exposure is necessary to insure the attachment of an adequate number of glochidia. In certain cases we have had to allow the fishes to remain with the glochidia for from two to three hours, or even longer, in order to obtain a satisfactory degree of infection.

In nearly all of our experiments we have used young fishes, from three to six inches in length, as for many reasons they are more convenient than larger ones.

BEHAVIOR OF FISHES—THEIR SUSCEPTIBILITY AND RESISTANCE.

The fishes when first placed in contact with glochidia give evidence of great irritation, and as soon as the gills begin to be infected they exhibit violent and rapid breathing movements, apparently in the attempt to expel the parasites.

After a time, however, they become quiet, and when removed from the presence of the glochidia behave normally, except that the more rapid respiratory movements may continue even for days afterwards.

The fishes we have used in our experiments have shown marked differences in their ability to retain the glochidia both on the fins and on the gills, more especially on the latter. They vary even more strikingly with respect to their capacity for withstanding the injurious effects of gill infection, and furthermore some fishes are undoubtedly much more susceptible than others, as the glochidia become attached, especially to the gills, more readily.

Of the fishes which we have had under observation, the following species have proved to be the most satisfactory: rock bass, large and small mouthed black bass, green sunfish, and red-spotted sunfish. All of these species are very susceptible and readily infected with gill parasites, large numbers of which may be carried without apparent injury to the fish. A single individual of any of the above-mentioned fishes, not more than 3 or 4 inches in length, will successfully carry at least 1,000 glochidia on its gills to the close of the parasitic period, a number that would speedily kill many other species.

Yellow perch, blue-gill sunfish, and crappie, although quite susceptible, are far less resistent to the injury and quickly succumb to overinfection. Young bullheads are apparently very difficult to infect, and we have not succeeded in causing glochidia to become attached to either their gills or fins in appreciable numbers.

German carp are easily infected on external parts with hooked glochidia, but thus far all efforts to infect this fish with gill parasites have been unsuccessful. The glochidia will attach themselves to the gill filaments, but for some unaccountable reason implantation is imperfect and they soon drop off. Apparently the epidermis of this fish does not react to the stimulus in such a way as to lead to the formation of a permanent cyst.

In still other cases it has been found that failure is due to the fact that, even after complete implantation on either the gills or fins, the walls of the cyst slough away in a day or two and liberate the glochidia. Whether this is caused by unfavorable physiological conditions in the fish or in the glochidia we are unable to say, but there are certain facts that would seem to indicate that such abortive implantations are the result of a physiological immaturity of the glochidia, which therefore fail to call forth the necessary response on the part of the fish's tissues.

DURATION OF THE PARASITIC PERIOD.

The duration of the parasitic period is very variable. With respect to the glochidia of those species of mussels which remain gravid over winter the duration depends upon the time of year when the infection is made. Fishes

infected in the late fall and winter will carry the glochidia for from two and a half to nearly four months, while in spring, when the same kind of glochidia are used, the metamorphosis is completed and the young clams liberated in a little less than a month. This great difference in the length of time that the glochidia remain on the fish can not be due primarily to temperature, although this may have some influence, for we have observed the same differences in the laboratory, where the temperature of the water remains practically constant throughout the winter and spring. As the glochidia of the mussels which have the long period of gravidity are not normally discharged until spring and summer, it is quite possible that the fall and winter glochidia are physiologically immature, although capable of causing the formation of the cyst on the fish, and require for this reason a much longer time for the post-embryonic development. Structurally, however, they seem to be identical with those taken from the marsupium in the spring.

In the case of the spring infections the young clams all leave the fish at about the same time, and within a very few days after the first are liberated the last to go have come off. This is not true, however, of the fall and winter infections, for in these cases the setting free of the young mussels may be extended over a period of three or four weeks, or possibly more.

We have no observations on the duration of the parasitic period in the case of the summer-breeding mussels. Although infections have been successfully made with several of these species and kept under observation for ten or twelve days, we have not yet had an opportunity of following the metamorphosis through to the end. The period is, however, undoubtedly short, probably not more than four weeks. Harms (Zoologischer Anzeiger, bd. XXXII, 1908) has recently recorded a parasitic period for two European species of *Unio*, a genus belonging to the group of summer breeders, of twenty-six to twenty-eight days.

POST-LARVAL GROWTH OF MUSSELS.

No data have been obtained on the rate of growth of fresh-water mussels beyond a short period after the metamorphosis, as we have not succeeded in keeping the young mussels alive in the laboratory for more than four weeks after leaving the fish. The amount of growth during that time was only a fraction of a millimeter. We have made, however, extensive plantings of young mussels which have been allowed to drop off the fishes in ponds and streams where the chances of reclaiming them in the future are very good, and it is hoped that by another year or two some data on the rate of growth will be available. Carefully measured and weighed young mussels of different sizes have also been placed in wire cages and set in ponds and rivers, and it is possible that additional data will be obtained from these experiments.

INFECTION OF LARGE NUMBERS OF FISH.

In order to test the feasibility of infecting large numbers of fish, which is a prerequisite of artificial propagation, an extensive experiment, in which over 25,000 fish were employed, was made at the substation of the Bureau of Fisheries at La Crosse, Wis., in November, 1907. Seven species of fishes and glochidia from four species of *Lampsilis* were used in the experiment. The fishes, with the exception of the German carp and the bullheads, were successfully infected and retained in the tanks of the station for over two months, when they were liberated in the west channel of the Mississippi River at that place. The experiment completely demonstrated the possibility of making infections successfully on a large scale, and of retaining the fish until near the close of the parasitic period.

In November, 1908, a similar experiment was carried out at the station of the Bureau at Manchester, Iowa, where about 12,000 large-mouthed black bass and crappies were infected with the glochidia of several species of *Lampsilis*. The fish were kept at the station for one month and then placed in the Maquoketa River between two dams. As the species of mussels used in the experiment in all probability do not occur in that stream, the results of the work may be determined if we succeed in reclaiming any of them at a future time.

During the fall and winter of 1908–9 infected fishes were put into ponds in the neighborhood of Columbia, Mo., where we are absolutely certain that the species of mussels used do not occur, and where there is every reason for the expectation of subsequent reclamation. The latter experiments should yield valuable data on the rate of growth.

A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES

By S. W. Downing

Superintendent U. S. Fisheries Station, Put-in Bay, Ohio

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In discussing this subject it will first be necessary that we understand something of the habits and the manner of reproduction of these fishes, and the probable increase and losses in numbers under natural conditions. Since the same conditions exist and the same reasoning will apply to all the lakes of the chain, we will confine our remarks to the conditions in Lake Erie.

BREEDING HABITS AND NATURAL REPRODUCTIVITY OF WHITEFISH.

The adult whitefishes are migratory, leaving the lower end of the lake and the deeper waters each year as the spawning season approaches and the breeding instinct prompts them, and seeking their natural spawning beds, which consist of the reefs among the islands and the rocky and sandy bottoms of the shoaler portions of the lake. Most of these reefs and shoals are of that peculiar formation called honeycombed rock; that is, instead of being gravelly or smooth these rocks are dotted with holes and small cavities into which the eggs, as they are voided by the fish, may drop and be comparatively safe from being eaten by the suckers and other spawn-eating fishes, water lizards, or other enemies, and also from being covered by mud, silt, and other filth, and smothered, as they would be if deposited on mud bottom.

Were the whitefish nest builders, and did they pair as some of the other fishes do so as to perform the function of fertilizing their eggs with any degree of certainty, the chances for a large production of young under such favorable conditions would be very good, indeed; but they are not nest builders, neither do they mate; on the contrary they approach the spawning grounds singly and in schools, and are what is known as "school spawners," the female extruding her eggs wherever she may happen to be, regardless of whether there is a male fish within close proximity or not. In consequence but very few of the fish come together so as properly to perform the functions of fertilization; and when it is

known, as was demonstrated by Mr. J. J. Stranahan by a very careful experiment in the fall of 1897, that the life of an unfertilized whitefish egg, if left in the water, is less than 4 minutes, while more than 50 per cent of them perish in 1½ minutes, and the life germ contained in the milt of the male fish may be fairly supposed to live no longer under the same conditions, it will readily be seen that the percentage of eggs fertilized under natural conditions must of a necessity be very small. In fact, it is estimated by those fish culturists who have had most to do with the propagation of whitefish that not more than 1 per cent of the eggs are fertilized when deposited under natural conditions. At this rate let us see how many fertile eggs each pair of whitefish will produce each season.

It is estimated that the average number of eggs produced annually by each female whitefish is 35,000. The greatest number the writer has ever known to be secured from one fish was 150,000, from a fish weighing 11 pounds, giving 13,636 eggs to the pound of fish. This would be equivalent to a little more than 37,000 eggs from a fish weighing 2¾ pounds, and as the average weight of the spawning whitefish is from 2½ to 3 pounds it will be seen that 35,000 eggs to the fish should be nearly correct. Then if each pair of whitefish produce 35,000 eggs, and but 1 per cent of them are fertilized, 350 fertile eggs to the pair is all that can be expected to commence with. As the period of incubation for whitefish eggs is from 128 to 150 days, and as these fertile eggs must lie on the lake bottom all this time, in danger of destruction by being smothered in mud and filth as previously shown, and exposed to the still greater danger of being eaten by all kinds of aquatic animals that feed at the lake bottom, it is quite evident that but few of these 350 fertile eggs will survive to reach the fry stage.

It is evident, moreover, that nature never intended there should be such a large increase in numbers as would result from anything like a perfect fertilization, for in that case the lake in a short time would be so densely inhabited that the waters could not produce sufficient food for all; neither would there be room in the lake for them if they came to maturity. It is therefore safe to suppose that naturally the number increases but little if it more than overbalances the loss, and reasoning from the known to the unknown we are sure that this is true.

The number of young produced each year by those fishes, of which there is a large family, that carry their young through the period of incubation and produce them alive, ranges, so far as the writer has been able to learn, from 1 to 22, giving an average of 11 young to each pair of fish; and as these fishes are very numerous where found, it appears that this rate of increase in the fry state is sufficient to more than overcome the losses under natural conditions. Thus by analogy we have the proof that an increase of 11 young from each pair of fish of any kind, including whitefish, is more than enough to overbalance the natural losses.

WORK OF THE HATCHERIES.

But the whitefish, on account of being such an excellent food fish, is more sought after than many others and is taken by every device that man has been able to invent and in the greatest numbers possible on all occasions, so that the natural losses are many times multiplied by this take of fish which may justly be termed "artificial" losses. If this artificial loss is continued, then in order that the loss shall not greatly overbalance the natural increase there must of necessity be introduced an artificial increase. Happily this can be accomplished, in fact is being accomplished, in several places by the aid of the hatcheries. The method employed is to have men go out with the commercial fishermen when they raise their nets and collect the eggs from the ripe fish. This is done by expelling the eggs into a common milk pan in as dry a state as possible, after which they are immediately fertilized by using the milt of the ripe male fish. They are then carefully washed, brought to the station and placed in the hatching jars, where they remain until hatched. In addition to this method of saving the eggs we also pen several thousand fish each year. To do this a net is hung on the back of that part of the pound net called the crib, and when the fish commence coming on the grounds, before they are ripe enough to spawn, the fishermen as they raise their nets take out the unripe fish and place them in these nets on the back of the crib. The station tug, which is provided with large tanks through which a stream of water is constantly pumped, visits these nets and takes the fish out, transferring them to the tanks and conveying them to the station, where they are then transferred to the pens. Here they are held until they ripen, when the eggs are secured; and the fish after a few days, when they have regained their normal condition, are returned to the fishermen from whom they were obtained and are sent to market. It is perhaps well to say in this connection that spawning the fish in this manner in no way injures them for food—in fact these fish that are spawned and then held a few days before being put on the market are in much better condition for consumption than if they had been marketed when first caught. Moreover, the whitefish, unlike many others, is in the best condition for food at spawning time, for the reason that it is very fat and the flesh is juicy, sweet, and, the water temperature at this time being low, firm and flaky, while earlier in the season when the water is yet warm the flesh is much softer and not of as fine a flavor.

Not to digress further, however, we will continue by saying that from the fish collected and held in pens as described above, at one point alone last season over 47,000,000 eggs of the very best quality were secured. In other instances, where the fishermen operate on a small scale and small boats are used for the purpose, arrangements are made whereby the fisherman collects the eggs himself

and is paid for them at so much per quart for fertile eggs. These men operate gill nets and fish on the reefs, and as the whitefish do not frequent the reefs to any extent until ready to spawn, usually more than 50 per cent of their catch is ripe fish.

MEASURES NECESSARY TO INSURE INCREASED PRODUCTION.

From a practical experience of sixteen seasons in the hatching of whitefish and by consultation with other fish culturists, we find that the average hatch of the eggs collected and taken to the hatcheries is from 75 to 80 per cent. Assuming the lower figure to be the correct one, if each pair of whitefish, as previously shown, produce 35,000 eggs, by the assistance of the hatcheries we get three-fourths of 35,000 or 26,331 fry as against the 11 the same fish would have produced if the eggs had been left to themselves, or 2,393 times as many as it was intended by nature for them to produce, as just now shown. Even allowing that the whole of the 1 per cent naturally fertilized hatch, giving 350 fry as the number produced by each pair of fish, the hatchery would still beat nature by 25,981 fry or 750 times as many, and the fry produced in the hatcheries are just as strong and vigorous and their chances for reaching maturity are just as great as are those hatched naturally. Then, if by the lower calculation we produce 750 times as many fry by collecting the eggs and hatching them at the hatcheries as the fish would produce if left to themselves, it is obvious that the best plan to promote the whitefish production of the Great Lakes is:

To so arrange matters that artificial propagation shall be generally applied to reproduction by having hatcheries established at every available point where a sufficient number of eggs can be secured to warrant their maintenance. It is not necessary that the hatcheries be operated on as large a scale as those at Detroit and at Put-in Bay, but wherever enough eggs can be secured to give a hatch of from 25 to 50 millions, if these points are remote from the larger stations put up a hatchery and operate upon as economical a scale as possible; to stock these hatcheries not only collecting the eggs from the ripe fish as caught by the fishermen, but penning and holding the green fish until they ripen, pursuing the method just described, so that practically all the fish caught will have contributed toward this production before being placed upon the market.

To make this plan the more effective, so as to get the greatest increase possible from the fish caught, a law should be enacted compelling the fishermen to collect, or allow the hatcheries to collect, all the eggs from the ripe fish, and to place the green fish in the auxiliary nets for penning; the fishermen to be paid a fair price for the eggs so taken by them and for their trouble in penning the fish, and to receive a fair remuneration for all fish lost by penning.

As a further part of the plan we would have a law enacted prohibiting the taking or the offering for sale of any undersized whitefish, making the size limit large enough so that every fish before being placed upon the market would have had a chance to have spawned at least once and thereby contributed toward increasing the production.

This plan should not only be universal with the states bordering upon the Great Lakes, but should be international, making the same conditions on the Canadian side as in the states and preventing any loophole through which the regulations could be evaded.

This plan would be strengthened by making a closed season during the summer months when it is so nearly impossible to get the fish to market in an edible condition on account of the warm weather and the high temperature of the water from which they must of a necessity be taken. All the fish so taken are a total loss to reproduction, as they go to market with all their unripe eggs still in the ovaries, and for every female whitefish taken at this period there is a loss to reproduction of 11 to 350 fry if left to spawn naturally, or of approximately 26,000 if the eggs were allowed to ripen and hatch at a hatchery.

If this plan is adopted, the writer will cheerfully stake his reputation as a fish culturist that at the end of ten years it will have been proved the best offered up to date.

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By Frank N. Clark

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In preparing the following discussion I considered it desirable to eliminate as far as possible the complicated and tiresome statistical details which, in almost every paper of this nature, go to make up a great portion of its subject-matter. I believe that the interest of those who may be called upon later on to devise some effective means of increasing the supply of this greatest of all American food fishes will be more easily aroused by demonstrating a simple and practicable solution of the problem. Some figures are necessary, of course, but in most instances I have made bold assertions of facts which I know to be true, and which I am going to take the liberty of asking my audience to accept for the truth.

CONDITIONS OF THE FISHERY AND THEIR CAUSES.

It is a universally conceded fact that in an early day when the forests of the states and provinces bordering upon the Great Lakes were for the most part still in their primitive splendor, when the rivers and streams emptying into these waters ran clear as crystal and when civilized man had not yet turned so extensively to the waters for his livelihood, whitefish were in very great abundance and were distributed in a wide range throughout the entire water system known as the Great Lakes. Even as late as from 1864 to 1870, as may be noted by reference to Mr. J. W. Milner's report in the Bulletin of the United States Fish Commission for the year 1872, whitefish were present in such large numbers that during a single season it was not unusual for a fishing ground to yield from 200 to 700 half barrels for each pound net in operation. In a long and very interesting conversation which I had a few years ago with a Mr. Woodward, who was then a very old man, I learned that sometime during the early fifties, while he was acting as a government surveyor and maintaining a camp at the mouth of the Thunder Bay River, his party caught more whitefish than it could use and took them all from the river itself. At the present time no whitefish

are caught within 9 miles of the river's mouth. In 1867 and 1868 my father, the late N. W. Clark, who was one of the pioneer fish culturists of America, took whitefish spawn on the Detroit River, and his observations made at that time indicate that the species was very abundant. At Grassy Island and Mama Juda, two of the best-known fishing grounds, 1,000 fish at a haul was no unusual occurrence. At the present time a haul of 30 fish is considered large. The same is true also of the Au Sable region upon Lake Huron, where during the sixties from 40 to 50 boats were doing a very lucrative business and at the present time not more than a half dozen are operated with only indifferent success. In varying degrees this same decrease in numbers has taken place upon every fishing ground of the Great Lakes, in a great many places to such an extent that operations have been entirely abandoned.

Why should this be so? If we can answer this question, and if the causes can be eliminated or in some measure restricted and controlled, we will have found a solution of our problem in so far as a solution is possible.

First. The cutting of our forests and consequent floods and erosion of the soil, the discharge of sawdust and other refuse from the lumber and pulp mills, chemical works, and sugar factories, which go to make up the industrial life of the cities situated on the Great Lakes, have made the deposits from the mouths of our rivers offensive to the dainty senses of the whitefish and have gradually encroached upon its spawning and feeding grounds to such an extent that in thousands and thousands of acres which at one time were teeming with this species it is now an absolute stranger. This damage can not now be undone, but by wise legislation the cause of it may be to some extent prevented from further offenses.

Second. The operation of the commercial fisheries under unwise laws and the nonenforcement of good laws has, in my judgment, contributed in a greater degree toward the decrease of the whitefish than all of the other causes put together. Most of the law-making bodies of the states bordering upon the Great Lakes have put the cart before the horse, so to speak. By their enactments they have permitted the taking of this fish at all times except during the spawning season and the period of incubation, which all students of fish culture insist is a kind of alleged protective legislation that does not protect. If we are to have closed-season laws they should cover the month or months when the largest lifts of unripe fish are made. It is then that our whitefish need protection, for their ova are immature and we can not half so well spare the parents as we can during the spawning season. When unripe adults are caught for market all their spawn is necessarily wasted, whereas if protected until the spawning season the different commissions would be given an opportunity to save the ova, hatch the fish, plant them in the lakes, and thus by artificial propagation cause each ripe female to furnish thousands of her kind. We have

hatcheries to care for the ova, and, if the present number is insufficient, let us build and equip others; in any event let us not expect nature to make a complete revision of her fundamental laws merely to accommodate herself to the lack of foresight and the inconsistency of mankind.

We need no protection for mature fish, except, as above stated, during the months when the largest lifts of unripe fish are made. The young fish should be protected against the adults. These are the enemies and food competitors of the growing generations, and the quantity of food that a dozen adults consume will suffice for the support of thousands of fry. The question may properly be asked, do the fry subsist upon the same individual food that the adults require? Strictly speaking, they do not; but the source from which the growing generations derive their food supply is at least indirectly dependent upon the higher groups which the adults do destroy.

For these reasons, therefore, I contend that the so-called closed-season laws as they now exist are all wrong. Of course, I am not one of those enthusiasts who believe that our lakes may be made to teem once again with the countless millions of the early days, even with the assistance of the wisest possible legislation and most successful artificial propagation. The conditions have been changed and I know of no way whereby they can be restored. The formerly vast and almost unlimited areas of spawning and feeding grounds have been gradually destroyed by sawdust, bark, slabs, water-logged timber and other refuse, and the water for miles out from shore in the neighborhood of cities and towns is constantly being polluted and infected by poisonous sewage and other impurities. Because of these unfortunate conditions the present spawning and feeding grounds are confined to a few localities.

REMEDIAL MEASURES.

But that the whitefish of the Great Lakes can be increased very materially in spite of these difficulties which the fish culturist is forced to encounter I am very strongly convinced. This can be done only by closely adhering to some such plan of action as I shall outline in the remainder of this paper, and which I contend, and shall endeavor to convince my hearers is the only possible solution of the problem.

(1) INTERNATIONAL PROTECTIVE LEGISLATION.

First, there must be concerted action, by means of a treaty or otherwise, on the part of the United States Government and the Dominion of Canada, and such action must be carried on to the point where there shall be one set of laws applicable to all the waters of the Great Lakes and their tributaries, and enforceable on the part of either government in any part of its own or

the other's territory. I would also repeal and abolish all of the existing laws of the several states and provinces in so far as they deal with the food fishes of the Great Lakes, so that the question of proper authority and jurisdiction could never arise. The greatest advantages to be gained by thus placing the Great Lakes under the control of the two governments would be the more rigid enforcement of the laws and the removal of legal proceeding from the universally conceded local influence over local juries. A uniform law such as I deem to be adequate to afford the fullest measure of protection for the whitefish should be framed along the following lines:

(1) Issue to the present United States and Canadian fishermen, or to anyone who shall subsequently apply therefor, a revocable license to fish the waters of the Great Lakes and their tributaries; such license to be suspended for six months for the first violation, one year for the second, and forever forfeited without hope of reinstatement upon a third violation of the protective laws.

(2) Provide for an open season during the months when the fish are spawning and a closed season during the month or months when the largest lifts of unripe fish are made.

(3) Prevent any sort of fishing in certain localities where large numbers of immature fish congregate upon the feeding grounds, this legislation to pertain to all portions of the Great Lakes system where the presence of such fish has been established and to be enforced during such month or months as they make their appearance in large numbers for feeding purposes.

(4) Prevent the sale or offering for sale or the use of immature whitefish in any manner except for charitable purposes, the size of a mature fish to be legally fixed for this purpose at 2½ pounds. This would discourage the capture of immature fish and protect them upon their feeding grounds, where they assemble in schools.

(5) Make no restrictions of any kind whatsoever as to the kind of nets or the size of the mesh which the fishermen may use in their operations, because, in my judgment, the provisions of this character which are now a part of the present local laws have furnished even more opportunities for the fishermen to escape conviction than the influence upon local juries. Rigidly enforce the provisions regulating the size of the fish which may be sold, and the size of the mesh, kind of net, and manner of capture will be regulated by the fishermen themselves.

(6) As a part of this legislation let there be a provision requiring all fishermen who operate in the territory comprising the Great Lakes and their tributaries to take and fertilize all of the spawn contained in every ripe female that is caught during the spawning season, further details of which plan I shall discuss under another topic.

The above-outlined six provisions would, in my judgment, constitute an adequate law for the greatest protection and consequent increase of the whitefish that it would be possible to give them. If a uniform law can be agreed upon and framed along these lines, and then enforced with the same watchful diligence with which the revenue laws of both countries are enforced to-day, there is no room for argument against the statement that, aided by artificial propagation on a large scale, the whitefish may be increased so materially that at no very distant future date the fisherman's net will be found to contain dozens where there is one to-day.

(2) ARTIFICIAL PROPAGATION.

Now while a uniform, adequate, and rigidly enforced set of laws is of the greatest necessity in bringing about a material increase in the whitefish, propagation upon a large scale is absolutely indispensable. That artificial propagation of the whitefish as it has been worked out and practiced during the past twenty years by the several states and the United States and Canadian governments has been the means of effecting an actual increase of this species, there is at this day no one so bold that he dare dispute. Statistics have been prepared and published which show that until within the past six or seven years from two-thirds to three-quarters of all plants of whitefish fry have been in Lake Erie and the Detroit River, and the fact is well known that in these waters there has been a large increase in their numbers. The United States Government during its operations at Belle Isle and Grassy Island in the Detroit River for the past few seasons has taken from 25 to 50 per cent more whitefish at these points than the Michigan Fish Commission did a decade ago, the fishing continuing for no longer a period each season and being with the same kind and length of seines.

Now, by artificial propagation on a large scale I mean the production of whitefish fry in such numbers that every suitable locality on the Great Lakes may have the same, or, if possible, greater opportunities to assist in this increase than have been afforded Lake Erie and the Detroit River. This would involve the planting of from two to five billion fry annually, and the following plan, if adopted, would easily furnish, in my judgment, a sufficient number to bring about the required results:

Every fisherman operating in the waters of the Great Lakes should be required to strip every ripe female caught during the spawning season and impregnate the eggs taken therefrom. This would operate as an annual tax upon the fishermen, the expense being probably from $25 to $100 per boat. At the present time from 50 to 75 per cent of the fishermen are perfectly familiar with the methods employed in successful spawntaking, and there

would be very little difficulty in having the inexperienced taught by the experts in the employ of the two governments. After impregnation all of the spawn should be turned over to United States and Canadian government agents for shipment to the several hatcheries, where the eggs could be cared for and the fry distributed in a wide range throughout the entire Great Lakes system. The eggs taken by each fisherman should be measured and kept separate from the others throughout the incubation period. This would involve but very little additional labor and would be of very material assistance to those agents of the two governments upon whom would be placed the responsibility of enforcing the protective laws; and such a record would not only show exactly which fishermen were improperly impregnating the eggs taken, but by comparison with the size of their catch during the spawning season it could be satisfactorily determined whether or not they obeyed the law prescribing that all ripe females should be stripped. Of course, a fisherman might be the victim of ill luck throughout one season, but a recurrence of an unsatisfactory showing would put him under suspicion, and with the penalty of a forfeiture of his license hanging over his head he could be very easily made to see the error of his way. Finally, the Detroit River must be closed to all fishing at all times, except with rod and line, and must be constituted a joint government reservation, controlled and used by the two governments for collecting stations.

If the present facilities for handling the product from these two sources are not sufficient, hatching and distributing stations can be arranged for easily and without any great amount of expense. Such a station with a producing capacity of 50,000,000 fry can be constructed and equipped at a cost not exceeding $1,500, and the same can be operated at an annual expenditure of $500.

This is my plan, in the rough to be sure, but with its essential outlines sufficiently distinct to make the work of preparing and putting into execution an adequate system for the proper protection and consequent increase of the whitefish in the Great Lakes a comparatively easy task. It is self-evident that, inasmuch as the life and growth of the whitefish industry of our inland seas are directly dependent upon the maintenance of supply, the plan which will best promote the industry will be the one which will insure the greatest increase in the species.

A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES

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Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded the prize of one hundred dollars in gold offered by the Wolverine Fish Company, of Detroit, Mich., for the best plan to promote the whitefish production of the Great Lakes

CONTENTS.

	Page.
Approach to the problem	645
Method of investigation	646
Natural history of the whitefish	649
Sources of information	649
Kinds of whitefish	650
Depths at which whitefish occur	650
Areas of bottom frequented by whitefish	652
Migrations	653
Local habits of whitefish	654
Whitefish areas of Great Lakes	655
Effect of propagation upon whitefish production in Great Lakes	660
Annual catch and plant in Michigan and Canadian waters	660
Discussion of average catch and plant for certain areas	666
Canadian and Michigan waters of Lake Superior	666
Canadian and Michigan waters of Lake Huron	668
Canadian waters of Lake Erie and Lake Ontario	669
Restricted areas of Lake Michigan	671
Production compared with intensity of plant	673
Conclusions as to effect of propagation	673
Effect of legislative enactment on whitefish production	676
Summary of conclusions	681
Measures recommended as means of increasing whitefish production in the Great Lakes	682
Bibliography	683

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APPROACH TO THE PROBLEM.

In attempting to devise a plan for the promotion of the whitefish production of the Great Lakes it appears that certain avenues of approach available in the case of cognate problems are in this case closed. This will perhaps become clear if we first consider the possible modes of accomplishing the purpose. The procedures that suggest themselves are those which might be followed in any like problem, and may be conveniently grouped in the following way:

Preservative measures:

1. Prevention of the water pollution which may occur through the agency of sewage, garbage dumps, sawdust or other manufacturing refuse, cinders, ashes, and other refuse from steamers and other boats.
2. Restriction of fishing operations (limitations on fishing season and on character and number of nets to be used).

Restorative measures:

3. Distribution of fry.
4. Introduction of improved races of whitefish.
5. Increase of the food of the whitefish.

Experiments on the effect of water pollution on fish have been conducted abroad and are summarized by Professor Prince (1900). The investigations carried out for the Canadian government by Mr. Knight (1901 and 1907) on the effect upon fish of the pollution of Canadian streams by the refuse of sawmills, pulp mills, gas works, and nail mills are noteworthy, but do not appear to have any application to the Great Lakes. In this country we appear to have no similar published investigation, so that we have no means of knowing the extent of water pollution in the Great Lakes or its effect on the whitefish. We are therefore compelled in this paper to disregard a possible means of increasing the whitefish production through the prevention of water pollution.

When it is desired to increase the production of domestic plants or animals, this is often most readily done by increasing the food supply. In other cases the result may be accomplished by creating a race of larger individuals, or one that breeds more rapidly. These two methods have been applied to domestic forms, but the first of them is often made use of also with game birds and mammals. The whitefish of the Great Lakes lives at depths of from 10 to 50 fathoms, scattered over an area of 25,700 square miles. (See p. 653.) Our knowledge of its mode of life, its daily and yearly movements, and its whereabouts during the growth period is meager. It is impossible, therefore, with present knowledge and under existing conditions, to attempt to increase the natural food of the whitefish. To suggest that it may be possible to produce a race of whitefish that would breed more rapidly than our present race, or appropriate food not utilized by the present whitefish, or occupy areas of the lake bottom now barren of whitefish, is to state a problem the solution of which must lie far in the future. The breeding of improved races of fish must begin with forms more readily controlled than the whitefish. There remain but two methods by which we may hope to increase the whitefish production of the Great Lakes, namely, to greatly increase the number of artificially hatched fry introduced into the lakes annually or to enact restrictive legislation which shall prevent the further depletion of productive waters and shall at the same time give an opportunity for depleted waters to become again productive. The present paper attempts a discussion of these two methods (2 and 3 of the foregoing analysis).

METHOD OF INVESTIGATION.

In undertaking an inquiry of this sort it is impossible to make personal investigation of the whitefish in the field. The vastness of the areas involved and the depth at which the fish lives precludes this in the case of the individual investigator. He must necessarily base his work on data gathered by those who have worked with the help of the various state and national governments bordering on the Great Lakes. The problem is essentially one of statistics. The investigator wishes to know what amount of whitefish have been taken in each part of the Great Lakes over a long period of years; what kinds and quantities of nets have been used in their capture; under what legislative restrictions these have been used; what quantities of young fish have been introduced into the Great Lakes and into each part of them to replenish the waters from which the adults have been taken.

Fishing operations are carried on, or have been carried on, wholly by private individuals or corporations in the waters of the following States: Indiana, Illinois, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, as well as in the waters of the Dominion of Canada. The fishery laws of these various governments are diverse, and have been changed from time to time in the past. It is

therefore difficult to find any well-defined area in the American waters of the Great Lakes which has been fished under uniform conditions for a period sufficiently long to permit conclusions to be drawn as to the effect of that fishing.

Not only have the conditions under which the fishing has been carried on varied from time to time in any one locality and at any one time from locality to locality, but no complete records are available of the fishing operations in the Great Lakes as a whole, or in any single lake, except Lake Huron, for any continuous period of years. The United States Fish Commission (now the Bureau of Fisheries) has caused statistics to be collected on the fisheries of the Great Lakes about once in five years, and these are available for the following years: 1880, 1885, 1890, 1893, 1899, 1903. The Michigan fish commission has since 1891 employed a statistical agent, who has annually visited each fisherman and personally taken from his books the records of the fish caught and of the nets used. The Canadian Department of Marine and Fisheries has for the past thirty-eight years published in its annual report detailed statistics of the fisheries in Canadian waters. The remaining governments, with the exception of Pennsylvania, are able to afford no information about the fishing operations within their borders.

Not only is investigation hampered by the paucity of statistics, but the reliability of the available statistics is often a matter of serious question. The difficulties in dealing with whitefish statistics arise from two sources. Even when statistics are available for like periods and over the same areas they are often widely at variance. The Michigan statistics are taken annually by a statistical agent who is in the field almost constantly and who by his long service, begun in 1891, has gained the confidence of the fishermen. They are taken under a law which requires the fishermen to make sworn returns of their catches. Considering all the circumstances, they are probably as accurate as such statistics can be made. The data that it has been found possible to use in this paper are chiefly those of the Michigan and Canadian fisheries.

The second source of difficulty referred to has to do with the use of the term "whitefish." Four fishes of commercial importance are referred to as whitefish. These are the common or true whitefish (*Coregonus clupeiformis* Mitchill), the longjaw (*Argyrosomus prognathus* H. M. Smith), the blackfin, bluefin, or bloater (*Argyrosomus nigripinnis* Gill), and the Menominee whitefish (*Coregonus quadrilateralis* Richardson). Subsequent to 1891–92 these forms are distinguished in the statistical reports of the United States Fish Commission, but previous to 1893 "whitefish" only are mentioned. The published reports of the Michigan Fish Commission, as well as the unpublished records of their statistical agent, exclude menominees, blackfins, and longjaws from the rubric "whitefish," which therefore includes only true whitefish. The statistics collected by the Department of Marine and Fisheries of the Dominion of Canada, I am assured, include true whitefish only and exclude longjaws and blackfins. Our com-

parisons are therefore necessarily limited to the whitefish production of those waters that lie within the borders of the Dominion of Canada and of the State of Michigan for the period 1892 to 1906, inclusive, and to the Great Lakes as a whole for the years subsequent to 1893. In the latter case, however, statistics are available only at five-year intervals.

The distribution of whitefish fry is carried on at the expense of the state and national governments, and the annual official reports therefore contain full statements as to the number of fry distributed and the location of each plant. Whitefish fry have been distributed by the states named above with the exception of Illinois, Indiana, and Minnesota, and by both of the national governments, although the states of Ohio and Michigan have not distributed whitefish fry in recent years.

By combining the statistics of the Michigan fisheries with those of the Dominion of Canada, complete returns are available of the catch of whitefish and of the nets used for Lake Huron for the years 1892 to 1906, inclusive. The exact number of pounds of whitefish brought in by each fisherman on this lake and the precise length of the nets used in the lake are recorded for each of these fifteen years. The plant of whitefish fry in this lake may be obtained by combining the figures of the Michigan and Canadian plants for the whole lake or for any part of it. We may thus study in this lake, or in any part of it, the effect of the distribution of whitefish fry on the catch of adult fish for a period of fifteen years. By comparing Canadian and Michigan waters for the same period, we may study the effect on the production of whitefish of certain restrictive enactments which have been enforced in Canada but not in Michigan. By similar methods we may study certain areas in Lakes Superior, Michigan, Erie, and Ontario, from which we have statistics from either Michigan or Canadian sources.

In statistics of the catch of whitefish, figures of single years have little significance, since the catch of one year may be large owing to the weather conditions of that year having been favorable for fishing, while the catch of another year with which the first may be compared may be small owing to unfavorable weather conditions during that year, or the market price in one year may have been high, with a consequent stimulation of fishing operations, while in another year it may have been low, with a consequent curtailment of those operations. These annual fluctuations make it necessary to compare with one another not single years but periods of years. In the present paper market fluctuations are not considered, since the price of whitefish does not tend to fluctuate but rather increases steadily, while by comparing the average outputs of the three successive five-year periods comprised in the years 1892 to 1906, inclusive, an attempt is made to avoid the errors introduced by annual variations in the weather of the fishing season.

The condition of the fisheries is usually expressed by giving the annual catch, but as was pointed out by Rathbun and Wakeham (1893), "the best statistical test of a decrease is a comparison of the average catches per unit of apparatus for the several years for which statistics are available." In comparing the catches of different periods I have therefore reduced the average catch of each period to "pound-fathoms" by dividing the actual catch expressed in pounds by the length of gill and pound nets expressed in fathoms. I have thus obtained the catch in pounds per unit of net length. Unfortunately in making these calculations I have been unable to separate the gill and pound nets which have taken whitefish from those which have not, so that the values given in the tables in this paper are the lengths of all gill and pound nets used in the waters in question whether the nets have or have not taken whitefish.

I have attempted, also, to consider the output of whitefish in its relation to the areas of the Great Lakes bottom occupied by them during that season of the year when they are not migrating. By dividing the number which expresses in pounds the catch of a lake or of any part of a lake by the number of square miles of lake bottom ordinarily occupied by the fish in question, I have obtained a pound-mile unit which is made use of in another part of this paper, where also the method of measuring the areas is described. By the device of the pound-mile it is hoped that in a measure errors have been avoided which arise from the comparison of the catches of different years when the areas fished over in those years have not been the same.

The present paper then attempts to utilize the available statistics in an examination of the individual Great Lakes and of parts of lakes to see what lessons may be learned by a comparison of those areas which have been fished under one set of regulations with those that have been fished under a different set of regulations, and by a comparison of those areas which have been abundantly planted with those that have been less liberally treated. I am indebted to the United States Bureau of Fisheries for kindly obtaining information for me from the states of New York and Pennsylvania, to the Wisconsin Fish Commission for information furnished, to the Michigan Fish Commission for permission to make excerpts from the original records on file in their office and as yet unpublished, and to the Department of Marine and Fisheries of the Dominion of Canada for printed documents and excerpts from official records.

NATURAL HISTORY OF THE WHITEFISH.

SOURCES OF INFORMATION.

In the report of the joint commissioners relative to the preservation of fisheries in waters contiguous to the United States and Canada, Messrs. Rathbun and Wakeham (1897) have collected a large amount of evidence concerning the

habits of the whitefish. This evidence, which is summarized in the report referred to above, consists of the statements of fishermen as to the depths at which whitefish are taken in the different lakes, their distribution, migrations, and other habits. This report, together with the statements of Prof. H. B. Ward in his report on Lake Michigan in the Traverse Bay region (Ward, 1896) form the basis of the following account. The earlier works of Milner (1874) and Smith (1893) have also been consulted.

KINDS OF WHITEFISH.

By the term whitefish as used in this section of the present paper is to be understood the true whitefish or common whitefish (*Coregonus clupeiformis* Mitchill) unless otherwise stated. Fishermen, while they distinguish readily between the true whitefish and other related species, nevertheless often report them together as whitefish and statistical reports are necessarily based on their statements. Thus in the most recent statistical reports of the United States Bureau of Fisheries, Alexander (1905) separates whitefish, longjaws, and bluefins in Lakes Superior and Michigan, and whitefish, longjaws, and menominees in Lake Huron, but lists whitefish only in Lakes Erie and Ontario, although the latter lake, at least, contains longjaws (Smith 1895). The Michigan and Canadian statistics refer to whitefish only. The data used in the present paper are those which refer to true whitefish only.

DEPTHS AT WHICH WHITEFISH OCCUR.

The following statements as to the depths at which whitefish are found are taken from Rathbun and Wakeham (1897) except that for Lake Michigan, which is from Ward (1896):

	Fathoms.
Lake Ontario	10–20
Lake Erie	12–30
Lake Huron	10–35
Lake Michigan	12–20
Lake Superior	10–50

The depth data given for Lake Michigan are specifically stated by Professor Ward to be depths of the true whitefish in summer, and to be the range over which the fish is the most numerous. It occurs in small numbers in both shallower and deeper water. The depths given for Lakes Ontario and Erie are no doubt also those at which the true whitefish is found during the greater part of the year. The greater depths given for Lake Huron possibly cover also the range of the longjaw, which is stated by Ward to occur in greatest abundance from 20 to 25 fathoms in Lake Michigan, although Smith (1895) states that in Lake Ontario they range as deep as 116 fathoms and in August as shallow as 20 fathoms. The range in Lake Superior also possibly covers more than the

true whitefish, but this is uncertain. It may cover in part the range of the blackfin (*Argyrosomus nigripinnis*), which is stated by Ward to be in Lake Michigan rare in less than 40 fathoms. I have placed the inshore range of the whitefish of Lake Superior at 10 fathoms, although Rathbun and Wakeham make no statement on this point, but say merely that the fish ranges "outward into depths of 40 to 50 fathoms, seldom farther, and in some places coming close upon the shore during the spawning season and in the spring." I have assumed the inshore range on Lake Superior to be about the same during most of the year as in the other lakes.

The most careful investigation of the food of the whitefish and of the related fishes we owe to Ward (1896), who finds as a result of the examination of 14 individuals taken in summer that on the average 63 per cent (by volume) of the food of the true whitefish consists of small bottom crustaceans, 26 per cent of small mollusks, 5 per cent of insect larvæ and 2 per cent of small fish. Small brown stones were also found commonly in the stomachs. "The considerable part played by the mollusks and insect larvæ, both of which are strictly bottom forms, shows that the common whitefish is to a large extent a bottom feeder. This view is strengthened by the down-pointed sucker-like mouth of the fish as well as by the presence in the stomachs of numbers of small stones, which were undoubtedly snapped up with some morsel of food" (Ward, 1896). The food of the longjaw Ward found to consist of small crustacea to the extent on the average of 97 per cent of the whole (volume), while the food of the two specimens of blackfin examined contained crustacea to the extent of 97 per cent of the volume. The absence of stones, mollusks, and insect larvæ from the stomachs of these two forms and the presence in them of free swimming crustacea, as well as the form of the mouth of the fish themselves, show that they feed not on the bottom, but just above it. All of these whitefishes therefore feed on the bottom or just above it, but differ in their depth range during the greater part of the year, the true whitefish ranging from 10 fathoms outward, but rarely being taken in more than 35 fathoms, the longjaw ranging from 20 fathoms outward, occurring in greatest abundance between 20 and 25 fathoms and reaching in winter a depth of 116 fathoms, the blackfin occurring rarely in less than 40 fathoms and most abundant at 70 fathoms and upward.

The ranges indicated above as occupied by the whitefish are its feeding grounds during eight or nine months in the year. It enters shallow water in the southern lakes in June and July, and returns again to the deeper water about the 1st of August. The cause of this shoreward migration is discussed by Milner (1874), but he does not mention one very probable cause, namely, that the period of this shoreward summer migration is that when the insect larvæ upon which the migrating fish feed (Kiel, 1874) are most abundant. It is quite possible that the migration takes place as a search for a more abundant

food. The summer migration of the whitefish occurs apparently in all the Great Lakes. Milner (1874) reports it in Lakes Superior, Michigan, Huron, and Ontario, and Rathbun and Wakeham (1897) report it in Lake Erie. The date of its occurrence no doubt varies with the latitude. A second inshore migration occurs in the fall, taking place in November in the more southern latitudes and occupying about a month in any latitude. It is the spawning migration, during which the fish visit the shallower water to deposit their eggs. From Lake Erie this migration formerly extended to the St. Clair River and Lake St. Clair and it still extends into the Detroit River, but in the other lakes the location of the spawning grounds and the related extent of the migration are little understood.

Milner states (1874, p. 85, 92) that the fish do not eat while spawning, or have very little in their stomachs. In this respect their habits are like those of many other Salmonidæ under like circumstances. If we accept this statement, then the food of the whitefish, except during the spring migration, is obtained within the depth range indicated above. During nine months of the year they are on this range; during June and July in southern latitudes and probably for a corresponding period in more northern latitudes they are engaged in the so-called spring migration; during one month (November in southern latitudes) they are engaged in the spawning or fall migration and during this time they do not feed or feed very little. The existence of the species therefore depends on the utilization of the range referred to. The capacity of any of the Great Lakes to produce whitefish must depend on the extent of this range, assuming the existence of suitable spawning grounds. If we accept Milner's statement (1874, p. 61–62) that young whitefish of less than 1¼ pounds weight are found in water from 20 to 45 feet deep and thereafter enter deep water, the above proposition still stands essentially unmodified, for the production of commercial whitefish or breeding whitefish would still be in relation to the area of the range which furnishes them with food during nine months in the year. These areas I shall refer to hereafter as whitefish areas.

AREAS OF BOTTOM FREQUENTED BY WHITEFISH.

In the accompanying maps (fig. 1 to 5) we have attempted to indicate the extent of the whitefish areas for each of the Great Lakes. These are the areas within which the fishermen find the whitefish when carrying on commercial fishing operations at other times than during the fall and spring migrations. They are the areas over which it is, or has been, profitable to fish, and outside of which the whitefish is found in relatively small numbers. The maps have been made by tracing the appropriate fathom lines on the United States engineer charts of the Great Lakes. They are sufficiently explained in the legends

attached to them. In the following table we have given the whitefish areas for each of the Great Lakes together with the extent in square miles of the lakes themselves. These whitefish areas have been obtained by measuring with a planimeter the areas plotted on the maps. The lake areas are taken from H. M. Smith, 1894.

AREA OF EACH OF THE GREAT LAKES, WHITEFISH AREA OF EACH, AND PERCENTAGE OF WHITEFISH AREA.

	Total area.	Whitefish area.	Percentage of whitefish area.
	Square miles.	*Square miles.*	
Lake Superior	32,000	7,400	23
Lake Michigan	22,000	2,600	12
Lake Huron	21,000	9,400	45
Lake Erie	9,500	4,100	43
Lake Ontario	6,500	2,200	34
Total	91,000	25,700	28

It is to be noted that the area occupied by the true whitefish is relatively least in Lake Michigan, where it forms but 12 per cent of the lake area. Lake Erie comes next with a whitefish area 14 per cent of its total area, if the eastern part of the lake only is taken, but if the western platform of Lake Erie be included over depths of 12 to 30 fathoms, its whitefish area is raised to 4,100 square miles, or 43 per cent of that whole area. Whitefish are taken on those parts of the platform of suitable depth, but in relatively small numbers.

MIGRATIONS.

The whitefish do not wander about at random in these areas, so that the fish of one lake pass into another lake, or those of one part of a lake to a distant part of the same lake. On the other hand, such evidence as we have indicates that the whitefish, like other fish, are during the greater part of the year local in their habits. Their migrations during the breeding season have been already sufficiently referred to, so that we need consider here only the wanderings of the fish during the rest of the year. In general it may be said that the wanderings of fish are by no means fortuitous and, except in the breeding season, are of limited extent. This subject is discussed at some length by Professor Prince (1907) and need not detain us further here. The relative local habits of the nonmigrating herring in England, of the shad in this country, and of the salmon are now well understood. It is well known to fishermen and to dealers who handle whitefish that the fish of different lakes are so unlike that one who is accustomed to them can readily distinguish them. Each lake has its own race and these races do not intermingle by running from lake to lake.

LOCAL HABITS OF WHITEFISH.

Not only does each lake have its race of whitefish, but there are reasons for the belief that parts of lakes are inhabited by races peculiar to them. On this point Milner (1874, p. 47) has the following to say:

> The presence of large whitefish in numbers in certain localities on the north shore of Lake Michigan, of a size that are never taken at other parts of the lake, would indicate a local habit, with no disposition to range through long distances.
>
> Another observation, sustaining the probability of this, is the fact that there are many localities on the lakes where the pound nets, a few years ago, found prosperous fishing, and in the first few years took the whitefish in great abundance, but found afterwards a decrease from year to year until the locality was abandoned, while 50 miles away the business continued successful.
>
> * * * * * * *
>
> The fact that certain types of whitefish are peculiar to certain localities, as the north shore of Lake Michigan, the Sault Ste. Marie Rapids, Bachewauna Bay on Lake Superior, indicates a local habit through many generations until certain characters of a race have become established. The same fact has been stated for the shad on the Atlantic coast.
>
> Some observations made in 1871 perhaps indicate the opposite of all the foregoing statements.
>
> In the early part of the season there had been a few fish caught on the west shore of Lake Michigan between Chicago and the Door Islands. South of Chicago, at the mouth of the Calumet River, the run of whitefish was in excess of anything had for years. But about the 15th of June the schools of fish left Calumet, and a few days later there was a decided improvement in the catch at Evanston. About June 22 the lifts at Waukegan began to be heavier than they had been before. During the first week of July the fishing was observed to improve at Milwaukee, Manitowoc, Baileys Harbor, and, a little later, at the Door Islands.
>
> The coincidence in dates rather indicates that the same schools of fish that clogged the nets at Calumet during six or seven weeks had ranged northward along 260 miles of coast. Still the effect upon the fishing would have been the same if it had been the migrations of schools of fish from deep water at these points in to the shore.

The explanation here offered by Milner, that the phenomenon described in the paragraph is indeed due to the inshore migration of local groups of whitefish beginning at the southern end of the lake and proceeding northward on the west shore, is most probable and is in harmony with the other facts which he cites, as well as with what we now know of local races in other species of fish.

We are concerned here only with those movements of the whitefish which take place out of the spawning season, yet it may not be without interest to cite further from Milner to show that even during the spawning run the movements of the fish are more local than would be thought. He says:

> It is a singular fact that the whitefish are not known to descend from Lake Huron into the St. Clair River. This is established by abundant evidence from continued fishing at Fort Gratiot, where Mr. Clark, between the years 1830 and 1842, took large quantities of the wall-eyed pike, *Stizostedion americana*, taking frequently 1,000 barrels a year. The catch of whitefish amounted to an occasional supply for his own table, except after long continued storms from the northward, when the fish sometimes entered

the river in schools. They were never found in this portion of the river in the spawning season.

The same fact is claimed by the Indians in the Sault Ste. Marie River, that the whitefishes of the lake above never descend the rapids, while the whitefishes of the river, it is also asserted, never ascend to Lake Superior. There is not as good evidence for the truth in this locality as at Fort Gratiot; still it may be the case.

The evidence collected by Rathbun and Wakeham points also to the local habit of the whitefish of Lake Ontario. They say (p. 60):

There does not seem to have been any regular migration of these fish lengthwise of the lake. They occurred along a narrow border of the lake and simply moved to feeding grounds in the spring and to spawning grounds in the fall wherever the shoal water was suitable. There they were most abundant, and on these areas we still find the remnant of them.

Again they say of Lake Huron:

The movements of the whitefish in Lake Huron are, in general, less definite than in Lake Erie, being confined to shoreward migrations in the spring and fall. These migrations appear to be accompanied by no extensive progress alongshore, except at Detour, where the spring run is said to have a general easterly direction, appearing first near Detour and then passing down the North Channel into Georgian Bay.

It would be easy to compile evidence from the statistical returns of the Michigan fish commission to show the local habit of the whitefish, from the fact that fisheries have often been depleted in one locality while remaining profitable in other localities 25 to 50 miles distant, but the facts already cited seem to be sufficient for the purpose.

WHITEFISH AREAS OF GREAT LAKES.

An examination of the whitefish areas as platted on the accompanying maps tends to strengthen this view of the local habit of the whitefish. In Lakes Superior, Ontario, and Michigan we see this area stretching in a relatively narrow zone along the whole shore. This zone incloses a central area of deeper water which separates the whitefish area of one side of the lake from that of the other side and is probably never crossed by these fish. Within it occur the blackfins and longjaws. In Lake Huron we see a similar condition of affairs for the main lake, but in Georgian Bay we find the greater part of the area taken up by whitefish grounds. Here the deep water is not central in the whitefish area but is displaced toward the southwest so as to leave the marginal whitefish area very narrow on one side of the lake and very broad on the other side. In the North Channel of Lake Huron a continuous whitefish area occupies its center uninterrupted by a deeper middle water. In this lake the reef which cuts obliquely across the main lake is said not to harbor whitefish in commercial quantities and not to afford them spawning ground. It is therefore not included in the whitefish area, although of suitable depth, and its extent is indicated on the map in outline only.

FIG. 1.—LAKE SUPERIOR.

Whitefish area (shown in black), 10 to 50 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1474. Scale: 1 in. = about 44 miles.)

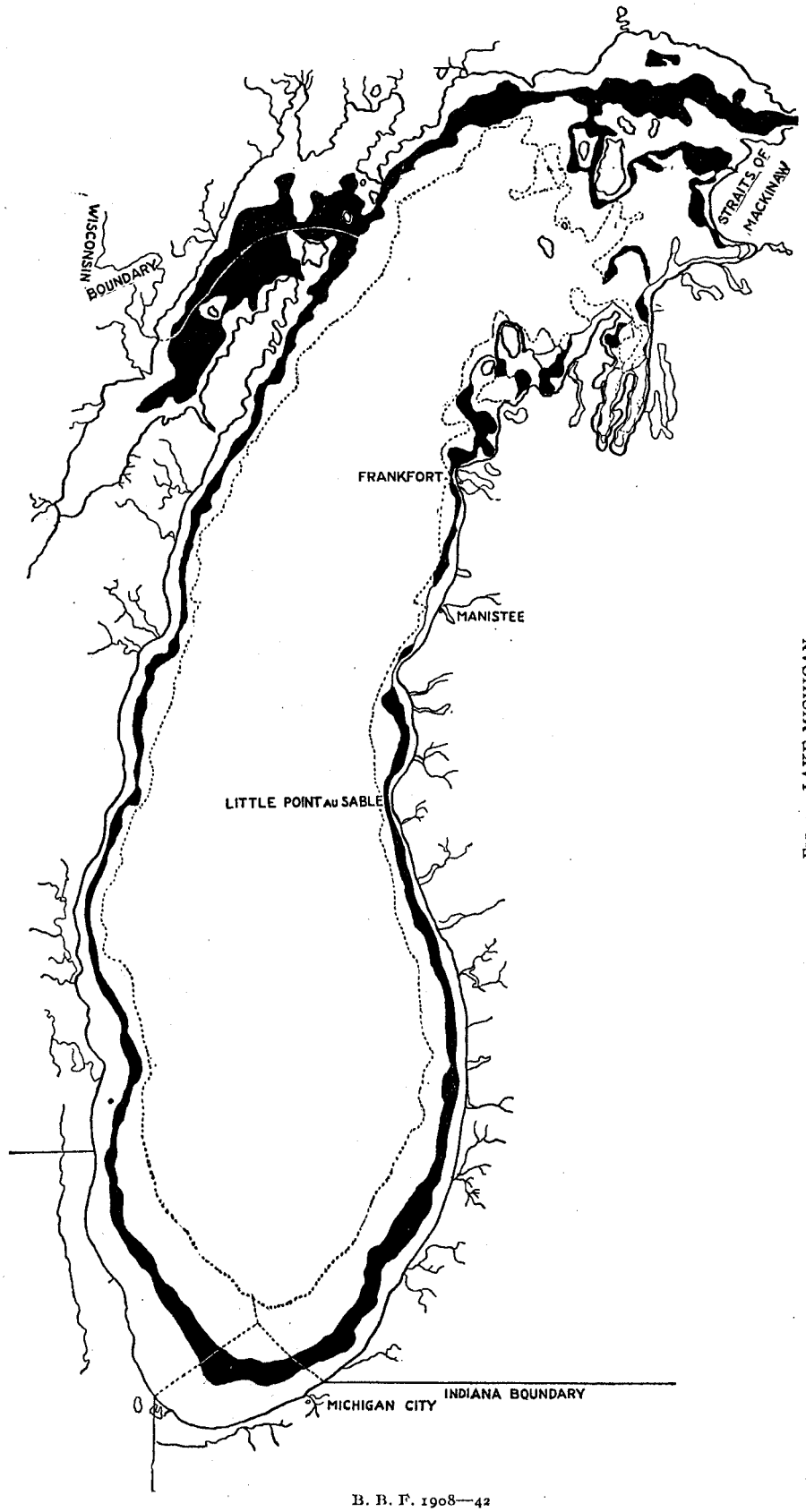

FIG. 2.—LAKE MICHIGAN.

Whitefish area (shown in black), 12 to 20 fathoms and (to dotted line) 20 to 40 fathoms. (Reduced from U. S. Engineer chart. Scale: 1 in. = about 41 miles.)

In Lake Erie the whitefish area is divided into two portions—a western, which occupies the central portion of the lake west of Conneaut and is not interrupted by deeper middle water, and an eastern, which lies eastward of Conneaut and contains a small central middle portion of deeper water. The two portions are connected by a narrow neck at their southern borders. So far as I can learn the whitefish appear to confine themselves during most of the year to the eastern portion of this area, though for what reason is unknown.

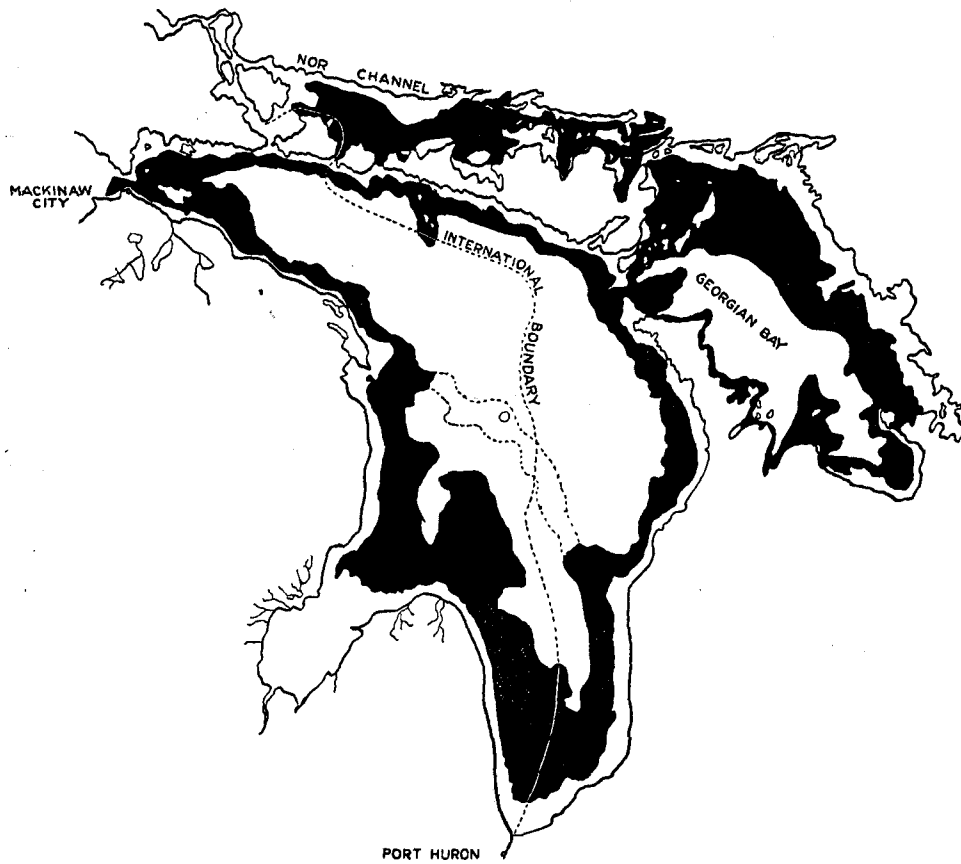

FIG. 3.—LAKE HURON.

Whitefish area (shown in black), 10 to 35 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1478. Scale: 1 in. = about 46.8 miles.)

More careful examination of the maps shows that while the whitefish area is continuous in most of the lakes about the whole border, this is not the case in Lake Michigan. Just south of Little Point Au Sable the area is nearly interrupted, and to the north of this it breaks up into numerous small areas which are either detached from one another or nearly so. Of course if the deeper

limit of the whitefish area had been taken as 30 or 40 fathoms the area would become more nearly continuous. In selecting 20 fathoms as the deeper limit of this area in Lake Michigan I have been guided by the statements of Ward (1896), which seem to merit every confidence. On the map of Lake Michigan I have, however, indicated also the 40-fathom limit by a dotted line. The area between the dotted line and the black area shows the region which contains longjaws in commercial quantities, especially along its shoreward margin. The blackfins rarely enter this area, but remain in deeper water. This area is one into which the whitefish doubtless wander to a greater or less extent, but according to the statements of Professor Ward, not in commercial quantities. The map shows that if this area between the dotted line and the black area be included within the range of the true whitefish, that range is even then not con-

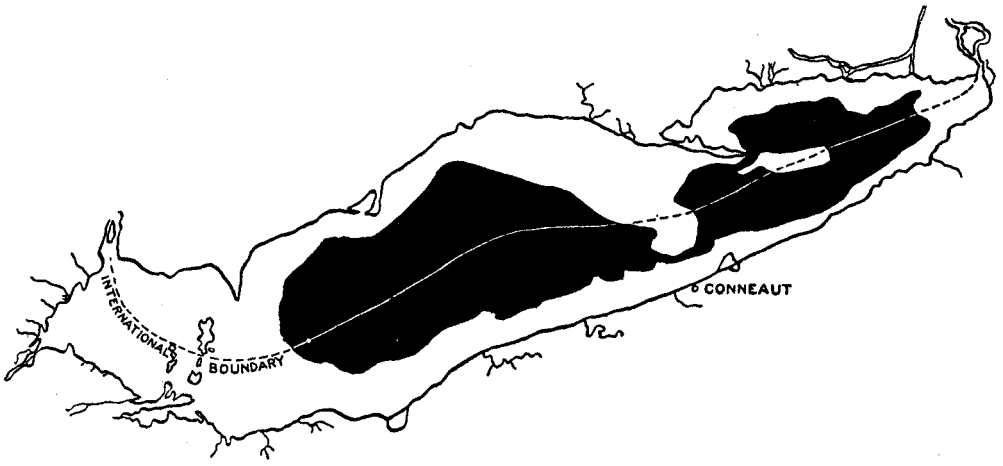

FIG. 4.—LAKE ERIE.

Whitefish area (shown in black), 12 to 30 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1477. Scale: 1 in. = about 50 miles.)

tinuous along the eastern shore of Lake Michigan. It is interrupted north of Big Point Au Sable and in a number of places still farther north. In handling the statistics of these fisheries we have attempted to study discreet areas within individual lakes. The extent of these is indicated in another place.

Within the whole whitefish area of the Great Lakes the production of marketable whitefish has greatly declined since the first statistics were taken in 1880. This is evident from a glance at the table given by Alexander (1905, p. 650), where is given the whitefish production for each lake for the years 1880, 1885, 1890, 1893, 1899, 1903. As to the cause of this decrease there is no difference of opinion among those who have investigated it. Investigators from Milner in 1871 to Rathbun and Wakeham in 1893 to 1896 have reached but one conclusion, namely, that the decrease is due to overfishing. Ward (1896)

strengthens this conclusion when he finds that on grounds where whitefish were formerly abundant, but on which they are now scarce, the food of the whitefish still exists in apparent abundance. The following quotations from Professor Ward are of interest in this connection. He says (p. 24):

> We are thus forced to the conclusion that the decrease in the whitefish supply can have no other cause than overcatching. This is not the place to discuss good and bad methods of fishing or remedies for the trouble. Our investigations point unmistakably to the cause of the depletion in the whitefish supply; it is the removal from the lakes of a larger number than can be replaced by natural processes and than has been successfully returned by artificial hatching.

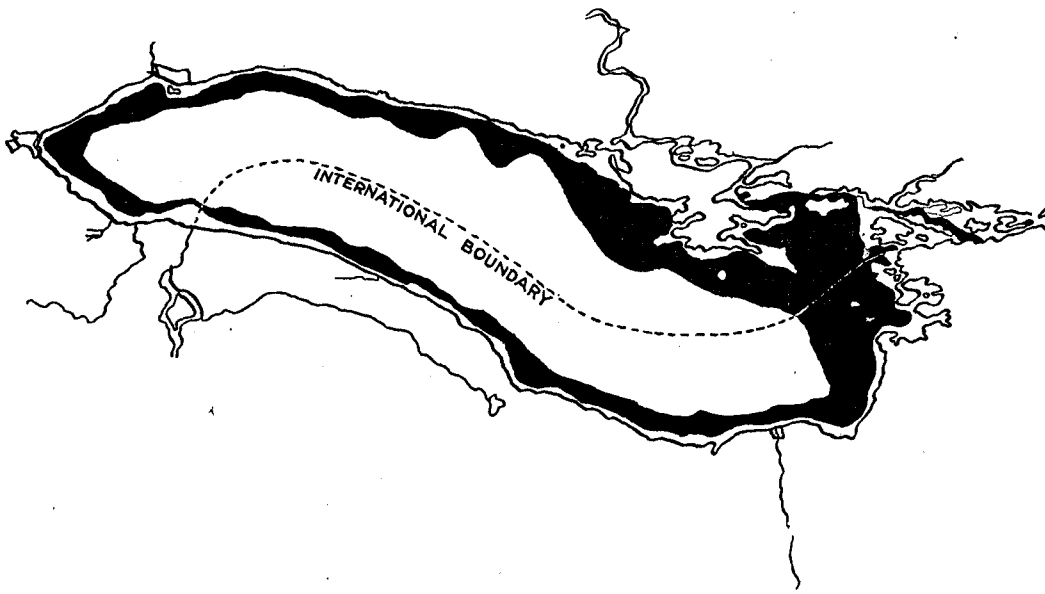

FIG. 5.—LAKE ONTARIO.

Whitefish area (shown in black), 10 to 20 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1477. Scale: 1 in. = about 48 miles.)

Again (p. 67) he says:

> There is a plentiful supply of whitefish food on the old fishing grounds. No reason can be assigned for the diminution in the supply of whitefish save overcatching.

I can only concur in these opinions, which are supported by incontrovertible evidence collected by many investigators.

EFFECT OF PROPAGATION UPON WHITEFISH PRODUCTION IN THE GREAT LAKES.

ANNUAL CATCH AND PLANT IN MICHIGAN AND CANADIAN WATERS.

In tables 1 to 10 are arranged certain data concerning the annual catch and annual plant of whitefish in Michigan and Canadian waters of the Great Lakes for the fifteen years 1892 to 1906, inclusive. The catch of whitefish

in Michigan has been taken directly from the original records on file in the office of the Michigan Fish Commission, while the catch in Canadian waters has been kindly furnished by the Department of Marine and Fisheries of the Dominion of Canada. The plants of whitefish that have been made in Canadian and Michigan waters have been taken from the reports of the Department of Marine and Fisheries of the Dominion of Canada, from the reports of the United States Fish Commission, and from the reports of the Michigan Fish Commission. In the column headed "Total gill and pound nets in fathoms" are given in fathoms the added lengths of gill nets and of pound-net leaders. The lengths of gill nets are given in fathoms in the official records. The lengths of pound nets are also given in fathoms in the Michigan records, but in the Canadian records the number only of pound nets is given, without their lengths. In order to obtain the lengths of pound nets used in Canadian waters I have averaged the lengths of approximately 1,000 Michigan pound nets selected at random, and have multiplied the number of Canadian pound nets in each year by this average value. In the last column of the tables 1 to 10 are given the values obtained by dividing the total catch of whitefish in pounds by the lengths of gill nets and pound nets in fathoms. The figures in this column therefore express in pounds for each year the catch of whitefish per fathom of nets used. It should be understood, however, that these tables give the total lengths of all gill and pounds nets used in the waters referred to whether the nets actually took whitefish or not. I have found it impossible to separate the nets which were set for whitefish or which took whitefish from those which were set for other fish, and I have been therefore under the necessity of taking the total lengths of all gill and pound nets used in the waters under discussion. As will appear in the discussion which follows, I attach relatively little importance to this part of the table.

I have already alluded to the difficulty encountered in obtaining statistics which deal with whitefish only and which do not include at the same time longjaws, bluefins, or menominees. We are assured by the superintendent of the Michigan Fish Commission that the data for the catch of whitefish in Michigan waters contained in tables 1 to 10 include true whitefish (*Coregonus clupeiformis*) only, and I am assured that the statistics of the catch of whitefish collected by the authorities of the Dominion of Canada and included in tables 1 to 10 refer to the true whitefish only and do not include bluefins or longjaws. These tables therefore have a peculiar interest in being, so far as I know, the only tables published of the catch of true whitefish for a continuous period of fifteen years.

TABLE 1.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE SUPERIOR FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892		1,800,640	78,820	22.84
1893		927,700	119,670	7.82
1894		1,087,733	162,650	6.68
1895		947,895	206,760	4.58
1896		850,600	189,640	4.43
1897		726,675	245,100	2.97
1898		663,230	215,380	2.61
1899	[a] 1,500,000	623,229	387,490	1.51
1900	[a] 2,000,000	461,546	224,980	2.05
1901		482,766	146,425	3.29
1902		398,943	133,450	2.98
1903		563,950	182,445	3.09
1904		436,520	237,595	1.83
1905		491,980	229,300	2.10
1906		420,700	247,400	1.70

[a] Planted by United States Fish Commission.

TABLE 2.—ANNUAL CATCH AND PLANT OF WHITEFISH, AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE SUPERIOR (EXCLUSIVE OF ISLE ROYAL) FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[a] 2,000,000 8,500,000	2,754,200	542,781	5.07
1893	[a] 11,000,000 8,000,000	2,423,600	596,220	4.06
1894	[a] 14,000,000 8,885,000	2,385,100	803,395	2.96
1895	[a] 13,350,000 28,900,000	1,618,220	705,306	2.39
1896	[a] 16,250,000 1,000,000	1,401,900	869,006	1.61
1897	[a] 8,000,000 11,990,000	1,329,284	744,809	1.78
1898	[a] 3,000,000 2,000,000	1,223,940	685,620	1.78
1899	[a] 4,000,000 5,200,000	1,128,650	724,271	1.55
1900	22,700,000	1,106,050	684,843	1.64
1901	[a] 12,800,000 20,800,000	1,056,325	911,995	1.15
1902	[a] 18,800,000 39,800,000	1,615,775	1,089,840	1.04
1903	[a] 16,600,000 13,300,000	1,345,000	1,060,990	1.26
1904	[a] 9,075,000	979,000	1,407,400	.69
1905	[a] 10,576,000 21,200,000	1,061,150	1,265,646	.83
1906	[a] 31,460,000 21,544,000	964,000	1,332,542	.72

[a] Planted by Wisconsin and United States Fish Commissions in Chequamegon Bay; adjacent to Michigan waters not included in calculations of table.

TABLE 3.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF THE NORTH SHORE OF LAKE MICHIGAN FROM WISCONSIN BORDER TO THE STRAIT OF MACKINAW FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.[a]

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	8,000,000	1,093,183	398,299	2.49
1893	8,000,000	952,050	391,682	2.43
1894	8,500,000	576,300	460,097	1.25
1895	4,000,000	461,661	295,502	1.56
1896	7,386,000	870,000	390,099	2.23
1897	19,540,000	1,346,120	553,672	2.63
1898	----------	1,179,350	495,426	2.37
1899	6,000,000	781,080	543,710	1.43
1900	4,000,000	601,450	465,700	1.28
1901	[b] 6,000,000	799,800	539,819	1.48
1902	2,000,000 [b] 12,000,000	1,036,950	703,020	1.47
1903	11,000,000	1,131,600	778,716	1.40
1904	3,000,000	1,070,000	867,310	1.24
1905	6,000,000	1,112,700	771,617	1.44
1906	7,000,000	1,563,200	1,088,429	1.43

[a] Strait of Mackinaw not included.

[b] Planted from Mackinaw City in waters adjacent to those of the north shore.

TABLE 4.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE MICHIGAN FROM LITTLE POINT AU SABLE TO THE INDIANA BORDER FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.[a]

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	8,500,000	30,615	497,371	0.061
1893	6,000,000	47,100	600,828	.078
1894	14,500,000	88,875	424,482	.209
1895	2,000,000	50,650	368,447	.136
1896	2,000,000	39,850	390,638	.102
1897	6,000,000	32,783	237,662	.138
1898	----------	24,150	261,736	.082
1899	----------	27,500	306,860	.078
1900	----------	27,850	506,921	.054
1901	[b] 4,000,000	29,350	560,291	.052
1902	----------	26,900	624,520	.043
1903	----------	38,400	598,690	.064
1904	----------	69,200	691,260	.100
1905	----------	185,200	858,691	.215
1906	----------	337,600	832,051	.405

[a] From the United States Fish Commission Report for 1887, p. 84, we find that the catch in this area in 1885 was 538,817 pounds.

[b] At Michigan City, Ind., very near the Michigan boundary line.

TABLE 5.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE MICHIGAN FROM MANISTEE TO FRANKFORT [a] FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	8,500,000	222,600	162,706	1.36
1893	6,000,000	155,000	151,090	1.02
1894	11,000,000	72,700	138,483	5.36
1895	8,000,000	78,150	150,447	.517
1896	6,000,000	109,800	181,966	.60
1897	6,500,000	145,200	80,583	1.80
1898		155,200	138,552	1.12
1899		140,750	134,490	1.04
1900	16,000,000	161,200	187,551	.86
1901		155,200	153,780	1.00
1902		261,000	195,472	1.33
1903		172,600	210,240	.82
1904		226,000	249,840	.90
1905		190,600	296,753	.63
1906		205,000	262,020	.72

[a] From United States Fish Commission Report for 1887, p. 84, we find the catch at Frankfort alone for 1885 was 885,504 pounds.

TABLE 6.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE HURON FROM MACKINAW CITY TO PORT HURON FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	21,750,000	555,350	588,019	0.94
1893	16,640,000	535,750	528,566	1.01
1894	16,050,000	396,350	505,497	.78
1895	15,500,000	357,317	657,255	.54
1896	19,850,000	659,234	347,799	1.79
1897	23,440,000	525,860	435,345	1.20
1898	5,600,000	387,740	537,704	.72
1899	12,000,000	482,980	622,686	.77
1900	34,200,000	493,020	766,278	.52
1901	26,000,000	600,620	873,896	.68
1902	42,000,000	639,600	843,691	.77
1903	30,000,000	722,560	1,050,667	.68
1904	30,000,000	618,960	1,056,170	.58
1905	25,000,000	329,260	1,235,910	.26
1906	20,000,000	265,320	772,098	.34

TABLE 7.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE HURON, INCLUDING NORTH CHANNEL, FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.[a]

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[b] 3,000,000	2,639,156	391,067	6.74
1893	3,000,000	2,278,300	679,395	3.35
1894	3,000,000	1,504,436	741,135	2.03
1895	3,000,000	771,475	535,670	1.44
1896	3,000,000	1,091,950	598,380	1.82
1897	3,000,000	740,041	240,525	3.08
1898	3,300,000	904,180	683,480	1.32
1899	4,000,000	864,240	335,772	2.57
1900	4,000,000	1,255,075	554,045	2.26
1901	4,300,000	935,003	471,732	1.97
1902	5,000,000	1,181,268	868,137	1.36
1903	4,000,000	831,610	659,835	1.26
1904	3,000,000	1,578,790	650,630	2.42
1905	4,000,000	739,410	824,610	.89
1906	4,000,000	922,800	709,440	1.32

[a] Exclusive of Georgian Bay.

[b] In the absence of exact information for the years 1892 and 1893 the plants of these years are assumed to have been the same as in the years immediately following and are so entered here.

TABLE 8.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN THE WATERS OF GEORGIAN BAY FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom
1892		3,635,700	40,000	90.89
1893		1,601,000	773,500	2.06
1894		1,199,300	581,250	2.06
1895		642,030	1,071,000	.59
1896		584,750	620,650	.90
1897		311,995	528,300	.59
1898	600,000	340,750	653,400	.52
1899	300,000	822,520	615,071	1.33
1900	550,000	274,180	419,450	.65
1901	600,000	501,842	326,950	1.53
1902		465,590	361,030	1.28
1903		467,080	844,100	.55
1904		470,670	441,650	1.06
1905		333,620	443,550	.75
1906		379,950	486,190	.78

TABLE 9.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE ERIE FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.[a]	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[b] 34,500,000	311,950	32,850	9.49
1893	[b] 58,000,000	256,240	49,540	5.17
1894	37,000,000	153,033	73,660	2.08
1895	61,000,000	148,010	84,410	1.75
1896	49,000,000	126,300	86,990	1.44
1897	60,000,000	270,290	92,360	2.92
1898	59,000,000	245,365	90,480	2.71
1899	60,000,000	431,022	107,910	3.99
1900	64,000,000	401,425	191,915	2.09
1901	60,000,000	523,366	141,460	3.69
1902	77,000,000	449,886	133,411	3.37
1903	62,000,000	303,280	169,250	1.79
1904	44,000,000	360,800	228,535	1.57
1905	72,000,000	304,400	236,200	1.29
1906	55,000,000	359,100	268,480	1.33

[a] Includes Detroit River.

[b] In the absence of exact information for the years 1892 and 1893 the plants of these years are assumed to have been the same for Lake Huron, Georgian Bay, and Lake Ontario as in the years immediately following, and the remaining plant was assigned to Lake Erie.

TABLE 10.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE ONTARIO FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[a] 3,800,000	489,900	144,775	3.38
1893	[a] 3,800,000	369,570	126,730	2.91
1894	3,800,400	299,930	158,705	1.88
1895	4,800,000	126,650	173,645	.72
1896	4,800,000	170,350	255,100	.66
1897	4,800,000	292,460	273,670	1.06
1898	4,900,000	410,420	233,810	1.75
1899	5,050,000	259,815	168,155	1.54
1900	4,800,000	129,126	231,405	.55
1901	4,550,000	133,192	156,480	.85
1902	3,000,000	77,071	153,920	.50
1903	3,000,000	96,980	186,352	.51
1904	4,000,000	190,650	221,512	.86
1905	4,000,000	472,770	249,820	1.89
1906	4,000,000	354,000	258,792	1.37

[a] In the absence of exact information for the plants in 1892 and 1893 it has been assumed to be the same from each hatchery as in the years immediately following, the total plant remaining constant, and is so set down here.

An examination of any one of these tables shows great fluctuation in the annual catch of whitefish, which may increase or diminish nearly 50 per cent between one season and the next, and in some cases varies 300 per cent between successive years. The cause of these annual fluctuations is to be found, no doubt, in part in the weather conditions, which permit almost continuous fishing in one season while they may greatly interfere with the fishing in the succeeding season. But these fluctuations may also be due in part to some feature of the habits of the whitefish themselves which we do not at all understand. It would be possible, by terminating almost any one of these tables at a suitable point, to convey the impression that there has been a very great falling off in the catch of whitefish in any one of the lakes. Thus if table 2 should terminate with the year 1902 it would show apparently a steady decrease in the catch of whitefish in the Canadian waters of Lake Superior and a like impression may be gained with respect to any other one of the lakes by terminating the table at the appropriate year.

DISCUSSION OF AVERAGE CATCH AND PLANT FOR CERTAIN AREAS.

It is evident from an examination of tables 1 to 10 that no conclusion of value is to be reached by comparing the whitefish production of the Great Lakes for individual years. The annual fluctuations, whatever may be their cause, vitiate any conclusions that may be drawn from such comparisons. It is further evident that any comparisons should take into account the relative whitefish areas of the lakes compared, and should consider both the catch and the plant with reference to these areas.

In tables 11 to 18 an attempt has been made to avoid the errors just mentioned by comparing the average catch for the three five-year periods from 1892 to 1906, inclusive. In the first column is entered the average annual catch in pounds for each of these five-year periods. In the second column is given the average catch per square mile of whitefish area, while in the third column is stated the average catch per fathom of net used. In the same tables are given the plants of whitefish; the annual average for each five-year period, the average per square mile of whitefish area, and the average per pound of whitefish caught. The same tables give the average annual number of fathoms of nets used for each period and the fathoms of nets per square mile. By nets is to be here again understood all nets used in the areas in question, not merely nets in which whitefish were taken. Not much value can therefore be attached to that part of the table which deals with nets.

Canadian and Michigan waters of Lake Superior.—In table 11 the data for the Canadian and Michigan waters of Lake Superior are brought together for comparison. The Michigan whitefish area of 2,400 square miles extends from the St. Marys River westward to the Wisconsin boundary line, as indicated on the map of Lake Superior. It does not include Isle Royal for the reason that

this offers an isolated whitefish area unconnected with that to the north or south of it, and for the further reason that the statistical returns from this remote area show such extraordinary fluctuations in catch, plant, and amount of nets used as to make them of little value. The Canadian side of Lake Superior shows a whitefish area of 3,600 square miles, stretching from the St. Marys River westward to the Minnesota boundary. On the Michigan shore there has been a very large annual plant of whitefish fry, averaging 11,000,000 in the first period, 22,000,000 in the second period, and 15,000,000 in the third period. This amounts to about 5,000 fry planted annually per square mile of area during the first period, 9,000 during the second period, and 6,000 during the third period. For each pound of fish taken out there has been planted during the first period an annual average of 5 fry, during the second period an annual average of about 19, and during the third period an annual average of more than 12. These values would be greatly increased if they were made to include the Wisconsin plants, which are indicated by the footnote in table 2, but not included in the calculations in table 11.

TABLE 11.—COMPARISON OF THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN AND CANADIAN WATERS OF LAKE SUPERIOR FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.[a]

Michigan waters, whitefish area 2,400 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	2,117,000	881	3.22	11,057,000	4,607	5.2	703,300	293
1897–1901	1,169,000	487	1.58	21,858,000	9,178	18.8	750,300	312
1902–1906	1,193,000	497	.91	15,268,900	6,362	12.8	1,231,300	513

Canadian waters, whitefish area 3,600 square miles.

1892–1896	1,123,000	312	9.27	----------	----------	----------	151,500	42
1897–1901	591,000	164	2.48	700,000	194	1.2	243,800	67
1902–1906	462,000	128	2.32	----------	----------	----------	206,000	57

[a] Exclusive of Isle Royal.

If we compare the catches over this area for the three periods, we see that while there was a decline of nearly a million pounds in the annual average between the first period and the second, there was a slight increase in the third period as compared with the second. The whitefish production of this area is therefore not decreasing; it is increasing. This increase has been accompanied by a considerable increase in the length of nets used, but as will appear in another place in this paper there seems to be good reason for the belief that an increase in the length of nets used is not sufficient to account for the increase

in the catch under the conditions existing in the Great Lakes. Furthermore, we have no reason to believe that the additional nets were used for whitefish.

If we turn now to the Canadian area of Lake Superior as shown in table 11 we see that there was no plant of whitefish fry during the first and third periods and during the second period a plant averaging but 700,000 annually, 194 per square mile, or but little over one fry per pound of fish. This plant was all made at a single locality—Port Arthur—and during the two years 1899 and 1900. The catch of whitefish in this Canadian area decreased from the first to the second period in about the same proportion as the catch on the American side and it continued to decrease notably in the third period. This decrease took place on the Canadian side while an increase was in progress on the American side, and it took place in spite of the fact that the length of nets in use on the Canadian side was but from one-third to one-fifth that on the American side. During the third period the fishermen on the American side were fishing nearly ten times the length of nets per square mile that their Canadian brothers were permitted to use and were enjoying an increase in the average annual catch of whitefish while the Canadian fishermen were suffering from a decrease in the average annual catch.

Canadian and Michigan waters of Lake Huron.—The data for these waters are given in tables 12 and 13. The Michigan waters are those of the west shore of Lake Huron from Mackinaw City to Port Huron. The Canadian waters are, in table 12, the eastern shore of Lake Huron, including the North Channel, and in table 13 the Georgian Bay. We see that on the Michigan side there has been a plant of from about 18,000,000 fry annually in the first period to nearly 30,000,000 annually in the third period. This is a plant averaging from 5,500 to 9,000 fry per square mile of whitefish area. In other words, from 36 to 58 fry have been placed in these waters for every pound of whitefish taken from them. The catch of whitefish has remained practically constant, but has increased somewhat in the last period as compared to the second. On the Canadian side of Lake Huron there has been a comparatively light plant of whitefish fry in each of the three periods, less than one-sixth that on the Michigan side. The catch of whitefish fell off very much in the second period as compared with the first, but recovered somewhat during the third period. If we compare the Michigan waters of Lake Huron with Georgian Bay (Canadian) we find that in Georgian Bay there has been comparatively little planting of whitefish and this confined to the second period. It averages but 152 fry per square mile of whitefish area and but 1 fry per pound of whitefish caught. The catch of whitefish has fallen off more than two-thirds in the second period as compared with the first and has diminished still further, though slightly, in the third period.

TABLE 12.—COMPARISON OF THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN AND CANADIAN WATERS OF LAKE HURON FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

Michigan waters, whitefish area 3,200 square miles.[a]

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathoms.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	501,000	158	0.99	17,958,000	5,559	36	525,400	164
1897–1901	480,000	148	.79	20,258,000	6,271	42	847,100	264
1902–1906	515,000	159	.58	29,400,000	9,101	58	991,700	309

Canadian waters, whitefish area 3,000 square miles.[b]

1892–1896	1,657,000	552	3.07	3,000,000	1,000	1.8	589,100	196
1896–1901	940,000	313	2.24	3,720,000	1,240	3.9	457,100	150
1902–1906	1,051,000	350	1.45	4,000,000	1,333	3.8	742,500	244

[a] From Mackinaw City to Port Huron.
[b] North Channel and Lake Huron exclusive of Georgian Bay.

TABLE 13.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN GEORGIAN BAY WATERS FOR THE THREE FIVE-YEAR PERIODS 1892–1906, INCLUSIVE.

Whitefish area 2,700 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	1,535,000	568	19.3	----------	----------	----------	617,300	228
1897–1901	450,000	166	.92	410,000	152	1	508,600	188
1902–1906	423,000	156	.88	----------	----------	----------	515,300	191

We appear to have disclosed in Lakes Superior and Huron a relation between the plant of whitefish fry and the catch of a subsequent period of such a sort that when the plant has been considerable the catch has either been maintained or has increased, while when the plant has been small the catch has usually diminished. There are no statistics available which enable us to compare for long periods the data for the two sides of the same lake, except those for Lakes Superior and Huron, but it will be of interest to compare with these two lakes Lakes Erie and Ontario and parts of Lake Michigan.

Canadian waters of Lake Erie and Lake Ontario.—The only statistics available for continuous periods are those of the Canadian sides of these lakes, but these are of especial interest, because they enable us to compare Canadian waters in which there has been relatively heavy planting of whitefish fry with those in which the plant has been light. The Canadian whitefish areas of Lake Erie,

including both the eastern and western portions, are 2,100 square miles. For each of the five-year periods considered the plant on this area has been enormous—from about 28,000 to about 30,000 fry per square mile of whitefish area, or from 139 to 230 fry per pound of whitefish caught. At the same time the catch has increased, nearly doubling in the second period as compared with the first and then remaining practically constant during the third period.

In Lake Ontario the area of whitefish ground on the Canadian side has been estimated at 1,400 square miles. The plant per square mile has been about one-tenth that in Lake Erie, while the catch has diminished appreciably, though not greatly.

TABLE 14.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN CANADIAN WATERS OF LAKES ERIE AND ONTARIO FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
Lake Erie, whitefish area 2,100 square miles.								
1892-1896	199,000	94	3.98	45,900,000	21,857	230	65,500	31
1897-1901	354,000	168	3.08	60,500,000	28,857	171	124,800	59
1902-1906	355,000	169	1.87	62,000,000	29,523	175	207,200	98
Lake Ontario, whitefish area 1,400 square miles.								
1892-1896	291,000	207	1.91	4,200,000	3,000	14	171,800	122
1897-1901	245,000	175	1.15	4,820,000	3,443	19	212,700	152
1902-1906	238,000	170	1.02	3,600,000	2,571	15	214,000	153

Unfortunately, we have no statistics of the catch of whitefish for the American side of either Lake Erie or Lake Ontario for any continuous period of years, so we are unable to make comparisons with the Canadian side. In table 22 there is shown the annual catch and plant in the whole of these lakes for the years 1899 and 1903, the only years for which statistics are available for the catch in which the true whitefish is separated from related forms in American waters.

The statistics of the catch need not detain us here, but those of the plant are interesting since they show that for the first of these years the total plant in Lake Erie from all sources, Canadian and American, was about 197,000,000 fry, while the plant in Lake Ontario for the same year was less than one-tenth as great. In 1903 the plant in Lake Erie was still nearly four times that in Lake Ontario. Not only is there this very great difference in the plant in these two lakes, a difference which exists in other years also, but it is extremely probable that the Lake Erie plant on the American side affects the catch on the Canadian side. The whitefish area of Lake Erie is practically continuous for the eastern

part of the lake and continuous in a nearly separate area for the western part of the lake. Any plants therefore on either side of the lake might well produce fish that would make their way to the opposite shore. In interpreting table 14 it is therefore to be taken into account that the plant affecting the Canadian catch is probably much greater than that entered in the table and would probably be more correctly represented by values similar to those entered in table 18. On the other hand, both the actual and the effective plants in Lake Ontario are very much less than in Lake Erie. We see thus in the Canadian waters of Lake Erie a very great increase in the production of whitefish correlated with very large plants of fry. In Lake Ontario we see a reduction in whitefish production correlated with a moderate plant of fry, a plant which is, for unit area, about half that of the Michigan waters of Lake Superior for the same periods.

Restricted areas of Lake Michigan.—In tables 15 and 16 there are brought together the data of catch, plant, and nets used in certain restricted areas of Lake Michigan. The data for the catch are all taken from the records of the Michigan Fish Commission, while those of the plant are published in the reports of the Michigan Fish Commission and the United States Bureau of Fisheries.

The areas selected are as follows:

(1) An area designated in table 15 as the "north shore" of Lake Michigan comprises the whitefish grounds from the Strait of Mackinaw westward to the Michigan-Wisconsin boundary in Lake Michigan. The eastern limit of this area is therefore well defined, but at its western limit it is broadly continuous with the waters of the State of Wisconsin. It contains 800 square miles, as shown on the map of Lake Michigan. The plant of whitefish fry in this area in the three successive five-year periods has been from 7,000 to 9,000 per square mile and from 5 to 9 per pound of fish caught. At the same time the catch in round numbers has been, in successive periods, 800,000, 950,000, 1,200,000. Here we have again a greatly increased catch correlated with a large and intensive plant.

(2) An area designated in the table as the "southeast" Michigan shore, comprises the whitefish grounds from Little Point Au Sable south to the Indiana-Michigan boundary. At its northern limit this area is nearly separated from the whitefish area to the north of it, but at its southern end it is broadly continuous with the Indiana waters of Lake Michigan. These waters, have, however, for a long time yielded very few whitefish, so that the area in question may be regarded as practically limited by barren waters at its lower end. Its area is 300 square miles. For the first period this area received a plant of 22,000 fry annually per square mile, an average of 125 per pound of fish caught. In the second period the plant was reduced to an average of about 7,000 annually, or 68 per pound of fish caught. The latter averages are based on a total which includes a plant of 4,000,000 made in 1901 at Michigan City, Ind., just beyond the Michigan border. If this plant be excluded the figures for the second period are reduced 40 per cent. Here again we have a very large increase in the catch

correlated with a very large and intensive plant. The catch of the third period exceeds that of the second more than fivefold. The number of whitefish appears, however, not to have increased in the period immediately following the greatest activity in planting, for while the plant of the first period was very great the catch of the succeeding period showed a decrease to little more than one-half that of the preceding period. This is possibly to be explained by the fact that in the nineties this area was considered to be nearly depleted of whitefish, and fishing for them was prosecuted with much less vigor than before. The number of fathoms of nets in use fell off, and it is probable that the nets set for whitefish fell off still more. It seems, therefore, probable that the whitefish may have begun to increase during the second period, but that this fact was not known to the fishermen until well into the third period. In other words, it is probable that the catch did not increase until some years after the whitefish themselves had increased. A glance at table 4 shows that this increase in the catch became noticeable in 1903.

TABLE 15.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN WATERS OF LAKE MICHIGAN (THE NORTH SHORE AND THE SOUTHEAST SHORE) FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

North shore, whitefish area 800 square miles. [a]

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	791,000	988	1.99	7,177,000	8,971	9	387,100	459
1897–1901	942,000	1,177	1.83	5,908,000	7,385	6	519,600	649
1902–1906	1,183,000	1,477	1.39	5,800,000	7,250	5	841,800	1,052

Southeast Michigan shore, whitefish area 300 square miles. [b]

1892–1896	52,000	170	0.117	6,600,000	22,000	125	456,300	1,521
1897–1901	29,000	96	.081	2,000,000	6,666	68	374,700	1,249
1902–1906	132,000	440	.165	----------	----------	----------	721,000	2,403

[a] North shore, from the Wisconsin border to the Strait of Mackinaw (excluding the Strait of Mackinaw).
[b] Southeast shore, from Little Point Au Sable south to the Indiana border.

(3) The Manistee-Frankfort area is an apparently isolated area of 90 square miles lying off the cities of those names. The data for this area are shown in table 16 (for annual data see table 5). Here we have a plant of fry which for the area is enormous, nearly 90,000 per square mile in the first period and nearly 60,000 per square mile during the second period. There was no plant during the third period. The catch has risen during the fifteen years from 128,000 pounds per square mile in the first period to 152,000 in the second and 211,000 in the third. Here again we have a correlation of heavy planting with increased yield of fish.

TABLE 16.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN WATERS OF LAKE MICHIGAN FROM MANISTEE TO FRANKFORT, INCLUSIVE, FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

Whitefish area, 90 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	128,000	1,422	0.80	7,900,000	87,777	62	156,900	1,743
1897–1901	152,000	1,688	1.16	5,300,000	58,888	35	138,900	1,543
1902–1906	211,000	2,344	.88	----------	----------	----------	242,900	2,498

PRODUCTION COMPARED WITH INTENSITY OF PLANT.

The data that have been presented seem to show that wherever, whether in American or Canadian waters, there has been a large plant of whitefish fry per unit area (20,000 in at least one period) this is correlated with a considerably increased average yield of adult fish per unit area in one or another period (Manistee and Frankfort and southeast Michigan areas of Lake Michigan, Canadian waters of Lake Erie); wherever there has been a moderate plant of fry per unit area (5,000 to 10,000 per square mile) this is correlated with a moderately increased yield of adult fish per unit area in one or another period or by a practically stationary yield (north shore of Lake Michigan, Michigan waters of Lake Huron from Port Huron to Mackinaw City, Michigan waters of Lake Superior); wherever there has been a small plant of whitefish fry per unit area (less than about 3,500) or no plant, this is correlated with a diminished yield of adult fish per unit area (Canadian waters of Lakes Superior, Ontario, and Huron and Georgian Bay, except for a slight increase in Lake Huron from second to third period).

CONCLUSIONS AS TO EFFECT OF PROPAGATION.

The result reached in this section is expressed in another form in tables 17 and 17*a*, in which the whitefish areas already discussed are arranged in the order of the intensity of the plant made on them per unit area. Arranged in this way the series falls into three groups. The first, including the Manistee and Frankfort area, the southeast Michigan shore, and the Canadian waters of Lake Erie, comprises areas which have in at least one of the three periods received plants of at least 20,000 per square mile. The increase or decrease in the catch of each area of this group is shown for the second and third periods in the right-hand column in percentages of the catch compared with that of the preceding period. Positive values indicate an increase in catch, negative values a decrease. These percentages are of considerable amount and are positive in every case but one; the catch for the southeast Michigan shore is less for the second period than for the first (43 per cent), but it increases again enormously in passing from the second period to the third (350 per cent).

The second group of areas as arranged in table 17 includes the north shore of Lake Michigan, the west shore of Lake Huron from Mackinaw City to Port Huron, and the south shore (Michigan waters) of Lake Superior. In this group the intensity of the plant of whitefish fry per square mile varies from about 5,000 to about 10,000. But two negative percentages appear in the table opposite these areas; these are both in passing from the first to the second period, and both are reversed in passing from the second to the third period, where they become positive.

The third group of areas includes the north shore of Lake Ontario, the east or Canadian shore of Lake Huron, the north shore of Lake Superior, and Georgian Bay. The plant per unit area has been largest in Lake Ontario, but has not there exceeded 3,600 per square mile. It diminishes progressively in the order in which the areas are named above, and becomes practically nothing in Lake Superior and Georgian Bay. The percentage column shows no positive value, while the sum of the negative values is very large.

TABLE 17.—SHOWING THE RELATIONSHIP OF THE AVERAGE PLANT OF WHITEFISH FRY PER UNIT AREA IN CERTAIN WATERS OF THE GREAT LAKES, TO THE AVERAGE CATCH IN THE SAME UNIT AREA FOR THREE FIVE-YEAR PERIODS.

	Whitefish areas.	Plant per square mile (to nearest 100).	Catch, pounds, per square mile (to nearest 10).	Per cent of increase (plus values) or decrease (minus values) of each period over the preceding period.
	1892–1896.			
1	Manistee and Frankfort	87,800	1,420	----------
1	Lake Erie (Canadian)	21,900	94	----------
1	Lake Michigan (southeast shore)	22,000	170	----------
2	Lake Michigan (north shore)	9,000	990	----------
2	Lake Huron (west shore)	5,600	160	----------
2	Lake Superior (south shore)	4,600	880	----------
3	Lake Ontario (north shore)	3,000	210	----------
3	Lake Huron (east shore)	1,000	550	----------
3	Lake Superior (north shore)	----------	310	----------
3	Georgian Bay	----------	570	----------
	1897–1901.			
1	Manistee and Frankfort	58,900	1,690	+ 18
1	Lake Erie (Canadian)	28,900	168	+ 78
1	Lake Michigan (southeast shore)	6,700	96	− 43
2	Lake Michigan (north shore)	7,300	1,200	+ 21
2	Lake Huron (west shore)	6,300	148	− 6
2	Lake Superior (south shore)	9,200	490	− 44
3	Lake Ontario (north shore)	3,500	175	− 16
3	Lake Huron (east shore)	1,200	310	− 43
3	Lake Superior (north shore)	194	164	− 47
3	Georgian Bay	152	166	− 70
	1902–1906.			
1	Manistee and Frankfort	----------	2,344	+ 28
1	Lake Erie (Canadian)	29,523	169	+ .5
1	Lake Michigan (southeast shore)	----------	440	+350
2	Lake Michigan (north shore)	7,300	1,500	+ 25
2	Lake Huron (west shore)	9,100	160	+ 6
2	Lake Superior (south shore)	6,400	500	+ 2
3	Lake Ontario (north shore)	2,600	170	− 2
3	Lake Huron (east shore)	1,300	350	− 1
3	Lake Superior (north shore)	----------	128	− 22
3	Georgian Bay	----------	156	− 6

TABLE 17*a*.—SHOWING THE RELATION BETWEEN THE AVERAGE PLANT OF WHITEFISH FRY PER SQUARE MILE PER PERIOD AND PER POUND CAUGHT PER PERIOD TO THE AVERAGE PERCENTAGE OF INCREASE OR DECREASE IN THE CATCH OF EACH PERIOD OVER THE PRECEDING PERIOD.

	Whitefish areas.	Average plant per square mile per area for five-year periods..	Average plant per pound caught per area for five-year periods.	Average percentage of increase (+) or decrease (−) of period 2 (1897–1901) over period 1 (1892–1896) and of period 3 over period 2.
1	Manistee and Frankfort Lake Erie (Canadian) Lake Michigan (southeast shore)	28,000	96	[a] +72.0
2	Lake Michigan (north shore) Lake Huron (west shore) Lake Superior (south shore) Lake Ontario (north shore)	10,000	32	+ 0.7
3	Lake Huron (east shore) Lake Superior (north Shore) Georgian Bay	2,200	11	−26.0

[a] If we exclude Lake Michigan, southeast shore, on account of the phenomenal increase of 350 per cent in the third period, this value becomes +31, but there appears to be no valid reason for such exclusion.

In table 17*a* is shown the relation of the average intensity of plant of each of the three groups of areas to the average catch in the same areas. The first column contains the average of the plant for the areas of each group for the three periods expressed in fry per square mile and the second column contains a like average expressed in fry per pound of whitefish caught. Thus the value 28,000 in the first column of table 17*a* is obtained by adding all the numbers in the first column of table 17 opposite the areas of the first group and dividing the sum by 9, and the remaining values in columns one and two of table 17*a* are obtained in like manner. The percentages in the third column of table 17*a* are obtained by adding for each group of areas the percentages given in the third column of table 17 and dividing by 6 in the case of groups 1 and 2 and by 8 in the case of group 3.

It thus appears that, on the average, a plant of approximately 30,000 per square mile of whitefish area or of 100 per pound of whitefish caught is correlated, under existing conditions, with an increase of 72 per cent in the catch; a plant of 10,000 and 32 with a practically stationary whitefish product; a plant of 2,200 and 11 with a decrease of 26 per cent in the whitefish product. This appears to the writer to amount to a mathematical demonstration of the efficacy of the planting of whitefish and to afford a measure of the intensity of plant necessary. This measure applies, of course, to present conditions; as the whitefish production increases it is possible that a plant of less than 100 per pound will suffice to maintain the fisheries.

In table 22 is given the total plant and catch for the Great Lakes and from this appears the average intensity of plant for 1903, the last year for which data are available for the catch. The intensity of the plant per pound caught is here

shown to be approximately 50. It appears therefore that the plant should be annually at least twice what it was in 1903. If the writer remembers correctly the cost of producing whitefish fry has been in the recent experience of the United States Bureau of Fisheries about two cents per 1,000 in Michigan. At this rate the cost of planting per pound of fish caught would be about 2 mills.

This correlation of an increased output of whitefish with a large intensive plant of fry and of a reduced production of whitefish or a stationary product with a small or diffuse plant of fry holds good in waters which are fished under the same restrictive legislative enactments. The Canadian waters of Lake Erie fall at one end of the above series, while the Canadian waters of Lake Superior fall at the other end of the series. These waters are fished under the same laws, dominion and provincial. The differences in their output can not therefore be referred to differences in legislative control. The Manistee-Frankfort area and the Michigan southeast-shore area are fished under American non-restrictive enactments, while the Canadian waters of Lake Erie are fished under the restrictive laws already referred to, and yet both, having received large and intensive plants of whitefish fry, have yielded increased returns in spite of differences in the fishing regulations.

The writer is forced to conclude that the increased production of whitefish in certain areas of the Great Lakes for the averages of five-year periods is due not to legislative enactment, but to the liberal and intensive planting of fry.

EFFECT OF LEGISLATIVE ENACTMENT ON WHITEFISH PRODUCTION.

An analysis of the fisheries regulations of the Dominion of Canada, the Province of Ontario, and the State of Michigan, under which the fisheries were carried on, the data of which are presented in this paper, can not be here undertaken. An act of the Michigan legislature of 1897 provides that, with certain minor exceptions, "it shall be unlawful for any person to fish with any kind of net whatever in the waters of this State from the thirtieth day of October to the fifteenth day of December." The fisheries regulations of the Dominion of Canada provide a close season for whitefish from November 1 to November 30, inclusive, in the Province of Ontario, but certain waters of Lake Erie and the Detroit River and Lake St. Clair are excepted by recent enactment. So far as the close season is concerned the Michigan and Canadian regulations are in essential agreement. They both aim to protect the whitefish during the spawning season. It is quite possible that the improvement in the whitefish fisheries in Michigan waters in recent years, as shown in the tables in this paper, is in part due to the close season which has been in force for about half of the period covered by these tables. That the improvement is not due wholly to the close season is clear when we remember that the Canadian whitefish catch has declined in many regions where a close season is enforced. The close season as

it now is limited is therefore not in itself sufficient to bring about an improvement of the fishery for whitefish.

Under the regulations of the Dominion of Canada fisheries officers are empowered to regulate the distances between nets, and if the writer understands these regulations, the fishing grounds are leased and the fishermen licensed. The result of this system is that a much smaller number of nets, or a much shorter total length of nets, is in use in the Canadian waters of the Great Lakes than in the American waters. In tables 18 and 19 are shown the data for the plant and catch of whitefish for the Canadian and American waters of Lakes Erie and Ontario for the only years for which American statistics are available in which it is possible to discriminate the true whitefish from related forms. From these it appears that the total length of gill and pound nets in use in the American waters of Lake Erie was in 1893 about twenty times that in use in Canadian waters, although the Canadian and American waters have approximately the same area. The Canadian nets in that year took about four times as many pounds of fish per fathom of length as the American nets. In 1899 the American nets are still of about twenty times the length in total of the Canadian nets, which are taking between four and five times the weight of fish per fathom. In 1903 the American nets still exceed the Canadian more than ten times, and the Canadian are taking more than ten times the weight of fish per fathom. In this year the weight of whitefish taken in the waters of the two countries is the same. An examination of tables 11 and 12 shows that in Lakes Superior and Huron the American nets exceed the Canadian in total length and the Canadian nets exceed the American in catch per net fathom. The latter statement is true only if we assume that the whitefish are taken in the waters of both countries in the same proportion to other fish.

TABLE 18.—COMPARISON OF THE ANNUAL CATCHES AND PLANTS OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN UNITED STATES AND CANADIAN WATERS OF LAKE ERIE FOR THE THREE YEARS 1893, 1899, 1903.

Canada, north shore, whitefish area 2,100 square miles.

Year.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1893	256,000	121	5.17	58,000,000	27,619	226	49,500	23
1899	431,000	205	3.99	60,000,000	28,571	139	107,900	51
1903	303,000	144	1.79	62,000,000	29,523	204	169,300	80

United States, south shore, whitefish area 2,000 square miles.

1893	1,292,000	646	1.3	22,570,000	11,285	18	988,900	485
1899	2,066,000	1,033	.88	104,930,000	52,465	50	2,325,200	1,164
1903	303,000	152	.16	90,961,000	45,480	30	1,816,300	908

TABLE 19.—COMPARISON OF THE ANNUAL CATCH AND PLANTS OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN UNITED STATES AND CANADIAN WATERS OF LAKE ONTARIO FOR THE YEARS 1899 AND 1903.

Canadian waters, whitefish area 1,400 square miles.

Year.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1899	259,000	185	1.5	5,050,000	3,607	19	168,200	120
1903	97,000	69	.52	3,000,000	2,142	30	186,400	133
United States waters, whitefish area 800 square miles.								
1899	161,900	202	2.0	13,475,000	16,847	83	79,700	99
1903	25,400	32	.22	43,920,000	54,900	1,729	114,400	143

It seems clear to the writer that limitation of the length of the nets in use has not resulted in an improvement of the whitefish production. The whitefish catch in Canadian waters of Lake Erie has diminished and again increased (see table 9), although the length of nets has remained but a fraction of that on the American side of the same lake. The same thing has happened on the American side of the lake, if we may judge by the only available statistics, those of the State of Pennsylvania, which are given in table 21.

In table 20 are shown the lengths of nets used in American and Canadian waters of Lake Erie, as compared to the total catch of all fish in the same waters. From this it appears that when all fish are considered the Canadian nets took in 1899 about four times as many pounds of fish per fathom as the American nets, while in 1903 they took about three times as many pounds.

TABLE 20.—COMPARING IN ROUND NUMBERS THE TOTAL LENGTH OF GILL AND POUND NETS AND THE CATCH OF ALL FISH IN CANADIAN AND AMERICAN WATERS OF LAKE ERIE FOR THE YEARS 1899 AND 1903.

Year.	Canadian waters.			American waters.		
	Nets.	Catch.	Catch per net-fathom.	Nets.	Catch.	Catch per net-fathom.
	Fathoms.	*Pounds.*	*Pounds.*	*Fathoms.*	*Pounds.*	*Pounds.*
1899	107,900	10,063,000	93	2,325,200	58,394,000	25
1903	169,300	5,409,000	32	1,816,300	23,189,000	12

TABLE 21.—SHOWING IN POUNDS THE ANNUAL CATCH OF WHITEFISH IN THE PENNSYLVANIA WATERS OF LAKE ERIE FOR THE YEARS 1892–1906, INCLUSIVE; FROM THE RECORDS OF THE PENNSYLVANIA FISHERY COMMISSION.

Year.	Pounds.	Year.	Pounds.
1892	15,000,000	1900 and 1901	57,840,000
1893	19,800,000	1902	44,560,000
1894	25,000,000	1903	19,836,000
1895	42,000,000	1904	39,200,000
1896	30,000,000	1905	34,489,000
1897	43,000,000	1906	36,468,000
1898 and 1899	32,000,000		

TABLE 22.—SHOWING THE ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS USED IN THE GREAT LAKES, EXCLUSIVE OF LAKE ST. CLAIR, FOR THE YEARS 1899 AND 1903.

Year.	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
Lake Michigan, whitefish area 2,600 square miles.								
1899	1,510,000	503	.58	53,500,000	20,577	35	2,605,600	1,002
1903	1,973,000	682	.77	6,000,000	7,307	3	2,564,400	986
Lake Huron and North Channel, whitefish area 9,300 square miles.								
1899	1,457,000	158	1.9	24,000,000	2,580	16	756,500	81
1903	1,525,000	163	2.3	39,000,000	4,193	25	649,600	69
Lake Superior, whitefish area 7,500 square miles.								
1899	1,316,000	175	1.7	16,700,000	2,226	12	736,600	98
1903	1,358,000	180	1.9	32,000,000	4,266	24	721,400	96
Lake Erie, whitefish area 4,100 square miles.								
1899	2,497,000	609	1.0	196,930,000	48,031	78	2,433,000	593
1903	606,000	147	.30	152,961,000	37,307	252	1,985,000	484
Lake Ontario, whitefish area 2,200 square miles.								
1899	422,000	191	1.7	18,725,000	8,511	44	247,800	111
1903	122,000	55	.40	41,000,000	18,636	336	300,800	136
All Great Lakes,[a] whitefish area 25,700 square miles.								
1899	7,202,000	280	1.0	309,855,000	12,056	43	6,779,500	263
1903	5,584,000	217	.89	270,961,000	10,543	49	6,221,200	242

[a] Exclusive of Lake St. Clair.

Total length of nets in use seems, therefore, not to have affected the total catch of whitefish. The explanation of this apparent contradiction is probably as follows, although this explanation is offered with much reserve: When fishing is begun in a virgin water, the catch depends necessarily on the amount of apparatus in use. As the rate of catch per unit of apparatus diminishes, which it invariably does, there comes a time when it ceases to be profitable to multiply the amount of apparatus, and as a consequence the number of units of apparatus ceases to grow. The relation of the amount of apparatus to the catch per unit of apparatus is, where no restrictions exist, a self-regulating one. The apparatus is sure to increase to the point where its use barely affords a profit to the user. The total apparatus is not in the water because required in order to catch the total amount of fish actually taken; it is there rather because each fisherman hopes to take the fish which would otherwise fall to another. If, now, the amount of apparatus be diminished, the same number of fish will still be taken in the diminished number of nets until the rate at which they are caught falls below the natural rate of increase of the fish, when, of course, the total catch of fish will increase. If these considerations are well grounded, the regulation of the number or length of nets per unit area does not act to preserve the fisheries unless that regulation proceeds to an extreme that it is not likely to reach in practice. So far as the preservation of the fisheries is concerned, the regulation of the length of nets to be used on unit area may well be left to competition, provided competition is in some way insured. These remarks do not apply, however, to regulation of the length or location of those nets which might impede the movements of fish during the spawning season; they assume, rather, that the spawning season is a close season.

To reduce the length of nets per unit area is, however, advantageous in another way, since it tends to lessen the cost of taking the fish and should make it possible to furnish them to the public at a less price. If fishing grounds are leased in such a way as to insure competition among lessees and to prevent the leases falling into the hands of a single lessee, and if the length of nets permitted on unit area is then restricted, the fish should come to the market at a lower price, for each fisherman would be compelled to take the fish at a less cost to himself and competition would compel him to market them at a less cost. This principle is commonly applied in another way by the licensing of hunters and sport fishermen and the limitation of the catch that they are permitted to take. Here, where pecuniary profit is not an inducement to increase the catch, it is not regulated by the cost of getting it. The sport fisherman tends to get all he can no matter at what cost, and hence it is necessary to regulate the size of his catch by law in order to prevent his exhausting the supply of fish. In commercial fishing exhaustion does not take place, because it is not profitable and it is necessary to regulate the apparatus used only in order to

lessen the cost of fishing. The conclusion reached in this section is that neither the close season nor regulation of the amount of apparatus is in itself sufficient to increase the output of the whitefish fisheries of the Great Lakes. The close season is presumably of assistance and should be preserved, since it protects the fish when they may be most readily taken in large numbers. The regulation of the length of apparatus to be employed in the whitefish fisheries has not resulted in preserving the fisheries, but is presumably advantageous in lessening the cost of operation, since it increases the number of pounds of fish taken per unit of net without reducing the total catch.

SUMMARY OF CONCLUSIONS.

1. The possible modes of increasing the production of whitefish in the Great Lakes are discussed and the conclusion reached that under existing conditions there are but two modes available, planting of whitefish fry and restrictive legislation. The problem is then stated to be a statistical one, that of determining by the study of existing statistical data the effect on the whitefish catch of the lakes of the planting of whitefish fry and of various forms of restrictive legislation. It is shown that it is necessary to have statistics for a continuous period of years for true whitefish only both for plant and catch and under various legislative restrictions. The necessity of discussing average catches with reference to unit areas of fishing ground is insisted on. Finally, it is shown that the necessary statistics are to be found only in the records of the Michigan Fish Commission and in those of the Department of Marine and Fisheries of the Dominion of Canada.

2. The habits of the whitefish are discussed, with the conclusion that the fish is a bottom feeder, restricted in its range during nine months of the year to waters of very definite depth. The depths assigned by investigators to the whitefish are then tabulated for each of the Great Lakes, the areas showing these depths are charted, and the extent of these areas measured in square miles. The whitefish areas as thus defined are then briefly described for each lake and it is shown that they are not in all cases continuous areas. Evidence is then adduced to show that the whitefish are local in their habits, so that each part of each area supports its own group of fish, which are in large measure confined to the area, leaving it only in fall when going inshore to spawn and in spring or summer for about two months.

3. In studying the relation of the plant of whitefish fry to the catch it is found that in those lakes or parts of lakes where there has been a large and intensive plant of whitefish fry (30,000 per square mile) there has been a correlated increase in the catch of whitefish (72 per cent); in those lakes or parts of lakes in which there has been a moderate plant of whitefish fry (10,000 per square mile) there has been a slight increase in the catch of whitefish or the

catch has remained nearly constant; in those lakes or parts of lakes in which there has been a small plant of whitefish fry (2,000 per square mile) or no plant, there has been a reduction in the catch of whitefish (26 per cent). (Certain exceptions to this statement are also noted.) It is shown that under Canadian restrictive legislation the whitefish have diminished in waters where planting of fry has been at a minimum and have increased in waters where planting has been liberal; that whitefish have increased in American waters where there has been no restrictive legislation (or little) and have diminished in Canadian waters of the same lake under restrictive legislation. These increases and decreases are stated to be, therefore, in relation to the plant of whitefish fry and not to legislative control.

4. Discussion of the effect of legislation on whitefish production leads to the conclusion that (*a*) a close season during the breeding period is probably advantageous to the production of whitefish, although the data at hand do not furnish any evidence on that score, and (*b*) that a practicable regulation of the number of nets or the length of nets to be used in unit area of the lake does not increase the production of whitefish, but does tend to greater economy in the fishing, since the same number of pounds of fish are taken with fewer nets.

MEASURES RECOMMENDED AS MEANS OF INCREASING WHITEFISH PRODUCTION IN THE GREAT LAKES.

1. It is recommended, as a result of the foregoing study, that the output of whitefish fry be increased as rapidly as possible, as affording the most certain means of increasing the whitefish production.

2. That an intensive plant of at least 100 fry per pound of whitefish caught be made on depleted areas. (Lake Ontario and the southern waters of Lake Michigan are in need of especial attention.)

3. That a close season be observed during the breeding season of the whitefish as at present, but only for such waters as are not under federal control (see sec. 4, below).

4. That commercial fishing with pound nets and seines be permitted in the waters of the Great Lakes during the breeding season of the whitefish wherever the state or national authorities are prepared to undertake to care for the spawn of the fish taken; the fishermen to be under legal obligation to permit the use of the fish taken by them for the purpose of spawntaking.

5. It is suggested that central control of the fishing operations of the Great Lakes is highly desirable. Whether this is possible in American waters through federal control or through concerted action of the states is a question that can not be discussed here. A central control, under which fishing grounds should be leased and fishermen licensed, would, if properly administered, reduce the cost of fishing and make possible more extended

artificial propagation. The central authorities should have power to modify the fishing regulations pending legislative action. Such a system might be made self-supporting.

6. The need of more exact knowledge of the habits of the whitefish and of all the conditions under which it lives is very evident. In the interest of the fisheries these matters should be subjects of investigations to be carried on under federal auspices, with suitable equipment and for a long period of years.

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DISCUSSION.

Prof. EDWARD E. PRINCE. I do not wish to usurp the time of the congress unduly, but I will say a word or two about the opinions expressed in the two or three papers this morning on the question of whitefish production in the Great Lakes. It is a matter which is of very, very great importance to us in Canada—in fact, I may say I am chairman of a commission appointed by the Dominion government which has the protection of the whitefish, especially of Lakes Huron and Erie, before it. I give the writers of the papers this morning credit for wishing to do something practical in the matter of preserving the whitefish. I give them credit for that. At the same time I, as Canadian commissioner of fisheries and having a good deal to do with administration of fishery laws, see difficulties in the suggestions which were made in the papers this morning, and especially I see this difficulty, that the prohibition of the capture of small whitefish, so long as pound nets or fish traps are allowed, is almost an impossibility—that is to say, the prevention of their destruction. You may try as you will to prevent the taking of small whitefish, but they will be taken. You may prohibit their sale, but they will be handled and in some way disposed of. Therefore the question comes to this: If you adopt a policy which will be extremely difficult or impossible to carry out, it is better to pause before adopting that policy. If you adopt a closed season—and we in Canada, have always favored closed seasons, and have to some extent carried them out (I say that, in justice to our official staff with which I am connected, we have tried to carry out the closed season in Canada)—if you adopt a closed season, which prevents any nets whatever being used and removes all nets from the water, that is an effective measure. You can do that. You can protect the fish by preventing the capture altogether—that is, by taking the nets out of the water for, say, the month of November.

I know that Mr. Clark and others will claim that hatcheries will make up for everything in the way of destruction of fish by nets if you also preserve the immature fish; and one of the strong points in favor of artificial hatching of fish (instead of allowing parent fish during a closed season to spawn) is that great loss arises from nonfertilization of eggs. I think that is a point which is open to discussion, and I will give you an illustration, and then I shall sit down. Sometime ago I was engaged in hatching sea fish, and I hatched about 70 different species; and I tried on more than one occasion to keep some eggs in the laboratory tanks free from fertilization. The sperms which the male shed in the open sea would reach those eggs through the supply pipes wherever they were placed. In other words, it was almost impossible to keep them unfertilized after they were taken from the ripe female. I investigated the same thing in sockeye salmon in British Columbia. I tried on the spawning beds to get eggs which were not fertilized. I went into the water knee-deep to get them and groped about on the spawning beds there, where the fish were engaged in spawning; and I tell you, gentlemen, I have gathered quantities of natural fish spawn on the beds, and I failed, in some thousands of eggs, to get one single egg that was not fertilized, which showed how scrupulously nature accomplishes the fertilization of eggs under natural conditions. At the same time, I do not deny that eggs may escape impregnation, yet, so far as my observations go, the eggs which were deposited by the parent fish are almost to an egg fertilized.

I do not wish to say more, Mr. President, but merely these few words.

The PRESIDENT. The next gentleman.

Mr. C. H. WILSON. I desire, as the representative of the State of New York, to congratulate the gentlemen who have furnished these most interesting papers upon this question. I wish to back it up by the protective element and the department of fisheries of the State of New York. While we give you great credit for what you have done, for what you, in your enthusiasm, hope to do, yet we do not believe the time is ripe when we should sever a partnership with nature and the Almighty. [Laughter.]

The first paper speaks of the effect of pollution of the waters of the Great Lakes upon the spawning beds of the whitefish. If the beds of the whitefish are destroyed by the thousands of acres, as stated in this paper, I submit to you, Mr. President and gentlemen of this congress, that the time has not arrived when we shall fail to take advantage of everything to conserve the food fishes of North America.

An argument is made in this paper regarding the closed season. The writer wishes to close the season for two months, that the commercial fishermen under the guise of gathering spawn for the hatcheries may rush in and slaughter by the thousands the whitefish of the Great Lakes. May I ask you, gentlemen, what risk do you run in having a closed season during the spawning period of the whitefish? By an open season you do invite the continuance of an illicit business already begun in the taking of whitefish eggs for caviare, one seizure of one and one-half barrels of eggs in transit having been made last year. You establish a precedent that will later plague you regarding other varieties of fish.

The enthusiasm of the writer of one of these papers sees the Great Lakes overcrowded with fish; the sober judgment of another says, "We may never expect to return to former conditions;" while the third, uncertain of his position, says, "A closed season may be advantageous." The showing of the enthusiastic and faithful operators of hatcheries is fine and gratifying to all; but the catch, after all, determines the real pounds pressure of their enthusiasm. Successful planting must follow successful hatching, and protection wait upon both; and the argument of all arguments in these papers is the statement that the propagation and protection show increase in the last few years. What protection? Practically all states and provinces bordering on the Great Lakes, save the state of Pennsylvania, with its 45 miles of shore line, have in recent years given protection by a closed season during the spawning time of this valuable fish.

The statement is made that a closed season will interfere with the taking of spawn. Mr. Chester K. Green, who operates a hatchery at Cape Vincent, N. Y., will tell you that the state of New York, which I represent on this floor, has given to the United States Government permission to take all the spawn it wishes for hatchery purposes.

Hon. PAUL NORTH. Representing the state fish and game commission of Ohio, I would state that the question of preserving the whitefish on Lake Erie is a very difficult one, owing to the fact that Lake Erie has four states and the Dominion of Canada bordering, and each and every state has a different law, to a great extent, governing the taking and catching of these fish. It is a notorious fact that up until the last year New York State permitted the fishing with gill nets of 2½-inch mesh, and tons of immature fish were caught at Dunkirk and those points—immature whitefish that were of absolutely no use whatever—in the summer when they are soft and no good. Of course there comes the question that if you stop the catching of fish there you will stop the commercial fishermen of New York from making a certain living. And if we, as a general government of Canada and the United States, regulate this and have a closed season until such a time as the fish come up the lake, why, then, the Ohio fishermen get all the benefit; and you can see where the trouble is going to come in and what a difficult matter it is to handle. But the main thing, in my mind, is that Mr. Clark and Mr. Downing are both absolutely right in their premises that one hatchery will produce more whitefish than all the whitefish in a natural state produce.

You must remember that as the whitefish have decreased the means of taking them have increased. The mileage of the gill nets has increased, and the pound nets have increased, until now in places you will see 30 in one string reaching out into the lake, and it is a wonder that any fish have been left. We should have regulation all along the line—the size, number of pounds they can have in one string of nets; and there must be a regulation, gentlemen, that every whitefish that is taken with spawn must, as far as possible, be put in the hatchery; and if we can have 50 hatcheries on Lake Erie there is no question but what we can have a very large increase in the quantity of that fish, as shown by the effect of the 2 hatcheries on the lakes, which have in the last five or six years increased the catch until last year we had the biggest catch on Lake Erie we have had in the last fifteen years; all due to those 2 hatcheries. Nature has been doing as much as she could; but those 2 hatcheries have done the work. Mr. Downing and Mr. Clark know what they are talking about; they know what the conditions are; they know that the hatcheries will do the work; and that if you can by this means conserve every whitefish until you get its spawn and then run that spawn through a hatchery you will have all the whitefish in Lake Erie and more than it ever had before. [Applause.]

Mr. KELLY EVANS. I should just like to take up my three minutes by calling attention to a point in one of the papers that was read this morning, in which the statement was made that while we had a closed season on the Canadian side of the Great Lakes the fish in our waters were not as plentiful as they were in the waters on your side of the lakes, at several points. I would remind one or two of the fishery commissioners present that they have already spoken to me at different periods of time in reference to using nets by arranging with the Canadian authorities to allow them to gather eggs on the Canadian side of the lakes. Does it not seem curious to you that if the fish are to be found in very much larger quantities on their side they should wish to come to our side for eggs? That is one point I wish to make.

The second point I wish to make is this, that if the condition outlined in the splendid papers read this morning is practically possible to bring about, you will have reached undoubtedly a Utopian condition; but on our side of the water, at any rate, I feel convinced that that Utopian condition of things will require a great many years to reach. In consequence, if this congress came out very strongly as supporting the general proposition that hatcheries could be depended upon entirely, and that nature might be ignored, it might result disastrously on our side of the water. If at any point in our international waters all the spawn-bearing fish can be so taken care of that their spawn is in no way lost, possibly the proposition of depending upon the hatcheries alone is the best one; but until that condition of things has been brought about it is a very dangerous thing to say to great nature, "We need your assistance no longer." I therefore, from these points of view, urge the congress to go very slowly on this question of abandoning great Dame Nature. [Applause.]

Dr. BARTON W. EVERMANN. Mr. President, I would like to discuss this question, but I think I shall refrain. I would like to ask one question, however, which I think can be answered by Superintendent Lambson, of the California station. If I have been correctly informed, the natural spawning beds of the Sacramento salmon in the Sacramento River basin have been practically wiped out of existence through mining and other operations of that kind, so that even if no salmon were caught in the Sacramento River either for commercial or for hatchery purposes and all salmon in that stream were allowed to ascend to such spawning beds as they might find they would probably amount to nothing; they would be unable to find any suitable spawning beds, because those beds have been destroyed. But through artificial propagation in the Sacramento basin I understand that the catch of salmon in that river now is very large. Some years it is larger than it was ever known to be before artificial propagation began and before

that river was so much changed physically because of the results of mining and agricultural operations. If those are the facts, it seems to me that they point a very important question and suggest very strongly the wisdom of the course which has been recommended by two or three gentlemen in the papers they have presented. It appears to me that we should no more depend upon natural reproduction in any of the species of fish that we can handle than we should depend upon natural reproduction of corn or potatoes or any other thing that may be left to the wild. [Applause.]

Dr. TARLETON H. BEAN (New York). Just a word, Mr. President and gentlemen of the congress, merely to remind you of the present condition of the shad fisheries of the United States, which, it appears to me, is one of the very best illustrations of what can be done by artificial culture as against natural reproduction in streams that have been more or less polluted. I shall go not very far south of the Hudson River and the Delaware for my illustration, and say the Potomac. You gentlemen know as well as I that to-day the fisheries—the commercial fisheries of those rivers, especially the shad fisheries—rest absolutely on an artificial basis; and they have so rested for the past quarter of a century. It is within my knowledge and within your knowledge that in 1874 shad were selling in the Washington markets at 75 cents apiece on the average. You know what they are worth to-day, and you know why it is that you can buy them to-day for one-third the price that you paid in 1874. I will not enlarge upon this topic, but merely remind you that the Hudson, the Delaware, and the Potomac for the past quarter of a century have been increasingly polluted. The natural spawning beds or grounds have been covered with cinders and other waste products of industries; and without artificial propagation there would be no such thing as a run of shad in the North River or the Hudson River to-day, as there has been in 1907 and 1908, equaling the catch of more than twenty years ago.

Mr. FRYER. I do not gather that all the spawning grounds of all the whitefish in the Great Lakes are polluted; neither do I gather that they are spoiled by refuse from timber works, sawmills, or from any other such cause.

Mr. FRANK N. CLARK. If I understand you correctly, you do not understand that the spawning grounds of the whitefish are polluted. They most certainly are. In my paper I speak of the Thunder Bay River region, where the beds are polluted out 9 miles in a bay that is 30 miles across, and there are no whitefish in that territory where they used to spawn in great numbers.

Mr. FRYER. If that applies equally to all the spawning grounds of the whitefish in the Great Lakes, then, of course, my point falls.

Mr. CLARK. It does not apply to all.

Mr. FRYER. Then the point I wished to make is that, assuming there are natural spawning beds still left in the Great Lakes——

Mr. CLARK [interrupting]. Oh, yes.

Mr. FRYER [continuing]. I am glad the assumption is correct for the sake of the fisheries themselves. My argument is this: There is a great distinction to be drawn between the case of the Great Lake fisheries and the cases that have been referred to, such as the shad fisheries of the Hudson and elsewhere, where it is found that all the spawning beds are either polluted or are so cut off from the fish as to be practically unavailable, and I expect that in the paper that is about to follow, on the fisheries of the Rhine, you will find information given which will enforce the point that there is a great distinction to be drawn between those cases where nature still has a little room left to perform its own functions and the cases where the natural conditions have been practically destroyed; and, on the premise that there are still natural spawning beds available for the whitefish, I would venture to support the view put forward by Professor Prince, that you have great cause for hesitation before you put aside the question of improving or endeavoring to improve these fisheries by restrictive measures and rely

solely upon the measures proposed in those three very excellent and admirable papers which were read this morning, the sincerity of whose authors one can not fail to appreciate and admire, however one may differ from their conclusions.

Professor Prince referred to the difficulty of regulating the sale of undersized fish. In England it has been found—as has been recorded in very quaint language in some old statutes—that although the law prohibited the sale of small fish their capture was inevitable; and when such methods of capture as hooks and lines were employed, and the small fish had to be thrown back into the sea, they were destroyed, and the public were thus deprived of a certain supply of fish. This is another illustration of the difficulty referred to by Professor Prince.

At the present moment we have in Europe a difficulty in connection with certain grounds on the southeastern part of the North Sea, where very large quantities of what are known as immature or undersized plaice are caught, with very few adults. The suggestion was therefore made in that case that an international regulation might be passed which would prevent the sale of fish under a certain size, the idea being that although the prevention of sale would not in itself prevent the capture, yet the proportion of small fish taken on those grounds is so large that if the sale were prohibited it would not be worth the while of the fishermen to fish there any longer, and so, indirectly, under those circumstances, the prohibition of sale would have the same effect as the prohibition of capture. A period of one hundred and eighty seconds is not very long to deal with such an important question as this, but I would like to enforce one point made in the last paper, namely, that our knowledge with regard to the spawning of fish is not as perfect as it ought to be. On the mere point of fertilization of the ova, a very simple test would settle the question as to the proportion of the ova fertilized naturally. I may, incidentally, indorse Professor Prince's experience in the matter of salmon eggs. I have myself collected salmon and trout ova fertilized naturally, under normal conditions, and I have not found 5 per cent of the eggs unfertilized, so that, prima facie, there seems very great reason to doubt that the proportion of unfertilized eggs in the case of the whitefish can possibly be 99 per cent, as suggested.

If I might intrude one minute longer, I would throw out the suggestion—I do it with great diffidence, because I do not know all the local details, but as a very broad proposition for consideration—that it might be possible to arrange between the United States of America and the Dominion of Canada for the waters of the Great Lakes to be treated as a common fishery, common to the two countries, subject to common laws, equally enforced on both sides, and based on the most perfect knowledge that it is possible to obtain with regard to the habits of fish, and of course with regard to the habits of man, as to which I personally, as I said before, have insufficient knowledge. I just make the suggestion for consideration, with the addendum that if such an idea were accepted it might be possible to arrange that the fishermen who are interested in conducting these fisheries should themselves contribute to the expense of the administration and regulation of the fisheries in these waters. Whether that administration were limited to regulations only or whether it included artificial culture does not matter. This might be done by means of a system of tolls leviable not merely by licenses to the fishermen, giving them the right to fish, but on the quantity of fish which they brought ashore, no matter where they landed it, so long as it was taken in the Great Lakes.

I make the suggestion with very great diffidence, but if it were possible to elaborate it I could give you several reasons in support of it.

Mr. J. W. TITCOMB. I will answer the question raised by Professor Evermann about the run of salmon in the Sacramento River. Practically all of the salmon which ascend the river by the canneries are caught at the Bureau's hatchery and stripped of their eggs. Occasionally, say once in three or four years, with a very high freshet, the fish get by, or a part of them get by. The fish in the Sacramento River have

increased steadily for the past ten or fifteen years. The proportion of eggs which the Bureau is able to collect to-day, as compared with that of ten or fifteen years ago, is several hundred per cent greater. The observations of Captain Lambson as to the natural fertilization of the salmon show that about 75 per cent are fertilized under natural conditions; but further observations show that of the 75 per cent which are naturally fertilized fully 95 per cent are smothered in the sand, so that eventually only a few hatch. Under artificial conditions we fertilize from 90 to 95 per cent; we hatch and develop as fry from 90 to 95 per cent of eggs fertilized. The fishery there is dependent entirely on artificial propagation, and during the last ten or fifteen years has steadily increased.

In the shad fishery, which Doctor Bean has alluded to, take, for instance, the Potomac River: After the Fish Commission began its work of artificial propagation the commercial fishery came up steadily until the figures for a great many years were perfectly wonderful. We can not show that tremendous fishery to-day, for the reason that the fish are not allowed to ascend the river where we can get their eggs. All our work in the propagation of shad must be done during the spawning season, and the collection of eggs is dependent on the run of shad during that season. They can not be caught at other seasons of the year because they are not there.

I think that both the salmon and shad are an illustration of the whitefish question, to show that the open season is desirable, if we can have along with it all the necessary hatcheries and spawntakers to conserve the eggs which would otherwise go to waste. [Applause.]

Mr. W. E. MEEHAN. Mr. President and gentlemen, I did not intend to take part in this discussion, for the reason that it occurred to me that the papers read this morning cover the question so completely and are so fully in accord with the experiences I have had in the fisheries of Lake Erie and the Delaware River in the case of shad, whitefish, herring, and other fishes that are caught in the commercial nets for market purposes. It seems to me that the maintenance of fish by artificial propagation is necessary—that the latter is necessary to maintain fisheries. The plea that, although we may believe a closed season for non-nest-building fishes is not needed because fish hatcheries can better keep up the supply of fish than natural propagation, we ought not publicly to say so for fear some harm will be done to some other country which does not propagate is, to my mind, much like the warning which the man gave another not to teach his children to read for fear they would later on come to read pernicious literature.

All experiments made have shown that artificial propagation is necessary for the maintenance of fish in the water; that with increased population and increased demand it is impossible to maintain a supply by natural propagation. Artificial propagation has increased the supply of whitefish in Lake Erie and probably in the other lakes; it has increased the herring; it has increased the shad in the rivers. Without artificial means we would have no shad to-day. Artificial propagation has made the whitefish industry once more profitable. The best policy, in my estimation, is that which is outlined by Messrs. Downing, Clark, and Reighard, to give the freest possible fishing for whitefish, herring, and the like during the summer months when the water is warm, when the fish are soft, and when the runs of fish are apt to be small and immature as to size. Catch the large fish and give the small fish a chance to grow. If closed seasons were made during the spawning period, there is scarcely a fish-cultural station on the Great Lakes that would be filled, unless the government and the states had about every boat employed in fishing. In the state of Pennsylvania, for the hatcheries set apart particularly for the propagation of the lake fishes, it will require every boat going out of the port of Erie to fill those hatcheries, and it is doubtful even then if the houses would be full. The more fish that are hatched, the greater must be the percentage of increase in suitable waters.

These are my reasons for supporting and believing the papers of this morning as enunciating the true doctrine of increasing the food-fish supply. [Applause.]

Mr. SEYMOUR BOWER (Michigan). Mr. President and gentlemen, I had not intended to take any part in this discussion. I will say, however, that for many years I have been in hearty accord with the views regarding whitefish propagation as expressed in the papers just read. In fact, I think Mr. Clark, Mr. Stranahan, and others here will bear me out in saying that I was one of the pioneers in advancing those views. To me this proposition seems so simple as to be hardly worth a moment's consideration if we are right as to the value of what is known as artificial propagation. As evidence of its value I can state that the catch of whitefish in Michigan waters of the Great Lakes is steadily increasing, has been for a number of years, and is now very nearly double what it was ten years ago. To be more exact, in the latter part of the nineties the annual catch was a little over 3,000,000 pounds on an average, while in 1906, the last year for which we have complete statistics, the catch was over 5,000,000 pounds. The figures for 1907 and 1908 are not compiled, but our agent who is now in the field is of the opinion that both years will show a still further increase.

There is just one thought in connection with this matter which I desire to present. There are two great divisions in the forces of nature, which we might term destructive and constructive. The existence and development of all forms of life are possible only through the destruction of some other form, either animal or vegetable Now, as fish spawn in nature, the ova are subject not only to the constructive forces of their environment, but also to many destructive ones; but when transferred from that environment to an artificial or protected one, they are separated from these destructive forces and are then subject only to those that are constructive, with the result that production is increased many fold. If that proposition is true, and we have most convincing evidence that it is, the situation is greatly simplified. We should apply this principle wherever practicable; should take advantage of every opportunity to prevent the ova of the better class of food fishes from being thrown into contact with the destructive forces of nature. This is the vital point or principle in fish culture.

The PRESIDENT. Professor Birge, have you something to say in this matter? We would like to know your views.

Prof. E. A. BIRGE. I have no right to speak with any authority on this subject. I have been in agreement with the views expressed in the papers which were read this morning, but I have no such personal knowledge of whitefish culture or the whitefish industry as those gentlemen who have spoken on the subject.

Mr. W. T. THOMPSON (Colorado). I would like to say a few words along the line of thought advanced by Professor Evermann. I believe I can bring evidence from Colorado which will place the result attained by hatchery methods beyond question. Mr. Titcomb stated in his lecture this morning that larger collections of eggs from wild brook trout could be made in Colorado than in any other section. I wish to call your attention to the fact that this species is not indigenous to our state, but was first introduced about twenty-five years ago. No trout were found in the state at that time except the native species, chief among which was the blackspotted trout (*Salmo clarkii*).

The brook trout was first introduced, in small numbers, about 1882 or 1883. Some two years later the introduction of the rainbow trout was commenced in a very limited way. Coloradoans had been accustomed to the native trout for years; the waters were thickly populated with them when the white man first arrived. Naturally, they thought they would always have them without effort on their part, consequently there was no demand on the hatcheries for them; hence, we produced none. The adult fish were allowed to deposit their spawn naturally, "according to the dictates of their conscience," as we might say. I might add that the spawning beds were not polluted to any extent and were and are still accessible.

Now, let us see what has been the result in Colorado after a period of twenty-five years: Our hatcheries, beginning with these first small plants made from eggs secured from other points, gradually began to secure both brook and rainbow spawn in increasing numbers from our own waters. The Gunnison River is one of our typical trout streams. Twenty-five years ago it was full of the native trout. None were taken from it for spawning purposes, consequently it can not be claimed that the hatcheries interfered in any way with their natural reproduction. The hatcheries, meanwhile, have been industriously collecting both brook and rainbow eggs, planting the resulting fry in public waters in increasing numbers, year by year. To-day, after twenty-five years of this policy of noninterference with the natives, this species has become practically extinct in the Gunnison River, and the condition in this river is typical of what has transpired in our other streams. This same Gunnison River is still celebrated for its trout, but the reputation rests entirely on the introduced species, the hatchery products, the rainbow of the Pacific slope and the brook trout of the east, which in our Colorado waters found a congenial home and attained a higher degree of excellence than in their native habitat. Sixty-five per cent, possibly more, of the trout in the Gunnison to-day are rainbows, the balance are brooks, with an occasional native, but the latter are very rare.

So far as Colorado is concerned, both of these varieties are entirely the product of the hatcheries. Nature, or, more properly speaking, the natural method of spawning, had practically nothing to do with this remarkable increase. That this is a fact is amply attested by the rapid decrease among the natives when left to propagate naturally. Through the work of the hatcheries, our streams are still well stocked, but with the brook and rainbow trout.

Mr. Titcomb spoke of a lake containing an island, around which the fish circulated in great numbers during the spawning period. If we allowed these fish to spawn according to nature, there is no doubt but that lake would continue to be thickly populated, but it would not benefit other waters. Operated under fish-cultural methods, assisting nature in her efforts, we have taken over 6,000,000 eggs from this island lake. We could have taken more had we proper facilities at the time. With the fry from these eggs, we were enabled to stock many of the lakes and streams of the state. I believe no better illustrations can be given of the value of fish-cultural methods than we can bring you from Colorado.

Mr. FRANK N. CLARK. Mr. President and gentlemen, I have very little information to add in the short time allotted to me in this discussion, but I shall try to answer the two or three points which are all I am willing to concede have been made on the other side of this question.

One question, I think possibly from Mr. Fryer, or some other member, in reference to the small fish—speaking of certain nets or grounds where it was almost impossible to get along without catching small fish. Remember what I said: "Prevent any sort of fishing in certain localities where large numbers of immature fish congregate upon the feeding grounds, this legislation to pertain to all portions of the Great Lakes system where the presence of such fish has been established and to be enforced during such month or months as they make their appearance in large numbers for feeding purposes." We do not propose to permit any fishing there at all; wherever the small fish are caught in large numbers should be a government reservation—that is my idea. That is all I have to say about the small fish.

Another gentleman, I think Professor Prince, spoke of the high percentage of impregnation of the fish eggs in a natural way. With the salmon there is no doubt of it; but with trout, i. e., lake trout, not the stream trout, and with the whitefish, I thought it was conceded by all who are interested in fish culture that the percentage of impregnation of the naturally spawned fish was very low. I have always supposed it was conceded. If I might be permitted to state, Mr. President, I think it is of record in some

of our early United States Fish Commission reports, where I personally made certain observations upon this phase of our subject, and I have always supposed that this was why we approved the dry method of impregnation instead of the wet method. Experiments made by me many years ago in taking eggs of the whitefish brought me to these conclusions: You take your eggs in a pan of water with the milt, and you get a fair impregnation; you take your eggs in a pail of water, say 10 gallons, and you get a medium impregnation—perhaps 20, 30, or possibly 40 per cent. If you take your eggs in a barrel of water you may get 15 or 20 per cent. Therefore I have always concluded that where the female whitefish spawned indiscriminately in the water, with the milt no doubt added in the same way, only partial fertilization would result. In fact I believe, Mr. President, that many female whitefish spawn when there is not a male fish anywhere in the vicinity. From that we must, it seems to me, draw the conclusion that where the whitefish spawn naturally it is not possible to have any high percentage of impregnation. Personally, I do not like the word "artificial." There is nothing under the sun artificial about the care or hatching of fish eggs, excepting that you give them care. It is "protected propagation," Mr. President, and I like to use that term. There is nothing artificial in taking the eggs. You merely bring the eggs and the milt together. That is all there is of it; and then you care for them, and the care and attention which is given them in our hatcheries is what I prefer to call protected propagation.

Some speaker mentioned pound nets. Here is the ground that I take. As you will see, I make the penalty very severe to the fishermen; it is the most severe punishment that was ever thought of, in my judgment. Think of it! The third violation stops his fishing. I do not care if he is but 20 years old, he stops fishing the balance of his life. Suppose some of our immensely wealthy fishermen on the Great Lakes—take the A. Booth Packing Company—violate this law the third time, what happens? They must stop fishing or the revenue boat will attend to them.

All this is contained in this paper, and my idea is based on the idea of federal control, not state regulation. I mean federal control by the Dominion of Canada and the United States; not state control or provincial control. Our warden boats go there, and they may find a man violating the law. He is arrested; his license is taken away from him for six months; for the second offense for a longer period.

Might I be permitted to state what I said to a fisherman on the lake? I gave him my idea of this federal control, and what I proposed. I said: "You do not obey these state laws very well?" "Oh, no;" he replied, "we take our chances on getting caught." "You caught a considerable number of fish here one fall out of season?" He replied: "Yes; oh, yes." "Well," I said, "John, I know how many you caught—about $10,000 worth." He answered: "Yes; and I was taken over here and fined $500, but I had $9,500 left." I said to him: "John, what will you do if you are licensed and you violate that law, and have to stop fishing six months?" "Why," he said, "it would almost ruin me for six months." I said: "What will you do if you have to stop for a year?" He replied: "I could not stand it." That is my idea. I do not know whether I have answered all questions or not.

Mr. J. J. STRANAHAN (Georgia). Mr. Clark, you have a better memory than mine, I know. You remember what we published with reference to the fertilization of whitefish eggs on the Detroit River?

Mr. CLARK. Oh, yes.

Mr. STRANAHAN. What was the percentage?

Mr. CLARK. It was very low. I do not know that I can give the exact figures. It might have been one-half of 1 per cent.

Mr. STRANAHAN. Less than 1 in 1,000.

Mr. CLARK. Very low, indeed.

Mr. STRANAHAN. I want to speak only a word. Under the direction of the United States Commissioner of Fisheries, I was instructed to make dredgings on the reefs with

our steamer, using the hose. We did so for several days the latter part of November and the early part of December. We had an inch hose and a rotary pump; and we took up only a few thousand eggs. I can not give you the percentage, but it was somewhere in the vicinity of one egg out of three or four hundred, and, as I remember it now, we got only eleven or twelve impregnated eggs during our two or three days' work. Our work was off North Bass Island, and around the island near the hatchery where I was then superintendent.

Professor PRINCE. There is just one error that I think Mr. Clark would willingly consent to having removed, and that is that spawning grounds in the Great Lakes are all polluted. On the Canadian side there are splendid spawning beds which are unpolluted. There are great spawning grounds in Lake Erie and Georgian Bay unpolluted, and the benefit of these spawning grounds must be felt on the Great Lakes, as the benefit of the hatcheries is also felt. I wish to say that I am as strong an advocate as anybody for artificial culture, and have said so in numerous official reports; but I also think that if you can combine that work with a closed season, then you have an ideal state of things.

Mr. SAMUEL F. FULLERTON (Minnesota). Mr. President and gentlemen of the congress, have you taken into consideration that men whom I claim to be the foremost in the United States to day in their profession have written papers, all in different directions and all coming to the same conclusion? If any of your family were sick and there were a horse doctor and a physician of high standing in the same community, which would you employ—the horse doctor? No, you would take the physician of high standing. Here is Mr. Clark, who has been in the business for forty years, and Mr. Downing has perhaps been in it as long—men whose word is law in regard to fish culture; and we should take their word, not that of the horse doctor. Now, in our state last year we had a law suit; and I think this will illustrate the point I want to make as well as anything else. At that law suit we had the evidence of eleven fish culturists—the foremost men we could get. We went all over the United States for them; and the conclusion they all reached was the same: That not one whitefish or pike perch egg in 500 ever came to maturity. They were sworn men; they had made tests. I have been at it eighteen years, and I have taken eggs off the bottom rocks and off the sand and brought them to our hatchery and hatched them; but I never got 1 per cent of fry. [Applause].

Mr. DWIGHT LYDELL (Michigan). I have been listening very attentively to the speakers, and did not intend to say anything; but when some of them stated that we could get along without Dame Nature, I desire to say that I think we can not. I think all fish culturists are willing to admit that Dame Nature is what we need up to a certain point, when they step in and beat Dame Nature where the whitefish are concerned for the next five months.

I took some dredgings on the Detroit River, under the instructions of the Michigan Fish Commission, several years ago, when they were engaged in the propagation of the whitefish; and out of two quarts that I gathered nearly every day with a dredge, I failed to find any impregnated whitefish eggs. This work was carried on during the months of March and April. No whitefish eggs were collected whatever that were good, although we got quarts and pails of poor ones. That was on the natural spawning grounds.

I do not think that we ought to compare our brook trout or any of our other species of fish, except the lake herring and wall-eyed pike, with our whitefish. The whitefish spawns promiscuously in the water wherever it happens to be. The brook trout clean off their beds in the streams and spawn on them; both the male and the female are there. Take the whitefish run on the Detroit River. The female whitefish come up there in great numbers after the male run has nearly passed by. The first run comprises nearly all males; in the second run you will get ten females where you will get one male. As they are all ready to spawn, I think it would be impossible for one male to attend to so many females; but if the males that are caught from the first run are

held in crates by the fish culturist, and used when the females come on, nearly every egg is saved to be turned loose later as a lively young fish. Our tally sheets which are on file in the Fish Commissioner's office show these statements to be true. So I do not think we ought to compare the brook trout with the whitefish in this discussion at all.

Mr. FRYER. I would like to ask one question, which is, What was the condition of the whitefish fisheries of the Great Lakes say sixty years ago, before there were many of the mischiefs that exist now, such as pollutions and pound nets and other wickednesses on the part of man, and when also there was no such thing as protected reproduction?

One other question on the point of the illustration given us from Colorado. I am in doubt whether the speaker from that State wishes us to infer that the native trout had died out because there was no protected reproduction in its case, or whether we are to assume that it had succumbed to the superior numbers and greater voracity of the alien fish imported into its water.

Mr. PAUL NORTH (Ohio). I do not go back sixty years, but Mr. Fryer would know the difference in conditions on Lake Erie now as compared with sixty years ago if he could realize that we have in Lake Erie on the American side a fleet of nearly 300 tugs with 6 to 8 miles of gill nets to the tug. He could appreciate that, if the same conditions which existed sixty years ago with regard to replenishing the lake were present to-day, we would not have a fish of that kind in Lake Erie.

The PRESIDENT. Now, in regard to the question about the native trout. Mr. Thompson will reply to that question.

Mr. THOMPSON. I intended my hearers to infer that it was owing to lack of artificial propagation that the native trout had died out to so great an extent. I will state that we have in recent years commenced an extensive work with the natives, with the intention of again making them a factor in our streams. The lake Mr. Titcomb mentioned this morning, where the fish circulate around the island in countless thousands, is one of our native trout-spawning fields. It is about 200 acres in extent and has yielded over 6,000,000 eggs in a single season, this quantity being limited merely by our existing facilities.

[The discussion of the whitefish question terminated at this point but was briefly taken up again on the following day.]

The PRESIDENT. Mr. Fullerton has just spoken to me about a matter of general misunderstanding in regard to the whitefish question, and it seems to me to be of sufficient importance to be brought again before the attention of the congress. I will ask him kindly to make that statement made to me a moment ago.

Mr. FULLERTON (Minnesota). A misunderstanding has arisen in regard to the open season of whitefish, that we had the discussion on yesterday. I have talked with several gentlemen who did not understand the position that we took in regard to letting the fishermen fish in the closed season.

We did not for a moment contemplate letting any fishermen fish in the open season, except it be under the jurisdiction and under the control of the state or federal authorities, both of Canada and of the United States. I hope this explanation will clear away a misunderstanding that existed, that the fishermen are allowed to go to the spawning beds and fish at will. That is not at all intended; that would not be tolerated for a moment. They must do their fishing and taking of the eggs only under the control of the authorities.

The PRESIDENT. The chair requests, then, that those who are here will explain to any members who are interested in this problem that this explanation has been made, because I can see how it is perfectly clear to those who are connected with our national hatcheries in the United States. It is so clear, indeed, that they did not emphasize it in the discussion yesterday afternoon.

GENERAL INDEX.

[Part 1 includes pages 1-696; part 2, pages 697-1412.]

Page.

Abnormal gas content of water 898-905
Acclimatization 947-989, 1402-1406
American fishes, Argentina 955-966
Austria 977-990
Italy 947-954
New Zealand 967-976
black bass, Austria 982
Italy 947-954
brook trout. *See* trout.
carp, United States 1405-1406
catfish, New Zealand 970, 973
European trouts, United States 1405
lobster, Pacific coast 1406
rainbow trout. *See* trout.
salmons, Argentina 955-966
New Zealand 967-976
shad, Pacific coast 1402-1403
steelhead trout, eastern states 1404
striped bass, Pacific coast 1403-1404
sunfish, Italy 947-954
trout, Argentina 955-966
Austria 977-990
Colorado 691-692, 1402
eastern states 1404
Italy 947-954
New Zealand 967-976
whitefish, New Zealand 970, 973
Adee, Alvey A., remarks 17
Adriatic Sea, sponge fisheries 477-478
Ægean Sea and Asia Minor, sponge fisheries 478-479, 513-543
Aeration apparatus for fish culture ... 716-717, 1033-1034
Aeration, remedy for fish disease 891-932, 937-940
Alabama, delegates 7
Alaska, delegates 7
salmon-inspection service 1392-1393
Alaska Packers Association, complimentary luncheon 60
Albatross, United States Fisheries steamer 1384
Aldrich and Company, Robert, on effects of gunfire on fishes 29
Algæ in fish-cultural waters, destruction 871-890
Algeria, sponge fisheries 484, 534
American Fisheries Society, award offered by 69
complimentary luncheon 36
delegates 10
American fishes abroad 955-966
See also Acclimatization.
American Microscopical Society, delegate 10
American Museum of Natural History, award offered by 69
reception 65
American societies, delegates 10-11
American states and territories, delegates 7-10

Page.

Anatomy of ear of squeteague 1211-1224
Angling 60, 61-62, 187-208
California and Florida 199-207
exhibit of fishes and fishing tackle 1311-1314
legislation 187-198
national aspects 193-198
privileges in private waters 60, 61-62
Anglo-Belgian fishery declaration 167
Anglo-Denmark fishery convention 121, 169
Anglo-French fishery conventions 97, 113, 151, 158
Antarctic seals and seal fisheries 317-319
Anthony, R., culture of turbot 859-870
Antipa, Dr. Gregoire, named as vice-president 25
Appalachian forest reserve advocated 67
Apparatus, fish culture 697-757, 767-779, 799-810, 991-1040
oyster culture 1299-1301
photography, subaquatic 1122-1125
radiographing pearl oysters 308-312
See also Fish culture, appliances.
Aquarium, cleaning devices 1032-1033
fungus disease on fishes 929-940
New York, reception to delegates 65
treatment of fungus 929-932
Aquatic mammals, protection 148-150
Aquiculture, new principle 759-780, 866-869
See also Fish culture.
Aquino, Radler de, named as vice-president 24
international fishery dictionary 49
Argentina, American fishes acclimatized 955-966
Artificial nests for bass 720-721, 993
Asia Minor and Ægean Sea, sponge fisheries 478-479, 513-543
Atkins, Charles G., award received 72
foods for salmonoids 839-851
sea mussels and dogfish as food 252
Atlantic Ocean, sponges 493-494
Atlantic salmon, culture 718-719, 1399-1400
parasites 1153-1173
Australia, sponge fisheries 492
Austria, American fishes acclimatized ... 977-982, 983-990
delegate 6
Austrian Fisheries Society, delegate 6
Awards, committee on 25-26, 68, 71
conditions governing 70
conferred, list of recipients 71-72
offered, list 69
Ayson, L. F., American fishes in New Zealand 967-976
Azygia sebago, a new trematode parasite 1176-1184

Bahama Islands, sponge fisheries 470-473
Barricades in salmon streams, designs 726-732
Bass, black, acclimatization 947-954, 982
nests, artificial 720-721, 993

Page.
Bass, protection..... 185
striped, culture..... 706–707
Bayer, H. von, fishways..... 1041–1058
measuring fish eggs..... 1009–1014
Beam-trawl fishing..... 88–89
Bean, T. H., remarks on anglers' rights..... 62
toadfish..... 1069
whitefish regulations..... 688
Belgian "devil"..... 85, 99
Bengoechea, Ramon, named as vice-president..... 25
Bermuda Natural History Society, delegates..... 7
Besana, Giuseppe, American fishes in Italy..... 947–954
Bigelow, H., award offered..... 70
Biological investigations, United States Government..... 1383–1385, 1406–1410
laboratories, United States Government..... 1384
Birds of Peru, guano-producing..... 358–362
Birge, E. A., gases in Wisconsin lakes..... 1273–1293
Black bass, acclimatization..... 947–954, 982
artificial nests..... 720–721, 993
protection..... 185
Blood of fishes, effects of changes in water density.. 1143–1150
Boardman, W. H., lobster question..... 214
Boats, fishing, Peru..... 341–345
Borodine, Nicholas, message..... 46
international fishery dictionary..... 47–48
proposal for international fishery dictionary..... 41, 49
Boston Fish Bureau, courtesies extended..... 66
Boston, visit to..... 66
Boundary waters, fisheries regulations..... 85, 181–186
Bower, Seymour, whitefish regulations..... 691
Bowers, George M., award offered..... 70
congress opened..... 18
Blue Ridge Rod and Gun Club, complimentary luncheon..... 41
Brazil, delegate..... 6
Breeding habits of horned dace..... 1125–1136
kelpfish..... 1140–1141
toadfish..... 1077–1087
Brook trout:
acclimatized in Argentina..... 955–966
Austria..... 981, 983–989
Colorado..... 691–692, 1402
Italy..... 947–954
New Zealand..... 971
culture..... 712–718
disease..... 941–946
Brooklyn Institute of Arts and Sciences, Museum, award offered by..... 69
Bumpus, H. C., award offered by..... 70
named as president..... 22
lobster question..... 213, 214
Bureau of Fisheries, United States. *See* United States Bureau of Fisheries.

Cail fishway..... 1049, 1052–1057
California, delegates..... 7
game fish and fishing..... 201–205
Canada, angling..... 62
delegate..... 6
Canada-United States fisheries commission..... 85–87, 181–186
Canal Zone, delegates..... 7

Page.
Carbo, Esteban F., fisheries of Ecuador..... 52–54
Carnegie Institution of Washington, delegate..... 11
Carp, acclimatized in America..... 1405–1406
fishery in United States..... 1405–1406
value in United States..... 1404–1406
Chars, acclimatization..... 947–990
culture in United States..... 712–718
See also Acclimatization, trout *and* Trout.
Cheyney, John K., award offered by..... 70
China, delegates..... 6
fisheries..... 367–373
Clark, Frank N., whitefish production of Great Lakes..... 635–642
whitefish regulations..... 688, 692–693
Cleaning device, hatching troughs..... 1030–1031
ponds and aquaria..... 1032
Cod culture, method and results in Norway..... 799–816
United States..... 736–737, 1401
Coker, Robert E., named as vice-president..... 25
fisheries and guano industry of Peru..... 333–365
Collection of fishes from overflowed lands..... 724
Collecting tub..... 995
Colombia sponge fisheries..... 475
Colorado, brook trout acclimatized..... 1402
delegates..... 7
trout culture..... 713–714
Columbia River salmon fisheries, preservation..... 186
Commercial fisheries, United States. 1385–1393, 1410–1411
Committees:
awards..... 25–26, 68, 71
report..... 71
organization..... 4
programme..... 27
resolutions..... 26, 63
Competitive awards..... 69–72
Congress, International Fishery, appeal to..... 542–543
awards..... 25–26, 68, 71–72
elections of officers..... 14
members..... 5–13, 14
minutes..... 15
object..... 14
officers..... 3–4
organization..... 1–15
papers and discussions..... 77–1412
permanent commission..... 35, 41, 73
publications..... 15
regulations..... 14–15
resolutions..... 14, 67–68
resources..... 15
sessional business..... 17–76
views adopted..... 67
Connecticut, delegates..... 7
Conservation of natural resources, resolution..... 67
remarks by Gifford Pinchot..... 57–59
Cooper, Alexander, remarks on menhaden fishing... 278
"Coopers"..... 81, 98
Copper-plating fish casts..... 1362–1363
Copper sulphate, algæ destroyer..... 871–890
Costia necatrix, prevention..... 917–928
Cotte, Jules, sponge culture..... 587–613
Counting fish eggs..... 739–741, 1009–1014
young fish..... 741, 1001–1004
Cuba, sponge fisheries..... 472–474
Curtis, W. C., culture of fresh-water mussels..... 615–626

Page.
Dace, horned, breeding habits 1125-1136
Dannevig, G. M., marine fish hatchery in Norway. 799-809
utility of sea-fish hatching 811-816
Debate in International Fishery Congress, rules 15
Delaware, delegates 7
Delegates, list 5-11
Dennis, Oregon Milton, fish protective legislation. 187-192
Density of water, Woods Hole region 1240
effect of changes upon fishes 1143-1150
Department of State, United States, meeting at 17
Departments of United States Government, delegates 5-6
Designs for fishways 1045-1057
Devices for fish culturists 739-741, 991-1040
See also Fish culture, appliances.
"Devil" in North Sea fisheries 85, 99
Dictionary, international fishery 41, 47-49, 64
Dioxide of hydrogen, remedy for fungus 929-932
Discussions:
acclimatization of fishes in New Zealand 974
effects of menhaden fishing 277-278
gaseous changes in lake waters 1293-1294
international fishery regulations 83-90, 179
lobsters and lobster problem 213-217
plea for observation of habits of fishes 1068-1069
Rhine salmon 829
sea mussels and dogfish as food 249-257
whitefish production of Great Lakes 685-695
Disease of fishes 907-946, 1409
See also Fish diseases.
Disease of sponge divers 518-522
District of Columbia, delegates 8
Fish and Game Protective Association, delegates. 11
Divers, disease 518-522
Diving for sponges 442-451, 484-485, 489-491, 498-502, 513-542
See also Sponge fisheries.
Dogfish, extermination or utilization urged 67
Dogfish and sea mussels as food 241-257
discussion 249-257
Donahue, James, lobster question 214-216
Downing, S. W., whitefish production of Great Lakes 627-633
Dragnet in sponge fisheries 517-518
Dredging for sponges 486-489, 517-518
effects on fishery 502-503

"Ear" sponges 424
Ecuador, delegate 6
delegate, address 52-54
fisheries 52-54
Educational exhibit of fishes, plans 1309-1351
See also Exhibits, fishes.
Elephant-ear sponges 423
Eggs of fishes, methods of counting ... 739-741, 1009-1014
transportation cases 741-751, 1039
Egypt, sponge fisheries 480
Elections of the congress 14
Embryology of toadfish 1095-1101
Erie, Lake, fisheries legislation 86
European trouts in America 1405
Evans, A. Kelly, anglers' rights 62
international control of Great Lakes 87
whitefish regulations 687

Page.
Evermann, B. W., international control of boundary waters 85
whitefish regulations 687
Exhibits, educational:
angler's equipment 1311-1314
fishes 1309-1351
arrangement and labeling 1319-1330, 1347-1348
copper-plating fish casts 1362-1363
game species 1311-1314
list of specimens 1330-1340, 1348-1351
material to be used 1317-1319, 1347-1348
plaster casts 1355, 1362
preparation of specimens 1353-1363
subjects to be illustrated 1340, 1343-1347
wax casts from glue molds 1360-1362
Exploration of Mediterranean Sea, international .. 54-56, 67

Fauna of Woods Hole region, study 1225-1263
Feeding of oysters, rate 1306-1308
Feeding salmonoid fry 795-798, 839-851, 1022-1023
Fertilization of salmon eggs 689
whitefish eggs 630-636, 685, 693-694
Field, George W., lobster problem in Massachusetts 209-212
lobster question 217
utilization of dogfish 253-254
Field, Irving A., sea mussels and dogfish as food 241-248, 256
Field Museum of Natural History, delegate 11
Figgins, J. D., preparation of fish specimens ... 1357-1363
Filters in fish culture 915-916
Fish acclimatization *See* Acclimatization
Fish and rye meal, fish food 850-851
Fish commissions, state, eggs received from United States 1394
Fish culture 647-1040
appliances:
aeration 716-717, 1033-1034
attendant's outfit 996
barricades in streams 726-732
bass nests, artificial 720-721, 993
cleaning devices 1030-1033
cod culture, Norway 799-810
collecting seine 997
collecting tub 995
counting eggs 739-741, 1009-1014
counting fry 739-741, 1001-1004
egg measure 1009-1014
fish retainer 996
food scraper 1034-1035
fry retainer and trap 944
hatching box 1015-1024
Norway, hatchery at Flödevig 799-810
oxygenation 716-717, 1033-1034
pond, artificial, and outlet 1027-1028
shipping cases for eggs 742-751, 998
sorting screen 717-718
turbot culture 866-867
collecting young pond fish 722-723, 997
devices. *See* Fish culture, appliances
distribution of hatchery products .. 752-757, 1380-1382
feeding salmonoid fry 1022-1023
food for young pond fish 720
salmonoids 795-798, 839-851, 1022-1023
See also Fish food.

Page.
Fish culture—Continued.
fresh-water shrimp as fish food 853–858
methods 697–809, 859–870
agitation of water, continuous 228–234, 767–779, 866–867
Atlantic salmon 718–719
brook trout 712–718
cod 736–737
Norway 799–816
flatfish 737
lake trout 710–712
marine, Norway 799–816
United States 736–737, 759–780
utility 811–816, 1401
Pacific salmon 725–736
pike perch 708–710
pollock 736–737
pond fishes 719–723
rainbow trout 712–718, 781–787
salmon, Atlantic 718–719
Pacific 725–736
salmonoids 781–787, 1015–1024
shad 702–703, 789–794
striped bass 706–707
trout 712–718
rearing methods 714–716, 781–787
special devices 716–718
turbot 859–870
whitefish 707–708
white perch 704–705
yellow perch 705–706
mosquito problem aided 831–838
new principle 228–234, 759–780, 859–870
ponds and pond construction 719–720, 1027–1028
food for adult fish 720
rescue from overflows 724
Rhine salmon 824–826
schools advocated 67
suitability of water supply 891–906, 1291–1292
transportation of eggs 741–751, 998
live fishes 752–757, 780, 1005–1008, 1039
water conditions 871–928
gas content 891–906, 1291–1292
natural impurities 893–894
poisonous substances 895–898
treatment to remove algæ 871–890
Fish diseases 907–946, 1409
brook trout 941–946
Costia necatrix, prevention 917–928
fungus, treatment 909–916, 929–932
gills of young fish 909–912
salmonoid fry 907–928
"staggers" 914–916
Fish eggs, measuring and counting 1009–1014
transportation 741–751, 998
Fish food 839–858, 1022–1023
device for preparing 1034–1035
fish and rye meal 850–851
fly larvæ 842–846
fresh-water shrimp 853–858
pond fishes 720
salmonoids 795–798, 839–851, 1022–1023
Spratt's prepared foods 846–850
Fish Hawk, United States Fisheries steamer .. 66, 1375, 1385
Fish, packing for shipment 295–301

Page.
Fish parasites 1151–1210
Fish ponds, artificial 719–720
with siphoid outlet 1027–1028
Fish products, Peru 347–354
Fish protection:
black bass 185
demersal species 145–148
difficulties 187–192
fishways 1041–1058
high seas 142–150
migratory species 143–145, 184
salmon, Pacific 184–185
sturgeon 185
whitefish 85–87, 89–90, 184, 627–695
Fish, wrapping for shipment 295–301
Fisheries Bureau, United States *See* United States Bureau of Fisheries
Fisheries Commission, International 85–87, 181–186
Fisheries Company, The, award offered by 69
Fisheries:
beam-trawl 88–89
China 367–373
Ecuador 52–54
fur-seal 315–322
Galapagos Islands, resources 52–54
Great Lakes, international control 85–87
Italy, economic conditions 323–332
Japan 375–379
mackerel, effects 281–294
menhaden, effects 269–294
Peru 333–356
preservation on high seas 142
publications, United States Government 1395–1398
schooner Grampus 1411
shad, depletion 1398–1399
sponge 401–544
See also Sponge fisheries
statistics 1386–1391
steamer Albatross 1384
Fish Hawk 1385
United States 1385–1393, 1410–1411
whitefish 87, 89–90, 627–695
Fishermen, sponge, appeal for 542–543
Fishery Congress, International 1–76
See also Congress, International Fishery.
Fishery convention, Anglo-Belgian 167
Anglo-Denmark 121, 169
Anglo-French 97, 113, 151, 158
fur-seal 96, 124, 173, 134
Great Britain-United States 67, 86
North Sea 98, 116, 163
submarine cable 122, 168
Sweden-Denmark 133, 174
Fishery dictionary 41, 47–49, 64
Fishery dispute, Moray Firth 81, 137, 179–180
northeast coast settlement 67
Fishery laws 60–62, 67, 77–198
See also Fishery regulations *and* Fishery convention.
Fishery regulations, Anglo-Belgian 167
Anglo-Denmark 121, 169
Anglo-French 97, 113, 151, 158
fur-seal 96, 124, 134, 173
Great Lakes 85–87, 89–90, 181–186, 627–695
high-seas 77–180

Page.
Fishery regulations, international..... 77-186, 627-695
investigations to precede..... 83-84 86
lobsters..... 209-217
national..... 186, 193-198
North Sea..... 98, 116, 163
private waters..... 61-62
shad..... 1400, 1401, 1407
simplification urged..... 67
sponge diving..... 522-540
sponge fisheries..... 503-510, 522-540
submarine cable..... 122 168
Sweden-Denmark..... 133, 174
United States and Canada..... 67, 85-87, 181-186
whitefish..... 85-87, 89-90, 627-695
Fishery schools, establishment advocated..... 67
Fishery treaty, United States and Canada..... 67, 86
Fishes, acclimatization. *See* Acclimatization.
anatomy..... 1211-1224
carriers of mussel larvæ..... 622-626
changes of density of water, effects..... 1143-1150
copper solution, effects..... 871-890
counting young..... 1001-1004
cultivated by United States, list..... 1372-1373
degeneration of American trouts in Austria.... 983-990
destroyers of mosquitoes..... 831-848
diseases..... 907-946, 1409
See also Fish diseases.
dissolved content of water, effects..... 891-906
distributions to public in United States..... 1379-1382
exhibit, plans..... 1309-1351
See also Exhibits, fishes.
foods for..... 795-798, 839-858
See also Fish culture, foods.
fungus..... 909-916, 933-940
game, California and Florida..... 201-207
gas content of water, effects..... 898-905
goldfish, Japan..... 381-397
gunfire, effects..... 29-32
habits..... 1059-1142
breeding of kelpfish..... 1140-1142
Semotilus..... 1125-1135
methods of study..... 1111-1142
schedule..... 1066
toadfish (*Porichthys*)..... 1068-1069
(*Opsanus*)..... 1071-1110
whitefish..... 649-660
hearing..... 29-32, 1211-1224
impurities in water, effects..... 893-894
mosquito destroyers..... 831-838
natural history..... 1059-1142
observation of habits..... 1059-1070, 1111-1142
plea for..... 1059-1069
schedule for..... 1066
output of United States hatcheries..... 1379-1382
parasites..... 1151-1210
See also Parasites.
photography..... 1122-1125
plans for educational exhibit..... 1309-1351
plaster casts, preparation..... 1355, 1362
plea for observation of habits..... 1059-1070
poisonous substances in water, effects..... 874-876, 895-898
protection..... 143-148, 184, 187-198
See also Fish protection.
relation to mosquito problem..... 831-838

Page.
Fishes, resistance to copper sulphate..... 871-890
sense of hearing..... 1211-1224
study of habits..... 1111-1142
See also Fishes, habits.
transportation alive..... 1005-1008, 1039
by Fisheries Bureau..... 1380-1382
wax casts from glue molds..... 1360-1362
wax molds and copperplating..... 1362-1363
Fishing craft of Peru..... 341-345
Fishing privileges in private waters..... 60 61-62
Fishing tackle, museum exhibit..... 1311-1314
Fishways..... 1041-1058
Atkins..... 1048
Brackett..... 1046
Brewer..... 1047
Cail..... 1049
Cail improved..... 1052-1057
Caméré..... 1051
Foster..... 1046
Hockin..... 1049
Kirk..... 1051
McDonald..... 1050
Recken..... 1052
Richardson..... 1048
Roberts..... 1045
Rogers..... 1046
Shaw..... 1047
Smith..... 1045
Steck..... 1046
Swazey..... 1047
Wheeler..... 1045
Flatfish culture..... 737
Flégel, Ch., appeal to Congress..... 542-543
awarded special prize..... 72
scaphander in sponge fisheries..... 513-542
Flödevig hatchery, Norway..... 799-810
Flora of sea bottom, Woods Hole region..... 1225-1263
Florida, delegates..... 8
game fish and fishing..... 205-207
sponge fisheries..... 425-469
regulation..... 503-510
statistics..... 456-469
See also Sponge fisheries.
grounds..... 426-431
Fly larvæ, food for fishes..... 842-846
Food and feeding of oysters..... 1295-1308
Food of oysters, volumetric determination..... 1304-1308
supply, determination..... 1297-1304
Food for fishes..... 795-798, 839-858, 1022-1023
See also Fish food.
Foreign governments, delegates..... 6-7
Foreign societies, delegates..... 6-7
"Forest and Stream," award offered..... 69
Forest reserves, establishment favored..... 67
France, sponge fisheries..... 477
Franke, Johann, Costia necatrix in salmonoid fry. 917-928
degeneration of American trouts in Austria.... 983-990
Franklin, Dwight, award received..... 71
preparation of fish specimens..... 1353-1356
Fresh-water mussels, culture..... 1409
life history..... 618-622
Fresh-water shrimp, a natural fish food..... 853-858
Fryer, Charles E., international fisheries regulations..... 91-102
beam trawling, effects on fish supply..... 89

Page.
Fryer, Charles E., exploration of Mediterranean Sea. 55
international fishery regulations..... 83, 179
lobster question..... 216
Moray Firth dispute..... 179
sea mussels and dogfish as food..... 250, 251
whitefish regulations..... 688-689, 695
Fry retainer and trap..... 994
Fuller, Alfred E., fish-cultural devices..... 991-1000
Fullerton, S. F., whitefish regulations..... 694, 695
Functions of ear of squeteague..... 1211-1224
Fungus, fishes in captivity..... 909-916, 929-940
young salmonoids in hatchery..... 909-912
Fur seals and seal fisheries..... 315-322
Fur-seal regulations..... 96, 124, 173, 134, 321

Galapagos Islands, fishery resources..... 52-54
Game fishes, California and Florida..... 201-207
museum exhibit..... 1311-1314
protection..... 187-192, 193-198
Game fishing..... 187-208
legislation..... 187-198
privileges in private waters..... 61-62
Gas content of water, correction in fish culture... 898-905
fishes affected..... 898-905
Wisconsin lakes..... 1273-1294
Georgia, delegates..... 8
German carp in United States..... 1405-1406
German Fisheries Society, delegates..... 7
German Society of Anglers, delegate..... 7
Gill, Theodore, award offered by..... 70
called to chair..... 63
observation of habits of fishes as against undue generalization..... 1059-1070
dogfish and sea mussels as food..... 249, 251, 256, 257
Semotilus..... 65
toadfishes..... 1069
Gills, disease of, in young fish..... 909-912
Gloucester, Mass., visit to..... 66
Board of Trade, courtesies extended..... 66
delegate..... 10
Glove sponges..... 419
Glue molds for casts of fishes..... 1360-1362
Godoy, José F., address..... 51-52
named as vice-president..... 25
Goldfish, culture in Japan..... 386-397
Japanese varieties..... 383-386
Grafting sponges..... 553-555
Grampus, United States fisheries schooner..... 1411
Grass sponges..... 416
Great Britain and United States fishery convention. 67
fisheries commission..... 181-186
Great Lakes, international control..... 85-87
whitefish fishery conditions..... 87, 637-639, 676-682
whitefish production..... 627-695
Greece, sponge fisheries..... 522-530
Greenland seal-fishery regulations..... 134
Guano industry and fisheries of Peru..... 333-365
Guano producing birds of Peru..... 358-362
Guatemala, delegate..... 6
Gudger, E. W., habits and life history of toadfish..... 1071-1110
Gunfire, effects on fishes..... 29, 30, 32

Habits of fishes..... 1068-1142
See also Fishes, habits.

Page.
Hardhead sponges..... 420
Harpooning sponges..... 485-486, 497-498
Hatch, Edward, jr., water pollution..... 42
Hatchery, diseases of fish..... 909-928
Hatching of fishes..... 697-780, 859-870
See also Fish culture.
Hathaway, Walter E., menhaden fishing, effects... 269-277
gun practice, effects on fishes..... 30
utilization of dogfish..... 254
Hearing in fishes..... 29-32, 1211-1224
Heterostichus rostrata, spawning habits..... 1140-1141
High seas, definition..... 105
international fishery regulations..... 77-180
jurisdiction..... 109-112
Hinrichs, Henry, international control of Great Lakes..... 90
Hoek, P. P. C., address..... 23
beam trawling, effects..... 89
named as vice-president..... 24
propagation and protection of Rhine salmon... 817-830
Holder, C. F., combating fungus..... 933-936
exhibit of fishes and anglers' equipment..... 1309-1314
sport fishing in California and Florida..... 201-207
studying life history of fishes..... 1137-1142
transporting live fishes..... 1005-1008
Holt & Co., Henry, award offered by..... 70
Honduras sponge fisheries..... 474
Honeycomb sponges..... 423
Hooking sponges..... 435-442, 497-498, 517
Horned dace, breeding habits..... 1125-1136
Hydrogen dioxide, remedy for fungus..... 929-932
Hydrophysics, Wisconsin lakes..... 1273-1294

Idaho, delegates..... 8
Illinois, delegates..... 8
Impurities of water, effects upon fishes..... 893-894
Indian Ocean sponges..... 493
Indiana, delegates..... 8
International committee on awards..... 68, 71
International explorations of Mediterranean.... 54-56, 67
International fisheries commission, United States and Canada..... 85-87, 181-186
International Fishery Congress..... 1-76
See also Congress, International Fishery.
International Fishery Congresses, Permanent Commission..... 35, 41, 73
International fishery dictionary..... 41, 47, 49, 64
International fishery regulations..... 77-186
See also Fishery regulations and Fishery convention.
International Office of Documentation for Fisheries, delegate..... 6
International waters of United States and Canada.. 67
Investigations, biological, United States..... 1383-1385, 1406-1410
laboratories of United States Government..... 1384
Mediterranean, international..... 54-56, 67
oyster fattening..... 1407
pearl mussel..... 615-626, 1409
precede legislation..... 83-84, 86
Iowa, delegates..... 8
Italian Fisheries Society, delegate..... 7
invitation to congress to meet in Rome..... 41
thanks offered to..... 67
Italy, American fishes acclimatized..... 947-954
delegates..... 6
economic conditions of fisheries..... 323-332

Page.
Jamaica sponge fisheries 475
Japan, American fishes 39
delegate 6
fisheries 375–379
goldfish and their culture 381–397
Johnson, F. M., award offered by 70
Jordan, David Starr, message 46
International Fisheries Commission 181–186

Kadich, Heinrich von, named as vice-president 24
Kelpfish, spawning habits 1140–1142
Kendall, W. C., effects of menhaden and mackerel fisheries 279–294
Kincaid, Walter S., transporting fish eggs and fish .. 1039
Kitahara, Tasaku, named as vice-president 25
American fishes in Japan 39
fisheries of Japan 375–379

Laboratories, biological, United States Government, 1384
Lacustrine physics 1273–1294
Lake Erie, fisheries legislation 86
Lake Ontario, fisheries legislation 87
Lake trout culture 710–712
Lakes of Wisconsin, gaseous changes 1275–1294
Lampedusa, sponge fisheries 483–484
Larvæ of flies, fish food 842–846
League of American Sportsmen, delegate 11
Lefevre, George, culture of fresh-water mussels .. 615–626
Legislation, fishery 67, 77–198, 209–217, 503–508, 522–540, 627–695
See also Fishery regulations and Fishery convention.
Libby, T. E., dogfish as food 251
Library of Congress, visit 37
Life history of fishes 1059–1141
methods of study 1111–1142
toadfish 1071–1110
Linton, Edwin, flesh parasites of marine food fishes 1195–1210
Lobster, acclimatization on Pacific coast 1406
culture, methods 219–240, 737–739
results 213, 1401
Rhode Island 213, 219–240
discussion of problem 213–217
habits of young 221–227
laws of Maine 214–216
Massachusetts 209–212
Rhode Island 213
problem in Massachusetts 209–212
protection 208–217
Louisiana, oyster culture 1408
Lucas, Frederic A., award received 71
educational exhibit of fishes 1341–1352
Luncheon by Alaska Packers Association 60
American Fisheries Society 36
Blue Ridge Rod and Gun Club 41
Lydell, Dwight, whitefish regulations 694

Machine diving in sponge fisheries 489–491, 498–502, 513–542
abuse 513–542
diseases of divers 518–522
effects on fisheries 498–502
regulations 503–504, 522–540
Mackerel, fisheries 279–293
habitat and movements 283–288

Page.
Maine, angling 62
delegates 8
lobster culture 214
lobster protection 214–216
Mammals, aquatic, protection 148–150
Marine fish culture:
methods 736–738, 799–810
Norway 799–816
United States 736–739, 1401
new principle 759–780, 859–870
turbot 859–870
utility 811–816, 1401
Marine fishes, flesh parasites 1195–1210
Marsh, M. C., destruction of algæ in fish-cultural waters 871–890
dissolved content of water in its effect upon fishes 874–876, 891–906
Maryland, delegates 8
Maryland Fish and Game Protective Association, delegate 11
Massachusetts, delegate 8
lobster question 209–212
Master Mariners' Association, courtesies extended .. 66
Matsubara, S., goldfish in Japan 381–397
Mead, A. D., awards received 71
aquiculture, new principle 759–780
lobster culture, method 219–240
Meal, rye, as fish food 850–851
Measuring fish eggs 739–741, 1009–1014
Meehan, W. E., whitefish regulations 690
Mediterranean, international explorations 54–56, 67
sponge fisheries 476–481
methods 484–491
regulation 522–538
Members of the congress 5–13, 14, 15
Menhaden, habitat and movements 283–287
fisheries, effects 269–294
spawning 288–290
Merrill aerating cone 717
Methods, fish culture 697–809, 859–870
fish disease, prevention 907–946
lobster culture 219–240, 737–739
mussel culture 615–626, 1409
packing fish for shipment 295–301
photography, subaquatic 1122–1125
sponge culture 545–614
study of fishes 1111–1142
volumetric determination of oyster food 1295–1308
See also Fish culture; Lobster culture; Sponge culture; Oyster food.
Mexico, delegate 6
address 51–52
sponge fisheries 475
Michigan, delegates 8
Mid-Atlantic Ocean, sponges 493–494
Miner, Roy W., award received 71
educational exhibit of fishes 1315–1340
Minnesota, delegates 8
Minutes of the congress 15
Mississippi, delegates 8
Missouri, delegates 8
Montana, delegates 9
Moore, Henry F., awards received 71
food and feeding of oysters 1295–1308
sponge culture 545–585
sponges and sponge fisheries 401–511

Page.
Moray Firth, fisheries dispute..... 81, 137, 179
Morocco, sponge fisheries..... 484
Mosquito problem, relation of fishes..... 831-838
Mowbray, L. L., effects of gunfire on fishes..... 32
Museum of the Brooklyn Institute of Arts and Sciences, award offered by 69
Museum exhibit of fishes, plans for..... 1309-1351
See also Exhibits.
Mussel culture, fresh-water, experiments..... 1409
method..... 615-626
salt-water..... 245-247
Mussels, fresh-water, life history..... 618-622
salt-water, as food..... 241-247

Narragansett Bay, visit..... 65
National aspects of angling..... 193-198
National Association of Audubon Societies, delegates 11
National Association of Fish Wardens and Commissioners, delegates..... 11
National Association of Scientific Angling Clubs, delegates..... 11
National fisheries control..... 186
National Museum, United States, delegates..... 5
Natural history of fishes..... 1059-1141
horned dace..... 1125-1135
Rhine salmon..... 819-824, 830
toadfish..... 1071-1110
Naumann, Walther, named as vice-president..... 25
Naval gun practice, effects on fishes..... 29-32
Navigation laws, international..... 99
Nebraska, delegates..... 9
Nebraska University, delegate..... 11
Nests for pond fishes..... 720-721, 993
Netherlands, delegate..... 6
Netherlands Reclamation Society, delegate..... 7
Nevada, delegates..... 9
New England Forest, Fish, and Game Association, delegates..... 11
exhibition of motion pictures..... 33
New Mexico, delegates..... 9
New York, delegates..... 9
Academy of Sciences, award offered by 70
Aquarium, award offered by..... 69
reception..... 65
Botanical Garden, award offered by 69
Zoological Society, delegate..... 11
New Zealand, American fishes acclimatized..... 967-976
delegate..... 6
geographical features..... 974
sponge fisheries..... 492
Nicaragua sponge fisheries..... 475
Nordqvist, Oscar Fritiof, named as vice-president... 25
dogfish as food..... 249
gas content of water..... 1293
North, Paul, lobster question..... 217
whitefish regulations 686-687, 695
North Carolina, delegates..... 9
North Sea fishery regulations..... 98, 116, 163
Norway, marine fish culture..... 799-816
Nude diving for sponges..... 484-485, 516-517
effects on fishery..... 498

Observation of fishes, photography..... 1122-1125
Officers of the International Fishery Congress..... 3-4
Ohio, delegates..... 9
Oklahoma, delegates..... 9

Page.
Olsen, O. T., named as vice-president..... 25
international fishery regulations..... 79-82, 179
international fishery dictionary..... 49
Moray Firth dispute..... 81, 179
Ontario Forest, Fish, and Game Protective Association, delegate..... 7
Ontario Lake, fisheries legislation 87
Opsanus tau, habits and life history..... 1071-1110
Oral incubation among fishes..... 1069
Oregon, delegate..... 9
Organization of the congress..... 3-16
Osborn, H. F., reception..... 65
Outlet, artificial fish pond..... 1027-1028
hatching trough..... 1029-1030
Oxygen changes, Wisconsin lakes..... 1287-1292
Oxygenation device for fish culture... 716-717, 1033-1034
Oysters:
culture, advance in southern states..... 1408
food supply determination 1297-1304
water-specimen cup..... 1299-1301
fattening experiments..... 1407
fisheries of English Channel, regulation..... 97
food and feeding, methods of studying..... 1295-1308
rate of feeding..... 1306-1308
grounds, suitability for planting..... 1297-1304
wholesomeness..... 259-267
pearl oysters and X-ray process..... 303-313
Ozone, a remedy for fungus on fishes..... 937-940

Pacific Ocean sponges 493
Pacific salmons:
acclimatization..... 955-976
culture..... 725-736
results..... 1400-1401
See also Salmon.
Packing fish for transportation..... 295-301
Paige, Charles L., foods for young salmonoids.... 795-798
rainbow trout culture 781-787
Parasites of fishes..... 1151-1210
Atlantic salmon..... 1153-1173
butterfish..... 1202-1206
marine fishes..... 1195-1210
new cestodes..... 1185-1188
new trematode..... 1176-1184
Pacific salmon..... 1172-1173
Sebago salmon..... 1151-1194
Parcage of sponges..... 598-599
Paris fur-seal tribunal..... 124, 173
Parker, G. H., structure and functions of ear of squeteague..... 1211-1224
Pearl fisheries and X-ray process..... 303-313
Pearl mussels, fresh-water, culture methods. 615-626, 1409
Pelagic sealing..... 42, 125-132, 321
Pennsylvania, angling..... 61
delegates..... 9
Fish Protective Association, delegates..... 11
Perce, H. Wheeler, national aspects of angling ... 193-198
Permanent Commission of International Fishery Congresses..... 35, 41, 73
Peru, delegate..... 6
fish products..... 347-354
fisheries and guano industry..... 333-365
fishing boats..... 341-345
geographic features..... 335-338
guano-producing birds..... 358-362
methods of preserving fish products..... 347-354

Page.
Pew, John J., anglers' rights 61
beam trawling 88
dogfish as food 252
Philadelphia Aquarium Society, delegates 11
Philippine Islands, sponge fisheries 491–492
Photography of live fishes 1122–1125
Physics of lake waters, Wisconsin 1273–1294
Pisciculture 627–1040
See also Fish culture.
Pinchot, Gifford, address on conservation 57–59
Pirko, Franz von, American fishes in Austria 977–982
Plaster casts of fishes, preparation 1355, 1362
Poisonous substances in water, effects upon fishes. 895–898
Pollock culture 737
Pollution of water 42, 896–898
Pond, artificial, with siphoid outlet 1027–1028
Pond culture 719–723
artificial nests 720–721, 993
brood fish 721–722
collecting young fish 722–723
seine 997
tub 995
fish retainer 996
food for adult fish 720
fry retainer and trap 994
pond construction 719–720, 1027–1028
Prince, Edward E., named as vice-president 24
acclimatization of fishes in New Zealand 974
fish culturist, training 44
habits of fishes 1068
sea-mussels and dogfish as food 252–253
whitefish beds, pollution 694
whitefish production 685
propagation 685
Proceedings of congress, editing and publication 67
Programme committee 27
Prepared foods for fishes 846–851
Preservation of fish for shipment 295–301
Preservation of fisheries. *See* Protection.
President of the United States, reception 36
remarks 36
stand for conservation commended 67
Propagation of fishes 627–1040
fresh-water mussels 615–626, 1409
lobsters 213, 219–240, 737–739
oysters, southern states 1408
Rhine salmon 824–826
sponges 545–614
See also Fish culture; Oysters; Sponge culture.
Protection of aquatic mammals 148–150
fishes 184–185, 186, 187–192
lobsters 209–217
pearl oysters 303–313
sponge fisheries 503–510
See also Fish protection.
Proteocephalus pusillus, a new cestode parasite .. 1186–1188
Publications of International Fishery Congress 15
United States Bureau of Fisheries 1395–1398
Published works presented to the congress, list 74

Racks in salmon streams, designs 726–732
Rainbow trout:
acclimatized in Argentina 955–966
Austria 977–982
eastern states 1404
Italy 947–953
New Zealand 967–976

Page.
Rainbow trout—Continued.
culture, methods 714–718, 781–787
diseases 907–928
food for 795–798
"staggers" in fry 914–916
Rathbun, Richard, named as vice-president 25
Reef sponges 419
Regulation of fisheries 67, 77–198, 627–695
See also Fishery regulations.
Regulations of the International Fishery Congress .. 14–15
Reighard, Jacob, award received 72
methods of studying life history of fishes 1111–1136
Reighard, Paul, award received 71
whitefish production of Great Lakes 643–684
Resolutions adopted by the congress 67–68
committee 26, 63
method of adoption 14
Resources of the congress 15
Rhine salmon, propagation and protection 817–830
Rhode Island, delegates 9
Fish Commission, reception 66
lobster question 213
Rights to members 14
Robinson, R. K., destruction of algæ in fish-cultural waters 871–890
counting young fishes 1001–1004
aerating apparatus 717
Rome, invitation to congress to meet 41
Root, Henry T., effects of gunfire on fishes 32
lobster question 213
Rosenberg, Albert, abating disease of trout 941–946
Rossati, Guido, fisheries of Italy 323–332
Roumania, delegates 6
Rowe, Henry C., courtesies extended 65
wholesomeness of oysters 259–267
Royal Geographical Society, delegate 7
Russia, nonparticipation in congress 38
Rye meal and fish as fish food 850–851

Salmon, Alaska inspection service 1392–1393
Salmon, Atlantic, culture 718–719, 1399–1400
feeding fry 1022–1023
hatching box 1015–1024
parasites 1153–1173
Salmon, Pacific:
acclimatized in Argentina 955–966
New Zealand 967–976
culture 725–736, 1400–1401
barricades 726–732
fertilization of eggs 689
fisheries of Columbia River 186
parasites 1172–1173
protection 184–185
spawntaking and hatching methods 732–736
Salmon of Rhine 817–830
natural history 819–824, 830
propagation and protection 824–827
Salmon, Sebago, culture 718–719
parasites 1151–1194
Salt-water mussels as food 241–247, 249–257
Salt-water treatment for fungussed fishes 929–932
Santa Catalina Island, sport fishing 201–205
Santo Domingo sponge fisheries 475
Scaphander in sponge fisheries 489–491, 498–502, 513–542
Schools of fisheries and fish culture advocated 67
Schooner Grampus, United States Fisheries 1411

Page.
Scientific fishery investigations, United States.. 1383–1385, 1406–1410
Scott, G. G., effects of changes in density of water upon blood of fishes..... 1143–1150
Sea bottom, fauna and flora..... 1225–1263
Sea-fish hatching, utility..... 811–816
Sea fisheries, international regulations..... 77–180
Sea mussels and dogfish as food..... 241–257
Seal, William P., relation of fishes to mosquito problem..... 831–838
Seal fisheries..... 315–322
Antarctic..... 317–319
pelagic..... 42, 125–132, 321
regulations..... 96, 124, 134, 173
Seals, Antarctic..... 317–319
northern..... 319–322
Sebago salmon, internal parasites..... 1151–1194
Secretary-General, resolution concerning..... 67
Sellers, M. G., anglers' rights..... 60
Semotilus, natural history..... 1125–1135
breeding habits..... 1125–1136
nest building..... 65
Sessional business..... 17–76
Shad, acclimatized on Pacific coast..... 1402–1403
culture, method..... 702–703
expansion of work..... 789–794
results..... 1398–1399
fishery, depletion..... 1398–1399
need of legislation..... 67, 1407
Sheepswool sponges..... 411
Shipment of fish, method of packing..... 295–301
Shipping cases for fish eggs..... 742–751
Shrimp, fresh-water, as fish food..... 853–858
Sicilian Sea, sponge fisheries..... 483–484
Simms, G. E., hatching boxes and feeding of fry. 1015–1024
Siphoid outlets for ponds and troughs..... 1027–1030
Smith, Hugh M., address..... 21
named as secretary-general..... 23
oral incubation among fishes..... 1069
menhaden..... 277
Smith, H. Stephenson, New Zealand, topography... 974
Smithsonian Institution, award offered by..... 69
delegates..... 5
Snyder sorting screen..... 717–718
Society for Promotion of Norwegian Fisheries, delegate..... 7
Sölling, A., packing fish for shipment..... 295–302
Solomon, John I., award received..... 72
process for preserving pearl oyster fisheries..... 303–313
South Carolina, delegates..... 9
South Dakota, delegates..... 9
Spain, sponge fisheries..... 477
Sparganum sebago, new cestode parasite..... 1185
Spencer, L. B., combating fungus..... 929–932
Spawning habits of horned dace..... 1125–1136
Spawntaking, Pacific salmons..... 732–736
trout in Colorado..... 713–714
See also Fish culture.
Sponge culture..... 545–614
collectors for larvæ..... 599–604
critical review..... 587–613
cuttings..... 555–585, 604–613
essential considerations..... 581–583
experiments by Bureau of Fisheries..... 1408
experiments reviewed..... 590–613

Page.
Sponge culture, financial aspects..... 583–585, 609–610
grafting..... 553–555
growing from dissociated tissues..... 555, 1265–1272
growing from eggs..... 554
not feasible..... 587–613
parcage..... 598–599
planting..... 594–598
practical method..... 545–585
Sponge divers, appeal for..... 542–543
disease of..... 518–522
Sponge diving..... 442–451, 513–543
Sponge fisheries:
Adriatic Sea..... 477–478
Ægean Sea and Asia Minor..... 478–479
Algeria..... 484
Australia..... 492
Bahama Islands..... 470–472
conditions and effects..... 494–503
Cuba..... 472–474
depletion of beds..... 494–497
diving, machine..... 442–451, 489–491, 513–542
nude..... 484–485, 498, 516–517
dredging or trawling..... 486–489, 502–503, 517–518
effects upon sponge beds..... 494–503
Egypt..... 480
Florida..... 425–469
methods..... 435–456
regulation..... 503–510
statistics..... 456–469
Greece, regulation..... 522–530
harpooning..... 485–486, 497–498
hooking..... 435–442, 497–498, 517
killing and curing the catch..... 451–453
Lampedusa..... 483–484
legislation..... 503–510, 522–540
Mediterranean..... 476–491, 522–538
methods, Florida..... 435–456
Mediterranean..... 484–491, 516–518
mid-Atlantic Ocean..... 493–494
Morocco..... 484
needs..... 547–550
New Zealand..... 492
Philippine Islands..... 491–492
regulation and protection..... 503–510, 522–542
statistics, Florida..... 456–469
scaphander, abuse..... 489–491, 513–542
Sicilian Sea..... 483–484
Spain and France..... 477
trawling or dredging..... 486–489, 502–503, 517–518
Tripoli..... 481–482
Tunis..... 482–483
United States..... 425–469, 538–540
wading..... 484
western Atlantic..... 470–475
Sponge trade, United States..... 453–456, 469–470
methods of buying..... 453
United States and foreign countries..... 469–470
Sponges..... 401–511, 587–614
bleaching..... 456
common names in different languages..... 410
development from tissue cells..... 555, 1265–1272
elephant-ear..... 424
fisheries..... 401–511
See also Sponge fisheries.
glove..... 419

Page.
Sponges, grass 416
hardhead 420
honeycomb 423
killing and curing 451-453
live 404
Indian Ocean 493
Mediterranean varieties 422-425
Pacific Ocean localities 493
packing 454
reef 419
requisites 407-410
sheepswool 411
Turkey cup 422
Turkey toilet 422
varieties 410-425
velvet 415
western Atlantic varieties 411-421
wire 421
yellow 413
zimocca 423
Sport fishing 187-208
California and Florida 201-207
legislation 187-198
museum exhibit 1311-1314
national aspects 193-198
private waters 61-62
Spratt's fish foods 846-850
Squeteague, structure and functions of ear 1211-1224
Squires, George P., menhaden fishing 278
"Staggers" in rainbow trout fry 914-916
State fish commissions, eggs received from United States 1394
Statistics, Florida sponge fisheries 456-469
United States fisheries 1386-1391
Steamer Albatross, United States Fisheries 1384
Steamer Fish Hawk, United States Fisheries 1385
Steam-trawl fishing 84-85, 88-89
Steindachner, Franz, message 29
Stevenson, Charles H., award received 71
international fishery regulations 103-178
Stranahan, J. J., fertilization of whitefish eggs 693-694
dissolved content of lake waters 1293
Straus, Oscar S., address 18
Striped bass acclimatized on Pacific coast 1403-1404
culture 706-707
Structure of ear of squeteague 1211-1224
Study of habits of fishes, methods 1111-1142
plea for observation 1059-1070
Sturgeon, protection 185
Subaquatic photography 1123-1125
Submarine cable convention of 1884 ..... 122, 168
Sumner, F. B., fauna and flora of sea bottom 1225-1263
effects of gunfire on fishes 30
Sunfish, acclimatization 947-954
Sweden, delegate 6
Sweden-Denmark fishery convention 133, 174

Tackle, fishing, museum exhibit 1311-1314
Temperatures, Woods Hole region 1238-1239
Tennessee, delegates 10
Territorial waters 79-80, 105-109, 136-142
definition 105-109
jurisdiction, extension of 136-142
Texas, delegates 10
Thompson, W. T., fish-cultural results in Colorado 691-692
trout of Colorado 695

Page.
Titcomb, J. W., fish-cultural practices 697-757
acclimatization of fishes in New Zealand 974
whitefish regulations 689-690
Toadfish (*Porichthys*) habits 1068, 1069
(*Opsanus*) habits and life history 1071-1110
Toilet sponges, Turkey 422
Townsend, C. H., fur seals and seal fisheries 315-322
reception 65
Transportation, fish eggs 741-751, 1039
fishes, method 752-757 780, 1005-1008, 1039
United States Fisheries Bureau 741-751, 1380-1382
Trap for bass fry 994
Trawl fishing 84-85, 88-89
Trawling for sponges 486-489, 517-518
effects 502-503
Treaty, fisheries 67, 113-136, 151-174
See also Fishery convention.
Tripoli, sponge fisheries 481-482
Trout:
acclimatized in Argentina 955-966
Austria 977-990
Colorado 1402
eastern states 1404
Italy 947-953
New Zealand 967-976
culture, aeration apparatus 716-717
brook trout 712-713
lake trout 710-712
methods 714-716, 781-787
rainbow trout 713-716, 781-787
rearing 714-716
sorting screen 717-718
spawntaking in Colorado 713-714
special apparatus 716-718
disease of fry 917-928, 941-946
European, in America 1405
foods 795-798, 839-851
resistance to copper sulphate 871-890
"staggers" in fry 914-916
T-wharf Association, courtesies extended 66
Tulian, E. A., American fishes in Argentina 955-966
Tuna Club, delegate 11
Tunis, sponge fisheries 482-483
Turbot culture 859-870
Turkey cup sponges 422
Turkey toilet sponges 422

United States and Great Britain fisheries commission 85-87, 181-186
United States Bureau of Fisheries 5, 70, 697-757, 1365-1411
acclimatization of fishes 1402-1406
award offered by 70
biological investigations 1383-1385, 1400-1410
extent of work 699-702
fish-cultural work 697-757, 1371-1385, 1398-1402
hatcheries 1373-1379
history and work 1365-1411
investment 1370
laboratories 1384
organization 1369
output of hatcheries 1379-1382
publications 1395-1398
relations abroad 1393-1395
with states 1393-1395
resources 699-702, 1370
species of fishes cultivated 1372-1373

Page.
United States, delegates to Fishery Congress..... 5-6
views of delegates..... 67
fisheries..... 1385-1393, 1410-1411
statistics..... 1386-1391
President's stand for conservation commended... 67
sponge fisheries..... 425-469, 538-540
University of Nebraska, delegate..... 11
Uruguay Lobos Fishing Company, message regarding pelagic sealing..... 42

Velvet sponges..... 415
Venezuela sponge fisheries..... 475
Vermont, delegates..... 10
Vice-presidents of the congress..... 24
Views adopted by the congress..... 67
Vincent, Eugene, causes of disease in young salmonoids..... 907-916
devices for fish culture..... 1027-1036
Vinciguerra, Decio, invitation to congress to meet in Rome..... 41
Mediterranean Sea, exploration..... 54, 55
named as vice-president..... 25
next meeting of congress..... 42
Virginia, delegates..... 10
von Bayer, H., fishways..... 1041-1058
measuring fish eggs..... 1009-1014
von Kadich, H., named as vice-president..... 24
von Pirko, Franz, American fishes in Austria.... 977-982

Wading for sponges..... 484
Ward, Henry B., internal parasites of Sebago salmon..... 1151-1194
Washington, delegates..... 10
Washington, D. C., Board of Trade, delegates..... 10
Chamber of Commerce, delegates..... 11
Water, conditions in fish culture..... 871-989
copper sulphate to destroy algæ..... 871-890
density changes, effect upon fishes..... 1143-1150
dissolved content, effect upon fishes..... 891-906
dissolved gases, effects on fishes..... 898-905
fish cultural, filter..... 915-916
gaseous changes..... 1291-1292
suitability..... 891-906, 1291-1292
removal of algæ..... 871-890
treatment with copper sulphate..... 871-890
gas content, Wisconsin lakes..... 1273-1294
impurities, effects on fishes..... 893-894
pollution, effects on fishes..... 896-898
treatment with copper sulphate..... 871-890
Water-specimen cup, for oyster culture..... 1299-1301

Page.
Wax casts of fishes, preparation..... 1355, 1360-1362
West, Henry L., address..... 20
West Virginia, delegates..... 10
Fish and Game Protective Association, delegates.. 11
Western Atlantic sponge fisheries..... 470-474
Wickford, Rhode Island, visit to..... 66
Wilson, C. H., international control of Great Lakes. 89
whitefish production..... 686
Wilson, H. V., development of sponges from tissue cells..... 1265-1272
Wire sponges..... 421
Wisconsin, delegates..... 10
lakes, gas content of water..... 1273-1294
Whitefish, acclimatization in New Zealand..... 970, 973
breeding habits..... 629-630
catch and plants in Great Lakes..... 660-673
culture, effects..... 673-676
method..... 707-708
plan to increase production..... 627-695
discussion..... 40, 43, 685-695
fertilization..... 685, 693-694
fishery, conditions..... 87, 89-90, 637-639
regulation..... 627-695
habits..... 184, 629-630, 649-660
legislation..... 86, 87, 639-641, 676-681
natural history..... 649-660
percentage of fertilization..... 630-636, 685, 693-694
production in Great Lakes, plans to promote... 627-695
propagation..... 627-695, 707-708
protection..... 184, 627-695
White perch culture..... 704-705
Whitman, E. C., utilization of dogfish..... 255, 256
Wholesomeness of oysters as food..... 259-267
Wolverine Fish Company, award offered by..... 70
Woods Hole, Massachusetts, visit to..... 66
Woods Hole region, density of water..... 1240
fauna and flora studied..... 1225-1263
temperature of water..... 1238-1239
Worms as fish food..... 1022-1023
Worth, S. G., expansion of shad-hatchery work.. 789-794
fresh-water shrimp as fish food..... 853-858
washing of lands..... 59
Wyoming, delegates..... 10

X-ray process in pearl fisheries..... 303-313

Yellow perch culture..... 705-706
Yellow sponges..... 413
Yen, Wei-ching W., named as vice-president..... 25
fisheries of China..... 367-373

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