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Element D: Characterization of the Shellfisheries

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ELEMENT D-1: A CHARACTERIZATION OF THE SOFT-SHELL CLAM FISHERY OF MAINE

by

Walter R. Welch

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INTRODUCTION

The soft-shell clam *(Mya arenaria)* was, in 1978, as it has generally been, the second most valuable marine resource in Maine in terms of landed value. The 1978 landings of 6,007,234 pounds of meats, valued at $7,469,611 at first sale, was second only to the American lobster in the state of Maine.

The clam resource is one of Maine's most widely exploited resources. The fact that it continues to produce as abundantly as it does is more of a testimonial to its prolificacy and resilience to environmental abuse than to the relatively meager results which the Department of Marine Resources (DMR) and resource-minded members of the State Legislature and municipal governments have been able to produce.

We believe the soft-shell clam resource has a large potential for substantially increased levels of production through the enlightened use of culture and management methods.

DISTRIBUTION OF THE RESOURCE

The soft-shell clam is found on both coasts of North America, in Europe, and along the northeast coast of Asia. On the Atlantic coast of North America it is found from Labrador to Cape Hatteras, North Carolina (Hanks, 1963).

In Maine, this clam is found all along the coast, in nearly all places where the habitat is suitable. It mainly occupies the intertidal zone, ranging from the upper third of the zone, reaching maximum density in the upper part of the lower third of the intertidal zone, and commonly extending to or slightly below mean low water. In some places, clams are found subtidally, but the actual extent of numbers or depth is not known.

The most productive clam flats are those with sediments of a silt-sand mixture, but clams can be found in nearly any type of sediment that they can burrow into, from coarse gravel to soft, organic silts and clays. These most productive flats may be in salt-marsh creek systems in the southwestern part of the state or in coves and bays and along the shores of estuaries all along the coast. Exposed, well-washed, sandy beaches are not generally populated.

The specific locations of productive clam flats are much too numerous to be described in narrative form. They may be found included in the resource maps of the Maine Coastal Inventory, Fish and Wildlife Series 2 (State Planning Office, undated).

AVAILABILITY OF THE RESOURCE

Over the history of recorded catch data, the quantities of Maine clams appearing on the market have fluctuated widely (Table D-1-1, Figure D-1-1) While we do not know all the causal factors influencing these fluctuations, especially the earlier ones, we do know that in the last four decades, such factors as war, competition in the market, and environmental change have had strong influences in the quantities of clams available, as well as the quantities actually appearing on the market.

Maine's commercial catch has been taken from the open (unpolluted) portions of the clam producing areas shown on the resource maps of the Maine Coastal Inventory, Fish and Wildlife Series 2 (State Planning Office, undated). Region I (York, Cumberland, and Sagadahoc counties, Figure 2) includes 24% of the state's total growing area, while its open area constitutes 17% of the state's total growing area (Table 2). Region II (Lincoln, Knox, and Waldo counties) includes 18% of the state's total growing area, while its open area is 13% of the state's total growing area. Region III (Hancock and Washington counties) includes 58% of the state's total growing area, while its open area is 53% of the state's total growing area. Over the past 15 years the catch from Region III has varied from 39 to 75% of the state's total, while during the major part of the period the landings from that area were well over 50% of the total.

OVERALL STATUS OF STOCK ASSESSMENT

The soft-shell clams in Maine are not considered for management as a single stock. There are several practical reasons for this: 1) municipalities have primary jurisdiction over the clams in their areas and thus set up political boundaries for their management systems; 2) the various municipalities have different management goals, based on different socio-economic circumstances; and 3) the physical and biological nature of the clam flats vary so from flat to flat, even within municipalities, that each clam flat has to be surveyed and considered on its own merits; the area to area variations are even greater and more significant along the Maine coast as a whole.

In view of these considerations, the estimation of clam stocks is done on a piecemeal, localized basis, rather than on a state-wide, single stock basis. With stimulation from DMR, and with the advice and assistance of the DMR area biologists, the municipalities participating in clam management carry out their own surveys to determine: 1) the standing crop of clams, 2) relative growth rates, 3) year class composition, 4) harvestable fraction, and 5) recommended means of administering the harvesting. These surveys are updated periodically, when deemed advisable by the towns or the area biologists.

It may be seen, therefore, that an accurate numerical representation of the total clam stocks in Maine is not possible under present conditions. However, Goggins (1975) attempted to develop the best estimates of potential clam production from information available at the time. From detailed interviews with area biologists, coastal wardens, clam diggers, and other coastal residents, he obtained data on number, location, and acreage of clam-producing areas and estimates of volumes of clams taken from such areas. The sizes of individual producing areas ranged from 1 to over 500 acres, and their carrying capacity (potential production) ranged between less than 25 and 300 bushels per acre. While the original data were obtained on the basis of individual areas and by towns, to make the array more workable it was grouped by counties and regions (Figure D-1-2). From the total growing areas and the total production capacity of those areas were subtracted the acreage of growing areas closed because of pollution and the estimated production capacity of these areas. The difference was the total acreage of growing area open to digging and the estimated production capacity of that open area. Table D-1-2 is adapted from Goggins (1975) data and updated through 1978 by adjusting for the acreage of formerly closed flats opened to unlimited digging through pollution abatement (Winters, 1979), and by using the 1978 catch data. From Table 2 it can be seen that the 1978 catch was 12% of the total estimated production capacity of the open areas in the state, and that this could be increased by about one-fifth if all closed areas could be opened.

A judgment of the relative status of the stocks can also be made through consideration of: 1) the results of town surveys that are reasonably correct, 2) the observations of DMR field personnel, 3) the current status of the commercial catch, and 4) a knowledge of the influence of demand and price on the level of the commercial catch. The status of clam stocks in Maine at the end of 1978, for example, may be characterized as only fair because of; 1) severe depletion of harvestable clams in at least 30% of the state's open area (Regions I and II, Table D-1-2); 2) general lack of successful year classes (except for 1976) throughout the same area, 3) moderate to heavy predation by green crabs *(Carcinus maenas)* over the past 5 to 6 years in 56% of the open area (Regions I and II and Hancock County, Table 2) and 4) intensive digging, stimulated by high prices, which has cut heavily into stocks in Hancock and Washington Counties.

VARIATIONS IN ABUNDANCE

A primary cause of variations in availability of clams to the market is variability in their natural abundance. This may result from either or both natural and man-related factors. The young, as planktonic larvae, are produced in enormous quantities but are also subject to enormous losses. They may be swept out to sea and lost to coastal bays and estuaries, or they may be consumed by zooplankton, filter feeders, or other predators. After metamorphosis, from the swimming stage, and settlement to the bottom (when it becomes "set"), the young clams utilize some byssal attachement and voluntary movement, but are largely at the mercy of hydrographic forces which determine final distribution. By the time the clams have reached 25 mm (1 inch) in length, usually in the second summer, movement from most causes has ceased, and the size of the year class may be determined. Ayres (1956) has calculated that, in general, 1% of the set must survive to the stage of reproduction for a population to remain stable.

The abundance of clams in the flats may be influenced by a number of factors. Such factors as environmental conditions (pollution, temperature, salinity, and others), diseases, and parasites have effects varying with time and place, effects which are very difficult to measure but whose total significance is minor compared with those following.

Predation as a whole can affect nearly all sizes of clams in the flats, from as small as 2 mm to at least as large as 75 mm (Dow and Wallace, 1961). Predators include boring snails, crabs (green and horseshoe), fish, and birds, but the most devastating in Maine has been the green crab. During the warm period of the 1950's, green crabs became sufficiently abundant all along the Maine coast to have virtually eliminated market clams from the flats of southwestern Maine and to a slightly less extent in other areas. Annual sets were repeatedly destroyed before they reached even 1 year of age. The annual landings of clams were reduced to an all-time low of 1.4 million lbs. of meats by 1959 (Welch, 1968). The same sort of devastation occurred in the southwestern half of Maine during the recent warm period of the 1970's. Although annual sets were repeatedly destroyed over at least a 5- to 6-year period, annual total landings were maintained at a relatively high level by virtue of: 1) large reserve stocks of clams accumulated during the 1960's; 2) increased digging pressure in northeastern Maine in response to high prices; and 3) the output of depuration plants, processing clams from mildly contaminated areas.

The likelihood of increased green crab predation can be predicted from the cyclic occurrence of periods of elevated water temperatures, but the severity of the predation and its effects on clam landings is so dependent on many other factors (reserve stocks, prices, digging intensity, output of depuration plants, influence of managed areas, and extent of use of predation prevention methods) that the results cannot be predicted at this time.

The other serious cause of loss of clams established in the flats is digging mortality (that in addition to the actual removal of harvested clams to market). Clams left in the flats by diggers are subject to several types of risk: 1) being broken too severely to survive; 2) being buried at a depth or in a position such that they cannot obtain the necessary water supply to survive; and 3) being exposed at the surface and subject to predation from birds, crabs, and fish. Average losses for the state as a whole from the first two risks alone were estimated to be 70% of the clams remaining in the flats each time an area is dug (Glude, 1954), (Dow, Wallace, Taxiarchis, 1954). From this it can be seen that repeated digging in popular areas causes extremely heavy losses in clams which never reach market.

INFLUENCE OF MANAGED AREAS

The application of management methods can be expected to improve the availability of clams to the market through such effects as: 1) the reduction of severe fishing mortality, 2) regulating product flow to more nearly match market demands, and 3) taking fullest advantage of the natural attributes (good setting, good survival, good growth) of clam producing areas. Thus far, most management efforts in the state (by municipalities) have been limited to: 1) resource surveys to determine year-class structure, growth, and potential yield; 2) alternation of open and closed periods to reduce unnecessary digging mortality in areas not ready to harvest; 3) restricting digging to residents only, resident quotas, or non-resident quotas; and 4) size limits on clam length. The present estimate of acreage under some sort of management is 8,669 acres, or nearly one-fourth of the state's total open growing area Tables D-1-3, D-1-4.

The influence of the supply of depurated clams on the total clam market is relatively minor. Production for 1978 was 14,990 bu. (Table D-1-5) or 3.7% of total landings for the year. This level of production can be expected to hold even as it has over the past 5 years, or perhaps increase somewhat over the next few years as pollution abatement efforts continue. The utilization of these moderately-contaminated clams also serves the purpose of: 1) providing additional employment, and 2) reducing stocks of clams which would otherwise tempt illegal digging and constitute law enforcement and public health problems.

In Maine, aquaculture of the soft-shell clam; that is, raising it from egg to market, is non-existent in the commercial sense and therefore exerts no influence on the availability of clams for market. In the future, there may be practical usage of hatchery-raised young clams (set or submarket size) for transplant to growing areas to supplement deficiencies in natural setting. There are also possibilities in the intensive culture of natural sets to increase growth rates and to reduce natural and harvesting mortalities, but such endeavors do not as yet seem economically feasible, nor as yet even technically feasible.

MAINE'S PROBLEMS IN AVAILABILITY

There are several problem areas which affect the availability of clams to the market:

1. The primary obstruction to efficient management of our clam resources and enhancement of availability to the market is the cumbersome and inadequate legal structure. Whether the present arrangement continues, wherein the towns have primary management responsibility, or whether the state assumes primary responsibility, changes are needed to: 1) improve the flexibility in implementing

management decisions, 2) to more readily enable the designation of geographic (rather than political) management units, and 3) to provide adequate legal protection for clam flats under management.

2. Pollution continues to be a major problem in that it still ties up sone 18% of the state's potentially productive acreage (Table D-1-2). Industrial contamination, heavy metals, and oil spills are included, but domestic pollution is by far the greatest contributor. Municipal and private residence abatement of polluting practices is proceeding at a modest rate and the future looks somewhat brighter than it has been. Table D-1-6 shows the acreage and estimated production of clams from areas that have had unrestricted openings due to pollution abatement, 1970 to 1978; Table D-1-7 shows the same for areas with conditional (seasonal) openings; and Table D-1-8 shows the same for areas where pollution has been sufficiently reduced to permit digging for depuration purposes.

   Longevity, long-range effects, and significant of oil, heavy metals, and radionuclide contamination is largely unknown and needs investigation.

3. Paralytic shellfish poisoning (*Gonaulax tamarensis* toxin)

is a seasonally serious problem in that when it occurs, it is generally during the season of greatest demand and high prices; hence, the losses to the market come at the most unfavorable time of the year. Additionally, in times of long period closures, the entire seafood market is affected through general fear of the effects of the toxin. The location and intensity of paralytic shellfish poisoning (PSP) outbreaks are monitored by DMR, but there is need for: 1) development of predictive capability to be able to forecast unacceptable increases in toxicity; 2) development of detoxification methods to utilize clams otherwise withheld from the market; and 3) determination of the effects of PSP on clam physiology, reproduction, growth, and survival, as well as its effects on other forms of marine life.

4. Inadequate resource information is a hindrance to the comprehensive management of the state's clam resource as a whole. At present, resource surveys are, for the most part, conducted only as required of the towns by DMR to fulfill state requirements for the towns to be able to pass their own ordinances pertaining to clam management. Many clam-producing areas remain unsurveyed (76.2%, Table D-1-4. Resource location maps (State Planning Office)

undated) give approximate locations of productive areas, but quantitative surveys have yet to be made in many cases. Data such as year class strengths, growth, natural mortality, standing crop and potential yield are needed to make management decisions on all producing areas.

5. The problem of irregular or inadequate sets in many areas renders regulation or management much more difficult. There is a need for the development of practical methods to circumvent such occurrences, such as: 1) transplanting of young clams from overpopulated or contaminated areas; 2) attracting or accumulating natural set metamorphosing from the planktonic stage or migrating over the surface, and 3) hatchery-raising juveniles for transplantation to growing areas. Limited work on gear development, use, and transplanting has been carried out in utilizing natural accumulations of set, usually with considerable success (Goggins, 1978). Specific and controlled studies need to be carried out on such aspects as: 1) refinements in gear and methods of use, 2) adaptability to various bottom types; 3) effects of dredging in the seed clam area; 4) repopulation of the seed clam area; and 5) fate of the transplanted clams (ability to burrow, mortality and other losses, growth).

6. Growth can be so slow in some areas, particularly in Hancock and Washington Counties, that clams require many years (7-12, or even more) to reach a marketable size. Effort is needed to try to develop means of utilizing these stocks of clams, either by transplanting to faster-growing areas, or by promoting faster growth in each particular area.

HARVESTING

PERSONNEL

The Maine clam digger is, in many ways, the personification of the highly independent fisherman who finds easy entry into a low investment fishery. If he is industrious and stocks of clams allow it, he can make a comfortable living for his family and remain relatively independent of supervisors and time schedules. Many, however, are not full-time clam diggers, or do not produce the total catch potentially available during each tide. Quotas are frequently set by buyers, particularly when the demand is low, but many diggers tend to produce up to a personal quota based on their actual requirements for money.

Capital investment is very low in this fishery. The bare minimum required includes a pair of hip boots, a clam hoe, and several clam hods. Motor vehicle transportation is usually required to areas with shore access, and a skiff and outboard motor may be required to get to areas without land access, or to nearby islands.

Table D-1-9 and Figure D-1-3 show the number of commercial shellfish licenses (state) issued over the past four decades. From Figure D-1-3, it appears that the number of licenses rose a few years following the increase in landings during the latter 1960's. The landings, licenses and average price per pound then rose in parallel for a few years. During the past 5 years, it appears that the overall availability of clams (as indicated by the landings) has had more influence on the number of licenses sold than the average price per pound, which has continued to rise steeply.

Although the correlations exist as shown above, the total number of commercial licenses sold by the state is not a very good measure of the amount of effort going into harvesting the annual total landings. Many license holders may not dig at all, or others perhaps only very infrequently. A somewhat better indication of effort can be obtained from Table 10 ,derived from the last analysis of shellfish license application questionnaires by DMR in 1973-74. From this table one can see that 73% of the commercial license holders dig less than 6 months out of the year, while 40% dig only a bushel or less per day. In Table D-1-11, converting the effort data to amounts harvested, it is evident that about three-quarters of the total clams dug per day are dug at the rate of 1.1 to 3.0 bushels per day, while about two-thirds of the annual landings are dug by men working from 3 to 8 months out of the year.

Fisheries are often spoken of as being manned by aging workers and lacking a healthy influx of the young. The results shown in Table D-1-12 and Figure D-1-4 seem to contradict this idea in the case of shellfishermen. It is evident from these data that a lot of young fishermen are in the clam fishery, but the complete picture still may not be apparent. If is entirely likely that the large percentages of younger diggers represented in Table D-1-12 and Figure D-1-4 may also make up the sizable groups shown in Table D-1-10 that dig minimal quantities per day during a minimal number of months out of the year. In other words, they may make up the major part of the part-time workers in the clam fishery. The data to determine whether or not this possibility is true probably exists in the questionnaires used by Goggins (1975), but the required analysis has not as yet been run.

METHODS

In Maine, soft-shell clams can be taken only by implements operated solely by hand, with the following exception. Under special license, a hydraulic or mechanical soft-shell clam dredge can be operated for aquaculture or research (DMR, 1979). Under such circumstances the harvesting of seed clams for transplanting has been carried out by municipalities.

In a typcal clam digging operation, the digger uses 1 4- or 5-tined, short-handled ford, called a clam hoe. The shape and angle of the tines may be modified to meet a digger's personal requirements or to suit the type of sediment in the flats commonly dug. Two generalized methods of digging the clams are used. In the first, if clams are not very deep in the flats (in hard sediments where clams cannot burrow deeply), the clam hoe is pushed in to the optimum depth and tipped to break out a solid chuck of flat. This chuck is tipped upside down into the area behind it, previously dug, and the clams are picked off the under side of the chunk. In the second and much more common method, where clams are deep in sandy or muddy sediments, the top layer of 3 to 5 inches is first skimmed off into the previously dug hole behind it. Then a deeper chunk of flat is turned out, containing or exposing the market-size clams. Both methods result in the burying of many of the remaining clams, particularly the smaller ones in the top 1 or 2 inches of flat, which has been dumped at the bottom of the previously dug pit. Such clams have only a 50% chance of surviving the burial. Breakage of clams in the process of digging averages about 20% (Dow, Wallace, Taxiarchis, 1954) and less than 1% of those broken can be expected to survive (Glude, 1954).

Clams dug out are placed in a clam hod, a slatted basket containing 1 to 2 pecks, are rinsed in nearby sea water, and are ready to be sold.

EFFECTS OF ECONOMIC CONDITIONS ON HARVESTING

The level of harvesting effort is influenced strongly at times by the economic conditions, both local and distant. The demands of the retail market have a direct and early effect on all levels of the supply chain because nearly all of the products are handled in the fresh condition and cannot be stockpiled. The output of the regular digger is controlled to a considerable extent by instructions from his buyer who may set a maximum quota to be dug, who will set the price, or who will refuse to buy. Usually, adjustment of the price offered is sufficient to control the level of harvesting, but under more severe reductions of production, the digger may be limited to a quota, or a maximum amount that he can dig. The buyer prefers the quota to a layoff because it keeps the regular diggers employed and tends to keep them selling to the same buyer. Under extremely poor market conditions, an absolute layoff may be necessary, which puts the digger out of business unless he can peddle his clams locally himself.

The most serious market competition the Maine soft-shell clam has, even within Maine, is the Maryland soft-shell clam (same species). In Chesapeake Bay, it is subtidal, fast-growing, and harvested by hydraulic escalator dredges. It is used in some segments of the market because it is often readily available; of desirable size; less often broken; more evenly sized; with clean, white shell; and very competitive in price.

Data are not available to determine how large a volume of clams are brought into Maine from Maryland. DMR personnel believe, however, that the quantities are sufficiently large to affect prices in Maine. When Maryland clams are readily available, the price to the diggers is held down; when Maryland clams are not readily available in New England markets and demand is strong, the Maine prices tend to rise.

Factors outside the clam market can exert some influence on the level of harvesting. Seasonal employment in other fields can affect harvesting, particularly if it comes during the high-demand summer season. Off-season jobs, such as working in other fisheries, picking blueberries, or wood-cutting, can be the result of lowered demand for clams, but in summer the lure of higher pay, more desirable jobs, or a change may remove diggers from the harvesting scene. Another aspect of the seasonal employment picture is that winter clam digging attracts some individuals who cannot find other employment in a season when the job market is poor.

EFFECTS OF LEGAL CONSTRAINTS ON HARVESTING

As described above, clam digging in Maine can only be done by hand. Digging by clam hoe is inefficient and destructive, with an average loss of 70% of the clams left in the flats at each digging (Dow, Wallace, Taxiarchis, 1954; Glude, 1954). About the best that can be said for hand digging is that it requires small capital investment of the fisherman and probably employs more people than a mechanized or hydraulic method would.

The laws authorizing, defining, and regulating local controls over clam harvesting are some of the most numerous and complex in the entire clam fishery. Except for the enabling state laws, most of the regulations are in the form of municipal ordinances and are aimed principally at:

regulating and/or licensing resident, non-resident, commercial, and non-commercial diggers; establishing areas to be controlled; and establishing size and catch limits.

The overall effect of local regulation on the level of harvesting is undoubtedly a favorable one, although a numerical value cannot be attached. The most important feature of such regulation is to limit repeated digging (and hence unnecessary clam destruction) in areas that are closed until ready for harvest. Overdigging, resulting in further increases in mortality and depleted flats, can be avoided by the municipal control of areas dug, number of licenses, catch limits, and periods of digging.

State regulations do not include control of size limits of clams. There are a number of reasons for this, the most important being: 1) size limits, particularly the minimum size, are not applicable on a statewide basis because of widely varying growth rates and maximum sizes; 2) current management philosophy, considering the destructiveness of the clam hoe, is that the less frequently a clam flat is dug, the better, hence each digging at prescribed intervals should be aimed at removing all marketable clams at that time; 3) there is little, if any, biological advantage to having a minimum size limit as long as most of the commercial catch is made up of clams exceeding the minimum size at spawning (25 to 35 mm, or 1 to 1-3/8"); and 4) in areas where a minimum size limit might be advantageous to a more efficient use of the resource, the municipality has the authority (through its ordinance) to establish the desired minimum. In addition to the above, buyers and dealers are free to establish their own lower size limits if it appears that diggers are bringing in too many small clams which are not utilized by the shucking houses.

The numerical effect of the general absence of a minimum size limit on harvesting is unknown, but such absence has permitted the harvesting of areas of stunted clams which seldom reach the 2-inch size; it has also undoubtedly allowed better utilization of more clams in areas where digging has been limited to prescribed periods.

The closing of clam producing areas because of public health restrictions has prevented substantial quantities of clams from reaching the market. These closures are of four general types: 1) long-term closures based on sustained levels of pollution (domestic or industrial) that are too high to permit depuration; 2) public closures based on sustained or seasonal levels of pollution which are sufficiently and consistently low enough to permit utilization of clams by means of the depuration process (in which case digging is by special permit and strictly controlled); 3) seasonal closures or "conditional areas" which are opened during seasons (usually winter) when pollution loads are low or absent; and 4) emergency closures for such occasions as outbreaks of paralytic shellfish poisoning (PSP) and which remain in effect only as long as the unacceptable conditions prevail.

Table D-1-2 shows that 16% of the state's total estimated production capacity is in closed growing areas, varying from 91% of York County to

8% of Washington and Hancock counties. However, since 1974, these levels of closure have been reduced from 20% of the state's total, varying from 98% of York County to 9% of Washington County (Goggins, 1975; Winters, 1979). This reduction has been possible because of continuing abatement of municipal and private residential domestic pollution. In the period 1970 through 1978, 1,577 acres have been reclaimed in this manner, with an estimated production capacity of 156,617 bushels of clams, valued at $3,445,574 (Table D-1-6).

During the same period 1970-1978, 1,836 acres were opened to depuration digging for the same reason. These areas were estimated to be capable of producing 141,114 bushels of clams, valued at $2,116,710 (Table D-1-8).

Again during the same period, 645 acres were opened to conditional (seasonal) digging because pollution levels were reduced, usually in winter, to a point where open digging (not requiring depuration) could be permitted. These areas were estimated to be capable of producing 37,998 bushels of clams, valued at $835,956 (Table D-1-7).

From the records of the depuration plants (Table D-1-5), one may see that actual amounts of clams processed have varied from 11,479 to 15,978 bushels per year, constituting 2.9 to 3.1% of total annual landings of clams.

It appears that substantial progress is being made in the freeing of productive clam flats from pollution and returning them to commercial and recreational use.

MAINE'S PROBLEMS IN HARVESTING

The greatest problem in harvesting is a supply which fluctuates widely and even at its best is less than optimum. As described in a previous section, the principal reasons for this are: 1) stocks locked up in polluted areas, 2) stocks reduced by cyclically-severe predation or unreliable setting, and 3) lack of adequate management of existing stocks.

In addition to these aspects of the supply problem, there are other problems directly related to harvesting:

1. The irregularity and undependability in harvesting effort makes it very difficult to maintain a constant or a desired level of harvesting. Some diggers work steadily and dependably at their jobs, but a great deal of harvesting is done by part-time diggers and those who have a tendency to produce only enough to satisfy immediate monetary needs. Buyers find it very difficult to balance actual market demands against the ups and downs of harvesting.

2. Methods for improving harvesting, such as the development and use of less destructive methods and gear, meet with little interest and cooperation from the diggers. They have strong preferences for the old ways and are very suspicious of any new methods or gear that might be less labor intensive and thus reduce the need for manpower. Hydraulic dredges of various types that have been proven efficient and relatively

non-destructive in certain types of areas have been bitterly opposed by diggers who have seen themselves threatened by such innovation.

3. The problem of thr tangle of municipal laws governing the who, where, when, and how of clam harvesting could be much simplified if the clam resource, state-wide, were a direct responsibility of DMR. Because of the extreme variability in the character of clam flats and the need for area-by-area survey and management, however, the monetary and manpower needs of DMR would have to be increased greatly. Since such a change is not likely, in the meantime the best that can be accomplished by DMR is to coordinate municipal regulation and to endeavor to have regulation based upon conservation objectives.

4. A major problem in evaluating the effectiveness of various types of management and various levels of management intensity is the lack of feedback from harvesting a given area. What is needed is total tally of the quantities of clams coming from a particular management area. Only with these data can the effectiveness of harvesting predictions be judged, or refinements be made in management methods.

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Table D-1-1.

Landings of Soft-shell Clams in Maine
(From Doggins, 1975 and DMR unpublished data)

	Bushels		Pounds of Meats		Total Value
Year	Thousands	Price per bu.	Millions	Price per. lb.	$ Thousands
1887	407	.570	6.1	.038	226
1888	400	.570	6.0	.038	228
1896	360	.690	5.4	.046	249
1897	353	.690	5.3	.046	244
1898	580	.480	8.7	.032	280
1899	547	.645	8.2	.043	347
1900	580	.600	8.7	.040	353
1901	507	.645	7.6	.043	329
1902	507	.660	7.6	.044	333
1903	440	.750	6.6	.050	437
1904	427	.765	6.4	.051	324
1905	413	.870	6.2	.058	356
1906	513	.735	7.7	.049	379
1907	607	.990	9.1	.066	602
1908	647	.840	9.7	.056	540
1909	487	1.01	7.3	.067	500
1910	627	1.14	9.4	.076	730
1911	520	1.11	7.8	.074	580
1912	633	1.22	9.5	.081	768
1913	347	.84	5.2	.056	291
1914	413	1.16	6.2	.077	481
1916	513	1.02	7.7	.068	524
1919	140	1.17	2.1	.078	163
1924	240	.96	3.5	.064	228
1929	447	1.05	6.7	.070	473
1930	660	.525	9.9	.035	349
1931	467	.51	7.0	.034	239
1932	487	.48	7.3	.032	234
1933	433	.51	6.5	.034	224
1935	467	.615	7.0	.041	286
1938	473	.675	7.1	.045	318
1939	333	.615	5.0	.041	210
1940	400	.600	6.0	.040	237
1941	453	.855	6.8	.057	390
1942	400	1.17	6.0	.078	470
1943	313	1.95	4.7	.130	614
1944	227	1.85	3.4	.123	415
1945	387	2.00	5.8	.133	776
1946	653	2.76	9.8	.185	1,815
1947	527	2.85	7.9	.190	1,497
1948	600	3.02	9.0	.201	1,801
1949	573	2.48	8.6	.165	1,420
1950	460	2.58	6.9	.172	1,184
1951	340	3.48	5.1	.232	1,187
1952	367	4.41	5.5	.294	1,623
1953	280	5.00	4.2	.333	1,382
1954	247	5.49	3.7	.366	1,360
1955	173	5.43	2.6	.362	949
1956	167	5.36	2.5	.357	897
1957	133	5.64	2.0	.376	700

	Bushels		Pounds of Meats		Total Value
Year	Thousands	Price per bu.	Millions	Price per lb.	$ Thousands
1958	107	5.61	1.6	.367	600
1959	93	5.67	1.4	.378	500
1960	140	5.82	2.1	.392	823
1961	120	6.62	1.8	.441	794
1962	127	7.07	1.9	.471	894
1963	120	6.56	1.8	.437	787
1964	120	6.89	1.8	.459	827
1965	133	7.23	2.0	.482	964
1966	200	6.93	3.0	.462	1,387
1967	213	6.93	3.2	.462	1,479
1968	227	6.29	3.4	.419	1,425
1969	280	6.33	4.2	.422	1,753
1970	353	7.13	5.3	.475	2,497
1971	353	7.70	5.3	.513	2,694
1972	407	9.06	6.1	.604	3,709
1973	484	11.78	7.3	.786	5,701
1974	394	11.46	5.9	.764	4,511
1975	436	13.00	6.5	.869	5,692
1976	516	15.00	7.7	1.00	7,812
1977	522	17.70	7.8	1.18	9,271
1978	400	18.65	6.0	1.24	7,469

Table D-1-2.

Soft-Shell Clam Growing Areas and Their Estimated Production Capacity, 1978
(From Goggins, 1975 and updated to 1978 from Winters, 1979)

	Total Growing Area			Total Production Capacity			Open Growing Area				Open Growing Area Production Capacity				Closed Growing Area				
		%			%			%				%				%			
	Acres	of Reg. Total	of State Total	Bushels	of Reg. Total	of State Total	Acres	of Reg. Total	of State Total	of State Open	Bushels	of Reg. Total	of State Total	of State Open	Acres	of County Total	of Reg. Total	of State Total	of State Closed
Region I	11,040	-	24	1,067,280	-	27	7,677	69	17	20	784,662	74	20	23	3,371	-	30	7	42
York	682	6	1	55,840	5	1	67	1	<1	<1	4,922	<1	<1	<1	615	90	6	1	8
Cumberland	7,998	73	18	869,195	82	22	6,680	60	14	18	714,715	67	18	21	1,318	16	12	3	16
Sagadahoc	2,388	21	5	142,245	13	4	930	8	2	2	65,025	6	2	2	1,438	61	13	3	18
Region II	8,211	-	18	642,472	-	16	5,829	71	13	15	464,944	72	12	14	2,382	-	29	5	29
Lincoln	3,299	40	7	225,120	35	6	2,542	31	6	7	189,627	30	5	6	757	23	9	2	9
Knox	3,236	40	7	281,591	44	7	2,615	32	6	7	225,686	35	6	7	621	19	8	1	8
Waldo	1,676	20	4	135,761	21	3	672	8	1	2	49,631	8	1	1	1,004	60	12	2	12
Region III	26,886	-	58	2,299,425	-	57	24,558	91	53	64	2,113,090	92	53	63	2,328	-	9	5	29
Hancock	10,115	38	22	728,925	32	18	9,277	34	20	24	668,815	29	17	20	838	83	3	2	10
Washington	16,771	62	36	1,570,500	68	39	15,281	57	33	40	1,444,275	63	36	43	1,490	9	9	3	19
State	46,145	-	100	4,009,177	-	100	38,064	-	82	100	3,362,696	-	84	100	8,081	-	-	18	100

	Closed Growing Area Production Capacity					1978 Harvest			
		%					% (Open Area)		
	Bushels	of County Total	of Reg. Total	of State Total	of State Closed	Bushels	of County Prod. Cap.	of Reg. Prod. Cap.	of State Prod. Cap
Region I	282,618	-	26	7	44	63,370	-	8	2
York	50,918	91	5	1	8	14,116	287*	2	<1
Cumberland	154,480	18	14	4	24	43,546	6	6	1
Sagadahoc	77,220	54	7	2	12	5,708	9	1	<1
Region II	177,528	-	28	4	27	66,411	-	14	2
Lincoln	35,493	16	6	1	5	28,630	15	6	1
Knox	55,905	20	9	1	9	37,781	14	8	1
Waldo	86,130	63	13	2	13				
Region III	186,335	-	8	5	29	270,701	-	13	8
Hancock	60,110	8	3	1	9	99,575	15	5	3
Washington	126,225	8	5	3	20	171,126	12	8	5
State	646,481	-	-	16	100	400,482	-	-	12

*Appears to point to a very large error in estimating open growing area and its production capacity for York County.

Table D-1-3.

Status of Resource Assessment and Clam Management, 1978
(From data in Goggins, 1978)

	Resource Surveys				Management											
	1975 1976	1976 1977	1977 1978	Total Acres	Ordinance	Licensing	Town Officer	Reciprocal Agreements	Commercial Digging	Depuration Digging	Catch Limits	Size Limits	Crab Control	Flat Rotation	Clam Transplanting	Other
Region I																
Kittery	-	8	8	16	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
York	12	-	-	12	Yes	Yes	No	No	No	No	Yes	No	No	No	No	Seasonal Openings
Ogunquit	12	12	12	36	Yes	Yes	No	No	No	No	Yes	No	No	Yes	No	-
Wells	-	-	-	0	No	No	No	No	Yes	Yes	No	No	No	No	No	-
Kennebunkport	218	-	-	218	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	-
Biddeford	205	-	-	205	No	No	No	No	No	No	No	No	No	No	No	-
Scarborough	-	-	-	0	No	No	No	No	Yes	Yes	No	No	Yes	No	No	-
South Portland	15	-	-	15	No	No	No	No	No	No	No	No	No	No	No	-
Falmouth	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	-
Cumberland	-	38	-	38	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	-
Yarmouth	31	-	-	31	Yes	Yes	No	No	Yes	No	Yes	No	Yes	No	No	Conservation Closure
Freeport	9	114	-	123	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Brunswick	213	121	-	334	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	Yes	-
Harpswell	-	-	-	0	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	Planned for 1979	Surveys to start 1979
West Bath	-	-	-	0	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Surveys to start 197[illegible]
Phippsburg	-	-	-	0	No	No	No	No	Yes	Yes	No	No	No	No	No	-
Region II																
Georgetown	-	169	169	338	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	Planned	-
Newcastle	-	-	17	17	No	No	No	No	Yes	No	No	No	No	No	No	-
Damariscotta	-	-	6	6	No	No	No	No	Yes	No	No	No	No	No	No	-
North Haven	277	-	-	277	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	# of licenses limited. Comm. catch unlimited
Islesboro	460	281	44	785	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	Same as above
Lincolnville	-	-	5	5	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Northport	-	-	20	20	No	No	No	Yes	Yes	No	No	No	No	No	No	-
Stockton Spr.	-	-	96	96	No	No	No	Yes	Yes	No	No	No	No	No	No	-

Table D-1-3. (continued)

	Resource Surveys 1975 1976	1976 1977	1977 1978	Total Acres	Management Ordinance	Licensing	Town Officer	Reciprocal Agreements	Commercial Digging	Depuration Digging	Catch Limits	Size Limits	Crab Control	Flat Rotation	Clam Transplanting	Other
Region III																
Brooksville	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Castine	-	-	-	0	Yes	No	No	No	Yes	No	Yes	No	No	No	No	-
Deer Isle	-	-	-	0	Yes	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No	-
Stonington	-	-	-	0	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No	No	Survey planned in '79
Sedgwick	-	-	-	0	No	No	No	No	Yes	No	No	No	No	Yes	No	-
Brooklin	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Surry	-	-	-	0	Yes	No	No	No	Yes	No	Yes	No	No	No	No	Survey planned in '79
Trenton	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Swans Island	300	300	300	900	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Bar Harbor	73	-	-	73	Yes	Yes	No	No	Yes	No	Yes	Yes	No	No	No	-
Mt. Desert	17	-	-	17	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	-
Southwest Hbr.	92	-	-	92	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	-
Lamoine	256	-	-	256	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	Survey planned in '79
Gouldsboro	349	188	-	537	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	Survey planned in '79
Winter Hbr.	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	-
Steuben	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Survey planned in '79
Milbridge	-	-	582	582	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	-
Harrington	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Survey planned in '79
Addison	-	138	483	621	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	-
Jonesport	-	245	-	245	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	-
Beals	-	123	-	123	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	-
Jonesboro	528	-	-	528	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Roque Bluffs	-	563	-	563	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Machiasport	303	-	-	303	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	-
Trescott	-	-	226	226	No	No	No	No	Yes	No	No	No	No	No	No	-
Whiting	-	-	-	0	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Survey planned in '79
Edmunds	-	300	-	300	No	No	No	No	Yes	No	No	No	No	No	No	-
Pembroke	-	-	427	427	Yes	No	No	No	Yes	No	Yes	No	No	No	No	-
Perry	-	-	9	9	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	-
Lubec	-	-	-	0	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No	No	Survey planned in '79
Cutler	-	295	-	295	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	Conservation Closure

Table D-1-4

Summary of Table D-1-3

	No. of towns taking some steps toward management	Area surveyed Acres	% of Total open growing area
Region I	16	1,028	14.8%
Region II	8	1,544	28.5
Region III	31	6,097	25.3
Totals	55	8,669	23.8

Total towns having clam resources 101

Total towns having taken no action 46

Table D-1-5.

Processing of Clams Through Depuration Plants

1974-1978

(DMR Unpublished Data)

YEAR	WASHINGTON Bushels	HANCOCK Bushels	WALDO Bushels	KNOX Bushels	LINCOLN Bushels	SAGADAHOC Bushels	CUMBERLAND Bushels	YORK Bushels	TOTAL FOR YEAR Bushels	% OF TOTAL LANDINGS
1974	--	47	2,227	--	--	--	7,069	2,136	11,479	2.9
1975	--	--	--	--	--	--	11,025	2,121	13,146	3.0
1976	--	--	--	--	--	--	14,530	1,448	15,978	3.1
1977	--	--	--	--	--	5,056	9,322	710	15,088	2.9
1978	2,242	163	13	2,435	--	4,794	4,533	810	14,990	3.7
	2,242	210	2,240	2,435	--	9,850	46,479	7,225	70,681	

Table D-1-6.

Commercial Clam Areas with Unrestricted Opening Due to Municipal and Private Pollution Abatement, 1970-1978

(Adapted from Winters, 1979)

	Reclaimed Area (Acres)	Productivity (Total bushels)	Value (Standing Crop $22 per bu.)
Region I	753	78,207	$1,720,554
York	54	3,947	86,834
Cumberland	699	74,260	1,633,720
Sagadahoc	—	—	—
Region II	404	45,690	1,005,180
Lincoln	326	39,120	860,640
Knox	78	6,570	144,540
Waldo	—	—	—
Region III	420	32,720	719,840
Hancock	420	32,720	719,840
Washington	—	—	—
Totals	1577	156,617	3,445,574

Table D-1-7.

Commercial Clam Areas with Conditional (Seasonal)

Opening Due to Municipal and Private

Pollution Abatement, 1970-1978

(Adapted from Winters, 1979)

	Reclaimed Area (Acres)	Productivity (Total bushels)	Value (Standing Crop $22 per bu.)
Region I	289	21,810	$479,820
York	20	1,000	22,000
Cumberland	194	13,160	292,820
Sagadahoc	75	7,500	165,000
Region II	144	4,200	92,400
Lincoln	104	2,600	57,200
Knox	40	1,600	35,200
Waldo	——	——	——
Region III	212	11,988	263,736
Hancock	212	11,988	263,736
Washington	——	——	——
Totals	645	37,998	835,956

Table D-1-8.

Commercial Clam Areas Opened to

Depuration Digging Due to Municipal

and Private Pollution Abatement, 1970-1978

(Adapted from Winters, 1979)

	Reclaimed Area (Acres)	Productivity (Total bushels)	Value (Standing Crop $15 per bu.)
Region I	785	55,830	837,450
York	10	750	11,250
Cumberland	331	19,860	297,900
Sagadahoc	444	35,220	528,300
Region II	570	47,734	716,010
Lincoln			
Knox	—	—	—
Waldo	570	47,734	716,010
Region III	481	37,550	563,250
Hancock	31	1,550	23,250
Washington	450	36,000	540,000
Totals	1,836	141,114	2,116,710

Table D-1-9.

Number of Commercial Shellfish Licenses, 1942 - 1978

(DMR Unpublished Data)

1942	1,292	1961	1,572
1943	1,260	1962	1,505
1944	1,487	1963	1,623
1945	1,501	1964	1,456
1946	1,837	1965	1,613
1947	2,474	1966	1,376
1948	3,326	1967	1,470
1949	2,823	1968	1,194
1950	2,281	1969	2,226
1951	2,006	1970	2,742
1952	2,394	1971	3,175
1953	2,341	1972	4,143
1954	2,553	1973	5,927
1955	2,239	1974	5,493
1956	2,100	1975	5,181
1957	1,976	1976	4,562
1958	1,623	1977	5,291
1959	1,554	1978	4,287
1960	1,553		

Table D-1-10.

Fishing Effort of Clam Diggers - 1973

5,933 total licenses, 3,147 (53%) reporting

(From Goggins, 1975)

Bushels Dug Per Day	No. of Diggers	%
0.1 - 1.0	1,269	40
1.1 - 2.0	1,320	42
2.1 - 3.0	432	14
3.1 - 4.0	81	3
> 4.0	45	1

Months Dug	No. of Diggers	%
0-1	644	20
1-2	676	21
3-5	997	32
6-8	530	17
9-11	117	4
12	183	6

Table D-1-11.

Extrapolation of Table 10 Data to Amounts

of Clams Harvested

Bushels Dug Per Day	No. of Diggers	Total Bushels Dug Per Day
* 0.5	1,269	634
1.5	1,320	1,980
2.5	432	1,080
3.5	81	284
5.0	45	225
		4,203 bu.

No. of Days Dug	% of Diggers Working	Total Bushels Dug Per Day	Total Bushels Dug During Working Period
** 10	20	4,203	8,406
30	21	4,203	26,479
80	32	4,203	107,597
140	17	4,203	100,031
200	4	4,203	33,624
240	6	4,203	60,523
			336,660 bu.

*Using midpoint of each class.
**Using midpoint of each class and based on 20 working days per month.

Table D-1-12

Age-Profile of Commercial Shellfishermen - 1974
(From Goggins, 1975)

	Age-Groups: Percentage of Total											
Number	<18	18-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-64	>64	
33	9.1	9.1	21.2	9.1	12.1	15.2	9.1	-	6.1	3.0	6.1	York
406	16.7	5.7	15.3	12.6	11.1	9.1	9.4	6.4	3.4	7.6	2.5	Cumberland
121	6.6	3.3	9.1	16.5	11.6	15.2	10.7	8.3	7.4	8.3	3.3	Sagadahoc
521	15.4	7.3	15.5	15.4	11.3	9.2	8.3	5.6	3.5	6.7	1.9	Lincoln
566	17.7	6.7	15.5	15.7	10.2	9.5	6.5	5.3	5.3	5.1	2.3	Knox
173	12.1	1.7	14.5	15.0	10.4	12.1	7.5	7.5	7.5	6.9	4.6	Waldo
2152	20.2	5.0	14.6	14.7	10.1	7.7	7.4	6.0	4.7	6.3	3.3	Hancock
1192	12.8	4.9	12.8	11.7	11.7	10.2	8.4	8.2	6.8	9.3	3.0	Washington
560	14.1	7.1	14.3	13.2	11.3	10.7	9.6	6.4	4.6	7.5	2.9	Region I
1260	16.0	6.3	15.1	16.1	10.7	9.8	7.4	5.7	4.8	6.0	2.4	Region II
3344	17.5	5.0	14.0	13.6	10.7	8.6	7.8	6.8	5.5	7.4	3.2	Region III
5333	16.4	5.4	14.5	14.2	10.8	9.1	7.9	6.5	5.2	7.1	2.9	State

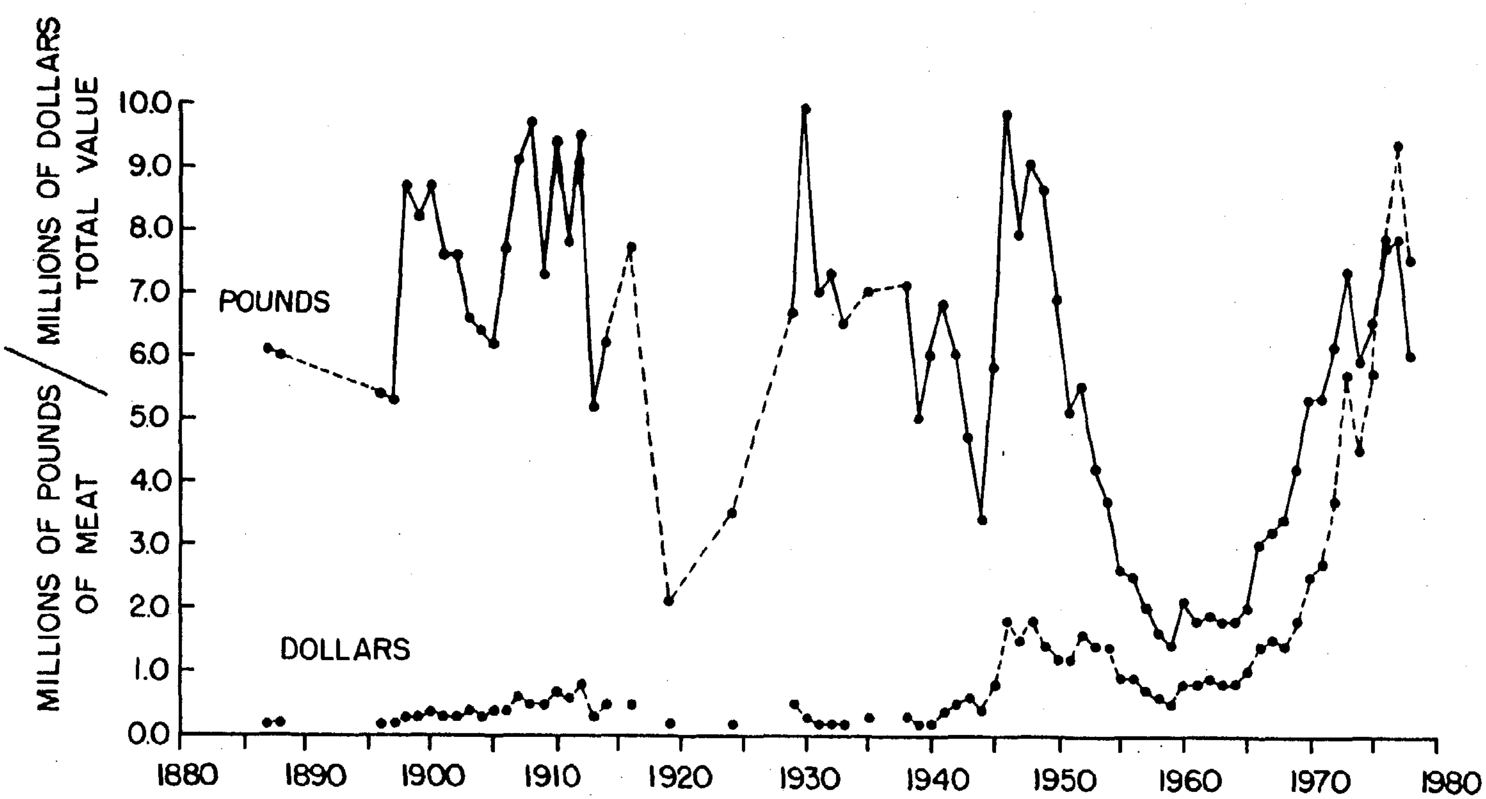

FIGURE D-1-1.
TOTAL LANDINGS OF SOFT-SHELL CLAMS IN MAINE, 1887 - 1978
(DMR UNPUBLISHED DATA)

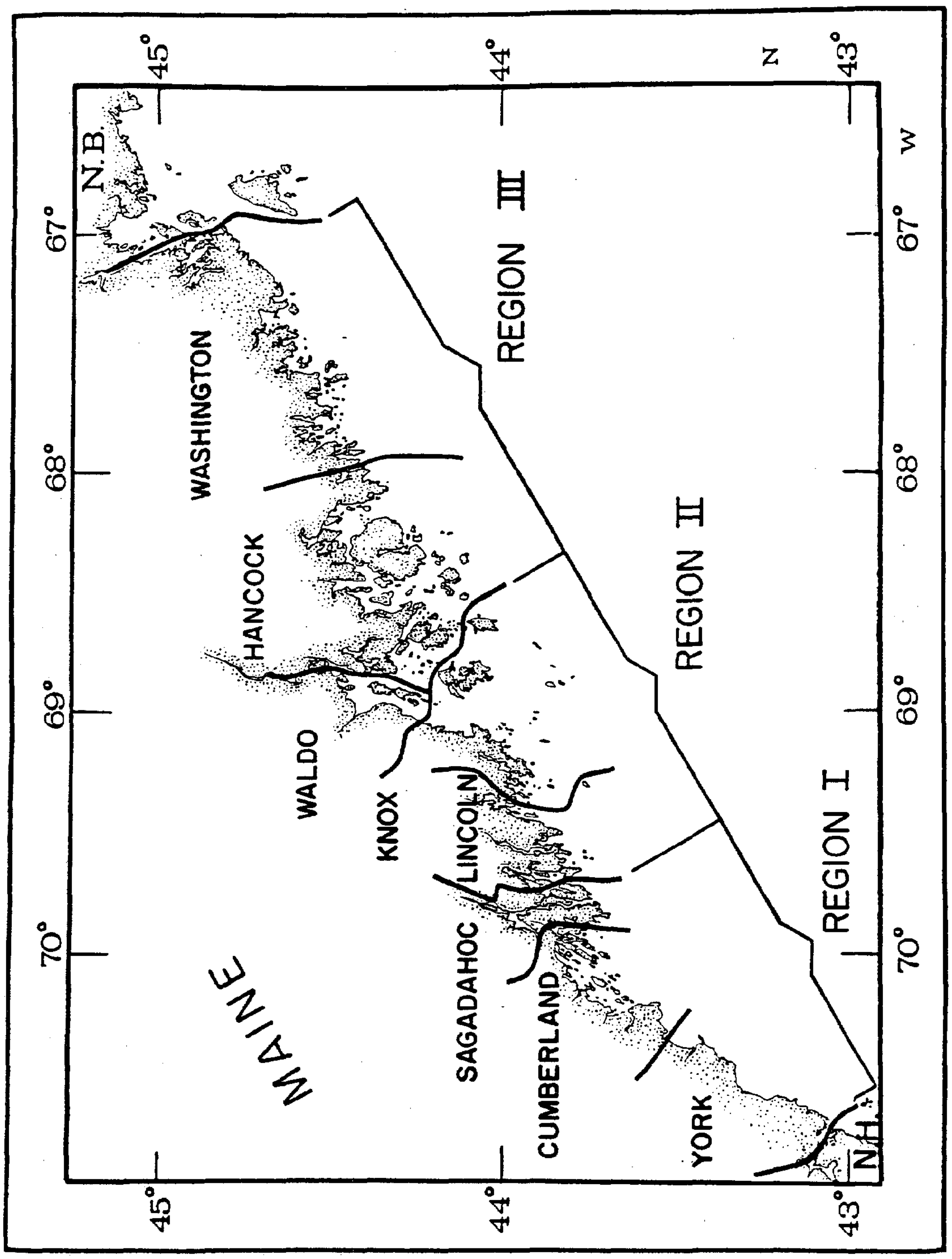
N.B.
WASHINGTON
HANCOCK
WALDO
KNOX
LINCOLN
SAGADAHOC
CUMBERLAND
YORK
N.H.
MAINE
REGION III
REGION II
REGION I
45°
44°
43°
67°
68°
69°
70°
N
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FIGURE D-1-2.

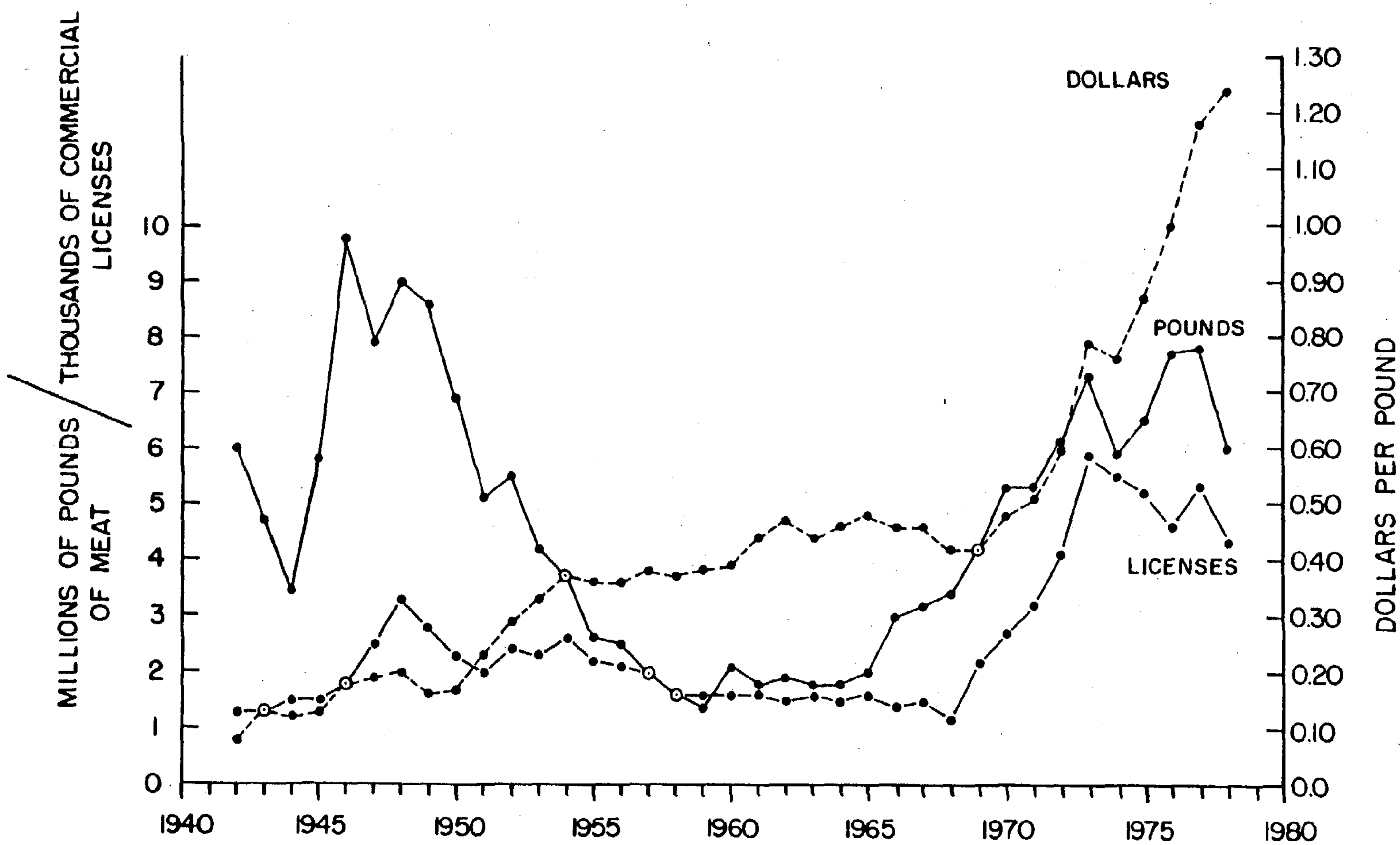

FIGURE D-1-3.
ANNUAL LANDINGS OF SOFTSHELL CLAMS, AVERAGE ANNUAL PRICE PER POUND OF MEATS, AND ANNUAL TOTAL COMMERCIAL SHELLFISH LICENSES, 1942 - 1978 (DMR UNPUBLISHED DATA)

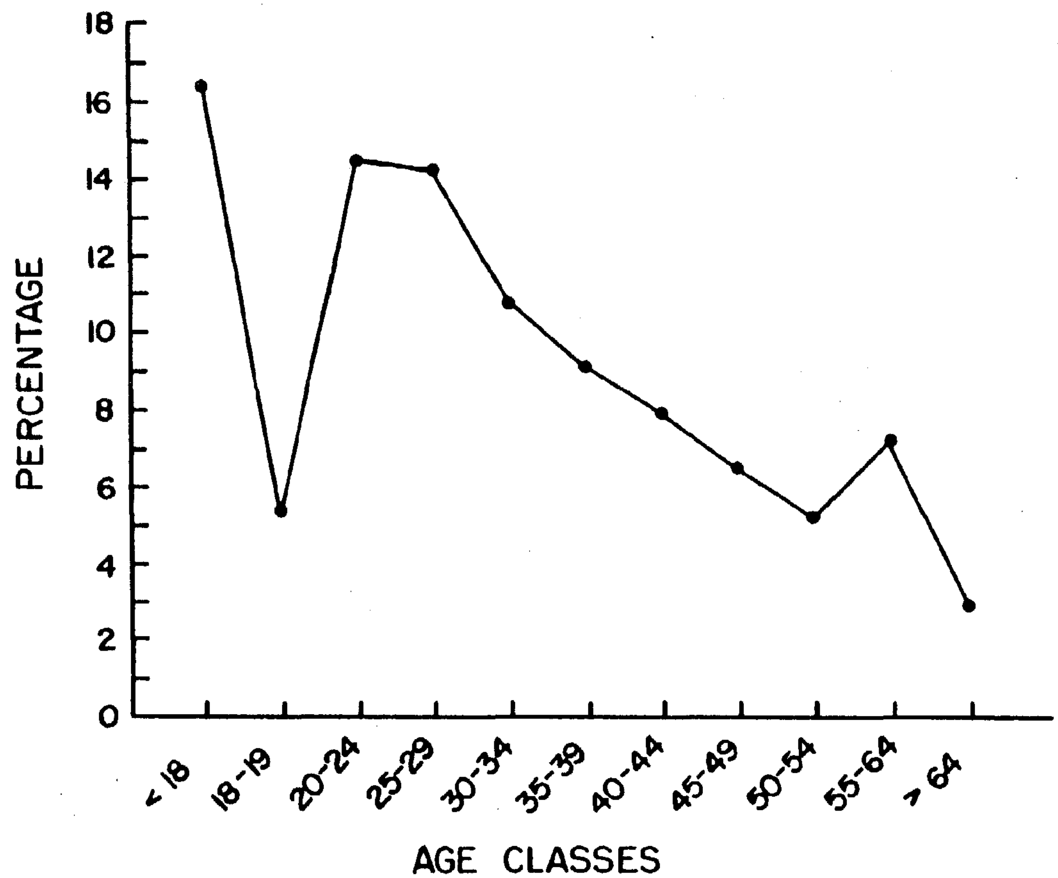

FIGURE D-1-4.
AGE PROFILE OF 5,333 COMMERCIAL SHELLFISHERMEN, 1974
(BASED ON DATA FROM GOGGINS, 1975)

ELEMENT D-2: A CHARACTERIZATION OF THE NORTHERN SHRIMP FISHERY OF MAINE.

by

Alden P. Stickney

I. GEOGRAPHICAL OCCURRENCE

The northern shrimp *(Pandalus borealis)*, sometimes called the pink shrimp, is circumboreal in distribution. Populations occur in the Barent's Sea, Norwegian Sea, North Sea; off the coasts of Iceland, Greenland and Labrador; in the Gulf of St. Lawrence and the Gulf of Maine. On the Pacific side, the species is found in the Gulf of Alaska, the Bering Sea and the Sea of Okhotsk. The southernmost limit is in the Gulf of Maine (Lat. 41° N); elsewhere none occur south of Lat. 45° N (Haynes and Wigley 1969). Although the northern shrimp requires relatively cold water—not above about 12°C (Allen 1959)—it does not reproduce well and grows very slowly at near freezing temperatures (Squires 1968; Horsted and Smidt 1965), hence it is not common in Arctic waters (Haynes and Wigley 1969).

In the Gulf of Maine, the densest populations of *P. borealis* are in the western, or inner, part (Fig. D-2-1) with localized concentrations near Jeffrey's Ledge, Wilkinson Basin, Cashes Ledge and Mt. Desert Rock. These population centers were described by Haynes and Wigley (1969) on the basis of surveys made during the period 1963-1965. Other centers may exist and all may change from time to time. Few shrimp were taken in these surveys in the eastern part of the Gulf and near the southern end of Nova Scotia, indicating a break in distribution from the more northern populations.

P. borealis occurs in depths from 20-900 meters (Hjort and Ruud 1938). A complete discussion of the distribution of the species within the Gulf of Maine requires an account of its life history because seasonal migrations associated with certain developmental periods create marked changes in distribution patterns (Apollonio and Dunton 1969). Briefly, the eggs hatch in late winter, the larvae are pelagic until metamorphosis sometime in mid-summer and the young shrimp, now bottom dwellers remain juveniles until the end of their second summer. At the end of the third summer they become mature males. For a brief period during the third winter and following spring the sex changes and the animals are in an intermediate sexual condition called transitional. They become fully female at the end of the fourth summer and lay eggs for the first time. These eggs are impregnated by the males of the up-coming year class. Females sometimes live to spawn once or even twice more so that the population of mature females may contain several age groups.

Migrations between the shallow waters near shore and the deeper waters offshore occur annually but involve different age groups at different times of the year. After extruding their eggs in August through September, the ovigerous females remain in deep water until December at which time they migrate inshore where they stay until the eggs hatch in February and March. After the eggs are hatched the spent females return to deeper water. The pelagic larval shrimp and the juveniles remain in inshore waters, but when they approach maturity as males they migrate offshore in November and December. The distribution of the various life history stages resulting from these movements is summarized in Figure D-2-2.

II. AVAILABILITY

The shrimp population varies in its availability to the fishery, reflecting several kinds of natural and artificial restraints. Artifically imposed legal restrictions may limit the times or places fished, the quantities captured and the effectiveness of the gear used. Economic factors determine whether the fishing is worth the investment in gear and effort, and of course weather conditions play a big part in the amount of fishing that can be done. The major factors, however, in determining the availability of the shrimp are biological: the abundance and distribution of the shrimp themselves.

1. Abundance. Historically, shrimp have been plentiful in the Gulf of Maine, at least intermittently. Rathbun (1884) stated that at that time shrimp were abundant though not extensively fished because of the limitations of contemporary gear for fishing in deep water. Although the otter trawl came into use about 1905 in the Gulf of Maine, few shrimp were taken, probably because the meshes of the nets used (for groundfish) were too large (Scattergood 1952). Birdseye (1928) records small quantities of shrimp being landed in 1927 and some years earlier. In 1927 and 1928 the General Sea Foods Corporation sponsored several exploratory cruises using commercial vessels and gear to make assessments of the shrimp populations in the Gulf of Maine off the Maine and New Hampshire coasts. Catches as high as 2000-3000 pounds a day were taken by one vessel between Cape Ann and Boone Island in January 1928.

Although the evidence indicated that shrimp were widely abundant in the Gulf of Maine, the company concluded that more study and effort were needed before a dependable fishery could be undertaken. Hjort and Ruud (1938) investigated the shrimp populations in the Gulf of Maine with the research vessel "Atlantis" in 1936, so that they might compare these populations with those in the North Sea and the Skagerak. Their conclusion was that the abundance of shrimp in the Gulf of Maine, based on the analysis of the samples by Bigelow and Schroeder (1939), compared favorably with that in Norway and Sweden.

Not until 1938 was a purposeful fishery for shrimp undertaken from which reliable catch statistics could be obtained. From 1938 to 1979, however, catch data are available from which estimates can be made of the relative abundance of shrimp (Table D-2-1 and Fig. D-2-3). This span of about 40 years can be divided into two major periods of abundance—one where effort was small and perhaps tentative and catches were modest, and a second following a four year period of scarcity which was characterized by increasing abundance and effort to culminate in the peak landings of over 10 thousand metric tons in 1969.

For many years the major producing areas were along the coast of Maine (Fig. D-2-4), off Cape Elizabeth, Cape Small, Sheepscot Bay and Pemaquid Point (Scattergood 1952). During the second phase of the fishery (1958 to the present time) a considerable expansion in the areas and seasons fished took place. Earlier, the coastal fishery had been a winter fishery because of the concentration of ovigerous females there at that time of year. Later a summer fishery developed on offshore areas such as Jeffreys Basin, Stellwagen Bank, or Scantum Basin. Although the vessels fishing these populations were mainly from Gloucester, Massachusetts their catches were frequently landed in Maine ports.

Since 1964 the shrimp and the shrimp fishery have been studied far more intensively than in previous years; for that reason data are available to provide a much better assessment of the shrimp population than was possible during the earlier years of the fishery. Abundance indices in terms of catch per day fished have been calculated for different size classes of fishing vessels. These data (Fig. D-2-5) give a better index of abundance than do landings by themselves. They show, however, the same general decline in abundance from 1969 on as do the landings. Similarly, the results of research cruises, both by the State of Maine and by the National Marine Fisheries Service, show a decline in abundance during that period. Estimated stock size (Northern Shrimp Scientific Committee 1979) dwindled from 27 thousand metric tons in 1969 to less than a thousand in 1979.

Unfortunately no comparable data are available for the period 1938-1953. The landings were, of course, several orders of magnitude smaller during that period, but the effort was much lower as well. While over 300 boats engaged in the fishery between 1969 and 1975, the greatest number fishing during the earlier period was 31. Between 1969 and 1977 the catch per day per vessel ranged from 0.73 to 2.57 metric tons. In 1938, a few incidental figures given by Scattergood (1952) for individual vessels, 0.75 and 0.56 metric tons per day, give an indication of abundance in that period. Although the abundance of shrimp in the earlier period may not have been as great as in the later period, it was probably much higher than landings would indicate.

Between the early and recent periods there occurred a four-year hiatus when virtually no shrimp were landed despite persistent attempts to find them; and as recent statistics show, there is at the time of this writing another period of low abundance. Thus in the past 40 years the shrimp populations have undergone two major cycles of abundance and scarcity. The causes of these cycles are not known with certainty but may include several factors.

The first of these is the ability of the species to reproduce itself, including the fecundity of the parents, and the survival of eggs and larvae. Each female shrimp produces from 800 to 3400 eggs, depending on her age and size (Haynes and Wigley 1969). Egg mortality and its causes have been discussed by Haynes and Wigley (1969); Apollonio and Dunton (1969); Stickney and Perkins (1977, 1979) and can occur through accident, parasitism and disease and unfavorable conditions. Stickney and Perkins reported that the incidence of parasitized (non-viable) eggs averaged 5% of the egg mass in 1974-75 and about 1% in 1978-79; percentages of females infected were 92% in 1974-75 and 55% in 1978-79. Haynes and Wigley (1969) found 74% of a sample collected prior to 1865 infected, with the average infection about 1% of the egg mass. These percentages do not include eggs that were killed and disintegrated prior to the observation, nor the additional ones that would have been killed if the shrimp had remained in the habitat. Egg losses from all causes may be high. Stickney and Perkins (1979), by comparing the egg numbers carried by shrimp just prior to hatching with an expected number derived from a size-fecundity curve, found that in 1974, for instance, the numbers of eggs at hatching time were 24% lower than they should have been. Substantial egg losses from ovigerous *Pandalus borealis* have been reported in Alaskan waters (Patrick Holmes, Alaska Dept. of Fish and Game, personal communication); in laboratory experiments, Stickney and Perkins (1975, unpublished report) observed egg losses of up to 25% during incubation. Even higher mortality occurs after the eggs hatch during the pelagic larval period.

No data are available which establish the mortality during this period with certainty, but larval surveys by Apollonio and Dunton (1969) and by Stickney and Perkins (1979) show attrition rates of larvae abundance ranging from 99.9999% to one hundred times that amount during the period of the 6 larval stages. The attrition is not necessarily nor entirely due to mortality, but a very high mortality rate is strongly suggested. The mortality from larva to maturity was estimated by Apollonio and Dunton (1969) as about 99%. A severe mortality befalls the adult females after the first reproductive period and only about 12% of the females survive to spawn a second time (Haynes and Wigley 1969).

The causes of natural mortality include both biotic and abiotic factors; some of these are known while others are either merely assumed or are unknown. Parasitism and disease are probably responsible for some losses in all stages of the life history of the shrimp. The "white egg" parasite described by Stickney (1978) and responsible for the so-called "non-viable" eggs mentioned by several authors kills large numbers of eggs and other egg parasites (Apollonio and Dunton 1969) undoubtedly kill many also. Parasites of juvenile and adult shrimp have also been described, including a bopyrid isopod (Hjort and Ruud 1938; Horsted and Smidt 1956) and a fungus (Uzmann and Haynes 1968; Apollonio and Dunton 1969; Rinaldo and Yevich 1968). The extent to which any of these parasites contributes to natural mortality in the Gulf of Maine is not known.

The principal biotic causes of natural mortality, however, are more likely predation, competition or inadequate food supply—the last named being more of a hazard to larvae than to adults. Bottom fish of many kinds of prey on adult and juvenile shrimp, some quite heavily. Maurer and Bowman (1975) found that 31 out of 80 species studied from Nova Scotia to Cape Hatteras had eaten pandalid shrimp and for size of these species pandalids made up more than 10% by weight of the food eaten. These six species were the barn door skate, the smooth skate, the red hake, the wrymouth, the weakfish and the four-spot flounder. The last two are not common in the Gulf, however. Many species abundant in the Gulf of Maine might have appeared more significant as predators of shrimp had the study of Maurer and Bowman included only that region.

The pelagic larvae of *Pandalus* spp. are undoubtedly consumed by large numbers of planktonic predators such as pelagic fish, ctenophores, or chaetognaths. The larvae themselves feed on diatoms and small zooplankton, the abundance of which is apt to be low in winter, and starvation could also be a major cause for larval mortality.

Among the abiotic causes of mortality, the most important is probably temperature (Dow 1979). *Pandalus borealis* in the Gulf of Maine are living at the southernmost limit of their range and where temperatures may reach detrimentally high levels. Temperature can affect survival at all stages, directly or indirectly, although seldom have deep water temperatures been recorded in the Gulf that are high enough to kill the shrimp directly. Adverse temperatures may affect egg development, behavior, physiology, or incidence of parasites (Stickney and Perkins 1977, 1979; Apollonio and Dunton 1969) in such a way as to increase mortality or reduce reproductive potential.

Dow (1973, 1979) has shown evidence that the abundance of *Panadalus borealis* in the Gulf of Maine is inversely correlated with water temperature. During periods of higher water temperature the abundance of shrimp decreases. A correlation coefficient of 0.66 was given by Dow (1973) between the mean annual water temperature for each year recorded at Boothbay Harbor, Maine, and the landings of shrimp four years later. This relationship suggests the effect of temperature is most strongly felt on the very early developmental stages since most of the shrimp catch consisted of 4-year-old females.

The correlation between temperature and shrimp landings has been criticized for not adequately taking into account the effect of increasing effort, which between 1967 and 1975 has accompanied the rising temperatures and declining catches. Dr. Steve Clark, of the National Marine Fisheries Service (personal communication) showed by using partial correlation analysis that, at least during this period, the correlation coefficient between effort and abundance independent of temperature was higher ($r = -.46$) than that between temperature and abundance independent of effort ($r = -.11$). This comparison, however, deals only with a minor part (9 years) of the larger temperature—abundance cycle, which seems, on the whole, to show a convincing relationship. Moreover, in all discussions of temperature cycles, the data used to support or refute the argument have been surface temperatures recorded at Boothbay Harbor. While these do show a relationship in annual trends to offshore bottom temperatures, they are obviously not the temperatures to which the shrimp are exposed. Unfortunately, the records for the latter are far less complete than the Boothbay Harbor surface temperature record (Fig. D-2-7). In this figure, the mean annual surface water temperatures are shown from 1940 to 1978. In addition, November offshore bottom temperatures, collected by the National Marine Fisheries Service groundfish survey cruises from 1963 to 1978, are also indicated. A third group of temperatures are shown, derived from the mean Boothbay Harbor surface temperatures for the month of August. The November offshore bottom temperatures are correlated closely with the August inshore surface temperatures (r = .92) and can be estimated by the relationship Y = -13.27 + 1.313 X. The month of November is useful as an index of incubation temperature because by November all eggs have been extruded but massive inshore migration has not started yet.

Probably the greatest toll on adult shrimp is taken by the fishery. A summary of the estimated population parameters related to stock size and mortality for the ten year period 1968-1977 is given in Yable D-2-2 (Northern Shrimp Scientific Committee 1979). The instantaneous fishing mortalities listed in the first column are equivalent to annual fishing mortality rates ranging from 51% in 1968 to 86% in 1977. These rates were computed from Maine survey data and an instantaneous natural mortality of 0.25 assumed.

2. Distribution. The second major factor that determines availability is where the shrimp are to be found—either as a result of seasonal movements or their general long term distribution. Until the development of the otter trawl just after the turn of the century, northern shrimp were for all practical purposes unavailable because their habitat was too deep to fish (Rathbun 1884; Scattergood 1952). Now, no known populations are completely unavailable because of their location. Although even modern fishing gear is of limited effectiveness where the shrimp lie close to or among rocky areas of the bottom, and fishermen tend to avoid these areas because of the danger of losing gear, recent improvements in sonar equipment have enabled fishermen to fish closer to ledges than has been possible in the past.

Even populations readily accessible to gear may be available only to vessels large enough to go after them, when they occur a great distance from port. Smaller boats are more apt to limit their fishing to winter inshore populations. Seasonal migrations also affect availability. When the egg-bearing females migrate shoreward in the winter, they become more available not only because of increased proximity to the shore, but also because they tend to be more concentrated in distribution.

It is possible also that winter temperatures influence availability through their effect on the duration of egg incubation. Stickney and Perkins (1977) found that a 2^{o}C difference in mean temperature (*in vitro*) could increase or decrease the incubation time by a month. Since the spent females leave the inshore fishing areas after the eggs have hatched, an additional few weeks of availability to inshore fishing might be assured by a cold winter.

Short term variations in availability may result from unfavorable weather preventing long trips to sea. The winter fishery in particular is subject to hazards of high winds, heavy seas and icing of boats and gear, and the number of days when fishing if possible is limited accordingly.

3. Problems relating to availability. There is little question that not only have stocks been declining drastically over the past ten years, but that excessive fishing pressure has been a major cause. There is also little doubt that the species exhibits severe fluctuations

in abundance as a result of natural but as yet unknown causes related among other things to temperature. Similar fluctuations are known for many other species, even those which are not exploited. The critical question, therefore, is the relative contribution of the two forces, fishing and environment, to the changes in stock size. Can the stock size, yield, or any other population parameter be optimized by regulating fishing pressure, or are they so dominated by uncontrollable environmental forces that regulation is futile? Both of these positions have been defended by knowledgeable people with long experience in the study of *Pandalus borealis* so that the resolution of the problem may have to await new information, or be based on other than biological considerations.

III. HARVESTING

1. The fishermen. The average Maine fisherman is about 42 years old, and has about 10 years of formal education. Actually, however, all age groups are represented about equally in the fishing community and more than 40% have completed high school. Fishing is likely to be a traditional family enterprise, younger men following the steps of their fathers in the trade. Many shrimp fishermen started in the business fishing for other species—groundfish, herring or lobsters and continue to do so for much of the year.

2. The vessels and gear. The first boats in the shrimp fishery were small side trawlers engaged during the summer in the whiting fishery.

Later, numerous lobster boats of various sizes from 28 to 40 feet joined the fleet. These smaller boats were modified in varying degrees, some with the addition of gallows frames, winches or booms, some with little more modification than using the pot hauler to tow a small net. The side trawlers, from 45 to 75 feet, already rigged for towing an otter trawl needed little modification. A few of the larger boats were purchased from southern waters where they had been engaged in the Gulf of Mexico shrimp fishery. Some of these were double rigged, although according to Bruce (1971) this gear was removed and the rig changed to side or stern trawler. A few boats, the largest being the 59 foot "Amy Jo" were built in Maine especially for the shrimp fishery. Others of more modest size were built along the lines of a lobster boat.

The number of vessels operating from Maine ports increased from 29 in 1964 to over 300 in 1974 (Table D-2-3). Until 1968, more than half of the fleet were the larger trawlers, but from 1969 on, there were about twice as many of the smaller lobster boat conversions than the trawlers.

The standard gear used by the larger vessels was the 50-70 trawl, having a 50 foot head rope and a 70 foot foot rope, the latter being either chain or roller gear, depending on the kind of bottom on which they were used. The simple chain footrope, used commonly on the trawls of the smaller boats limited their fishing to relatively smooth bottoms. The doors (otter boards) of the large trawls were rectangular from 5 to

7 feet long and weighed 350 to 800 pounds. Smaller vessels carried smaller gear of various designs, depending on the tastes and experience of the individual fishermen.

The net itself was of nylon or polypropylene twine with 2" (stretched) mesh in the wings, square and belly of the trawl, 1-3/4" to 1-7/8" mesh in the cod end. Also used occasionally by the larger trawlers were the semi-balloon trawl and the 4-seam trawl.

In the last few years of the fishery, the trap was introduced. Similar in function to a lobster trap, the typical shrimp trap was made of wire mesh in the form of a rectanular box with a slit in the top. It was ballasted and buoyed in much the same way as a lobster trap and baited with fish. Although the contribution from traps to the total shrimp landings was very small (not over 3%), the method nevertheless had several advantages. Traps can be fished on irregular bottoms not suitable for trawling, trap caught shrimp are likely to be in better condition when landed, hence of potentially more value; and the method is suitable for a small one man operation with a minimum investment. A good harvest for the trap fishery might average 200-300 pounds per trap per season (Bruce 1971).

3. Fishing practices. Typically, a trip to the fishing grounds and return is made in one day. Most of the localities fished, especially in the inshore winter fishery are not more than 2-3 hours steaming from ports, so that a boat can leave early in the morning and return in the late afternoon before dark. Tows are made for 1-2 hours before hauling

back. Typical catches might be 100-300 pounds of shrimp per tow during periods of abundance.

Fishing boats operate from many ports along the coast, a few of the more important being Portland, Boothbay Harbor, New Harbor, Rockland, Vinalhaven, and Southwest Harbor.

4. Effects of economic conditions on harvesting. When the fishery for northern (pandalid) shrimp first began in the late 30's, the consuming public was generally unfamiliar with the product. Its size and color differed from the southern shrimp usually found in the market. For several years, therefore, the demand for the northern shrimp was low and undependable (Scattergood 1952) and less than maximum fishing effort reflected this. The price, about $.07 a pound (Fig. D-2-3), was hardly an incentive. To improve demand, the Maine Department of Sea and Shore Fisheries (now Department of Marine Resources) undertook the promotion of northern shrimp. Eventually, in 1949, the price reached $.20 a pound but by that time the availability of shrimp was decreasing, and effort that was once only sufficient to meet the demand was increased in an effort to keep up with it. Supply rather than demand was determining the price.

Withe the reappearance of shrimp in 1958, a waiting market offered a premium price of $.40 a pound. This, plus an apparently increasing supply, stimulated the expansion of the fishery, investment in which increased tenfold in the following decade. But with the ever increasing availability of shrimp, there came an inevitable saturation of the domestic market and a decrease in price. Fortunately for the industry, however, a decline in the supply of shrimp in northern European waters which took place in the late 60's resulted in a new and fortuitous overseas market, especially in Scandinavian countries. This development had the effect of boosting prices and encouraging additional effort. A decline in the availability of certain popular food fish (e.g., haddock) at the time also tempted fishermen to turn to fishing shrimp. A healthy, profitable fishery continued for about five years until 1976 when signs of declining abundance were clear. This trend has continued until the present, so that although the price has reached $.70 a pound, so few shrimp are left that virtually no fishing for them is carried on in Maine.

5. Legal constraints on fishing. Legal constraints have been minimal. Virtually no restrictions were imposed prior to 1973 with the exception of the application to the shrimp fishery of certain closed area regulations for trawling in general and the requirements of a fishing license. But because of concern over declining stocks a state-federal conservation program was initiated in 1972 by the National Marine Fisheries Service and the states of Massachusetts, New Hampshire and Maine. Several regulatory schemes were discussed, including minimum size limits on the shrimp in the catch, closed seasons and gear limitations. Of these tentative schemes, all were abandoned except the last and a study to establish a minimum mesh size was begun. In October 1973, an interim minimum mesh size of 1.5 inches (stretched) was adopted

by all three states. As a result of the study the minimum mesh size of 1.75 inches (stretched) was ultimately adopted in 1975. This mesh opening was designed to permit the retention of shrimp larger than 4.7 inches, and permit the escape of 75% of the mature males. A closed season was implemented from July 5 to September 27 in 1975, but this probably had little effect on the Maine fishery which is predominantly a winter fishery. A closure of the fishery in the winter of 1977-78 did have a traumatic effect and in response to pressure from the industry this closure was not repeated the following winter. By that time, however, the reduced supply had made fishing a doubtful risk, anyway.

One legal constraint on fishing generally that applies to the shrimp fishery, although the extent to which its influence is felt is uncertain, is the federal law that requires vessels over 5 tons used for coastal trades (including fishing) to be built in the United States. This limits the choices that a fisherman may have when buying a boat in matters of design, construction, size, etc. vs. cost. Another federal law which levies substantial duties on the imported fishing gear (much of the better gear is imported) adds to the fisherman's costs. It is significant in this respect that while duties on fishing gear have been increasing, the duties on imported fish and fish products have not. Thus federal tax laws seem to hinder the American fisherman while helping his foreign competition (Henry and Halperin 1970).

6. Problems in harvesting. When shrimp are plentiful there are, from the point of view of the fisherman, no major problems in harvesting.

From the biological point of view there are several problems. When the egg-bearing females migrate shoreward in the winter they present the fisherman with an ideal opportunity: high concentrations only a short distance from port. It is obvious why the Maine fishery has been primarily a winter fishery since its inception. There are other reasons why the egg-bearing females are desired—they do not shed (molt the egg carrying period and hence are firmer and more easily handled without damage; furthermore the load of eggs adds to the weight of any given number of shrimp.

Unfortunately, the practice of fishing on a spawning population is not generally viewed as conducive to conservation. Even where such fishing is customary (e.g., the salmon fishery) some escapement is allowed for in managing the fishery. This is not the case in harvesting the shrimp, where fishing pressure is continuous from the time the shrimp arrive in coastal waters to the time the survivors leave. Because the larvae are extremely vulnerable it is imperative that as many eggs as possible be permitted to hatch in order that adequate recruitment to the population be assured. The management of the shrimp fishery in some countries (e.g., Greenland) is designed to permit the escapement of at least half of the ovigerous females.

Another problem related to the harvesting of shrimp is the by-catch of finfish, which may even exceed the shrimp catch. In the 1975 gear evaluation studies, for instance, a total of 30 thousand pounds of shrimp were taken, but along with these were taken 40 thousand pounds of cod, whiting, hake and flatfish. Often this by-catch consists of small, non-marketable individuals which are discarded and thus are a loss to the ultimate yield of those species.

A third, and probably the most serious problem, is related to availability. When shrimp become scarce, it is necessary for the fishermen to shift to other species. Usually this involves costly and time consuming changes in vessel rig or gear. Many fishermen, for this reason or others, cannot afford to shift and are compelled to go out of business. In a questionnaire sent to Maine fishermen (Dunham and Mueller 1976) eight individuals (15% of respondents) replied that they would have to quit fishing if the shrimp fishery collapsed.

It would be highly desirable, therefore, if new fishing boats were designed and built with as much flexibility as possible for multiple-fishery use. Such vessels can be built and have been used, especially on the Pacific coast (Captiva, 1971). Shifts from shrimp fishing to lobstering, groundfishing or herring seining could then be made rapidly and with little additional expense.

IV. PROCESSING

During the prime of the shrimp fishery (1968 through the early 70's), there were over 20 shrimp processing plants operating in Maine in 16 localities (Fig. D-2-4, Table D-2-5); by 1976 there were 7. At the present time there is only one, in Portland.

1. Methods. Shrimp are processed in any of several ways for the market. The processing techniques have largely been adopted from those

of southern U.S. shrimp industry or of Scandinavian countries. Northern shrimp are marketed with the following kinds and degrees of processing:

a. Fresh, whole

b. Cooked, whole

c. Cooked, peeled

d. Cooked, peeled and frozen

e. Raw, peeled and frozen

f. Peeled and canned

a. Fresh, whole shrimp. Marketing shrimp in this condition requires the least processing, but the markets must be readily accessible to minimize deterioration. The catch is first culled to remove unwanted trash species, broken shrimp and debris, then washed. Since this process can be time consuming, a "cleaner" catch is more desirable and trap caught shrimp may be favored for this market.

b. Cooked, whole. This process became prevalent with the expansion of the European market. Although more shrimp can be handled faster in shore based automated processing lines, it was found expedient for about a third of the catch to cook the shrimp on board the fishing vessels before landing them. This procedure was adopted because the Scandinavian market required the shrimp to be cooked very shortly after capture so that the curl of the tail would be retained (Bureau of Commercial Fisheries, 1969).

The process of cooking requires culling and washing as with fresh shrimp. The clean catch is then boiled 3 to 5 minutes in a brine made up of sea water with one part in eight or ten of added salt. After landing, the cooked shrimp are sorted carefully to select intact and properly curled individuals and packed whole in boxes. Usually the eggs, if present, are left on. Most of these shrimp are shipped as rapidly as possible under refrigeration, but some may be frozen in polyethylene bags for storage. At one time cooked shrimp for the Swedish market were artificially colored with a red dye, the use of which has now been discontinued (Savoie 1971).

c. Cooked and peeled. Removal of eggs from shrimp is a time consuming process, so that many cooked shrimp for the domestic market are peeled, thus removing both eggs and shell. The meats are sold refrigerated or frozen. Peeling of cooked shrimp is often done by hand.

d. Cooked, peeled and frozen. When cooked meats are to be frozen, they may either be packaged dry in plastic or cardboard containers or frozen in brine in polyethylene bags. A more recently developed freezing technique is the individually quick freezing (IQF) process. The individually frozen meats can then be stored in containers of any desired size and removed in any quantity as needed without thawing. Several methods of IQF have been used. The meats may be spread out in trays and frozen in a blast freezer, or in evacuated polyethylene bags injected with nitrogen. The latter process improves preservation and retards dehydration.

c. Raw, peeled and frozen. This is probably the most universal process in the Maine industry (Table D-2-4). Automatic machine peeling is customary. The machinery has been developed largely by a single company (the Laitram Corporation of New Orleans) and is rented to the processor on an hourly basis. A royalty fee is also charged for each thousand pounds of shrimp processed. The freshly caught shrimp, culled and washed, are soaked in fresh water for 12 to 18 hours to loosen the connective tissue between the meat and the shell. They are then fed into the peeling machine along with a copious flow of water, which helps move them along the processing line. The machine can process 500-900 pounds an hour, consuming 5000 gallons of water or more while doing so (Demarest 1971). Bits of shell and other inedible parts are removed after peeling in the last stage of the machine, the cleaner and separator. The meats are inspected, dipped in brine and frozen in plastic bags, or dipped in boiling brine and then individually quick frozen.

f. Peeled and canned. For canning, the peeling process is as just described, but after final inspection the meats are vacuum packed and heat sterilized in cans. Only a few firms in Maine have undertaken canning as a means of processing shrimp.

7. Legal constraints on processing. There are presently no state laws that restrain the processing sector, except for a single statute that requires labeling packaged shrimp as to the state or country of origin. The legal authority to promulgate regulations and establish standards for processing is possessed by both the Department of Marine

Resources and the Department of Agriculture. Federal health and sanitation standards must be met since the industry involves interstate and overseas shipments of the product.

8. Problems relating to processing. One of the major problems for processors is the continuity of the supply. Once money is invested in facilities and equipment, it is necessary that a dependable flow of shrimp pass through. During periods of scarcity the supply may be irregular. It has been estimated (Northern Shrimp Scientific Committee 1979) that 700 thousand pounds of shrimp a year must be processed by a machine to offset its cost to the processor.

V. MARKETING

1. Levels of distribution. The markets for northern shrimp fall into three categories—local, interstate and foreign. The product and the pathways of distribution vary accordingly. Basically, the steps of marketing are the fisherman, the processor, the wholesaler (who may also be the processor), the retailer (who may also be any of the other three), and the consumer. The fisherman, who sometimes sells directly to the consumer when the demand is low, seldom goes to this trouble when the demand and proce are high, and processors or wholesalers will take all he can provide. Processors may also stop selling directly to the consumer under these circumstances. Wholesalers, who are not necessarily close to the supply, deal largely with the canned or frozen product. Retailers, consisting of chain food stores, local grocery stores and fish markets, roadside dealers often selling from the backs of pickup trucks

and restaurants, may buy the product from fishermen, processor or wholesaler.

2. Shipping. Shrimp are customarily shipped in regrigerated trucks; those destined for European markets are packed in 22 pound containers and transferred to commercial airliners in New York or Boston.

3. Legal constraints. State laws affecting the marketing of shrimp are minimal. According to Henry and Halperin (1970) "...no provision of Maine law is a significant impediment to the exploitation and marketing of marine products as food," and shrimp have fewer provisions under the law than many other sea foods. Licenses are required for wholesale marketing of fish generally. The pertinent Maine laws apply to all foods and are intended to protect the consumer from such things as fraudulent labeling or unsanitary or unwholesome products. These laws, administered by the Department of Agriculture also make special provisions for perishable foods including sea foods, providing for the inspection of food products and, if necessary, the condemnation of spoiled items. Inspections of this kind are limited in scope and frequency by funds and personnel available. The Department of Agriculture also publishes guidelines, without force of law, called Good Management Practices.

The Maine food laws also deal specifically with frozen foods and the Department of Agriculture sets standards for temperature control in storage and transportation. Processors of food products may request regular inspections of their products: a service for which a fee is charged, but since the product may then be labelled "inspected," the service may have some advertising benefits (Henry and Halperin 1970).

Federal laws, after which Maine food laws are patterned apply to interstate shipments. They are administered by the Food and Drug Administration.

4. Economic factors. Marketing of northern (Maine) shrimp is competitive on three levels—with fish, meat and poultry products generally; with southern shrimp of other species; and with Alaskan, Canadian and Scandinavian shrimp of the same or similar species. Recently, also, frozen small shrimp meats resembling those of Maine shrimp have been imported from Asia.

Regarding the competitive relation of shrimp to other fish and meat products, this appears to be no problem as long as the economy of the country as a whole is good (National Marine Fisheries Service 1978). Shrimp is a so-called "luxury" food item, is consumed to a large extent by higher income groups, and consumption has been increasing contrinuously over the past two decades (Fig. D-2-6).

Competition with southern shrimp is not a problem as a general rule. The demand for all shrimp is high, as is reflected by increasing consumption and increasing price, and the prices paid for Maine shrimp have kept pace (Fig. D-2-6). One exception to this can be noted during the period 1960 to 1965, when the price of Maine shrimp dropped as the supplies began to increase, even though prices generally held firm. The apparent reason for this is that for several years prior to 1960, Maine shrimp had been scarce or off the market entirely, and their return was slow to be accepted by the consumer. Their place in the domestic market was eventually recovered, although a simultaneously developing European market helped boost the demand in 1969 and 1970.

If the demand for shrimp generally were to decrease, it is possible that competition with southern shrimp would be felt more. These larger shrimp are more familiar nationwide and are probably preferred. In 1969, a year when Maine shrimp were being landed in peak quantities, Maine landings were about 8% of the total shrimp landings in the United States, yet they represented only 3% of the total United States consumption. Fortunately, Scandinavian and other European countries, plagued by shortages in their own supply, provided a needed market and about one-third of the Maine catch, or roughly 8 million pounds per year were exported (U.S. Bur. Comm. Fish. 1969).

These foreign markets are not always available, however. Their own supplies have been increasing in recent years, and both Canada and Greenland are able to supplement their needs if necessary. Alaska shrimp, being the same or closely related species to the northern shrimp harvested in Maine, are a potential source of competition. The Alaska landings which were 43 million pounds in 1969, not quite twice the Maine landings, reached 116 million pounds by 1977: 300 times the Maine landings for that year and over 4 times the biggest Maine catch in any year. Because of marketing problems, and the quantities landed, the price of Alaska shrimp is low: less than 5 cents a pound in 1973, now not over 15 cents. In the past competition from Alaska shrimp may not have been a serious problem. Certain properties of their tissues made machine peeling difficult (U.S. Bur. Comm. Fish. 1969) and most were canned, a market toward which the Maine industry was not strongly oriented.

ECONOMIC IMPORTANCE

From the time the shrimp are landed until they are purchased by the consumer either as a product for home consumption or as a meal in a restaurant, many segments of the economy share in the profit. The landed values of the shrimp have already been mentioned (Table D-2-1). The retail values can be estimated by multiplying these values by an appropriate factor (the shellfish multiplier), which for shrimp is approximately 2.8 to 3.0 (Hamlin and Ordway 1974). Thus for the year of highest value (1971) the retail value was probably between 6 and 7 million dollars for the two-thirds of the catch marketed domestically.

Of the landed value (that paid the fisherman) 45 to 50%, depending on the category of vessel, goes to pay the crew, captain or owner (if owner operated); most of the rest goes for expenses which include maintenance of vessel and gear, purchase of supplies, equipment, depreciation, insurance, etc. (Table D-2-5). About 3% accrues to the state and federal government as taxes (not including income taxes).

About 44-45% of the earnings of the boat when shrimp fishing go to pay expenses. In a year of relatively great value of landings (e.g., 3.6

million dollars in 1971) 45% of this or 1.62 million dollars would thus add to the earnings of shipyards, repair shops, skilled tradesmen, and miscellaneous laborers. Other portions of it would go to food dealers, fuel dealers, hardware stores, ship chandlers and numerous other enterprises.

No reliable information is available to indicate precisely the number of people employed as fishermen in the shrimp fishery. At the peak period (1969-1975) between 270 and 300 Maine boats were engaged in the fishery and the average crew size was a little over three men (Dunham and Mueller 1976). The number of fishermen earning all or part of their income from shrimp fishing would appear to have been from 800 to 1000.

The number of all persons employed in one way or another in the shrimp industry was estimated (Northern Shrimp Scientific Committee 1979) to be about 800 in 1976, with nine processors in operation. This figure includes fishermen, handlers, plant personnel, truckers, etc. In 1970, with 20 processors in business, it can be assumed the total number employed was about double the 1976 figure.

EVALUATION OF REGULATORY FRAMEWORK

The shrimp fishery in Maine is relatively new and its regulation in all phases is minimal. This is partly due to a reluctance on the part of lawmakers and regulatory agencies to inhibit a developing industry and partly because for a long time nobody knew enough about the shrimp or the fishery to formulate a sound management policy. Only in recent years have circumstances combined to make regulation both necessary and feasible. Even now, although most people concerned agree that some kind of management is necessary, there is no general agreement on how or how much.

1. Management of the resource. The management of the shrimp fishery has been almost entirely relegated to a joint federal-state authority under the auspices of the Atlantic States Marine Fisheries Commission. This authority, the Northeast Marine Fisheries Management Board comprises the directors of the marine fishery conservation departments of the seaboard states from Virginia to Maine. The representatives from Maine, New Hampshire and Massachusetts and the Regional Director of the National Marine Fisheries Service make up the Northern Shrimp Sub-board. Members of this sub-board serve also on the Northern Shrimp Section of the ASMFC along with representatives from the legislatures and the shrimp industries of the three states. The Northern Shrimp Sub-board has associated with it a Northern Shrimp Scientific Committee, composed of fishery scientists from the three states and the National Marine Fisheries Service. The joint, three-state management agency seems reasonable since the shrimp of the Gulf of Maine are a common resource for the three states involved.

The need for some regulation was first seriously recognized when a declining trend in shrimp abundance was becoming apparent in 1972. Of three management strategies considered—maximum counts per pound in catch, closed seasons, or minimum mesh sizes for gear—only the last appeared feasible at that time and standard minimum mesh sizes were recommended. Until a gear evaluation study could be made, an interim minimum mesh size of 1.5 inches was adopted by each of the three participating states, and ultimately a standard minimum mesh size of 1.75 inches was adopted by the board in June 1975. Although this mesh size was supposed to have been scientifically calculated to permit the retention of mature females and the escapement of most of the transitionals and males, it appears to have been no larger than the standard mesh size in general use already (Bruce 1971).

Besides the mesh size regulation, which is still in effect, several seasonal closures and quotas have been instituted at one time or another for limited periods of time, none of which seemed either to have had a noticeable effect on the shrimp stocks or to have been accepted enthusiastically by all parties concerned. Although heavy fishing on spawning populations is generally disfavored when conservation of stocks is called for, and is restricted to some degree in many northern shrimp fisheries, it is practiced freely in Maine. The egg bearing females are considered to be the most desirable for harvesting, and protection during that period is not the kind of management that Maine industry is seeking. They would prefer seasonal restrictions on the offshore summer fishery which takes a high percentage of the young males. On the other hand, the Massachusetts industry, while not adverse to closures in the winter time, is not enthusiastic about summer closures in the offshore fishery, which they pursue almost exclusively.

Closed seasons have been in effect on three occasions: July 5 to September 27, 1975, April 15, 1976 - Jan. 1, 1977 and May 15, 1977 through 1978. The latter closure was terminated early in 1979, after considerable debate. The position of the various segments of the industry in the matter of management is based largely on economic arguments, which are understandable, if not without considerable self-interest. Unfortunately, the position of those responsible for management, although presumably objective, is divided by disagreement and lack of information about the basic ecology of the shrimp. The divergence of opinion hinges on whether the abundance of shrimp is so overwhelmingly determined by the environment that attempts to maintain it or change it by control of fishing effort are futile, or whether it is so strongly affected by overfishing that any reduction of the latter will restore depleted stocks more quickly, or will prevent depletion altogether. The above arguments represent the extreme polarization of views; there are many opinions as well that lie somewhere in the middle.

Although neither the Northern Shrimp Sub-board nor the Atlantic States Marine Fisheries Commission have been unanimous in their views toward management or have so far produced an effective management scheme, a draft for a comprehensive management plan has been recently prepared by the Scientific Committee for consideration by the Northern Shrimp Sub-board.

2. Research. Whatever the fate of the management plan, the Scientific Committee has, to its credit, accumulated a respectable

volume of scientific data which should render management decisions and appropriate regulations much easier to make. Federal and state laws which authorize this research should be mentioned, therefore, as part of the total legal framework applicable to the shrimp fishery. The Commercial Fishery Research and Development Act of 1964, P.L. 88-309 is one of the more important of these. Under this law half the cost of a fishery research project undertaken by a state is funded by the federal government and half by the state. Maine currently has two P.L. 88-309 research projects on shrimp.

3. Problems. The overriding problem with the present legal framework is that it was not adequate to cope with the rapid expansion of the fishery. Inadequate information and basic philosphical disagreements about management, self-interest and ineffectual enforcement of even existing regulations have all been contributory to the failure of managing the fishery before it declined, assuming that it could have been managed even if stricter measures had been taken. The first two of the difficulties mentioned above have been discussed; the last, the problem of enforcement, stems mainly from the by-catches of shrimp with other species. This can occur purposefully, even assisted by the use of smaller than legal sized meshes. The illegal harvesting of shrimp in this manner is difficult to prevent.

CONFLICTS IN RESOURCE UTILIZATION

In the earliest period of the shrimp fishery, the resource was essentially fortuitous, in a sense almost a recreational fishery, pursued in the off season of other fisheries. There was little conflict in the utilization of the resource because it was not that important in the fishing industry generally. It is still an off-season resource for many fishermen, but for others it has become a year round and, until recently, a primary pursuit. This and other factors lead to a number of conflicts in its utilization.

In Maine, the fishery is essentially a winter fishery on egg-bearing females. In Massachusetts the fishery is year round and in the summer takes all age groups including males. This leads to a conflict between the Maine and Massachusetts fishing interests, not only on biological issues relevant to conservation, but also in respect to the kind of management restraints employed.

Of lesser concern is a conflict resulting from the kind of gear employed. The trap fishery, which developed rather precipitously in 1970, found itself in conflict with the established trawl fishery wherever both attempted to harvest the same areas. Because traps can fish in areas impractical for trawling, however, reasonable arrangements should be possible for alloting certain areas for each fishery. Analagous conflicts between shrimp trawler and lobster fishermen may occur, but since many shrimp trawlers are also lobstermen, the problem is probably incidental.

The possibility of conflicts among various kinds of fishermen and with other marine interests for the use of dock facilities and mooring space has been suggested. The shrimp industry declined before such problems actually arose, but since shrimp fishermen and fishing boats were, for the most part, the same people and the same boats as helped make up the already existing fishing fleet, no additional pressure was likely to be put on facilities. If a great expansion should someday occur in the shrimp fishery, especially with corresponding expansion of other marine activities, such conflicts might be possible.

The greatest conflict in the shrimp picture at the present time is between a large body of the industry supported by some elements of the scientific sector on one hand and management interests supported by other scientists on the other, who seem to have taken opposing views as to the nature of the periodic declines in shrimp abundance and the philosophy of managing the resource.

SUMMARY

Unfortunately, at the present time the shrimp fishery in Maine has to be discussed in retrospect. Whether the brief prosperity of the late sixties and early seventies will ever return no one can say. It is widely assumed, that the nature of *Pandalus borealis* in the Gulf of Maine is such that its abundance is more or less cyclical and that any fishery based upon it will be subject to rather severe extremes of dearth and plenty. Many hope that rational management might smooth out these extremes so that a fishery could be carried on at at least modest levels even on the down swing of the cycle, or at least so that the high fishing effort that develops when shrimp are plentiful and the market good does not continue irresponsibly when shrimp abundance clearly starts to decline. Until the ecology of the shrimp is more clearly understood, especially the causes for extreme fluctuations in abundance, any method of management and its outlook for success will probably remain debatable.

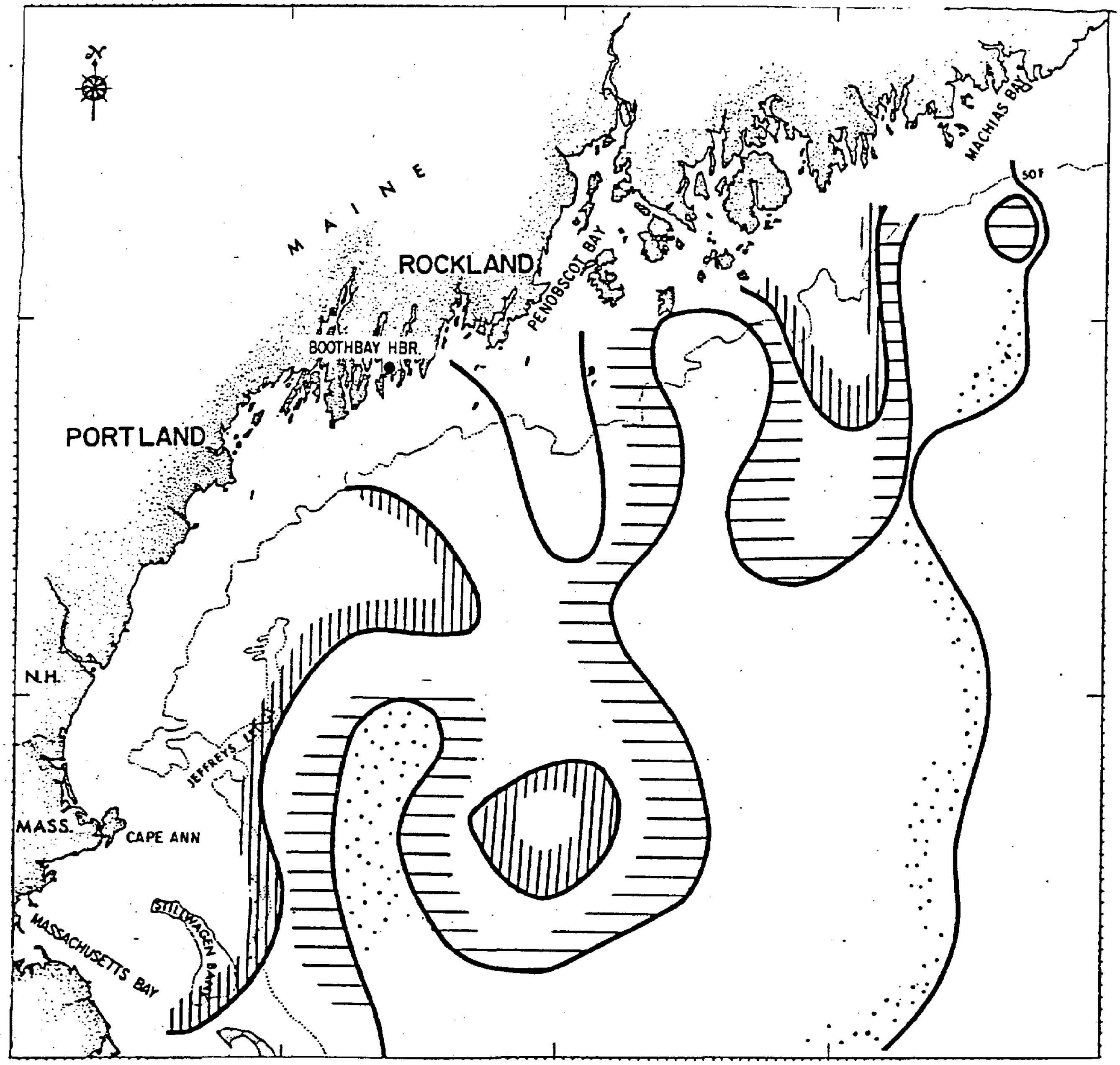

Figure D-2-1. Gulf of Maine, showing areas of relatively dense (vertical shading), medium (horizontal shading), and sparse (stippled) populations of *Pandalus borealis*, from surveys made in spring and fall of 1963-65. (Adapted from Haynes and Wigley, 1969).

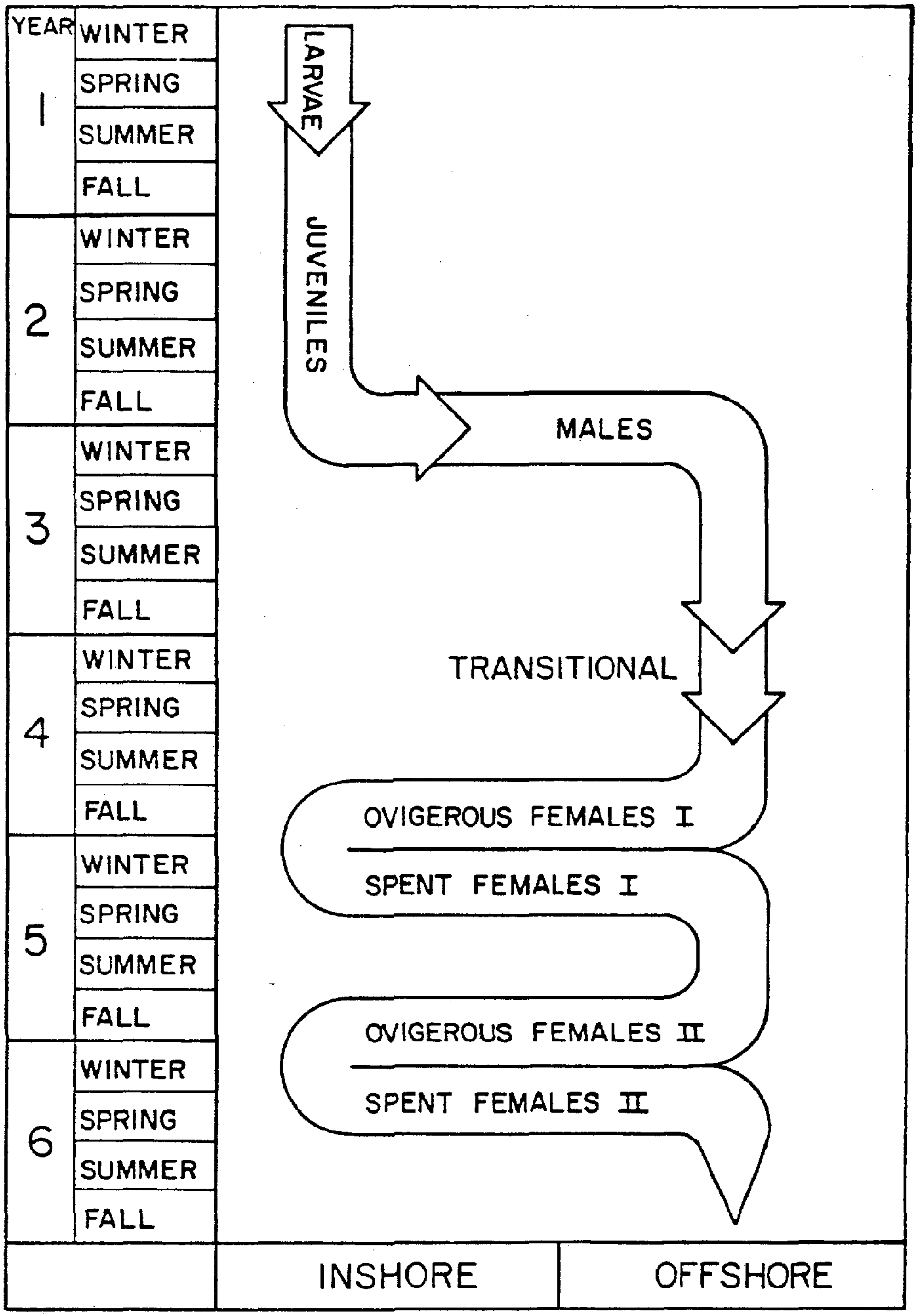

Figure D-2-2. The life history of *Pandalus borealis* showing approximate times and durations of life history stages and offshore-inshore migrations.

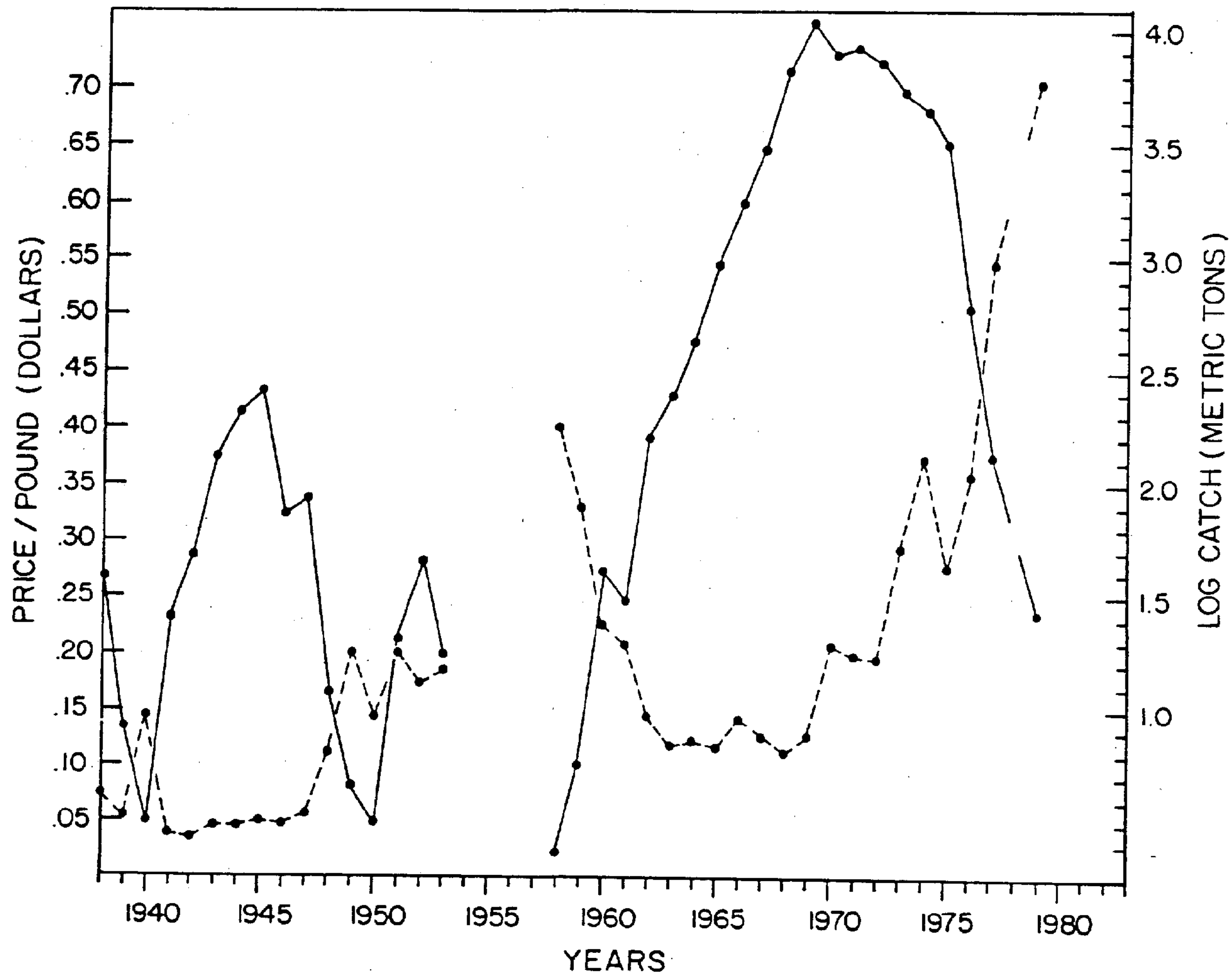

Figure D-2-3. Maine landings of *Pandalus borealis* since 1938 and price per pound to the fisherman. The landings in metric tons are shown on a logarithmic scale to exaggerate those of the 1940-1950 period and to emphasize the cyclic nature of shrimp abundance.

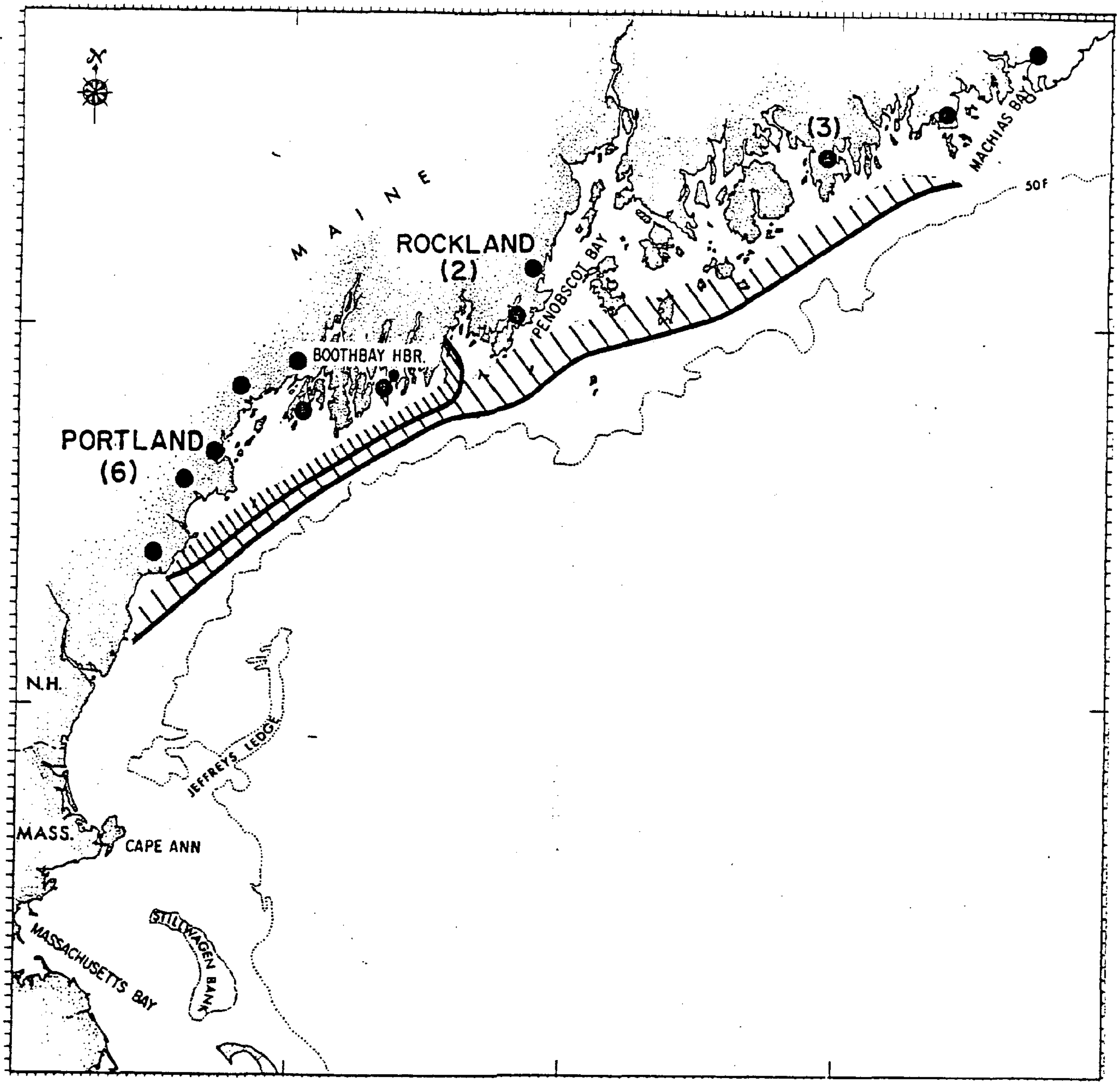

Figure D-2-4. Gulf of Maine, showing the distribution of egg bearing females in the winter (heavy shading: during periods of abundance; light shading: since 1976) and the location of the winter fishery, as it was at its zenith and in more recent times. Locations of shrimp processing plants in 1969 are shown as black dots.

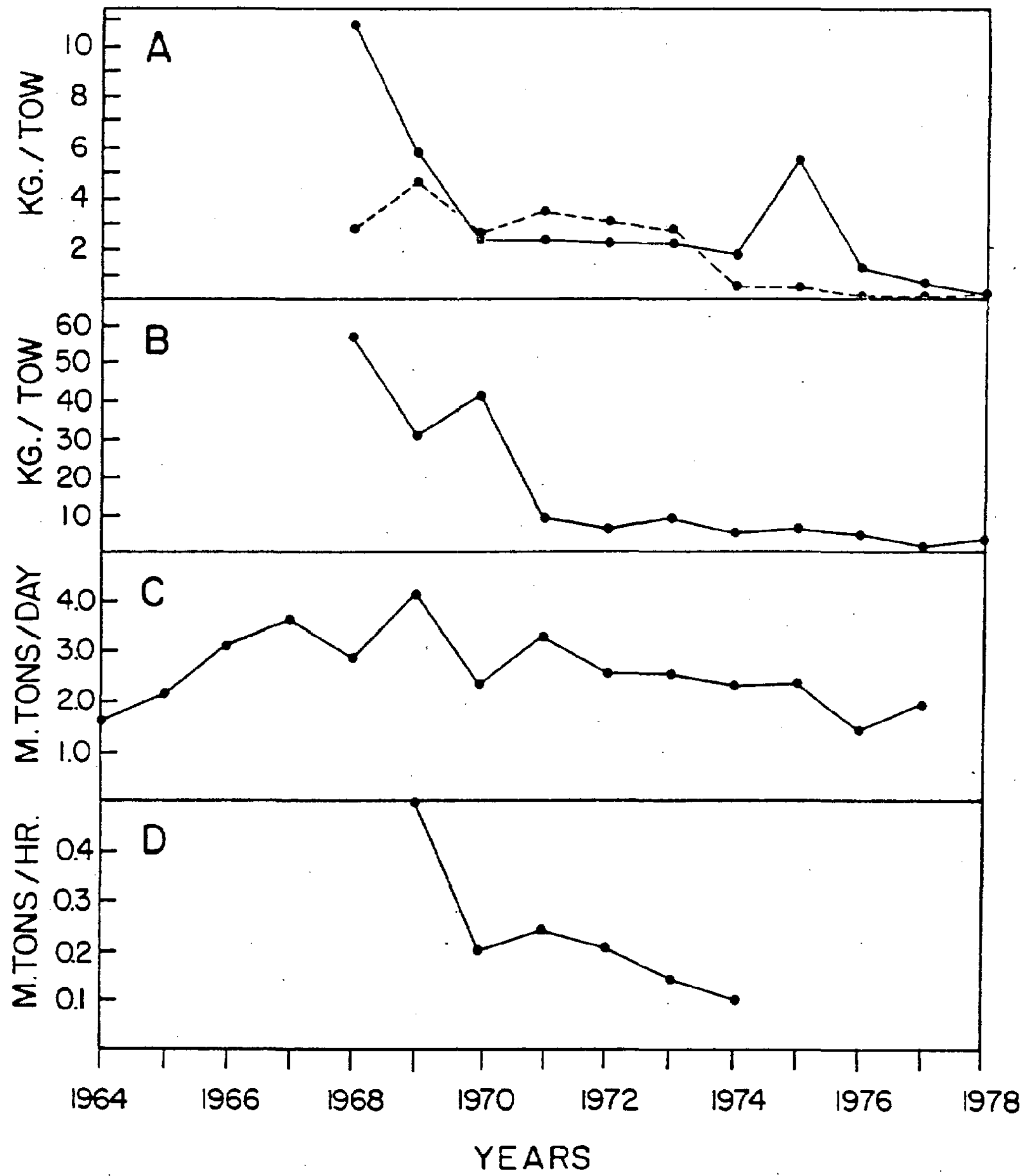

Figure D-2-5. Abundance indices, based on catch per unit effort of various classes of fishing vessels.

A. Mean kilograms per tow from National Marine Fisheries Service research cruises: dotted line, autumn; solid line, spring.
B. Mean kilograms per 30-minute tow, Maine summer research cruises.
C. Metric tons per day; total for all commercial vessels in 34-50 gross tonnage class.
D. Metric tons per hour; total for three selected vessels in winter fishery (from Rinaldo, 1976).

Data taken from Northern Shrimp Scientific Committee, 1979.

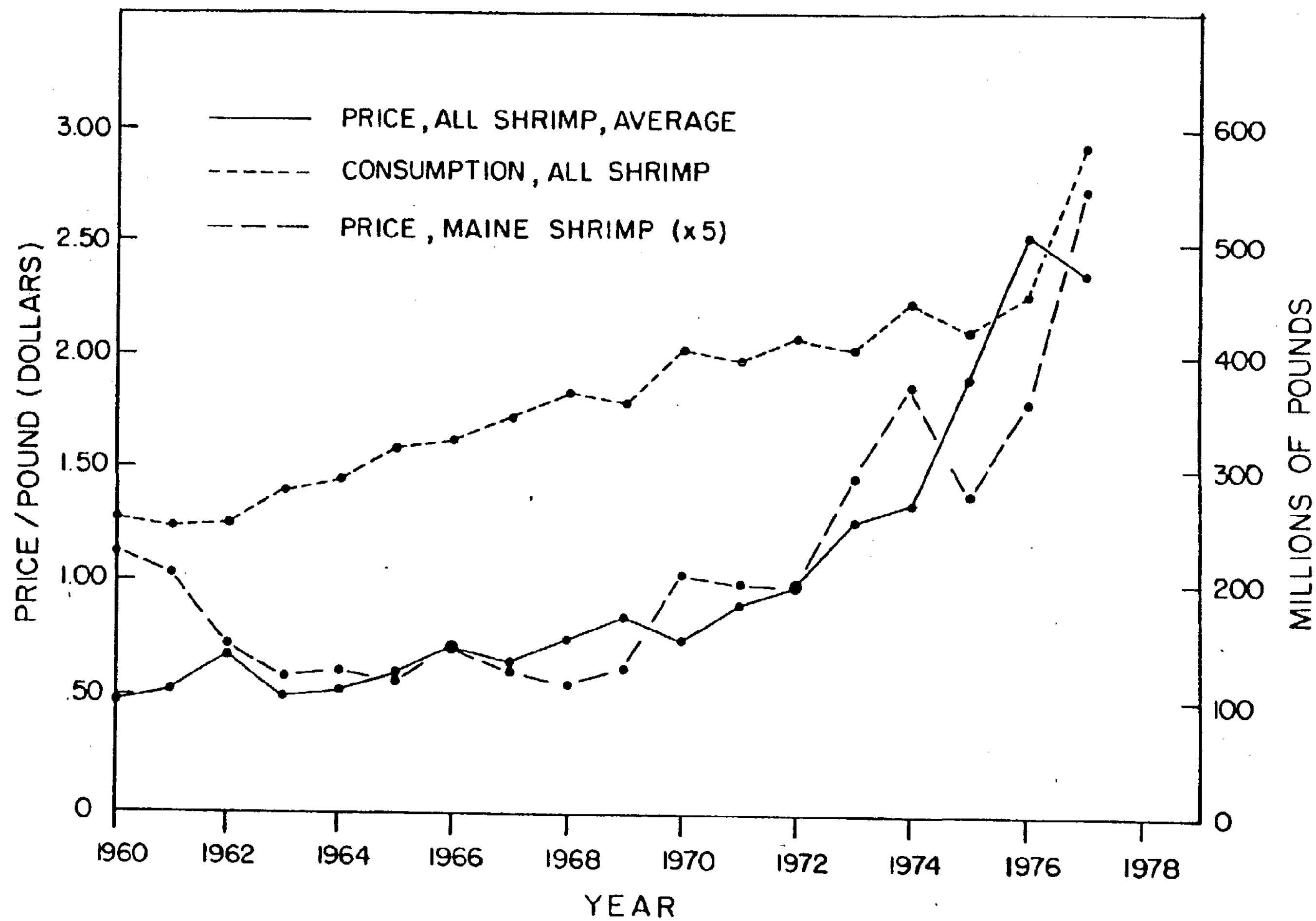

Figure D-2-6. Trends in nationwide consumption of shrimp (all species), average price per pound to fisherman (all shrimp) and price per pound to fisherman for Maine shrimp (multiplied by a factor of 5 so that all three trends would fit on a single scale).

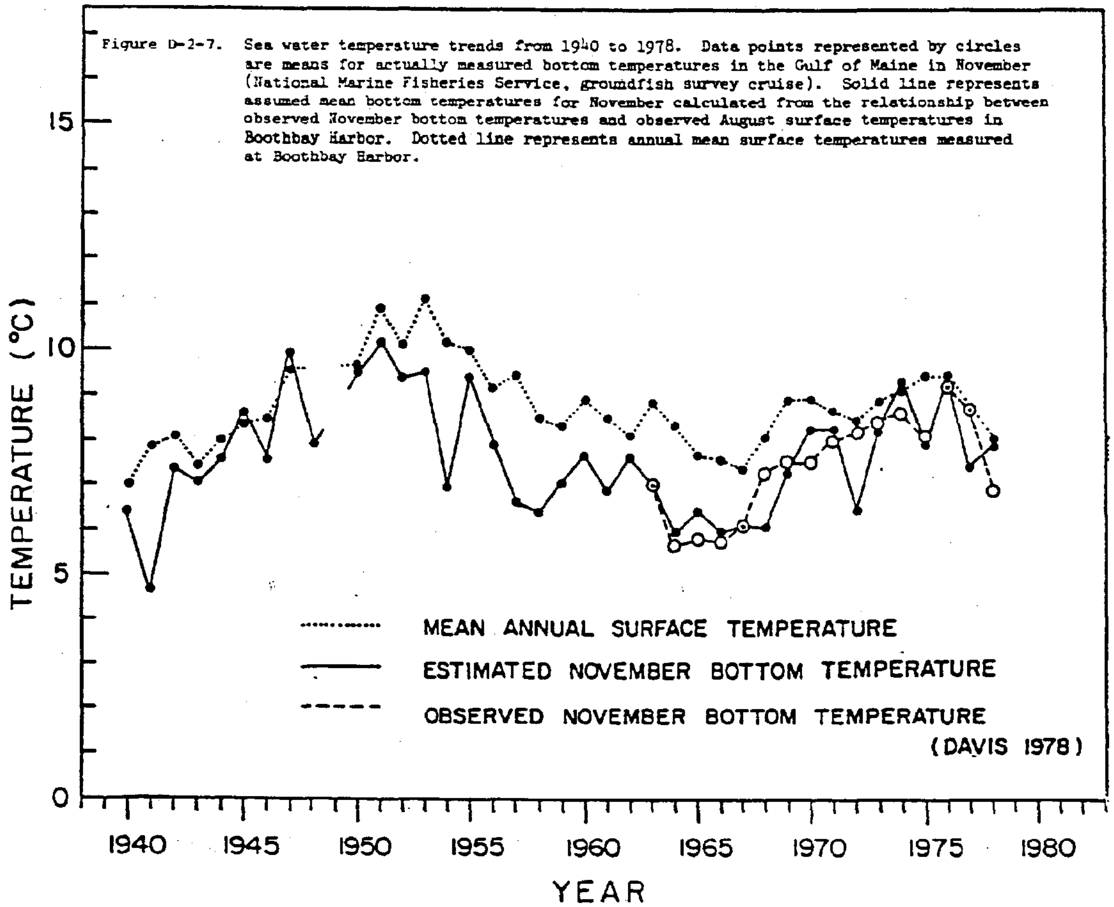

Figure D-2-7. Sea water temperature trends from 1940 to 1978. Data points represented by circles are means for actually measured bottom temperatures in the Gulf of Maine in November (National Marine Fisheries Service, groundfish survey cruise). Solid line represents assumed mean bottom temperatures for November calculated from the relationship between observed November bottom temperatures and observed August surface temperatures in Boothbay Harbor. Dotted line represents annual mean surface temperatures measured at Boothbay Harbor.

Table D-2-2. Catch, stock size, recruitment estimates, and related parameters used in assessment of the Gulf of Maine northern shrimp stock.[1] Estimates of instantaneous fishing mortality (F) were calculated from analysis of Maine survey catch at age data assuming M = 0.25 (from Northern Shrimp Scientific Committee 1979).

Year	Instantaneous fishing mortality (F)[2]	Exploitation rate (u)	Survival rate (S)	Catch ($MT^3 \times 10^{-3}$)	Stock Size[4] ($MT \times 10^{-3}$)	Recruitment[5] ($MT \times 10^{-3}$)
1968	0.71	0.456	0.383	6.6	14	--
1969	0.75	0.474	0.368	12.8	27	22
1970	0.69	0.447	0.391	10.6	23	13
1971	1.95	0.788	0.111	11.1	14	5
1972	1.72	0.752	0.139	11.1	15	13
1973	0.87	0.524	0.326	9.4	18	16
1974	1.80	0.765	0.129	7.9	10	4
1975	1.41[6]	0.688	0.190	5.3	8	7
1976	0.98	0.564	0.292	1.0	2	1
1977	1.98	0.792	0.108	0.4	1	1
1978	0.54	0.373	0.454	-	-	-

[1]Data taken from Clark and Anthony (in press)

[2]Weighted by catch in numbers at age

[3]Metric tons

[4]Calculated by dividing catch by exploitation rate

[5]Calculated by subtracted survivors (year i) from stock size (year i+1), e.g., the 1979 estimate is calculated as 27-14 (0.383)

[6]Estimate of F could not be calculated directly for 1975 due to introduction of a new survey vessel. Accordingly, the 1973-1977 average was used.

Table D-2-3. *Vessels in the Gulf of Maine northern shrimp fishery by year and state.[1]

Year	-Maine-	-MA-	-NH-	Total
1965	[29]	-4-		33
1966	74	-11-	1	86
1967	[107]	-22-	2	131
1968	[223]	32	2	251
1969	[287]	-42-	3	332
1970	[284]	60	3	347
1971	[285]	55	3	343
1972	[251]	54	4	309
1973	[292]	53	3	348
1974	331	46		377
1975	[270]	(47)		317
1976	[127]	(18)		145
1977		(23)		23

[1] Data are derived from various sources as indicated.

[] = State of Maine records

() = State of Massachusetts records

-- = Wigley, 1973

Otherwise NMFS data files

* From Northern Shrimp Scientific Committee 1979

Table D-2-4. *List of firms processing shrimp in Maine during 1969, including location and types of shrimp products.

Bath Canning	Prospect Harbor	Raw meats, raw headless
Belfast Canning Co.	Prospect Harbor	Raw meats
Windjammer Sea Farming Corp.	Eastport	Peeled, raw (canned natural)
A.M. Look Canning Co.	East Machias	Dip (canned and natural)
Three Rivers Fish Co.	Jonesport	Raw meats
Brown Fish Company	Portland	Raw meats
Central Wharf Fisheries, Inc.	Portland	Raw meats
Eastern Fish Company	Portland	Raw meats
Mid-Central Fish Co.	Portland	Raw meats, raw headless
Stinson Canning Co.	Prospect Harbor	Raw meats
F.J. O'Hara & Sons, Inc.	Rockland	Raw meats, raw headless
Royal River Packing Co.	Yarmouth	Raw meats, raw headless
Scandia Seafood Co., Inc.	Bailey Island	Cooked whole
Malpeque Shrimp, Ltd.	Boothbay Harbor	Cooked whole
Maine Biological Supply & Development Corp.	Brunswick	Raw meats
Maine Lobster Co.	Portland	Raw meats
Maine Crabmeat Co.	Portland	Raw meats
Gulf of Maine, Inc.	Portland	Raw meats, breaded
Paul Bayley Seafoods Company	Scarborough	Raw meats, raw headless
Port Lobster Company	Kennebunkport	Raw meats
Rockland Shrimp Corp.	Rockland	Cooked whole
Mill Cove Lobster Co., (No. 2)	Southport	Cooked whole
Atwood Brothers, Inc.	St. George	Cooked headless, raw meats
Mill Cove Lobster Co., (No. 1)	Trevett	Raw meats

*From Whitaker 1971

Table D-2-5. Breakdown of average income and costs for vessels engaged in the New England shrimp fishery (based on Dunham and Mueller, 1976).

	Incorporated Vessels		Owner Operated Vessels	
Gross Earnings	$97,847		$53,975	
Captain and Crew	47,072	(48 %)	24,302	(45 %)
Maintenance	10,466	(10.7%)	6,124	(11.3%)
Equipment	4,868	(5.0%)	3,162	(5.8%)
Supplies	21,012	(21.0%)	9,484	(18.0%)
Miscellaneous	7,828	(8.0%)	4,920	(9.1%)
Taxes	4,107	(4.2%)	1,431	(2.6%)

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ELEMENT D-3: A CHARACTERIZATION

OF

THE MAINE LOBSTER FISHERY

by

Walter R. Welch

INTRODUCTION

The American lobster *(Homarus americanus)* was, in 1978 as it has been for some time, the most valuable marine resource in Maine. With 1978 landings of 19,130,459 pounds, it was valued at $33,878,376 at first sale.

The lobster resource is intensively exploited, but miraculously, the year-to-year fluctuations in landings over the past 3 decades have occurred at fairly high levels.

To ensure continued high levels of production of this valuable resource and perhaps even bring about modest increases, serious consideration of workable management strategies seems called for.

TABLES

FIGURES

Distribution of the Resource

The American lobster *(Homarus americanus)* is found from Labrador and Newfoundland to the Carolinas, from shallow coastal waters to 370 meters (200 fathoms), and in a wide variety of habitats. The greatest commercial concentrations occur along the Maritime Provinces of Canada.

In Maine waters the lobster is distributed all along the coast, around the islands, and into bays, harbors, and estuaries as far as relatively high salinities (in excess of 20%, Dow, et. al., 1975) extend. Ledges, reefs and rocky bottoms seem to be preferred for habitat, but the species can be found on practically all types of bottom. The specific areas inhabited by the resource are too numerous and widespread to be described in narrative. They may be seen as designated on the Maine Coastal Inventory maps of the Maine State Planning Office (Anon., 1976).

AVAILABILITY OF THE RESOURCE

Lobster fishing seems to have begun in the Boston area and lobsters were marketed there at least as early as 1740. By 1880 the fishery had extended northward into the Canadian provinces and south to Delaware. In that year, United States landings totaled 20.3 million pounds, of which 19.9 million pounds came from New England, and 14.2 million pounds from Maine alone (Anon., 1978). Over the years of record, Maine's landings have fluctuated widely from 25.0 million pounds in 1887, to 5.1 million pounds in 1936, to 24.4 million pounds in 1957 (Table D-3-1, Figures D-3-1 and D-3-2). Over the past 3 decades, the catches have been at a fairly high level.

The lobster producing areas of the Maine coast are shown on the Maine Coastal Inventory charts, Fish and Wildlife #1 (Anon., 1976). From these, it appears that the lobster is fished all along the Maine coast and its islands, coves, harbors, and estuaries. However, from Table D-3-2 and Figure D-3-3 it may be seen that Knox and Hancock counties are consistently major producing areas, while York and Sagadahoc counties are consistently minor producing areas. There are probably many reasons for the differences in the lobster landings among the several counties, but it seems certain that the relatively small amounts of shoreline and adjoining ocean areas in York and Sagadahoc counties (Figure D-3-4) must play a large part in their limited landings.

Variations in Availability

Lobster larvae are planktonic and remain so for 2 to 5 weeks after hatching, depending upon temperature. During this period the larvae are distributed by water currents and may settle to the bottom many miles from where they were hatched. Because of this, the lobster population and therefore the fishery in one area may be dependent for larval recruitment upon the spawning stock of lobsters in another area. Because the larvae of this species have not been studied extensively, there is little known about their distribution and abundance along the northeast coast of America. The existence of a counterclockwise current flow in the Gulf of Maine, however, gives reason to speculate that stocks of adult lobsters in the north to northeast parts of the Gulf of Maine may be important sources of larval recruitment to the coast of Maine. Similarly, larvae hatched in inshore areas may contribute to recruitment in offshore areas.

The movement of lobsters over the bottom also contributes to the intermingling of stocks from different areas. Krouse (1978) reviewed all lobster tagging studies conducted along the coast of northeastern America and found certain patterns of movement to be evident. The one most pertinent to the Maine lobster resource was the south or south-westerly movement of predominantly large, mature lobsters. Extreme distances of movement cited were: 113 nautical miles in 7 months (Dow, 1974); 185 nautical miles in 199 days; and 63 nautical miles in 369 days (Krouse, 1977a). However, several studies of lobster movement showed it to be very minimal for the most part. Krouse (1978) interpreted the overall results to indicate that certain sizes of lobsters (primarily smaller, sexually immature) inhabiting certain areas are generally nonmigratory.

Because of the above evidence of intermingling and movements of larvae and adults, and until more is known about migrations and larval recruitment relationships, the American lobsters in the Northwest Atlantic should be considered as a single stock (Anon., 1978).

At present there is not sufficient information at hand to estimate the size of the spawning stock necessary to sustain a given level of recruitment. There is need for studies to produce basic information on annual egg or larvae production and subsequent recruitment to the fishery.

Table D-3-4 summarizes the status of development of lobster population parameters that have evolved from various lobster research projects. These data form an important basis for assessment of the condition of Maine lobster stocks and for recommending management strategies.

The availability of the resource to the fishery must be primarily dependent on the size (in numbers) of the resource. This is particularly true in the case of the Maine lobster resource, in which 86% of the legal-sized lobsters are removed by the fishery each year, and in which the commercial catch is largely dependent (77%) on lobsters molting from sublegal to legal size (Thomas, personal communication).

The Lobster Project of DMR, in progress since 1966, was set up to conduct a statistical (probability) sampling of the commercial lobster catch in Maine to obtain detailed data on the catch, on the effort expended, and on certain biological aspects of the lobster resource. In addition to the development of some of the population parameters mentioned below, summary data on fishery statistics and catch-effort aspects were compiled as shown in Table D-3-3 and Figures D-3-5, D-3-6, and D-3-7.

Some information has been developed which bears upon recruitment problems. For instance, Krouse (1973) found that only 6% of females in Maine waters mature (as judged by extrusion of eggs) under 90 mm carapace length, whicle nearly all are mature by the time they are 105 mm, and accomplish egg extrusion between Mau and July. It is evident that in Maine, with a minimum size limit of 81 mm (3-3/16 inches), many females would be caught before they even become sexually mature. In fact Thomas (1973) indicated in length frequency plots of samples from the 4 years 1967-1970 that 60 to 90% of the females in the catch were below the size at maturity could be expected.

Mortality must be considered as having a very strong influence on the abundance of the lobster resource. Thomas (1973) assigned a range of instantaneous total mortalities of 1.14 (67.9%) to 2.92 (94.6%), depending upon the methodology used in deriving the values. Similarly, he gave a range of 0.02 (2.0%) to 0.35 (29.3%) for instantaneous natural mortality but favored a level of 10% or below.

In the wild, lobsters are subject to the usual types of predation. The larvae are preyed upon by ctenophores and other types of zooplankton. The juveniles on bottom are taken by a wide variety of bottom-feeding fish such as cunner, pollock, and lumpfish. Fishes such as cod and wolf-fish prey upon a wide range of sizes of lobsters (Anon., 1978). Cannibalism can be a problem during molting in dense populations or when sufficient cover is not available.

Two potentially serious diseases are found in lobsters taken in the wild. The blood bacterium, *Aerococcus viridens*, causes gaffkaemia or the so-called "red-tail." It is the more virulent of the two and can lead to death by impairing the oxygen-carrying ability of the blood. The other, called "shell disease" is caused by the destruction of the chitinous outer layer of shell by chitinivorous bacteria. It causes erosion of the shell surface and lowers the quality of the lobster, but seldom causes death unless the gills are affected (Dow, et. al., 1975).

Neither of these diseases appear to be serious contributions to natural mortality in the wild, but under more densely-populated conditions such as in lobster pounds they can be much more serious, the gaffkaemia even becoming epidemic.

Environmental factors, such as temperature, salinity, and oxygen appear to exert relatively minor influence on natural mortality under natural conditions. Lobsters can acclimate to changing conditions of temperature, salinity, or oxygen if the rate of change is not too rapid. McLeese (1956) determined the ultimate lethal level of temperature to be 32.0°C at optimum levels of 30 o/oo for salinity and 6.4 mg/l for oxygen; the minimum lethal level of temperature to be 1.8°C for lobsters acclimated to 17°C; the minimum lethal level of salinity to be 8.0 o/oo at 15°C and 6.4 mg/l of oxygen; and the minimum lethal level of oxygen to be 0.44 mg/l at 5°C and 25 o/oo salinity. Once caught and stored alive in floating crates or cars, or in pounds, the lobsters may be subjected to changes in their environment which occur at a rate too rapid for them to become acclimated. Heavy commercial losses are then likely to occur.

Long-range changes in the average conditions under which the lobster exists may have important effects on its overall abundance. Dow (1969, 1977) has shown lobster landings to be correlated with annual mean sea surface temperatures (at Boothbay Harbor) 5, 6, and 7 years earlier (correlation coefficient = 0.86).

Pollution is not generally an important contributor to lobster mortality. Domestic pollution (sewage) would be a threat only in areas of high-volume dumping, where the oxygen content of the water near bottom might become depleted. Industrial pollution is not generally a problem in Maine, except for the threat of, and occasional occurrence of, oil spills. In such infrequent circumstances, economic losses are more likely to occur from the off-flavoring and consequent unmarketability of lobsters than through actual mortality.

Growth is extremely important to the availability of lobsters to the market. Thomas (personal communication) stated that 86% of the available legal-size lobsters are removed by the fishery each year.

In addition, he has found that 77% of this annual catch is made up of lobsters that have just become legal by virtue of growth through a recent molt. It is evident that growth must be sustained at or above the current rate in order to maintain the flow of lobsters to market. Krouse (1977b) stated that 5.2 years were required for a lobster at Jonesport to grow to the minimum legal size of 81 mm (3-3/16 in.) and that this period probably varied from 5 to 7 years for the Maine inshore resource. Thomas (1973) gave an average of 6.8 years for the whole Maine coast. The calculated growth curve for inshore Maine lobsters from 0 to 20 years of age is shown in Fig. D-3-8 (curve 1). Using probability modes from commercial length-frequency data, Thomas (1973) calculated an increase of 8% in carapace length from premolt to postmolt sizes, while laboratory and tagging studies have shown average molt increase of 14% in length and 40 to 50% in weight.

The availability of lobsters to the fishery decreases with the onset of colder weather. Some fishermen attribute this to an offshore movement of lobsters but the evidence indicates a closer relationship with the reduced activity of lobsters in lower temperatures. Since all lobsters taken in Maine are caught with baited traps, catchability is directly dependent on the activity of the lobster. McLeese and Wilder (1958) found that activity of lobsters increased from 2 to 10°C and from 20 to 25°C, but was constant between 10 and 20°C. As inshore waters cool down in late fall, the activity and therefore the catch of lobsters decreases; but fishermen find that in the deeper offshore waters, where temperatures are slower to decline and remain higher through the winter, lobsters are still sufficiently active to be trapped, although in smaller quantities than are taken in the inshore fishery.

Another important reason for the late-season decline in catch due to unavailability of lobsters is the marked decline in abundance as the newly-molted lobsters that have just attained legal size are caught in the highly intensive summer fishery. This important molt takes place mostly during July and August and, as described above, an estimated 77% of the annual catch is made up of these new recruits to the fishery.

The combined effects of these two seasonal factors on the monthly catches are shown in Table D-3-5, Figure D-3-9.

Maine's Problems in Availability of Lobsters

Maine's problems in the availability of lobsters to the fishery are largely those concerning the size, nature, and stability of the natural stocks of lobsters.

1. The fact that 86% of the legal sized lobsters are caught each year and that 77% of this catch depends upon a single molt and growth from sublegal to legal should concern the fishing industry and the general public far more than it apparently does. The failure of a single year-class of lobsters, for whatever reason, would mean the nearly total collapse of the fishery for at least 1 year and possibly several. It is hard to believe that such has not occurred as yet, since wide fluctuations in year-class strength are very common in marine resource species.

2. There is serious doubt that the resource can sustain the presently very intensive fishery for very long on the basis of the limited breeding stock available. Since only a small percentage of females have an opportunity to breed before being caught, the proposed increase of minimum size to 89 mm (3 1/2 inches) in order to increase this percentage should be considered seriously.

3. The extremely intense fishing effort expended and the high percentage of the stock taken in the annual catch should be a matter of great concern. As stated in the American Lobster Fishery Management Plan (Anon., 1978), "Increasing the minimum size limit to near the size at which the majority of female lobsters are mature will increase the abundance of brood stock and, depending on the stock-recruitment relationship, may benefit recruitment. However, increasing the minimum size limit will not affect (sic) an increase in the number of size groups in the exploited phase. The number of size groups present is affected by the fishing mortality rate, given available information on lobster growth and natural mortality rates. So long as the fishery operates essentially on one size group which is subject to natural failure of recruitment, as is presently the case in the inshore areas, the stability of the fishery will be threatened. Even with a substantial increase in the minimum size, this aspect of the overfishing problem may continue in the absence of a program to control fishing mortality" (emphasis added).

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TABLE D-3-1.
CATCH OF LOBSTERS IN MAINE, 1880-1978

	Total Catch (Millions of lbs.)	No. of Licensed Lobster Fishermen (Thousand)	Total No. of Traps Fished (Thousands)	Average Price Per. lb. ($)	Total Landed Value (Millions of $)
1880	14.2	2.8	104	.021	0.3
1886	23.0	-	-	-	-
1887	22.9	1.9	109	.022	0.5
1888	21.7	2.0	107	.023	0.5
1889	25.0	2.1	121	.020	0.5
1890	20.0	-	-	-	-
1892	17.6	2.6	153	.039	0.7
1894	-	-	200	-	-
1897	11.2	2.4	234	.074	0.8
1898	12.3	3.1	279	.076	0.9
1899	12.7	3.1	335	.076	1.0
1900	14.4	3.1	327	.072	1.0
1901	14.0	2.8	304	.072	1.0
1902	14.3	2.5	289	.085	1.2
1903	13.1	2.6	268	.093	1.2
1904	12.1	2.5	-	.088	1.1
1905	11.1	2.6	254	.125	1.4
1906	15.0	2.7	304	.109	1.6
1907	17.4	-	-	.108	1.9
1908	17.6	-	-	.088	1.6
1909	17.0	-	-	.105	1.8
1910	19.9	-	-	.107	2.1
1911	16.2	-	-	.126	2.0
1912	16.3	-	-	.125	2.0
1913	8.1	-	-	.199	1.6
1914	8.6	-	-	.192	1.7
1915	11.5	-	-	.203	2.3
1916	10.2	3.3	-	.219	2.2
1919	5.8	3.1	-	.247	1.4
1924	5.5	-	154	.321	1.8
1928	7.1	-	211	.283	2.0
1929	6.6	-	-	.295	2.0
1930	7.8	-	205	.258	2.0
1931	5.4	-	168	.245	1.3
1932	6.1	2.9	208	.180	1.1
1933	5.9	3.0	180	.169	1.0
1934	5.4	2.9	183	.164	0.9
1935	7.7	3.1	185	.229	1.8
1936	5.1	-	185	.184	0.9
1937	7.3	-	186	.189	1.4
1938	7.7	3.6	258	-	-
1939	6.6	3.7	260	.156	1.0
1940	7.6	3.7	222	.166	1.3
1941	8.9	3.6	194	.177	1.6
1942	8.4	3.5	187	.217	1.8
1943	11.5	4.2	208	.256	2.9
1944	14.1	4.9	252	.288	4.0
1945	19.1	6.2	378	.401	7.7
1946	18.8	6.6	473	.383	7.2
1947	18.3	5.3	516	.373	6.8
1948	15.9	5.3	459	.404	6.4
1949	19.3	5.4	462	.348	6.7

TABLE D-3-1. (continued)

CATCH OF LOBSTERS IN MAINE, 1880-1978

	Total Catch (Millions of lbs.)	No. of Licensed Lobster Fishermen (Thousands)	Total No. of Traps Fished (Thousands)	Average Price Per. lb. (Dollars)	Total Landed Value (Millions of $)
1950	18.4	5.2	430	.349	6.4
1951	20.8	4.6	383	.348	7.2
1952	20.0	5.0	417	.425	8.5
1953	22.3	5.5	490	.377	8.4
1954	21.7	5.8	488	.373	8.1
1955	22.7	6.0	532	.384	8.7
1956	20.6	5.9	533	.443	9.1
1957	24.4	6.1	565	.367	9.0
1958	21.3	6.2	609	.490	10.4
1959	22.3	6.5	717	.504	11.2
1960	24.0	6.6	745	.457	11.0
1961	20.9	6.5	752	.532	11.1
1962	22.1	5.7	768	.507	11.2
1963	22.8	5.7	731	.553	12.6
1964	21.4	5.8	754	.664	14.2
1965	18.9	5.8	789	.751	14.2
1966	19.9	5.6	776	.749	14.9
1967	16.5	5.4	715	.824	13.6
1968	20.5	5.5	747	.727	14.9
1969	19.8	5.8	805	.808	16.0
1970	18.2	6.3	1,180	1.000	18.2
1971	17.6	6.7	1,278	0.994	17.5
1972	16.3	7.0	1,448	1.14	18.6
1973	17.0	7.9	1,172	1.37	23.3
1974	16.5	10.5	1,790	1.41	23.2
1975	17.0	10.5	1,771	1.62	27.5
1976	19.0	9.0	1,754	1.54	29.2
1977	18.5	8.9	1,700	1.57	32.1
1978	19.1			1.75	33.9

TABLE D-3-2.

ANNUAL CATCH OF LOBSTERS IN MAINE BY COUNTIES, 1969-1978

(Millions of Pounds)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
York	1.1	1.0	1.1	1.0	1.1	1.1	1.1	1.0	1.0	0.8
Cumberland	2.9	2.9	3.0	2.6	2.4	2.4	2.7	3.1	3.2	3.6
Sagadahoc	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.5	0.5
Lincoln	2.3	2.2	2.1	1.8	1.7	1.9	1.9	2.3	2.4	2.3
Knox	5.3	4.7	4.4	4.4	4.6	4.5	5.2	5.2	5.1	5.4
Hancock	5.3	4.6	4.3	4.0	4.7	4.0	3.9	4.6	4.2	4.5
Washington	2.6	2.2	2.2	1.9	2.2	2.1	1.9	2.5	2.0	2.1
Total	19.8	18.2	17.6	16.3	17.0	16.5	17.0	19.0	18.5	19.1

TABLE D-3-3.

SOME TOTAL ESTIMATES FOR LOBSTER FISHERY IN MAINE (Thomas, 1978)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
CATCH IN POUNDS	16,491,195	20,506,500	19,838,385	18,175,815	17,560,620	16,259,670	17,046,855	16,460,325	17,017,411	19,001,053	18,487,138	19,130,459		
CATCH IN NUMBERS	13,975,589	17,232,353	16,531,987	15,273,794	14,633,850	13,549,725	14,325,088	13,492,070	14,300,345	16,102,587	15,535,410	16,212,253		
TOTAL VALUE	13,247,026	14,696,325	15,935,752	16,943,556	17,235,424	16,784,175	21,782,093	22,666,677	27,568,206	27,888,643	29,024,807	33,382,208		
TOTAL TRAP HAULS	27,034,746	34,177,500	32,521,943	30,806,466	32,519,667	26,225,274	31,568,250	26,984,139	34,034,822	30,646,860	34,881,392	32,983,550		
TOTAL BOAT DAYS	194,429	215,216	240,430	183,051	208,104	157,793	180,462	165,182	187,595	187,763	195,342	185,373		
TOTAL MAN DAYS	240,396	262,030	290,800	227,881	261,397	206,708	234,257	227,730	245,031	263,757	266,500	257,962		
TOTAL MAN HOURS	1,764,595	1,875,120	2,018,558	1,735,658	1,948,582	1,502,187	1,857,988	1,641,371	1,894,085	1,928,454	2,027,096	2,020,112		

TABLE D-3-4.

MAINE LOBSTER POPULATION PARAMETERS

Parameter	Reference	Calculated or Estimated Values
MSY (Equilibrium Yield)	Dow (pers. comm. in Anonymous, 1978)	10,000 metric tons (22.3 million pounds) and optimal level of effort of 800,000 traps.
	Dow (1976)	In years with same water temperature (1958-1973), catch declined 1000 metric tons per increase of 175,000 traps.
	Dow (1964)	Available abundance fluctuates ± 5% with each degree (F) of April-May temperature change.
Yield per Recruit	Thomas (1973)	Most advantageous if size at first capture were at least 3 1/2 inches (89mm) carapace length, age 8 years, yield in weight per recruit of 355 to 440 grams. (See his Fig. 18, curve "F", and Table 11).
Age at First Harvest (Actual)	Thomas (1973) Krouse (1977a)	Average for whole coast of Maine: 6.8 years. 5.2 years at Jonesport, probably 5 to 7 for inshore Maine.

TABLE D-3-4. (continued)

Age at First Harvest (Optimum: to provide maximum yield per recruit).	Thomas (pers. comm. in Anonymous, 1978).	14 years (5.3 inches, 135 mm CL)
	Anonymous (1978)	13 years (5.1 inches) or 6.4 to 13.2 years depending upon various combinations of natural and fishing mortalities. (See Table 23, 24).
Estimate of Annual Available Legal Lobster Supply.	Dow (1964)	1947-1956: 23 to 28 million pounds. 1951-1963: 25 to 28 million pounds.
Mortality: Instantaneous Natural.	Thomas (1973)	0.02 (2.0%) to 0.35 (29.3%)
Instantaneous Fishing	Thomas (1973)	0.79 (54.6% to 2.90 (94.5%)
Instantaneous Total.	Thomas (1973)	1.14 (67.9%) to 2.92 (94.6%)
Most plausible interpretation of data.	Thomas (1973)	Instantaneous Natural: 0.10 (10%) " Fishing: 2.30 (90%)

TABLE D-3-5.

CATCH OF MAINE LOBSTER BY MONTHS

Millions of Pounds

	1975	1976	1977	1978
Jan.	0.7	0.6	0.4	0.3
Feb.	0.2	0.1	0.1	0.2
Mar.	0.2	0.1	0.2	0.1
Apr.	0.4	0.5	0.4	0.4
May	1.2	1.0	1.2	0.8
June	0.8	1.0	0.8	0.7
July	1.6	2.1	2.0	2.0
Aug.	2.4	3.6	3.3	4.3
Sept.	2.8	3.7	3.6	4.0
Oct.	2.9	3.2	3.1	2.9
Nov.	2.6	2.2	2.4	2.2
Dec.	1.2	0.9	0.9	1.3
Total	17.0	19.0	18.5	19.1

FIGURE D-3-1

TOTAL LOBSTER LANDINGS, TOTAL VALUE, AVERAGE PRICE PER POUND
MAINE, 1880 - 1978

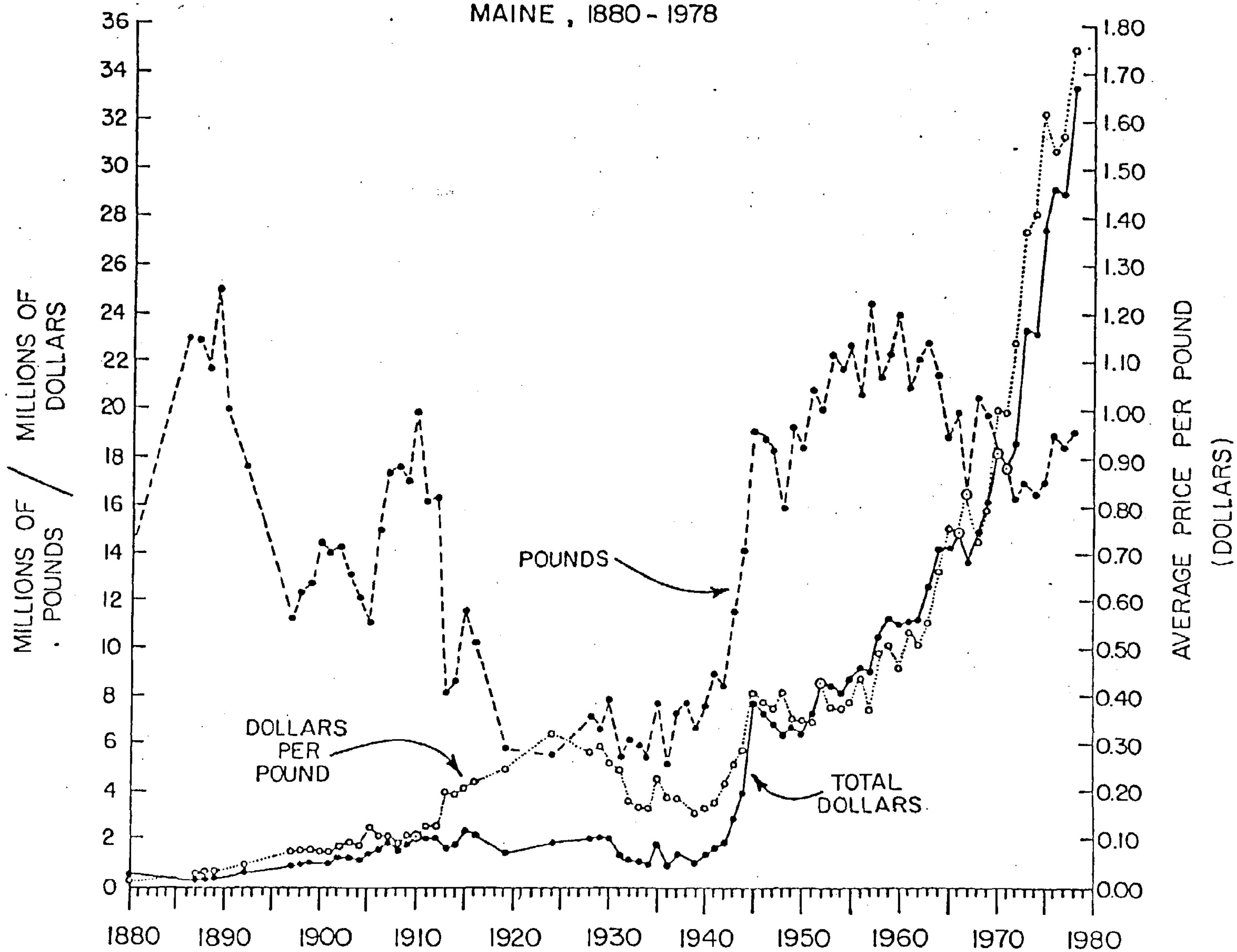


FIGURE D-3-2

TOTAL LOBSTER LANDINGS, TOTAL NUMBER OF FISHERMEN, TOTAL NUMBER OF TRAPS
MAINE, 1880-1978

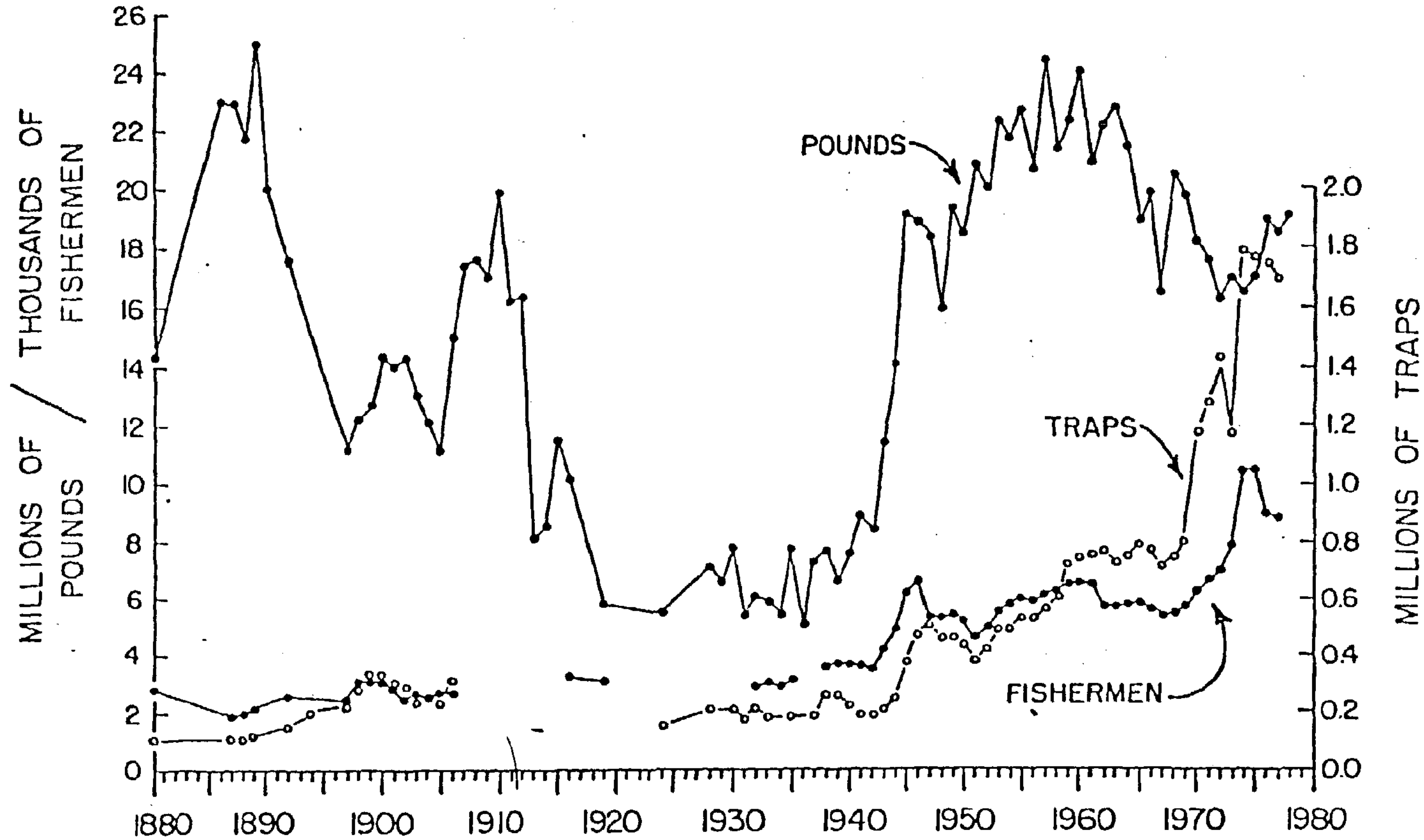
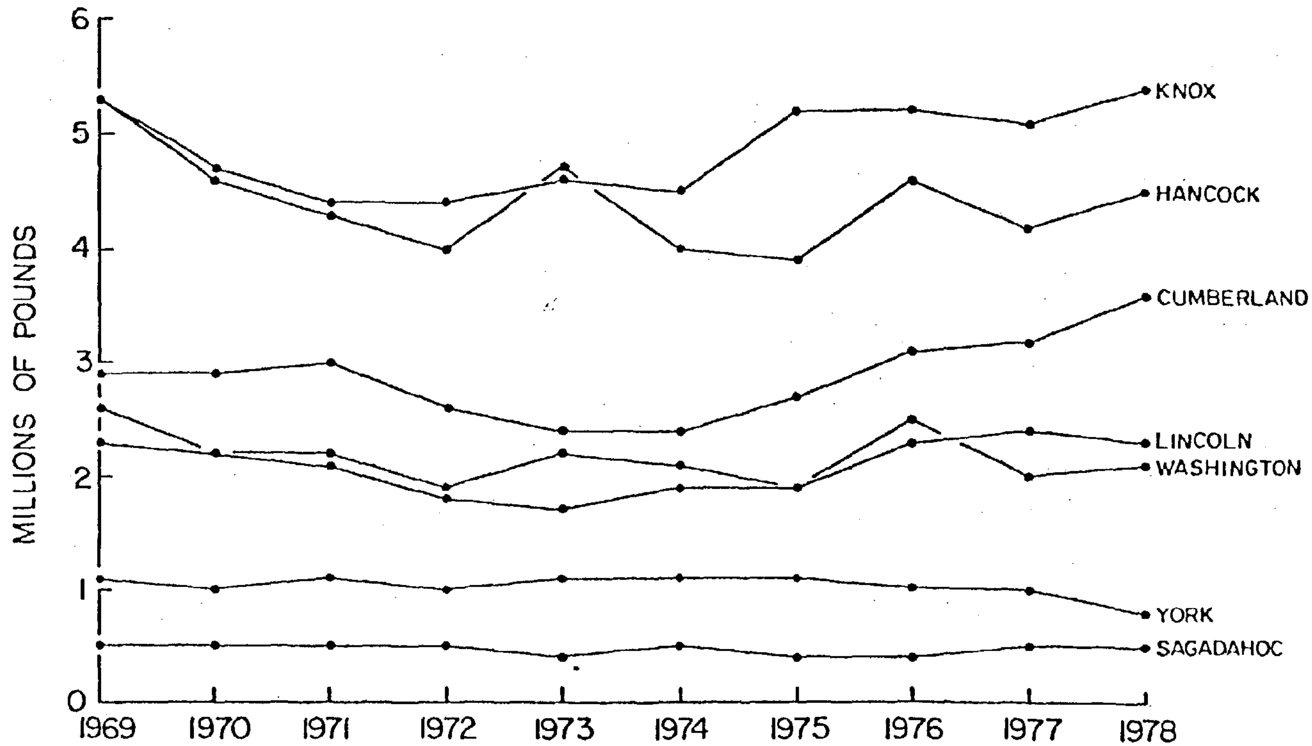


FIGURE D-3-3

ANNUAL CATCH OF LOBSTERS IN MAINE BY COUNTIES, 1969 - 1978



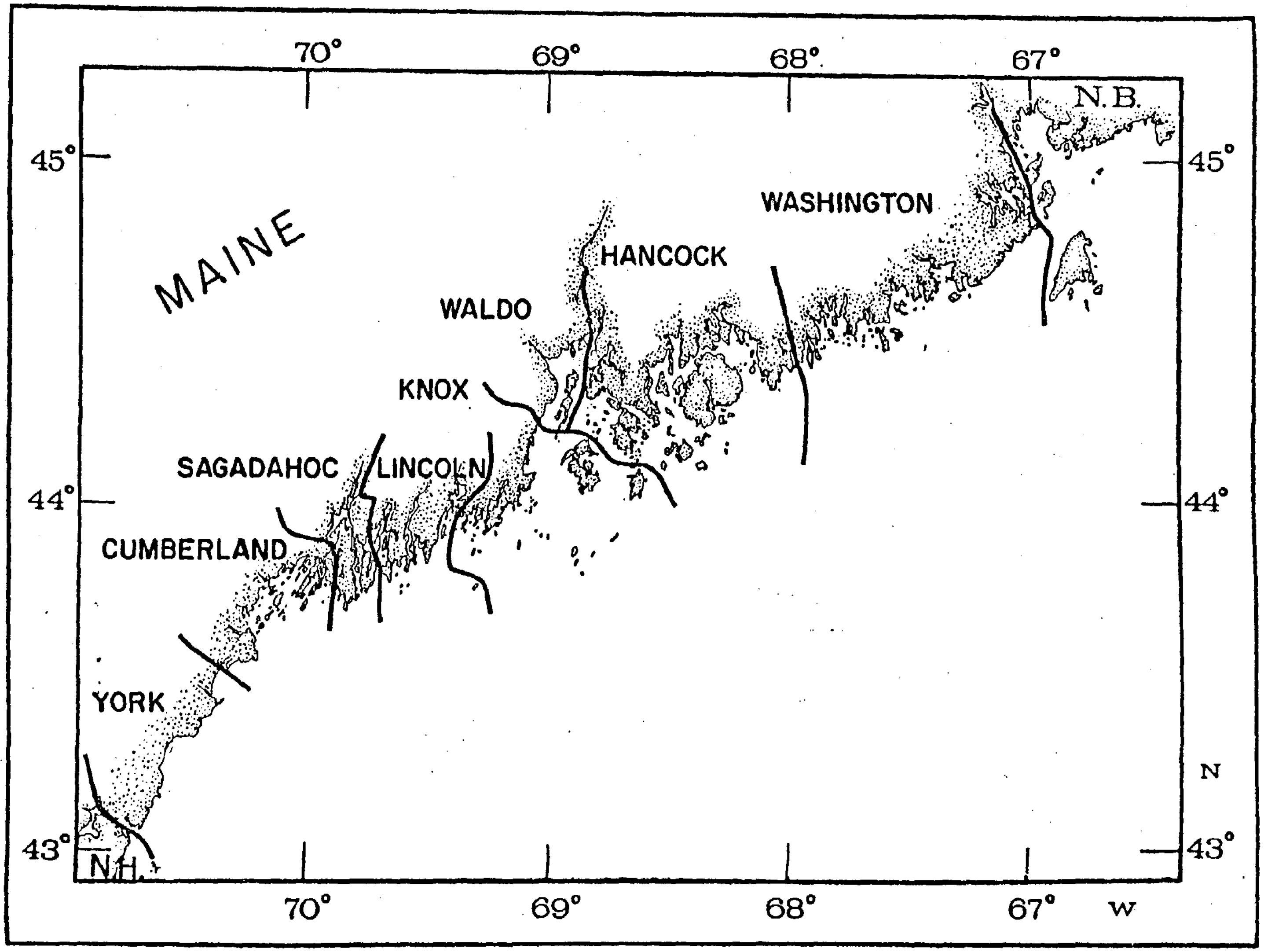


FIGURE D-3-4. State of Maine map with county designations.

Figure D-3-5

TRAPS PER BOAT IN MAINE LOBSTER FISHERY (THOMAS 1978)

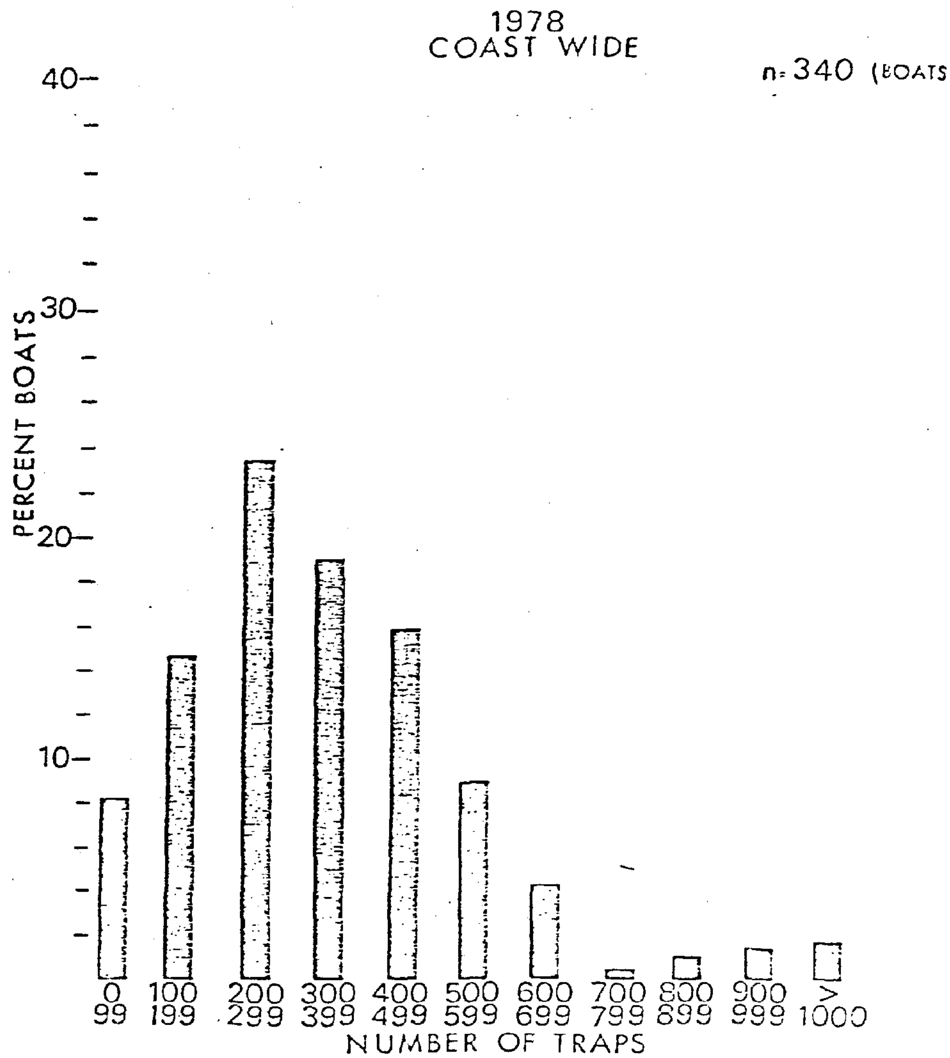


FIGURE D-3-6

LOBSTER CATCH-EFFORT 1897-1976 (THOMAS 1978)

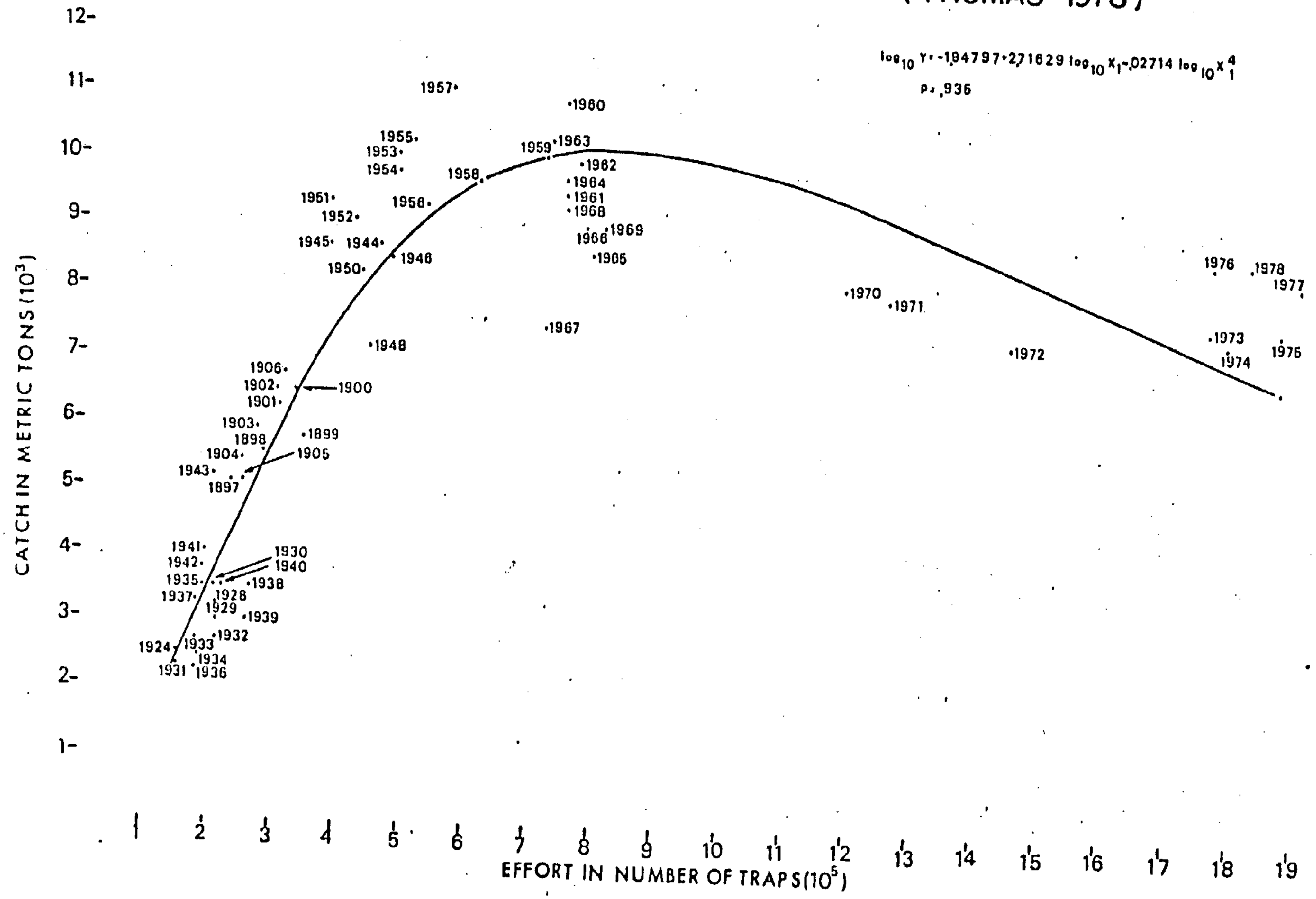
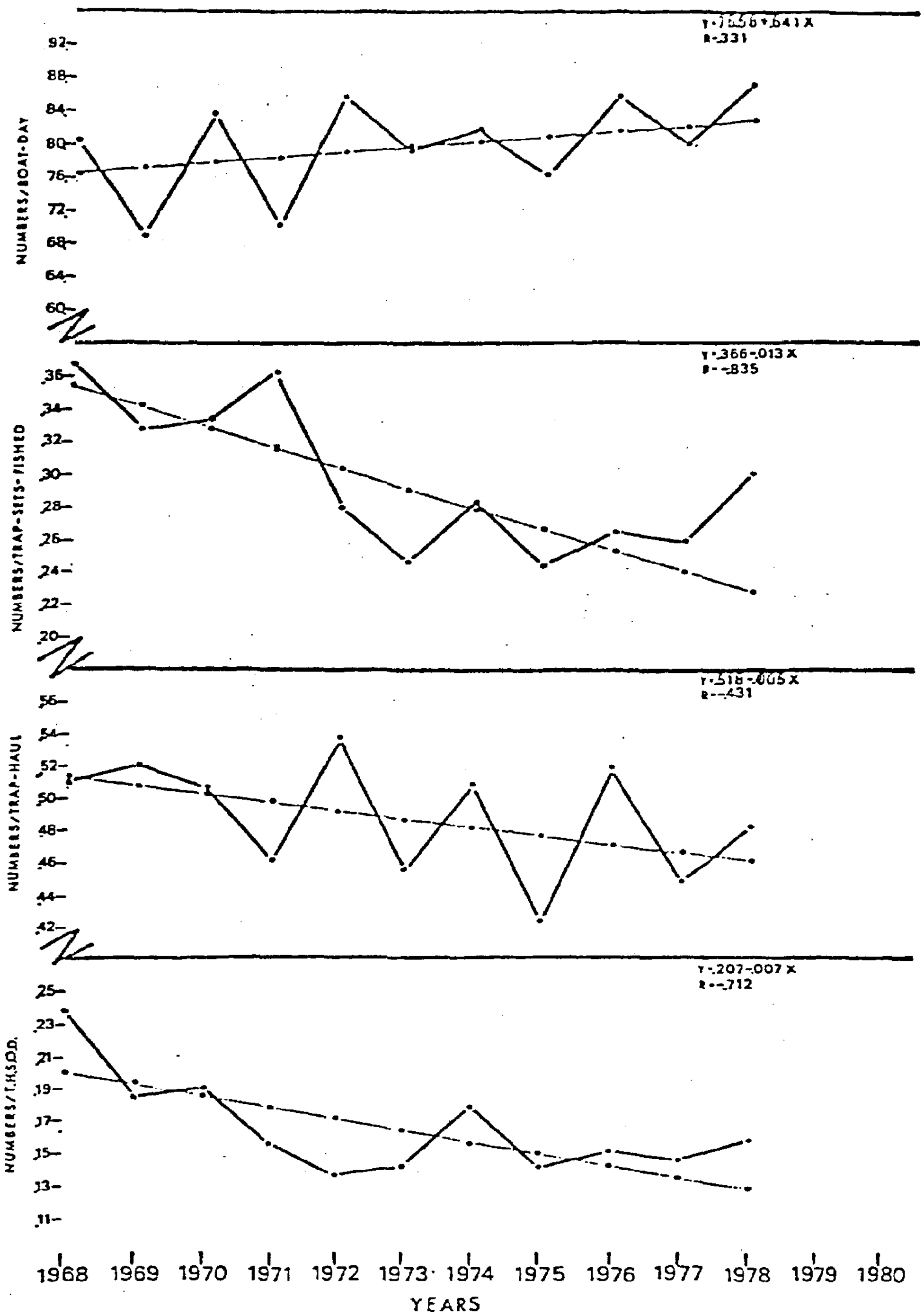


Figure D-3-7.

CATCH PER UNIT OF EFFORT IN LOBSTER FISHERY (THOMAS 1978)



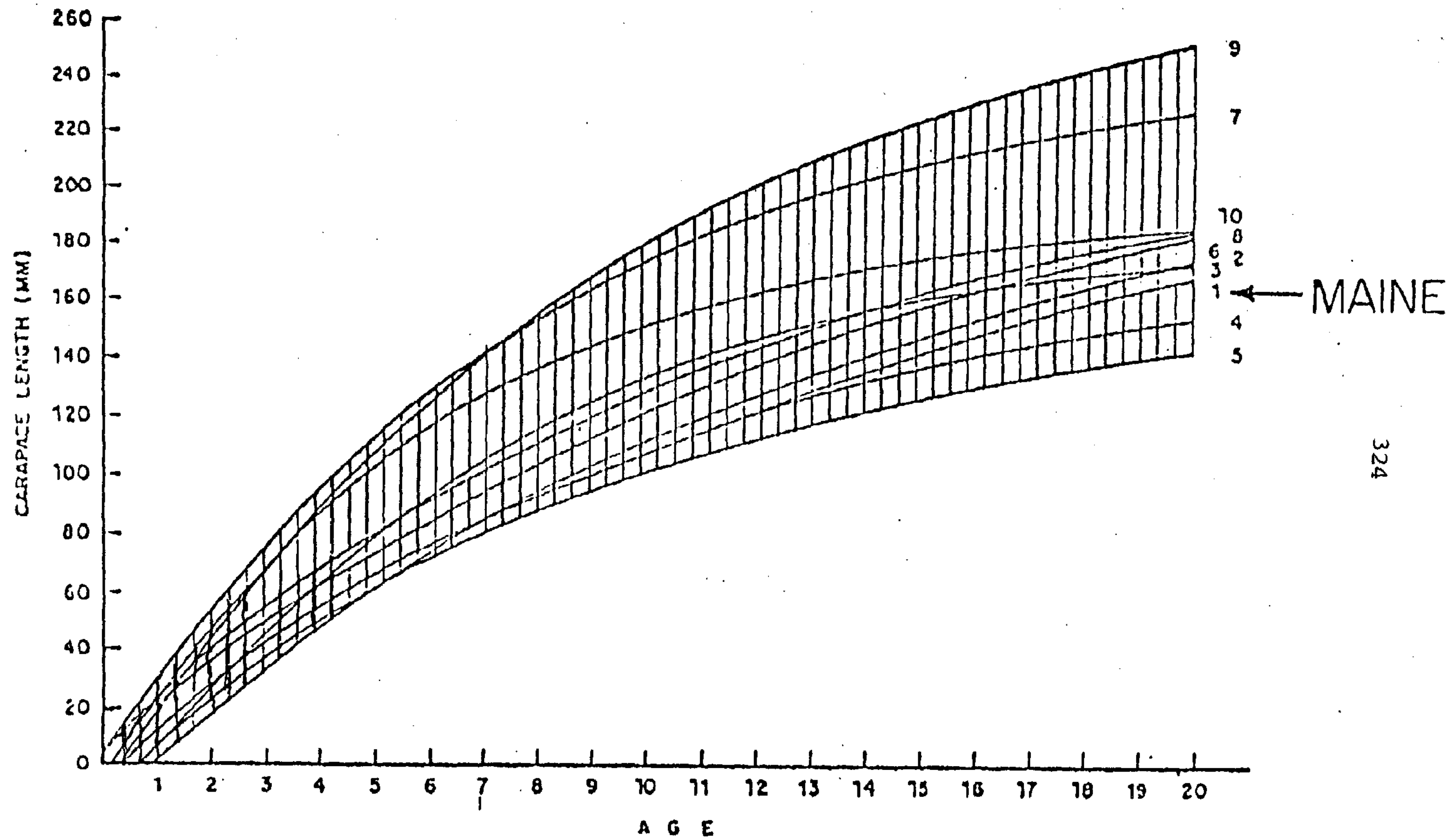
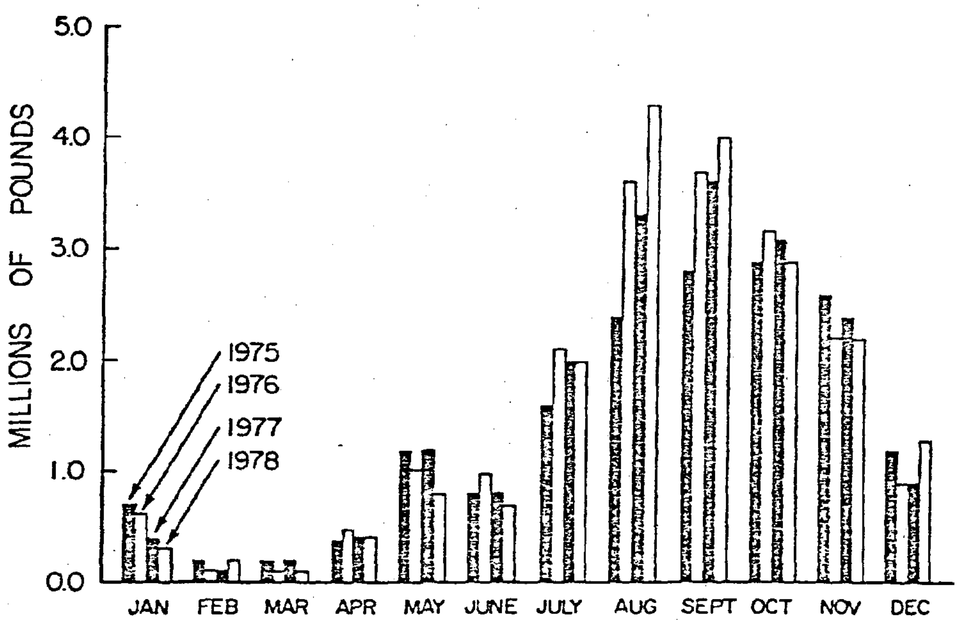


Figure D-3-8. Band of lobster growth curves (von Bertalanffy) examined in yield relationships.

FIGURE D-3-9.

CATCH OF MAINE LOBSTERS BY MONTHS, 1975-1978



ELEMENT D-4:

A CHARACTERIZATION OF THE SCALLOP FISHERY OF MAINE

by

Clement J. Walton

Distribution:

Sea scallops *(Placopecten magellanicus)*, range from the northern shore of the Gulf of St. Lawrence and Newfoundland to Cape Hatteras. The north-south distribution of sea scallops, and probably inshore distribution south of Cape Cod, is temperature limited. Scallops tend to be found in deeper water in the southern portion of their range and populations are sparse or scattered at the extremities of the range.

Scallops are found along the entire Maine coast and harvestable beds occur close inshore at depths of only a few fathoms. This species prefers hard bottom such as rocks, cobble, gravel, sand and firm mud and is only rarely found on soft mud. Spatial distribution may also be limited by hydrography and scallops appear to be more abundant where there are currents near the bottom.

The Maine Coastal Inventory map series, 1-1 through 11-2, prepared by the Maine State Planning Office, details a number of inshore scallop producing areas. These data provide a qualitative sketch of some of the scallop beds and caution should be exercised in their interpretation since they were based on anecdotal information.

Availability:

The availability of scallops within the territorial waters of the state is limited by a regulation which imposes a closed season from April 16 to October 31 each year. The closed season does not apply outside the territorial waters of the state as defined in the Maine

Marine Resources Laws and Regulations (§6722). A minimum size limit of three inches (longest diameter) with a 10% tolerance is provided for scallops under §6721:1,2; this restriction is usually enforced for landings and thus will apply to scallops taken outside the territorial waters but landed in Maine ports.

There are a number of area and gear restrictions which also affect availability of scallops. These include:

> A maximum combined drag size of 8' in Blue Hill Bay. §6723.
>
> A prohibition against the use of otter trawls for scalloping in the Penobscot River. §6724.

Regulations of the Commissioner of the Department of Marine Resources which may affect the taking of scallops include:

> Prohibitions against drag seines in the Damariscotta River (Sect. 9, IV); Georges River (Sect. 9, V); Sargentville Harbor (Billings Cove) (Sect. 32).
>
> Prohibitions against beam trawls in Sedgwick Harbor (Sect. 34).
>
> A closure of areas of the Harrington River and Bay and Pleasant River to scallop dragging from April 15 through December 1 each year (Chapter C, Sect. 3).
>
> A maximum combined drag size of 4' for scalloping in Gouldsboro Bay, Hancock and Washington Counties (Chapter C, Sect. 4).

Regulations against the taking of marine mollusks from polluted areas have not been interpreted as including scallops although this could be enforced and could preclude the taking of scallops in a number of inshore areas.

Closures to the taking of shellfish because of paralytic shellfish poisoning (PSP) have not included scallops because the portions consumed are not toxic. If consumption patterns change and a market for whole scallops develops, such that muscles and viscera are eaten, the PSP closures would be enforced for scallops. This could affect the harvesting of scallops outside the territorial waters of the state.

The distribution, abundance and size range of scallops affect their commercial availability. Beds close to ledges and shoal areas frequently cannot be harvested by conventional drag and are vulnerable only to SCUBA divers. Thinly dispersed populations and those with a sizable proportion of small (less than three inch diameter) scallops are not usually profitable to harvest.

The historical production data presented in Table D-4-1 must be interpreted with caution; some Maine boats started fishing offshore in the 1930's but the landings prior to 1950 were primarily representative of the inshore fishery. Since 1950 the offshore harvest has become a significant proportion of the total landings. An allocation of landings to inshore and offshore fisheries has been made by various authors (Dow, 1956; Baird, 1956, 1967) by assuming that landings made during the closed season were entirely offshore harvesting. This method is of questionable accuracy for open season landings since they represent combined inshore and offshore harvesting and available data do not permit accurate allocation of catches to inshore and offshore fisheries.

Commercial scallop fishing apparently started in the midcoast area

TABLE D-4-1.

MAINE SCALLOP LANDINGS
(shucked meats in thousands of pounds)

YEAR	TOTAL	YEAR	TOTAL	YEAR	TOTAL
1887	220	1918	-	1949	509
1888	181	1919	73	1950	525
1889	306	1920	-	1951	677
1890	-	1921	-	1952	1,496
1891	-	1922	-	1953	1,697
1892	117	1923	-	1954	708
1893	-	1924	296	1955	1,114
1894	-	1925	-	1956	970
1895	-	1926	-	1957	745
1896	-	1927	-	1958	394
1897	170	1928	326	1959	1,134
1898	71	1929	359	1960	1,875
1899	53	1930	436	1961	2,740
1900	174	1931	587	1962	2,169
1901	219	1932	608	1963	1,186
1902	126	1933	1,073	1964	917
1903	137	1934	-	1965	414
1904	142	1935	743	1966	320
1905	628	1936	-	1967	188
1906	561	1937	-	1968	220
1907	521	1938	793	1969	152
1908	952	1939	395	1970	180
1909	1,858	1940	455	1971	387
1910	2,027	1941	316	1972	967
1911	1,462	1942	131	1973	804
1912	1,857	1943	227	1974	445
1913	777	1944	101	1975	1,594
1914	850	1945	105	1976	629
1915	-	1946	137	1977	395
1916	587	1947	507	1978	908
1917	-	1948	454	1979	1,644

during the 1880's and expanded to the region between Mount Desert Island and the Sheepscot River (Baird, 1956). The early fisheries were limited to shallow (<25 fathoms) scallop beds due to the nature of the gear and fishing vessels. The addition of powered winches and motorized vessels to the fishing fleet extended the area that could be fished and allowed the deeper scallop beds to be harvested. The commercial fishery concentrated on the inshore grounds east of Penobscot Bay prior to 1950. The inshore closed season, mid-April through November, was suspended during World War II to increase food production. A closure from April 1 through October 31 was re-established in 1947 and subsequently modified to the present mid-April through October closure (Dow, 1956).

Landings between 1945 and 1970 were primarily (66 to 100%) scallops from six to nine years of age with six year olds predominating (Dow, 1971). The mean shell diameter of scallops in the commercial harvest has apparently declined since the 1920's. This probably reflects a gradual decrease in the mean age of the harvested scallops and can be associated with the expansion in fishing effort (number of boats in the fishery).

Major scallop producing areas have traditionally included the inshore waters from Penobscot Bay to Mount Desert Island, eastern Penobscot Bay in the vicinity of Castine, Jonesport and the Harrington and Addison Rivers. Some inshore scalloping has also occured in Casco Bay and the Sheepscot, Damariscotta and Piscataqua Rivers.

Offshore areas are not as completely documented but localized fisheries have occurred in the vicinity of Jeffreys Ledge and Cashes Ledge. Other areas may include Platts Bank and off Machias Seal Island. It is difficult to quantify historical production for these areas since data are not available and production peaks tend to coincide with the appearance of one or more successful year classes in a given area.

The sea scallop has been characterized by irregular abundance in most areas of the coast and this probably results from biological and environmental factors. This variability has tended to generate cyclic fisheries in which the discovery of a large population of harvestable scallops leads to a rapid expansion of the fishery and the subsequent depletion of the stock. This variability occurs in both inshore and offshore areas; the 1975-76 scallop fishery in the Castine area of Penobscot Bay and the 1979-80 fishery off Jeffreys Basin are examples of the rapid expansion of harvesting of newly discovered scallop beds.

Assessment of the scallop stocks of the Gulf of Maine has been a difficult problem since the landings have exhibited large fluctuations due to social and economic factors (e.g., competing fisheries such as for shrimp; market demand, price, etc.) and changes in population abundance. Significant increases in landings have been produced by successful year classes of scallops such as the 1972 year class on Georges Bank and in the Middle Atlantic Bight (Serchuk *et al.*, 1979) and the 1975 year class off southern Maine.

Successful year classes are one source of variations in abundance.

The scallop is enormously fecund and a five or six year old female can produce two million eggs (Posgay, 1979). There is no biological evidence that different stocks occur within the Gulf of Maine and the spatial and temporal distributions of scallop populations are probably a result of their reproductive biology. Spawning occurs in late summer or early fall and the larvae are pelagic for three to four weeks; thus the progeny are not apt to settle in the vicinity of the parental beds and the distribution of scallop spat is determined by currents and environmental conditions in the area of spatfall.

Scallops generally occur in high salinity waters; survival may be limited in some shallow estuarine areas where coastal runoff is occasionally high. Spawning and/or larval development can be prevented or delayed by very low summer temperatures and this probably causes small or patchy distributions of scallop sets in the northern portion of their range (Medcof and Bourne, 1964). Mortalities may also be induced by exceptionally high summer temperatures (Dickie, 1958).

The relationship between temperature and commercial landings of scallops is not clear. Dow (1971a) reported a negative correlation ($r = -.91$) between Boothbay Harbor mean annual seawater temperature and scallop landings lagged seven and eight years. Dow (1971b) also reported a strong ($r = -.7$) negative correlation between these mean annual temperatures since World War II and landings with a six year lag. Sutcliffe, et al. (1977) reported a high positive correlation ($r = +.88$)

for November mean seawater temperatures at Boothbay Harbor and New England scallop landings lagged by five years. These authors also reported a very high positive correlation (r = +.79) for St. Andrews temperatures in November and New England scallop landings with a six year lag.

Populations are also limited by predation and mortalities may be high, especially in larvae and juveniles. Starfish *(Asterias vulgaris)* feed on juvenile scallops (Welch, 1950; Dow, 1969). Adult and juvenile starfish are major predators on scallop spat and may be the most important factor influencing spat survival (Naidu and Scaplen, 1979). Predators on juvenile scallops include cod *(Gadus morhua)*, plaice *(Hippoglossoides platessoides)*, and wolffish *(Anarhichas lupus)*, Medcof and Bourne, 1964). Merrill and Posgay (1964) reported an annual natural mortality of about 10% for sea scallops.

Fishing mortality can be significant in some areas and mortalities may also be induced by dragging activities due to burial in soft bottom areas, breakage of small scallops in the dredge or during culling and dumping operations. Some small scallops may also die from exposure to low air temperatures during the Maine winter fishery.

Weather conditions also affect landings of scallops. Strong winds, high seas and low temperatures reduce fishing effort and cumulative effects may be deduced from monthly landings data. Larger vessels fishing offshore beds may not be adversely affected by sea conditions which preclude fishing by the smaller vessels in inshore waters.

Maine appears to have a greater proportion of small vessels (mostly concentrated in the inshore fisheries) than is found in other coastal states where offshore fishing is the rule. This suggests that the Maine fleet may be more vulnerable to adverse weather conditions. Rising fuel prices may also have a greater proportional impact on the Maine fleet since small vessels operating a day-trip fishery are probably less efficient than larger vessels working offshore beds.

Harvesting:

The available data are inadequate for the development of comprehensive social and economic profiles of the scallop harvesting sector. Lobstermen and the owners of small draggers appear to participate in the inshore scallop fishery although the value of the scallop fishery as winter employment for lobstermen is probably insignificant.* Switching between different winter fisheries is quite common and probably depends upon the fishermen's evaluation of the prospects for the different fisheries in the immediate future. Rigging for scallop dragging is easier and less expensive than rigging for bottom trawling for shrimp or groundfish and this may affect the switching process. Most scallop vessels are used for some other type

---

*In 1976 Maine issued 9,041 lobster licenses and 604 scallop licenses. If all scallopers were lobstermen the scallop fishery would employ less than 7% of the licensed lobstermen in winter.

of fishing. The allocation of capital and operating costs for a typical inshore scallop fishing vessel could be estimated as a proportion of the annual costs of operating a lobster boat. This proportion could be based on the relative time spent lobstering vs scalloping; with the present five and one half month scallop season this should be something less than 5/12 of the costs of operating a lobster boat.

Wilson and Peters (1978) provided some data on the characteristics of vessels in the scallop fishery. The results of their census are summarized in Table D-4-2 and the authors estimated a response of about 60%. It should be noted that some of the vessels that reported shellfishing activity may have been dragging for mussels and/or surf clams (York-Cumberland counties). These census data are an estimate since there were 192 vessels reporting shellfishing activity in 1977 and 440 scallop licenses were purchased.

The census data suggest that almost 92% of the vessels owning scallop drags are less than 46 feet in length and therefore vessel capital investment and operating costs could reasonably be based on lobster boat characteristics. Winter weather conditions limit the number of days that scallops can be fished during the inshore open season and therefore not more than 25% of the annual investment and expenditures for the operation of an average lobster boat should be attributed to vessels in the scallop harvesting sector. Capital investment involved in rigging the average lobster boat for scallop

TABLE D-4-2.

MAINE FISHING VESSEL CENSUS DATA: 1977

Vessel Characteristics:	Vessel length		
	46'	46'-65'	66'+
Percentage size distribution and number of Maine fishing vessels. (n=438)	86.1%/374	10.7%/47	3.2%/14
Percentage and number of Maine vessels owning scallop drags	47.1%/176	25.5%/12	28.6%/4
Percentage of Maine boats which fished for shellfish in 1977:*			
Nearshore**-Eastport to Monhegan:	63.6%	87.5%	0%
Nearshore**-Monhegan to Cape Ann:	38.2%	87.5%	0%
Jeffreys & Cashes Ledges:	9.6%	25.0%	0%
Georges Bank:	0.4%	12.5%	100%

Based on data from Wilson and Peters, 1978.

*Percentages do not sum to 100 because some vessels fished more than one area.

**Nearshore is defined as being within 20 miles of the coast.

dragging should involve roughly $2,000 for gear (1979). Fuel expended in the inshore fishery could be a significant cost item and may exceed $2,000 for the open season.

Scallop dredge gear is enormously variable because of the fishermen's habit of adapting the gear to fish in their particular area. Inshore gear for gravel and rock bottom usually involves scallop drags of three to four foot width towed singly, as doubles or triples. The multiple dredge rigs can adapt to uneven bottom contours and will fish better than the single wide dredge often favored for relatively smooth bottom. For softer sand and clay bottoms, especially when smaller scallops are abundant, small beam or otter trawls with a chain footrope have been used. The beam or otter trawl is rare in the Maine scallop fishery but is occasionally used offshore and in the Penobscot Bay area. Toothed or rake type drags are not commonly used in Maine. The number and size of dredges towed by any specific boat are dictated by the bottom topography and, to some extent, by the powered deck gear on the boat and the available manpower.

The large (66 ft. +) offshore draggers usually tow two multiple drags which may consist of gang rigged dredges, 12 or more feet in width. Individual dredges are usually rigged with three inch or larger steel rings and chain on the bottom and a heavy mesh nylon net bag on the top. In areas of very rough bottom chain and rings may be substituted for the top webbing. In sand and rocky areas the chain and rings wear rapidly and gear repair costs may be quite high. There have been relatively few technological advances in dragging gear since the advent of powered deck gear and there seems to be little immediate prospect for a dramatic increase in fishing power.

There is a modest recreational fishery conducted with SCUBA gear (see Element C, Recreational Fisheries) and a small amount of commercial harvesting by divers. Commercial harvesting by SCUBA usually involves local sales and few landings data are collected. SCUBA gear has obvious advantages in that it is suitable for rough bottom and scallops can be harvested from areas which cannot be fished by dredge gear. The disadvantages are that diving is confined to relatively shallow water in a small area and diving time is limited.

Prices paid for scallop meats are comparatively high but the processing is labor intensive and the return per pound of shellstock harvested is more modest. Dow (1956) pointed out that the economic factors involved in production are probably quite different for the inshore and offshore fisheries. He based this conclusion, in part, on the correlations between price and production in these fisheries. Harvest in the offshore fishery is probably influenced by price ($r = .74$ for the 1949-1955 period) whereas the inshore fishery exhibited a negative correlation ($r = -.65$ for the 1949-55 period) which suggested that production levels influenced prices.

Imports of Canadian scallops are quite large but their distribution in Maine is not documented. Most imports are shucked meats, either fresh or frozen, transported by truck through Houlton, Calais or Eastport. There are also some landings by vessel at Portland. The import data are available through the U.S. Customs and are tabulated in the "Blue Sheets" (NMFS Fishery Market News Report). A review of the import data in a six month segment of these reports suggests that the bulk of the scallops imported from Canada pass to or through Maine. The magnitude of these imports may be surmised from the 1978 scallop imports and landings data; Maine landed 908,000 pounds and imported 24,332,000 pounds of scallop meats. These imports probably do not have any significant impact on the Maine scallop fishery although they may tend to stabilize prices.

Economic conditions in other fisheries may affect the scallop harvest, this occurs in the fishermen's decisions on whether to rig for scalloping in the fall or to fish for some other species such as shrimp. These effects cannot be easily quantified with the available data. Regressions of the number of scallop licenses against effort (number of vessels) in the shrimp fishery for a series of years do not yield significant negative correlations that might be expected if systematic switching occurred. There are a great number of lobster boats in Maine and a majority of these are relatively inactive during the winter; this under utilized harvesting capacity acts as a buffer to mask the effects of switching from one fishery to another.

Legal constraints appear to have only a moderate effect on harvesting and a negligible effect on abundance. A license is required for commercial harvesting or any harvesting in excess of two bushels (four quarts of shucked meats) per day. The license fee is modest ($25 in 1979) and it includes the license holder's boat crew. The closed season (mid-April through October) applies only to the state's territorial waters (inside three miles) and offers obvious advantages for the lobster fishery. This open season covers an area fished by typically small (lobster) vessels and is appropriately timed to permit off-season lobstermen to participate in the scallop fishery. The closed season, of course, restricts fishing at the time that these vessels are engaged in lobstering; this coincidence also eliminates some gear conflicts. During warm years lobsters tend to remain active through November and gear conflicts between scallopers and lobstermen have occurred in such locations as Blue Hill Bay, Penobscot Bay and the Harrington River. Such conflicts can be averted by judicious postponement of the open season on scallops in selected areas, e.g., the extended closure to December 1 each year in the Harrington and Pleasant Rivers (Chapter C, Sect. 3).

Some conservation of the resource may be achieved through the closed season since most scallop beds cannot sustain intensive year round fishing. It is probable that, without the closed season, the average newly discovered bed could be fished out in one year; with the closed season it takes two years. The inshore scallop populations may derive some benefit from the closures since fishing is, fortuitously, prohibited during the spawning season although there is no evidence to suggest that inshore abundance is related to the spawning success of inshore populations.

Offshore scalloping is not well documented for the Gulf of Maine fisheries. Landings data for 1979 (Richard Barnard, NMFS, personal communication) do indicate some recent harvesting patterns and are presented in Table D-4-3.

Area and gear restrictions, in sum, have little effect on scallop abundance although they do affect the fishery. Limitations on the size of drags appear to favor small vessels since they reduce the efficiency of larger craft capable of operating with multiple drags. Some area and gear restrictions tend to avert gear conflicts but other restrictions are based solely on restraint of competition. Perhaps one example of the latter would be the prohibition of otter trawls for scalloping in the Penobscot River (§6724). This restriction presumably arose because of a unique situation in which a scallop bed on relatively flat soft bottom in Penobscot Bay was harvested with great efficiency by otter trawls with chain gear on the footropes.

The three inch size limit is probably advantageous since most of the scallops are old enough to have spawned at least once. Shucking is conducted aboard the boats and enforcement of a size limit is extremely difficult since the evidence is rapidly discarded during fishing

TABLE D-4-3.

MAINE SCALLOP LANDINGS, 1979
(shucked meats in pounds)

Location:	COASTAL AREA Eastern (511)	Central (512)	Western (513)	Totals
0 - 3 miles, offshore	128,741	461,678	12,054	602,473
3 - 12 miles, offshore	0	1,903	492	2,395
Beyond 12 miles	0	32,606	67,424	100,030

Location	Landings	Combined
Jeffreys Ledge (514)	11,012	558,777
Cashes Ledge (515)	69,646	
Georges Bank (523)	292,826	
Georges Bank (524)	85,263	

Total landings: 1,643,645

operations. During rapid growth periods in some areas scallops can exceed four inches prior to spawning and the size limit would confer no advantages associated with reproduction. Serchuk, et al., (1979) provided analytic data to demonstrate that, for most fishing mortality rates, scallop meat yield increases as size at first capture increases. Optimal yield for Gulf of Maine scallops would probably result if the minimum size limit were increased from three inches (76 mm) to at least four inches (101 mm). For Gulf of Maine scallops this increased size limit would raise the age at first capture one additional growing season and, at moderate to high levels of fishing mortality ($F \geq 0.3$), increase the meat yield by 20% or more.

Harvesting of scallops by divers has been characterized as very efficient and doubts have been expressed about the wisdom of allowing this method of fishing. In view of the limitations inherent in SCUBA operations and the observed tendency for divers to operate in areas where draggers cannot fish, and the converse, the two fisheries generally do not compete for the same resource. Dow (personal communication, 1978) estimated that divers take less than one percent of the landings (see also Element C, Recreational Fisheries).

Processing:

Shucking is usually conducted aboard the fishing vessel during dragging or while returning to port. Shells and viscera are usually discarded on or near the fishing grounds. The recent (1979-80) scallop fishery off Jeffreys and Cashes Ledges has been an exception to the rule and shucking has been performed ashore. The meats are washed in sea water at the time of shucking and are then dumped into pails or large plastic bags.

Dealers receive the scallops from the boats, weigh them and then dump them into bulk shipping containers. The scallop meats may be washed again at this stage. Most meats are packaged in bulk containers or plastic shipping bags in boxes for immediate truck shipment. Scallops may be chilled by ice packed around the boxes (or snow if available).

Scallop handling is practiced by a number of fish and shellfish dealers in the state and comprises a small segment of their activities. Few dealers arrange their operations to emphasize the handling of scallops and only a very few operations, usually secondary dealers, engage in the preparation of specialty products, or freezing of scallop meats.

Wholesale dealers handling scallops must possess a wholesale seafood license ($50 fee in 1979) and retailers are also required to have a license ($10 fee in 1979). Sanitary standards in the processing sector are a problem in that the Shellfish Sanitation Act does not cover scallops. The Department of Marine Resources has not assumed responsibility for scallop handling under the Fish Inspection Act. The U.S. Department of Agriculture, under the pure food laws, has responsibility for monitoring same handling practices but this has little effect on handling procedures in Maine.

Sanitation practices can be substantially improved but state and federal agencies do not have the manpower and/or funding to inspect and enforce existing regulations at this time. Major wholesale dealers are reasonably prudent in the observance of sanitary standards but small dealers, mostly those buying from day trip inshore vessels, are a potential problem.

There are few serious processing problems involved in handling shucked meats purchased from fishermen. The recent offshore fishery from Casco Bay to Kittery has some unique problems since shucking is done by the wholesale dealer or by people under contract to the dealer. The landings are large and shucking has occupied available labor and space in York and Cumberland County coastal towns. Disposal of shells and scallop viscera has become a major problem and conflicts over both legal and illegal dumping have arisen.

Landings have been characterized by an unusually high proportion of sublegal scallops on occasion since harvesting and landing has been conducted with little or no culling. Some attempts to utilize shucking machines have been attempted but these machines operate efficiently only when handling scallops of uniform size. Most of the bulk landings in this fishery have been mixtures of different sized scallops and culling and sorting is necessary before machine processing.

A large proportion of the landings of scallops are distributed through direct sales from harvester to consumer or retailer (restaurants and local markets). This practice is almost universal east of Penobscot Bay and in some other areas. Most of the scallopers in the eastern Casco Bay area sell directly to consumers or restaurants (DMR Warden Charles Hutchings, personal communication). These landings are unrecorded and comprise a significant proportion of the Maine scallop harvest. Dow (1979) estimated that reported landings in the 1967-72 period represented only 59% of the actual inshore catch.

The processing sector of the scallop industry is conducted primarily by the wholesalers and, aside from packing and shipping, there are no elaborate procedures involved. The wholesaler usually buys from fishermen and other wholesalers and sells the scallops directly to retailers or out of state wholesalers. The marketing structure of the scallop industry is not clearly defined and direct sales to the consumer may occur at any level from harvester to retailer.

There are few legal constraints imposed upon the processing sector and, aside from license fees, there are no outstanding expenditures involved in regulatory compliance. Intrastate distribution is covered by the wholesale seafood license. Interstate shipments do not require any licensing or inspection.

The proposed U.S.-Canadian fishery agreement for the Gulf of Maine may affect scallop harvesting by Maine fishermen and the level of imports sold through Maine shellfish dealers. The proposed allocation (based on historical catches) of 75% of the total allowable catch (TAC) of offshore scallops to Canadian fishermen (Georges Bank area) is a current subject of debate. The problem has been aggravated by the fact that U.S. harvesting in recent years has risen to roughly 50% of the TAC on Georges Bank. Georges Bank scallops comprised 23% of the Maine scallop landings in 1979 (Table D-4-3). A negotiated reduction in the U.S. share of this scallop harvest could adversely affect the Maine fishery and may increase fishing effort on other offshore areas such as Cashes and Jeffreys Ledges.

Economic Importance:

Scalloping has traditionally been a source of off-season income for commercial fishermen in Maine. The expansion of harvesting to offshore waters during the 1950's added a new dimension to the fishery; scalloping remained an off-season fishery except that larger vessels, seasonally engaged in ground fishing, were added to the scallop fishing fleet. The economic importance of the scallop fishery is difficult to assess in terms of impacts on harvesters and processors. The fishery has never employed large numbers of harvesters (Table D-4-4) and few of these fishermen consider scalloping as a major source of income.

The distribution of income from the scallop fishery is probably more important than the actual dollar value of the harvest. Fishermen usually do the shucking, a labor intensive process, and therefore a significant portion of the landed value of the scallop harvest is

TABLE D-4-4.

MAINE SCALLOP LICENSES

YEAR	LICENSES	YEAR	LICENSES
1948	272	1964	76
1949	290	1965	103
1950	295	1966	96
1951	226	1967	98
1952	120	1968	231
1953	116	1969	196
1954	90	1970	232
1955	103	1971	298
1956	100	1972	495
1957	83	1973	586
1958	62	1974	537
1959	59	1975	572
1960	67	1976	604
1961	59	1977	440
1962	68	1978	417
1963	61	1979	615

distributed as wages in the harvesting sector. Income from scallop harvesting (inshore fishery) is primarily distributed in coastal communities from Rockland to Eastport, an area of the state usually characterized as "economically depressed" and therefore this income has significant social impact. The number of scallop licenses reported in Table D-4-4 **do not represent** participation in the fishery since deck hands are not licensed. Participation in the inshore scallop fishery may be estimated at approximately 2.5 individuals per license issued and therefore the scallop harvesting sector in 1979 may have provided some income for roughly 1500 people.

The distribution of income from the offshore fishery is probably concentrated in the coastal area from Rockland to Kittery (major ports) and involves a small number of large vessels with larger crews and greater efficiency in terms of harvest and landed value per fisherman. The economic parameters associated with the offshore scallop fishery cannot be adequately defined with available data.

There are no adequate estimates of the number of processors, wholesalers and retailers involved in the scallop industry. Anecdotal information suggests that scallop handling does not constitute a major portion of the business transactions of any fish or shellfish dealer and, at this time, no valid economic assessments of the processing sector can be made.

Product values, other than the reported landed values, are not known. Current landed values for scallops (1980) ranges from \$4.20 to \$4.50 per pound of shucked meats. The total landed value for the Maine fishery in 1979 was approximately \$3,878,413 (at an average price of \$3.33 per pound of shucked meats). The 1979 value per pound of scallop meats closely approximates that of softshell clam meats. This close correspondence indicates that economic values for Maine scallop production could be approximated through the use of a shellfish value multiplier (Wong, 1969). (See also: Appendix E-6 of this report).

Consumption of goods and services by the inshore scallop harvesting sector can be approximated at 5/12 of the cost of operating a lobster boat (based on vessel characteristics and the length of the inshore open season). A comparable approximation for the offshore fishery could be derived from estimates of operating costs for medium sized draggers. This has not been done because there are no data on the time spent in scalloping by the average offshore vessel.

Evaluation of the Regulatory Framework:

Some regulations imposed upon the Maine scallop fishery have been justified as being necessary or advisable because of biological implications. The existing regulations, for the most part, do not have any discernible biological justification or any demonstrable effect on abundance or recruitment.

A minimum size limit could, theoretically, adjust the age at recruitment and therefore optimize yield per recruit. The current three inch minimum size limit does affect the age at first entry to the fishery and has a tendency to increase yield. The yield estimates computed by Serchuk *et al.* (1979) clearly indicate that a significant increase in meat yield could be achieved by increasing the minimum size of scallops to four inches (approximately ≤35 meats per pound). From a bioeconomic viewpoint an increase in the mean age at recruitment, specified as a shell measurement or a stated number of meats per pound, is a most reasonable and prudent regulatory measure. This would increase the mean age at recruitment by approximately one year.

There are some obvious problems with a statewide minimum size limitation for scallops. In some areas, such as Penobscot Bay, scallops apparently do not grow as rapidly as the norm nor do they reach a large size. This, of course, indicates that a completely different set of yield per recruit computations are needed for these slow growing stocks. In these situations a four inch minimum length limit (and perhaps even three inches) is not reasonable and should not be imposed.

The value of any regulatory measure is tested by the standard of enforcement. A restriction that cannot be enforced will invariably be ignored. Enforcement of a minimum length limit for scallops is difficult and expensive since it requires the examination of the catch during fishing. It cannot be enforced at dockside because shells and viscera are discarded at sea. This fact was clearly established in the recent (1980) offshore fishery in the Gulf of Maine. Massachusetts attempted to enforce a three-inch minimum length on shellstock landed by this fishery; the fishery rapidly responded by shucking at sea and landing only meats. In view of these problems minimum size restrictions should probably be established on the basis of meats per pound, a restriction that could be enforced at the point of landing.

Regulation of the minimum size of scallops through restrictions on the size of dredge rings has been proposed as an alternative to minimum size limits. Bourne (1965) compared the size frequency distributions of scallops harvested by drags with three and four inch rings and found that the larger ring conferred no selective advantage, i.e., that the size frequency distributions of scallops taken by drags with different ring sizes were similar. Selective escapement of small scallops ends as soon as the drag is plugged with debris or larger scallops, usually after a few minutes of towing. There is a slight disadvantage for increased ring size; on rocky bottom the larger rings hang and break more easily and gear maintenance costs are increased. This problem might be resolved by using heavier gauge rings.

Management regulations, such as dredge size limitations and the prohibition of some gear types are apparently selective measures which evolved from competitive interactions within the harvesting sector. These regulations have no apparent advantage in resource management and may not even reduce fishing effort. The imposition of such regulations should be avoided if possible since their only net effect is to complicate enforcement and obscure the evaluation of other management measures. Competitive restrictions, e.g., those which discriminate against certain types of gear, are appropriate only when economic management objectives are necessary and when such objectives are clearly defined before the regulation is proposed.

The fortuitous coincidence of the scallop spawning period with the inshore closed season on harvesting has been discussed in a previous section. The net effect of the closed season, in terms of resource management, is slight. The closure does impose a seasonal interruption in the systematic exploitation of some inshore scallop beds which may provide some scallops with an opportunity to spawn. The magnitude of this spawning and the net effect on abundance cannot be evaluated at this time.

The closed season does have economic and social benefits; it prevents harvesting of scallops during the time that traditional participants in the scallop fishery are more profitably employed in lobstering. The season also effectively prevents gear conflicts between scallop draggers and the lobster trap fishery. The closed season also tends to reduce gear conflicts with the inshore gill net fishery which is conducted during spring and fall.

Regulation of the scallop fishery outside the territorial waters of the state is the responsibility of the federal government under the provisions of the Fishery Conservation and Management Act of 1976

(Public Law No. 94-265). A scallop management plan is being prepared under the FCMA which will address management of scallop resources of the Gulf of Maine outside the territorial waters of the state. One of the provisions of this plan will probably be a minimum size regulation of 30 meats per pound. This would restrict the taking of scallops less than 5 years of age (those under four inches shell height).

Some Maine fishermen have challenged this minimum size with the contention that Gulf of Maine scallops do not grow as rapidly as Georges Bank and mid-Atlantic scallops. This argument for exemption may be specious; slow growth has been reported for some populations inside the state's territorial waters (e.g., Penobscot Bay) but there are apparently inadequate data to support a slow growth hypothesis for offshore scallops.

Resource Utilization:

Conflicts in resource utilization are almost a tradition in the Maine scallop fishery and have generated some of the regulations imposed on the fishery. Drag damage to lobster traps and gillnets appears to be an occasional problem that has been rectified by negotiation or by adjustment of the closed season. Occasionally scallop draggers are prevented from fishing desirable areas because of lobster traps and these conflicts have usually been resolved in favor of the lobstermen.

Conflicts within the fishery are usually generated by competition for specific harvesting areas and, in some cases, these have been resolved through the regulatory framework (e.g., the Penobscot Bay otter trawl prohibition, §6724). Conflicts between scallop draggers and SCUBA divers have not been a significant problem because these types of harvesting activity are usually not competing in the same fishing area. There have been some competitive interactions between resident and nonresident draggers in the recent southern Maine offshore fishery but most of these conflicts have been resolved by traditional territorial agreements among the fishermen. Most scallopers are involved in other fisheries for a signficaint portion of the year and competition between full-time and part-time fishermen has not been a problem.

Competing use of shore facilities for landings and gear storage have not been a serious problem in most Maine ports. Most landings are shucked meats and offloading is not a time consuming process. Scallop drags and gear are relatively durable, compact and portable and gear storage is not a problem.

Aquaculture of scallops has not been attempted in Maine although it is, technically, feasible. Naidu and Scaplen (1979) have documented aquacultural research for this species in Newfoundland and there appear to be few major problems involved in culture. There has been an adequate supply of high quality scallop meats produced in the Gulf of Maine and this has probably restrained attempts at culture of this species.

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ELEMENT D-5: A CHARACTERIZATION OF THE *Cancer* CRAB FISHERY ALONG THE COAST OF MAINE

by

Joel Cowger and Jay S. Krouse

INTRODUCTION

The commercial crab fishery in Maine comprises the Jonah crab *(Cancer borealis)* and rock crab *(C. irroratus)*. These two crab species, which are primarily harvested as an incidental catch in the American lobster *(Homarus americanus)* fishery, support a small but increasingly important fishery which in 1979 had landings of 1,344,179 pounds valued at $213,616 (ex-vessel price).

Since 1966, the price per pound of crabs paid to the fisherman has increased from 4¢ to 16¢ (Figure D-5-1). Consequently, more Maine lobstermen have been selling their incidental catches of crabs (which might have been discarded in the past) to offset the upward spiraling operational costs (bait, fuel, etc.). Considering the increasing commercial value of *Cancer* crabs, higher levels of fishing effort are expected to be imposed on the crab fishery in future years. In view of this, the application of biologically sound management practices may be necessary to insure the protection and enhancement of the crab resource.

DISTRIBUTION OF THE RESOURCE:

The rock crab is distributed in the coastal waters of eastern North America from Labrador to Florida (Williams 1974). The depths inhabited range from the intertidal area to about 575 m. In the southern portion of their range, rock crabs are generally found at greater depths where lower water temperatures prevail; however, during the winter months when inshore waters cool, rock crabs have been observed to move into these areas until temperatures rise in spring-summer (Shotton 1973, Terretta 1973).

Jonah crabs are found from Nova Scotia to south of Tortugas, Florida and in the Bermudas (Williams 1974). Like the rock crab, the Jonah crab occurs near the low water mark in the more northern latitudes and offshore in the south. Jonah crabs have been reported in depths up to 800 m. Of the two cancrid crabs, the Jonah crab generally shows preference for greater depths. Observations of several investigators (Jeffries 1966, Haefner 1976, Krouse 1980) indicate that Jonah crabs undertake limited seasonal movements. These movements are probably more dramatic in the crabs' southerly habitats.

Although both cancrid crabs occur along the entire coast of Maine, the distribution and abundance of each species is related to substrate type in association with depth and water temperature (Krouse 1980). Rock crabs are extremely abundant at inshore areas (estuaries and embayments) characterized by soft sand-mud bottoms, whereas Jonah crabs show preference for more seaward coastal areas having hard bottoms of rock, sand, and clay. This contrast in habitat preference has been explained by Jeffries (1966) to be due to morphological and behavioral differences between the two species. The generally smaller rock crab, with its greater walking ability, capability for burrowing, and quickness, is better adapted for life on soft, featureless substrates than its heavy clawed counterpart, the Jonah crab, which is relatively less active and slower, and is dependent upon coarse substrates not only to attract food organisms, but also to provide shelter from predators.

AVAILABILITY OF THE RESOURCE:

According to Fishery Statistics of the U.S., the first recorded commercial catch of *Cancer* crabs (not separated by species) in Maine was in 1919 when about 32.2 metric tons were landed (Figure D-5-1). Interestingly, since the catch first peaked in 1930, rather pronounced peaks have occurred about every 10 years thereafter, with the exception of the 1950-60 period when the greatest catch (912.4 metric tons) in the history of the fishery was made in 1963 (13 years after the last peak). Sampling results indicate that more than 90% of the commercial crab catch in Maine consists of rock crabs (Cowger 1978).

Fluctuations in the crab catch may be the result of many factors such as overfishing, natural population cycles, and market demand. Explanation of these catch variations is further confounded by the inaccuracy of the landings values. In view of Cowger's (1978) estimate that about half of the commercial crabmeat production in Maine results from unreported "home-picking" operations, the reliability of the landings data is seriously undermined. Nevertheless, this information still provides a relative index of catch size.

Cowger (1978) gives a detailed characterization of major crab-producing areas. These areas are primarily located in the mid-coastal region, where the large embayments provide suitable habitat for rock crabs.

The Penobscot Bay-Deer Isle-Blue Hill Bay region is the most productive area on the coast. Hancock County over the past thirty years has produced about 45% of all Maine crab landings, and virtually all of it has come from the Penobscot Bay-Deer Isle-Blue Hill Bay region.

Casco Bay is another productive area, and accounts for about 25% of Maine crab landings. The Sheepscot and Damariscotta Rivers are both fished heavily for crabs. East of Blue Hill Bay there is little crab fishing. The Jonesport area and the Machias Bay area are the only areas in Washington County where crabs are caught in any numbers.

Variations in Availability:

The larval development of the Jonah and rock crab consists of five zoeal stages and one megalops stage followed by the first crab stage, at which time the crab first becomes a member of the benthic community (Sastry and McCarthy 1973). During the larval period, which lasts 6-8 weeks, the young crabs are planktonic and, depending largely upon ocean currents, may be distributed considerable distances from where they were hatched. While young rock crabs (<40 mm carapace width) seem to prefer rocky substrates, at least in their northern distribution (Scarratt and Lowe 1972, Krouse 1976), little is known about the distribution of juvenile Jonah crabs. In fact, the smallest Jonah crab caught in Maine waters reported in the literature was 67 mm carapace width (Krouse 1980).

As might be expected, larvae of both cancrid crabs require certain temperature regimes for normal development and optimum survival (Sastry 1977). Significant deviation from these requirements could certainly result in year class failures. Even though the two species have rather similar environmental requirements, the variation is sufficient to indicate the possibility of temporal succession in larval development, thereby minimizing interspecific competition within the pelagic environment (Sastry and McCarthy 1973).

Water temperature is not only an important factor during the early life history of *Cancer* crabs, but also affects the distribution of adult crabs. Along the mid-Atlantic coast the distribution and abundance of Jonah and rock crabs have been clearly demonstrated to be associated with temperature along with depth and substrate (Shotton 1973, Terretta 1973, Haefner 1976, 1977). Moreover, in the same region, population movements have been shown to be related to seasonal variations in temperature. Similarly, along the Maine coast, seasonal changes in sex ratios and relative abundance indices of *Cancer* crabs indicate limited movements (Krouse 1972, 1980).

Another important factor with regard to crab availability is the fishing activity of man and the resultant fishing mortality. Unfortunately, without catch and effort information it is difficult to quantify this parameter and its effect on crab stocks. However, based on comments of Maine commercial fishermen and limited crab catch data (research traps) collected by the Maine Department of Marine Resources, following the male rock crabs' molting period in late winter-early spring (Krouse 1972) when many crabs are recruited into the fishery (attain carapace width >95 mm), the abundance of harvestable-sized crabs diminishes drastically throughout the summer (Cowger and Krouse 1978). Of course, part of this reduction in the crab catch may be the result of emigration, but it seems that most of the market-sized crabs are removed by the fishery. Although this may explain, in part, the fluctuations in rock crab abundance levels at many areas in Maine, the same may or may not be true for Jonah crabs, which are the least understood of the two crab species.

Cowger (1978) found only one good crab-producing area on the coast which was not fished fairly heavily. That area, upper Penobscot Bay, is now supporting two full-time crab boats. It seems probable that the crab resource in Maine is not capable of supporting significantly increased fishing effort.

HARVESTING:

Most crabs harvested in Maine are taken by lobstermen as an incidental catch, although there is a small directed fishery on crabs.

Most lobster traps are of wooden construction, but metal traps (anodized aluminum or vinyl-clad steel) are becoming increasingly common. Variations in the basic design occur along the coast. All traps, however, have features in common: side entrances ("heads") lead to a bait chamber which in turn leads to a "parlor," from which the lobsters are removed when the trap is hauled.

To save time in handling, many lobstermen have wide lath spaces to allow undersize ("short") lobsters to escape. This technique also allows crab escapement. Small crabs (including most female rock crabs) will escape through the normal lath spaces. In 1979 a trap vent law went into effect, which required that an oblong escape vent at least 44.5 mm (1-3/4 in.) wide and 152.5 mm (6 in.) long, or two circular escape vents at least 57.2 mm (2-1/4 in.) in diameter, be incorporated into each lobster trap. Fishermen who wish to retain market-size crabs often use the circular vents.

In some areas of the coast, fishermen may set traps exclusively for crabs, particularly during the spring before the lobsters come inshore. These fishermen, still usually interested in lobsters, have a number of lobster traps in use, augmented by traps specifically designed to catch and hold crabs. Although similar to a lobster trap in size and shape, the entrances ("heads") are on top of a crab trap, rather than on the sides. Crabs will crawl vertically over the the trap sides much more readily than will a lobster, and by entering the trap through the top, escape is virtually impossible, as neither the rock crab nor the Jonah crab are swimming crabs. Lobsters are only rarely found in crab traps; they may be hesitant to drop through the top heads. Heads on Maine crab traps are usually constructed of Chlorox bottles or equivalent which have had the top and bottom portions removed, creating a smooth cylinder through which the crab drops.

The only other type of crab trap seen by the authors in use in Maine is a trap designed for the blue crab *(Callinectes sapidus)* fishery of the mid-Atlantic states. A crab fisherman in Cobscook Bay, who has fished for rock crabs for 20 years, uses this type, a metal trap which has low side entrances and a parlor above the bait chamber to trap the blue crab, a swimming crab. He claims to have tried the traditional top-head trap and found the blue crab trap superior. He now fishes this trap exclusively.

Bait:

Lobstermen harvesting crabs as an incidental catch do not use any particular bait to attract crabs - whatever is available for lobster bait is what is used (generally ocean perch, herring, alewives, flounder, or hake heads). Most fishermen agree, however, that crabs prefer fresh bait. Marchant and Holmsen (1975) found a similar feeling among Rhode Island fishermen.

Those fishing crab traps have their own pet favorites for bait; one may prefer fresh mackerel, another may prefer dogfish, but they all end up taking what they can get. If a small, live codfish is taken in a lobster trap , it is often kept to be strung up in a crab trap.

Crabs are attracted quickly to bait. Fishermen tending crab traps in productive areas during peak season (late spring, early summer) often haul the traps twice per day, and each time the trap may be filled. Rock crabs, in particular, also leave a lobster trap quickly after the bait is consumed. When lobstermen are unable to tend their traps for several days, the crab catch is smaller than when traps are tended daily. Crab trap harvest, on the other hand, is relatively unaffected by frequency of hauling (until the bait is consumed), as the crabs are unable to escape through the top heads.

HANDLING:

Many lobstermen and dealers refuse to handle crabs, for various reasons. The problems most commonly cited can be summarized as follows:

1) Low value - many lobstermen do not want to bother saving a product which is only worth about 16¢ per pound (or about 5-8¢ per crab) when lobsters are worth from $1.25 to $3.50 per pound. Saving crabs on the boat does require some handling, and separate holding facilities are required. These lobstermen would prefer to spend their labor hauling an extra dozen traps for lobsters.

2) Difficulty in keeping crabs alive on boats - crabs are not hardy creatures out of water, and care must be provided to ensure that they are kept alive after being placed in the boat. Soft-shell crabs, which are abundant in early spring, are particularly tender.

Simple steps can be taken to minimize desiccation and overheating. Crab loss is not a major problem during the cooler months of spring, but when warmer weather arrives, an occasional dousing of the crabs on board will prevent crab loss. One dealer on Deer Isle, who found that too many dead crabs were being brought in during the summers, has rigged up a small circulating water system for crab storage in lobster boats, and provides the system free to his crab fishermen.

3) High mortality in dealers' storage crates - many lobster dealers have found high crab mortality when crates are stored for more than 2-3 days. Soft-shell crabs store poorly.

Most dealers try to minimize storage time. Many will cull the crabs when they arrive, and fill storage crates only halfway during the summer months. Some will ship 90 lb. crates in the spring and fall, and then drop back to 80 lb. crates during the summer.

4) Fluctuations in demand - several lobstermen and dealers refuse to handle crabs because they have had bad experiences in the past with poorly managed picking facilities buying their crabs only sporadically. This situation is unlikely to happen at this time, as picking facilities are searching hard for supplies, and are likely to provide a firm market.

The above problems tend to occur in the marginal crab producing areas. In areas where crabs are abundant, it is to the advantage of both the lobstermen and the dealers to save crabs and exert the small effort required to keep them alive. This is done, and crab loss is negligible.

THE CRABMEAT INDUSTRY:

Crabs are usually sold by the crate; each crate normally contains about 90 pounds of crabs. A crate of crabs in 1979 sold for an average of about $14-15 (16¢/lb.). The fishermen usually sell their crabs to wholesale dealers (the lobster dealers, in most cases), who in turn cull the crabs and sell to the picking houses. Some fishermen may sell directly to the picking houses.

Although a small number of crabs are sold fresh or frozen at the retail level, the vast bulk of the crabs harvested in Maine are picked out by hand and the meat sold wholesale and retail (usually in 6, 7, or 8 ounce cartons). The crabmeat industry is a small but important coastal industry in Maine, worth well over a million dollars a year. There are about 40 licensed crabmeat picking facilities.

It is only possible to get a rough estimate of the economic value of the crabmeat industry because there are an unknown number of "home pickers" - usually lobstermen's wives or housewives who pick out crabs in their homes, and who sell on the roadside or to the local market. The authors estimate that unreported home-picking may account for perhaps a third of the total crabmeat production in Maine. Home-pickers are most prevalent in Hancock and Washington Counties, where they have often made it difficult for the larger, licensed operations with standard business overhead expenses to compete. Sanitary regulations have never been enforced by the State Department of Agriculture.

In general, the demand for Maine crabmeat is greater than the supply, as indicated by the 25% jump in prices to the fishermen from 1978 to 1979. Crabmeat is in particularly high demand during the summer tourist season. Many people prefer crabmeat to lobster meat, even though crabmeat costs about half as much as lobster meat. Crabmeat is not generally considered to be a substitute for lobster meat - it caters to a separate market.

The twelve largest picking operations on the Maine coast, from Portland to Machias, together produced about 150,000 pounds of crabmeat in 1977, from a total of about 1,250,000 pounds of crabs. Total crabmeat production from all sources for that year may have been as much as double that figure, or 300,000 pounds. Recent expansion of licensed picking facility capability since 1977 is an indication that the percentage of production from these facilities is increasing, and may now account for perhaps two-thirds of total crabmeat production.

The retail price of crabmeat varies from \$6-\$8 per pound. Using both a conservative estimate of 150,000 total pounds of crabmeat produced each year in Maine, and a high estimate of 300,000 pounds, the total value of the product would be:

150,000 lbs. x \$6/lb. = \$900,000 (low estimate)

300,000 lbs. x \$8/lb. = \$2,400,000 (high estimate)

The number of people employed in the crabmeat-picking industry fluctuates constantly. Turnover is high, and variations in supply force daily changes in the work force. Therefore, only a rough estimate of the work force can be made. The commercial picking operations employ pickers for the period from April into November. The twelve large commercial picking operations employ approximately 100 workers (mostly in the Portland and Mount Desert Island areas). With the addition of other licensed facilities, there are probably 150 pickers. Most of the smaller facilities do not pick full-time, however. Pickers are usually paid by the pounds of meat produced, in the range of \$1.00/\$1.35/lb., and may pick out anywhere from 2-5 pounds of meat per hour, depending on experience and on the meat yield of the crabs at the time.

Most Maine crabmeat is sold right along the coast, and virtually the entire supply is sold within New England.

MANAGEMENT CONSIDERATIONS:

Crab landings have varied considerably from year to year, probably a result of natural population cycles and overfishing in many areas. Two factors tend to self-regulate the industry: one is that it is not economical to pick meat from crabs smaller than about 90 mm in size (carapace width), so there is an informal minimum size regulation in the industry; the other factor which has helped protect the population is the small size of sexually mature females; most female rock crabs are under 90 mm in size, and therefore have not been harvested. This situation is now changing somewhat, as the high price of traditional lobster bait (alewives, herring, redfish, etc.) has led some lobstermen (particularly in the Casco Bay area) to use small crabs as bait. Continued expansion of this practice may have serious consequences for the crab fishery, and should be watched closely.

There has been recent interest in machine processing of crabs. At present there are two prototype machines in operation which extract crabmeat from hand-picked shell waste. This poses no management problems. However, machine processing of whole crabs could create serious problems, since small and female crabs would likely be harvested in that case.

There are no conflicts with other fisheries.

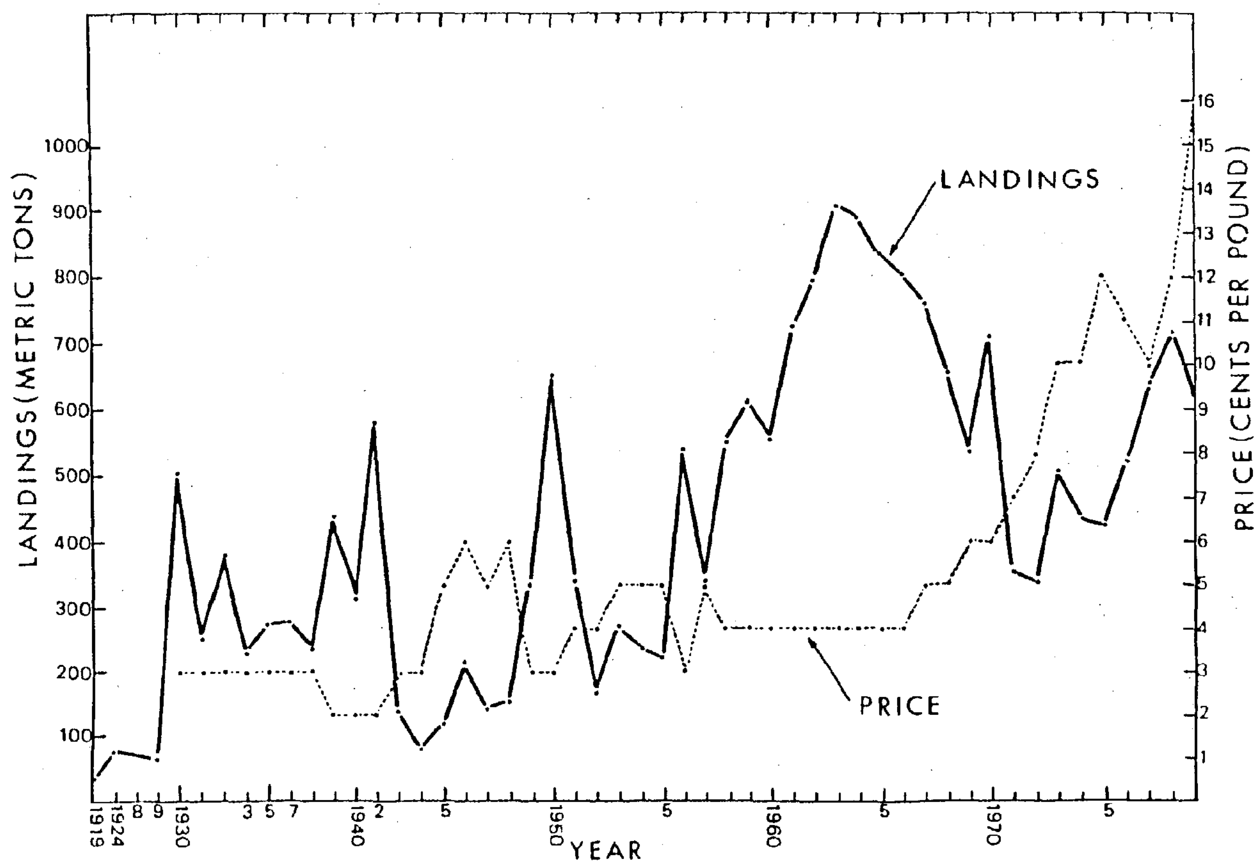

Fig. 1. Maine Rock Crab (Cancer irroratus and C. borealis) Landings.

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ELEMENT D-6: A CHARACTERIZATION OF THE MAINE MUSSEL FISHERY

by

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Mussels can be found along the entire Maine coast. Commercial harvesting of mussels occurs from Casco Bay to the Machias River. South of Casco Bay mussels are primarily limited to rocky shores with relatively few commercially harvestable beds of mussels. Most of this area (York, Cumberland counties) is closed for fecal pollution. Few mussels occur, at least intertidally, between Eastport and the Machias River.

Efforts to establish a commercial fishery for blue mussels commenced many years ago. Biennial reports of the Department of Sea and Shore Fisheries (now the Department of Marine Resouces) indicated that Department personnel and members of the fishing industry were aware of the extensive mussel beds along the Maine coast early in the 1900's. The possibilities of establishing a market for mussels were discussed in these reports but no systematic harvesting or marketing attempts were made.

In 1918, Irving A. Field of the U.S. Fish Commission (now the National Marine Fisheries Service) made a survey of mussels along the Maine coast from Portland to Eastport and estimated a total of 127,000 bushels of marketable mussels in the 52 localities surveyed (Field, 1922). The stimulus for this survey was the interest of the fishing industry during World War I in obtaining an additional source of protein foods for canning. This canned product did not prove satisfactory with the canning methods available at that time and the project was discontinued.

In 1942 and 1943, Leslie Scattergood and Clyde Taylor of the Fish and Wildlife Service (now the National Marine Fisheries Service) surveyed mussel beds in central and eastern coastal Maine (Scattergood and Taylor, 1949 a,b,c). In the areas that Scattergood and Taylor surveyed they estimated that the total harvestable supply of mussels from Eastport to eastern Penobscot Bay was approximately 320,000 bushels. This estimate, as the previous estimate in 1918, did not include many productive areas. In 1977, Maritec surveyed mussel stocks from the Damariscotta River estuary to Jonesport (Maritec, 1979). They estimated a standing crop of 544,000 bushels. This survey covered a large portion of the coast but it did not include some of the current harvesting areas.

Mussel landings were very high during the war years, reaching a peak production of 2.6 million pounds (173,000 bu.) in 1944. Most of these mussels were canned. The popularity of mussels was due to the low cost of the product and because they were not rationed. Canning continued on a limited basis until the mid 1950's. Mussel landings between 1947 and 1956 averaged approximately 200,000 lbs. (13,000 bu.) per year. From 1957-1965, annual landings averaged 34,500 lbs. (2,000 bu.), a very low production. From 1966-1974, annual landings rose to an average of 300,000 lbs. (20,000 bu.). Beginning in 1975 an increased demand for mussels occurred: 1975 - 600,000 lbs. (40,000 bu.); 1976 - 1,200,000 lbs. (80,000 bu.); 1977 - 2,100,000 lbs. (180,000 bu.); 1978 - 3,000,000 lbs. (200,000 bu.); and 1979 - 3,000,000 lbs. (200,000 bu.).

There is no evidence that shortages of available mussels were responsible for the historical variations in mussel landings; apparently consumer demand has been the source of this variability. Today's market is for fresh mussels, unlike the war years when the mussels went into the canned market.

Maine mussel harvesting methods have evolved as the market demand increased. One of the earliest harvesting techniques was used for intertidal mussel beds and involved beaching a dory on the mussel bed at ebb tide, filling it with mussels during low tide and then floating it off on the flood tide. Harvesting was thus limited by the number of low tides during daylight hours and the height of those tides. A measure of independence from the tidal cycles was gained when harvesters employed long handled rakes and, subsequently, tongs to harvest subtidal mussels. As market demand increased the harvesting and selling of larger quantities of mussels attracted more sophisticated gear and small day trip vessels began dredging mussels. This was the first significant advance in Maine's mussel harvesting technology and it has induced some problems for the industry. Dredging has provided an ample supply of mussels for the market but they sell at a relatively low price and quality control is negligible. Advances in mussel production technology will probably occur in the aquacultural field rather than in harvesting and culling technology.

In 1955, Maine, Massachusetts, Rhode Island, Connecticut, and New

York conducted a one year cooperative study on the handling of mussels. This study was a part of a long-range program to establish shellfish sanitary standards by species and by areas instead of the current general regulations for shellfish. The blue mussel was selected for this study for two reasons: (1) this species has caused problems because of its susceptibility to high bacterial scores in receiving states; and (2) it was believed that a greater market for mussels could be developed if recommendations to insure a high quality product could be implemented.

The cooperative study resulted in the following recommendations:

Harvesting: must be from an open shellfish area.

Cleansing: should be sufficient to remove all dirt and mud, the mussels should be thoroughly washed, culled and free of dead and broken mussels. The mussels may only be washed with water of drinking water quality or from an approved growing area.

Shipping: mussels should be shipped in suitable clean containers but not in bags of burlap or similar materials.

Temperature of shipping: mussels shall be kept at all times under 50^{o}F and above 32^{o}F.

Shipping containers were discussed at length in the study report since it was recommended in 1956 that burlap bags were unsuitable for mussel shipments and should be banned. Burlap bags are still used and continue to be a problem. Selection of mussel shipping containers is still dependent upon availability and cost. At the present time there is a decline in the use of burlap bags. This is not due to a concern about mussel quality but rather the availability of used bags and the high cost of new ones. Burlap bags are being replaced by plastic mesh bags. Mussels continue to provide all of the sanitary problems found in 1956 along with the added problems of paralytic shellfish poisoning (PSP).

The washing and culling of mussels has evolved during the last several years from hand culling to the use of a grader-washer (drum cage). The grader-washer is mounted upon the harvest boat or on a float in the growing area. The washer, properly used, produces well separated mussels free of mud and debris. Mussels smaller than 2" in length are discarded in the growing area in the case of the boat mounted washer, and to a pile of debris and mussels when the float mounted washer is used. The mortality of the discarded mussels may be quite high. We have very little information about the survival of the mussels returned to the growing area after the dredging and washing aboard the harvest boats.

Dredging of mussels has opened many additional areas to harvesting and has resulted in an increase in mussel landings because of harvesting efficiency. Although dredging reduces the temptation to harvest polluted mussels, it complicates the PSP monitoring program. High mussel landings have continued and the harvest boats continue to search for new sources of mussels. This has expanded the harvest areas and much larger areas must be tested for PSP. We have sufficient information to properly sample for PSP in these new areas, but it will be necessary to vastly expand our monitoring program to define suitable harvest areas during increases in PSP levels.

Maritec (1978) implied that the increase in mussel landings has been due to the marketing of a higher quality product. Unfortunately there are no real guidelines and product standards and there is little incentive for the mussel industry to voluntarily impose such standards. In most instances the current mussel market does not distinguish between high and low quality mussels. This depresses the landed prices paid for mussels. These low prices, in turn, work against meaningful attempts to improve the quality of mussels. There is a real and growing interest in a high quality product. This is particularly true of the cultivated mussel, with a limited specialized attempt to market selected wild mussels. Protecting the public from PSP and polluted mussels is relatively simple in comparison to the development of a continuously high quality product.

There is no doubt that Maine has a limited supply of mussels. This has been documented by Scattergood and Taylor (1943), who estimated that there was a usable supply of mussels at approximately 310,000 bu. (4,650,000 lbs.) and by Maritec (1978) who estimated a standing crop at 544,000 bu. (8,160,000 lbs.), with approximately 200,000 bu. (3,000,000 lbs.) of high quality. Maritec has estimated that Maine could sustain an annual production of approximately 100,000 bu. (1,500,000 lbs.). Landings in 1978 and 1979 of 200,000 bu. (3,000,000 lbs.) are far in excess of this estimate. Mussels are currently being harvested from areas not surveyed by Maritec bu the mussel resource is indeed limited and declines in annual harvests due to scarcity should be anticipated. The mussel industry does not recognize a shortage of mussels. Although it has been speculated that the drop in landings of mussels in the late 1940's was due to a shortage of mussels, it is highly likely that a decline in demand was the real cause. This is because these mussels were used in the canned trade that, with the return of other foods the market, no longer existed. Mussels for the fresh seafood market accounted for the increased landings in the mid 1970's.

Mussels continue to be a fairly inexpensive food and with other shellfish in short supply they apparently have taken part of this market. Maine fishermen receive a low price for their mussels ($3.00/bu.) and this means that quantity takes precedence over quality. This does not imply that Maine is shipping only poor quality mussels, but the market apparently does not pay for quality and does not expect it.

Maine harvested mussels are marketed in Boston and New York. A portion of this market is, reportedly, for processed mussels, frozen on the half shell. Processing does not occur in Maine and this suggests that Maine processors should investigate the possibility of entering the processed and packaged mussel market. Several Maine processors have investigated expansion into the shucked mussel market but have not found it to be a profitable venture. Currently, there are approximately 50 firms dealing in mussels, with only a handful doing most of the business (see Table B-6, pp. 108-114). The mussel industry has shown little or no interest in any conservation or management of the resource.

Mussel aquaculture shows a great potential for a high quality product. Lutz, 1979, has discussed the perspective of mussel mariculture. He states in his abstract that, "Mussel cultivation presents an effective means of expanding the resource base, and the accelerated growth and superior quality of cultured mussels makes this product an attractive addition to the industry. Experimental and pilot commercial mussel culture systems have been successful in various areas of the United States (including Maine) and continued expansion of mariculture operations offers the potential for a dependable commercial supply of high quality mussels. To enable production at a competitive cost, labor-intensive processes should be mechanized. Considerable research is required in order to obtain an adequate understanding of the manner in which biological and physical parameters will affect production efficiency of large-scale commercial operations."

While there remain many unresolved biological and production problems in mussel aquaculture, the most serious problems to be resolved are probably social. The conflicting uses of the growing area waters such as boating, recreational and commercial fishing, while not always real, are definite deterrents to developing the full potential of shellfish aquaculture. These conflicts are currently resolved through the public hearing process involved in the Department of Marine Resources' aquaculture permit system.

TABLE D-6-1

MAINE MUSSEL LANDINGS 1942-1979

Year	Pounds	Bu.	Value	Cents per Pound	Bu.
1942	114,000	7600	$ 910.00	$.008	.12
1943	1,983,450	132230	91,142.90	.049	.74
1944	2,633,635	175576	65,086.33	.025	.38
1945	2,574,945	171663	60,940.37	.024	.36
1946	2,314,210	154281	61,254.00	.026	.41
1947	40,260	2684	859.00	.021	.32
1948	124,129	8275	13,365.00	.108	1.62
1949	386,321	25755	15,345.00	.040	.60
1950	325,155	21677	11,370.00	.035	.53
1951	477,120	31808	13,472.00	.028	.42
1952	287,570	19171	8,725.00	.030	.45
1953	51,368	3425	1,301.00	.025	.38
1954	81,243	5416	2,048.00	.025	.38
1955	104,559	6971	2,829.00	.037	.41
1956	121,730	8115	2,170.00	.018	.27
1957	38,760	2584	4,547.00	.117	1.76
1958	120,417	8028	9,093.00	.076	1.14
1959	24,120	1608	1,705.00	.071	1.07
1960	49,755	3318	2,989.00	.060	.90
1961	2,179	145	92.00	.042	.63
1962	7,250	483	750.00	.103	1.55
1963	20,505	1367	1,407.00	.069	1.04
1964	15,410	1027	1,024.00	.067	1.00
1965	31,725	2115	3,025.00	.095	1.43
1966	239,789	15986	20,364.00	.085	1.28
1967	370,703	24714	31,473.00	.085	1.28
1968	389,402	25960	30,978.00	.080	1.20
1969	352,830	23522	28,625.00	.081	1.22
1970	301,118	20075	64,431.00	.214	3.21
1971	150,208	10014	35,051.00	.233	3.50
1972	280,740	18716	70,826.00	.252	3.78
1973	439,489	29299	116,000.00	.264	3.96
1974	308,328	20555	82,626.00	.268	4.02
1975	612,346	40823	198,036.00	.323	4.85
1976	1,203,194	80213	344,424.00	.286	4.29
1977	2,112,718	140848	680,309.00	.322	4.83
1978	2,997,432	199829	719,383.00	.240	3.60
1979	3,000,472	200031	716,128.00	.239	3.58

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