Development of a Mechanical Seed Oyster Relaying Program in North Carolina

DEVELOPMENT OF A MECHANICAL SEED OYSTER RELAYING PROGRAM IN NORTH CAROLINA

by

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ABSTRACT

A ground-truth survey of the southern coastal area of North Carolina showed that 10 sites offered potential for the harvest of seed oysters by mechanical methods. Detailed field surveys of these polluted and slow-growth oyster stocks indicated a potential seed oyster source of 87,219 hl of intertidal oysters. Subtidal seed oyster stocks were estimated at 12,556 hl.

In order to test the feasibility of mechanical transplanting, a seed oyster harvester was designed, constructed, and installed on a self-propelled barge. A smaller barge was constructed and equipped for transporting and replanting the harvested seed oysters. This equipment was used to harvest 11,614 hl of seed oysters in 130.6 hours of operation. These oysters were relayed into unpolluted public shellfish harvesting areas. Blueprints and technical specifications for construction of the harvester and associated equipment were prepared.

Monitoring of intertidal and subtidal seed oyster transplants showed favorable rates of growth and low levels of mortality. It was determined that harvesting and relaying of seed oysters by mechanical methods did not produce significant physical damage to oysters or the oyster-producing habitat.

The project demonstrated the practicality of large-scale mechanical harvesting and transplanting of seed oyster stocks. The activity produced rapid returns to the fishery at low cost. Further development of a large-scale mechanical relay program was recommended.

INTRODUCTION

The commercial fishery for the American or eastern oyster, *Crassostrea virginica*, has declined drastically in North Carolina. Table 1 shows state-wide landings data for the public fishery from 1956 to 1978. Unlike many other Atlantic coast states, the North Carolina oyster harvest is primarily from public bottom; therefore, significant changes in landings impact a large segment of the fishing industry.

Table 2 shows landings for the southern coastal area of North Carolina. The large contribution of this region to the total North Carolina oyster harvest is evident from the data. The reduction in landings of 84% between 1960 and 1977 has had a severe economic impact upon the large numbers of individuals who depend upon the oyster resources for a livelihood. Records of the Division of Marine Fisheries indicate that a total of 4,994 vessels and boats participated at some level in the southern area oyster fishery in 1978.

Harvestable oyster stocks in the southern coastal area are found in a limited number of private leases, and "deeded" bottoms, as sparse natural oyster stocks, and as concentrations which occur in managed public shellfish areas created and maintained by Division of Marine Fisheries culture activity. The contribution to the harvest from leases and "deeded" bottoms is relatively small and seldom exceeds 15 percent of total landings. Natural oyster stocks have been severely depleted due to overfishing and presently contribute little to the oyster harvest. Managed public oyster stocks, which supply 80 - 90% of the oyster harvest, are also being heavily overfished and if this trend is continued, it is likely that the oyster fishery in the southern coastal area will not remain economically viable.

Table 3 shows southern area oyster culture activities by the Division of Marine Fisheries for the 13-year period from 1966 to 1979. Early seed oyster and shell planting efforts utilizing contracted hand labor were extremely costly, inefficient, and produced questionable returns. The harvest declined by almost 60% during one 5 year period of this activity. A reorganized public oyster culture program was begun in 1971 utilizing Division personnel and equipment. This activity showed temporary success and drastic cost reductions; however, due to increased oyster harvesting effort, the magnitude of the

Table 1. Annual commercial oyster landings from public bottom in North Carolina, 1956 - 1978

Year	Pounds of meats	Ex-vessel value in dollars
1956	1,239,000	539,000
1957	977,000	451,000
1958	940,000	401,000
1959	1,214,000	557,000
1960	1,117,000	525,000
1961	1,094,000	555,000
1962	840,000	419,000
1963	616,000	315,000
1964	650,000	373,000
1965	779,000	427,000
1966	461,000	253,000
1967	420,000	256,000
1968	352,000	236,000
1969	326,000	230,000
1970	298,000	207,000
1971	340,000	231,000
1972	339,000	277,000
1973	453,000	365,000
1974	466,000	361,000
1975	294,000	227,000
1976	266,000	231,000
1977	207,000	198,000
1978	430,000	519,000

Table 2. Annual commercial oyster landings from public bottom, southern coastal region (Brunswick, New Hanover, Pender, Onslow Counties) of North Carolina, 1956 - 1978.

Year	Landings in pounds	Ex-Vessel value in dollars	Percentage of total state landings (lb)
1956	155,600	33,718	13
1957	149,200	33,122	15
1958	335,500	93,551	36
1959	358,300	90,520	30
1960	412,300	144,305	37
1961	493,200	160,049	45
1962	434,100	148,308	52
1963	356,400	141,626	58
1964	326,500	157,232	50
1965	396,100	185,771	51
1966	268,600	147,685	58
1967	200,800	113,868	48
1968	196,500	128,248	56
1969	148,200	98,794	45
1970	112,700	73,752	38
1971	97,400	65,465	29
1972	167,300	116,240	49
1973	152,600	118,780	34
1974	157,000	118,433	34
1975	98,222	107,993	33
1976	124,729	82,820	47
1977	64,700	58,655	31
1978	267,700	308,887	62

Table 3. North Carolina, Division of Marine Fisheries oyster culture activity, production, and costs in Brunswick, New Hanover, Pender, and Onslow Counties during 1966 - 1979 (from Division of Marine Fisheries records).

Year	Planted seed oysters (bu)		Planted shells (bu)		Reported commercial production in bu.	Oyster culture costs per unit of commercial production
	Amount	Cost	Amount	Cost		
1966	112,345	$30,124	123,414	$28,332	78,268	$0.75
1967	114,884	33,534	143,028	30,535	52,652	1.22
1968	91,357	30,980	113,109	24,299	50,602	1.09
1969	59,768	20,383	78,682	13,625	40,345	0.84
1970	60,806	20,820	56,100	12,283	30,568	1.08
1971	11,985	3,966	23,035	7,089	27,917	0.40
1972	5,500	1,650	21,054	9,268[1]	43,274	0.25
1973	1,414	434	28,672	9,987[1]	36,660	0.28
1974	11,285	3,914	43,700	16,683[1]	36,646	0.59
1975	0	0	59,300	28,884[1]	27,542	1.05
1976	0	0	51,250	34,238[1]	29,042	1.18
1977	0	0	76,650	30,083[1]	18,795	1.60
1978	5,245	3,252	61,158	23,411[1]	56,358	0.47
1979	27,740	15,080	55,660	19,907[1]	N.A.	N.A.

[1]Includes Division planting costs

N.A. - Not yet available

activity has not been sufficient to revitalize the fishery. A review of the oyster culture practices of the Division showed that, in many areas, techniques relied upon to produce harvestable oyster stocks were susceptible to environmental changes accompanying the rapid development of the coastal zone. The lag time between shell cultch "planting" and growth to harvestable oyster sizes (2-3 years) leaves the planting susceptible to damage from man-made perturbations.

The major goal of this project was to develop a method to increase the oyster resource base by making additional harvestable oysters available to the fishery in a relatively short time period at costs competitive with present culture methods. Effort was directed toward low-cost mechanized harvest of seed oysters from polluted waters and slow growth shellfish areas and mass relay of these stocks to public harvesting areas with rapid growth potential.

Objectives of the project were as follows:

1. To determine the location and magnitude of seed oyster stocks which could be utilized by mechanical harvesting equipment;
2. To design, fabricate, and assemble gear and equipment necessary to facilitate low-cost mechanical harvesting of available seed oyster stocks;
3. To harvest, transport, and relay seed oysters into suitable growing areas; and
4. To monitor the results of the relaying operations.

STUDY AREA

The southern coastal region of North Carolina is designated as the estuarine area between Bogue Inlet, North Caroline and Little River Inlet, South Carolina and covers approximately 175 km of coastline (Figure 1).

Unlike the large open sounds of the central and northern portions of the coast, the southern area is characterized by bar-built barrier islands with adjacent salt-marsh filled lagoons. Waters in the estuarine zone are affected by tidally-driven currents from numerous ocean inlets; by the fresh-water input of numerous small coastal plains streams; and by the Cape Fear River, a major watershed originating in the Piedmont. The area is characterized by lunar tides

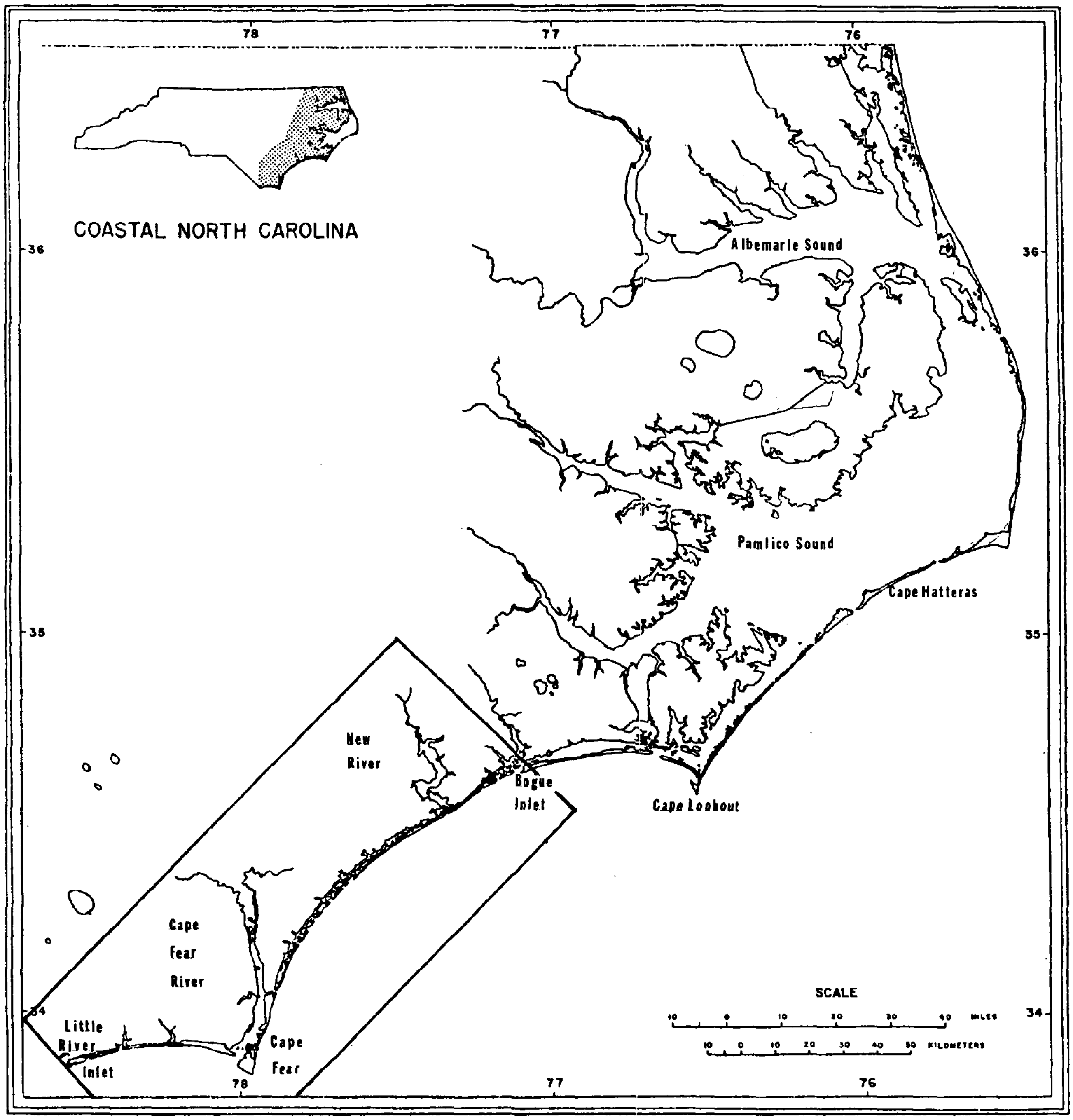

Figure 1.--Project location map showing southern coastal area (Bogue Inlet, North Carolina to Little River Inlet, South Carolina)

of 65 to 175 cm. Due to the tidal amplitude, there are extensive intertidal areas and most water depths do not exceed 3m at mean low tide. Salinity in this zone is variable, but exceeds 25 parts per thousand (ppt) in much of the area.

Most natural oyster concentrations are located in the intertidal zone and occur as sparse bands along shorelines or as oyster "rocks" which are exposed at low tide. The distribution and density of these stocks is limited primarily by elevation, bottom type, and salinity. Due to the very heavy harvesting effort in the region, only areas which are closed to shellfishing due to pollution and areas where oysters do not attain harvestable size contain natural oyster concentrations of significance. Most harvestable oyster stocks are found in areas maintained and managed by the Division of Marine Fisheries as public harvesting areas created by plantings of shell cultch or as less dense concentrations of seed oysters scattered over intertidal flats or shorelines. Some areas, such as New River, contain predominately subtidal oyster stocks which have been created as oyster beds by Division shell plantings or occur as sparsely populated remnants of older reefs.

The intertidal areas contain varying sediment types and are at varying elevations in the tidal zone. Primary intertidal oyster areas contain a sediment type of firm sandy mud and are in the lower half of the intertidal zone. A characteristic of the intertidal flats is rapid change in elevation and sediment type in response to man-made changes in physical parameters of adjacent land and water areas. These rapid changes often result in losses of managed and natural oyster areas.

MATERIALS AND METHODS

Seed Oyster Stock Survey

A review of the literature pertaining to oyster surveys was conducted to determine statistically-accurate methods for use in the project. A survey of intertidal oysters from Charleston to the North Santee River, South Carolina was conducted in 1942 and 1943. Methods used in this study consisted of the measurement of oyster beds and random square yard sampling for density and other information (Lunz 1943). Linton (1967) reported on a survey of intertidal oyster stocks on the Georgia coast using actual measurement of exposed oyster concentrations and random square meter samples. A survey of low-intertidal and subtidal areas was conducted in Apalachicola Bay, Florida in 1966 and employed one-quarter square meter samples at predetermined sites along transect lines and random square meter subtidal samples (Menzel, Hulings, and Hathway 1966). A detailed survey of subtidal oyster resources in Mobile Bay, Alabama consisted of random subtidal quadrant sampling using yard square grids at predetermined points on known oyster reefs (May 1971). Gracy and Keith (1962) reported on the use of color aerial photography to survey intertidal oyster resources in South Carolina, while Dugas (1977) used random square meter sampling in the determination of subtidal oyster densities in southeastern Louisiana.

Numerous references were examined to determine the most statistically-valid methodology to employ in the survey of seed oyster stocks, including information on sampling methods, and discussion of data analysis. In the literature review works by Gulland (1975), Brazigos (1974), Saville (1977), Holden and Raitt (1974), Steel and Torrie (1960), and Simpson, Roe, and Lewontin (1960) were studied.

Files of the Division of Marine Fisheries were also reviewed for data on prior surveys conducted in the southern coastal area, and procedures were analyzed for accuracy.

Aerial photography was used to locate potential oyster concentrations within the study area. A ground-truth survey was then conducted to determine areas which contained oyster concentrations that appeared suitable for investigation, and those areas were identified on work maps.

Criteria used for selection of areas to be investigated included designation as a closed shellfish area or as an area where oysters did not attain commercial size, accessibility of the area to mechanical harvesting equipment, proximity of the area to managed public shellfish bottom, the amount of oyster area contained in the site, and concentration and density of oysters. Other factors considered during the survey to determine the suitability of the area were oyster size, stock mortality, and the percentage of live oyster material in the concentration.

When an area was selected for investigation, it was designated on a standard Coast and Geodetic Survey topographic map. These maps were taken into the field by the survey crew, and locations of individual oyster concentrations were plotted and numbered. Each oyster concentration was measured with a metered survey wheel to determine total oyster bottom area and the area containing live oysters. Many oyster concentrations were discontinuous and contained void spots or small areas of non-productive bottom; therefore, the total area of oyster bottom and the area containing live oysters were often different. Statistical testing for sample size showed that 25 cm square samples produced the lowest variance per unit of effort. Samples of 25 cm square were taken from random locations at each concentration and returned to the laboratory for analysis where oyster density (volume of material per area), recent mortality (boxes), size distribution, and percentage of live oyster material in the sample was determined. Due to the non-random distribution of intertidal oyster stocks in the systems surveyed, a stratified sampling design was used in the field. Visibility of oyster concentrations at low tide made identification of the desired strata facile and eliminated the necessity of sampling visually non-productive strata. Due to the expected variance between and within individual oyster concentrations, statistical analysis of sample results was required.

A predetermined level of precision for the mean density of live oysters from each area was set at a 95% confidence interval of not more than 0.71 l/m^2 (the smallest accurate measurement practical). To calculate this mean density, it was necessary to compute the percentage of live oyster material and recent mortality in each oyster concentration.

A preliminary set of samples was taken and analyzed for variance and the formula

$$n = \frac{t_I^2 s^2}{d^2}$$ (Steel and Torrie, 1960)

where n= number of samples required

t= cumulative Student's t value for the desired confidence level

s= standard deviation

d = the half-width of the desired confidence interval

I = degrees of freedom

was used to determine the number of samples required to produce the desired degree of precision. That number was then set as the minimum sampling effort for the area. Once the required number of samples was collected, the mean oyster density in $1/m^2$ was computed using data from all samples.

The calculation

$$\bar{x} \pm t \left(\frac{s}{\sqrt{N}}\right)$$ (Simpson, Roe, and Lewontin, 1960)

where $\bar{x}$ = mean oyster density

t = cumulative Student's t value for the desired confidence level

N = number of samples

s = standard deviation

was used to determine the exact confidence limits for the oyster density mean. An estimate of oyster standing crop for each area was then made using measurements from the individual survey areas and the calculated oyster density mean. Utilization of this sampling design reduced both random and systematic error to the lowest levels feasible.

In the laboratory analysis of oyster samples, size distribution was determined by measuring the length of all live oysters in each sample. Recent mortality was determined by counting the number of boxes (valves attached) present in each sample. The percentage of live oyster material was calculated after separation of all shell material without live oysters attached from the remainder of the sample and subsequent measurement of the volume of each in calibrated containers.

No attempt was made to undertake a valid subtidal oyster survey due to the lack of quantitative sampling gear and methodology. Areas containing subtidal oyster stocks were limited and could not be surveyed with SCUBA due to strong tidal currents and very low bottom visibility. A rough estimate of subtidal oyster stocks was made from plots on topographic maps and an approximation of the harvest rate per unit of area for the mechanical seed oyster harvester. This estimate was subject to considerable bias due to the unknown fishing efficiency of the harvester and distribution of the subtidal stocks.

Equipment Design, Fabrication, and Assembly

A review of the literature pertaining to mechanical shellfish harvester was conducted. Based upon this review, the prototype mechanical harvester developed at the Virginia Institute of Marine Science (VIMS) under PL 88-309 project 2-124-R was selected as the basic design for the harvesting equipment (Haven and Loesch 1973).

The R/V STONES BAY, a flat-deck, self-propelled cargo barge 15.2 meters long and 5.5 m in width with a loaded draft of 1 m was modified for use in the project (Figure 2). This vessel was originally constructed by the Division in 1971 as a shell cultch planting barge. An escalator-type conveyor as shown in Appendix Figure 1, was constructed and mounted on the harvesting vessel. A mechanical seed oyster harvester head (Figure 3) was designed and constructed based upon photographs and measurements taken from the prototype developed at VIMS. The VIMS design was subsequently modified and redesigned as shown in Figures 2-14 of the Appendix. The harvesting vessel was equipped with booms, a hydraulic system and winch, and a diesel-driven centrifugal pump of 300 gmp, 80 psi capacity. Details of the conveyor and hydraulic system are shown in Figures 1 and 15 of the Appendix. A 9.1 m planting barge was constructed from two surplus aluminum mark-4 bridge pontoon halves joined and covered with wood deck (Figure 4). The barge was equipped with a gasoline powered centrifugal pump of 250 gpm, 80 psi capacity. A 5.2 m fiberglass boat was modified and equipped with an 85 horse-power outboard motor for use as a push-boat for the planting barge.

Seed Oyster Relaying

Several publications were located which evaluated and analyzed oyster relaying programs. Hendrickson (1975) explored the methodology of trans-planting polluted oysters to clean waters as a viable management alternative in New York. Linton (1967) reported on the successful transplanting of inter-tidal and polluted subtidal oysters on the Georgia coast, and Gracy and Keith (1972) reported on the results of subtidal oyster transplants from the Wando River, South Carolina.

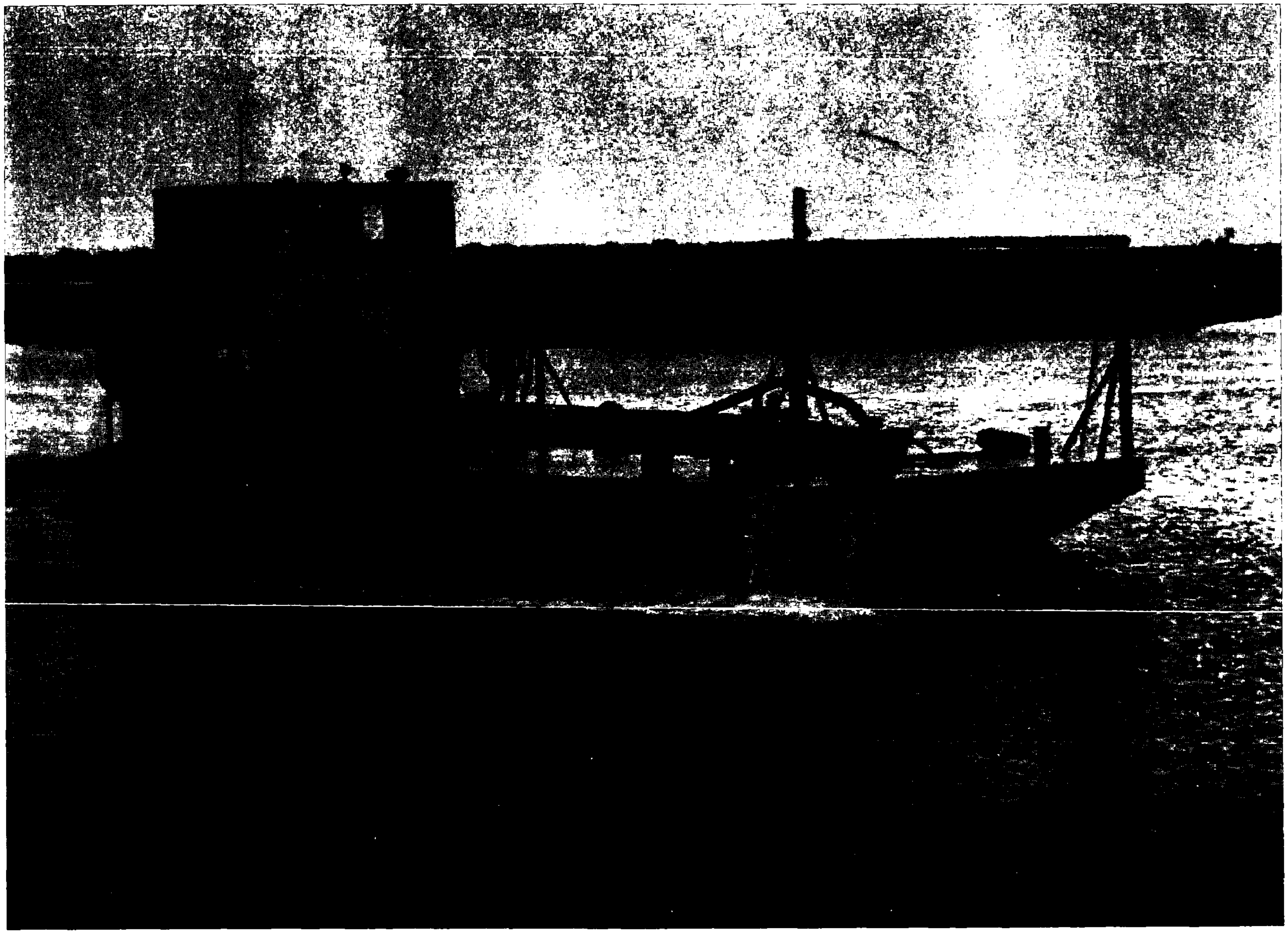

Figure 2 - R/V STONES BAY, 15.2 meter cargo barge harvesting vessel, North Carolina, 1977 - 1979

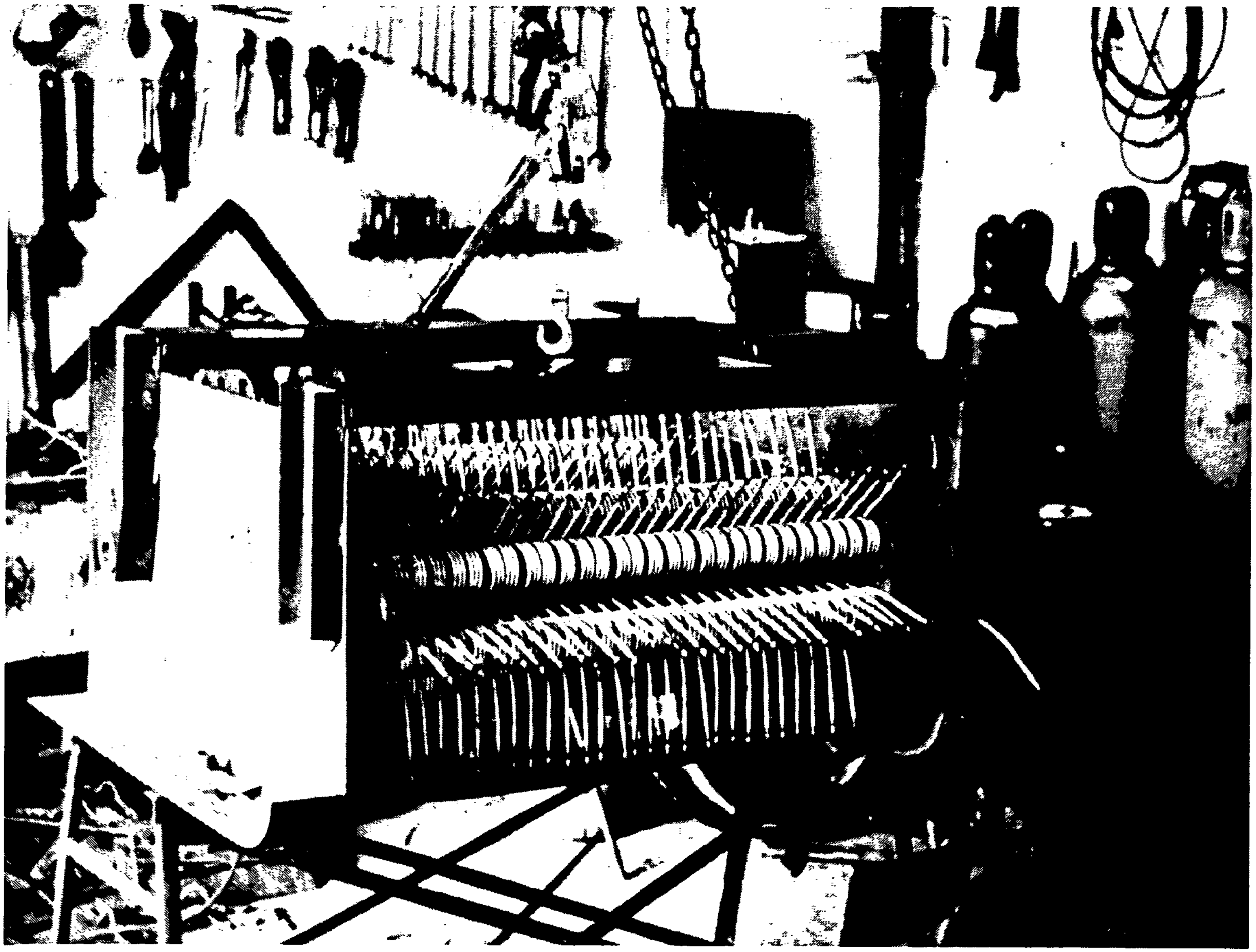

Figure 3 - Mechanical seed oyster harvester head constructed for harvesting seed oysters in North Carolina, 1977 - 1979.

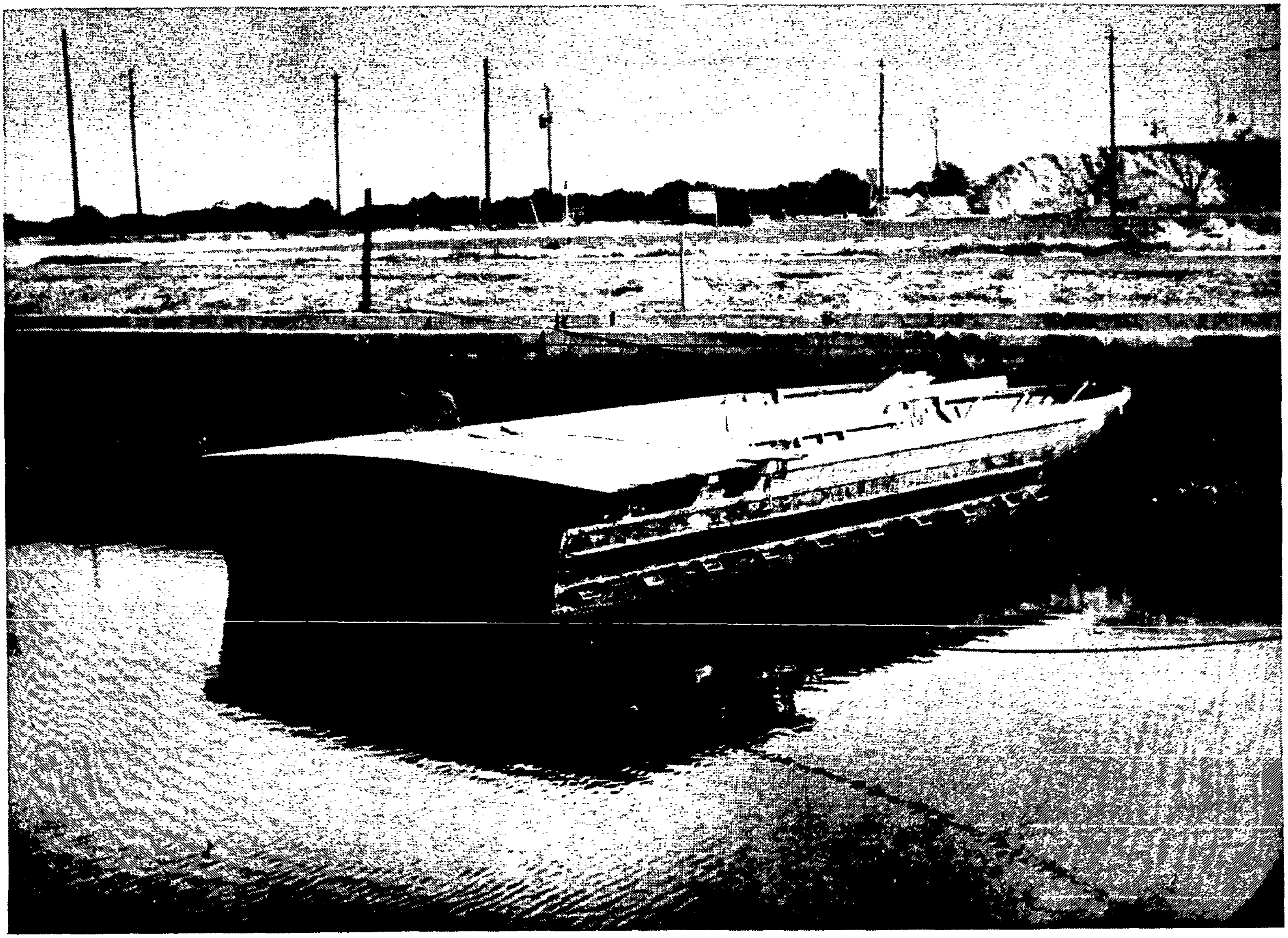

Figure 4. - Construction of 9.1 meter pontoon barge planting vessel, North Carolina, 1977-79.

Areas selected as harvest sites were marked at low tide with stakes and flagging. The R/V STONES BAY was maneuvered onto the intertidal rocks on the rising tide and the planting barge was positioned under the end of the conveyor to receive the harvested oysters (Figure 5). The vessel was then maneuvered within the marked oyster area with the mechanical harvester on the bottom until the planting vessel was loaded or until decreasing water depths from the ebbing tide prohibited harvesting operations. In order to quantify the amount of seed oysters loaded onto the planting barge, wheelbarrows of known volume were used to catch the material falling from the end of the conveyor and distribute it onto the deck surface.

Several samples of harvested material were taken from the escalator belt at each location and returned to the laboratory for determination of size distribution, recent mortality (boxes), shell damage from harvesting, and percentage of dead shell material of the harvested source.

When loaded, the planting barge was detached from the harvesting vessel and moved into the planting site where the seed oysters were washed overboard by high pressure water (Figure 6).

Areas designated to receive seed oyster plantings were surveyed prior to planting to determine area and presence of natural oysters, plotted on work maps, and marked with stakes and flags.

Harvested areas were observed at low tide to determine if enough oysters were left to allow additional harvesting.

During time periods when tide and weather conditions resulted in water levels less than those required for vessel operation in the intertidal area, the harvesting operation was moved to channel areas which contained subtidal oyster concentrations.

Monitoring

Planted seed oysters were monitored at the time of relocation, about one month after planting, and approximately quarterly thereafter. Methodology employed in the monitoring program was the same as that used in survey work and consisted of statistically-valid samples of 25 cm square at the planting

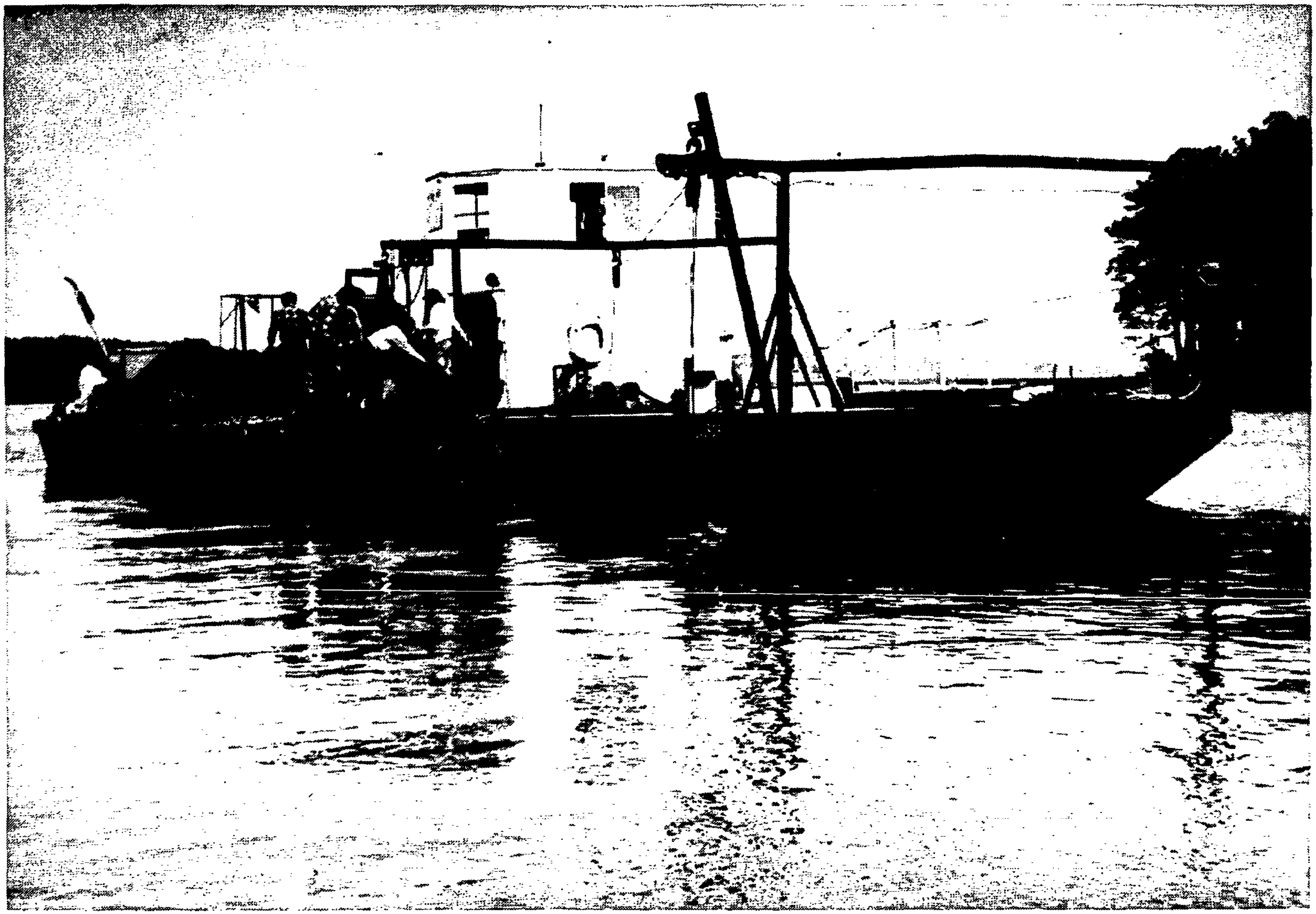

Figure 5.--Equipment used to relocate seed oysters in Shallotte River, North Carolina, 1977-79

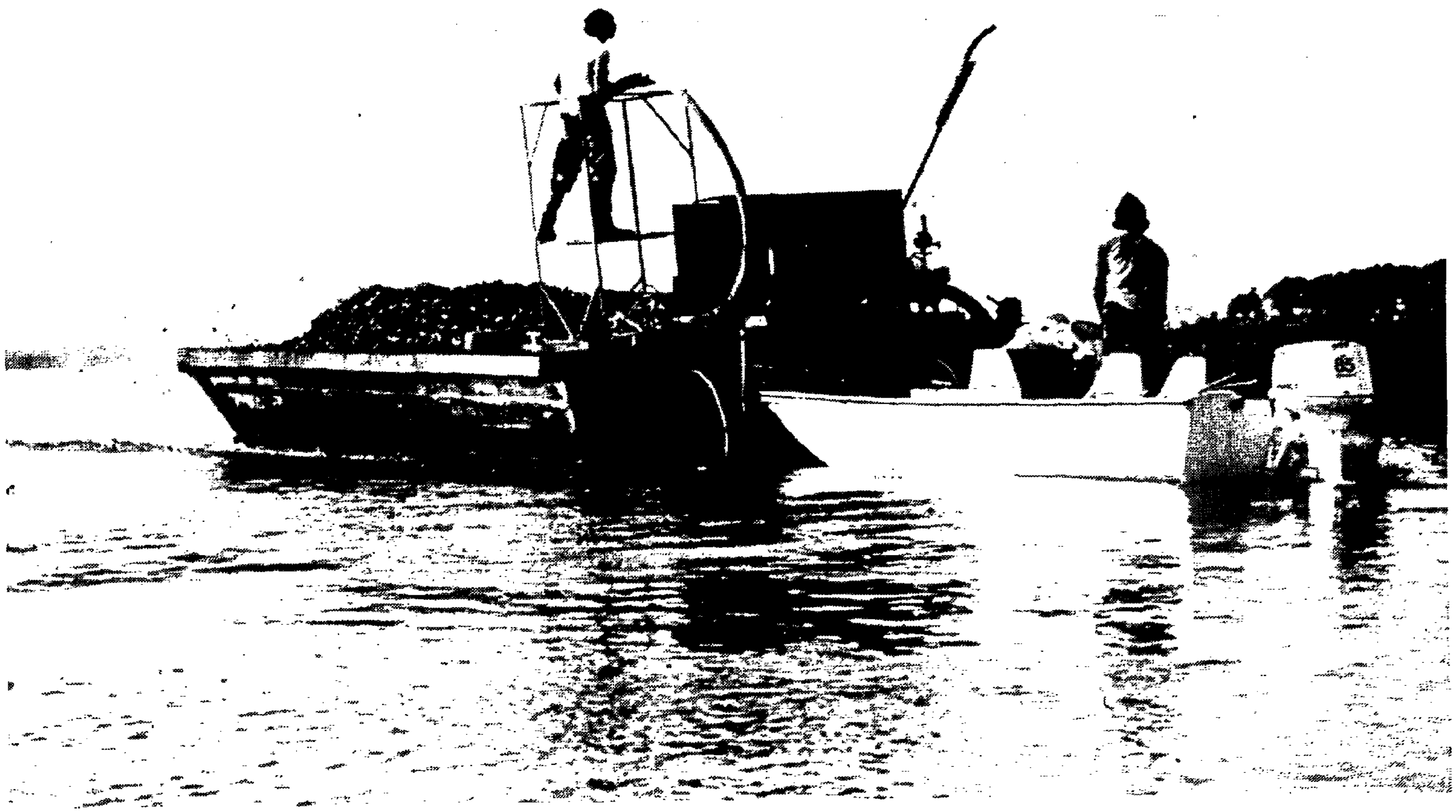

Figure 6 - Pontoon barge "planting" seed oysters in Shallotte River, North Carolina, 1977 - 79

sites. The samples were returned to the laboratory and analyzed for size distribution, recent mortality and percent of live oyster material in the sample.

At some sites, relocated seed oysters were subjected to both legal and illegal harvesting within a few months of planting and such occurrences were noted on data sheets.

In some areas, intertidal oyster concentrations were photographed and monitored before and after mechanical harvesting to determine the effectiveness of the harvesting and the affects of removal of the material from the oyster rocks.

RESULTS AND DISCUSSION

Seed Oyster Stock Survey

As a result of the ground-truth survey of southern region waters, a total of 10 areas were located which appeared to offer some potential for mechanical harvesting (Figures 7 and 8).

In Brunswick County significant usable oyster stocks were located in Elizabeth River, Dutchman Creek, and Shallotte River. Detailed surveys were conducted in those areas (Table 4). Usable stocks in Lockwoods Folly River were limited to a small area of subtidal oysters; therefore, no detailed survey was conducted.

Significant intertidal oyster concentrations which appeared to meet most mechanical harvesting requirements were found in Elizabeth River and Dutchman Creek where some oyster concentrations contained several thousand square meters (Figure 9). The combined standing crop of oysters in this system was estimated at 29,298 hl and represents the largest single polluted seed oyster resource in the southern coastal area (Table 4).

In Shallotte River both subtidal and intertidal oyster concentrations were found (Figure 10). Survey results indicated an intertidal seed oyster source of 9,115 hl (Table 4). The subtidal oyster stocks were estimated to occur over an area of 1.2 ha and estimated to total 6,116 hl. Shallotte River also represents a very significant seed oyster source adjacent to heavily utilized harvesting areas.

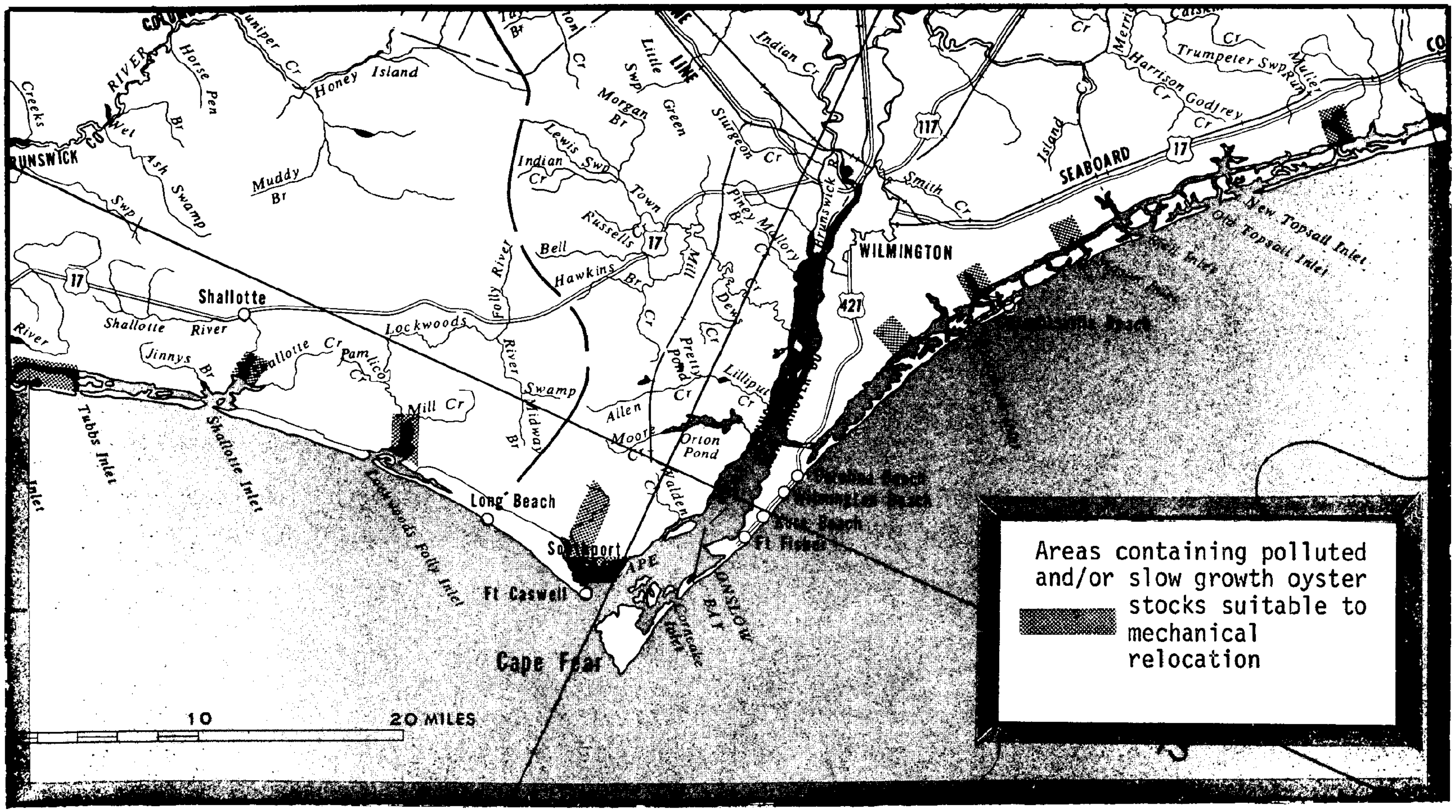

Figure 7 - Location map of seed oyster stocks in polluted and slow-growth areas where mechanical harvesting appeared feasible, southern coastal region, North Carolina, 1977-79.

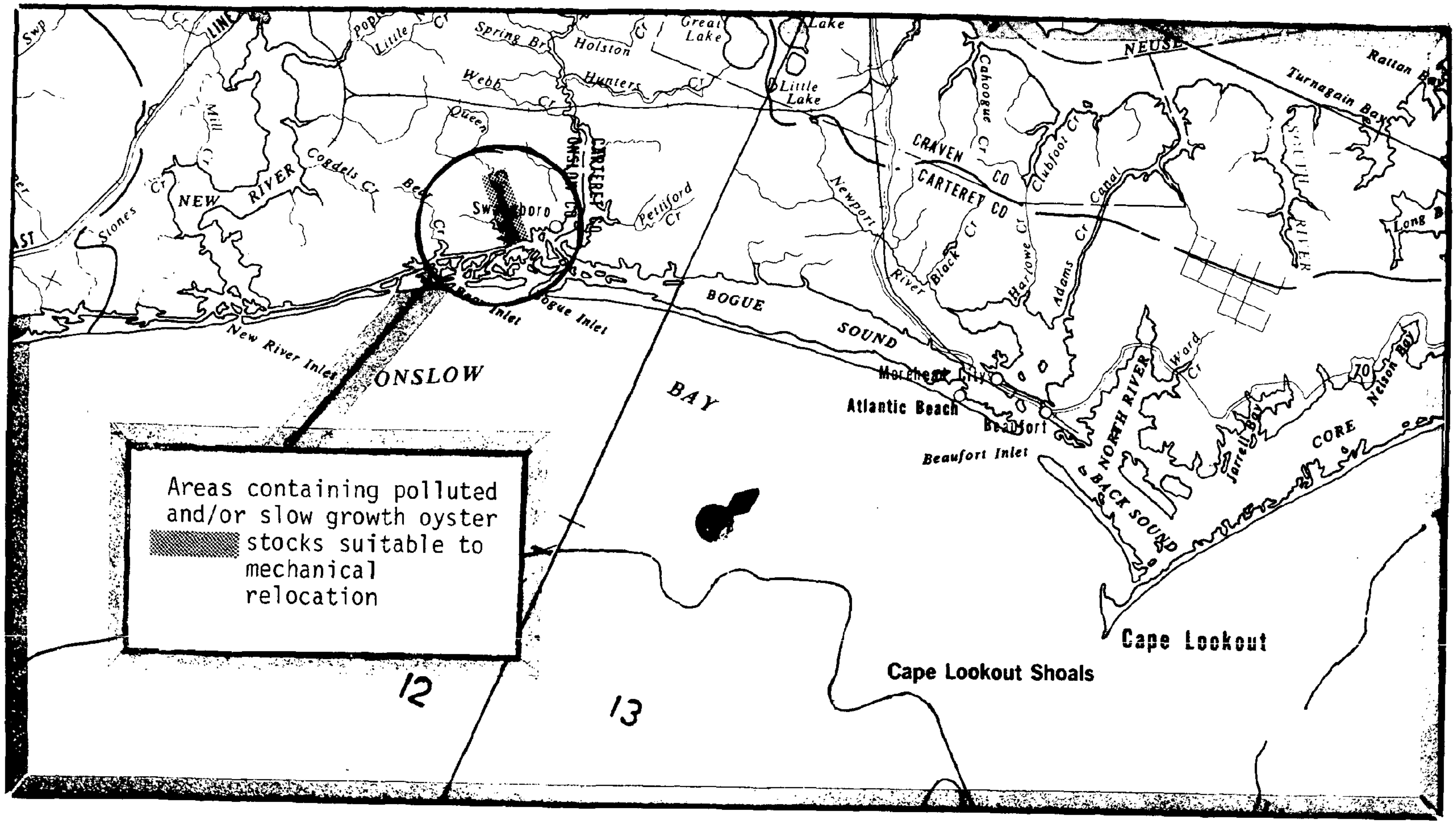

Figure 8 - Location map of seed oyster stocks in polluted and slow-growth areas where mechanical harvesting appeared feasible, southern coastal region, North Carolina, 1977-79.

Table 4.--Results of field survey of polluted and slow growth intertidal seed oyster stocks in the southern coastal area of North Carolina, 1977-79.

Area	Number of oyster reefs, rocks, etc.	Area of live oysters (ha)	Estimated mean oyster density ($1/m^2$)	Average percent mortality (boxes)	Average percent live oyster material in samples	Estimated standing crop (hl)	Calculated range of standing crop at 95% confidence limits (hl)
Brunswick County							
Elizabeth River	101	4.76	61.97	7	95	26,034	24,024 - 27,989
Dutchman Creek	37	0.73	50.17	5	94	3,255	2,902 - 3,610
Shallotte River	70	3.07	49.06	11	68	9,115	8,543 - 9,688
New Hanover County							
Bradley Creek	47	2.44	41.76	6	74	7,090	6,198 - 8,003
Whiskey Creek	39	2.18	48.86	9	90	8,729	7,628 - 9,830
Pages Creek	44	1.67	24.29	9	73	2,694	2,377 - 3,367
Pender County							
Virginia Creek	35	1.83	36.55	12	68	1,778	1,529 - 2,016
Onslow County							
Queen Creek	20	0.46	48.58	9	69	1,414	1,255 - 1,583
TOTALS	393	17.14				60,109	54,456 - 66,086

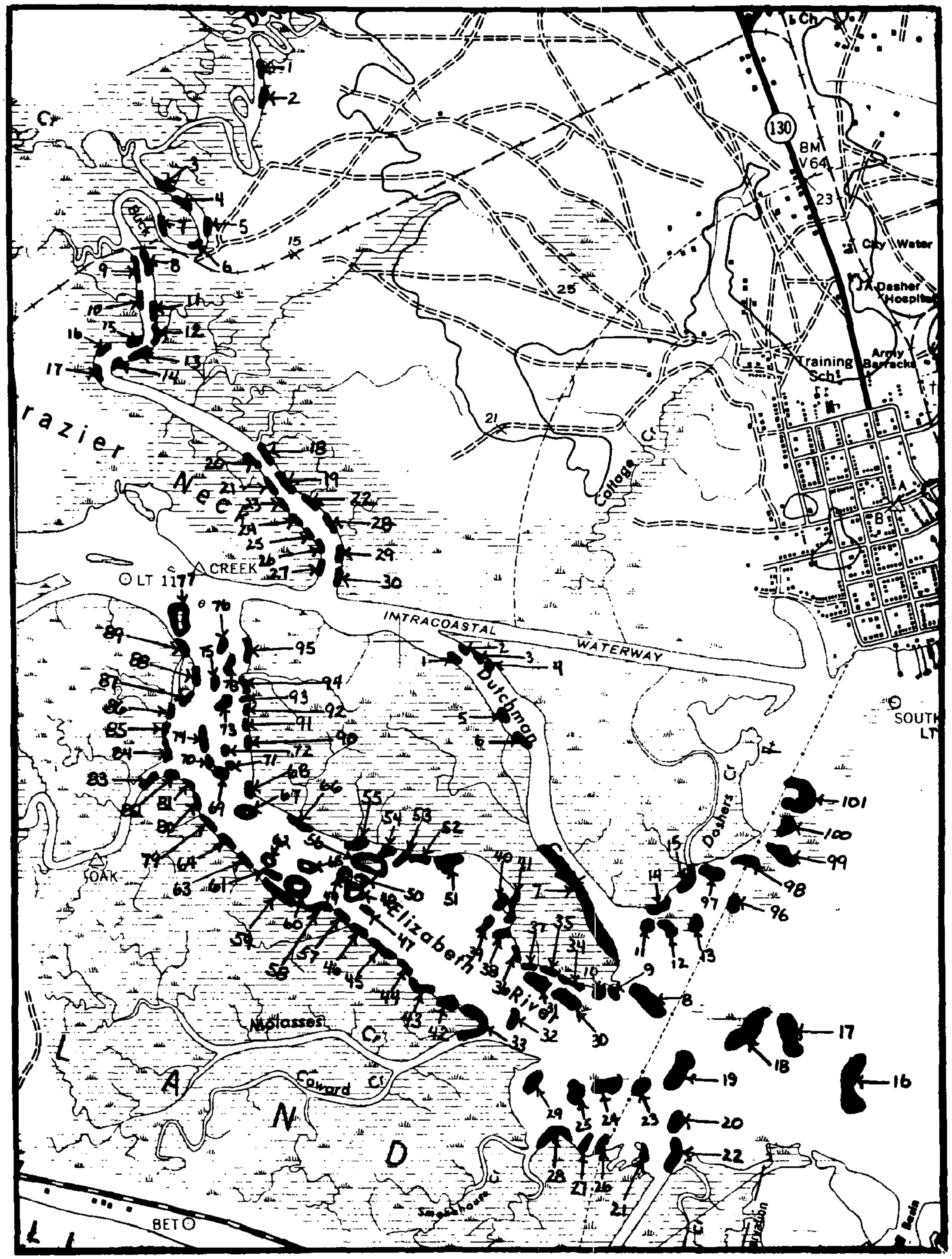

Figure 9 - Location map of oyster stocks in Elizabeth River and Dutchman Creek, Brunswick County, North Carolina, 1977 - 79 (numbers identify individual oyster concentrations)

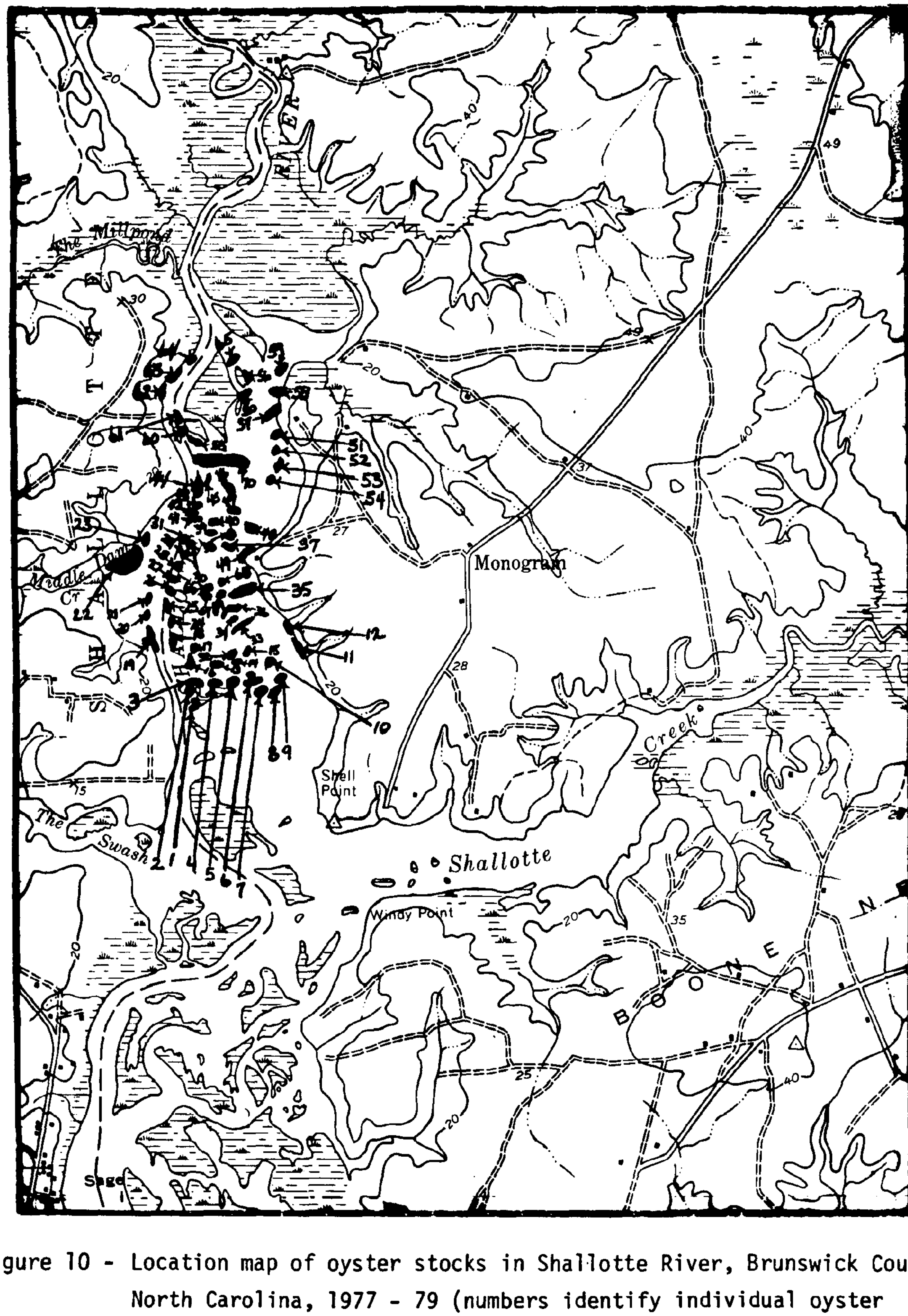

Figure 10 - Location map of oyster stocks in Shallotte River, Brunswick County, North Carolina, 1977 - 79 (numbers identify individual oyster concentrations)

Additional polluted shellfish stocks in the western portion of Brunswick County were surveyed by the Division of Marine Fisheries in 1976-1977 using methodology similar to that used in this project (Figure 11). The results showed an estimated standing crop of 27,110 hl present in the closed shellfish area.

In New Hanover County stocks of polluted oysters were located in Whiskey Creek, Bradley Creek, and Pages Creek (Figures 12, 13, and 14). The results of the detailed surveys are shown in Table 4. The combined estimate for these stocks is 18,513 hl. Although the stocks are smaller and of inferior quality to those of Brunswick County, they are of vital importance in the restoration of public shellfish management areas in New Hanover County.

In Pender County only one source area could be found (Figure 15). A detailed survey of polluted and slow-growth oysters in Virginia Creek showed that 1,778 hl were available. This stock is of relatively low quality but represents the single available source in Pender County, and as such, is of great importance.

The survey of Onslow County waters also resulted in location of a single usable polluted seed oyster source (Figure 16). A total intertidal stock of 1,414 hl was found to occur in Queen's Creek (Table 4). This intertidal resource is of low quality and moderate importance. The survey also revealed a subtidal seed oyster source containing 1.8 ha with an estimated standing crop of 6,440 hl. The subtidal resource is of better quality than the intertidal stock and is of great importance to the public shellfish management program of Onslow County.

The overall results of the southern area seed oyster stock survey showed an intertidal resource of 87,219 hl and subtidal stocks of 12,556 hl. It can readily be seen that the economic value of this resource if transplanted to clean water areas would be extremely large. These stocks are renewable in most areas every second or third year and should support a large relaying operation for an extended period of time.

EQUIPMENT DESIGN, FABRICATION, ASSEMBLY, AND TESTING

A seed oyster relaying system consisting of the R/V STONES BAY, a 9.1 m pontoon barge, and a mechanical seed oyster head and conveyor were assembled

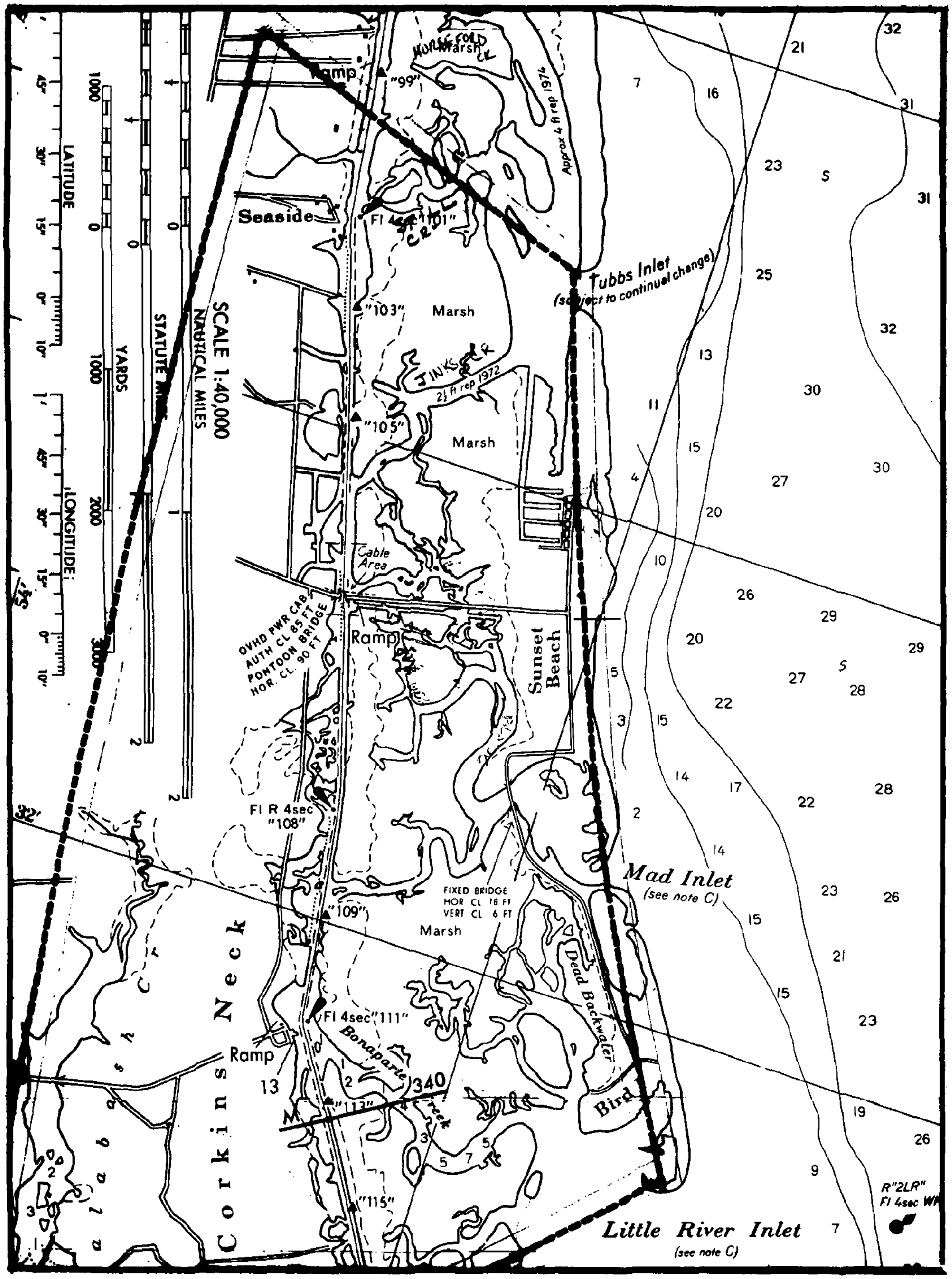

Figure 11 - Map of closed shellfish area survey, Brunswick County, North Carolina, 1976-77 (boundaries of survey area outlined)

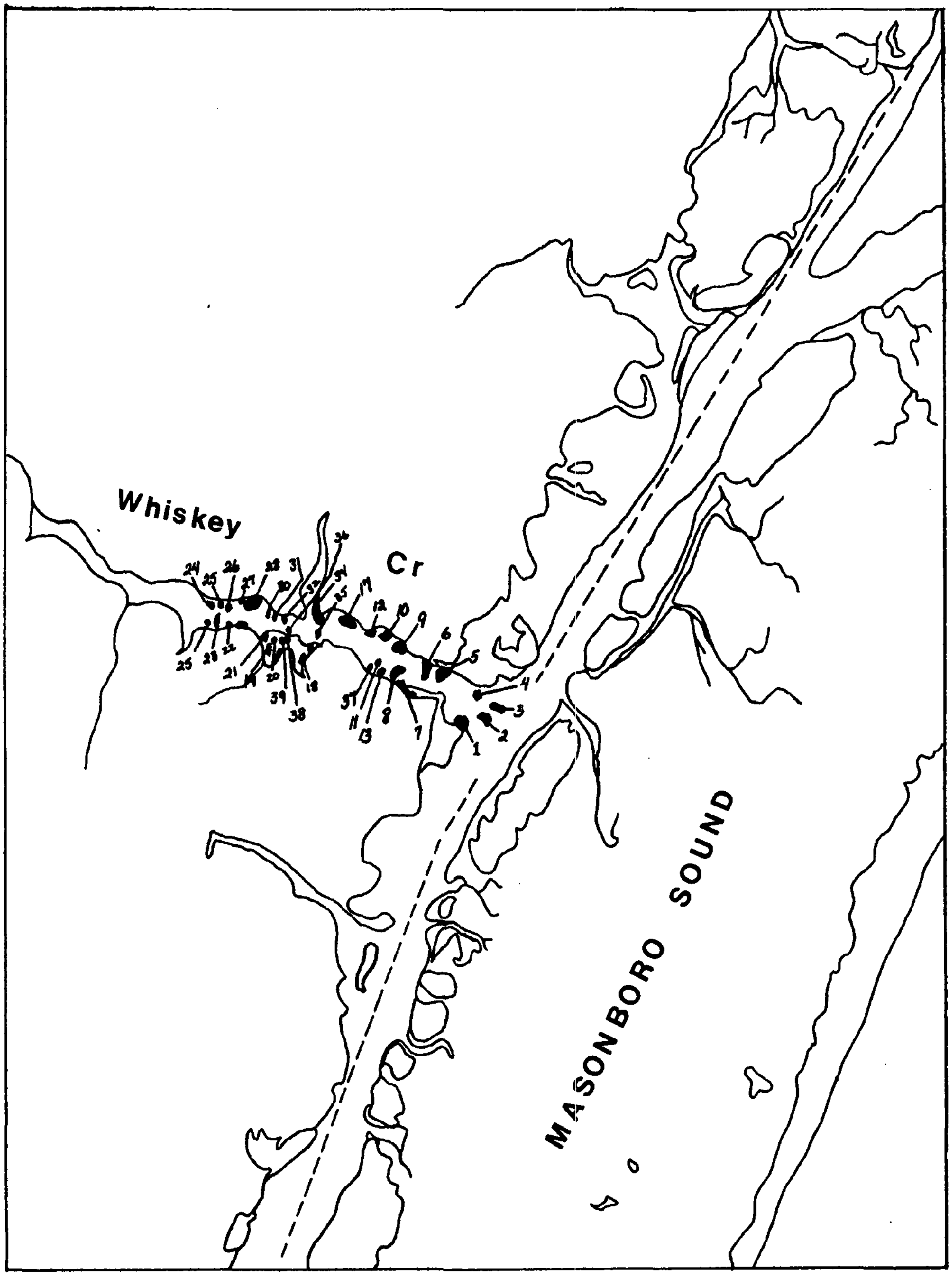

Figure 12 - Location map of polluted oyster stocks in Whiskey Creek, New Hanover County, North Carolina, 1977 - 79 (numbers identify individual oyster concentrations).

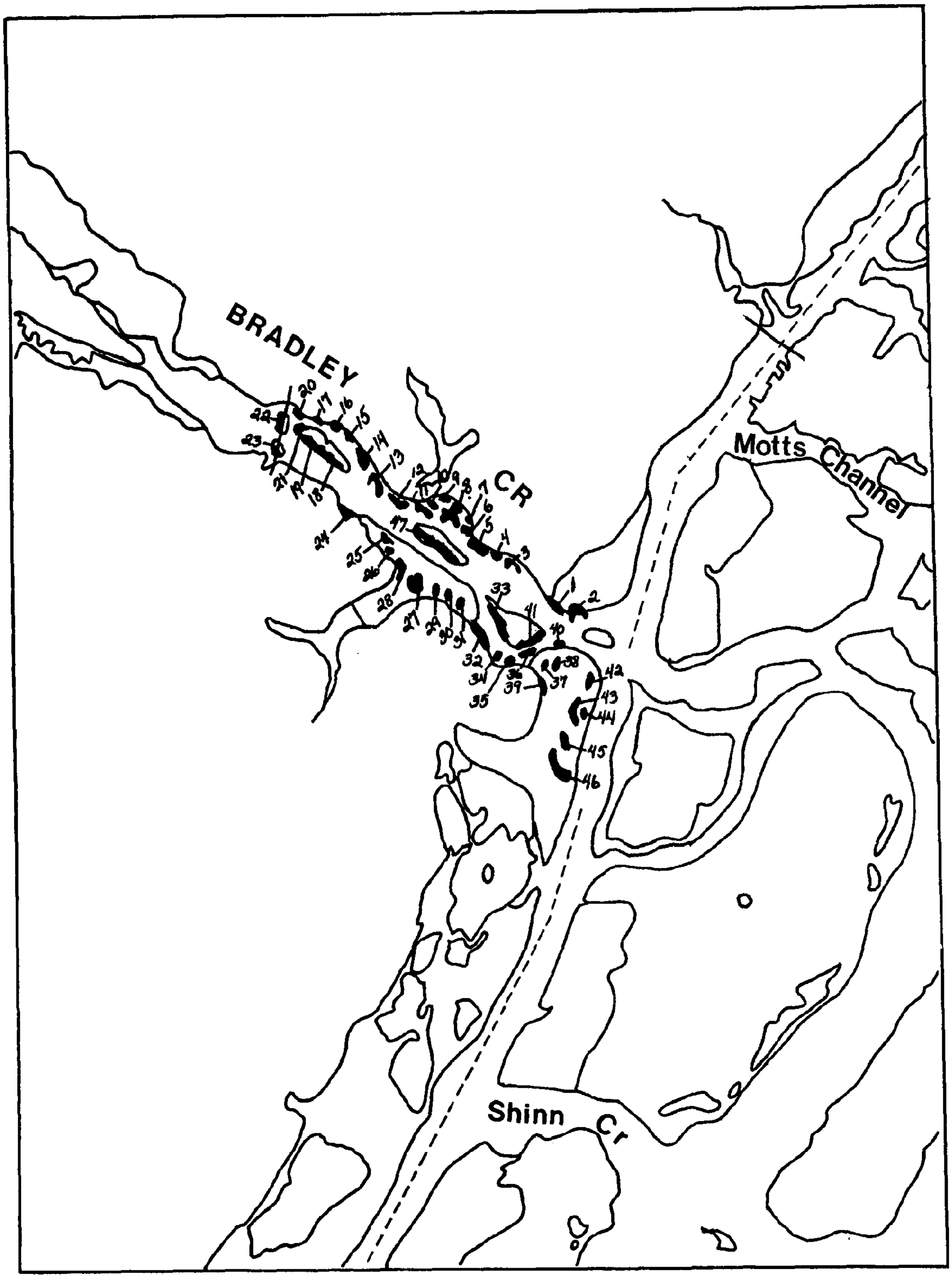

Figure 13. Location map of polluted oyster stocks in Bradley Creek, New Hanover County, North Carolina, 1977-79 (numbers identify individual oyster concentrations).

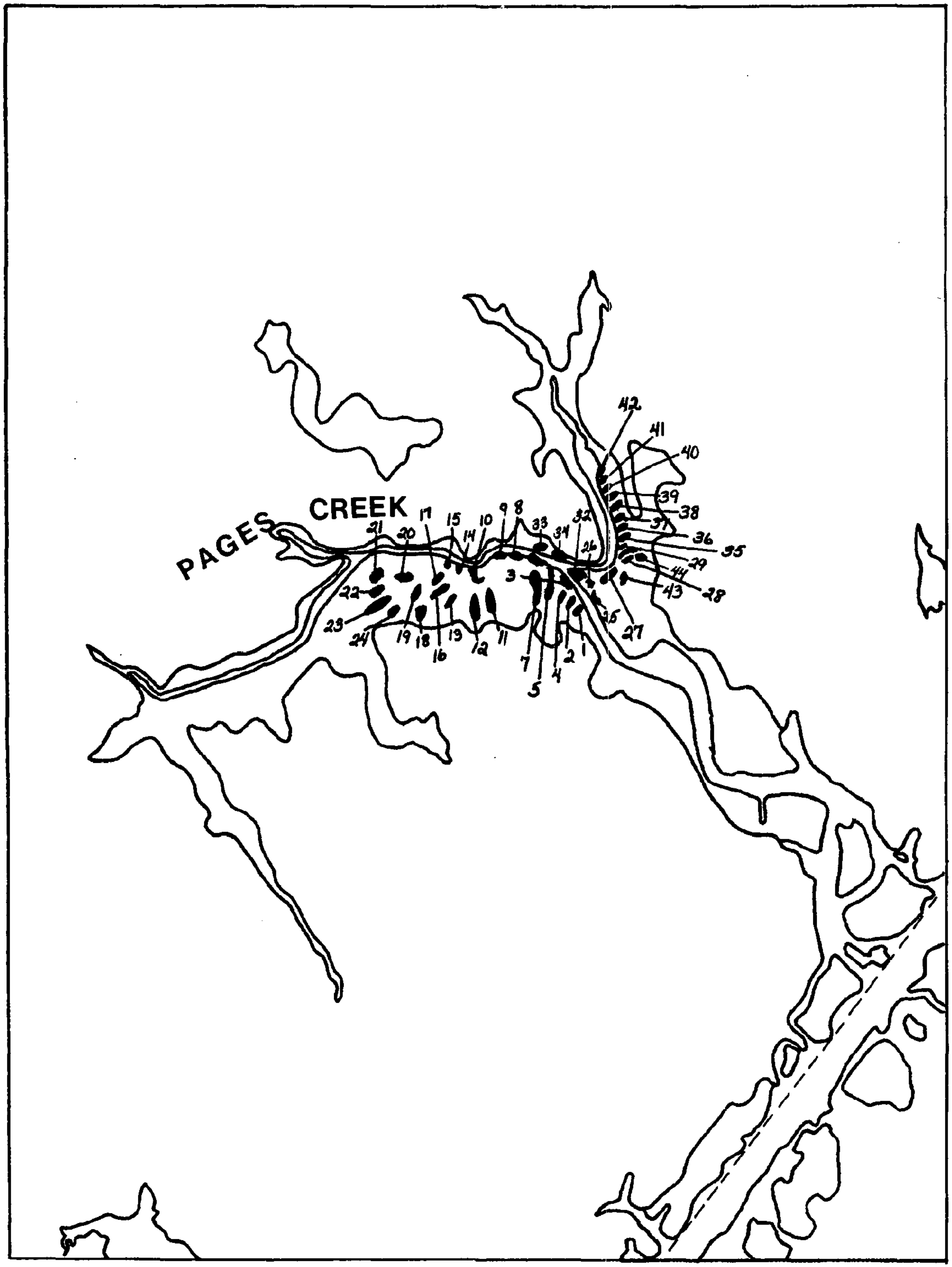

Figure 14 - Location map of polluted oyster stocks in Pages Creek, New Hanover County, North Carolina, 1977-79 (numbers identify individual oyster concentrations).

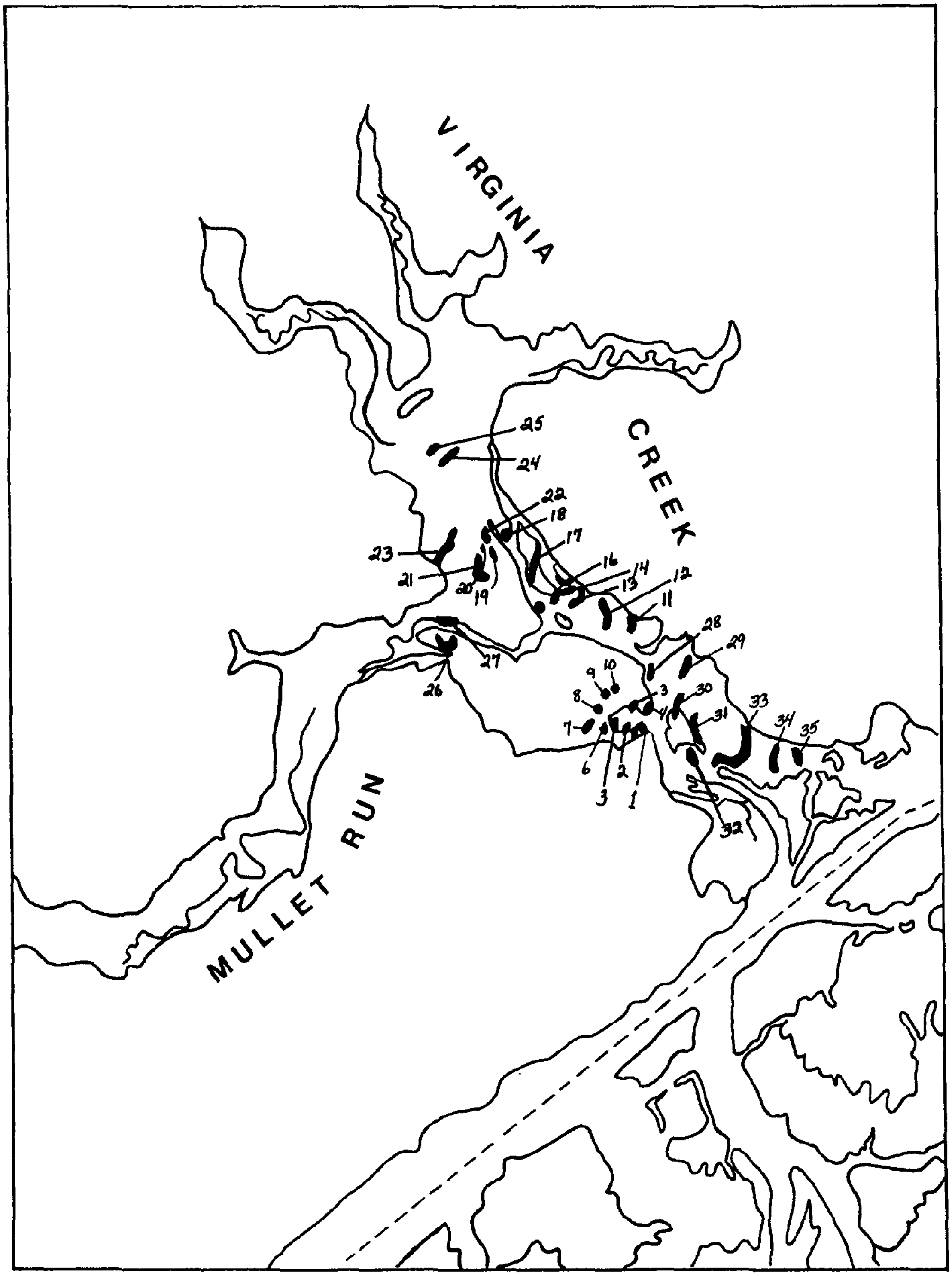

Figure 15. Location map of polluted and slow-growth oyster stocks in Virginia Creek, Pender County, North Carolina, 1977-79 (numbers identify individual oyster concentrations).

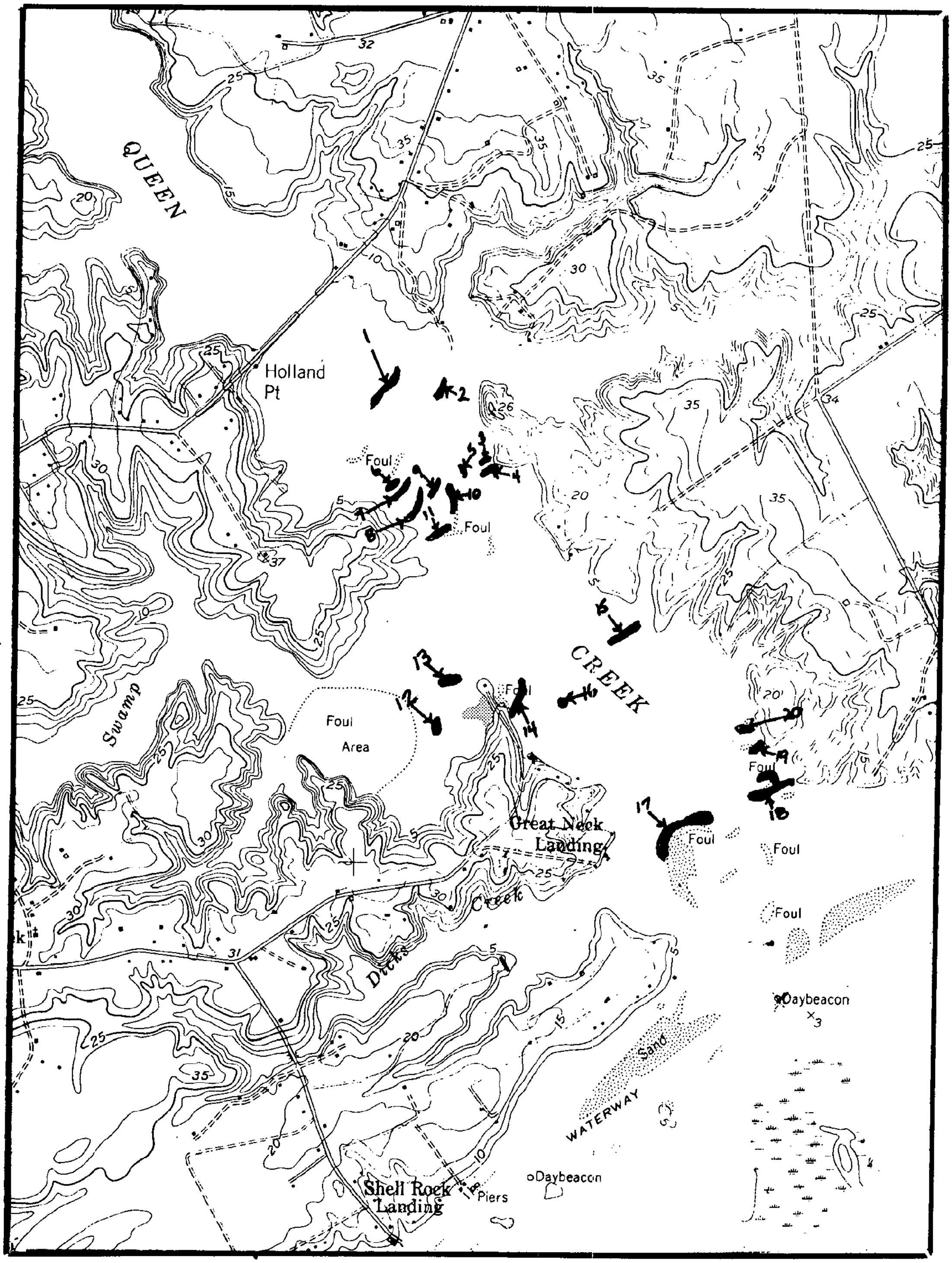

Figure 16 - Location map of intertidal polluted oyster stocks in Queen Creek, Onslow County, North Carolina, 1977-79 (numbers indicate individual oyster concentrations).

and modified for use in the project (Figures 2, 3, 4, and 5).

The initial mechanical harvester used was designed and constructed based upon photographs and measurements taken from the prototype developed at the Virginia Institute of Marine Science. The basic design of the harvester includes a steel box 90 cm in length and width. It narrows to a width of 45 cm at the throat plate where it is attached to a 15.2 m endless chain belt conveyor suspended alongside the harvest vessel. Inside the harvester head are six rows of flexible steel tines attached to each of two steel cylinders which are rotated by a chain-drive powered by a hydraulic motor. As the box slides on steel sleds over the bottom, the rotating tines rake live oysters and shells from the substrate and horizontal jets of water wash the material onto the chain-belt conveyor where it is carried to the surface. The 9.1 m planting barge, with a load capacity of 211 hl, is secured in position under the end of the conveyor and alongside the harvesting vessel. As the oysters and shells fall from the end of the conveyor, they are deposited onto the deck of the planting barge. When loaded, the planting barge separates from the harvesting vessel, and the load is transported to a preselected planting site where the seed oysters are washed overboard with a high pressure water spray.

The mechanical harvester was tested in Shallotte River on both intertidal and subtidal seed oysters.

During the first stage of testing, 21.8 hours were expended in the harvest of 1,847 hl of seed oysters. The rate of harvest ranged from 38 to 145 hl per hour depending upon the density of oyster concentrations. In this testing period problems were encountered which severely reduced the efficiency of the harvester. During harvesting, oysters and shells would lodge between the idler sprocket and secondary drive chain causing the mechanism to fail. When this occurred manual removal of the debris was required before operations could be resumed. Problems were also encountered with primary drive-chain failures which resulted in excessive side torque on the hydraulic motor shaft. This caused a fracture of the shaft and complete failure of the unit.

The harvester was then redesigned to eliminate the idler sprocket, to move the primary drive-chain to the outside of the box, and to mount the hydraulic motor drive sprocket between two pillow blocks.

A second stage of testing with the modified harvester resulted in the harvest of 4,004 hl of seed oysters in 49.0 hours of operation. The rate of harvest ranged from 47 to 170 hl per hour and represented a maximum efficiency increase of 17% over the initial design; however, drive-chain failures continued and the unit was completely redesigned to eliminate the side plates, relocate the secondary drive-chain assembly to the outside of the box, build new shaft bearing assemblies, and extend the shafts through the sides of the box to accommodate the outside drive-chain assemblies.

A third stage of testing resulted in the harvest of 3,472 hl of seed oysters in 29.3 hours of operation. The rate of harvest ranged from 70 to 234 hl per hour of operation and was dependent upon oyster source density. The maximum efficiency of the harvester after the second modification increased 61% over the initial design.

As the harvester became more efficient during the third testing period, additional flaws in the initial design appeared. The increased thrust load resulting from higher harvest rates caused wear problems in the tine hub assemblies and shaft bearings. These problems were corrected with the use of roller bearings and a shock-mounted tine hub assembly. This change also reduced the initial construction and maintenance costs. As the harvest rate increased, oysters and shells began to lodge in the throat plate due to insufficient water volume from the horizontal jets to wash the material onto the conveyor belt. A water chamber with two additional jets was designed to eliminate this problem. As the harvester slides over the bottom, it pivots on the chain-belt conveyor. The pivoting action abrades against the conveyor causing excessive wear and occasionally stopping the belt movement. This problem was corrected with the installation of a hinged throat plate and angle iron slides in the front conveyor box.

Details of the redesigned mechanical harvester are shown in the Appendix (Figures 2 - 14). We feel that this unit has now reached near maximum efficiency for this basic design. The redesigned harvester also represents the greatest economy in construction and ease of parts replacement and maintenance.

There were limiting factors imposed by using the R/V STONES BAY as a harvesting vessel. The size, excessive draft, and lack of maneuverability of this vessel resulted in the utilization of only 10% of the available intertidal seed oyster concentrations in the Shallotte River testing area.

Operating experience during this project has provided an insight into the physical characteristics of the most suitable vessel for use in harvesting seed oysters from small, intertidal areas. This vessel should be a 9.75 m by 4.57 m by 1.22 m self-propelled, steel, flat deck cargo barge with a light draft of 45 cm and a loaded draft of 70 cm. The vessel should be powered by twin diesel 6-cylinder stern drive engines, have a load capacity of 13 metric tons and be self-loading. These size and draft requirements will allow the vessel to maneuver in areas of limited space and water depth. The use of a self-loading vessel in conjunction with a planting barge will considerably increase capacity and reduce operating costs.

SEED OYSTER RELAYING

During the two-year project a total of 131 hours were expended to harvest 11,614 hl of seed oysters for an average harvest rate of 88.7 hl per hour. A record of seed oyster relaying activity for 1978 and 1979 is shown in Appendix Tables 1-4. The average cost of operation of the system was estimated at $37.50 per hour; thus seed oysters were harvested at an operating cost of $0.42 per hl. Actual costs of the harvesting and transplanting activity were nearer $1.40 per hl due to uncontrollable fixed costs (salaries, equipment depreciation, etc.) and the limited working time with the existing equipment. The activity was normally carried out by a crew of four, but on occasions only three crew members were available for the work.

The rate of harvest was reduced by breakdowns of older equipment, design flaws in the harvester, and the use of a single planting barge. Use of the R/V STONES BAY as a harvesting vessel resulted in limited working time in the intertidal seed oyster source areas. Early efforts showed that the equipment used for the harvest of dense intertidal stocks would be subjected to extreme stress. The requirement for new, high quality equipment became apparent during the early phases of the harvesting operation. The original design of the harvester proved troublesome when used on dense oyster concentrations due to frequent jamming of the drive mechanism by shell material. When this occurred, the harvester was lifted and several minutes were required to clear the shell material from the chain and sprockets. On several occasions when operating on very dense oyster concentrations, drive chains were damaged or broken.

Due to the physical characteristics of the work areas, most seed oyster planting had to take place during high tide when the planting barge could be maneuvered into the designated intertidal site. This limited the amount of time during any one day when the equipment could be used in transplanting operations. This problem could have been reduced by the use of a second planting barge or a self-loading harvesting vessel. On many occasions it would have been feasible to load two planting barges during the available working time of the harvesting vessel.

Oysters transported into the designated planting areas were washed overboard with high pressure water to evenly distribute the seed oysters at planting rates of 1,235 to 2,000 hl per ha.

In 1978, seed oyster relaying activity was conducted during 30 days of field operations between 7 April and 22 December. The 47.6 hours of harvesting resulted in the transplanting of 2,443 hl of intertidal seed oysters and 1,303 hl of subtidal seed oysters. These seed oysters were relayed into nine sites in the Shallotte River Shellfish Management Area and Boones Island Shellfish Management Area in Brunswick County and into seven sites in the Masonboro Sound Shellfish Management Area and Wrightsville Beach Marshes Shellfish Management Area in New Hanover County (Figures 17, 18, 19, and 20).

There was a significant difference in harvest rates between Brunswick County (84.6 hl/hr) and New Hanover County (70.0 hl/hr) areas. This difference was a result of better quality seed oyster stocks in Brunswick County and differences in mean tide levels between Brunswick County source areas (70.1 cm) and New Hanover County source areas (57.9 cm). The higher mean tide levels of Brunswick County allowed easier maneuvering in source areas and slightly longer working times during high tide periods.

In 1979, seed oyster relaying activity was conducted during 42 days of field operations between 3 January and 22 April. The 83 hours of harvesting resulted in the transplanting of 2,503 hl of intertidal seed oysters and 5,365 hl of subtidal seed oysters. The average harvest rate of 94.8 hl per hour was a significant improvement over the 1978 rate of 78.7 hl per hour and

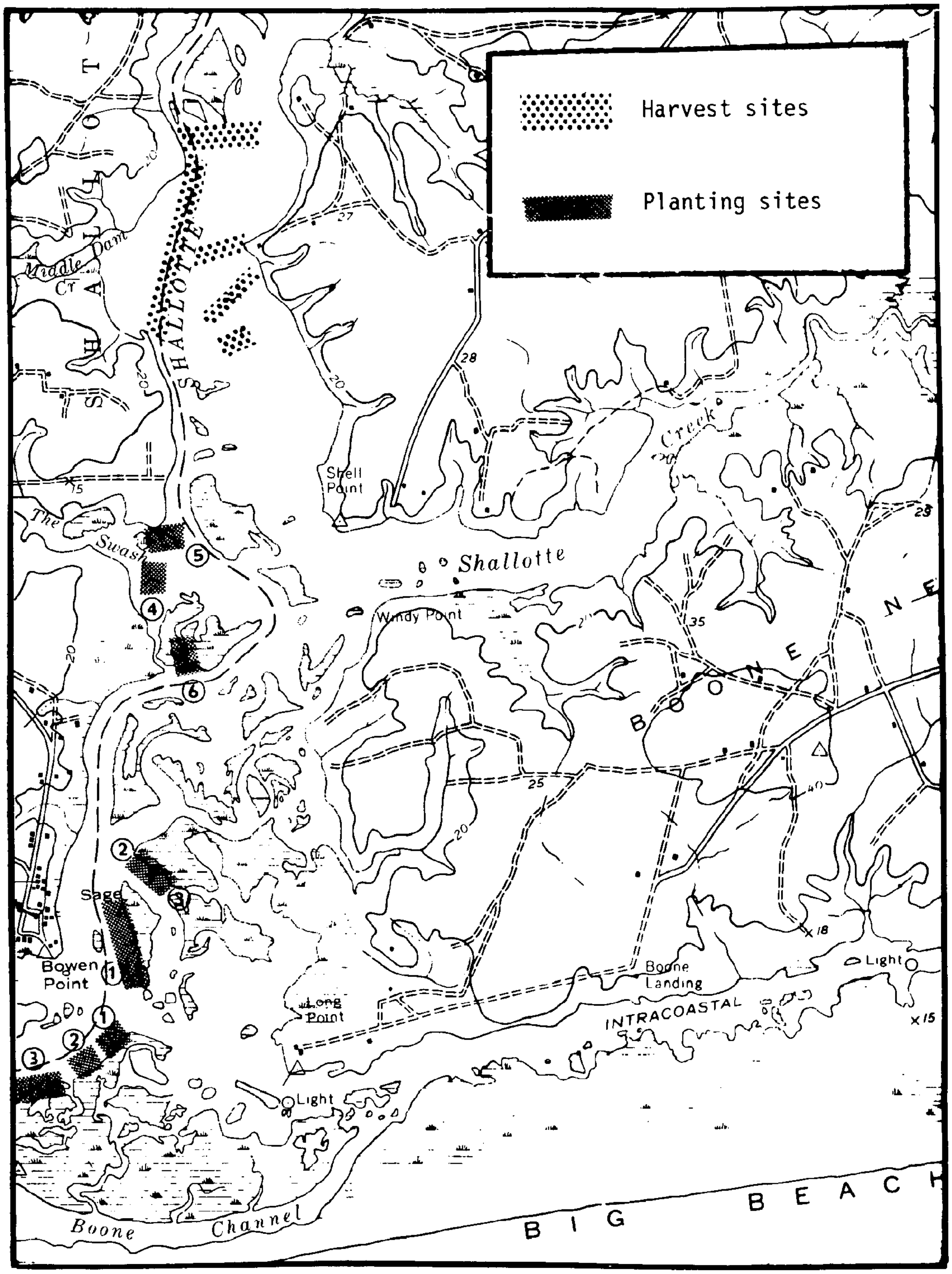

Figure 17 - Map of seed oyster harvesting area and relaying sites for Shallotte River and Boones Island, Brunswick County, North Carolina, 1978 (numbers indicate planting sites).

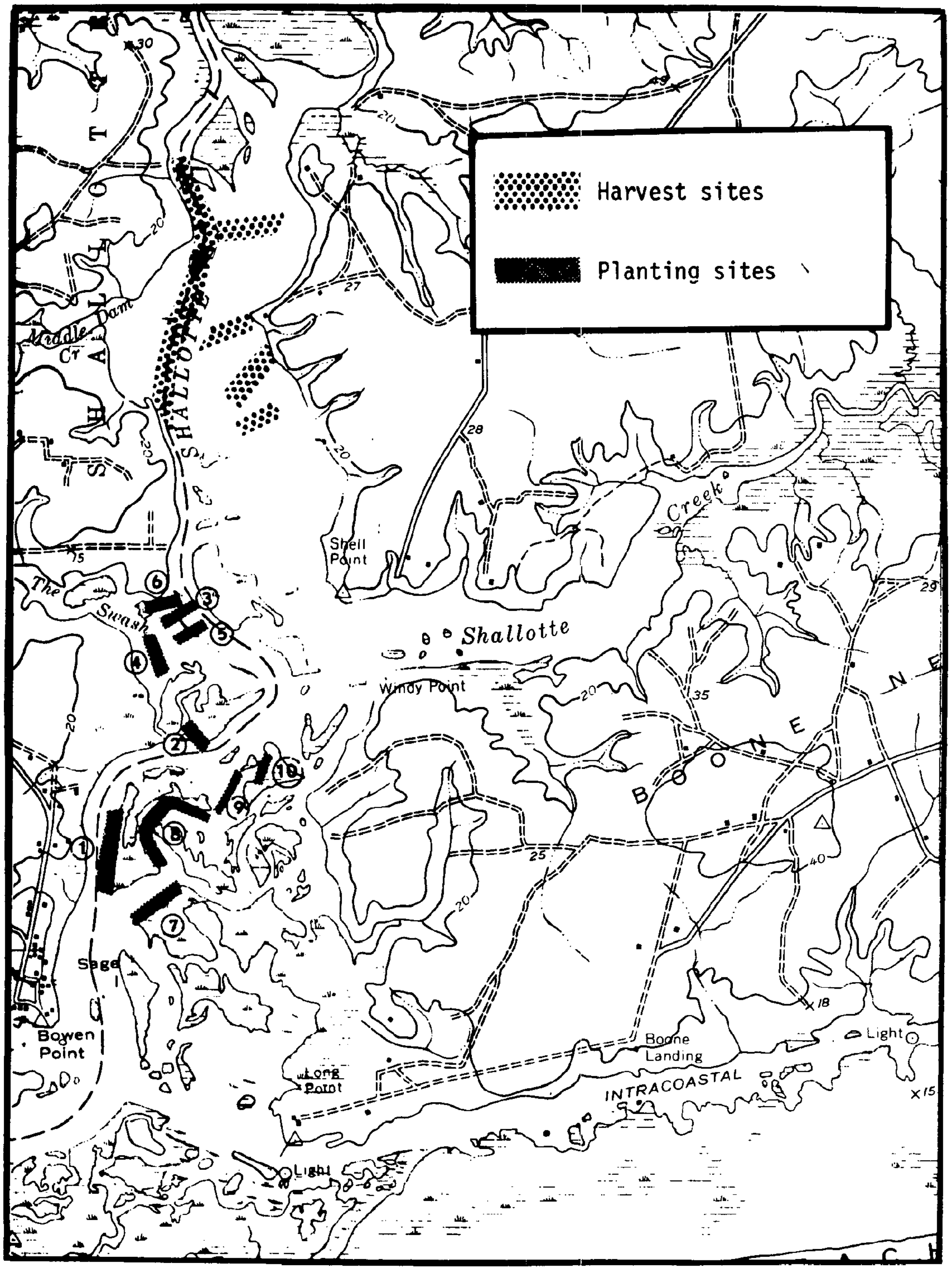

Figure 18 - Harvest area and seed oyster planting sites for Shallotte River, North Carolina, 1979 (numbers represent individual planting sites).

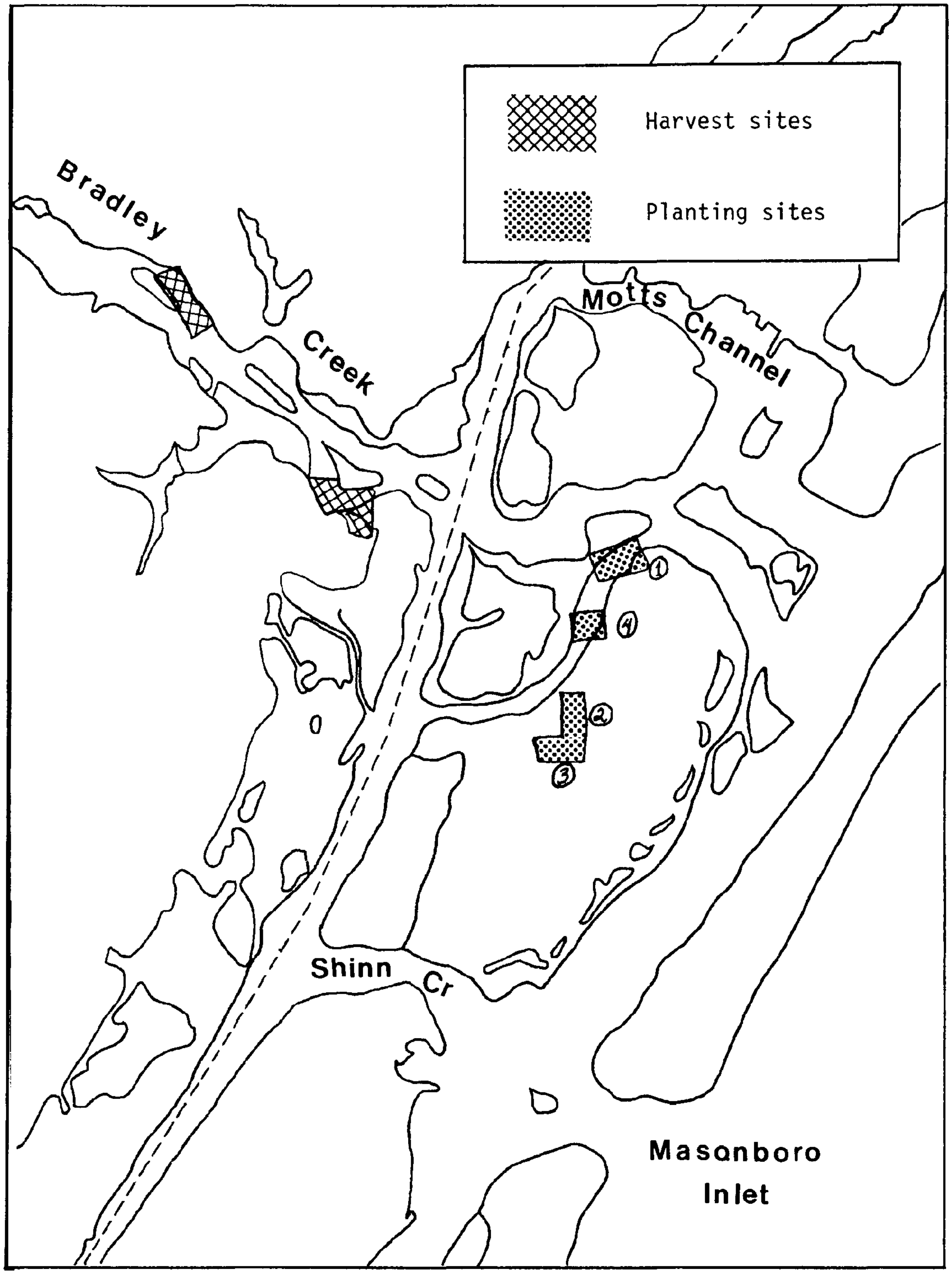

Figure 19. Harvest area and seed oyster planting sites for Wrightsville Beach Marshes, New Hanover County, North Carolina, 1978 (numbers represent individual planting sites).

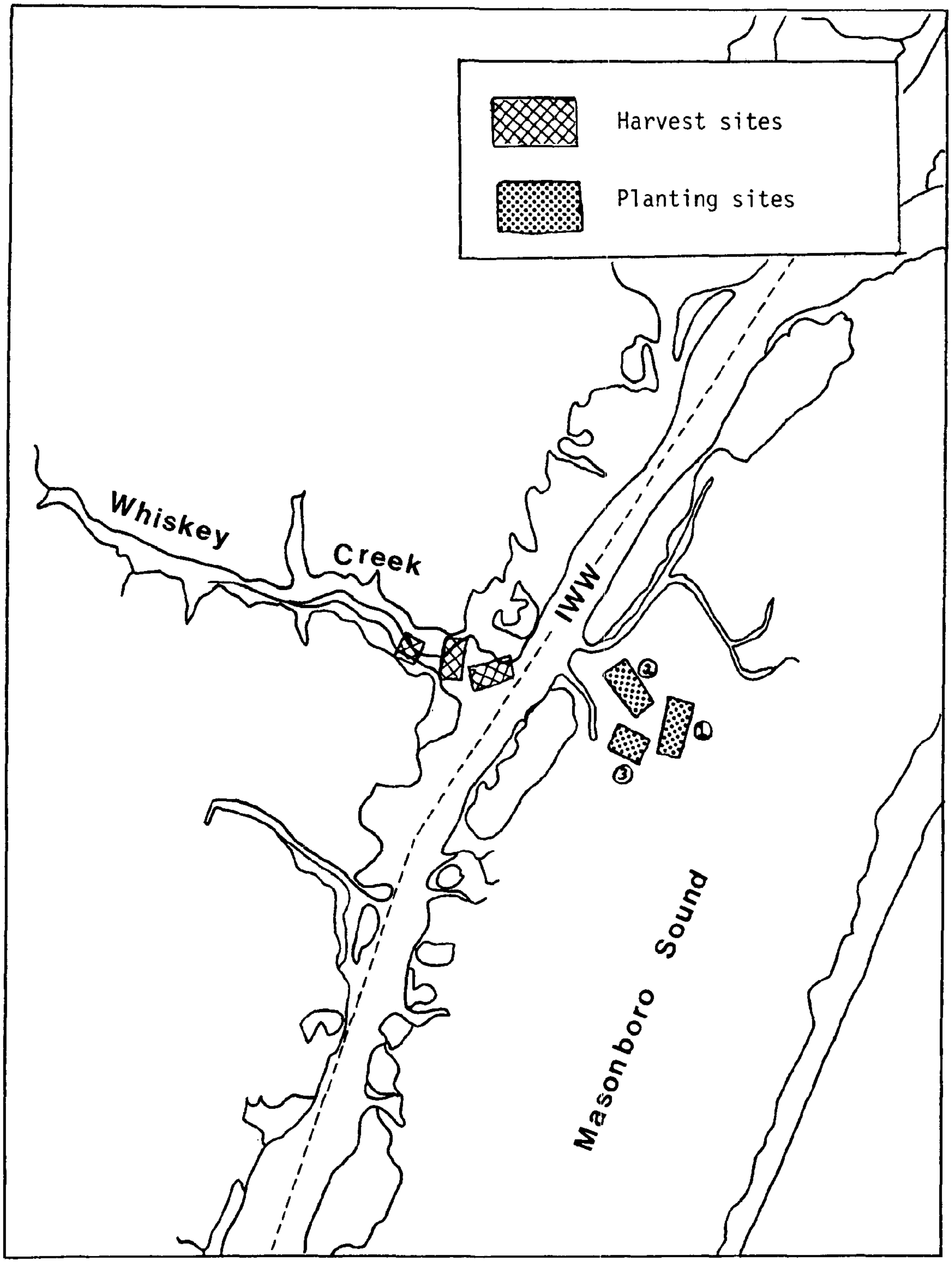

Figure 20. Harvest area and seed oyster planting sites for Masonboro Sound, New Hanover County, North Carolina, 1978 (numbers represent individual planting sites).

was primarily a result of the increased efficiency of the redesigned harvester. Seed oysters were relayed into 16 sites in the Shallotte River Shellfish Management Area, Saucepan Creek Shellfish Management Area, Eastern Channel Shellfish Management Area, Sol's Creek Shellfish Management Area, and Lockwood Folly River Shellfish Management Area in Brunswick County and into a single site in the Mason Channel Shellfish Management Area in New Hanover County (Figures 18, 21, 22, 23, and 24).

The practicality of a large scale relaying program utilizing the mechanical harvester was clearly demonstrated during the project, and it was recommended that a fully-funded program be implemented.

Monitoring

A total of 849 monitoring samples was taken in the 33 seed oyster planting sites during the 18-month monitoring period from April, 1978 through October, 1979. Monitoring results for each Shellfish Management Area are shown in Tables 5 through 19 and figures 25 through 39.

Subtidal seed oysters sustained mortality rates of less than 3% as a result of harvesting and transplanting. Mortality from commercial harvesting was as high as 16% and was often accompanied by a significant increase in the dead shell component of samples. Growth rates of planted subtidal seed oysters averaged about 10 mm per quarter; however, on some plantings conducted in early spring months, growth rates of 30 mm were recorded for the first quarter following planting. Most subtidal plantings sustained spat sets which contributed to the productivity of the sites. Density of subtidal plantings increased rapidly as a result of growth and recruitment, and standing crops at the sites often exceeded 3,500 hl per ha within nine months of planting.

The mortality rate of planted intertidal seed oysters was usually less than 2% in Brunswick County sites, but ranged from 8 to 10% at New Hanover County sites. Mortality resulting from commercial harvesting of the planted seed oysters was as high as 13% and was usually accompanied by an increase in the dead shell component as a result of culling. The growth rate of planted intertidal seed oysters averaged 10 to 20 mm per quarter; however, some plantings attained a growth rate of 40 mm within a three-month period. Most

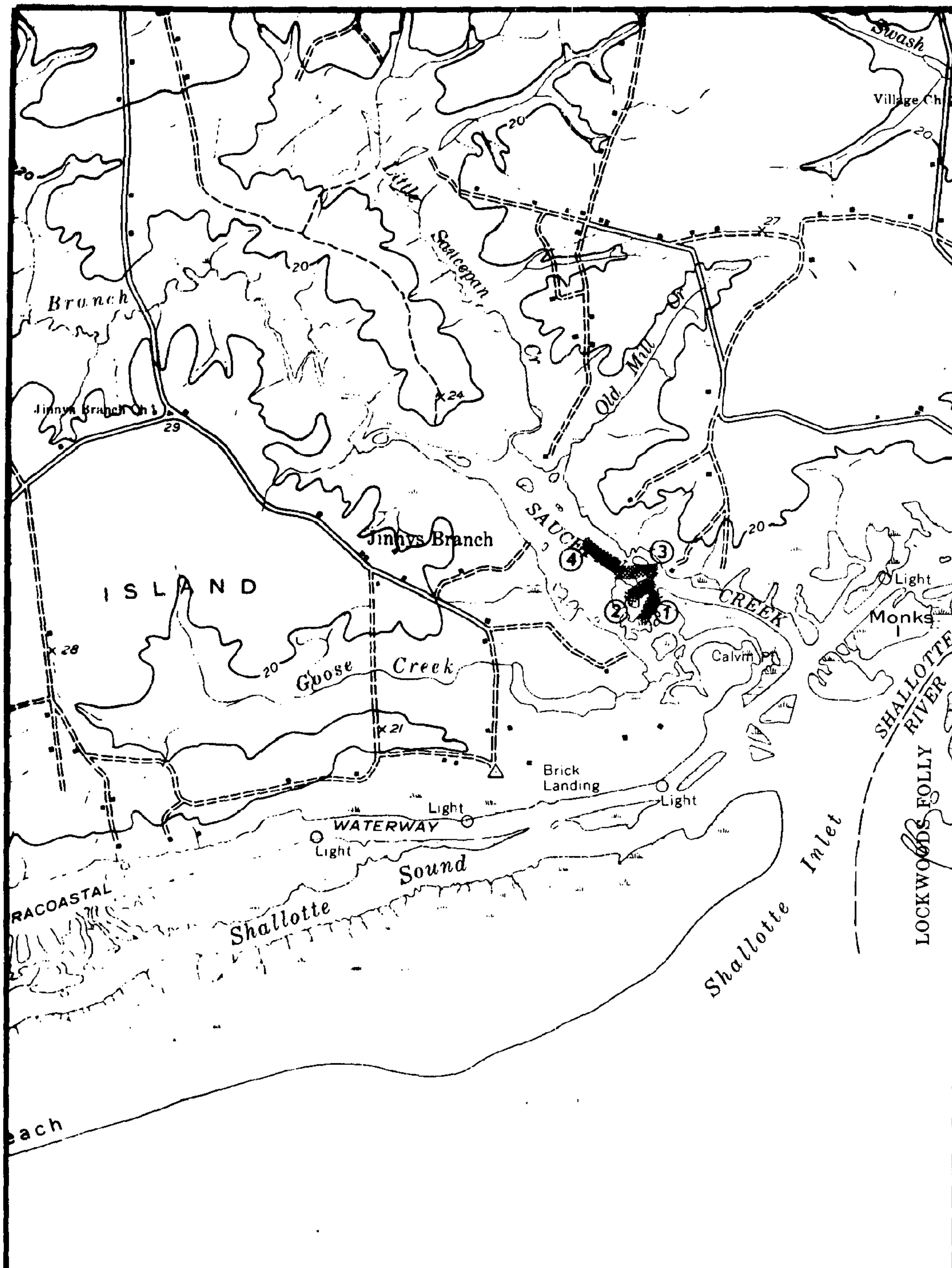

Figure 21 - Seed oyster planting sites for Saucepan Creek, Brunswick County, North Carolina, 1979 (numbers represent individual planting sites).

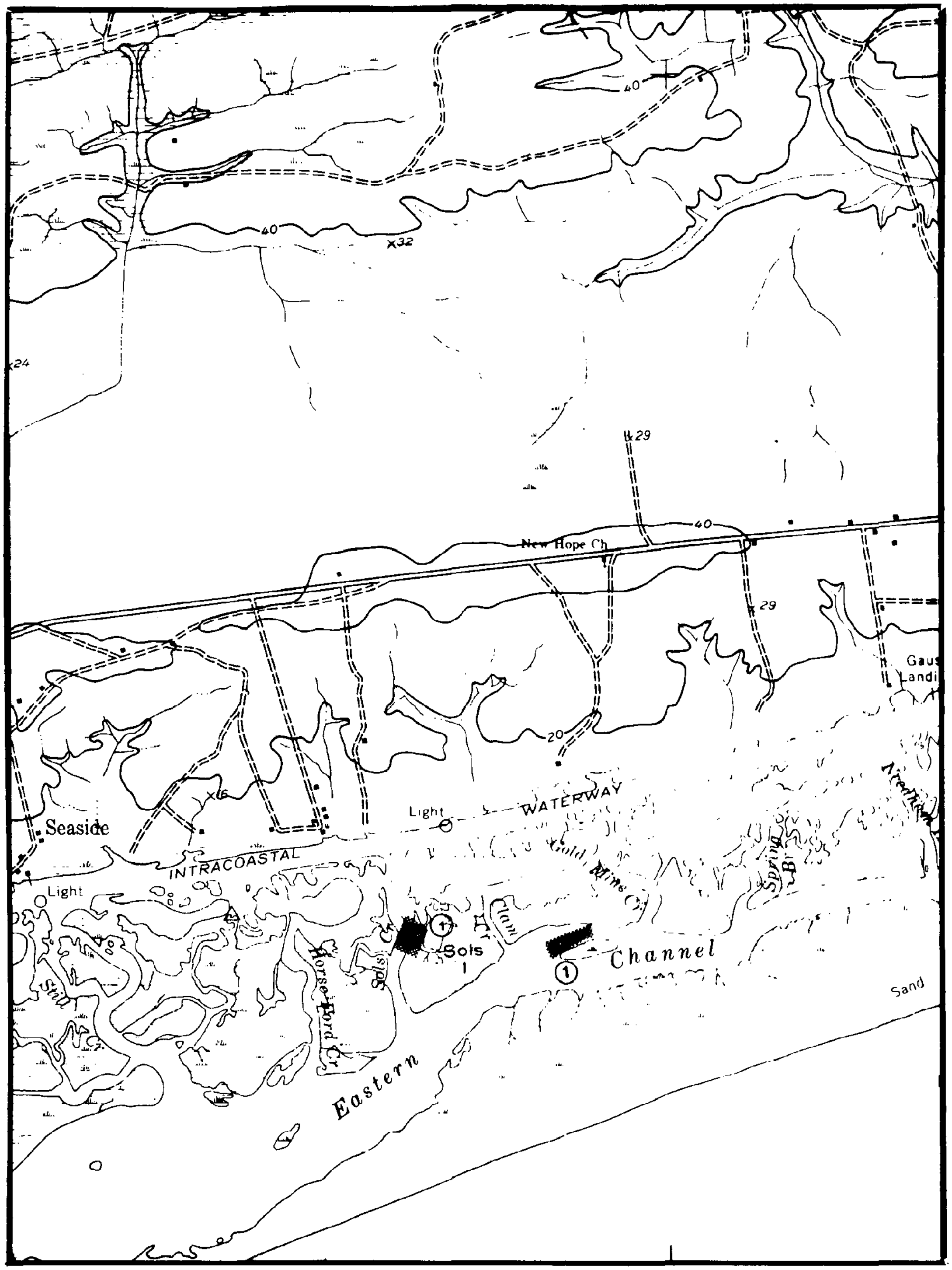

Figure 22 - Seed oyster planting sites for Eastern Channel and Sol's Creek, Brunswick County, North Carolina, 1979 (numbers represent individual planting sites).

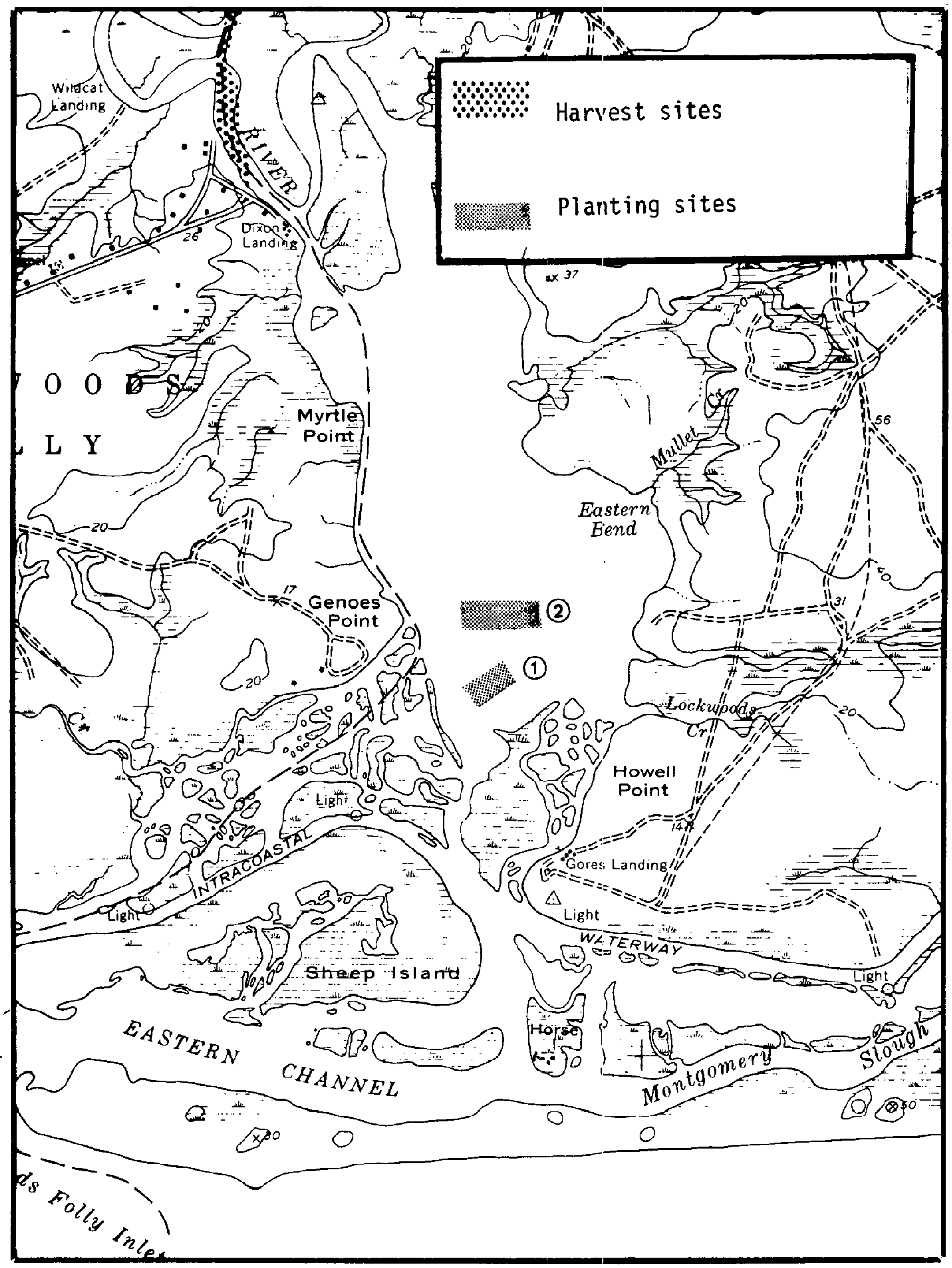

Figure 23 - Harvest area and seed oyster planting sites for Lockwoods Folly River, Brunswick County, North Carolina, 1979 (numbers represent individual planting sites).

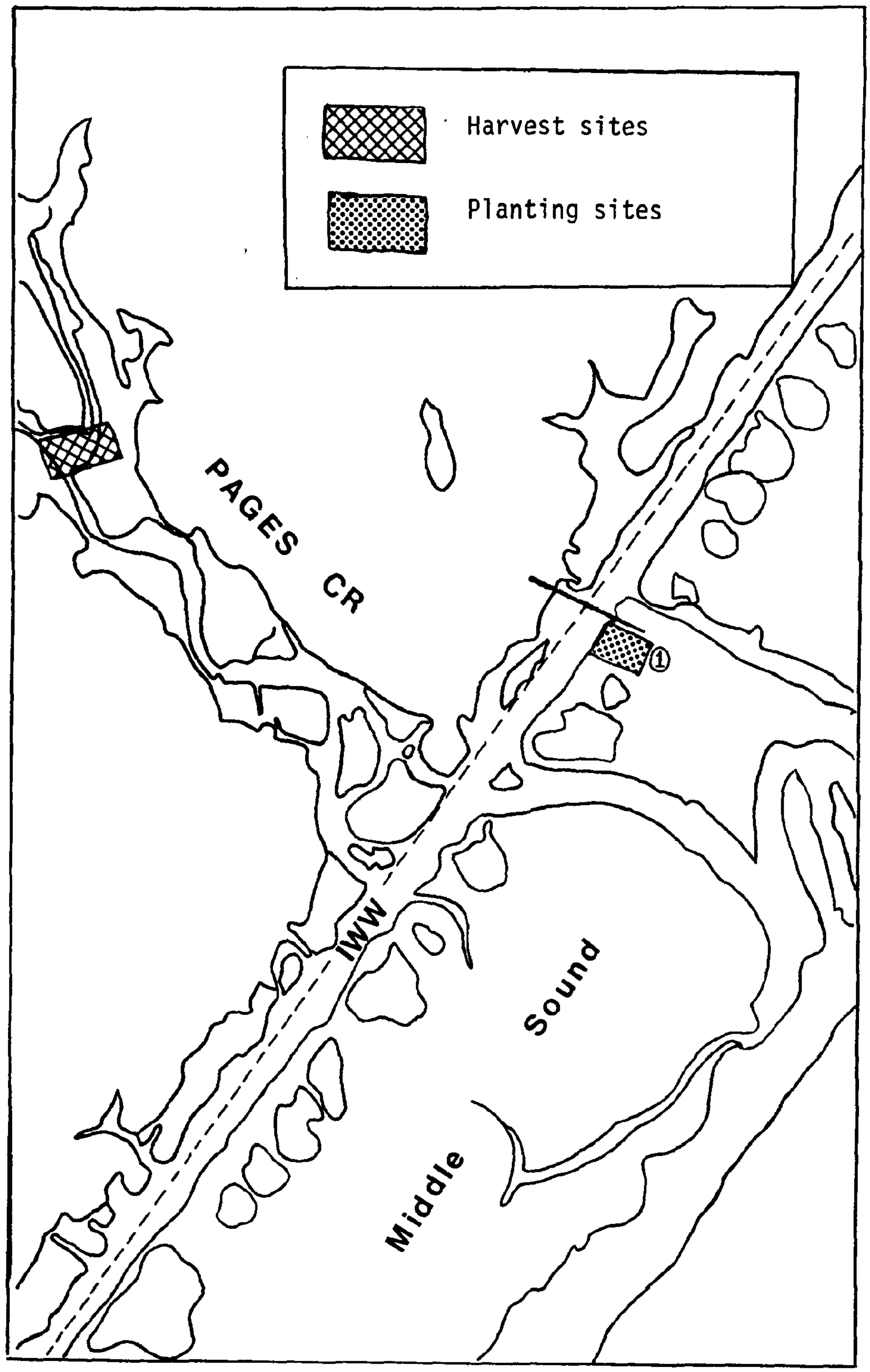

Figure 24. Harvest area and seed oyster planting sites for Mason's Channel, New Hanover County, North Carolina, 1979 (numbers represent individual planting sites).

Table 5. Results of monitoring of subtidal seed oysters planted in 1978 in Boones Island Shellfish Management Area Brunswick County, North Carolina, 1978 - 79.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (spring)	40	-	31	6	24
1-month after planting (spring)	40	27.13	29	8	34
3-months after planting (summer)	10	35.24	6	4	30
6-months after planting (fall)	30,50	38.90	8	4	38
9-months after planting (winter, 1979)	50	44.05	10	8	30
12-months after planting (spring, 1979)	20	25.37	33+	4	20
15-months after planting (summer, 1979)	30	26.31	21+	8	24
18-months after planting (fall, 1979)	40	22.55	17+	15*	21

* Harvesting mortality

\+ Culled shell from harvesting

Table 6. Results of monitoring of intertidal seed oysters in 1978 in Shallotte River Shellfish Management Area, Brunswick County, North Carolina 1978 - 79.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	40	-	7	8	18
1-month after planting (spring)	30	45.20	13+	9	25
3-months after planting (summer)	60	43.34	1	7	17
6-months after planting (fall)	60,70	41.58	4	7	16
9-months after planting (winter, 1979)	60	25.37	4	13*	23
12-months after planting (spring, 1979)	20	17.57	6	25*	21
15-months after planting (summer, 1979)	80	33.45	4	16*	14
18-months after planting (fall, 1979)	60	21.61	24+	21*	12

* Harvesting mortality

+ Culled shell from harvesting

Table 7. Results of monitoring of subtidal seed oysters planted in 1978 in Shallotte River Shellfish Management Area, Brunswick County, North Carolina, 1978 - 79.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	40	-	4	7	25
1-month after planting (spring)	40	-	3	3	32
3-months after planting (summer)	50	43.34	1	2	20
6-months after planting (fall)	50	59.20	2	10*	22
9-months after planting (winter, 1979)	40	24.22	5	8	36
12-months after planting (spring, 1979)	60	15.15	14+	24*	24
15-months after planting (summer, 1979)	50,60	23.49	20+	22*	16
18-months after planting (fall, 1979)	50	33.83	33+	30*	10

* Harvesting mortality
+ Culled shell from harvesting

Table 8. Results of monitoring of intertidal seed oysters planted in 1978 in Masonboro Sound Shellfish Management Area, New Hanover County, North Carolina, 1978 - 79.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (fall)	30	-	49	5	22
1-month after planting (winter, 1979)	30	50.75	42	13	12
3-months after planting (spring, 1979)	10,40	39.53	35	7	16
6-months after planting (summer, 1979)	40	13.85	48+	14++	18
9-months after planting (fall, 1979)	30	17.60	47+	12*	19

* Harvesting mortality

+ Culled shell from harvesting

++ Spat mortality

Table 9. Results of monitoring of intertidal seed oysters planted in 1978 in Wrightsville Beach Marshes Shellfish Management Area, New Hanover County, North Carolina, 1978 - 79.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (fall)	30	-	34	3	28
3-months after planting (winter, 1979)	30	16.87	30	11	26
6-months after planting (spring, 1979)	30	18.79	40+	24*	17
9-months after planting (summer, 1979)	30	31.25	31	13	18
12-months after planting (fall, 1979)	40	11.98	25+	8	21

* Harvesting mortality

+ Culled shell from harvesting

Table 10. Results of monitoring of subtidal seed oysters planted in 1979 in Sol's Creek Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	20	-	34	11	47
3-months after planting (spring)	50	27.62	40+	27*	18
6-months after planting (summer)	30	45.11	9	18*	23
9-months after planting (fall)	20	46.16	7	13*	21

* Harvesting mortality

+ Culled shell from harvesting

Table 11. Results of monitoring of intertidal seed oysters planted in 1979 in Eastern Channel Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (spring)	20	-	41	20++	24
1-month after planting (spring)	20	29.47	52+	20*	10
3-months after planting (summer)	60	6.7	67+	25*	9
6-months after planting (fall)	20,40	18.32	19	19	11

* Harvesting mortality

\+ Culled shell from harvesting

++ Seed oyster source winter mortality

Table 12. Results of monitoring of subtidal seed oysters planted in 1979 in Lockwoods Folly River Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (spring)	20	-	24	9	47
1-month after planting (spring)	10	35.54	20	11	35
3-months after planting (summer)	30	57.32	25+	5	19
6-months after planting (fall)	40	44.07	6	7	19

+ Culled shell from harvesting

Table 13. Results of monitoring of subtidal seed oysters planted in 1979 in Gibbs Creek Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	20	-	33	8	42
3-month after planting (winter)	20	38.76	19	7	25
3-months after planting (spring)	20	51.69	18	8	34
6-months after planting (summer)	30	54.19	10	13*	25
9-months after planting (fall)	30	26.50	8	11*	28

* Harvesting mortality

Table 14. Results of monitoring of intertidal seed oysters planted in 1979 in Gibbs Creek Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	30,40	-	36	8	23
1-month after planting (winter)	60	30.26	13	10	44
3-months after planting (spring)	20	56.38	13	7	21
6-months after planting (summer)	10	66.72	10	7	21
9-months after planting (fall)	20,30	13.16	0	18*	38

* Harvesting mortality

Table 15. Results of monitoring of intertidal seed oysters planted in 1979 in Shallotte River Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent morality (percent)	Number live oysters per liter sample material
Initial planting (winter)	20	-	38	6	28
1-month after planting (winter)	20	18.23	27	10	50
3-months after planting (spring)	20	27.89	21	14	26
6-months after planting (summer)	50	43.08	10	16	16
9-months after planting (fall)	40,50	24.17	7	17	17

Table 16. Results of monitoring of subtidal seed oysters planted in Shallotte River Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	20	-	33	10	23
1-month after planting (winter)	20	29.32	10	4	55
3-months after planting (spring)	30	37.59	20+	9	27
6-months after planting (summer)	40	21.61	4	23*	20
9-months after planting (fall)	30	25.56	4	21*	17

* Harvesting mortality

+ Culled shell from harvesting

Table 17. Results of monitoring of intertidal seed oysters planted in 1979 in Saucepan Creek Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	20	-	34	12	19
1-month after planting (winter)	20	42.29	13	9	28
3-months after planting (spring)	20	39.47	21+	12*	19
6-months after planting (summer)	30	41.23	18	10	19
9-months after planting (fall)	30	13.34	23+	9	33

* Harvesting mortality

\+ Culled shell from harvesting

Table 18. Results of monitoring of subtidal seed oysters planted in 1979 in Saucepan Creek Shellfish Management Area, Brunswick County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	20	-	32	9	50
1-month after planting (winter)	20	26.78	19	16*	42
3-months after planting (spring)	20	28.0	19	9	36
6-months after planting (summer)	30	33.83	21+	6	20
9-months after planting (fall)	40,50	23.59	16	8	25

* Harvesting mortality

+ Culled shell from harvesting

Table 19. Results of monitoring of intertidal seed oysters planted in 1979 in Mason's Channel Shellfish Management Area, New Hanover County, North Carolina, 1979.

Monitoring period	Modal length (mm)	Mean density ($1/m^2$)	Dead shell component in samples (percent)	Recent mortality (percent)	Number live oysters per liter sample material
Initial planting (winter)	40	-	43	9	15
3-months after planting (spring)	50	49.34	36	19	13
6-months after planting (summer)	40	26.92	56+	23*	18
9-months after planting (fall)	30,50	32.07	65+	16	9

* Harvesting mortality

+ Culled shell from harvesting

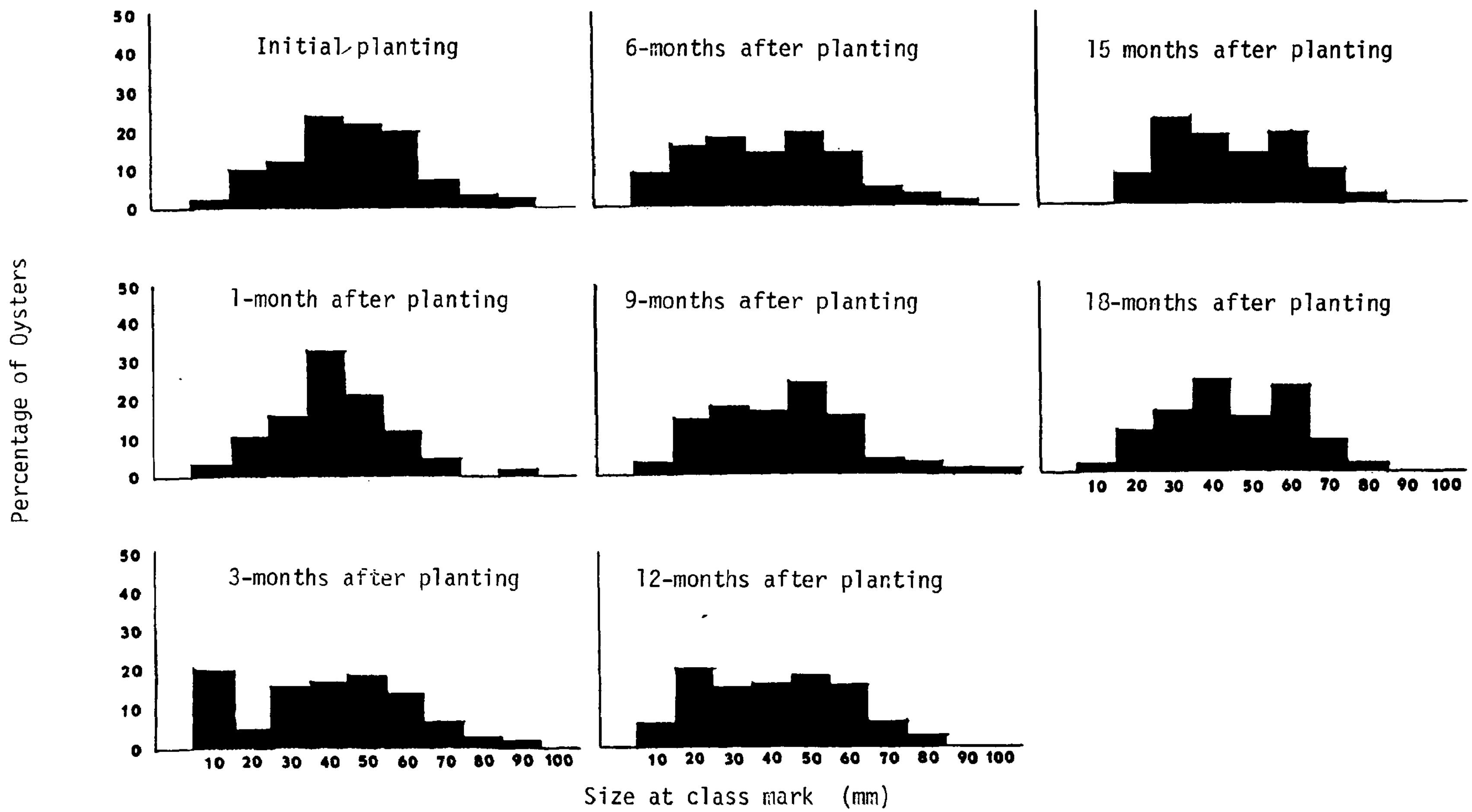

Figure 25. Size distribution of planted subtidal seed oysters during monitoring period, Boones Island Shellfish Management area, North Carolina, 1978-79.

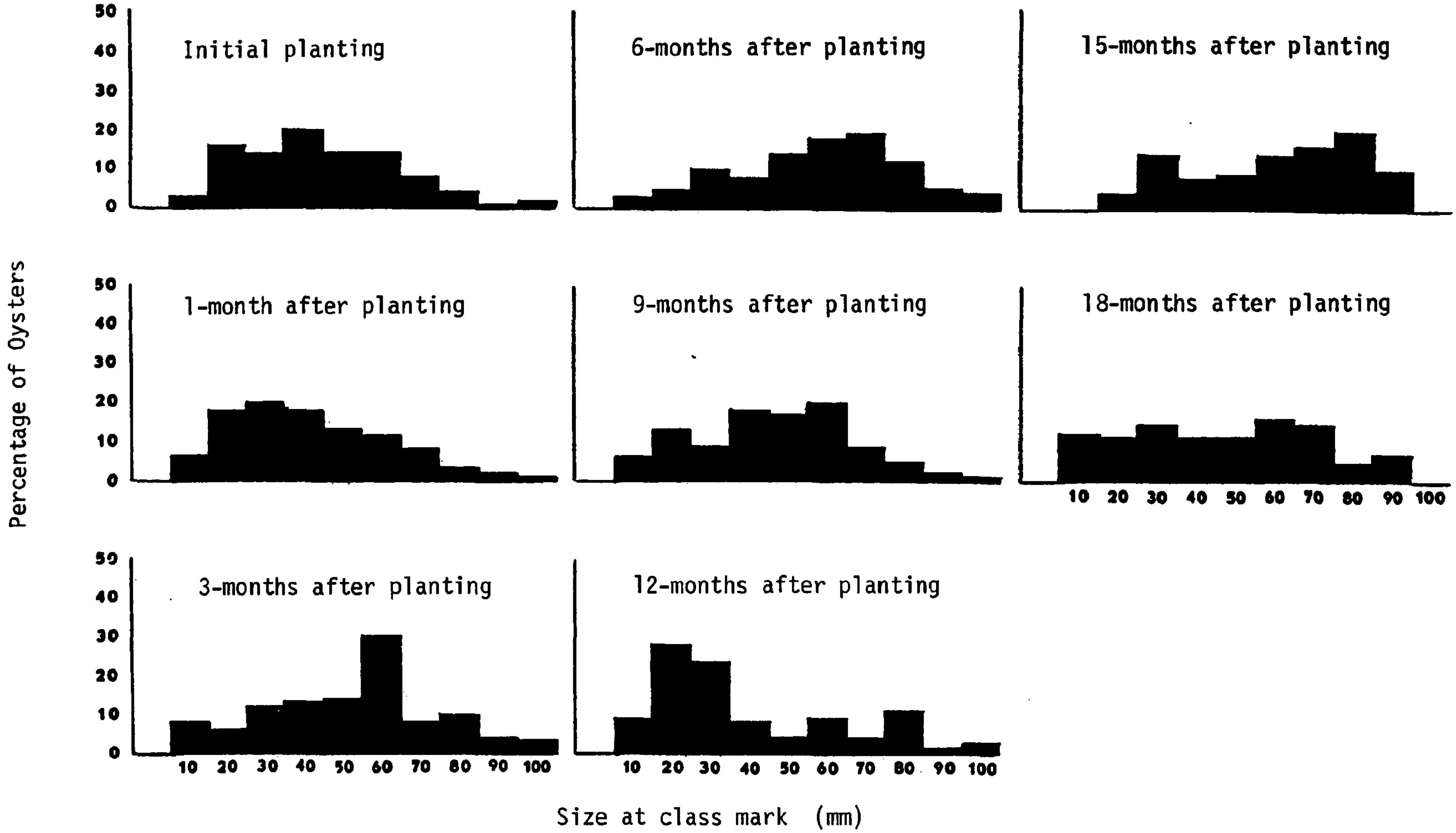

Figure 26. Size distribution of planted intertidal seed oysters during monitoring period Shallotte River Shellfish Management area, North Carolina, 1978-79.

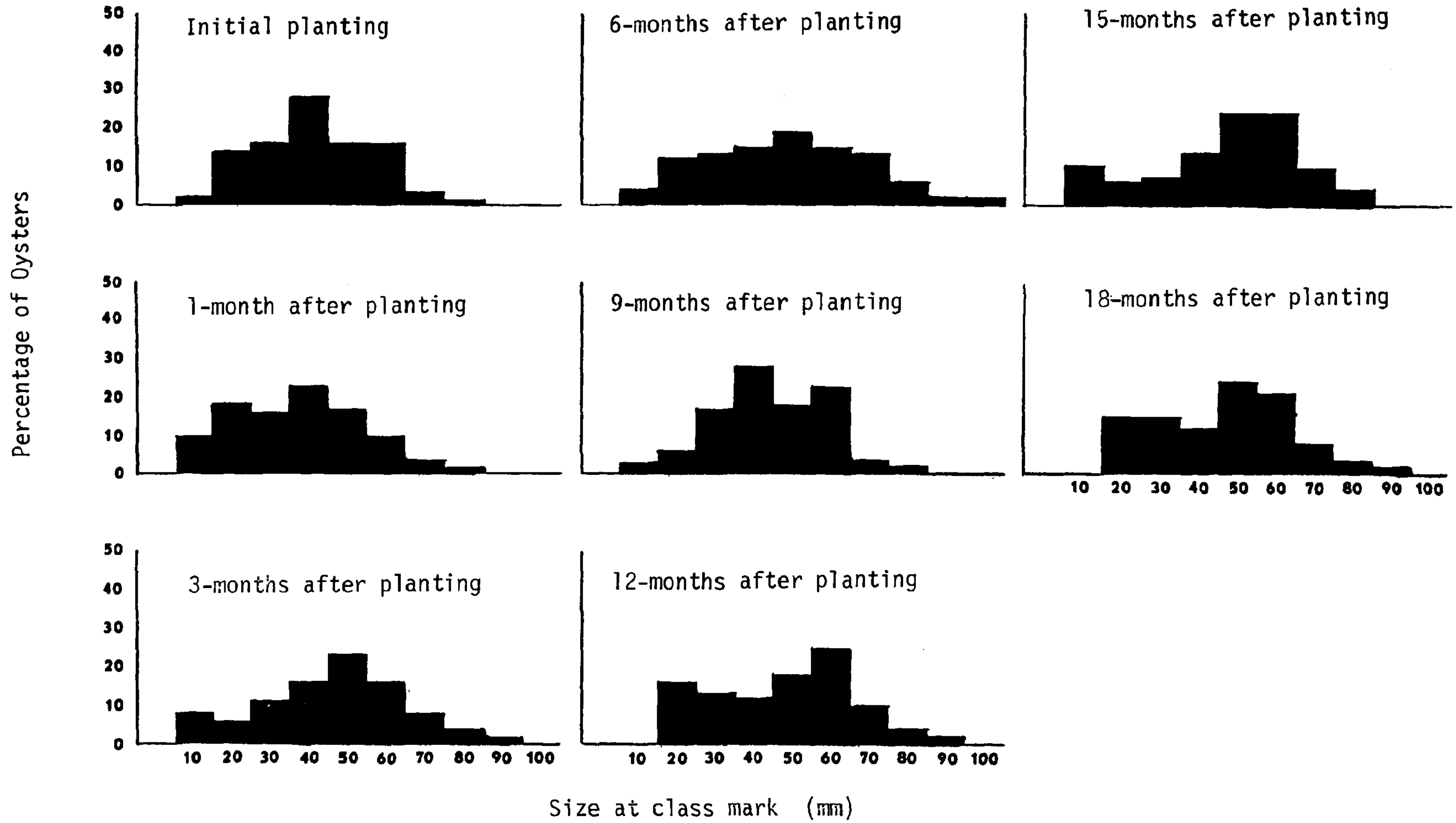

Figure 27. Size distribution of planted subtidal seed oysters during monitoring period, Shallotte River Shellfish Management area, North Carolina, 1978-79.

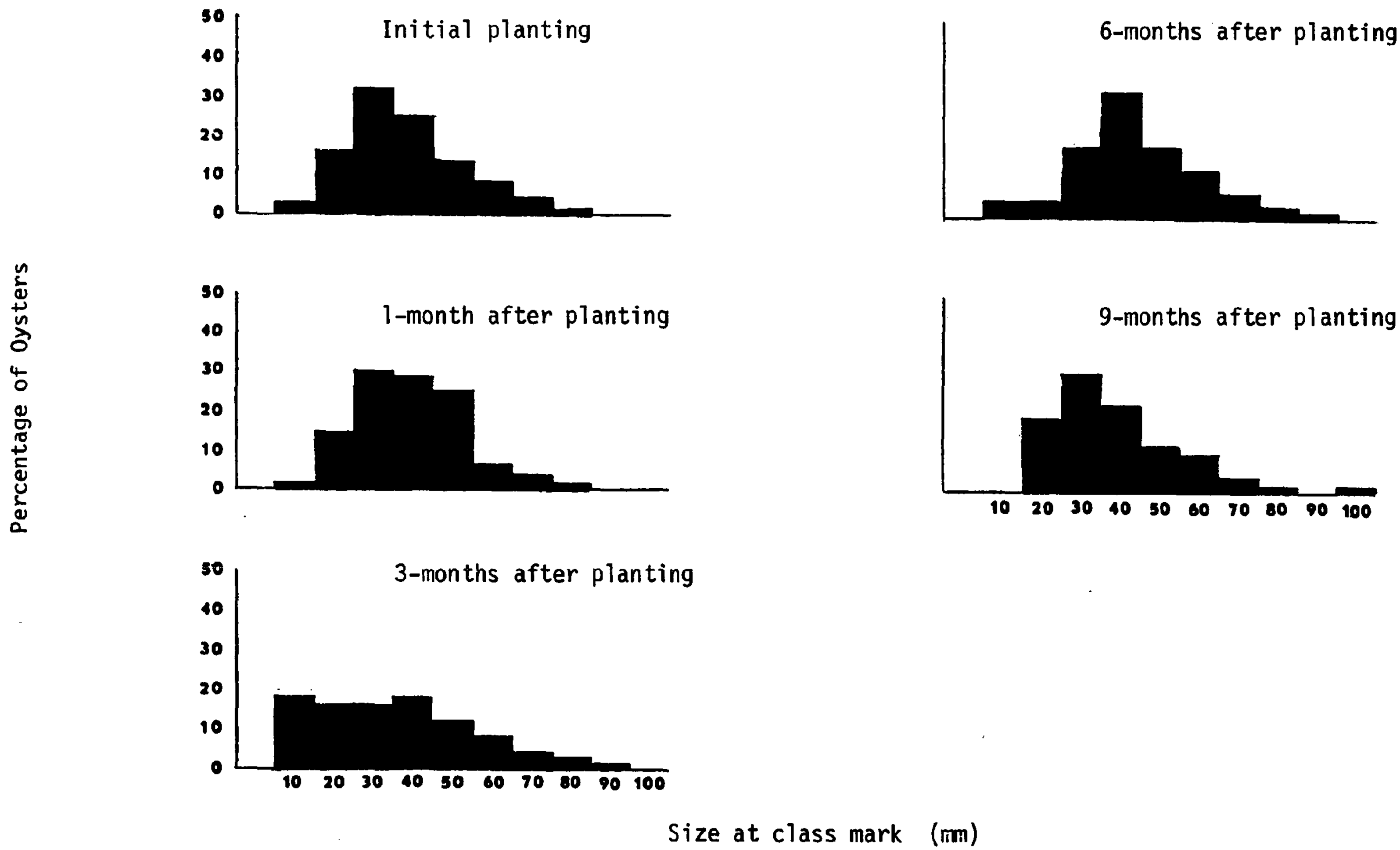

Figure 28. Size distribution of planted intertidal seed oysters during monitoring period, Masonboro Sound Shellfish Management area, North Carolina, 1978-79.

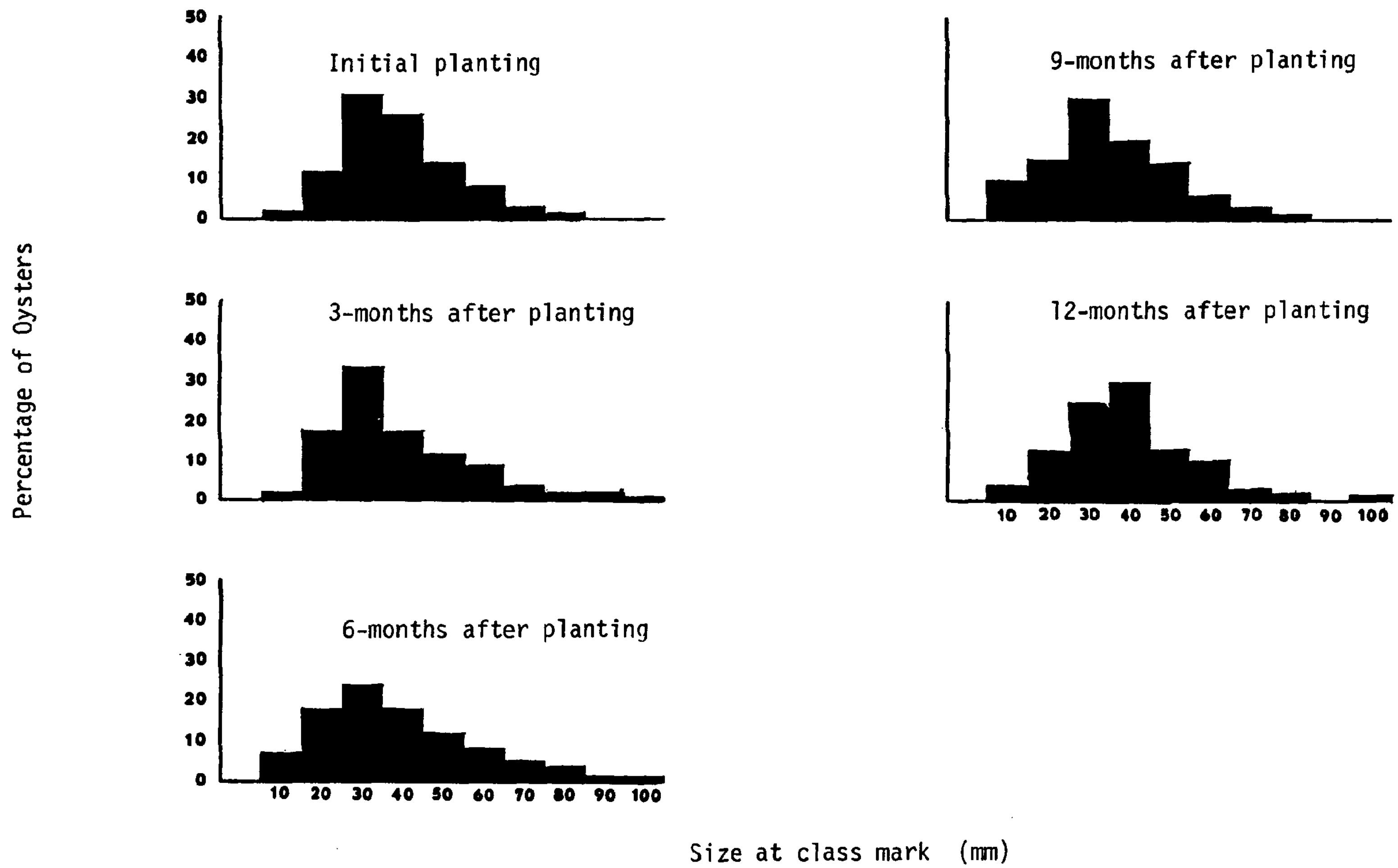

Figure 29. Size distribution of planted intertidal seed oysters during monitoring period, Wrightsville Beach Marshes Shellfish Management area, North Carolina, 1978-79.

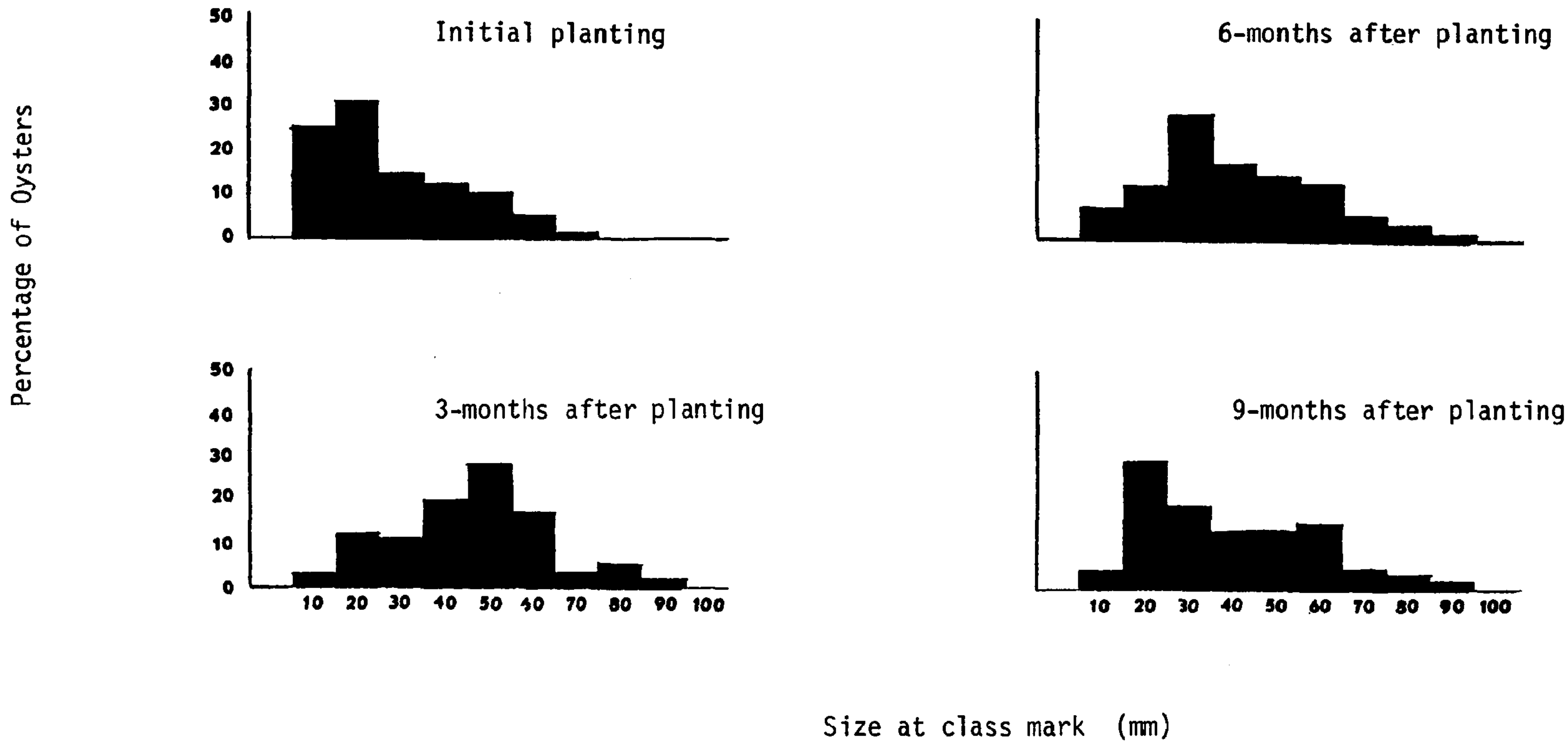

Figure 30. Size distribution of planted subtidal seed oysters during monitoring period, Sol's Creek Shellfish Management area, North Carolina, 1979.

Figure 31. Size distribution of planted intertidal seed oysters during monitoring period, Eastern Channel Shellfish Management area, North Carolina, 1979.

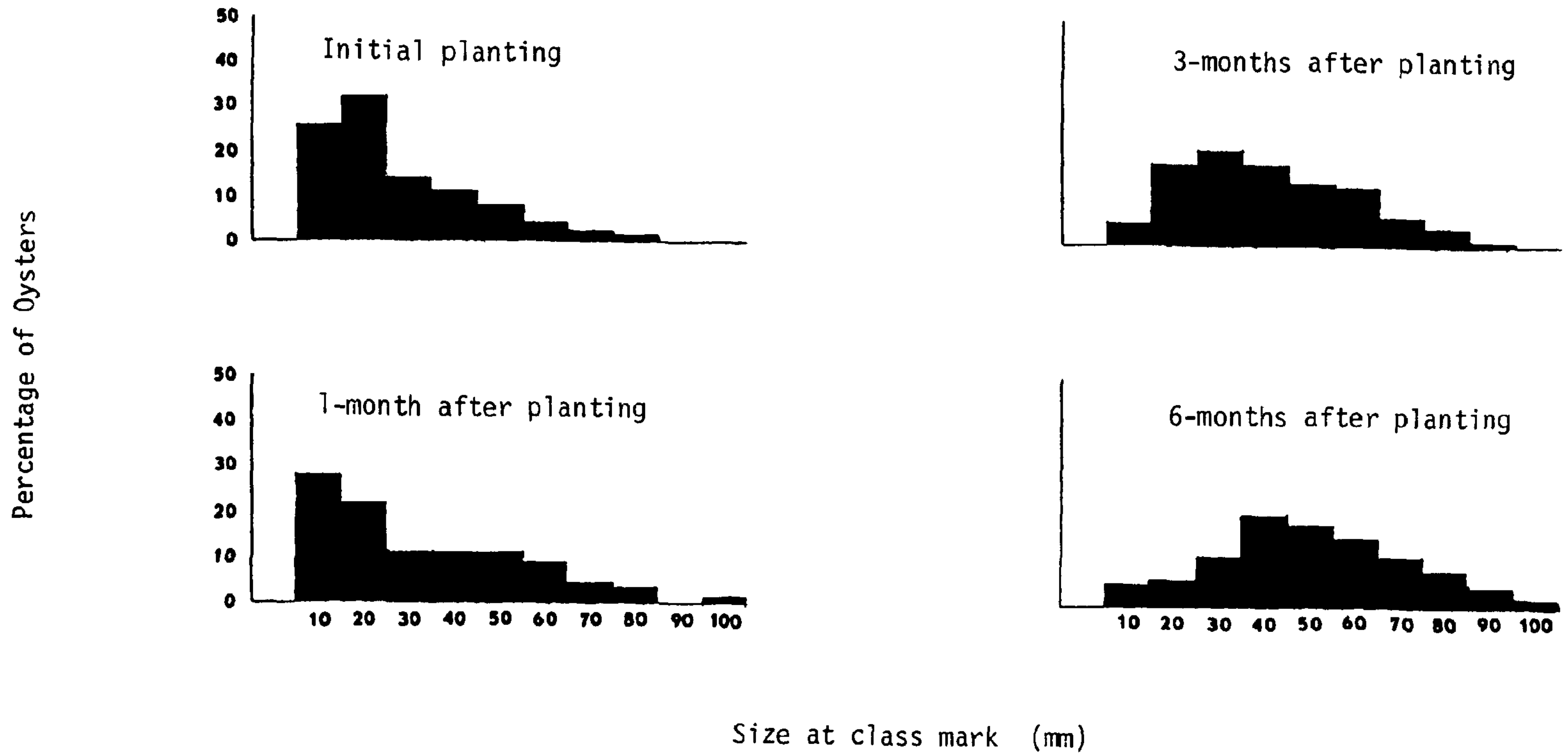

Figure 32. Size distribution of planted subtidal seed oysters during monitoring period, Lockwoods Folly River Shellfish Management area, North Carolina, 1979.

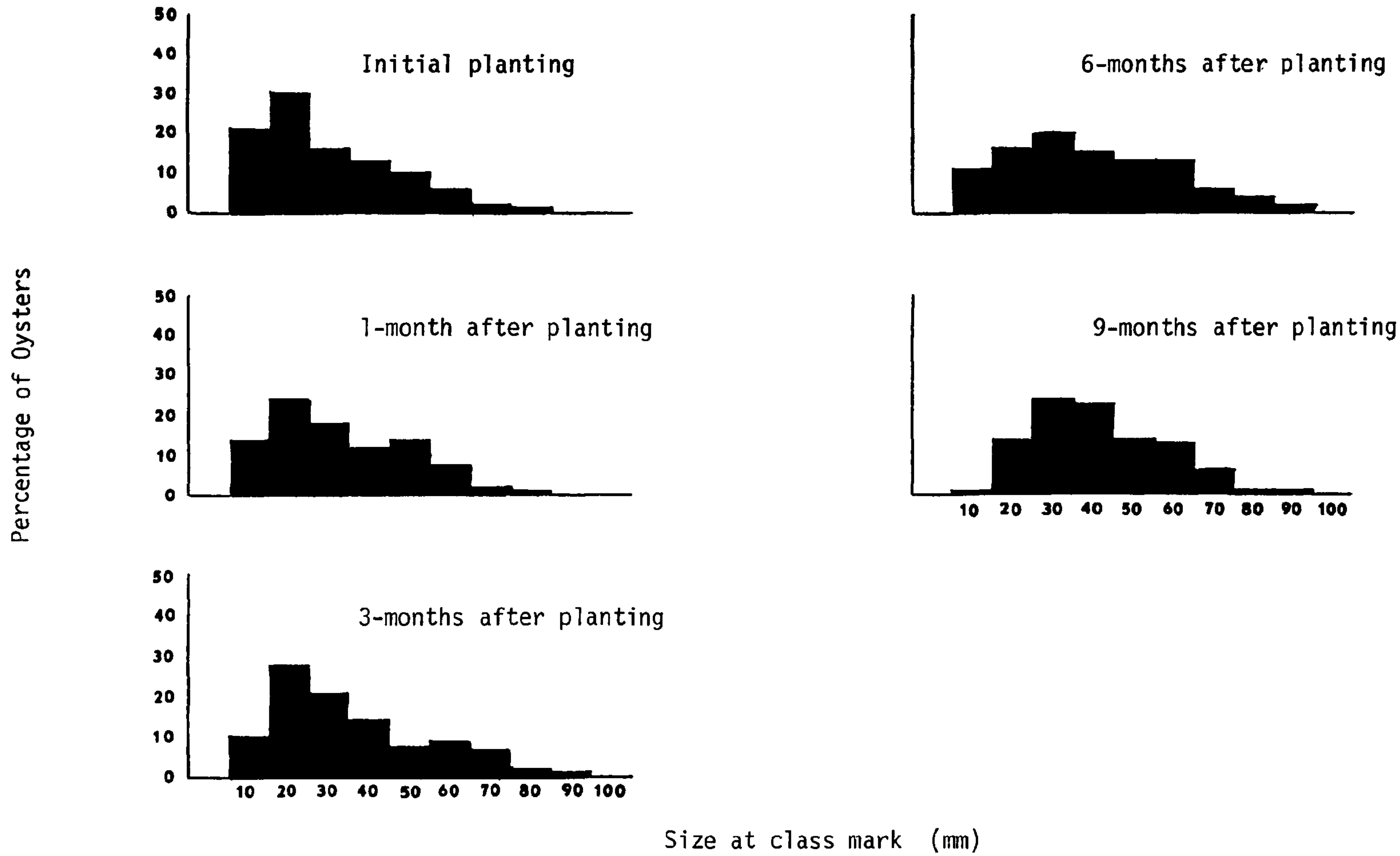

Figure 33. Size distribution of planted subtidal seed oysters during monitoring period, Gibbs Creek Shellfish Management area, North Carolina, 1979.

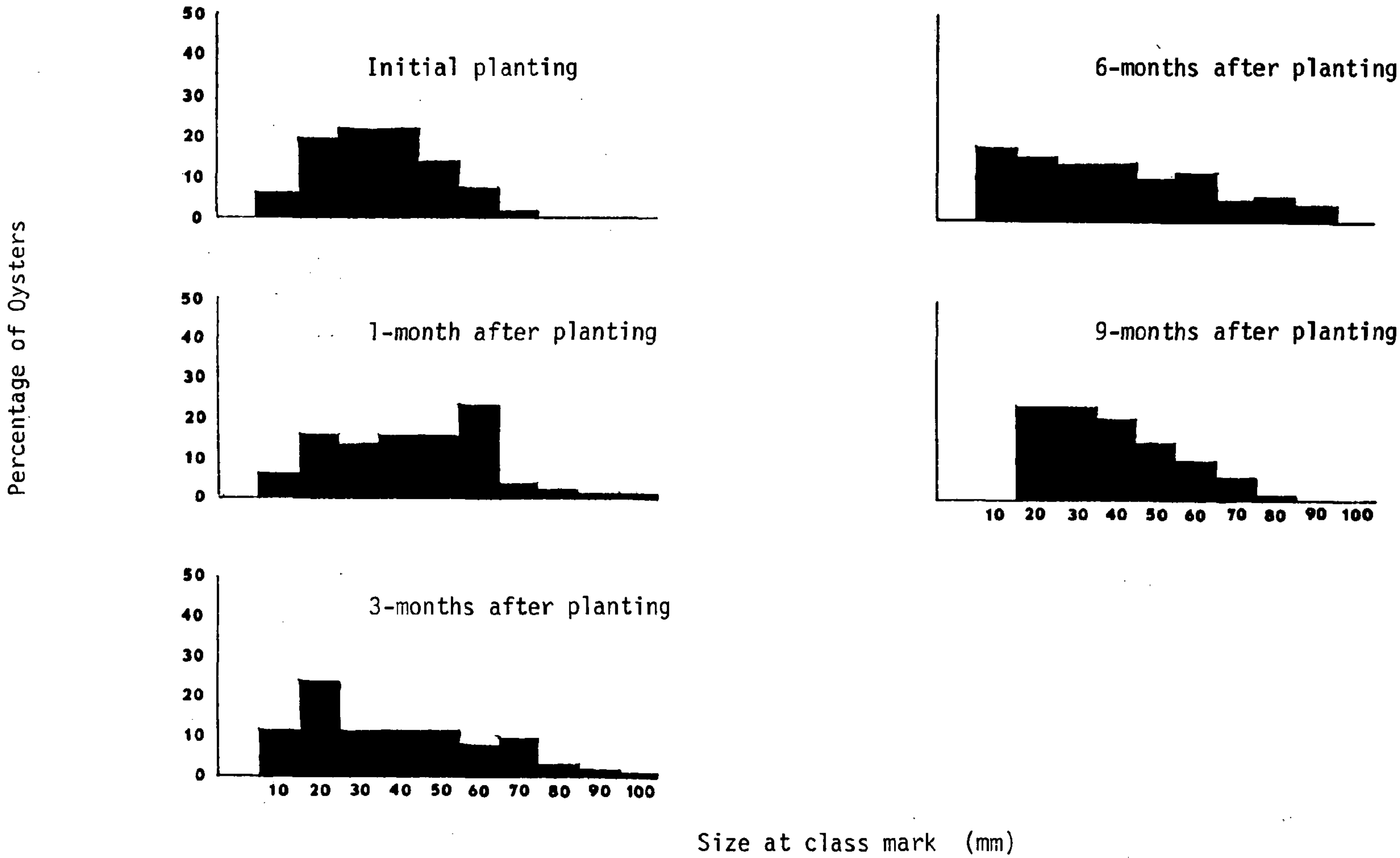

Figure 34. Size distribution of planted intertidal seed oysters during monitoring period, Gibbs Creek Shellfish Management area, North Carolina, 1979.

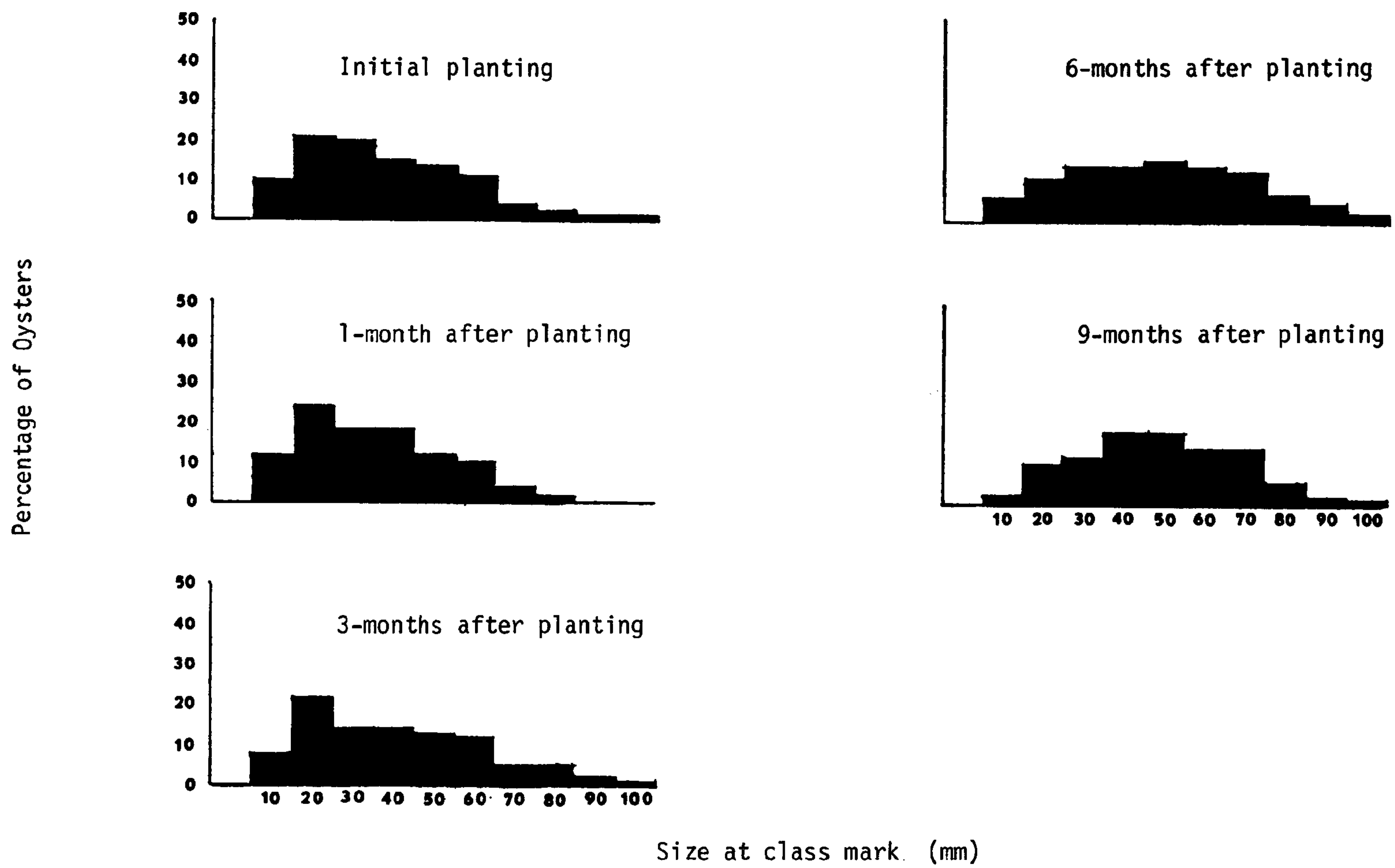

Figure 35. Size distribution of planted intertidal seed oysters during monitoring period, Shallotte River Shellfish Management area, North Carolina, 1979.

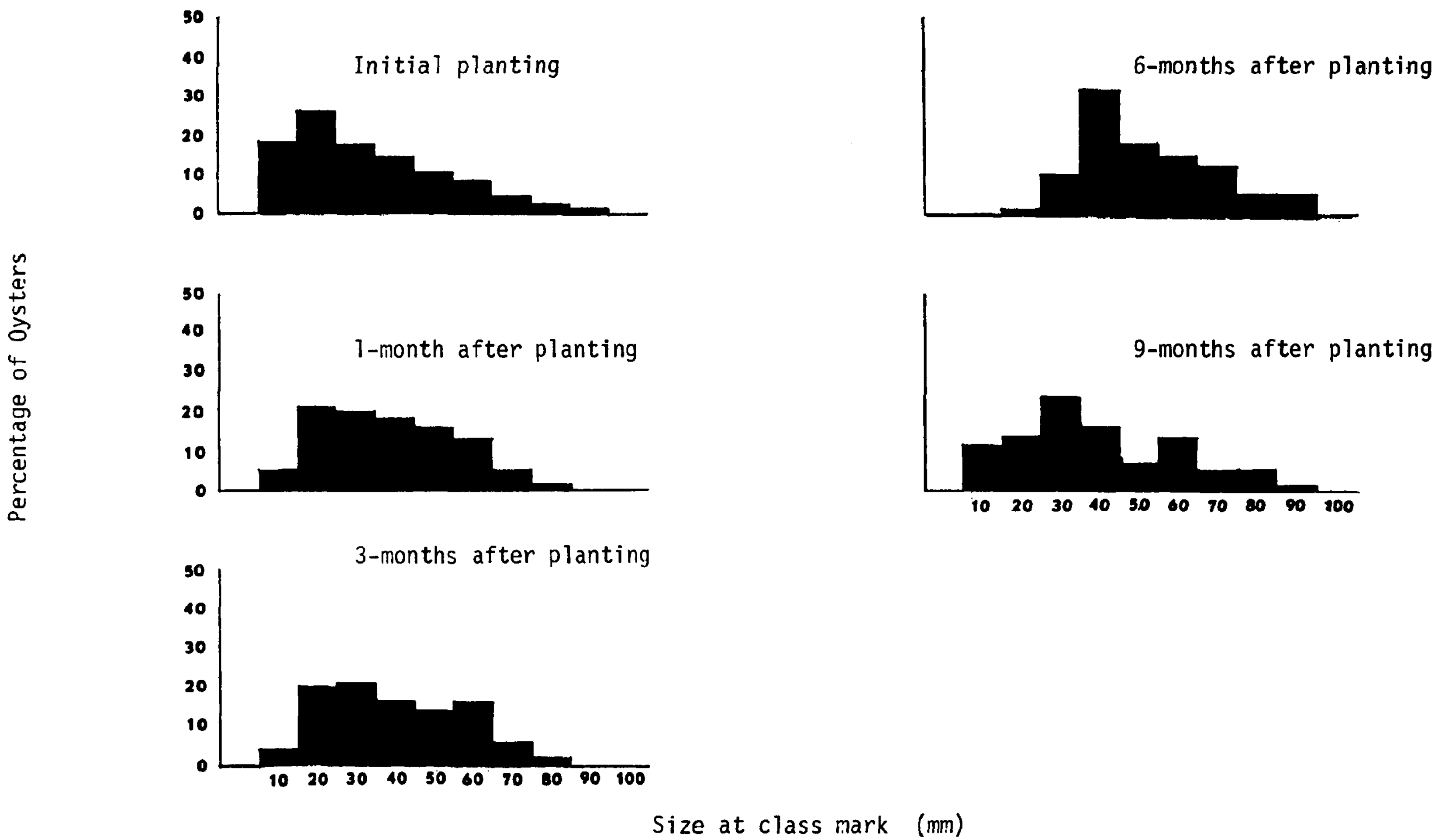

Figure 36. Size distribution of planted subtidal seed oysters during monitoring period, Shallotte River Shellfish Management area, North Carolina, 1979.

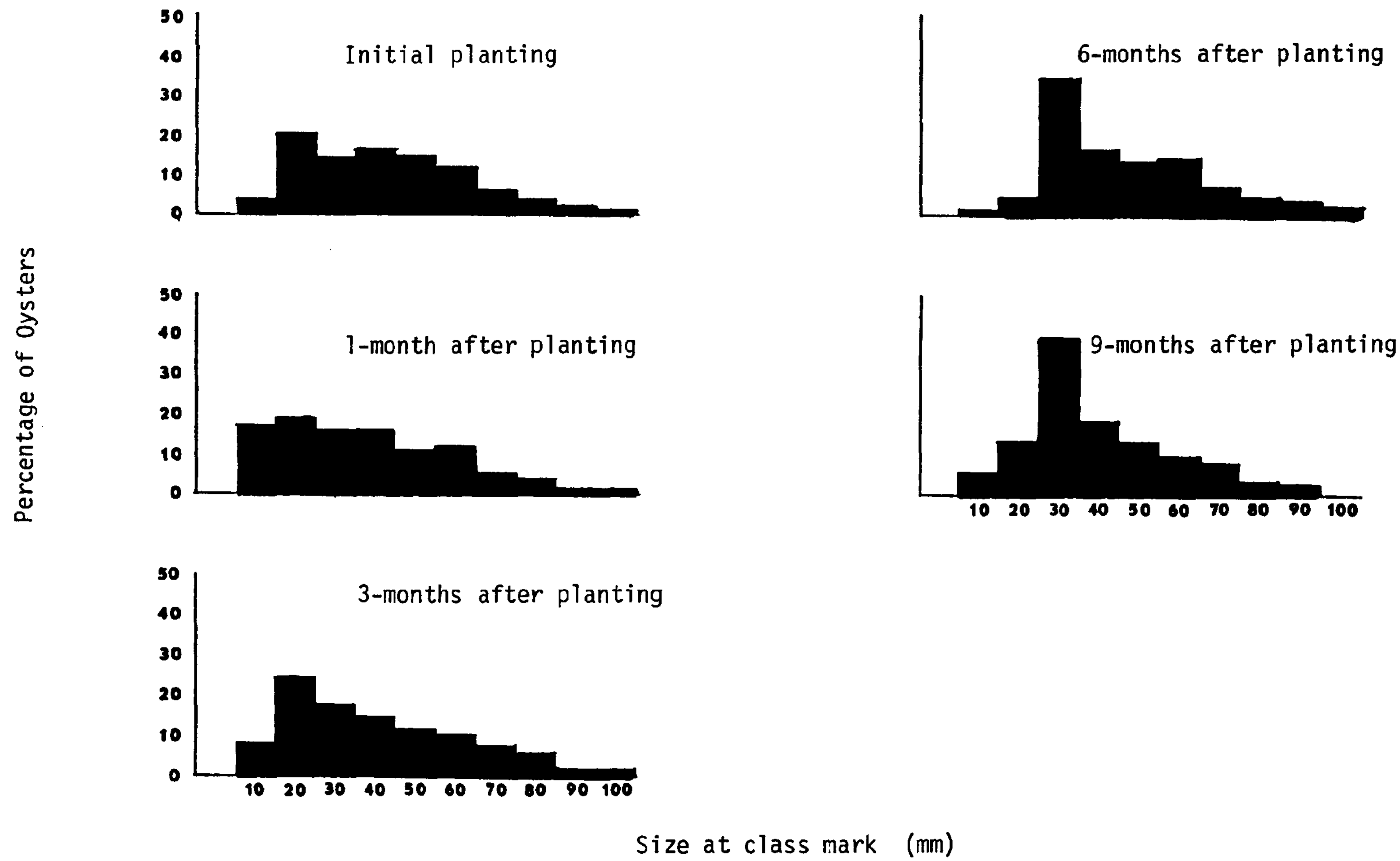

Figure 37. Size distribution of planted intertidal seed oysters during monitoring period, Saucepan Creek Shellfish Management area, North Carolina, 1979.

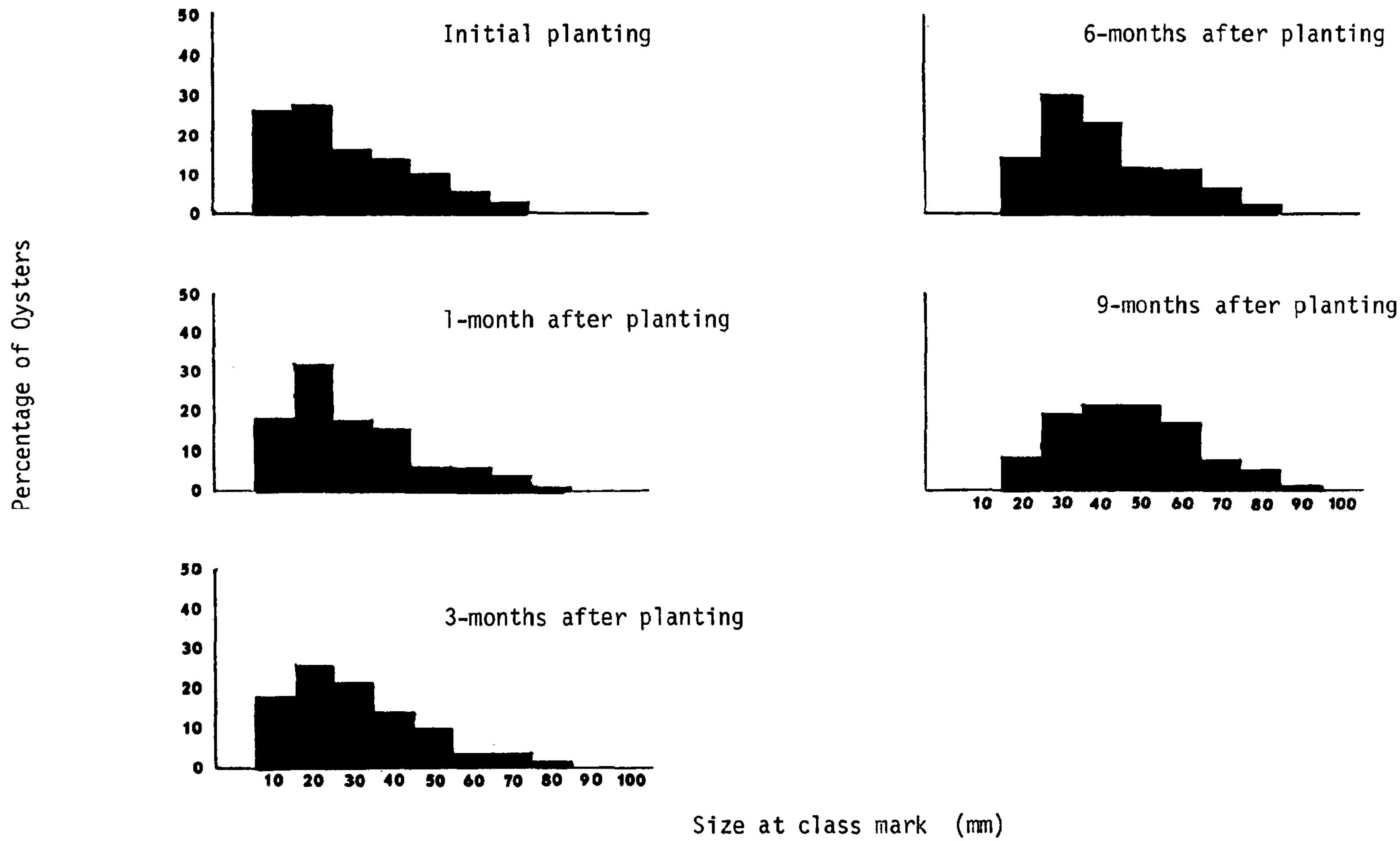

Figure 38. Size distribution of planted subtidal seed oysters during monitoring period, Saucepan Creek Shellfish Management area, North Carolina, 1979.

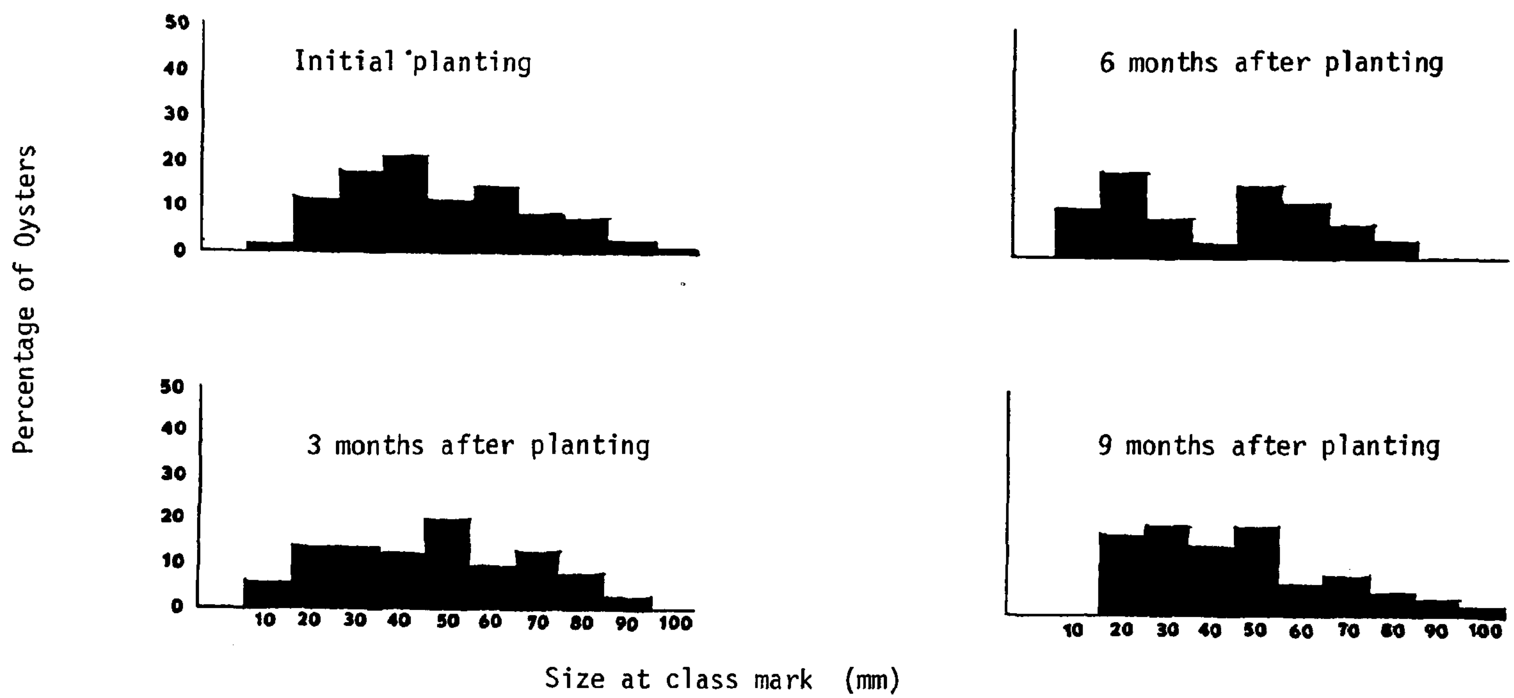

Figure 39. Size distribution of planted intertidal seed oysters during monitoring period, Masons Channel Shellfish Management area, North Carolina, 1979.

intertidal plantings received spat sets which contributed to the total productivity of the site. Densities of intertidal plantings often exceeded 4,000 hl per ha within nine months of planting as a result of growth and recruitment of new spat.

The overall monitoring results were very encouraging. Both subtidal and intertidal seed oyster transplants exhibited relaying mortalities much below the normal annual natural mortality of oyster stocks in these areas. The higher transplant mortality of New Hanover County intertidal oysters was a result of the relatively poor quality of seed oyster stocks in that area. The most significant mortality encountered during the monitoring period resulted from culling activities of commercial harvesting.

The growth rate of both subtidal and intertidal seed oysters was excellent and many of the transplanted seed oysters were harvested within three months of planting. Subtidal oysters grew slightly less in shell length but increased more in volume than intertidal oysters. The growth rate in 1979 was somewhat less than in 1978.

Most transplants received spat sets which increased stock density. Overall productivity of the plantings was excellent and was often almost double the initial planting rate. The large increases in stock density were a result of seed oyster growth and recruitment of new spat. Most plantings produced about 1.5 hl of harvestable oysters for each hl of seed planted.

From these results it appears that relaying of both subtidal and intertidal seed oysters can be accomplished with the mechanical harvester, and that seed oysters transplanted into good growing areas will produce significant harvestable oyster crops within a short time period. The benefit/cost ratio of this activity appears very favorable and, if conducted on an adequate scale, could serve to reverse the trend in the oyster fishery of the southern coastal region of North Carolina. Application of this activity to other suitable areas should also produce similar results.

The results of monitoring of the mechanical oyster harvester efficiency and effects on three oyster concentrations are shown in Table 20. The mean density on the test oyster concentrations was reduced by 90 - 92%, and standing crops were reduced by 87 - 92% as a result of mechanical harvesting. Only one test area showed an increase in mortality after harvesting. This was a result

Table 20 - Results of monitoring of seed oyster harvester efficiency, North Carolina, 1978-79

Area	Time period	Estimated mean oyster density ($1/m^2$)	Average mortality (percent)	Dead shell component in samples (percent)	Estimated standing crop (hl)	Calculated range of standing crop at 95% confidence limits (hl)
Shallotte River rock #33	Before harvesting	65.80	10	12	274	257-291
	After harvesting	7.67	20	75	28	23- 36
Shallotte River rock #70	Before harvesting	62.72	17	11	644	608-677
	After harvesting	4.81	12	78	52	33- 71
Bradley Creek rock #8	Before harvesting	22.90	4	36	408	313-507
	After harvesting	1.93	4	80	56	37- 82

of inexperience in operation of the equipment and concentrated effort in a small area. The dead shell component in samples was increased by a magnitude of six to ten times as a result of mechanical harvesting.

These results show clearly that the mechanical harvester is extremely efficient and does not result in significant mortality of oyster stocks remaining after harvesting once some experience is gained by the operator. The harvest consisted mostly of live oysters, and the harvester does not remove the shell matrix of oyster rocks when operated properly. Later observation of test areas showed that the harvesting operation resulted in the exposure of clean shell material which is capable of supporting significant spat sets.

ACKNOWLEDGEMENTS

Appreciation is expressed to Mr. Dexter Haven of the Virginia Institute of Marine Science for allowing project personnel to photograph and take measurements from the prototype mechanical oyster harvester. Many Division of Marine Fisheries personnel provided assistance on this project. Thanks are due Marine Biologist Alice S. Brown for assistance in field surveys, vessel operations, statistical design, data analysis, and photographic documentation. Fisheries Technician James C. Falconer, Jr., prepared engineering drawings and design specifications for the mechanical oyster harvester, assisted in the long, hard hours of field surveys and vessel operations, and assisted in the engineering of the hydraulic system and vessel rigging. Fisheries Technician Jack A. Hunter designed and constructed the pontoon-hull planting barge, assisted in field surveys and vessel operations, and assisted in the engineering of the hydraulic system and vessel rigging. Fisheries Technician Joseph F. Kimel and Technician Assistant Steve Delaney assisted in field surveys and vessel operations. Without the dedication and technical expertise of these staff members, completion of this project would not have been possible. Marine Laboratory Technician Martha E. Griffin completed laboratory processing of the many hundreds of samples taken during the project. Margaret R. Stafford spent many hours typing the manuscript. Fisheries Management Section Chief Michael W. Street reviewed the manuscript and provided helpful suggestions.

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A P P E N D I X

Appendix Table 1 - Record of seed oyster relaying activity, Brunswick County, North Carolina, 1978 (Individual harvesting sites are shown in Figure 10, planting sites are shown in Figures 17 and 19.)

Date	Harvesting area	Harvesting time (min)	Planting area	Oysters relocated (hl)
4/07/78	Shallotte River Rock #10	90	Shallotte River #6	88*
4/10/78	Shallotte River Rocks #6, #9	60	Shallotte River #6	35*
4/12/78	Shallotte River Channel	150	Shallotte River #1	211+
4/14/78	Shallotte River Channel	90	Shallotte River #1	176+
4/17/78	Shallotte River Channel	60	Shallotte River #4	123+
4/18/78	Shallotte River Channel	120	Shallotte River #4	106+
4/20/78	Shallotte River Channel	60	Boones Island #2	141+
4/22/78	Shallotte River Channel	90	Boones Island #2	123+
4/25/78	Shallotte River Rock #3	90	Boones Island #1	88*
4/27/78	Shallotte River Channel	120	Shallotte River #4	106+
5/01/78	Shallotte River Channel	45	Shallotte River #3	35+
5/01/78	Shallotte River Rock #33	105	Shallotte River #2	194*
5/02/78	Shallotte River Rock #70	30	Shallotte River #5	44*
5/08/78	Shallotte River Rock #70	80	Shallotte River #5	194*
5/10/78	Shallotte River Rock #70	120	Boones Island #3	183*
12/14/78	Shallotte River Rock #35	60	Shallotte River #5 (1979)	88*
12/14/78	Shallotte River Channel	45	Shallotte River #1	88+

Appendix Table 1 (continued)

12/15/78	Shallotte River Rock #35	90	Shallotte River #3 (1979)	158*
12/22/78	Shallotte River Channel	180	Shallotte River #1 (1979)	194+
		1,685		2,375

*Intertidal seed oysters
+Subtidal seed oysters

Appendix Table 2 - Record of seed oyster relaying activity, New Hanover County, North Carolina, 1978. (Individual harvesting sites are shown in Figures 12 and 13, planting sites are shown in Figures 19 and 20.)

Date	Harvesting area	Harvesting time (min)	Planting area	Oysters relocated (hl)
11/01/78	Bradley Creek Rock #8	75	Wrightsville Beach Marshes #3	44
11/03/78	Bradley Creek Rock #8	75	Wrightsville Beach Marshes #3	79
11/06/78	Bradley Creek Rock #8	70	Wrightsville Beach Marshes #2	124
11/07/78	Bradley Creek Rock #8	60	Wrightsville Beach Marshes #3	70
11/08/78	Bradley Creek Rock #8	80	Wrightsville Beach Marshes #3	85
11/09/78	Bradley Creek Rock #6	100	Wrightsville Beach Marshes #3	70
11/10/78	Bradley Creek Rock #37	120	Wrightsville Beach Marshes #1	106
11/15/78	Bradley Creek Rock #42	135	Wrightsville Beach Marshes #4	70
11/16/78	Whiskey Creek Rock #6	105	Masonboro Sound #1	176
11/17/78	Whiskey Creek Rock #6	105	Masonboro Sound #1	194
12/06/78	Whiskey Creek Rock #8	90	Masonboro Sound #2	141
12/07/78	Whiskey Creek Rock #2	90	Masonboro Sound #1	106
12/08/78	Whiskey Creek Rock #8	70	Masonboro Sound #3	106
	TOTAL	1,175		1,371

Appendix Table 3 - Record of seed oyster relaying activity, Brunswick County, North Carolina, 1979, (Individual harvesting sites are shown in Figures 10 and 23, planting sites are shown in Figures 18, 21, 22, and 23.)

Date	Harvesting area	Harvesting time (min)	Planting area	Oysters relocated (hl)
1/03/79	Shallotte River Channel	90	Shallotte River #1	71+
1/03/79	Shallotte River Rock #35	90	Shallotte River #6	71*
1/03/79	Shallotte River Channel	120	Shallotte River #1	125+
1/05/79	Shallotte River Rock #35	180	Shallotte River #7	194*
1/10/79	Shallotte River Channel	45	Shallotte River #1	71+
1/12/79	Shallotte River Channel	180	Shallotte River #8	176+
1/15/79	Shallotte River Rock #35	150	Shallotte River #2	176*
1/16/79	Shallotte River Rock #33	120	Shallotte River #4	176*
1/16/79	Shallotte River Channel	75	Shallotte River #8	213+
1/17/79	Shallotte River Channel	90	Saucepan Creek #4	176+
1/17/79	Shallotte River Channel	90	Shallotte River #8	176+
1/18/79	Shallotte River Channel	90	Saucepan Creek #2	176+
1/18/79	Shallotte River Channel	105	Shallotte River #8	176+
1/19/79	Shallotte River Channel	120	Shallotte River #8	176+
1/22/79	Shallotte River Channel	120	Lockwoods Folly River #1	176+
1/23/79	Shallotte River Channel	150	Lockwoods Folly River #1	194+
1/26/79	Shallotte River Channel	150	Shallotte River #1	176+

Appendix Table 3 (continued)

1/29/79	Shallotte River Rock #35	120	Saucepan Creek #1	176*
1/29/79	Shallotte River Channel	120	Shallotte River #1	107+
1/31/79	Shallotte River Rock #35	90	Saucepan Creek #3	176*
2/02/79	Shallotte River Channel	180	Shallotte River #8	176+
2/06/79	Shallotte River Channel	90	Lockwoods Folly River #1	142+
2/22/79	Shallotte River Channel	120	Lockwoods Folly River #2	194+
2/23/79	Shallotte River Channel	50	Sol's Creek #1	194+
2/26/79	Shallotte River Rock #35	60	Shallotte River #5	176*
2/27/79	Shallotte River Rock #35	90	Saucepan Creek #3	176*
2/27/79	Shallotte River Channel	15	Shallotte River #1	20+
3/01/79	Shallotte River Rock #36	60	Saucepan Creek #3	176*
3/01/79	Shallotte River Channel	90	Shallotte River #10	176+
3/02/79	Shallotte River Rock #36	45	Saucepan Creek #3	88*
3/02/79	Shallotte River Channel	45	Saucepan Creek #3	88+
3/02/79	Shallotte River Channel	150	Shallotte River #10	176+
3/05/79	Shallotte River Channel	90	Shallotte River #10	176+
3/07/79	Shallotte River Channel	90	Lockwoods Folly River #2	176+
3/09/79	Shallotte River Channel	90	Sol's Creek #1	176+
3/12/79	Shallotte River Channel	90	Shallotte River #10	176+
3/13/79	Shallotte River Channel	180	Shallotte River #9	352+

Appendix Table 3 - (continued)

3/14/79	Shallotte River Rock #70	70	Shallotte River #9	176*
3/19/79	Shallotte River Channel	90	Sol's Creek #1	176+
3/20/79	Shallotte River Channel	90	Eastern Channel #1	176+
3/27/79	Shallotte River Rock #70	15	Shallotte River #1	36*
3/28/79	Shallotte River Rock #70	90	Eastern Channel #1	176*
3/30/79	Shallotte River Rock #70	15	Shallotte River #9	36*
4/02/79	Shallotte River Channel	120	Shallotte River #1	176+
4/04/79	Lockwoods Folly River Channel	90	Lockwoods Folly River #2	107+
4/05/79	Lockwoods Folly River Channel	90	Lockwoods Folly River #2	176+
4/10/79	Lockwoods Folly River Channel	30	Lockwoods Folly River #2	36+
4/11/79	Lockwoods Folly River Channel	120	Lockwoods Folly River #2	107+
	TOTAL	4,650		7,374

*Intertidal seed oysters
+Subtidal seed oysters

Appendix Table 4 - Record of seed oyster relaying activity, New Hanover County, North Carolina, 1979, (Individual harvesting sites are shown in Figure 14, planting site shown in Figure 24.)

Date	Harvesting area	Harvesting time (min)	Planting area	Oysters relocated (hl)
4/17/79	Pages Creek Rock #31	120	Masons Channel #1	106
4/24/79	Pages Creek Rock #32	75	Masons Channel #1	106
4/25/79	Pages Creek Rock #30	75	Masons Channel #1	176
4/27/79	Pages Creek Rock #31	60	Masons Channel #1	106
	TOTAL	330		494

CONVEYOR TECHNICAL ABSTRACT

The mechanical seed oyster harvester is designed to accept an 18-inch wide conveyor chain only.

The specific length of the conveyor is determined by maximum water depth to be worked. An excessive conveyor angle will reduce harvesting efficiency. A ratio of conveyor length to water depth of 3:1 with the back end of the conveyor suspended approximately eight feet above the water surface is recommended as the minimum working length.

In order to prevent abrasion to the conveyor chain it is suggested that angle iron slides 1" x 1" x 1/8", three inches in length, be installed on each side of the front box of the conveyor, one inch above the conveyor chain. The slides should be installed at an angle to coincide with the upward movement of the hinged throat plate as it pivots on the conveyor. This modification will prevent conveyor chain wear when working varying water depths

A technical drawing of the conveyor follows.

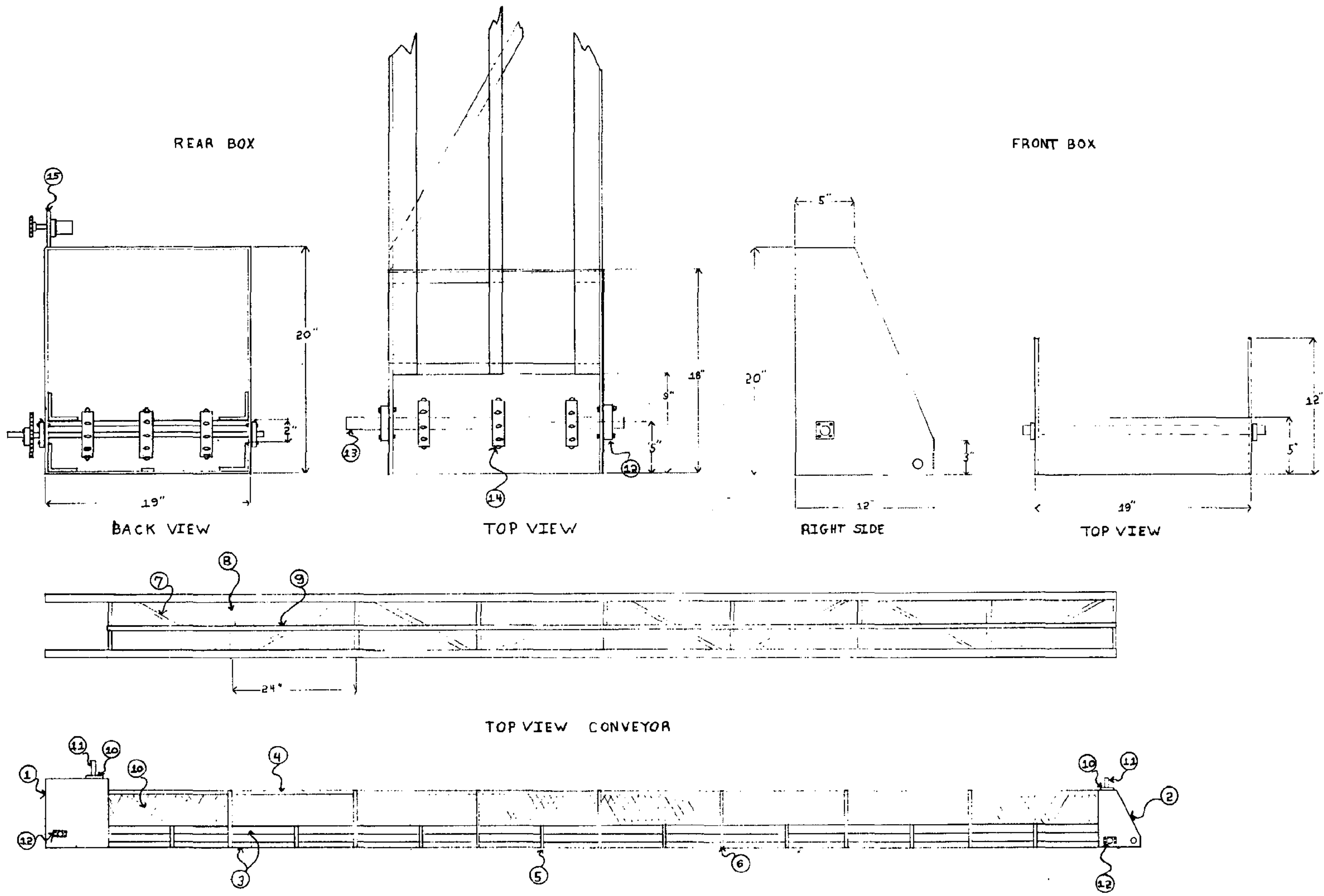


FIGURE 1 - CONVEYOR DESIGN

Bill of materials
for conveyor

Item #	No. of pieces	Material required	Length
1	2	18" x 20" x ¼" PL*	
	2	18" x 19" x ¼" PL	
2	2	20" x 12" x ¼" PL	
	1	12" x 5" x ¼" PL	
3	4	2½" x 2½" x ¼" L**	See note ++
4	2	1" x 1" x 3/16" FB+	See note
5	16	1" x 3/16" FB	7"
6	14	1" x 3/16" FB	17"
7	16	1" x 1" x 3/16" L	36"
8	18	1" x 1" x 3/16" L	18½"
9	1	1" x 3/16" FB	See note
10	2	6" x 3" x 3/4" PL	
11	2	6" x 4" x 3/4" PL	
12	4	#Fafnir RCJ 1" Flange Block	
13	2	Shaft 1" dia.	25"
14	6	LaPort Mat Belt 4CTL13H Sprocket Bushing 2517 1"	
15	1	6" x 4" x ½" PL	
16	2	10" x 3/16" Expanded Metal	See note

*PL - Plate

** L - Angle

+FB - Flat Bar

++Note - Length is same as conveyor length

#Use of brand names does not imply endorsement by the Division of Marine Fisheries

SEED OYSTER HARVESTER
TECHNICAL ABSTRACT

Technical drawings of the seed oyster harvester (Figures 2-14) follow this technical abstract.

Right and left sides of the box (Figure 2, item 18) are identical except that a 2½ inch king nipple is installed on the left side for the water chamber intake (Figure 11).

All bolts are 3/8" NC except for two 1" bolts used at the rear of the sleds (Figure 13), those supplied with the P1 bushings for the Everflex Couplings (item 14), and those used for sprockets (item 23).

Care must be taken in assembly of the tine and spacer plates (Figure 3, items 7 and 8) to the hub (Figure 4) to insure correct alignment of both bolt holes and tine rods. Guide holes and pins may be added at the time of fabrication, if desired.

The tines should be cut initially to 6 inches from the center of the loop to the working tip. The working tips can then be trimmed as needed after assembly to clear each other at the closest point of approach.

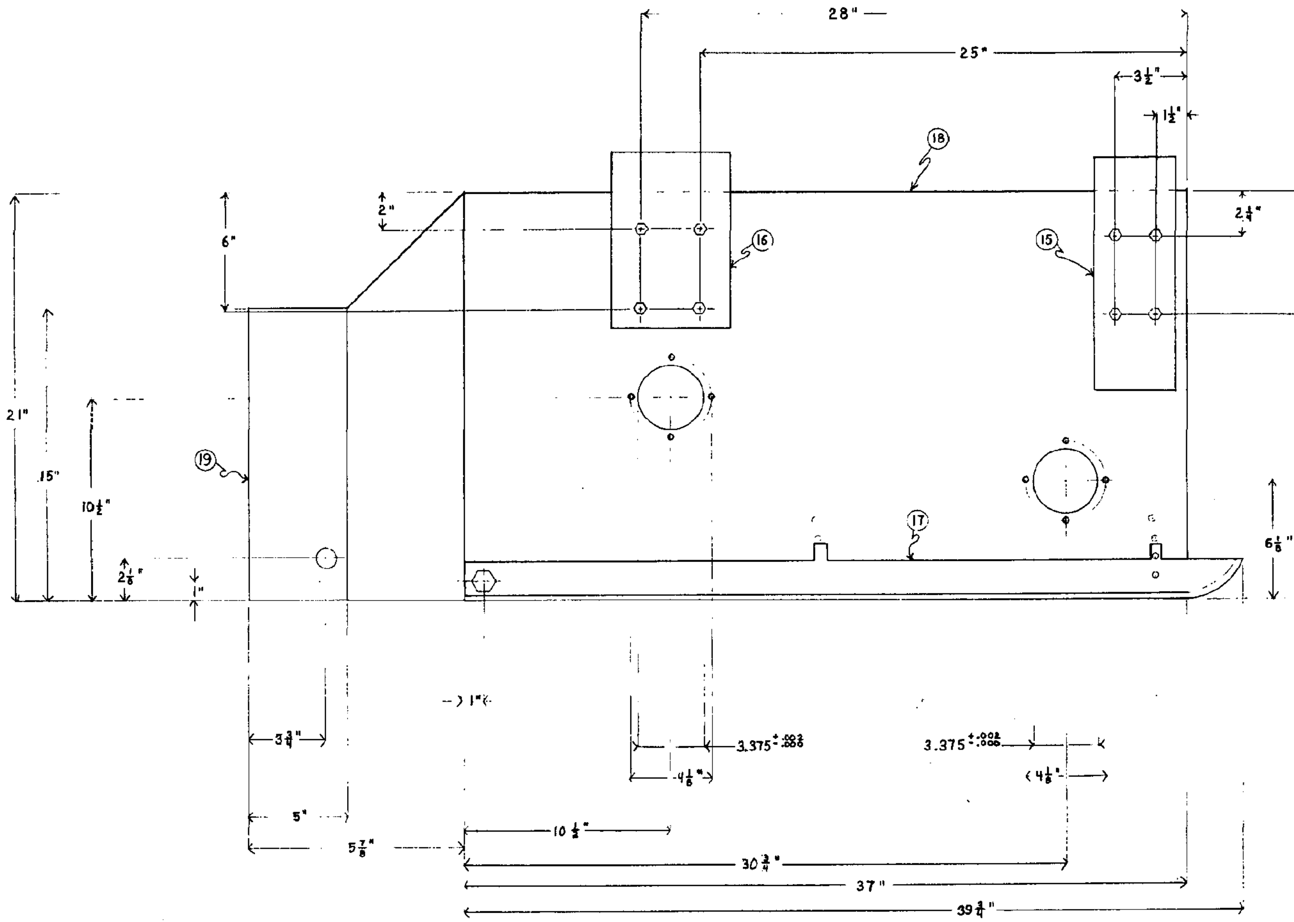
Positioning of the intake (item 29) and nipples (item 28) on Figure 12 are approximate and can be adjusted as necessary for ease in fabrication in the limited working space. The rear water jets (item 26) are positioned to force shell material up the throat plate as shown in Figure 12. Side water jets (item 27) are adjusted so as to clear the rotating tines and force the shell material into the harvester throat.

The leading edge of the throat plate (Figure 11) may be cut back to as little as one inch to facilitate clearance of the tines. Minimum clearance space is desired so as to reduce damage to harvested oysters.

The drive motor assembly (Figure 10) may be installed on either side; however, the drive unit should always be installed on the outboard side of the harvester in order to prevent contact with the harvesting vessel hull.

The required digging depth of the harvester will be determined by bottom type and oyster density. The adjustable sleds shown in Figure 13 may be set at varying angles to regulate tine penetration into the substrate. The harvest may also be regulated by a hydraulic control valve (Hydraulic System Component No. 4) which determines position of the harvester in relationship to the bottom. After some experience the operator will be able to regulate the harvest by varying tine rotation speed and conveyor belt speed using variable control flow dividers (Hydraulic System Components 8 and 9).

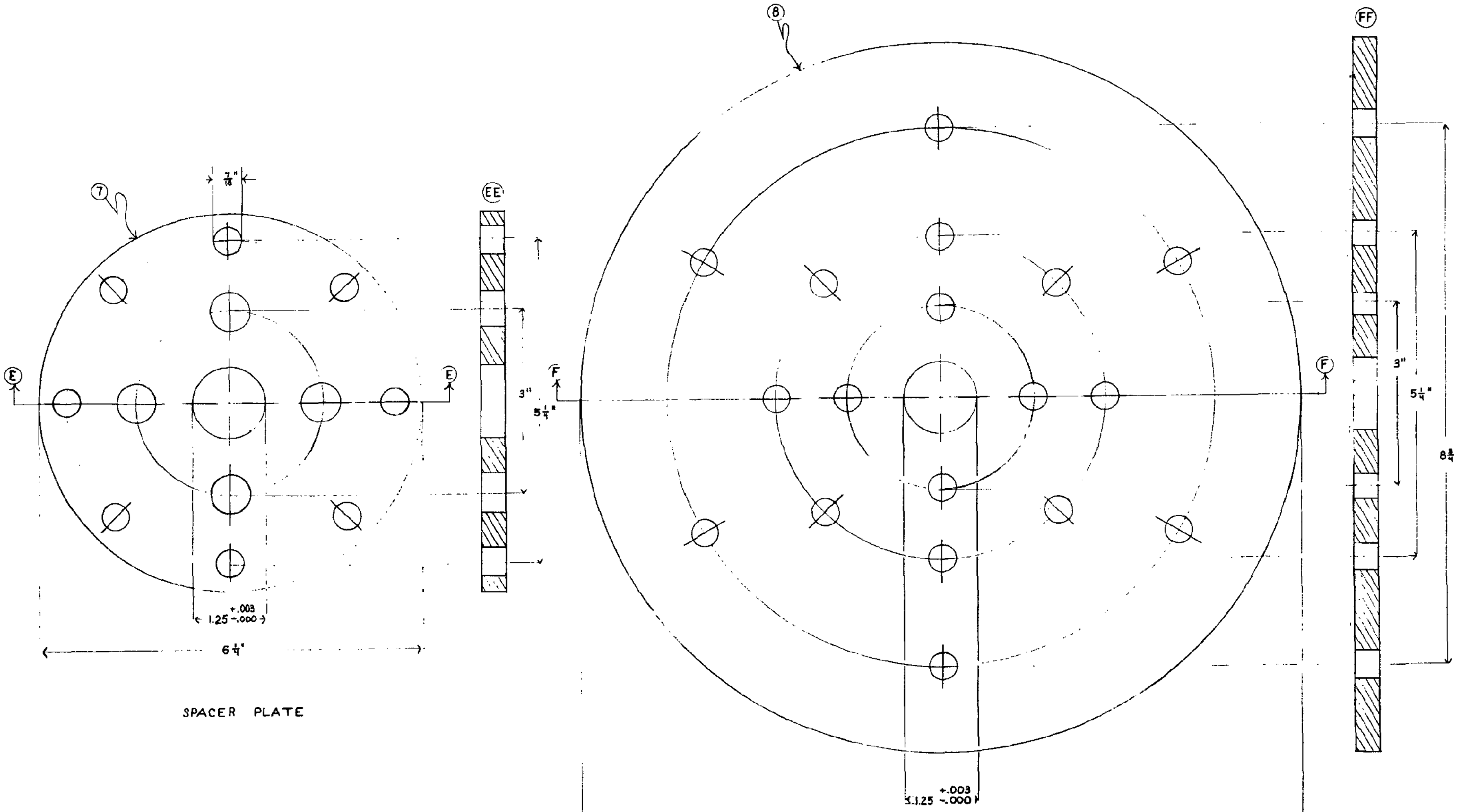
In order to adjust the harvester-to-conveyor angle, an eye is welded to the front brace (Figure 2, item 15) and a length of heavy chain is installed between the eye and lower block by which the harvester is suspended from the lifting boom. Adjustment of this chain length determines the angle of suspension of the front of the harvester and acts as a stop to prevent damage to the harvester in rough bottom conditions.



NOTE: ALL BOLT HOLES DRILLED TO 7/16" UNLESS OTHERWISE SPECIFIED
HOLES IN BOX TO BE 1" APART ON AN ARC TO COINCIDE WITH HOLES IN SLED
HOLES AT REAR OF SLED AND BOX TO ACCOMODATE 1" BOLT

FIGURE 2 - SEED OYSTER HARVESTER, RIGHT SIDE VIEW.

SEED OYSTER HARVESTER	
RIGHT SIDE VIEW	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-1-B
DRAWN BY: James C. Fulmer Jr.	



NOTE: ALL BOLT HOLES DRILLED 7/16"

FIGURE 3 - SEED OYSTER HARVESTER, TINE AND SPACER PLATES.

SEED OYSTER HARVESTER	
TINE & SPACER PLATES	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-2-B
DRAWN BY: [signature]	

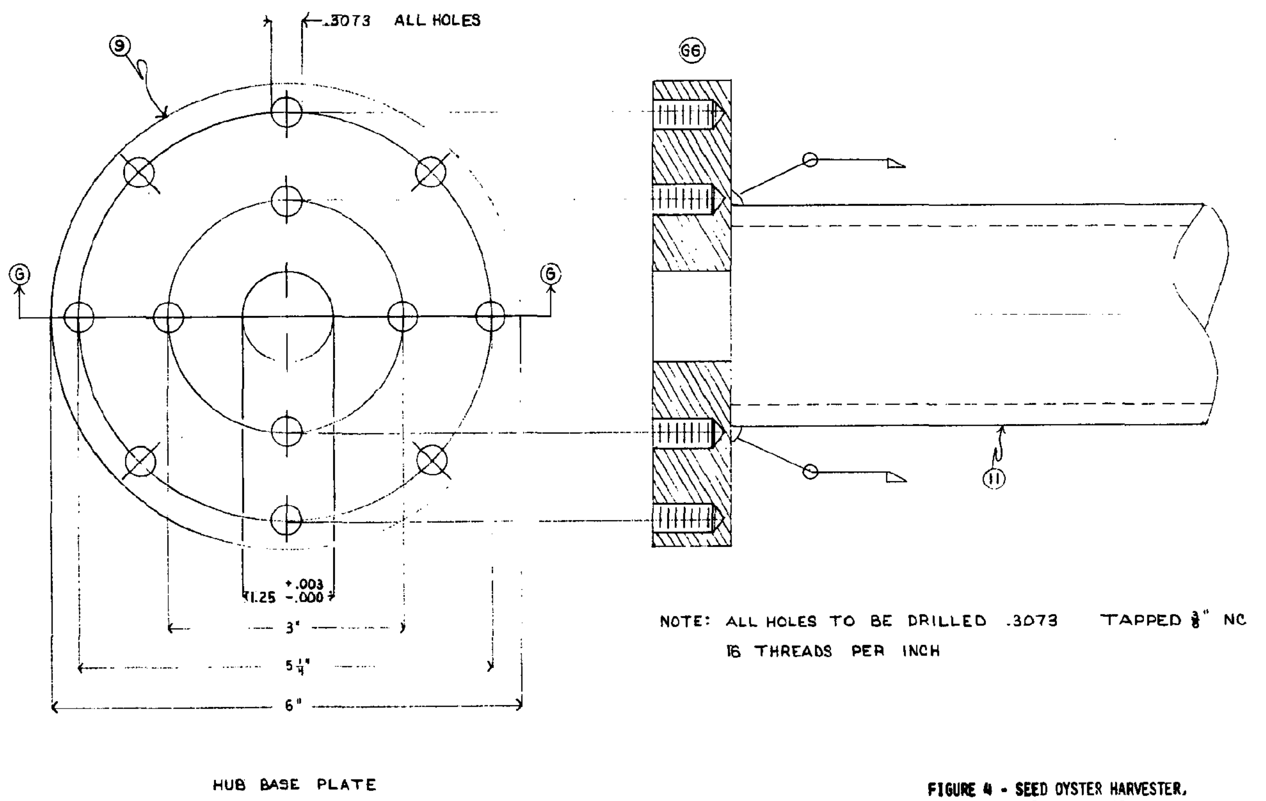
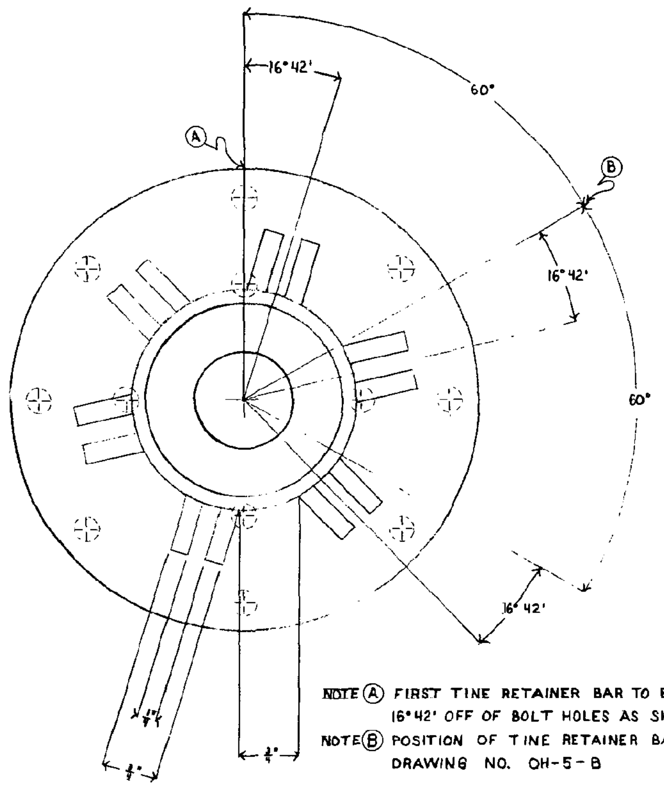


FIGURE 4 - SEED OYSTER HARVESTER,
HUB BASE PLATE.

SEED OYSTER HARVESTER	
HUB BASE PLATE	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-3-B
DRAWN BY: [signature]	

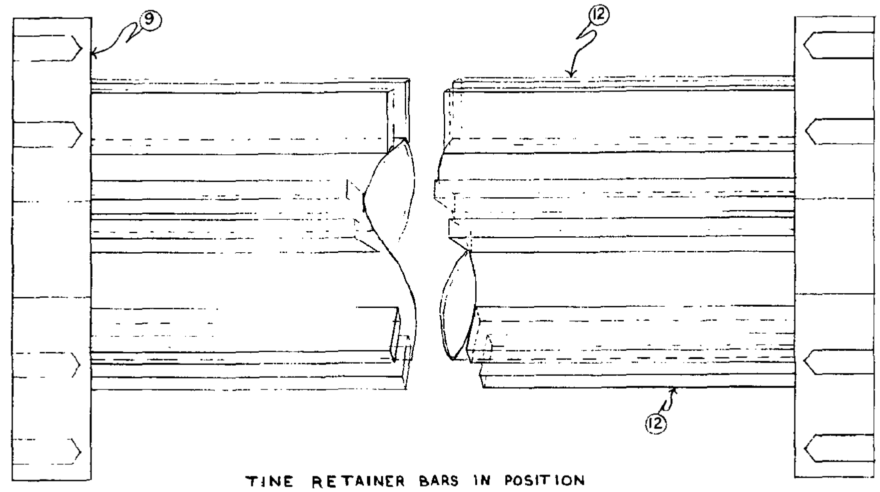


NOTE (A) FIRST TINE RETAINER BAR TO BE POSITIONED 16°42' OFF OF BOLT HOLES AS SHOWN

NOTE (B) POSITION OF TINE RETAINER BAR BC REF. DRAWING NO. OH-5-B

TINE HUB

INSIDE VIEW



TINE RETAINER BARS IN POSITION

FIGURE 5 - SEED OYSTER HARVESTER, TINE RETAINER BARS.

SEED OYSTER HARVESTER	
TINE RETAINER BARS	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-4-B
DRAWN BY: James C. [signature] Jr.	

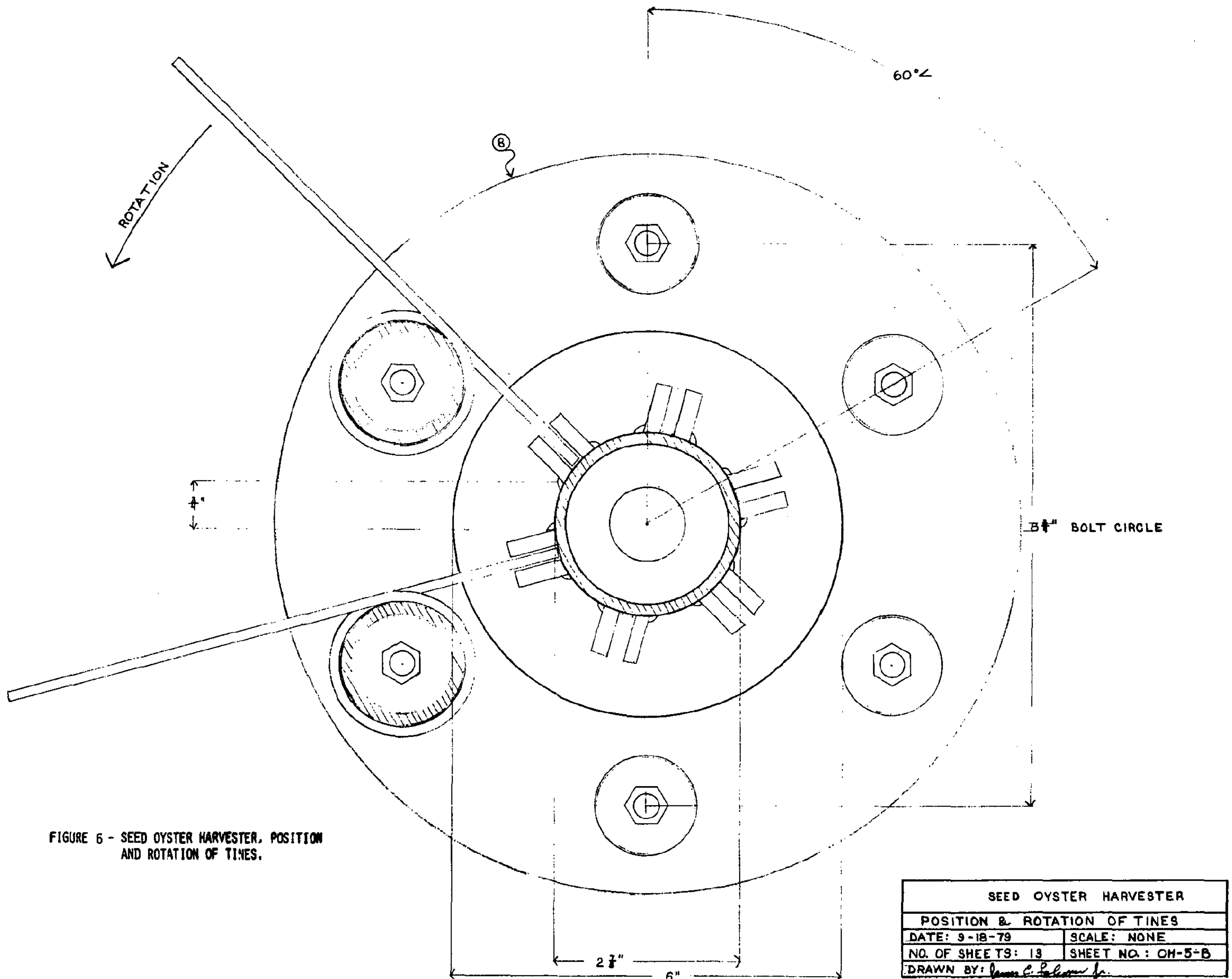


FIGURE 6 - SEED OYSTER HARVESTER, POSITION AND ROTATION OF TINES.

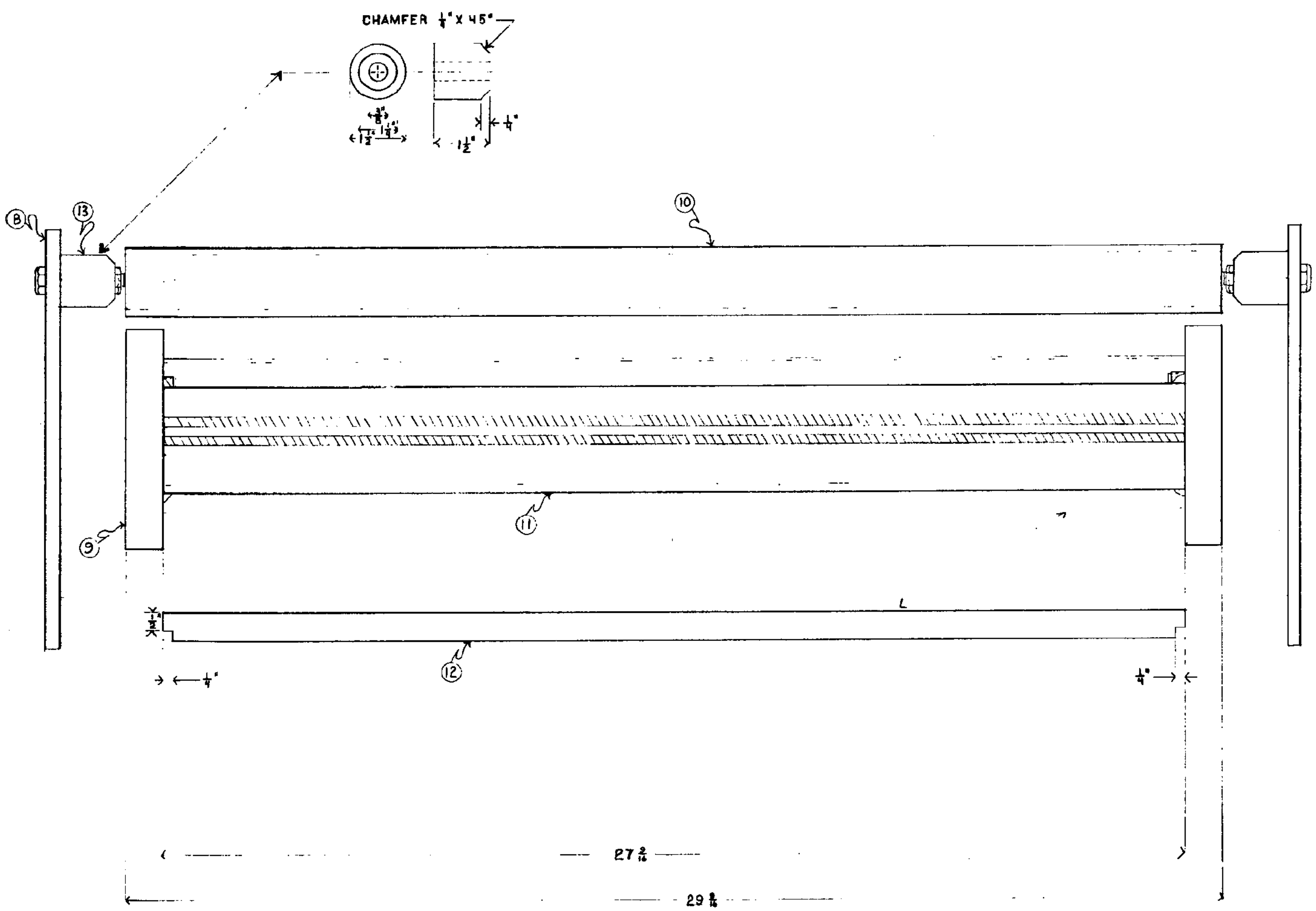


FIGURE 7 - SEED OYSTER HARVESTER, TINE HUB, ROD AND RETAINER ASSEMBLY.

SEED OYSTER HARVESTER	
TINE HUB, ROD, & RETAINER ASSEMBLY	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-6-B
DRAWN BY: James C Falconer Jr.	

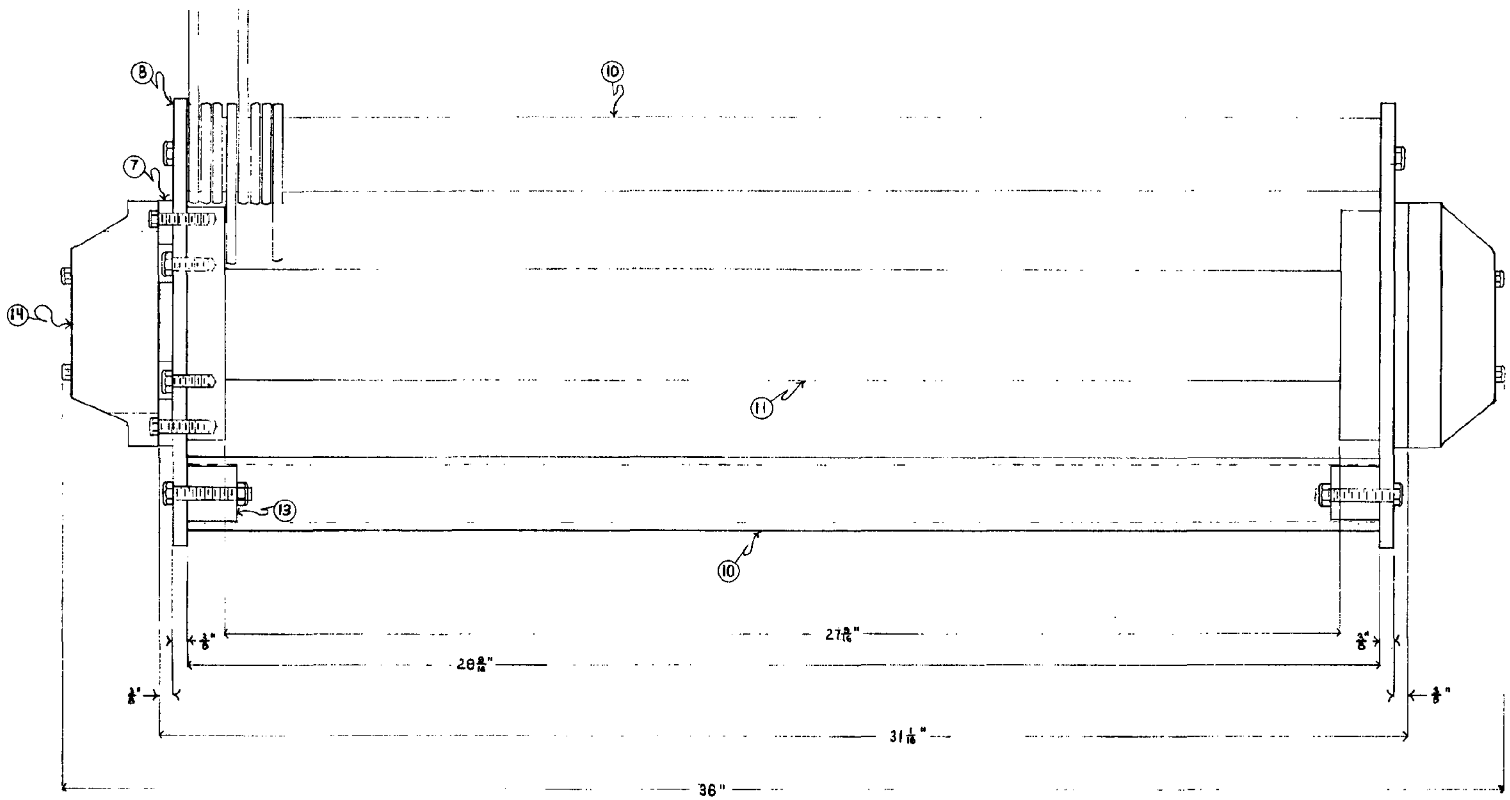


FIGURE 8 - SEED OYSTER HARVESTER, TINE HUB ASSEMBLY WITH COUPLINGS.

SEED OYSTER HARVESTER	
TINE HUB ASSEMBLY WITH COUPLINGS	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-7-8
DRAWN BY: James C. Folsom Jr.	

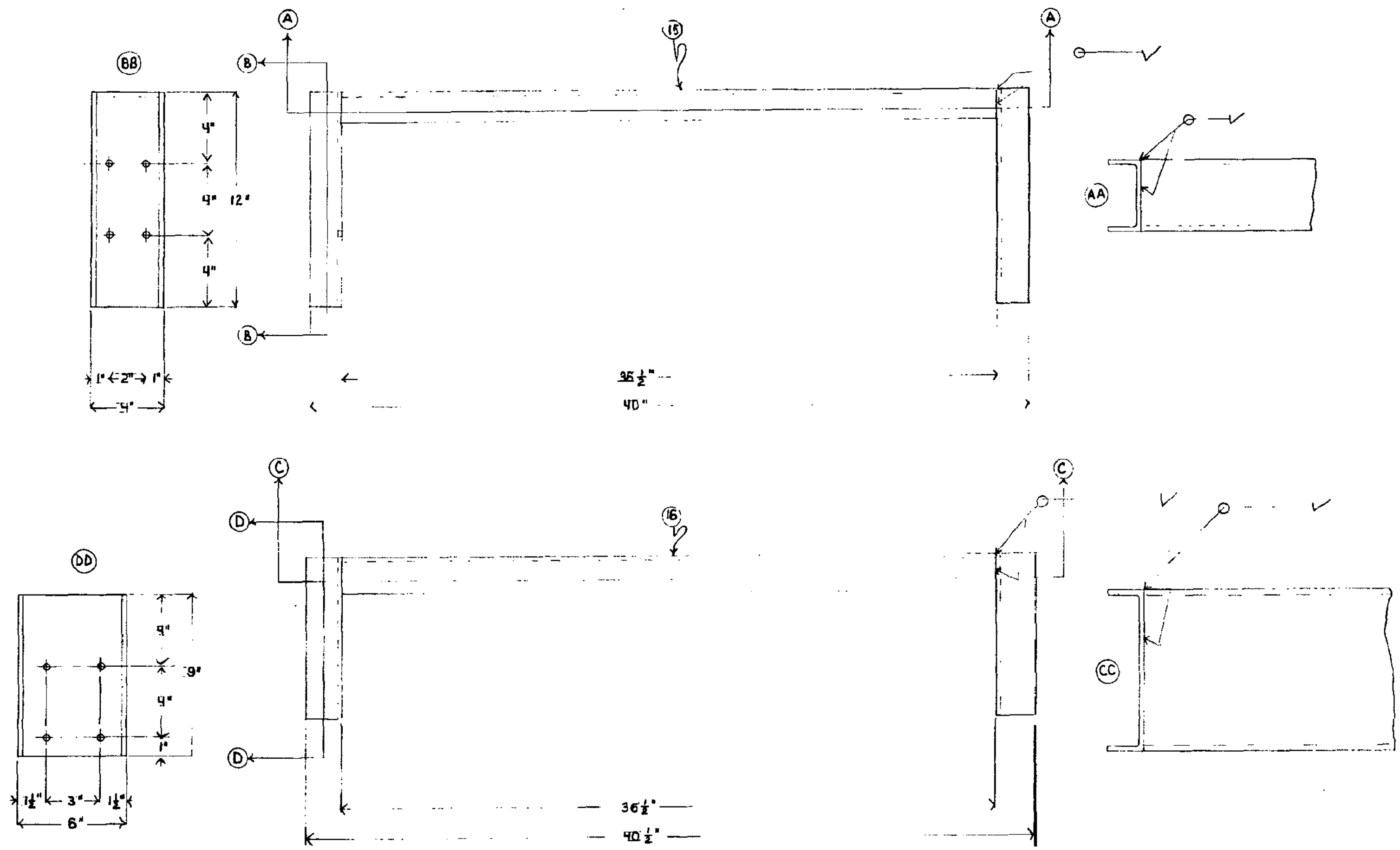


FIGURE 9 - SEED OYSTER HARVESTER, BRACE SUPPORTS.

SEED OYSTER HARVESTER	
BRACE SUPPORTS	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-8-B
DRAWN BY: James C. Falconer Jr.	

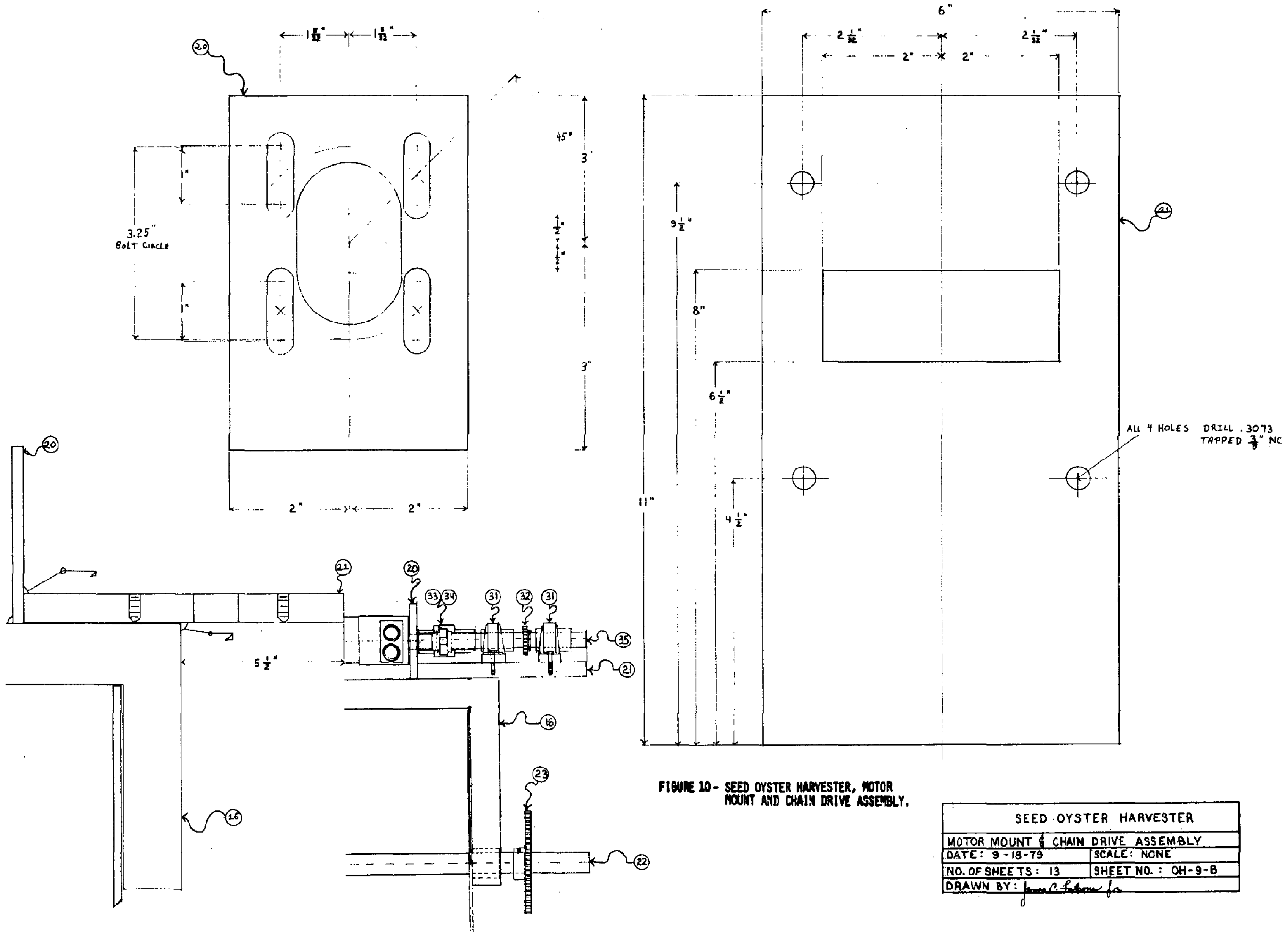
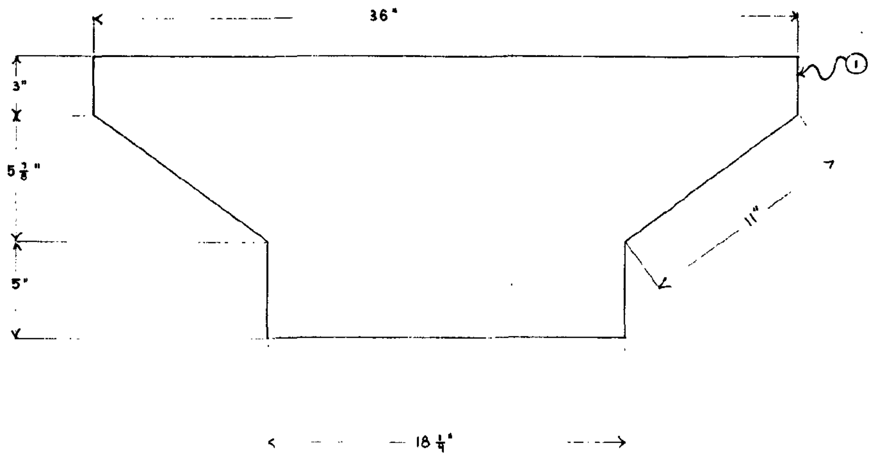
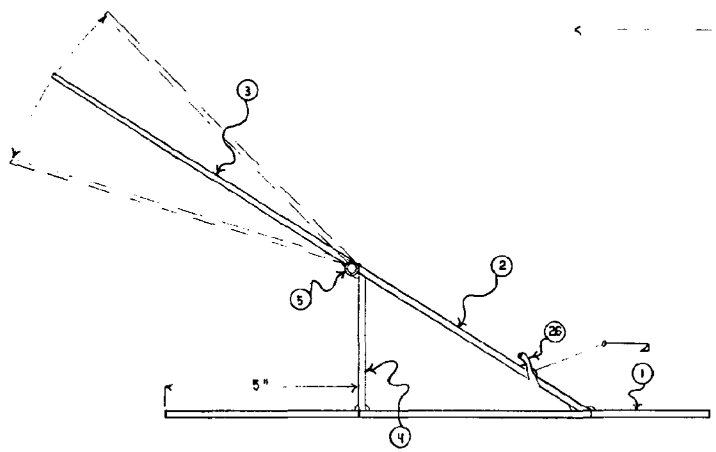
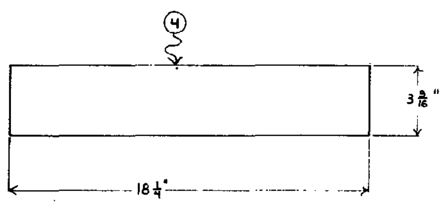


FIGURE 10 - SEED OYSTER HARVESTER, MOTOR MOUNT AND CHAIN DRIVE ASSEMBLY.







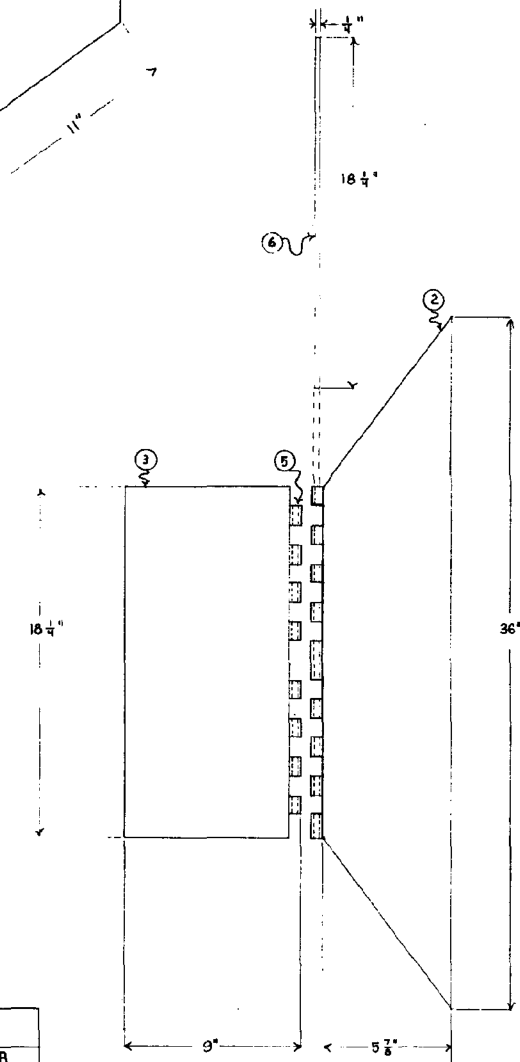


FIGURE 11 -SEED OYSTER HARVESTER, THROAT PLATE AND WATER CHAMBER.

SEED OYSTER HARVESTER	
THROAT PLATE &	WATER CHAMBER
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-10-B
DRAWN BY: James C. Falconer Jr.	

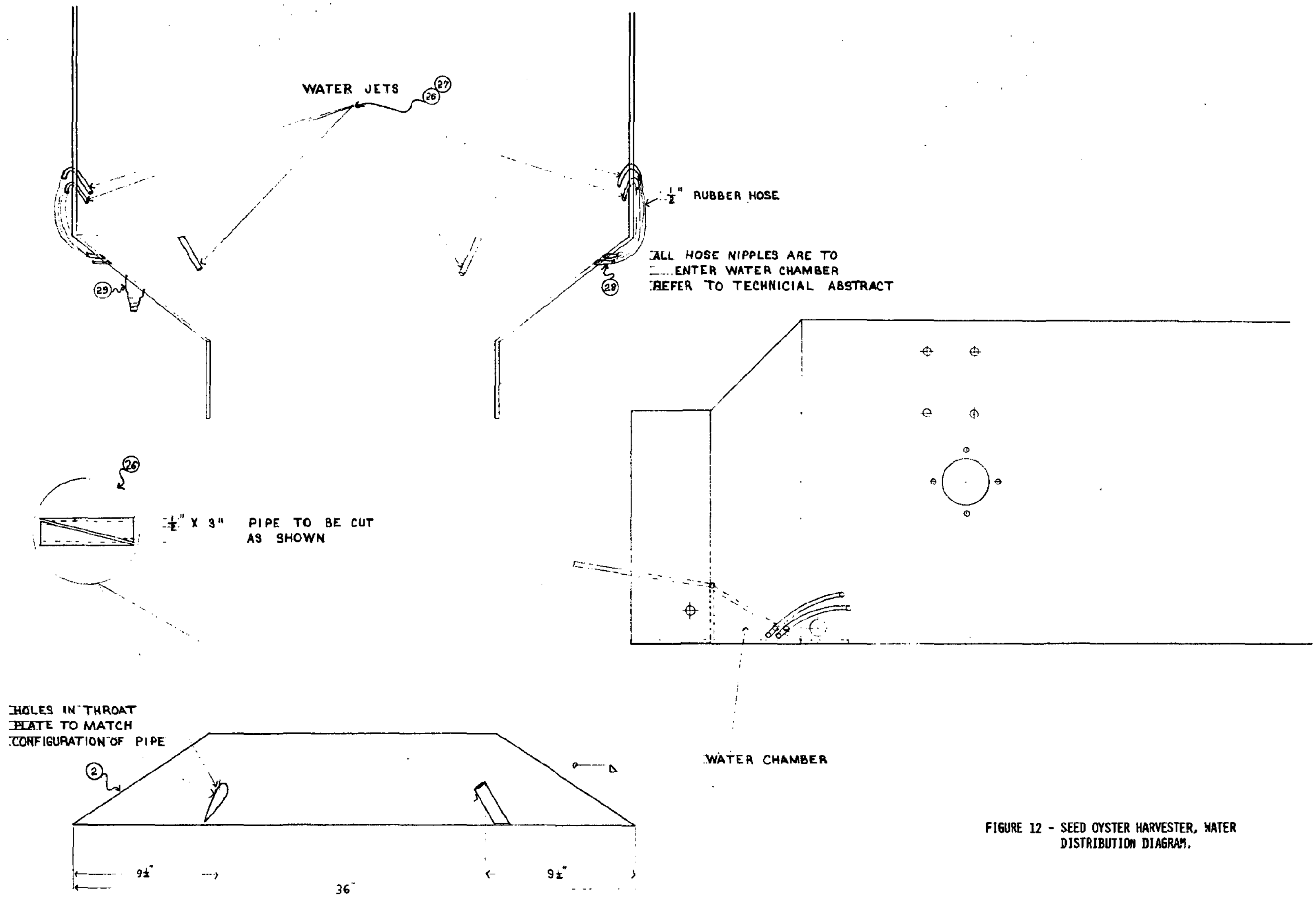
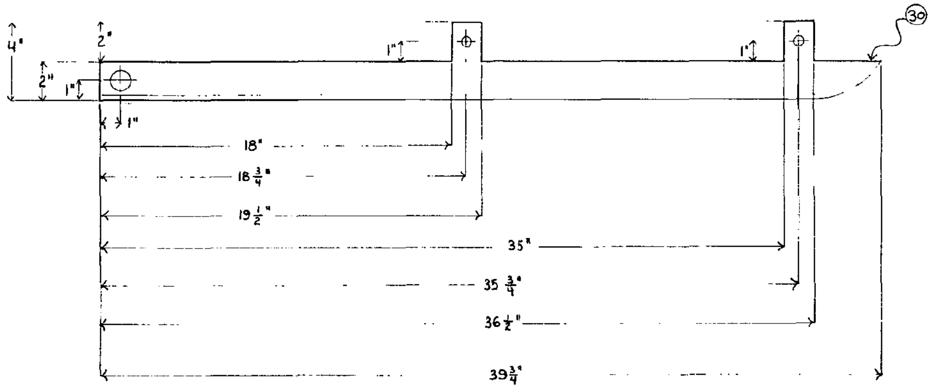


FIGURE 12 - SEED OYSTER HARVESTER, WATER DISTRIBUTION DIAGRAM.

SEED OYSTER HARVESTER	
WATER DISTRIBUTION DIAGRAM	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-11-B
DRAWN BY: [signature]	



NOTE: CHECK NOTES ON OH-1-8

ITEM NO.	NO. OF PIECES	SHAPE	MATERIAL REQUIRED	LENGTH
1	1	PL	$13\frac{7}{8}$" X $\frac{1}{4}$"	36"
2	1	PL	$5\frac{7}{8}$" X $\frac{1}{4}$"	36"
3	1	PL	9" X $\frac{1}{4}$"	$18\frac{1}{4}$"
4	1	PL	$3\frac{9}{16}$" X $\frac{1}{4}$"	$18\frac{1}{4}$"
5	1	PIPE	$\frac{1}{4}$" SCH 40	$18\frac{1}{4}$"
6	1	SHAFT	$\frac{1}{4}$" I.D.	$18\frac{1}{4}$"
7	4	PL	$6\frac{1}{4}$" Φ X $\frac{3}{8}$"	
8	4	PL	$11\frac{1}{2}$" Φ X $\frac{3}{8}$"	
9	4	PL	6" Φ X 1"	
10	12	PIPE	$1\frac{1}{2}$" Φ SCH 40	$29\frac{3}{16}$"
11	2	PIPE	$2\frac{1}{2}$" Φ SCH 40	$27\frac{3}{16}$"
12	24	FLAT ROD	$\frac{3}{4}$" X $\frac{1}{4}$"	$29\frac{3}{16}$"
13	24	SHAFT	$1\frac{1}{2}$" Φ	$1\frac{1}{2}$"
14	4		BROWNING EVERFLEX CHCFR6P W/P1 BUSHING	
15	1	⊏	4" X $1\frac{3}{4}$"	$60\frac{1}{2}$"
16	1	⊏	6" X 2"	$54\frac{1}{2}$"
17	2	L	4" X 4" X $\frac{1}{4}$"	$39\frac{3}{4}$"
18	2	PL	21" X $\frac{1}{4}$"	48"
19	2	PL	9" X $\frac{1}{4}$"	15"
20	1	PL	4" X $\frac{3}{8}$"	6"
21	1	PL	6" X 1"	11"
22	2	SHAFT	$1\frac{1}{4}$" Φ	$42\frac{1}{2}$"
23	3		BROWNING 60P24 W/P1 BUSHING	
24	360		TINE: SEE NOTE	
25	4		BROWNING FC 350 FLANGE BEARING $1\frac{1}{4}$" BORE	
26	1	PIPE	$\frac{1}{2}$" SCH 40	3"
27	4	PIPE	$\frac{1}{2}$" SCH 40	APPX. 6"
28	4	PLAIN END	$\frac{1}{2}$" NIPPLE	
29	1	PLAIN END	$2\frac{1}{2}$" NIPPLE	
30	2	L	4" X 4" X $\frac{1}{4}$"	$39\frac{3}{4}$"
31	2		BROWNING PB251-1 PILLOW BLOCK	
32	1		BROWNING 60B12 W/P1 BUSHING	
33	2		$\frac{1}{2}$ BROWNING FLEXIBLE COUPLING CHJP4	1"
34	1		INSERT NEOPRENE JP4	
35	1	SHAFT	1" Φ	11"

NOTE: TINES ARE SPERRY-NEW HOLLAND HAY RAKE MODEL 56, PART NO. 64562

FIGURE 13 - SEED OYSTER HARVESTER, ADJUSTABLE SLEDS AND MATERIALS SPECIFICATIONS.

SEED OYSTER HARVESTER	
ADJUSTABLE SLEDS	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO: OH-12-B
DRAWN BY: [illegible]	

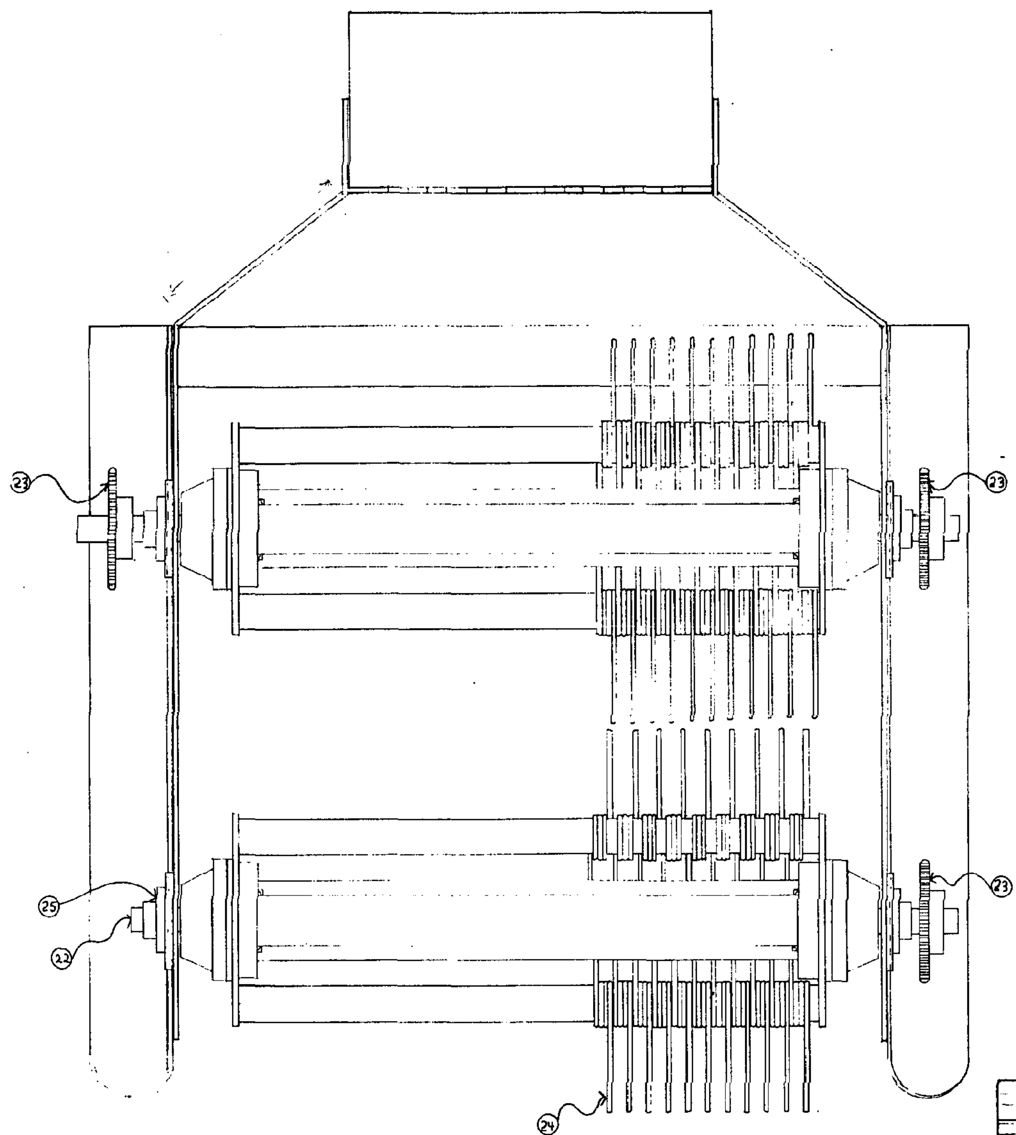


FIGURE 14 - SEED OYSTER HARVESTER, TOP VIEW.

SEED OYSTER HARVESTER	
TOP VIEW	
DATE: 9-18-79	SCALE: NONE
NO. OF SHEETS: 13	SHEET NO.: OH-13-B
DRAWN BY: James C. [signature]	

Hydraulic System Components*

1. Reservoir tank, 35 gallon capacity
2. Gresen hydraulic pump, DCB 20 gallon/6 gallon, DCB - 20 - 6 - 150 - 100 - 75 - B - CCW
3. Gresen relief valve, PK - 75
4. Gresen directional control valve, one spool, double acting WP - 4
5. Char-Lynn hydraulic motor, model AE, 6 gallon
6. Koening hydraulic winch, model HD-100, upright
7. Gresen relief valve, PK - 100
8. Gresen variable control flow divider, DCA - 25
9. Gresen variable control flow divider, DCA - 25
10. Char-Lynn hudraulic motor, model AE, 9 gallon
11. Char-Lynn hydraulic motor, model AE, 6 gallon
12. Gresen in-line filter, FR - 258 - 1A1C

A schematic drawing of the hydraulic system follows.

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*Use of brand names does not imply endorsement by the North Carolina Division of Marine Fisheries

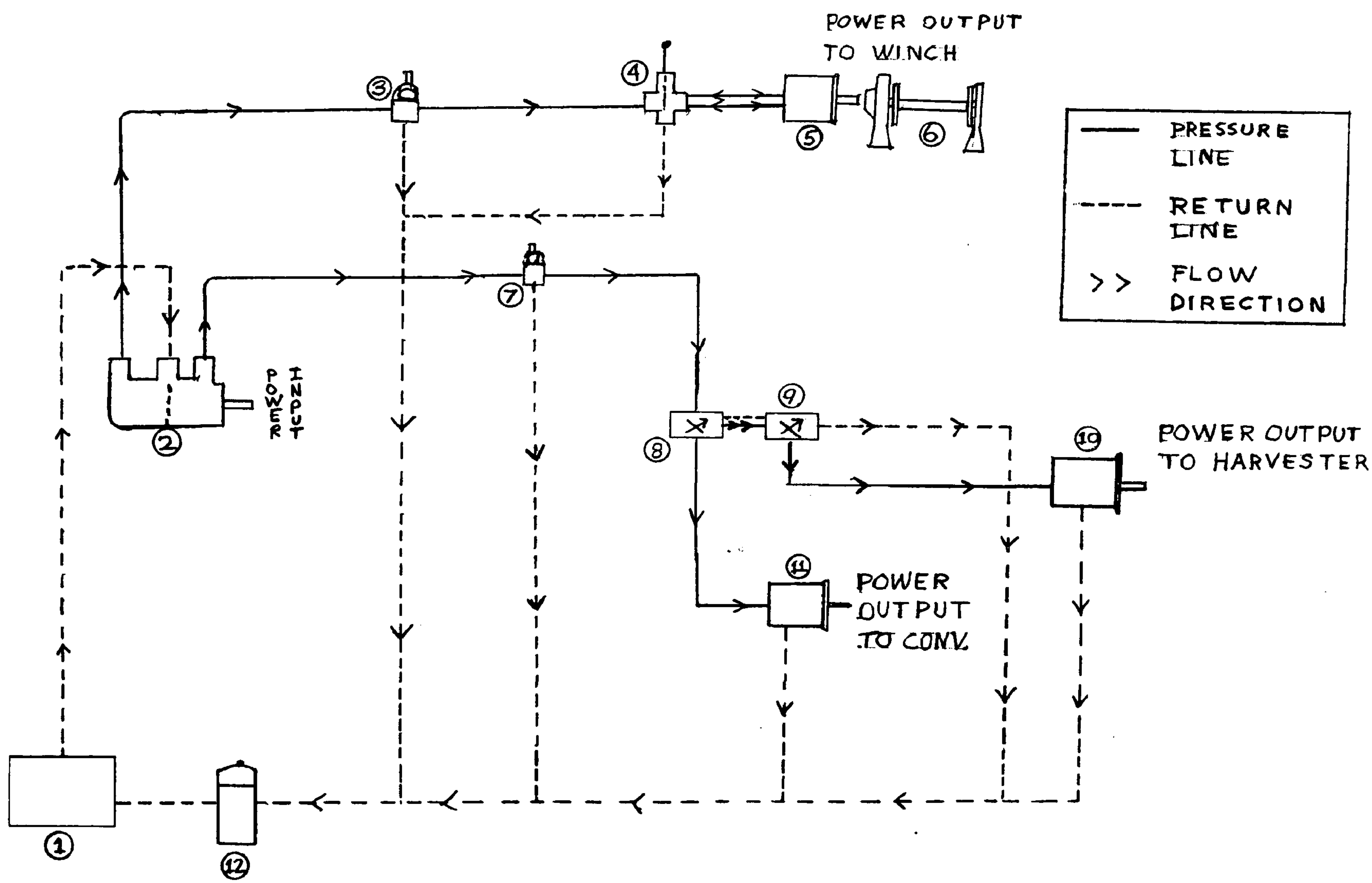

Figure 15 - Design of hydraulic system