A RANGE AND DISTRIBUTION STUDY OF THE NATURAL EUROPEAN OYSTER, OSTREA EDULIS, POPULATION IN CASCO BAY, MAINE

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ABSTRACT

A range and distribution study was conducted on naturally occurring European oyster, *Ostrea edulis*, populations in Casco Bay, Cumberland County, Maine. Observations were made by SCUBA diving using underwater transect lines and meter square frames. Distribution is related to substrate type and depth below mean low water (MLW). Observations on spawning season, using in-shell larval development index, and spat recruitment potential are discussed.

INTRODUCTION

In an effort to establish a new shellfishery in Maine, a Dutch variety of the European oyster, *Ostrea edulis,* originating from the Oosterschelde of Holland was introduced in the fall of 1949 at Basin Cove, Harpswell, Boothbay Harbor and the Taunton River in Franklin. Additional introductions were made at Small Point in Phippsburg in 1955, Peters Island, Bristol in 1959 and Merepoint Bay, Brunswick in 1961 using new imports from Holland as well as progeny from the original stocks of 1949 (Welsh. 1963).

Throughout the period of introduction numerous observations were made in the vicinity of the introductions to determine survival and propagation of the species and are summarized by Welsh (1963). These observations indicated that *O. edulis* could survive in Maine, despite mortalities at some sites, and natural propagation was also possible. Aquaculture practices and potential problems relevant to bottom culture in Maine are discussed by Foster (1976).

During the early 1970's at least two additional introductions of *O. edulis* were made in the Casco Bay are by pilot-scale ventures. One consisted of 3,000-4,000 oysters introduced by Montescue Moree and Winthrop Brown in 1974-75 at Leavitt Island, Cundy's Harbor and a second 100,000 in 1977 by INTERTIDE CORPORATION at Wilson Cove, Middle Bay, Harpswell Neck. INTERTIDE CORPORATION continued a nursery/grow-out operation through 1983. All of these oysters originated from Dutch oysters, either as seed from the University of Maine's Darling Center at Walpole or from broodstock provided to INTERTIDE CORPORATION by the University.

A further introduction of 500 oysters was made by researchers at Bowdion College's Bethel Point Marine Laboratory in 1978. These oysters originated in Brittany, France and were brought to the marine facility as part of a study of the effects of the Amoco Cadiz incident on oyster populations. These oysters were held in flow-through systems and presumably spawned, thereby adding to the already existing population.

Despite the previous successes with the bottom plantings, emphasis was placed on the suspension culture of *O. edulis* and little further consideration was given to the natural spread of the species. In the Fall of 1982 it was reported that commercial fishermen were finding substantial numbers of European oysters in the Quahog Bay area of Harpswell and by the fall of 1983 significant commercial quantities of oysters were being harvested in the area.

Since the discovery of these beds, considerable interest has developed in the commercial harvesting of these oysters. Unfortunately, very little is known about these natural populations that appear to be unique along the Eastern coast of the United States.

The study presented here is an attempt to identify, in general terms, the geographic range and distribution of *O. edulis* in the Casco Bay region with respect to depth below mean low water ass well as substrate type. Observations on spawning and settlement are also discussed.

METHODS AND MATERIALS

Preliminary locations of oyster concentrations were obtained through interviews with local fishermen in selected areas of the northeast region of Casco Bay. Once identified, these general areas were surveyed by SCUBA using a towed diving sled to locate concentrations and establish approximate boundaries. Based on these approximations, a 250 foot transect line was used to measure the areas of greatest concentration.

A modification of a grid sampling method described by Petrov (1981) was used to estimate population density. Loops placed at 10 foot intervals along the transect lines were used as attachment points for additional 10 foot lines fitted with hooks at one end and a weight at the other. These secondary lines were placed perpendicularly to the transect line at adjacent loops in order to form three sides of a 100 ft^2 grid. Where densities were too great to allow practical use of a 100 ft^2 grid, a 10 ft^2 (approximately m^2) steel frame was randomly dropped along the transect line for density determinations. Length and height measurements were recorded for 25 individuals from each site as well as observations on depth below mean low water (MLW) and substrate type and composition.

In order to assess the period and frequency of spawning, four sampling stations were established within the Quahog Bay area representing differing zones within the estuary. Samples of 10 individuals were collected weekly from each station and the level of larval development recorded according to the index described by Welsh (1963) and Walne (1979).

General observations were made on the spat settlement within the survey area to ascertain the recruitment potential for natural as well as artificial cultching.

DATA AND OBSERVATIONS

A. Geographic Range and Distribution*:*

The area surveyed was the northeast section of Casco Bay between Cape Small, Small Point and Flying Point, Freeport, Figure 1. For ease of presentation the survey area has been divided into ten (10) sections, Figure 2. Summarized data on population and size distribution is included where applicable with complete data included in Appendices 1 and 2, respectively.

Figure 1. Maine Coast from Cape Elizabeth to Pemaquid Point Showing Survey Area.

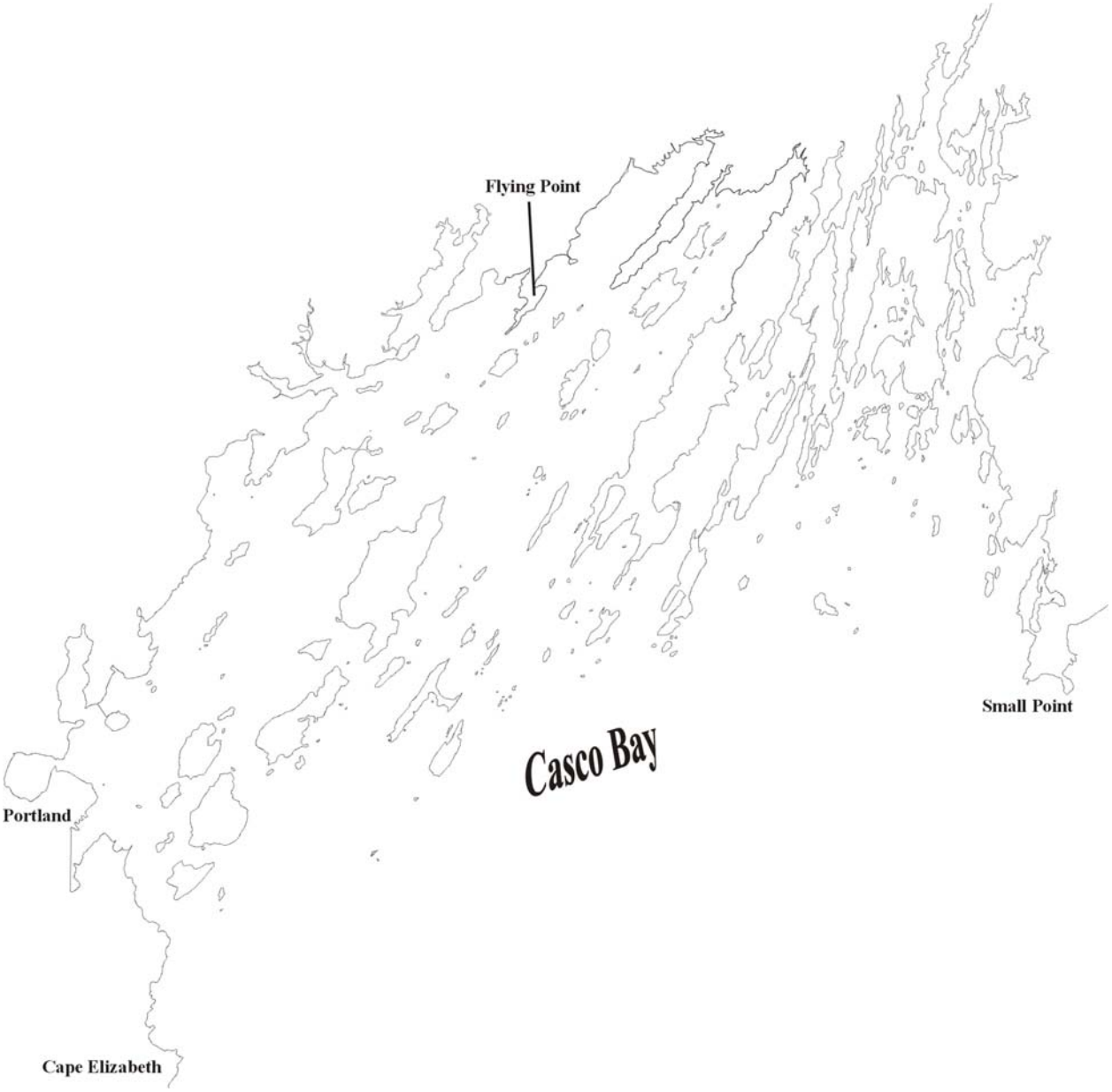
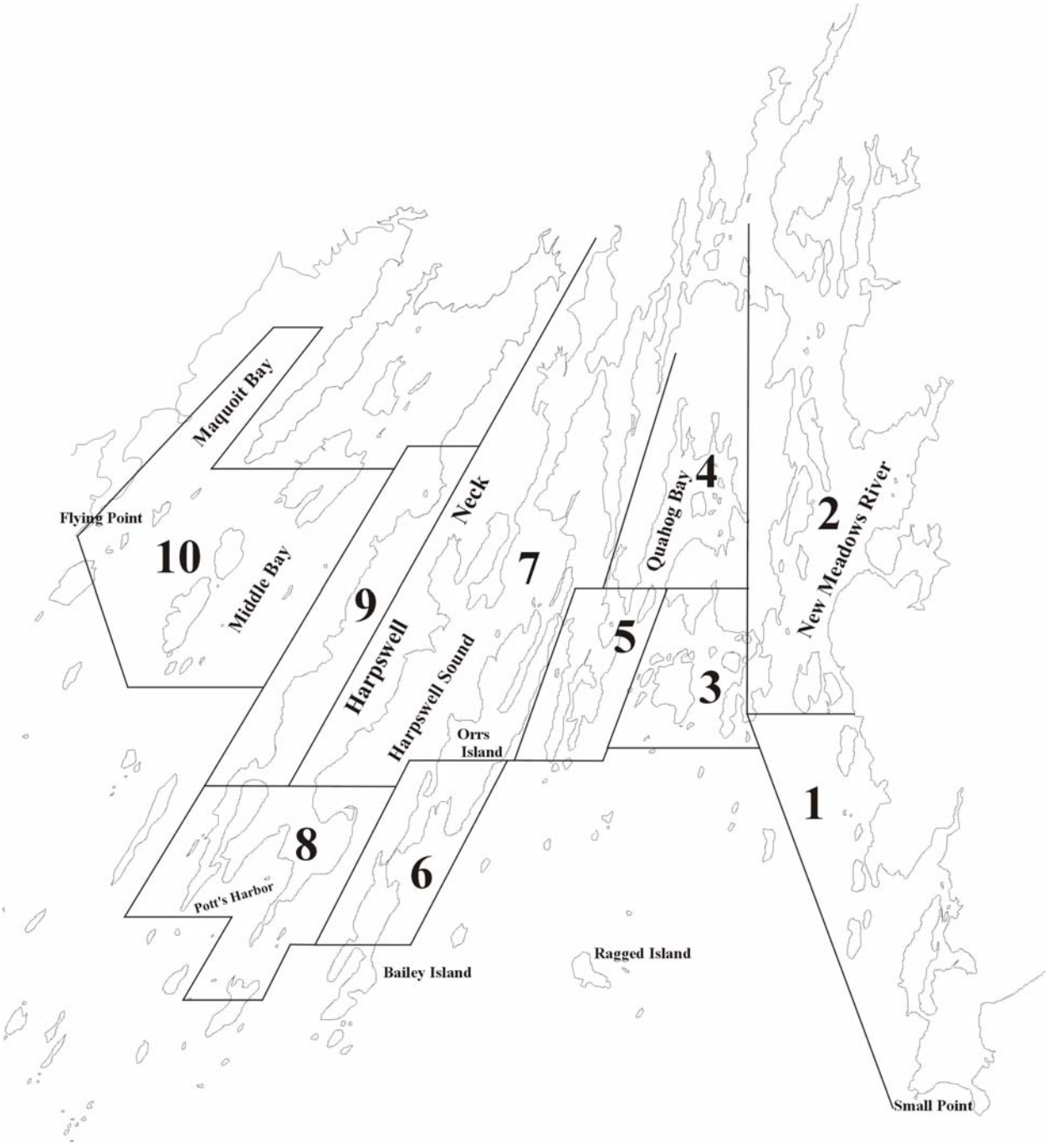
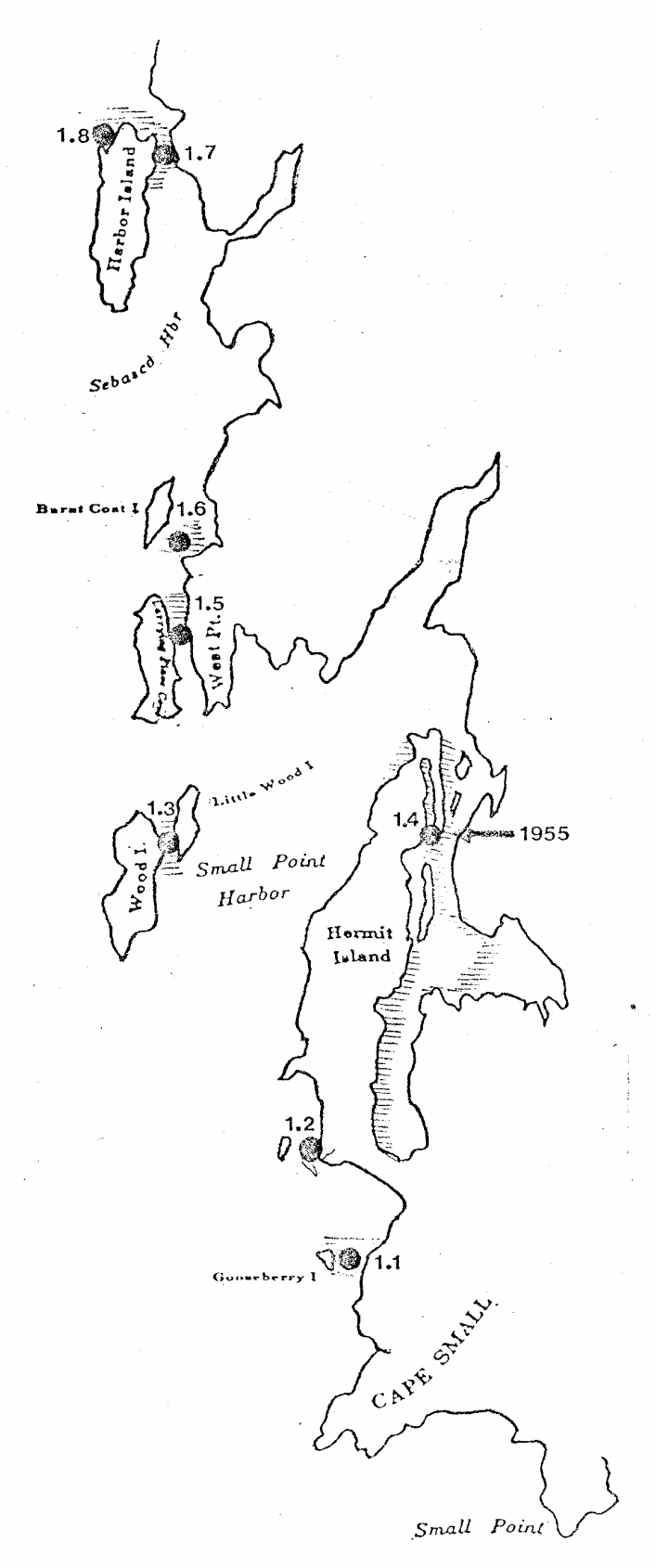


Figure 2. Survey Area Showing Sectional Areas



Section 1. Cape Small to Harbor Island, New Meadows River

Figure 3. Section 1. Cape Small to Harbor Island.



1.1 Gooseberry Island: sand and shell bottom with indications of high energy, shifting, rippled sand bottom; no oysters observed; depth -6' to -8' MLW.

1.2 Wallace Head: Ledge bottom with kelp; no oysters observed.

1.3 Gut between Wood Island and Little Wood Island: high activity area with sand/shell bottom and sporadic eelgrass; 2 oysters observed with 1984 set present on both individuals; appears to be seaward limit of existing population.

1.4 Hermit Island: site of original introduction of 4,000 Dutch oysters at a lobster pound, 1955. Channel entering Cape Small Harbor: muddy bottom with mussel beds to -2.0' MLW followed by deep mud below, no oysters observed. At mouth of lobster pound: bottom composed of relic shell overlaying firm mud bottom; moderate number of oysters observed $<1/m^2$; moderate 1984 set observed; Area reported to have been heavily harvested in 1992 and 1983; depth -2.0' to -3.0' MLW. Size Sampling: mean L 78.2mm H 70.4mm S.D. L 21.7mm H 21.1mm

1.5 Carrying Place Cove: hard bottom, fine sand with little relic shell or other cultch, barren; 3 oysters observed in $500m^2$; no 1984 set observed; area reported as harvested; depth -1.5' to -2.0 MLW.

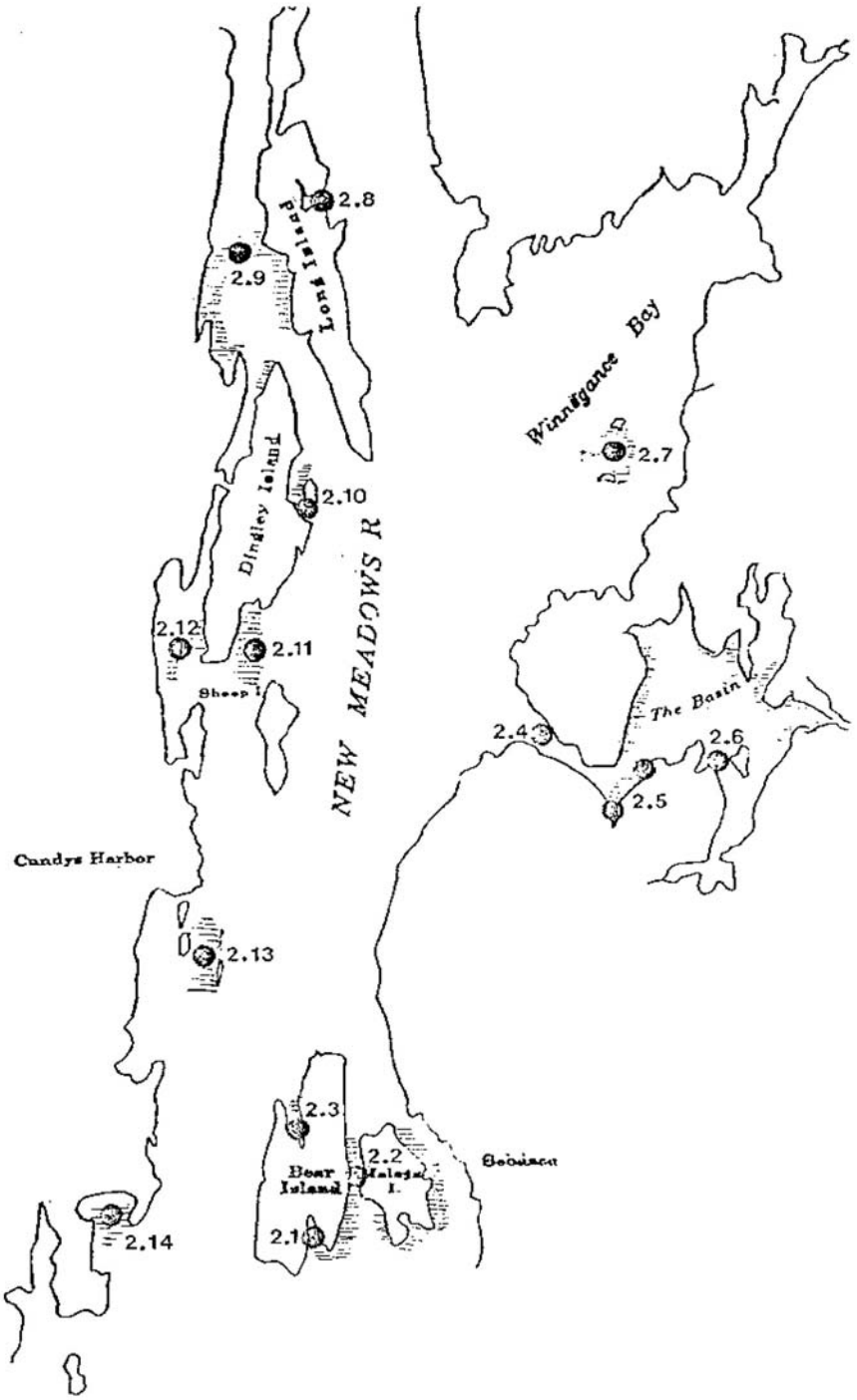
1.6 Northwest end of West Point: bottom sand with periwinkle and mussel shells, sporadic eelgrass; sporadic oysters ($<1/m^2$), with very few 1984 set in band approximately 10m wide; depth -4.0' to -8.0' MLW.
Size sampling: mean L 70.0mm H 65.3mm S.D. L 19.3mm H 16.3mm

1.7 Harbor Island: bottom varies from fine sand to small rocks, relic periwinkle and mussel shells, coarse gravel; area appears to represent expanding population; depth -1.5' to -3.0' MLW. Area transected: Mean No. oysters/m^2: 8.1 S.D. 9.2 Total area: $50,000ft^2$ Est. No. oysters: 40,500 ($0.81/ft^2$)
Size sampling: mean L 68.6mm H 61.4mm S.D. L 13.3mm H 10.9mm

1.8 Northwest Shore Harbor Island: hard bottom with kelp; crushed shell; no oysters observed; depth -6.0' to -12.0' MLW.

Section 2. New Meadows River: Area north of a line drawn between Malaga Island and East Cundy Point

Figure 4. Section 2. New Meadows River



2.1 Gut between Malaga Island and Bear Island: bottom hard composed of sand and crushed shell with mussel bars in shallows. Few oysters found (<1/m^2) despite ideal conditions; 1984 set observed; area reportedly heavily harvested in 1982 and 1983. Survey of southwest side yielded very few oysters; area possibly too exposed; depth -1.0' to -3.0' MLW

2.2 Bear Island South Cove: bottom hard relic shell and sand, ideal conditions but no oysters observed; depth -4.0' to -10.0' MLW.

2.3 Bear Island North Cove: bottom firm mud with relic shell, silt; small quantity of oysters found (<1/m^2) ; 1984 set observed; depth -2.0' to -4.0' MLW

2.4 Entrance to Basin: ledge to 30', no oysters observed

2.5 The Basin and Cove at Southwest Corner: bottom firm mud overlaid with periwinkle and quahog shells; oysters observed from old pier ruins running north toward channel (11m^2) ; some 1984 set observed; depth -2.0' to -5.0' MLW.
Size sampling: mean L 71.9mm H 66.5mm S.D. L 16.0mm H 15.3mm

2.6 The Basin East of Denny Reed Road: bottom soft mud from point of land into cove and out toward small island in main cove; no oysters observed; depth -2.0' to -5.0' MLW.

2.7 Winnegance Bay at Bushy Island and Ram Island: bottom hard overlaid with quahog shell; sporadic oysters (<1/m^2) ; some 1984 set observed; depth -2.0' to -6.0' MLW.
Size sampling: mean L 87.7mm H 81.4mm S.D. L 18.3mm H 14.3mm

2.8 Long Island Cove on northeast shore: bottom soft mud without cultch; no oysters observed; depth -2.0' to -3.0' MLW.

2.9 Long Island Cove: soft mud bottom throughout cove with little cultch available; apparently high siltation rate; no oysters observed; depth -1.0' to -3.0' MLW.

2.10 Dingley Cove-cove on east side: bottom firm mud with relic shell overlay in narrow band near shoreline giving way to soft mud; some oysters found (1/m^2); depth -3.0' to -8.0' MLW.

2.11 Dingley Cove between Dingley Island and Sheep Island: bottom firm but overlaid with relic shell and small stones; oyster concentration 1/m^2 but over a large area; winter-kill observed in shallow water (-1.0' MLW); insufficient concentration for transecting; 1984 set observed; depth -7.0' to -12.0' MLW.
Size sampling: mean L 89.5mm H 81.1mm S.D. L 20.1mm H 19.1mm

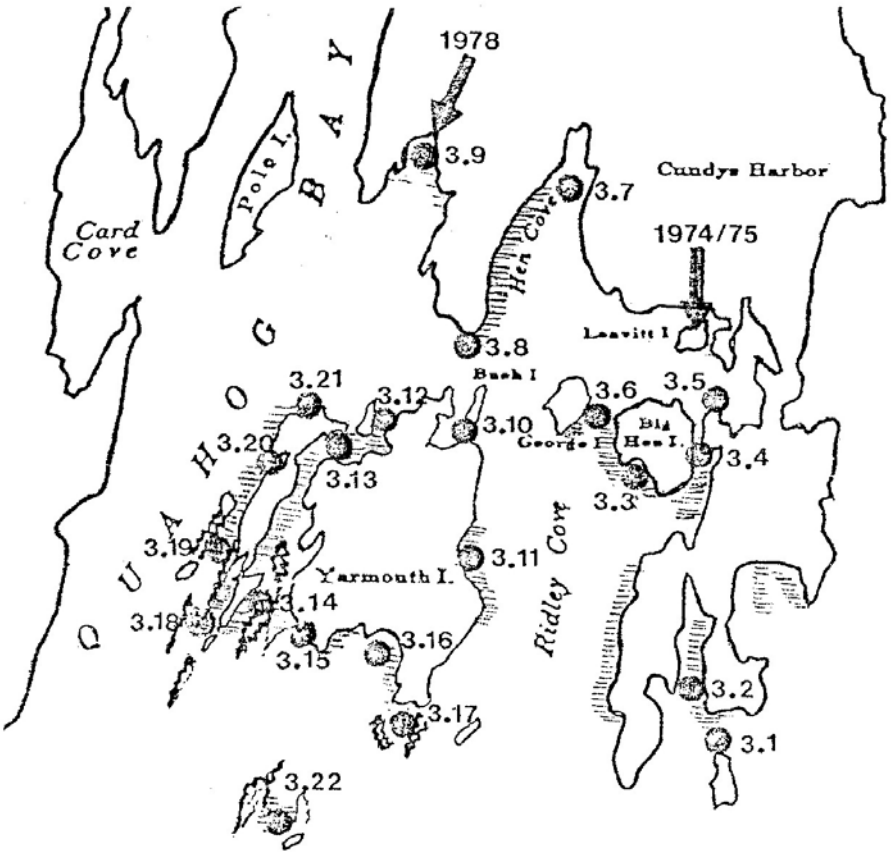
2.12 Northwest reach-Dingley Cove: soft mud bottom; no oysters observed.

2.13 Cedar Ledges-Cundy's Harbor: bottom hard ledge and sand overlaid with clean relic shell; high current area; some oysters found but density 1/m^2 ; very little 1984 set observed; area may have been harvested; depth -2.0' to -3.0' MLW.
Size sampling: mean L 73.8mm H 70.1mm S.D. L 30.2mm H 28.9mm

2.14 Sandy Cove-East Cundy Point: bottom firm sand with sporadic eelgrass; rippled bottom indicating high energy area; one oyster found; area reportedly had large population-recently harvested.

Section 3. Vicinity of Ridley Cove and Yarmouth Island

Figure 5. Section 3. Vicinity of Ridley Cove and Yarmouth Island



3.1 Rogue Island: bottom hard, relic shell; exposed area with kelp; no oysters observed; depth -3.0' to -8.0' MLW.

3.2 Cundy Point Cove: upper cove soft mud, band along lower cove shore of sand and firm mud with shell and cultch; oysters observed at density of $1/m^2$; area apparently dragged--oysters found only in depressions and not on flat bottom; numerous generations found set upon one another with considerable number of small oysters; depth -3.0' to -8.0' MLW.

3.3 South end Big Hen Island: bottom firm with rock and shell overlay; steep slope drops quickly to -20'+; few oysters found.

3.4 Gut between Big Hen Island and West Cundy Point: bottom firm varying from fine sand with shell overlay to soft mud on east side of lower channel; moderate current area; appears to be ideal nursery area; area heavily harvested; excellent 1984 set; depth -2.0' to -5.0' MLW. Area transected. Mean No. of oysters/m^2 ($10ft^2$): 17.8 S.D. 14
Total area: 17,200 ft^2 Est. No. of oysters: 30,616 ($1.78/ft^2$)
Size sampling: mean L 68.8mm H 64.4mm S.D. L 23.9mm H 17.5mm

3.5 North end Big Hen Island: bottom firm mud with mussel and quahog shells; small concentration of oysters at high density (area too small to transect); area reportedly heavily harvested in 1982 and 1983; depth -1.5' to -6.0' MLW.
Size sampling : Mean L N/A H 67.8mm S.D. L N/A H 18.4mm

3.6 George Island, east side: hard bottom varying from ledge to sand with crushed shell and periwinkles; oysters observed although sporadic in clusters around rocks and in depressions - evidently harvested; depth -1.5' to -8.0' MLW.

Leavitt Island: site of introduction by Montescue Moree and Winthrop Brown in 1974-1975.

3.7 Hen Cove: bottom varies from soft silty mud with relic shell at head of cove to firm silty shell-covered western shore to soft mud at center; band of oyster habitat between 7-8m wide along shore; density $<1/m^2$ with sharp demarcation at edge of soft bottom; depth -2.0' to -5.0' MLW.

3.8 Bethel Point: firm bottom with relic shell - substantial amount of cultch becoming more silty with depth; many young oysters (40-60mm); found pile of dead oyster shells - apparently dumped; depth -2.0' to -5.0' MLW.

3.9 Cove west of Bethel Point: site of introduction of French stocks from Brittany by researchers at Bowdion College in 1978; bottom relic shell scattered over mud bottom; oysters found in small concentrations of 10-50m^2 areas where adequate substrate is present; numerous generations represented - primarily restricted to head of cove; area reportedly harvested 1982-1983; depth -2.0' to -4.0' MLW.

3.10 Bush Island: hard sandy bottom with some crushed shell; oysters found along shores and center; density $<1/m^2$ within cove up to mouth on Ridley Cove where bottom gives way to soft mud; thermocline noted at -15.0' to -18.0' MLW which coincides with the lower limit of oysters despite abundant cultch below thermocline.
Size sampling: Mean L N/A H 78.4mm S.D. L N/A H 13.2mm

3.11 Eastern shore of Yarmouth Island: bottom composed of small stones and relic shell over sand bottom at -2.0' to -15.0' MLW giving way to soft mud below -15.0' MLW; small number of oysters found with smallest in shallows and larger oysters in deeper water; density $<1m^2$.

3.12 North end of Yarmouth Island : firm mud and sand bottom overlaid with shell and small stones; area of high density; evidence of dragging; excellent 1984 set; depth -1.5' to -5.0' MLW. Area transected:
Mean no. of oysters/m^2 : 13.9 S.D. 8.9
Total area: 150,000 ft^2 Est. No. oysters 208,500 (1.39/ft^2)
Size sampling: Mean L N/A H 66.1mm S.D. L N/A H 7.7mm

3.13 North end of gut between Yarmouth Island and little Yarmouth Island :
firm mud and sand bottom overspread with relic shell; strong current; area reported to have had oysters since the early 1950's; oysters found throughout at depth of -1.5' to -2.5' MLW. Area transected:
Mean No. oysters/m^2 : 9.5 S.D. 14.5
Total area: 125,000 ft^2 Est. No. oysters: 118,750 (0.95/ft^2)

3.14 South end of gut between Yarmouth Island and Little Yarmouth Island : hard sand bottom affected by strong current and exposed to storm action; oysters sporadically spread across bottom, particularly in depressions; multiple generations found set on one another; area reportedly harvested by draggers; depth -2.0' to -9.0' MLW.
Size sampling: Mean L N/A H 61.5mm S.D. L N/A H 21.2mm

3.15 Cove at southwest corner of Yarmouth Island : firm mud and sand bottom with rocks, gravel and relic shell; young oysters found but very few larger individuals; depth -1.5' to -5.0' MLW.

3.16 Deep Cove - Yarmouth Island : shell and gravel bottom with kelp; a few oysters found along band parallel to shoreline at -8.0' MLW; area reportedly harvested by draggers and divers in 1983; no evidence of large concentration found.

3.17 Southeast tip of Yarmouth Island : ledge bottom with sand and relic shell; oysters of various sizes found but at very low density; area possibly harvested in 1983; depth -2.0' to -4.0' MLW.

3.18 Southwest cove of Little Yarmouth Island : shell and stone fragment bottom covered with coralline algae and kelp; some oysters found including one very old specimen; area highly exposed; slow growth apparent, possibly due to exposure and low temperature; depth -3.0' to -12.0' MLW.

3.19 Cove at west of Little Yarmouth Island : narrow band of firm mud overlaid with shell fragments along shore giving way to soft mud at center and mouth at south; a few oysters found along firm band in -1.5' to -2.5' ML; many generations, but primarily young oysters attached to projections from the bottom; reportedly heavily harvested in 1983; winterkill or dragging mortalities evident.
Size sampling: Mean L 65.5mm H 63.2mm S.D. L 24.1mm H24.3mm

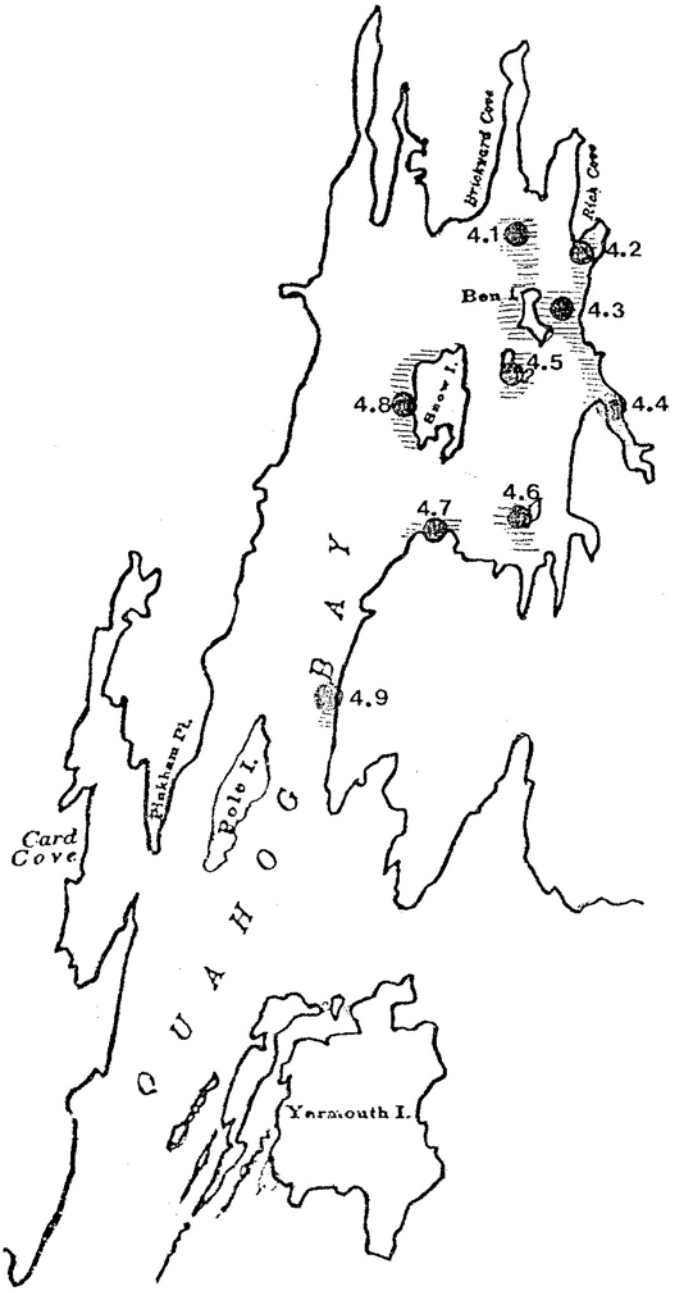
3.20 Cove at northwest side of Little Yarmouth Island : firm mud bottom with shell and gravel; oysters of various year classes present; density $<1/m^2$; depth -2.0' to - 7.0' MLW.

3.21 North shore of Little Yarmouth Island : firm mud bottom with shell overspread; oysters present in narrow band parallel to shoreline; evidence of winterkill near - 1.5' MLW; density $<1m^2$; depth -2.0' to -5.0' MLW.

3.22 Duck Rock : bottom covered with stone fragments and mussel and periwinkle shells (ideal cultch conditions); very few oysters retrieved - all small with evidently slow growth rates; may represent seaward limit of population; depth - 1.5' to -7.0' MLW.

Section 4. Upper Qu8ahog Bay

Figure 6. Section 4. Upper Quahog Bay.



4.1 Ledges off Brickyard Cove : ledge bottom down to soft mud; no oysters observed on ledge or mud bottom; depth -1.0' to -1.5' MLW.

4.2 Rich Cove : firm mud bottom overlaid with small stones and quahog shells with evidence of moderately high siltation rate; oysters found throughout mouth area of cove at density of $<1/m^2$ to approximately $4/m^2$; considerable cultch available; depth -4.0' to -8.0' MLW. Size sampling: Mean L 80.9mm H 77.7mm S.D. L 20.6mm H 19.0mm

4.3 Ben Island : firm mud and sand bottom with quahog shell overlay giving way to soft mud around area of concentration which extends from main-land out towards Ben Island; area reportedly intensively harvested in 1983-84 by draggers and divers with an estimated 2,000 bushels harvested (pers. comm., Phil Carroll). Area transected:
Mean No. oysters/m^2 : 1.6 S.D. 1.5
Total area: 30,000 ft^2 Est. No. of oysters: 4800 (0.16/ft^2)

4.4 Cove southeast of Ben Island : firm mud bottom with considerable cultch available; oysters present at density <1/m^2 ; possibly harvested; depth -3.0' MLW.

4.5 Small islands southwest of Ben Island : firm mud bottom with considerable cultch available; oysters present at density <1/m^2 ; evidence of 1983 set survival; area reportedly harvested by divers in 1983; depth -2.0' to -6.0' MLW.

4.6 'Center Island' southeast of small islands : bottom variable from coarse gravel and broken shell near shore to firm mud overlaid with quahog shells giving way to soft mud; oysters present in band parallel to western shore and off southern end; possibly harvested in 1983; 1984 set present; depth -2.0' to - 4.0' MLW. Area transected:
Mean No. of oysters/m^2 : 3.9 S.D. 4.5
Total area: 25,000ft^2 Est. No. of oysters: 9,750
Size sampling: Mean L N/A H 87.9mm S.D. L N/A H 9.4mm

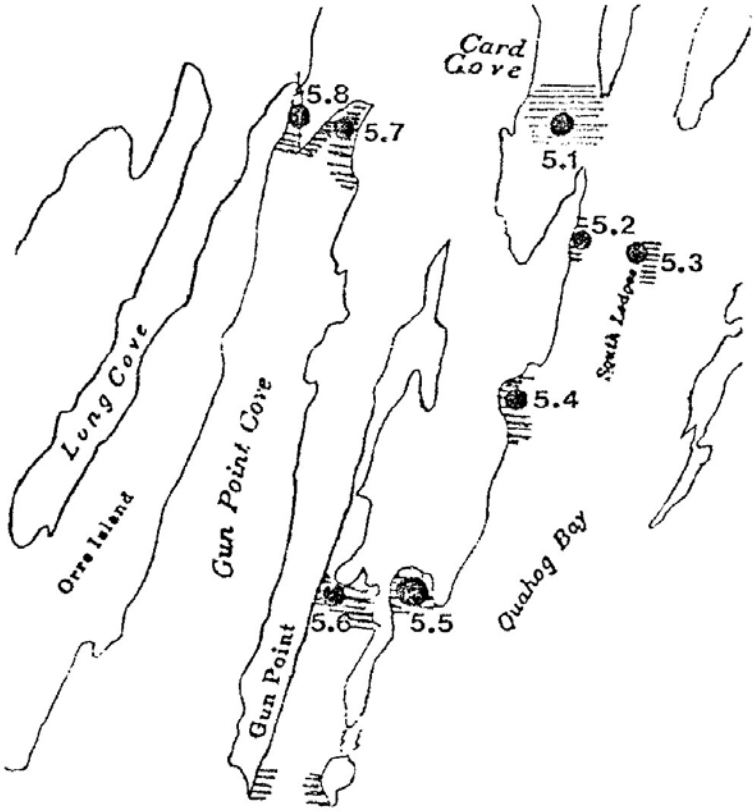
4.7 Cove at northwest tip of Great Island : bottom variable from ledge and shell to small stones and relic shell with silty mud; oysters present in band parallel to shoreline approximately 6-8m from MHW mark; depth -3.0' to -10.0' MLW.
Area transected:
Mean No. of oysters/m^2 : 0.97 (1.0) S.D. 0.93
Total area: 25,000 ft^2 Est. No. of oysters: 2,425
Size sampling: Mean L N/A H 80.3mm S.D. L N/A H 9.4mm

4.8 Snow Island, west shore : firm mud bottom overlaid with quahog and mussel shells and small stones; oysters found covering substantial area across two small coves from a depth of -2.0' to -8.0' MLW; density <1/m^2 ; area in process of harvest by divers; reportedly contained large numbers of oysters prior to 1983.
Size sampling: Mean L N/A H 87.9mm S.D. L N/A H 9.4mm

4.9 Great Island opposite Pole Island : steep ledge down to -30+' MLW; no oysters found

Section 5. Lower Quahog Bay and Gun Point Cove

Figure 7. Section 5. Lower Quahog Bay and Gun Point Cove



5.1 Card Cove: soft mud bottom without cultch; no oysters found

5.2 Shore along point opposite Pinkham Point: stone bottom with shell overlay and mussel beds on steep ledge; very few oysters found, primarily small attached to mussels and shell; depth -2.0' to -20.0' MLW.

5.3 South ledges: ledge with shell fragments covered with kelp on steep slope: two oysters found over extensive area; very limited habitat; depth -1.5' to -5.0' MLW.

5.4 Cove just south of Card cove : hard bottom of shale stone and shell; oysters found sporadically attached to stones and shell as well as ledge and live mussels; smaller clusters concentrated near shore at -2.0' MLW; depth -1.5' to - 5.0' MLW.

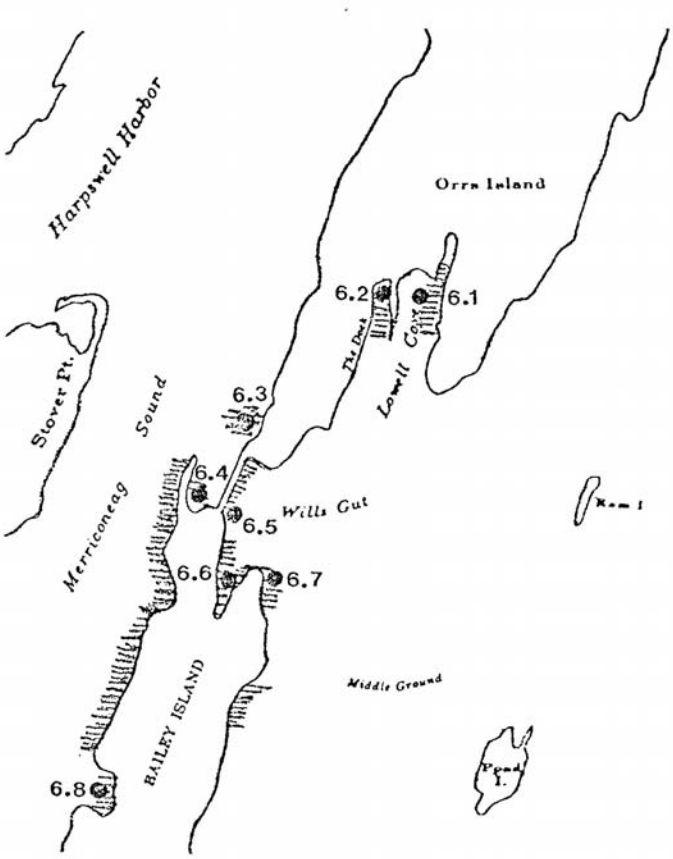
5.5 Cove on east shore of East Gun Point: firm bottom around ledges giving way to soft mud in deeper areas; some cultch available but no oysters found; possibly harvested; depth -2.0' to -8.0' MLW.

5.6 Gun Point Creek: firm mud bottom with relic shell between ledges and across shallow channel; significant numbers of oysters found with several generations represented; depth -2.0' to -7.0' MLW. Area transected:
Mean No. of oysters/m^2: 4.7 S.D. 3.9
Total area: 20,000 ft^2 Est. No. of oysters: 9,400
Size sampling: Mean L N/A H 69.2mm S.D. L N/A H 9.2mm

5.7 Head of Gun Point Cove: soft mud bottom with exception of very narrow band of small stone and relic shell parallel to shoreline; oysters found only on narrow band but numerous oysters were found attached to projections from bottom, *i.e.* branches, rocks, etc., and on ledge just above mud line; density <1m^2 ; depth -2.0' to -8.0' MLW
Size sampling: mean L 59.8mm H 53.7mm S.D. L 20.9mm H 16.8mm

5.8 Orr's Island Bridge: hard bottom with relic shell covering; very strong current; oysters of various year classes found; density <1m^2 ; depth -2.0' to -10.0' MLW.

Figure 8. Section 6. Vicinity of Bailey Island Bridge



6.1 Lowell's Cove : bottom variable from fine sand overlaid with shell to ledge; oysters found sporadically throughout area with some areas of slightly higher concentrations; oysters also found set on ledge and rocks with good 1984 set observed; area reportedly heavily harvested in 1983; depth-4.0' to -5.0' MLW.
Size sampling: Mean L 58.8mm H 54.1mm S.D. L 27.6mm H 26.2mm

6.2 The Dock - West Lowell's Cove : fine sand bottom with eelgrass, without much cultch; few oysters found on bottom but moorings, rocks and other projections heavily covered with oysters; heavy 1984 set observed; area reportedly harvested in 1983; depth -2.0' to -7.0' MLW.

6.3 West Orr's Island at bridge : bottom firm to soft mud with periwinkles and sporadic eelgrass; oysters of various sizes found; density <1/m^2 ; depth -2.0' to -12.0' MLW.

6.4 Cook's Lobster wharf : bottom firm with relic shell, primarily discarded scallop shells; no oysters observed and no 1984 set present; depth -1.0' to -4.0' MLW.

6.5 Bailey Island at bridge (east shore) : tide pool - firm mud and sand over ledge; oysters observed in tide pool with 1984 set present; depth -5.0' to -1.0' at +2.0' MLW.

6.6 Water Cove : variable bottom from shale stone along shoreline to soft mud at depth; oysters found along both shores of cove parallel to shoreline with western shore more concentrated; oysters set on shell and stone as well as projections; depth -2.0' to -10.0' MLW. Area transected:
Mean No. of oysters/m^2 : 27.3 S.D. 11.0
Total area 15,000 ft^2 Est. No. of oysters: 40,950
Size sampling: Mean L 65.2mm H 59.4mm S.D. L 18.5mm H 18.6mm

6.7 Northwest corner - Bailey Island : hard sand bottom with relic shell overlay between ledges; very exposed area; few oysters observed; depth -1.5' to -3.0' MLW.

6.8 Cove on west shore of Bailey Island : firm bottom with mussel and periwinkle shells and sporadic eelgrass; no oysters observed despite ideal conditions; depth -2.0' to -6.0' MLW.

Section 7. Harpswell Sound: Stover's Point to Doughty's Point

A detailed summary of this area is unnecessary for no oysters were found within this section. The bottom throughout the area, from Orr's Island up the eastern side of Harpswell Sound to Doughty's Point and back down along the western side to Stover's Point, consists primarily of soft mud covered by dense eelgrass overgrowth.

Selected areas were found where oyster habitat is present. These include Prince's Point where, despite soft mud bottom, relic mussel shells are abundant as cultch. At Ewin's Narrows, directly under the bridge, mounds of ancient American oyster, *Crassostrea virginica*, shells were found extending almost the entire width of the channel. Although representing the best conditions observed in this section no spat were seen. Finally, a small number of oysters were reportedly found by scallop divers off the southern tip of High Head. No oysters were found in this area during the present survey and no evidence of setting was found. This may suggest that the oysters previously found had been transplanted into the area.

Figure 9. Section 7. Harpswell Sound: Stover's Point to Doughty Point.

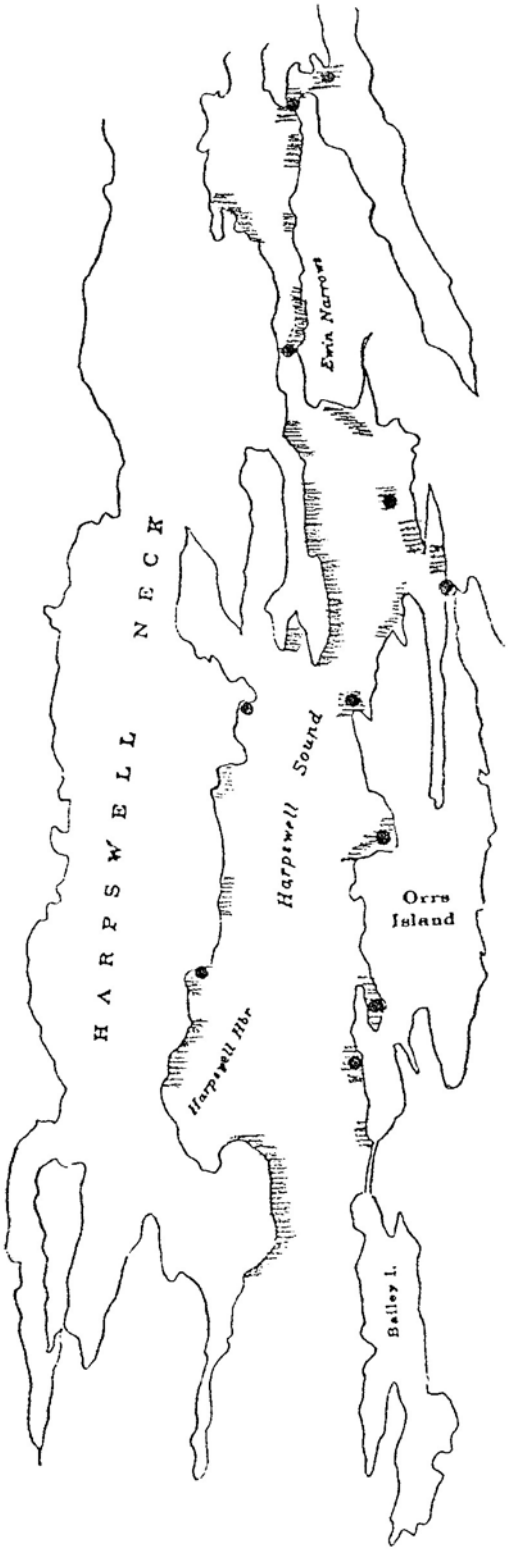
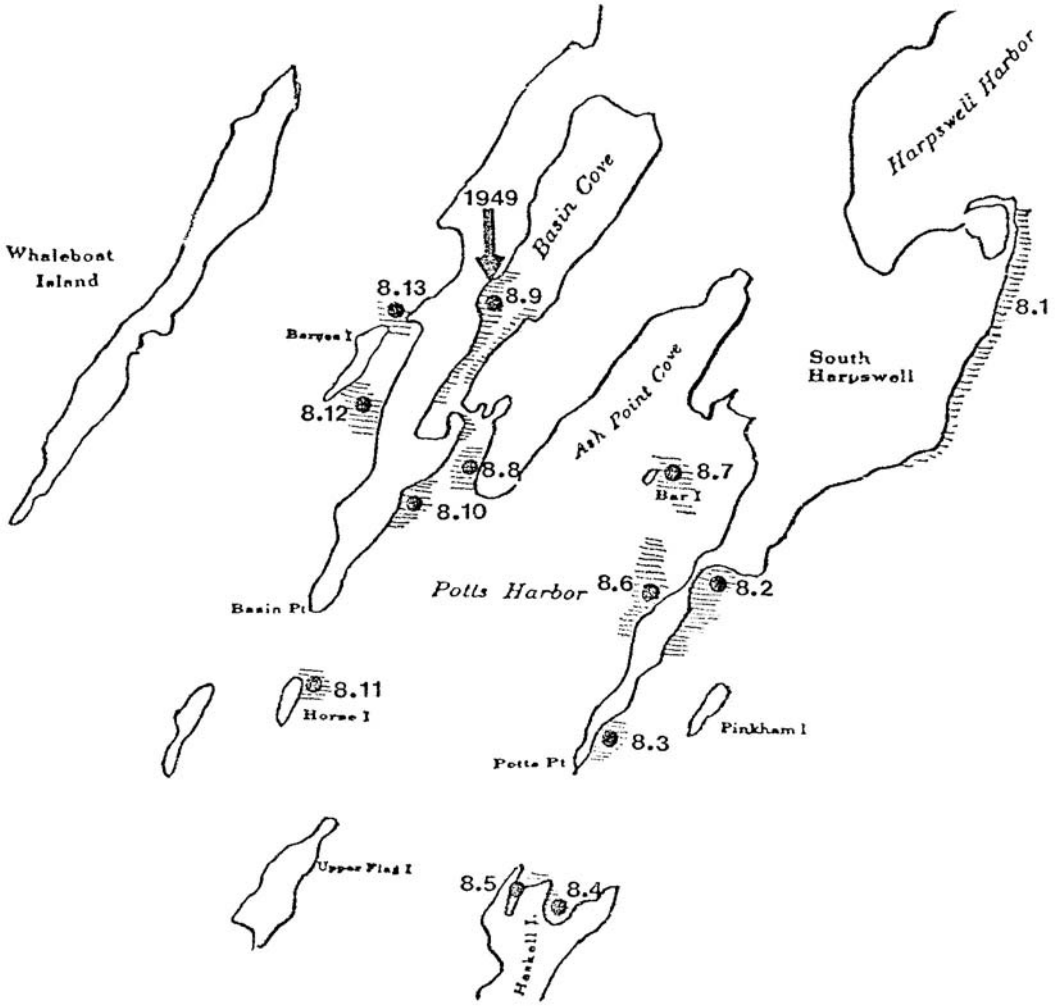


Figure 10. Section 8. Potts Harbor: Stover's Point. Harpswell Sound to Peter's Cove, Middle Bay.



8.1 Stover's Point: soft mud bottom with eelgrass; no oysters found; depth -1.5' to -3.0' MLW.

8.2 Estes Beach: firm bottom (mud) and sand with relic shell and sporadic eelgrass between ledges; no oysters found; area reportedly harvested for 50mm+ seed but no evidence was found of any oysters; depth -1.5' to -12.0' MLW.

8.3 Potts Point: firm sand bottom with relic mussel and periwinkle shells; no oysters observed despite excellent cultching conditions; depth -2.0' to -10.0' MLW.

8.4 Great Harbor Cove, Haskell Island: hard bottom overlaid with mussel and periwinkle shells; no oysters observed despite ideal conditions; depth -2.0' to -6.0' MLW.

8.5 Northwest Cove, Haskell Island: soft mud bottom with little relic shell; no oysters found; depth -2.0' to -5.0' MLW.

8.6 Pott's Harbor at Pott's Point bridge: bottom variable from soft mud with eelgrass to firm mud with relic shell and rock around ledges; oysters representing several generations found on firm bottom with slight 1984 set present; density <1m^2 ; depth -1.0' to -5.0' MLW.
Size sampling: Mean L 87.3mm H 79.6mm S.D. L 18.3mm H 16.2mm

8.7 Bar Island, Ash Point Cove: firm mud bottom to fine sand with mussel beds; oysters found as singles and set on live mussels; area reportedly harvested by clamdiggers wading along bed and draggers (oysters incidental to mussel harvesting); density <1m^2 ; depth -1.5' to -4.0' MLW.

8.8 Channel to Basin Cove: sand bottom with relic shell overlay cleaned by strong current; no oysters observed, but shore drops off rapidly limiting habitat; depth -1.5' to -20.0+' MLW.

8.9 Basin Cove: site of original introduction in fall of 1949; bottom variable from soft mud with eelgrass to firm mud and sand overlaid with relic shell; oysters found along band parallel to shoreline; total of 44 oysters recovered during complete survey; area reportedly contained several thousand oysters in the 1960's to early 1970's but area has been heavily harvested by scallop divers and the oysters presumably harvested; 1984 set present; depth -1.5' to -6.0' MLW.

8.10 Basin Point just North of Dolphin Marina: firm mud bottom with eelgrass and some relic shell; very few oysters found; depth -1.5' to -6.0' MLW.

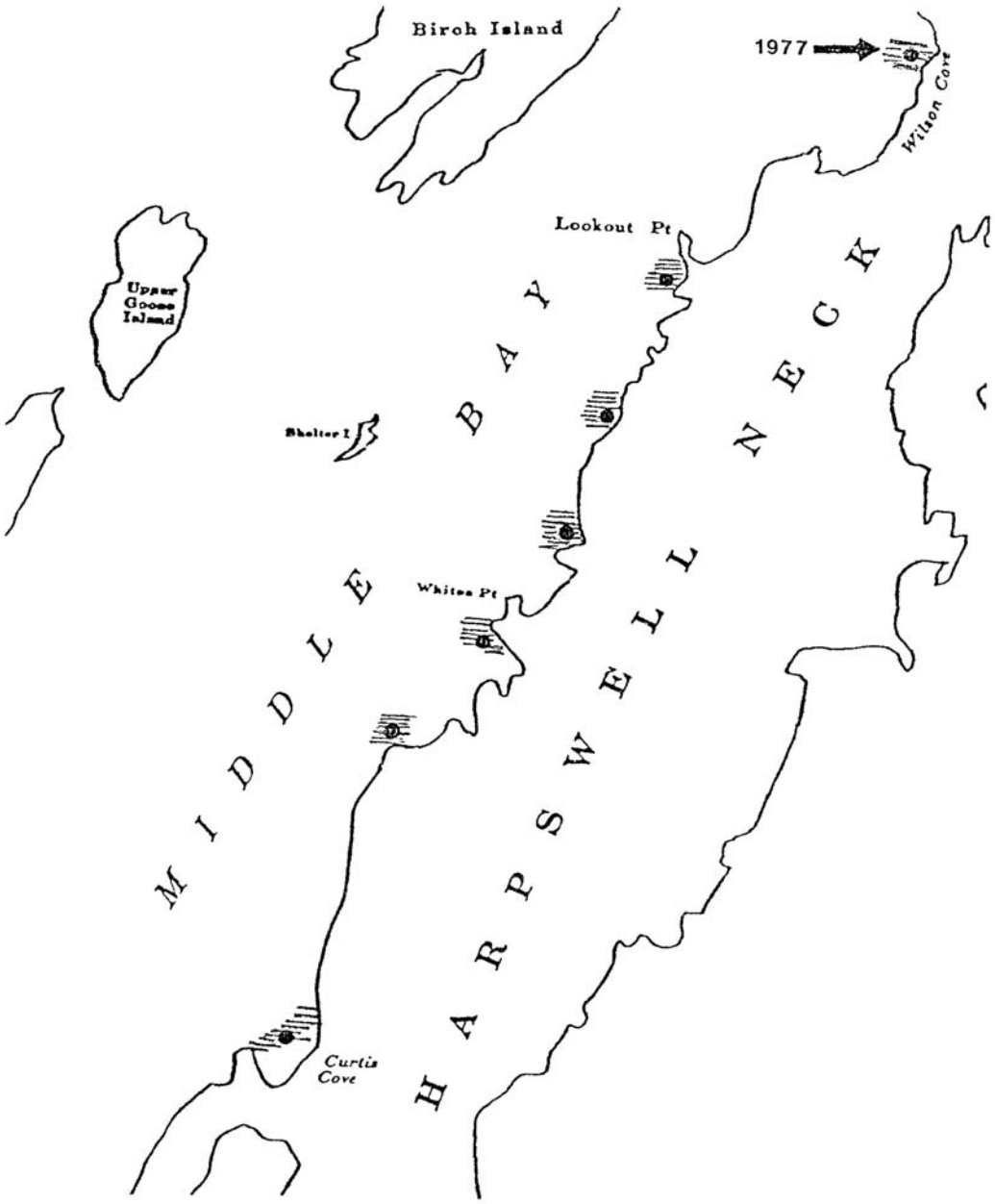
8.11 Horse Island: hard sand bottom with shell fragments between kelp covered ledges; highly exposed area dropping off rapidly - little habitat present; no oysters found; depth -1.0' to -4.0' MLW.

8.12 Cove between Barnes Island and mainland: firm mud bottom with eelgrass and patches of relic shell; oysters found within shell patches; density <1m^2; no 1984 set found; depth -1.0' to -4.0' MLW.
Size sampling: Mean L 82.1mm H 73.3mm S.D. L 25.1mm H 22.4mm

8.13 Peter's Cove: soft mud bottom with mussel beds, no oysters found; depth -1.5' to -8.0' MLW.

Section 9. Middle Bay - Curtis Cove to Wilson Cove

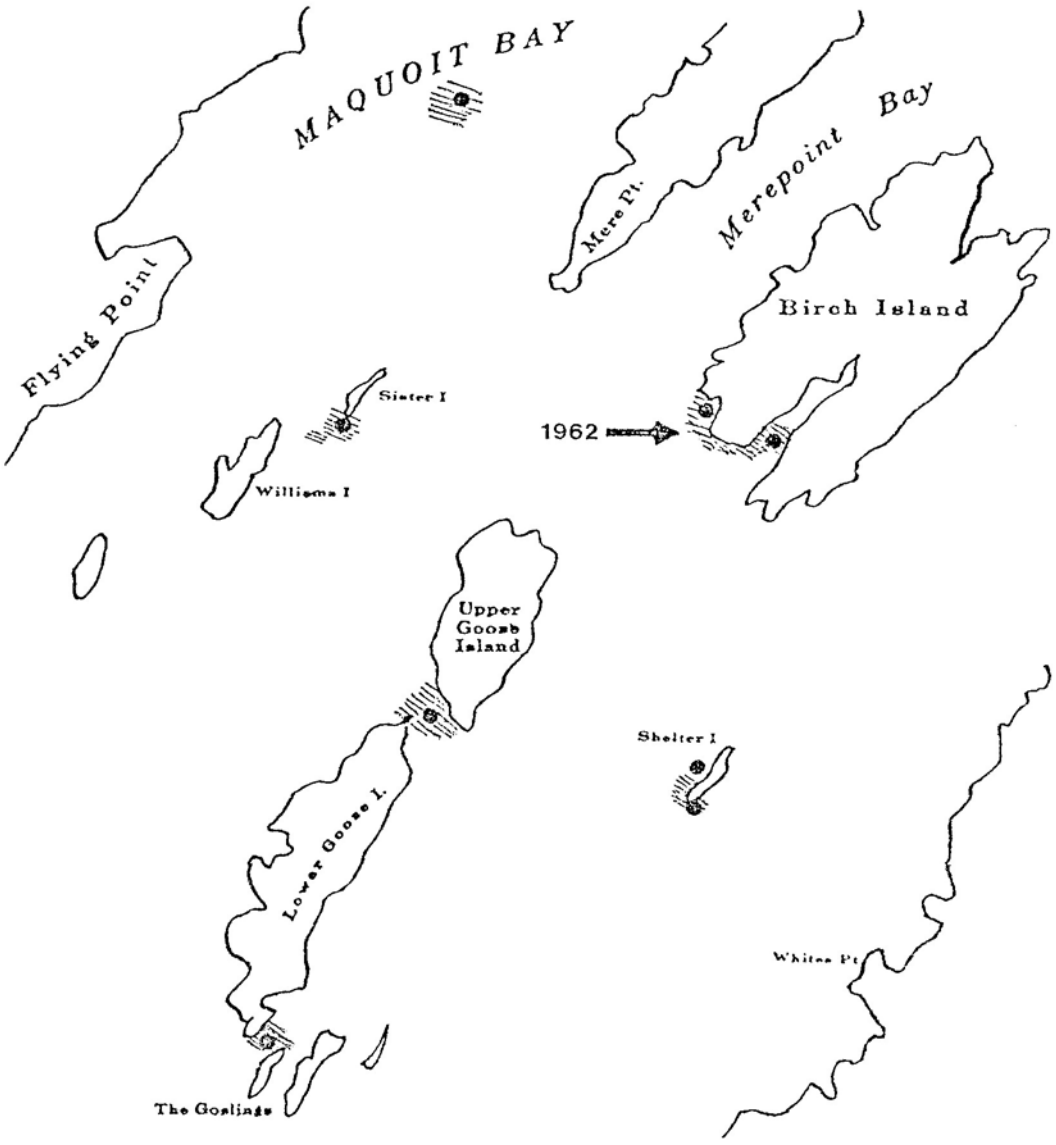
Figure 11. Section 9. Middle Bay, Curtis Cove to Wilson Cove.



All stations along the western shore of Harpswell Neck were found to be devoid of naturally occurring oyster populations. As in Harpswell Sound, many of the areas are not conducive to settlement and growth. There are, however, several small concentrations of oysters which have been introduced into the area by individuals interested in stimulating the expansion of the oyster in Middle Bay. These individuals did allow observations of the oysters to be made but requested that their location not be published. The only exception is the location of INTERTIDE CORPORATION's which is already well known.

Despite the small population which exists in Middle Bay, numerous 1984 set were found on the oysters observed. At Wilson Cove set was also found on relic shell and was the only site within Middle Bay where this was observed. The total population of the Bay is 1,000-3,000 individuals.

Figure 12. Section 10. Shelter Island, Middle Bay to Flying Point, Freeport



No oysters were found anywhere within the area surveyed despite adequate, and in some cases excellent, substrates. European oysters have reportedly been harvested by clamdiggers in the upper Maquoit Bay area which was not covered by this survey, but no evidence of progeny was found. Oysters have also been reported along the mussel beds just north of Flying Point. None of the oysters introduced at Birch Island in 1962 were found and no progeny of recent settlement was observed.

B. Spawning Period and Frequency*:*

The larval index data recorded over the study period is summarized in Table 1 below and Figures 13-16. Note that as of 8-21-84 the sampling station in upper Quahog Bay was changed from Ben Island to Snow Island.

Table 1. Summary of Larval Index Data

Station 1 Quahog Bay

Date	Cond.	Black	Grey	White	Spawned	Total	Total spwn/larv	% Spawned	% Female spwnd
7/10	0	0	4	1	5	10	10	100	50
7/17	8	1	0	1	0	10	2	20	20
7/24	4	2	1	0	3	10	6	60	30
7/31	8	0	0	0	2	10	2	20	0
8/07	2	0	2	0	6	10	8	80	20
8/14	7	1	0	0	2	10	3	30	10
8/21	2	0	0	2	6	10	8	80	20
8/28	7	0	0	1	2	10	3	30	10
9/04	2	0	0	0	8	10	8	80	0

Station 2 Big Hen Island, Ridley Cove

Date	Cond.	Black	Grey	White	Spawned	Total	Total spwn/larv	% Spawned	% Female spwnd
7/10	5	0	4	1	0	10	5	50	50
7/17	7	1	0	2	0	10	3	30	30
7/24	3	0	2	3	2	10	7	70	50
7/31	5	1	0	0	4	10	5	50	10
8/07	9	0	0	0	1	10	1	10	0
8/14	5	0	0	1	4	10	5	50	10
8/21	5	0	0	1	4	10	5	50	10
8/28	4	0	1	0	5	10	6	60	10
9/04	4	0	0	1	5	10	6	60	10

Station 3 Yarmouth Island

Date	Cond.	Black	Grey	White	Spawned	Total	Total spwn/larv	% Spawned	% Female spwnd
7/10	1	1	4	4	0	10	9	90	90
7/17	8	0	1	1	0	10	2	20	20
7/24	6	3	0	0	1	10	4	40	30
7/31	7	0	1	0	2	10	3	30	10
8/07	3	0	0	3	4	10	7	70	30
8/14	4	0	0	0	6	10	6	60	0
8/21	4	0	0	0	6	10	6	60	0
8/28	5	0	0	0	5	10	5	50	0
9/04	6	0	0	0	4	10	4	40	0

Station 4 Gun Point Creek

Date	Cond.	Black	Grey	White	Spawned	Total	Total spwn/larv	% Spawned	% Female spwnd
7/10	4	0	1	3	2	10	6	60	40
7/17	7	0	0	3	0	10	3	30	30
7/24	7	0	0	1	2	10	3	30	10
7/31	7	2	0	0	1	10	3	30	20
8/07	7	0	0	0	3	10	3	30	0
8/14	3	0	0	1	6	10	7	70	10
8/21	4	0	0	3	3	10	6	60	30
8/28	3	0	0	0	7	10	7	70	0
9/04	3	0	0	0	7	10	7	70	0

The spawning record of each station is shown graphically below where the solid royal blue line indicates percent of total oysters spawned and the broken dark blue line indicates percent of females spawned.

Figure 13. Spawning Record - Station 1.

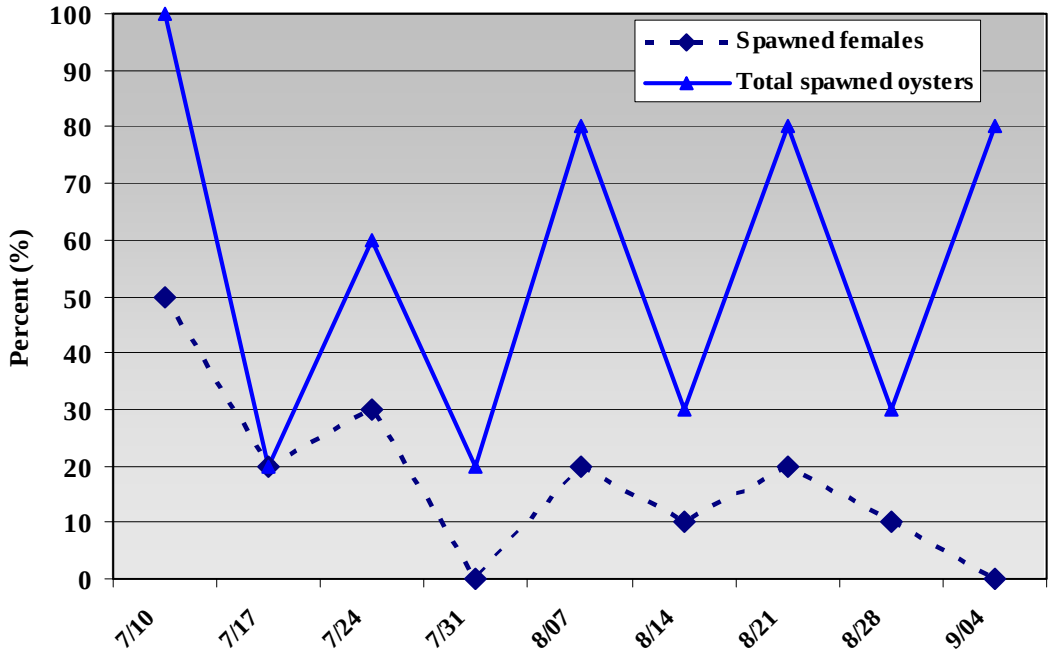


Figure 14. Spawning Record - Station 2.

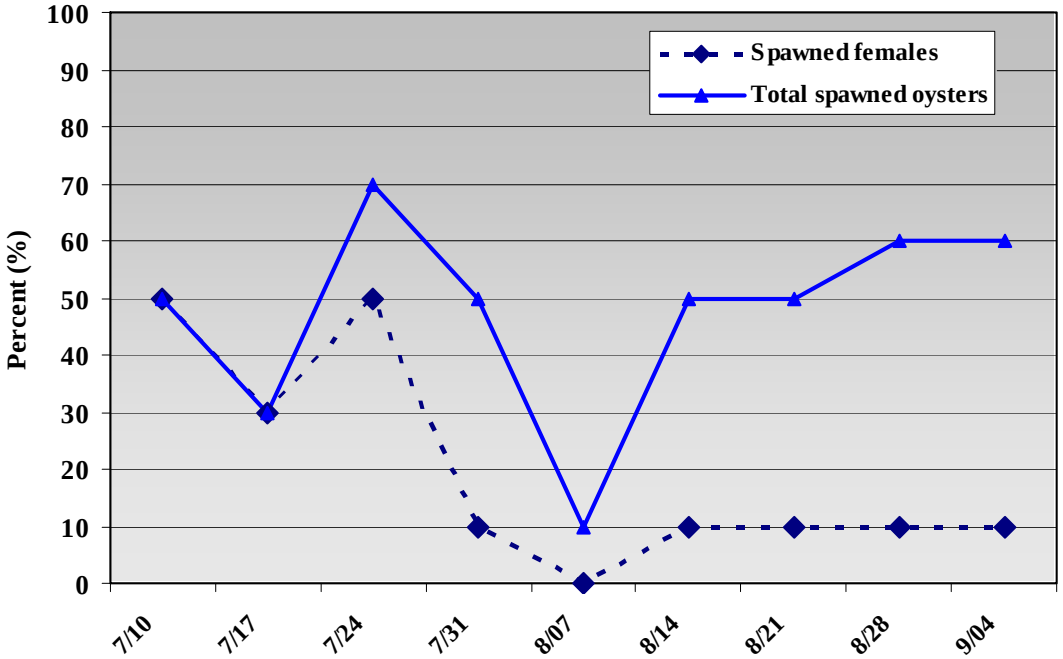


Figure 15. Spawning Record - Station 3.

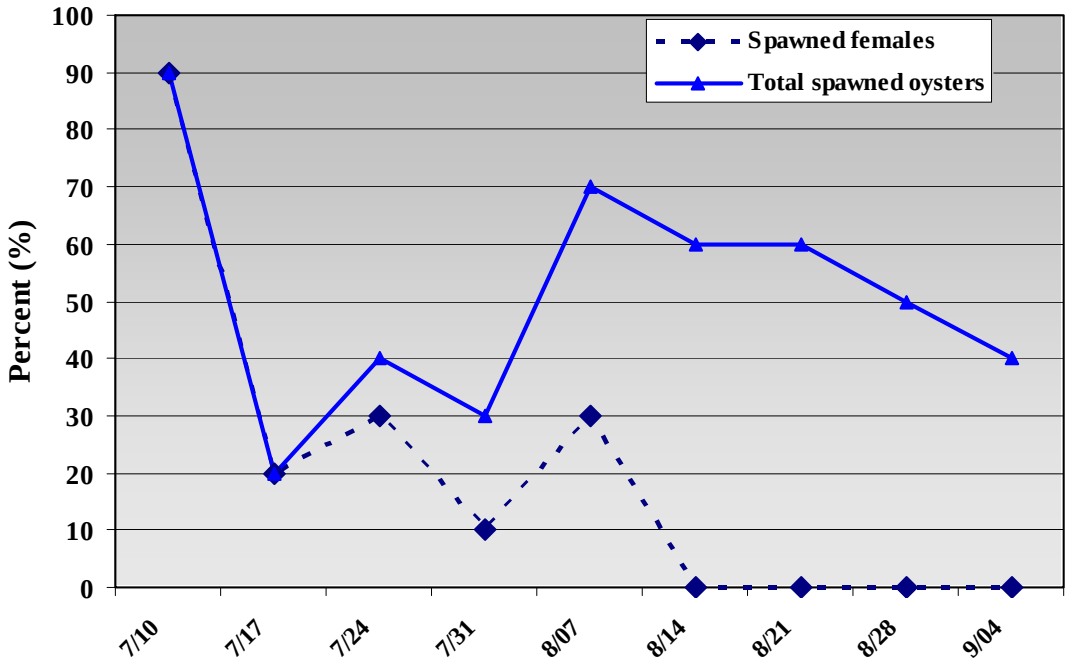
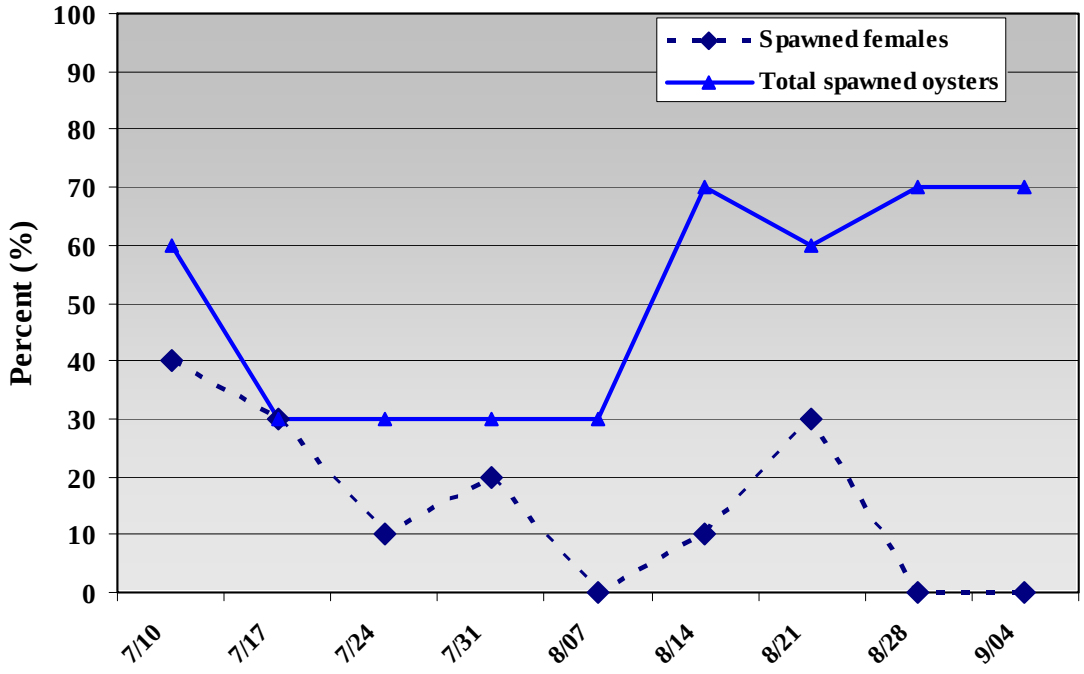


Figure 16. Spawning Record - Station 4.



DISCUSSION

The works of Loosanoff (1955) and Welch (1963), which discuss the original introductions of 1949, showed conclusively that the European oyster, *Ostrea edulis*, was capable of surviving as well as reproducing in Maine waters. However, as late as 1962 the rate of population increase was still very slow causing concern as to whether commercial quantities could ever be expected.

The results presented here show that significant expansion of the original population has occurred and commercial quantities, while limited, have become established. It should be borne in mind that the current study does not attempt to provide a complete assessment of these oyster resources but seeks to shed some light on the habitat occupied by *O. edulis* in Maine and the extent to which it has ranged.

The largest oyster concentrations are located in the Quahog Bay and Yarmouth Island areas, but oysters were found at nearly every dive site within the survey area with the exceptions of Harpswell Sound and Middle Bay. This suggests that larvae, while concentrated around the population center, are widely distributed throughout the area and are able to set and survive provided adequate cultch and favorable conditions exist.

The seaward extent of the population appears to be limited directly or indirectly by exposure to wave action, directly by physical abrasion and indirectly by the effect of wave action on substrate composition and movement. Such conditions are found in the areas of Gooseberry Island, Wood Island and Duck Rock, all three areas being highly exposed. Oysters were found in the latter two areas, but growth was clearly slow. Low temperatures may play a roll in reducing the growth rate in these areas thereby increasing the predator exposure time of juveniles.

A second set of limiting factors affects the distribution of *O. edulis*, in Maine, within its normally acceptable tidal range. Welch (1963) speculated that three possible limiting factors may impede an increase in the population size and range: the reduction of suitable habitat due to exposure of intertidal areas to lethal temperatures below 0^0 C during winter months, the reduced amount of suitable setting substrate as a result of the predominance of soft mud bottom in the subtidal area and the relatively short period during which seawater temperature exceeds 15^0 C, the minimum spawning temperature of *O. edulis*.

Welch (1963) and Loosanoff (1955) reported finding oysters in the 0 - 2 ft. mean low water (MLW) and +1 to +3 ft. MLW range, respectively. No live oysters were found above -1 ft. MLW during the current study and some mortalities were observed in the 0 to -1.5 ft. MLW range, particularly off the northern end of Little Yarmouth Island. There is little doubt that these mortalities are due to coincidental low tides and low, freezing temperatures, for no mortalities were observed below the -1.5 ft. MLW level.

The substrate requirements for *O. edulis* have been described by Cole (1956). The Casco Bay populations exhibit similar substrate preference, with the majority of oysters found on firm mud or sand bottom overlaid with relic shell and small stones. Within the region these substrate characteristics are found predominantly in the areas of moderately strong currents such as in narrow channels between islands or islands and the mainland. Examples of such conditions exist between Bear Island and Malaga Island, Big Hen Island and West Cundy point and Yarmouth Island and Little Yarmouth Island. Some large oysters were found on moderately soft bottoms suggesting that oysters are able to survive on softer substrates provided they are initially large enough or sufficiently fast-growing to avoid being smothered.

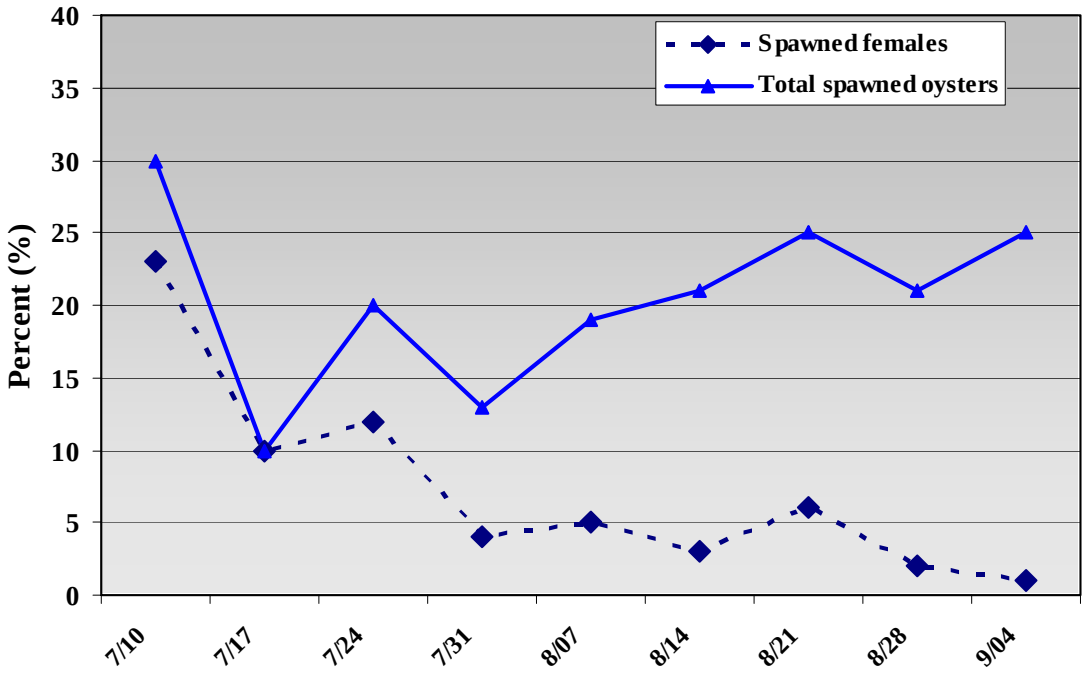
The absence of oysters in Harpswell Sound may be due to the lack of adequate conditions, for the substrate within the Sound is characteristically soft mud with eelgrass overgrowth. In Middle Bay, however, certain areas do exist which provide conditions similar to those found in the vicinity of Quahog Bay. Here, the absence of oyster populations may be due more to the lack of an established spawning population rather than suitable substrate. This is substantiated by the fact that the 1984 year class set was found on several adult oysters observed in Middle Bay even though the spawning population has only recently been introduced and is very small. Similar observations of natural recruitment of set produced from small populations in Maine have been previously reported by Loosanoff (1955).

Temperature undoubtedly plays a major role in determining the initiation and duration of spawning. Korringa (1940) suggested that the spawning temperature of *O edulis* in the Oosterschelde of Holland is between 15^0 to 16^0 C. In Maine the minimum temperature of 15^0 C is normally reached in late June to early July and rarely exceeds 18^0 C before dropping below 15^0 C in early to mid-September. The initiation of spawning in the Casco Bay population seems to follow the suggested temperature of 15^0 C. (refer to Appendix 3.) It is also interesting to note the unusually high temperature of 1979, for it was three years later, in 1982, that the first large quantities of oysters were reportedly observed in the vicinity of Quahog Bay.

O. edulis, as a protandric oyster, regularly alternates between male and female, a characteristic first discovered by Orton (1927) and fully described by Walne (1979). Under normal conditions each oyster would complete two spawnings per year, one as male and another as female. In a study on the spawning of *O edulis* in Maine, Loosanoff (1962) suggested that perhaps only one spawning occurred annually in Maine due to the short, relatively cool summers. He concluded, further, that conditioning began between late April to early May with spawning occurring between the second and third week in July through the end of August. The results of the current study, however, indicate that two spawnings may take place, one in early July and a second during early to mid-August, with the first appearing to be greater than the second, refer to Table 1 and Figures 13-16.

Since histological examinations were not performed on the gonads, only those oysters holding larvae on the gills were considered as females. On the basis of these observations it is interesting to note the predominance of females spawning in early July as compared with mid-August, presumably the time of the second spawn, Figure 17.

Figure 17. Comparison between the combined total number of spawned oysters and total number of spawned females for all four stations



The large proportion of spawning females recorded on July 10 may account for the large number of conditioned oysters found the following week, for according to Walne (1979), a spawned female may develop into a ripe male in a matter of a few days. A predominance of males appears to continue throughout the remaining summer months which may account for the erratic spawning observed in late July and August.

Even though conditioned oysters were observed at the beginning of September, sampling was discontinued since it was questionable whether the larvae from such late spawnings could set and survive the winter in sufficiently large numbers to affect the overall population.

Although not a formal part of the survey, several observations were made on spat settlement during the course of routine sampling. Spat was first observed on adult oysters on August 14 and measured approximately 1-2mm. Thereafter, a conscious effort was made to look for spat at all stations. Spat was subsequently found at nearly all stations where adult oysters were present with the exception of the area between Basin Point and Barnes Island in Middle Bay. Settlement occurred primarily on live oysters but was also observed on other substrates including quahog, mussel and periwinkle shells, stones and even a horse shoe crab carapace.

The areas mentioned earlier as being favorable for growth are, not surprisingly, also the areas of greatest spat settlement. Whether this results from the presence of existing populations or simply favorable conditions is difficult to determine, but it is likely that both are contributing factors

Regardless of the factors at work, the spatfall of 1984 appears to be very heavy. However, since no recent observations have been made on natural settlement in the area it is impossible to say whether this year's set is extraordinary or normal. Furthermore, little information is available on the survival rate of naturally set juveniles over their first winter in Maine. While the set may, in fact, be extraordinary, winter attrition may be very high. This is a subject deserving of further study. As a basis for such work, spat counts and measurements were taken at two stations and are included in Appendix 4. Similar counts and measurements at these sites in the spring of 1985 should provide information on survival.

The extent of the recent spatfall and the existence of commercial quantities of oysters are encouraging indicators that *O edulis* can become and important shellfishery in Maine. However, as demand for the oyster increases so too will the fishing pressure. At present the State of Maine has no regulations pertaining to the harvesting of natural European oyster stocks with the exception of the conservation closure in the Boothbay Harbor area.

Based on the results of this study and interviews with local fishermen, two management recommendations can be made. The first is the establishment of a minimum harvestable size. The implementation of a size restriction would provide the marketplace with a suitably sized product while safeguarding against depletion of the spawning stock. According to Walne (1979) the number of larvae produced by female oysters increases dramatically with size during the first four years as shown in Table 3.

Table 3. Larval/egg production of *O. edulis* as a function of age and size. (After Walne, 1979)

Age in years	Mean size (mm)	Number of larvae
1	40	100,000
2	57	540,000
3	70	840,000
4	79	1,100,000
5	84	1,260,000
6	87	1,360,000

Once the oyster reaches approximately 85mm the rate of larval production rate of larval production rapidly drops off. It is therefore suggested that the minimum size limit be set in the 85-90mm range so that full advantage might be taken of the reproductive capacity.

Secondly, it is recommended that harvesting be prohibited during the full spawning season, from April or May through October. A closure for this period would include maturation through settlement and would not only provide protection for the spawning stocks but also for the habitat. This is particularly important during the settlement and early juvenile period, for *O. edulis* is less capable of handling heavy silt loads than are other species of shellfish.

Consideration should be given to the question of artificial cultching. Several techniques used throughout the world are discussed by Bardach (1972). Many of these techniques are applicable in Maine and could be used by both the private and public sector in developing bottom culture methods and assisting the natural spread of the species.

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