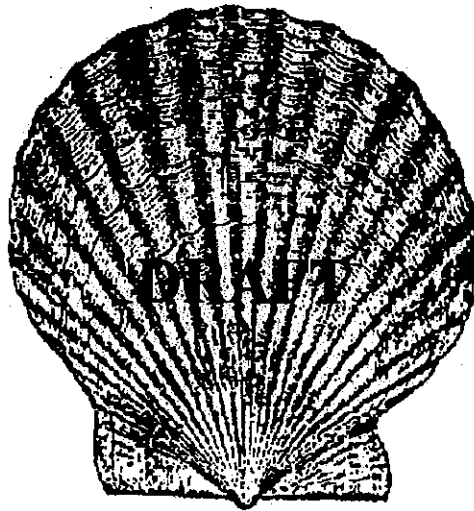


BAY SCALLOP RESTORATION

WESTERN PECONIC BAY

PROJECT REPORT



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V. INTRODUCTION

Bay scallops, *Argopectin irradians irradians* (Lamarck, 1819), have historically been an important marine resource in New York. This species supported a commercial fishery conservatively estimated to annually produce over 300,000 pounds of meats (Figure 1) worth in excess of \$1 million. This fishery occurs on the East End of Long Island and for the most part in the Peconic Bay system (Figures 2, 3 and 4). The landed value of the bay scallop fishery contributed over \$4 million dollars each year to the regional economy. Of equal importance were the hundreds of jobs supported by this fishery between September and March every year. During this time scallops were traditionally harvested by baymen using dredges pulled behind small outboard powered skiffs. It was normal to see hundreds of boats on the scallop grounds on opening day. Unfortunately, this fishery was virtually eliminated after the brown tide events of the mid to late 1980's. During this time landings fell from an average of 318,400 pounds of meats for the period 1970-1984, to 300 pounds of meats in

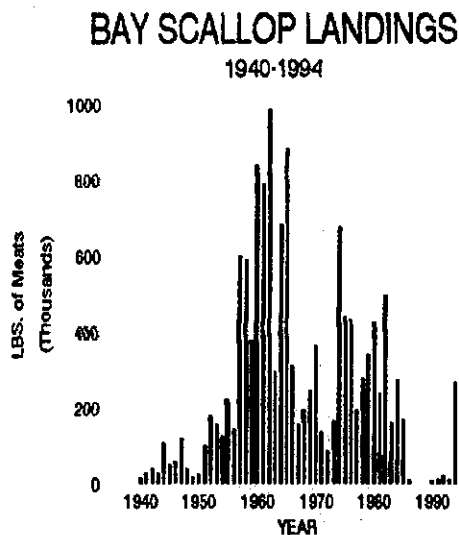


Figure 1. Bay Scallop Landings-NY

1987 and 1988. By 1992, the fishery had only barely recovered to 24,518 pounds of meats. [Authors note] In 1994 the fishery experienced its first significant harvest since the brown tide. Landings of bay scallop meats for 1994 were over 270,000 pounds of meats with a landed value of over \$1.7 million. These landings were just slightly below the average harvest from 1970-1984 of 318,400 pounds of meats. [End note] For the most part, the recovery of bay scallop stocks has been confined to the eastern range of the Peconic system. Historically, the western Peconic system has been a major producing area for bay scallop landings, however this area has not experienced recovery of bay scallop populations since the first brown tide bloom in 1985. In an effort to begin repopulating the western Peconics with bay scallops, this project focused on a restocking program for that area.

V.1. PROJECT OBJECTIVE AND GOALS

The major objective of this project was to create a spawning stock of bay scallops in Flanders Bay for the Spring/Summer spawning of 1994. The goals of this project were:

- 1- to plant hatchery reared and natural set scallops in Flanders Bay,
- 2- to evaluate and compare survival of the two groups of planted scallops,
- 3- to compare temporal patterns of spawning in the scallops transplanted to Flanders Bay with those from the area from which the scallops were obtained,
- 4- to investigate recruitment in Flanders Bay via deployment of spat collectors.
- 5- to compare survival and spawning of hatchery reared and natural scallops held in enclosures in Hallocks Bay, and

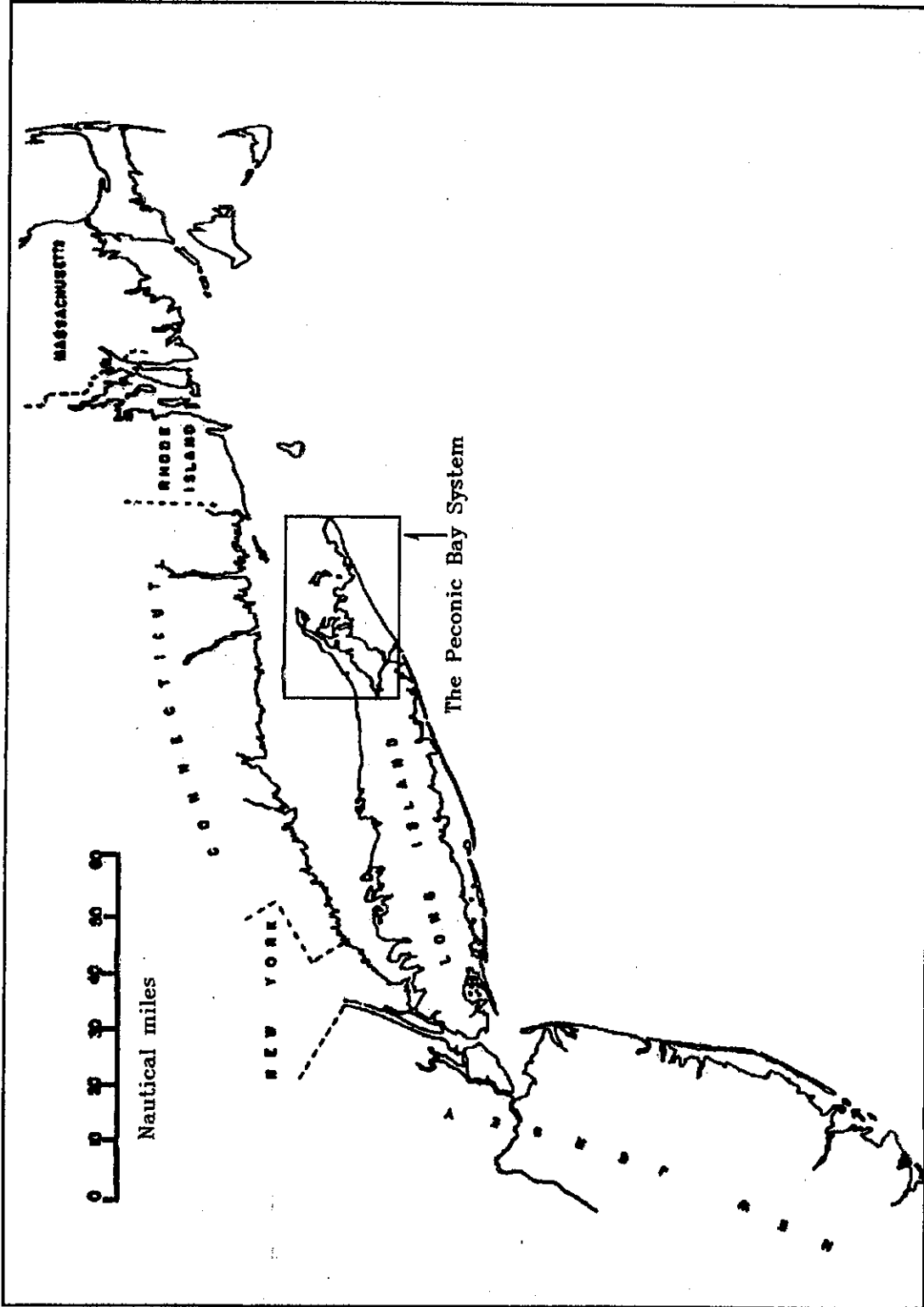


Figure 2. Peconic Bay Location

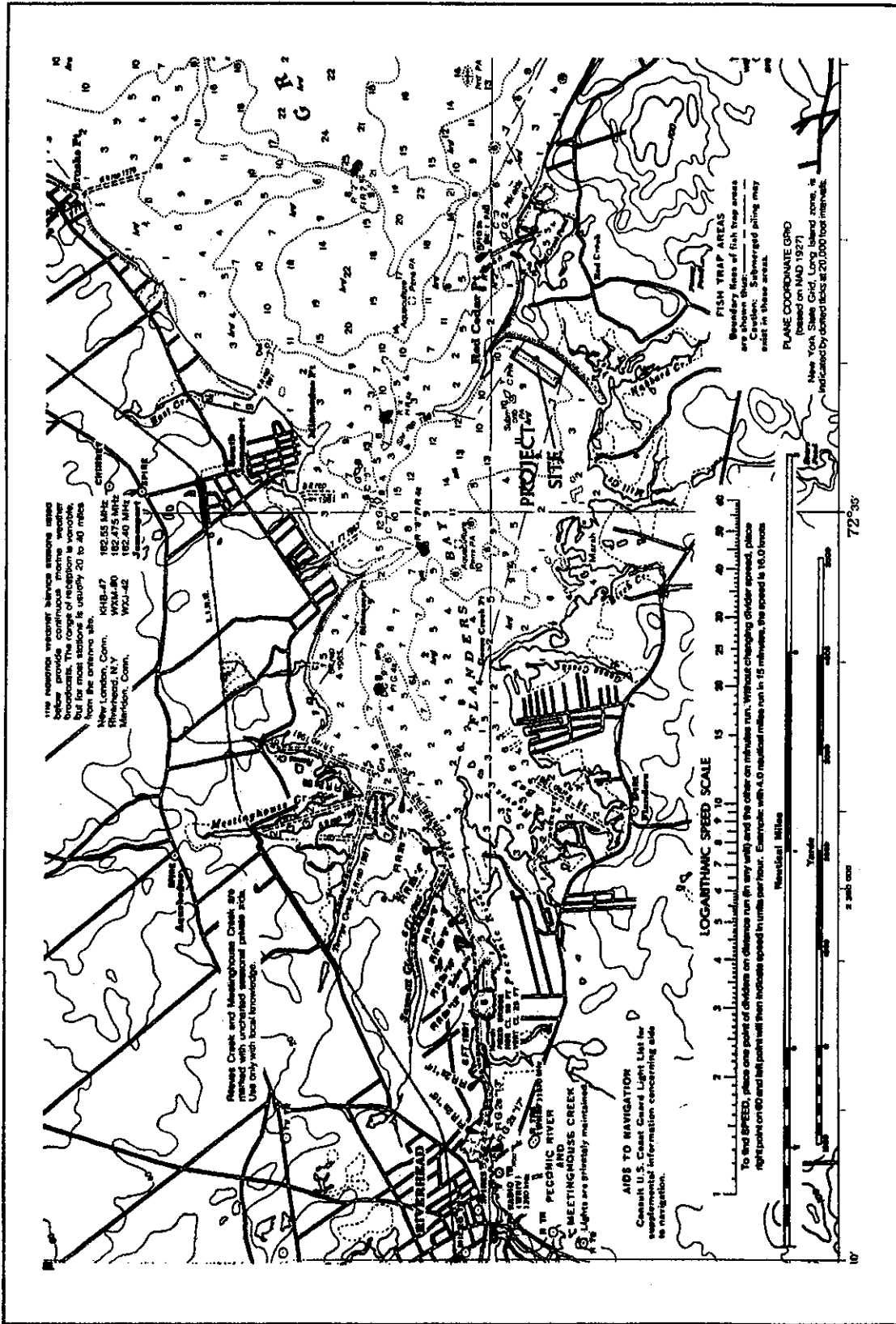


Figure 3. Project Site Location in Flanders Bay, New York.

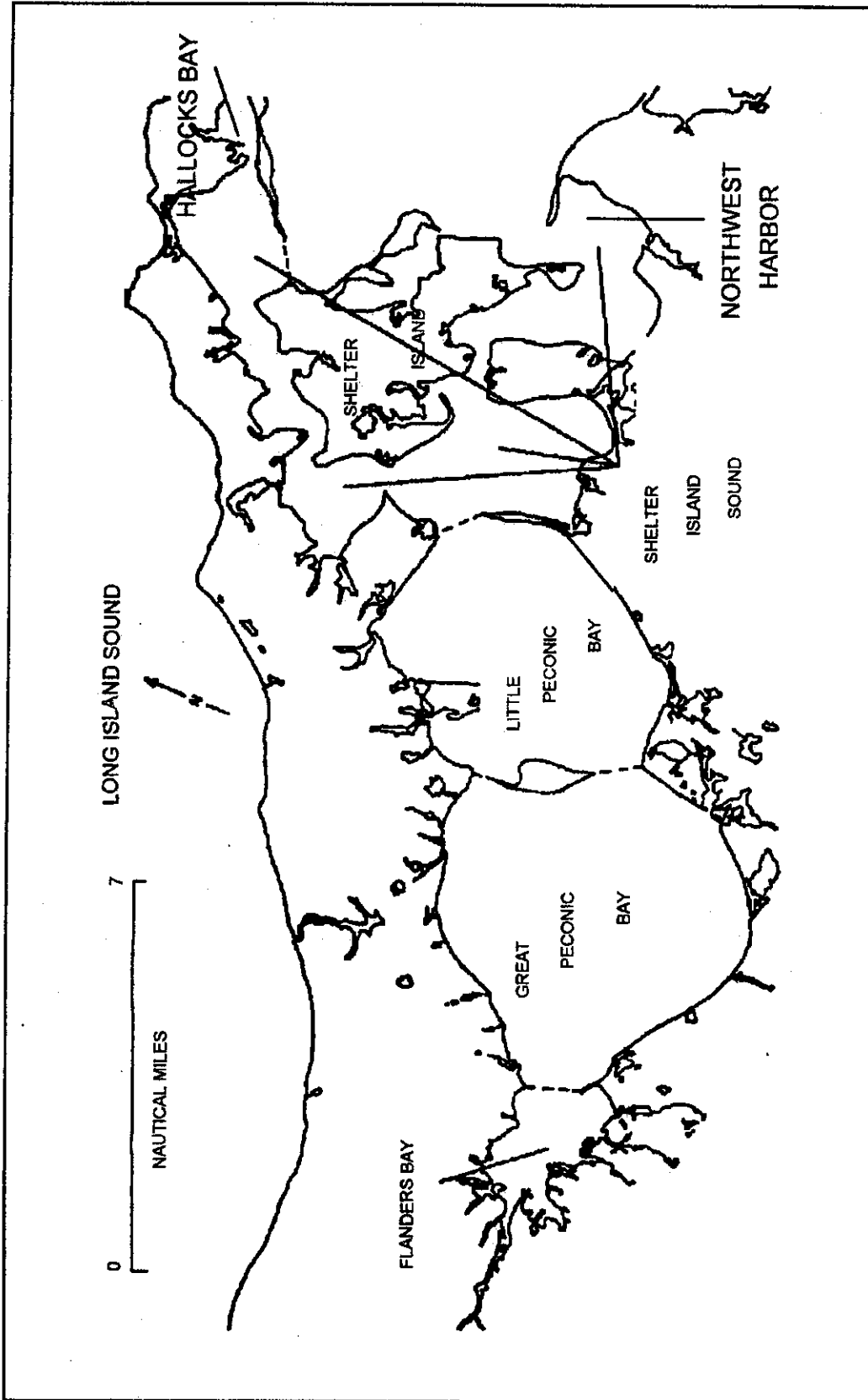


Figure 4. Peconic Bay Geographic Features

VI. BACKGROUND

VI.1. The Brown Tide

The brown tide is comprised of an exceptionally large bloom of the phytoplankton species *Aureococcus anophagefferens* (Sieburth *et al.*, 1988).

This organism (Figure 5) is approximately 2 microns in diameter and is capable of reproducing every 3-8 hours (Casper *et al.*, 1987). This fast doubling time can quickly lead to bloom concentrations of 1-2 million cells per milliliter, as occurred during the brown tides of 1985, 1986, and 1987. The effect of these blooms on the Peconic Bay system was catastrophic. Large expanses of eelgrass were lost due to the shading effect of the dense bloom (BTCAMP, 1990). Bay scallops, mussels, and oysters died after exposure to bloom conditions. The tourism industry was devastated, as few people enjoyed recreational activities in coffee colored water. The overall economic loss to the East End economy was extensive. Research on the brown tide organism in the laboratory and in the field began in earnest in 1986, and is continuing. Although a great deal has been learned about the brown tide organism (Casper *et al.*, 1987; Tracey, 1988) and its impacts on the marine ecosystem, to date, the reason for its sudden appearance and reoccurrence remains a mystery. However, the bloom's impact on bay scallop populations is no mystery and can be clearly seen in Figure 1. In order to understand why the bay scallop is particularly vulnerable to this bloom, knowledge of the scallop's life history is useful.

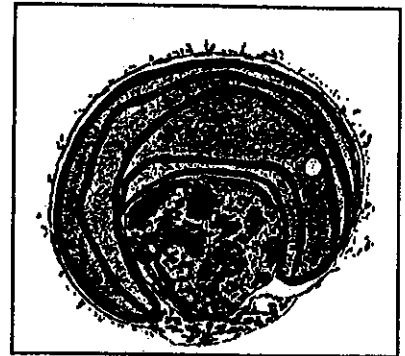


FIGURE 5. *Aureococcus anophagefferens*

VI.2. Bay Scallop Life History and the New York Fishery

Bay scallops commonly live to an age of 20 - 26 months old (Belding, 1910). During their lifetime, the majority of individuals live to spawn but once, at an age of 10-16 months. (Bricelj *et al.*, 1987). Spawning usually occurs in late spring as water temperatures rise. Due to the presence of ripe gonads, some feel that there may be a smaller spawn during the fall months. Although the fall spawn would be less intense due to the smaller numbers of ripe gonads, it would nevertheless be important if the spring spawn had failed. On Long Island, it is thought that the 1992 fishery was entirely individuals spawned during the Fall of 1991. Fertilization of eggs is external in the water column. Following fertilization, larvae drift in the water column for about 7 to 14 days. During this time the scallop develops a minute shell and eventually settles to the bottom where it attaches via byssal threads to a variety of substrates. Figure 6 illustrates the scallop's life history progression. Since the majority of scallops only spawn once, their populations are usually highly volatile. Each year class is almost entirely dependent on the spawning efforts of the year class before it. Should the spawning effort of an entire year class be lost the population will cease to exist a year later

unless larvae drift into the area from distant locations. The brown tide brought a million dollar fishery to its knees by doing just this. Figure 1 shows quantitatively what happened to the fishery. Commercial bay scallop landings in New York decreased from 500,300 pounds of meats worth \$1.8 million in 1982 to approximately 300 pounds of meats in 1988 worth \$2,375. These landings were mostly from Napeague Harbor, a small embayment near the eastern extreme of the Peconic system. For all practical purposes the bay scallop had been eliminated from the Peconic system by Fall 1988. The brown tide impacts bay scallop populations in three ways; 1) by causing mortality of the planktonic larval stage (Gallagher *et al.*, 1989), 2) by causing direct mortality of adults (Tracey, 1988; Bricelj *et al.*, 1989; Gallagher *et al.*, 1989) and indirectly, 3) by causing shading and subsequent die off of eelgrass, the scallop's preferred habitat (Casper *et al.*, 1987; Eckman, 1987; Pohle *et al.*, 1991). Bay scallop reseeding programs were initiated in 1986 in order to begin repopulation of bay scallop stocks in the Peconic Bay system.

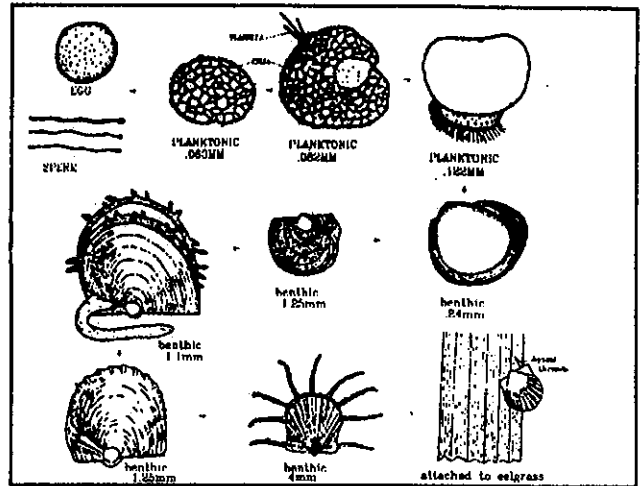


Figure 6. Bay scallop life history (Belding, 1910; Sastry, 1965).

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VI.3. History of Reseeding Programs in the Peconic Bays

Tettelbach and Wenczel (1993) review the history of reseeding of bay scallops in the Peconic Bay system. Bay scallop reseeding began in 1986. Reseeding programs were conducted by the individual town governments as well as by State and County entities. The most extensive reseeding program was carried out by the Long Island Green Seal Committee (LIGSC) with funding from the State of New York and Suffolk County. The LIGSC is an Island wide association of baymen's groups established during the early 1980's to deal with resource enhancement and shellfish marketing opportunities. Wenczel, et al., 1993 discussed in detail the results of LIGSC reseeding activities from 1986 to 1992. This project utilized many of the techniques and approaches developed in the Green Seal initiative. These related to site selection and layout, transportation, packaging, planting density and monitoring. During the Green Seal project, Krause (1992) performed electrophoretic analyses of tissue proteins from 1989 Peconic Bay seed, 1988 planted seed, and 1988 natural stock and concluded that 25% of the natural scallop set in 1989 resulted from spawning of Green Seal planted scallops. These results have provided the justification for continued seeding programs.

Also of note are the bay scallop transplant programs that have occurred under supervision of the NYSDEC. In these programs, pre-adult scallops are transplanted in the Spring before they spawn. These transplant programs have occurred for many years,

primarily supplying more western waters such as Great South Bay and others with spawning stocks of scallops. These type of transplants have also been periodically conducted within the Peconic Bay system.

VII. METHODS

VII.1. Selection of Planting Site

VII.1a Selection Criteria

The identification of areas of bay bottom suitable for planting seed is a critical component to a reseeding program. The present state of the art of this endeavor is poor at best. This is because of the poor understanding of the cause and effect of the abundance and distribution of marine organisms, in this case the most important being predatory crabs. The success of a seed planting program is contingent on successfully evaluating the physical and biological parameters that characterize an area of bay bottom. One of the most important sources of information on bay bottom characteristics are the baymen that work the area. Areas that have historically produced harvests of bay scallops are good candidates for future seed plantings. The site selection criteria used to identify suitable planting sites for this project were:

A. Historic Productivity - Trends and locations of scallop populations are known by baymen throughout the Peconics. Site selection for placement of hatchery produced scallops and transplanted scallops took into account typical locations where scallops had been found in the past.

B. Predator Populations - Site selection also took into account the type, abundance and distribution of predators. Potential predators such as rock, green, blue, lady, horseshoe, mud and spider crabs, and starfish and whelks exist in the Western Peconic Bays. Surveys for these species were made as part of the site evaluation process.

C. Overwintering Survival - It is widely known that waves and tides can sweep scallops up on the beach in large quantities. Site selection took into account wind direction and fetch as it related to water depth.

D. Habitat - Presence of macrophytes and other structure (e.g. shell material) that provide relief on the bottom are believed to increase the survival of bay scallops. Also considered in the habitat evaluation was water depth, sediment type and bathymetry.

E. Presence of Commercial Activity - Navigation channels and other commercial activities such as clamming and trawling were avoided.

F. Research Information - In 1986, the State University of New York undertook a project to evaluate sites for the transplant of bay scallops in the Peconic-Gardiners Bay system based on a computer simulation of larval drift (Siddall *et al.*, 1986). Newly formed bay scallop larvae typically spend 7-14 days in the water column (Belding, 1910). During this time they are transported by water circulation within the estuary. Consideration of this movement is important in the seed planting process if the purpose of seed planting is to create spawner sanctuaries. There would be little or no direct benefit from a reseeding program if the larvae were transported out of the area targeted for repopulation. For this reason some level of consideration of larval dispersion must be made prior to selecting a sanctuary site.

In this program a numerical model of larval dispersion was used to evaluate proposed sites selected by the Green Seal Program, namely Flanders Bay, Northwest Harbor, and Orient Harbor (Siddall *et al.*, 1986). This study concluded that Flanders Bay was the location resulting in the greatest retention of larvae to the Peconic system. Furthermore, it was determined that in order to establish settling larvae in Flanders Bay, it would be necessary to place spawning scallops in Flanders Bay. This is because the west to east direction of tidal circulation in Flanders Bay precludes larvae from entering the system from the east where bay scallops had been reestablished. Using this information and established goals and knowledge of the environment, field activities were begun.

VII.1b. Reconnaissance of Prospective Field Sites

The western Peconic Bay system is comprised primarily of an area called Flanders Bay. Flanders Bay is that portion of the Peconics that lies westward of an imaginary line from Red Cedar Point on the South shore to Simmons Point on the North (Figure 3). Flanders Bay ends to the west at the mouth of the Peconic River. Flanders Bay is generally shallow, with most water depths less than 10 feet. Large areas of Flanders Bay are less than 6 feet deep. A wide variety of bottom types exist in Flanders Bay. Hard sandy bottom is the predominant type, but in deeper waters mud predominates. Often, bay scallops survive in the transitional areas between these bottom types on slopes of bottom starting at 5 feet and sloping downward to 10 feet. These areas often contain beds of shell and shell fragments (called shell hash) that serve as a protective nursery for scallops. Most commercial landings of scallops in Flanders Bay were from these areas. Prior dive surveys of bottom types and characteristics during the Green Seal project enabled quick application of the following site selection criteria.

Potential scallop planting sites in Flanders Bay were investigated through a series of SCUBA dives made between 4 October - 8 November 1993. Observations were made of the bottom type (sediments, presence of shell hash, macroalgae), predator and bay scallop populations. Four of the six areas surveyed were ruled out immediately because the bottom type was not considered suitable and/or the predator populations were deemed too high. The bottom just to the east of Goose Creek Point (Fig. 3) was largely bare sand; very high concentrations of starfish (*Asterias forbesi*) were present. The area between Simmons and Miamogue Points was virtually all bare sand. The area just north of the mouth of Mill Creek was bare sand at a depth of 1.5 m, then dropped off quickly to a soft silt bottom at 3 m. The area to the SW of the mouth of Reeves Creek dropped off rapidly from a narrow band of hard bottom to soft silt at 2 m depth. At least one natural scallop seed was observed at each of the above sites except off Goose Creek Point.

The two sites which showed the greatest promise for scallop seed planting were off Indian Island, outside the mouth of Meetinghouse and Terry Creeks, and the area to the South of Red Cedar Point (Fig. 3). The former area supported a dense cover of macroalgae, including *Codium*, *Ulva* and *Gracilaria*, and live *Crepidula*. Several scallop seed were observed here; these averaged 34.4 mm in shell height. This site was eventually ruled out because the preferred planting area was a rather narrow band near the shore, which dropped off to soft silt to the south. The bottom to the south of Red Cedar Point was bare

sand inshore, which dropped off to a sandy-mud bottom with considerable cover of shell hash, *Codium*, *Gracilaria* and other macroalgal species. The preferred planting area here was just offshore of or on the slope, but the bottom had a fairly good cover of shell hash even out to 100 m further offshore. While the bottom became somewhat muddier offshore, it was not very soft and it did support a low density of natural scallop seed. During the course of two dives at the Red Cedar site few predators were noted: 3 lady crabs (*Ovalipes ocellatus*) and ~ 15 starfish. Our main concern with this site was the potential for scallop stranding on the beaches due to NW winds in the winter. However, we felt that the sharp slope from the planting depth of 2.5-4 m up to the sand flats inshore would likely minimize that possibility. Mario Carrera, a local bayman who had worked this area for bay scallops in years prior to the brown tide, cited an historical lack of stranding in this area. The fact that this area also supported the highest concentration of natural seed we had seen in our surveys of Flanders Bay helped us to decide on this site as our planting site.

On 18 November 1993, the site to the south of Red Cedar point was buoyed off in preparation for scallop planting. A corridor 40 ft wide and 1300 ft long, which ran along the drop-off in a N-S direction and roughly paralleling the shore, was marked with 22 buoys. Buoys were placed along both the inshore (east) and offshore (west) sides of the site, at intervals of every 130 ft. Thus, the site was divided into 10 sections, each measuring 40 ft wide by 130 ft long. Buoy lines were tied to cinder blocks with enough scope so that the inshore set (8-9 ft deep at MLW) and the offshore ones (10-12 ft deep at MLW) were visible at high tide.

Natural bay scallop seed concentrations at the study site were quantified on two occasions prior to the planting of hatchery seed. On 15 October 1993, counts of scallops in five $1/4 \text{ m}^2$ quadrats revealed a mean density = $2.4 \text{ scallop seed/m}^2$, with a standard deviation (SD) = 3.6. Measurements of 29 scallops collected at the site gave a mean shell height (tangential distance from the tip of the umbo to the ventral margin) of 32.7 mm, SD = 3.8. On 8 November 1993, 20 $1/4 \text{ m}^2$ quadrats were randomly sampled in the study area; mean scallop density was $0.8/\text{m}^2$; SD = 2.1.

VII.2. Seed Scallop Planting and Monitoring Protocol

Transplanted and hatchery produced scallops were planted according to the following protocol, developed as a successful technique by the Green Seal Committee. During site selection the area of bay bottom suitable for placement of seed is defined. In some cases this area is quite large, as in a large eelgrass bed. In other cases such as a shell bed drop off, the area might be along an edge and therefore be long and narrow. It is important to know the size of the plantable bottom. This will determine the number of seed that can be placed on this bottom at a target density. For this project we chose a target density of 5 per square meter. During the Green Seal plantings this density seemed to provide for better survival and did not appear to attract predators. Also, this density is reflective of those that commonly occur on natural bottom. Knowing the total number of scallops harvested it is possible to calculate the required area needed to receive the seed at the predetermined density. For this project, we established grids on the planting site the day before harvesting activities. Our grids were 130 feet by 80 feet. These were the dimensions of the shell bed

drop off established as our planting site at Red Cedar Point. Twelve grids (only 7 were used) were created using lobster pot buoys at the corners of each grid. Two methods were used to determine distance between buoys. The first was accomplished by a diver using a tape measure, and the second approach used a range finder. Planting commenced once the grids were established and harvesting occurred. Knowing the number of scallops in each burlap bag, it was possible to calculate how many grids this number would cover. By directing the boat to cover the entire site it was possible to come close to the desired density. Planting took four people to complete the job.

VII.2a. Harvesting, Transporting and Planting Activities

The primary purpose of this project was to establish spawning stocks of bay scallops in Flanders Bay by transplanting naturally set and hatchery produced scallops. As previously mentioned, this technique had been used in the past as a management tool by resource agencies.

VII.2b. Planting of Scallop Seed - Fall 1993

Hatchery seed were produced at the Town of East Hampton Shellfish Hatchery in Montauk, New York. These seed were contributed to this project by the NYSDEC which had control over this portion of the East Hampton production. The seed used for our planting in Flanders Bay were reared in the hatchery and then grown out in 6 mm mesh pearl nets in Three Mile Harbor, East Hampton, New York. On 19 November 1993, scallops were removed from nets and estimates of the total number of scallops in two size groups (small and large) were made volumetrically. A total of 40,496 scallops was obtained: 26,654 "small" seed and 13,842 "large" seed (see below for sizes).

After counts had been made, scallops were placed into coolers with chill packs and moist burlap bags and transported to the Marine Station at Southampton College of Long Island University. Here, 3000 "large" scallops were placed into pearl nets (at a density of 100 scallops/net) and hung off the docks. These scallops were held here for later use in the comparative growth/reproduction studies in Hallock Bay. At the time of this transfer, the scallops showed no signs of gaping or other indications of poor condition; air temperature was 53 F and skies were overcast.

Scallops were then taken by car to a boat in South Jamesport and then brought to the Red Cedar Point site, ~ 4 km to the southwest, for planting. At the planting site, a representative sample of both the "large" and "small" groups was measured to the nearest mm with calipers. Scallops in the "small" group averaged 25.4 mm, SD = 3.0, n=100; the range in shell height was 18-35 mm. Individuals in the "large" group averaged 28.0 mm, SD = 4.1, n = 101; the range in shell height was 18-45 mm. Planting was accomplished by transiting north and south across a given 40 ft by 130 ft section of the site, tossing scallops by hand off both sides of the boat. The target planting number for each section was ~ 4687; this worked out to a planting density of 9.7/m² (roughly 1 scallop/ft²). (This density is slightly higher than the planting density of $\leq 6/m^2$ recommended for seeding of *Mizuhopecten yessoensis* in Japan (Sekino, 1992). We attempted to plant the scallops as evenly as possible, so each section was transited several times until the appropriate number of scallops was

planted. Overall, eight 40 ft by 130 ft sections at the site were planted with a total of ~ 37,500 seed: 26,654 and 10,842 from the "small" and "large" groups, respectively. All scallops were planted by 1530 hrs, approximately 7 hrs after they were taken from the nets at Three Mile Harbor.

VII.2c. Monitoring of Scallop Seed Planted in Fall 1993

The survival and condition of planted scallop seed were monitored on 19 November 1993 (the date of planting) and on a weekly basis for the next month. Sampling after this was more infrequent because of severe winter conditions (described below). Monitoring was accomplished by one or more divers on each date. Counts were made of the number of live scallops and dead scallops which still had both valves attached at the hinge (cluckers) which were present in 1/4 m² quadrats. Quadrats were placed randomly on the bottom by divers after swimming for varying distances with their eyes closed. For the first five sampling dates, 10 quadrat counts were made in each of the 8 sections of the site which had been planted with scallop seed. Changes in scallop density over time were used as a relative indication of survival; it was assumed that missing scallops were dead. The virtual absence of any hatchery seed from bottom areas immediately inshore and offshore of the buoyed sections, as determined through periodic observations, suggested that little movement of planted seed was occurring. In fact, while completing dive surveys it was often possible to determine underwater that one had crossed beyond the border of a given section because there was a sudden absence of scallops. Where possible, hatchery-reared scallops were differentiated from natural scallops. This was done on the basis of the frequent, heavy growth checks which are common in hatchery scallops but relatively rare in natural scallops.

After 15 December 1993, the weather turned progressively colder and by 28 December, the Red Cedar Point site and most of Flanders Bay were iced over. Because the planting site was only easily accessible for diving by boat we were forced to wait until the ice broke up. This did not occur until March 1994. Quadrat counts were made at the planting site on 25 March, then discontinued due to an almost total absence of scallops at the site.

VII.2d. Scallop Seed Planting - Spring 1994

Diver surveys of several areas were conducted to establish potential donor sites. This was important because it was not the intention to deplete a donor site known to possess good concentrations of scallops. After several surveys it was decided to use Northwest Harbor as the source site. Scallops were harvested on two days, April 25 and May 1, 1994. These seed were collected with permission from the NYSDEC and a scientific collectors permit. Seed were harvested over a two day period by a commercial baymen from a vessel equipped with 8 dredges. The seed collected were enumerated volumetrically. Seed were placed in burlap bags and protected from the sun by a tarp. Desiccation of seed was prevented by frequently bucketing water over the burlap bags. Scallops were transported to the site via boat and were planted according to the previously discussed protocol.

A second planting of juvenile scallops was done during Spring 1994. The two primary reasons for this activity were that the Fall 1993 planting was far short of the planned

planting of 100,00 scallops due to the difficulties which were encountered in growing scallops by local hatcheries and because the poor survival of the Fall 1993 planting meant that there was little likelihood of a successful spawning of adult scallops in Flanders Bay during 1994. After receiving permission from the Shellfisheries Division of the New York State Department of Environmental Conservation to collect juvenile scallops from natural populations in state waters, the decision was made to collect natural seed in the Northwest Harbor area with scallop dredges. Peter Wenczel, an experienced commercial scalloper, was contracted to collect the scallop seed and to transport and assist in the transplantation of the scallop seed in Flanders Bay.

The first of these transplanting activities occurred on April 25, 1994 when 25,000 scallops with a mean ($n=100$) shell height of 49mm ($SD=4.4$) were transplanted to three buoyed areas (130'x 40'). The second transplanting activity occurred on 1 May 1994 when 25,000 scallops with a mean ($n=100$) shell height of 51.2mm ($SD= 4.3$) were transplanted to three buoyed areas (130'x 40'). Thus six areas, each having dimensions of 130'x 40' were created to receive transplanted scallops. These areas were delineated using a tape measure and range finder. Verification of bottom type enclosed was completed by SCUBA dives and some minor adjustments were made to buoy locations. Scallop seed were transported from the collection site in Northwest Harbor to Flanders Bay by boat. Scallops were held in burlap bags which were kept moist throughout the transplanting period. A half bushel wire basket was used as a unit of measure for counting numbers per bag.

On 9 June 1994, an additional scallop planting was done in a 130 x 40 ft area at the Red Cedar site just to the south of where the main Spring transplant was conducted. These scallops, which had primarily been collected from natural populations in Shinnecock Bay during Summer-Fall 1994, had been overwintered at the Southampton College Marine Station on Old Fort Pond, Southampton. Measurement of a subsample of 165 individuals on 8 June revealed that the mean size of the scallops was 38.3 mm ($SD=5.6$). The target planting density was $\sim 7.8/m^2$. Scallops were monitored at the same time as those transplanted from Northwest Harbor, but no assessment was made of their reproductive condition.

VII.2e. Monitoring Spring 1994 Transplant

Dive surveys to monitor the survival and reproductive condition of transplanted scallops were made approximately every 2 weeks after the last scallops were transplanted on 2 May 1994 until the end of August. During the 8 dives made on the Red Cedar site during this period, counts of live scallops and cluckers were made in 10 1/4 m² quadrats in each of the 40 x 130 ft sectors which had been planted. Methods were the same as for the monitoring of the Fall 1993 plantings.

Reproductive condition of scallops was assessed from samples taken on 29 April 1994 from the Northwest Harbor collections and from samples collected at the Red Cedar transplant site on the same days on which survival monitoring was done, except for 16 May 1994. Where possible, scallops ranging in size from ~ 50 -60 mm were sampled (as was done for all natural populations as well) so that comparisons of reproductive timing could be made directly between different groups (Barber *et al.*, 1988; Barber and Blake, 1991).

Three methods were used to assess reproductive condition. Gonadal indexes and gonad weights were calculated for between 8-20 individuals on each sampling date. For each individual, shell height was measured to the nearest mm, then the gonad was dissected proximal to the foot (so the foot remained attached to the excised gonad). The gonad and the remaining tissues were weighed separately for each individual after drying at ~ 82 C until a constant weight was reached (≥ 48 hrs). A gonad index (GI) value was calculated for each individual using the following equation (Barber and Blake, 1991):

$$\frac{\text{Gonad wt (g)} \times 100}{\text{Gonad Wt} + \text{Remaining Tissue Wt (g)}}$$

Temporal changes in mean gonadal weight or mean gonadal index values were examined to determine if spawning may have possibly occurred, as inferred from a significant drop in gonad weight or gonad index. Examination of histological preparations (see Bricelj *et al.* (1987); Epp (1989) for methodology) made on 2-10 individual scallops collected on each of the above sampling dates was done to confirm patterns revealed by changes in gonadal weights or gonadal indexes. Histological sections were examined qualitatively for changes in reproductive stage, as described by Sastry (1963), Taylor and Capuzzo (1983), and Epp (1989); analyses focused on the samples taken immediately before and after the first dramatic decrease in gonad weight and/or gonad index values at a given site. A continuous temperature recorder (RYAN RTM2000) was deployed on 25 May 1994 at the Red Cedar site until 30 September 1994 so that temporal patterns of reproduction could be examined in light of temporal fluctuations in water temperature.

Two objectives of the reproductive monitoring were: (1) to provide an idea of when spawning occurred in Flanders Bay so that spat collectors could be deployed to monitor larval settlement, and (2) to provide comparative data so that it could be determined whether spawning in Flanders Bay occurred earlier, later, or at the same time as scallops from the natural populations in Northwest Harbor. The latter comparison was particularly interesting because it had been speculated that if transplants were done in the spring then reproduction might be delayed due to the shock incurred during the process of moving scallops from one body of water to another (S. Siddall, pers. comm.).

VII.2f. Monitoring of Reproduction in Natural Scallops at Northwest Harbor

Reproductive monitoring of the natural populations in Northwest Harbor was done in the same manner as for the scallops transplanted to Flanders Bay. Samples were collected from near the SE corner of Northwest Harbor, an area from which scallops had been collected for transplanting to Flanders Bay, on 29 April 1994 and every 2-4 weeks between early June - late September 1994. Samples of from 14-20 individuals were collected for gonad weights and indexes, while 6-10 individuals were collected for histological analyses. Water temperatures were taken at each sampling date between June-September.

VII.3. Deployment and Sampling of Spat Collectors in Flanders Bay

Four spat collector units were deployed at the Red Cedar study site in Flanders Bay on 23 June 1994 to monitor relative settlement of scallop larvae. The units consisted of a polypropylene line to which two spat collector bags were tied: one ~ 1 m above the bottom and one ~ 2-3 m above the bottom. Each spat collector bag was comprised of an onion bag with 3-5 mm mesh into which two similar onion bags had been folded and placed inside. Each spat collector unit was anchored with a cinder block and was held afloat by a lobster pot buoy at the surface. The spat collector units were placed just offshore of buoys marking the middle sectors of the planting site. The top spat collector bag from one unit was examined on 5 August 1994; the bottom collector from this unit was redeployed and examined on 16 September 1994. The other two units which could be recovered were sampled separately on 26 August and 30 September 1994. On each sampling date, counts of all scallops were made in the collector(s) examined and individuals from a subsample were measured to the nearest mm.

VII.4. Comparative Survival and Spawning of Hatchery Reared and Natural Scallops

VII.4a. Rationale for and Design of Study

Extensive plantings of bay scallops which have been conducted over the last 10 years in the Peconic Bays by the Long Island Green Seal Committee and local towns have predominantly relied on hatchery-reared scallops (Tettelbach and Wenczel, 1993; Wenczel et al., 1994). This dependence on hatchery-reared scallops was necessitated by the virtual absence of natural populations of bay scallops in the Peconic Bay system following the occurrence of the brown tide algal blooms (Tettelbach and Wenczel, 1993; Wenczel et al., 1994). The relative survival and reproductive patterns of hatchery-reared versus natural northern bay scallops, *Argopecten irradians irradians*, however, have not been investigated.

The purpose of this part of the study was to provide some preliminary data on the survival and reproduction of hatchery-reared scallops and two groups (small and large) of scallops collected from natural beds in Hallock Bay (Fig. 4). The original plan was to deploy the three groups of scallops in late November or in December 1993 so that survival could be examined over the winter. However, due to the early and severe onset of winter we were not able to collect the necessary numbers of appropriately sized scallops from natural populations before the Peconic Bays froze. Therefore, it was necessary to delay collection of natural scallops and the deployment of the experiment until March 1994.

Juvenile natural scallops were obtained from two sites in the northern portion of Hallock Bay (Fig. 4) on 14 and 18 March 1994. Scallops were collected with conventional bay scallop dredges, then measured and sorted on the boat into 'small' (28-40 mm shell height) and 'large' (50-59 mm shell height) groups. After collection, scallops were held in flow-through seawater tables at the Suffolk County Marine and Environmental Learning Center (SCMELC) in Southold.

The hatchery-reared scallops used in this experiment were obtained from the East

Hampton Shellfish Hatchery on 19 November 1994 and subsequently held at the Southampton College Marine Station on Old Fort Pond, Southampton. Scallops ranged in height from 28-39 mm, and were stocked at a density of ~ 100 per pearl net (=920 scallops/m²) on 16 December 1993. Nets were suspended in vertical strings of three from a floating dock, with the top net situated ~ 30 cm below the surface. Mesh size of pearl nets was 3 or 6 mm. Survival between 16 December 1993 and 20 March 1994 ranged from 90-100 % in individual nets; the overall (average) survival rate was 95.7 %.

On 21 March 1994, the hatchery and natural scallops were brought to Hallock Bay for deployment in the experimental area in central Hallock Bay (Fig. 4). Subsamples of scallops from each of the three groups were measured to the nearest mm; the mean sizes of the hatchery, 'small' natural, and 'large' natural groups were 32.6 (SD=2.6), 37.6 (SD=2.0), and 53.4 (SD=2.1) mm, respectively. Scallops were then stocked in circular pearl nets (diameter = 38 cm; mesh size = 3 mm) at a density of 15 per net (=128 scallops/m²). The tops of the nets were closed by tying the polypropylene line sewn into the net and also by securely twisting a wire closure next to the knotted line. Individually numbered tags comprised of segments of plastic tape were then tied to the top of each net. Eighty (80) nets were stocked for each of the three scallop groups. It took 3 1/4 hrs to complete the above procedures, thus it was necessary to rewater the scallops several times during this period. Pearl nets were then deployed into a grid of 15 nets by 15 nets, located within the center of a 50 m x 50 m buoyed area that had been officially closed to any fishing activities by the Town of Southold trustees. Positions within the net grid were randomly selected for the scallops of the three groups; unassigned positions were left undisturbed. Nets were spaced ~ 1 m apart, and were anchored using two steel stakes which were bent and then pushed through the mesh of the net into the sediment. The bottom at this site was comprised primarily of sand, with sparse eelgrass and shell hash and some drift macroalgae. A continuous temperature recorder identical to the one used at the Flanders Bay site was deployed on 23 May and removed on 28 July 1994.

Sampling of the pearl net scallops was first done on 15 April 1994, and then done approximately every 2 weeks between 10 May and 28 July. On each sampling date, two nets of each of the three scallop groups were randomly sampled. These were returned to the laboratory where each scallop was measured to the nearest mm and % survival in each net was determined. Five scallops from each net were removed for histological preparations, while the rest from a given net were used for calculation of gonad weights and gonad indexes. Monitoring of reproductive condition was done in the same manner as for the scallops sampled at the Flanders Bay and Northwest Harbor sites. Sampling of scallops from pearl nets was discontinued in late July because it appeared that shell growth of these individuals (particularly the large natural scallops) was stunted in comparison to those from the natural population adjacent to the nets.

Sampling of scallops from natural populations at the pearl net site and at the easternmost dredging site in Hallock Bay (Fig. 4) were begun on 20 May and 2 June, respectively, after it became apparent that differences in growth and reproductive condition might exist between these scallops and those being held in the pearl nets. Sampling of the natural scallops at these two sites was conducted approximately biweekly until 1 September; a further sample was taken on 28 September 1994.

VIII. RESULTS AND DISCUSSION

VIII.1. Scallop Seed Planting - Fall 1993

VIII.1a. Survival

On 19 November 1993, the day on which hatchery-reared scallops were planted at the Red Cedar site in Flanders Bay, *in situ* counts of scallops made immediately afterward by divers showed that the observed scallop density (9.04 live scallops + 0.57 cluckers/m²) was close to the expected planting density of 9.70 live scallops/m². The observed densities were calculated by excluding the counts made in sectors #1-3 on the day of planting. This was done because they were considerably lower than those obtained by the other two divers in sectors #4-8 on 19 November and were also considerably lower than those obtained for sectors #1-8 on 22 November 1993. While it wasn't possible to differentiate hatchery and natural scallops on 19 November due to the reduced light level in the late afternoon, if a conservatively high figure of 0.8 natural scallops/m² is used (the density observed on 8 November 1993) then the density of the observed hatchery plantings works out to be 8.81/m² for 19 November.

The maximum immediate mortality of hatchery-reared scallops that may have resulted from the transplant activities on 19 November was calculated to be 6.1%. This was calculated by dividing the number of cluckers (0.57/m²) by the (minimum) density of both live hatchery-reared scallops and cluckers (9.38/m²). Based upon our prior experience with scallop transplants done over the last 8 years, we believe that the actual mortality attributable to the Fall 1993 transplant was probably much less than 6.1%. At least some of the cluckers were probably dead prior to harvesting.

Survival of the planted scallops appeared to be very good through 22 November 1993, but then density of the hatchery-reared seed declined rapidly during the next month (Fig. 7). By 15 December, the overall density for all scallop seed was only 0.95/m², with the density of hatchery seed estimated to be 0.3 - 0.55/m². Observations made along the edges and just outside of the planted sectors suggested that there was little movement of the planted seed during this period. Thirteen starfish, *Asterias forbesi*, were counted in the planting area on 22 November (and removed), but we never observed high concentrations of starfish or any other predators during the November and December 1993 dive surveys. Nevertheless, the relatively high water temperatures recorded during this period may have contributed to a higher level of predation on the planted scallops than we would have expected on the basis of our prior experience (Wenczel et al., 1991).

The next (and last) dive to monitor the Fall 1993 planting, done on 25 March 1994, revealed that the scallop density at the Red Cedar site was very low. The calculated density of live scallops was 0.32/m²; all of these appeared to be natural scallops. Thus, the density of hatchery scallops was at or near zero (Fig. 7). The bottom conditions at the planting site were dramatically different from those evident during Fall 1993. The surface sediment was mostly a cohesive flocculent layer. Virtually all of the extensive population of *Crepidula fornicata* was dead. Several dead crabs and starfish were also observed. Other than the few scallops that we observed there were virtually no live

macroinvertebrates evident at the site at this time.

VIII.2. Scallop Seed Transplant - Spring 1994

VIII.2a. Survival

The first dive to monitor the Spring 1994 scallop transplants, done on 16 May 1994, revealed that the density (8.20 scallops/m²) appeared to be higher than the projected planting density of 5.0 scallops/m². While the variability of the quadrat counts was high (as seen by the magnitude of the SD's), a subsequent dive done on 25 May was also above 8.0 scallops/m² - suggesting that the number of scallops planted in late April/early May was probably closer to 48,000 rather than the original estimate (made on-board the collecting vessel) of 30,000.

While estimated density in sectors # 1-6 fluctuated after 9 June (Fig. 8), the estimated survival through 26 August (at which time density = 4.27 scallops/m²) was still excellent compared to that seen in the Fall 1993 planting and significantly higher than virtually all of those done by the Long Island Green Seal Committee between 1986-1991 (Tettelbach and Wenczel, 1993; Wenczel *et al.*, 1994). The high survival of the Spring 1994 transplants was anticipated on the basis of previous predation experiments with a variety of crabs (Tettelbach, 1986), in which the survival of scallops > 40 mm was significantly higher than that of smaller individuals. High survival of the Spring 1994 transplants also undoubtedly reflected the fact that scallops did not have to overwinter at the transplant site.

VIII.2b. Reproduction

Plots of changes in gonad weights and gonad indexes of the Spring 1994 transplants (Fig. 9) suggested that spawning of scallops at the Red Cedar site initially occurred between 25 May and 9 June 1994. A significant drop (*t*-test: *p* < .001) in both of the above parameters between these two dates (Fig. 9) suggested that it was the release of gametes through spawning that was responsible for the observed patterns.

Analyses of histological sections revealed that both the male and female portions of scallop gonads sampled on 25 May appeared ripe, but spawning did not appear to have yet begun. Two of the six scallops from the 9 June histology sample appear to have partially spawned, but only sperm appeared to have been shed and not eggs. The apparent lack of evidence for the release of eggs by the sampled scallops by 9 June may be due to a small sample size. However, Sastry (1966) noted that in laboratory experiments with bay scallops that sperm were released at a lower temperature than eggs. This phenomenon may have occurred in the field such that sperm and eggs were not released synchronously in late May/early June. Further histological analyses suggested that spawning of both sperm and eggs had indeed occurred by the time of the 8 July sample.

Spawning before 25 May can not be completely ruled out since the sample taken

prior to this date was nearly a month earlier (29 April). Furthermore, scallops sampled on 25 May shed sperm (but not eggs) between the time they were removed from the water and processed in the laboratory. Temporal reproductive patterns of scallops in Hallock Bay which are detailed later in this report also suggest that late May - early June is the earliest that scallops spawned in 1994. Bricelj *et al.* (1987) found that the earliest spawning of scallops in Northwest Harbor occurred in late May; only the female portion of the gonad was examined.

Histological analysis of scallop gonads sampled from Northwest Harbor in the present study suggested that spawning had not occurred by 2 June, but had in fact started by 27 June. Of the six scallops sampled on the latter date, three appeared to have shed sperm. One of these three scallops also appeared to have released some eggs.

Examination of the continuous temperature recorder readings at the Red Cedar site (Fig. 10) revealed that the water temperature range at the time of the apparent spawning between 25 May - 9 June was 15.9-21.9 C. The most rapid water temperature increase during this period (from 18.9-21.4 C) occurred between 0005-0735 hrs on 7 June. The level of water temperatures and the rapid rise which were observed are both consistent with the conventional stimuli which have been demonstrated to induce spawning of ripe bay scallops, *Argopecten irradians irradians*, in the laboratory and the field (Loosanoff and Davis, 1963; Barber and Blake, 1991).

Comparison of the plots of temporal changes in gonad weights and gonad indexes for both the Flanders (Figs. 9) and Northwest Harbor (Fig. 11) sites suggests that spawning may have occurred earlier in Flanders (between 25 May and 9 June) than in Northwest Harbor (between 2 and 27 June). The water temperatures in Northwest Harbor appear to have been slightly cooler than those in Flanders during late May/early June, for e.g., at ~ 1315 hrs on 27 June, water temperatures in Northwest Harbor and Flanders Bay were 22.7 and 24.7 C, respectively. Thus, it is reasonable to expect that spawning should be earlier in the warmer location because an increase in water temperature has been suggested to be the major environmental variable controlling the timing of spawning of *Argopecten irradians irradians* (Bricelj *et al.*, 1987). If spawning did occur earlier (it was certainly not later) in Flanders than in Northwest Harbor this would mean that the process of transplanting scallops from the latter to the former site did not delay spawning. This is of particular interest because it suggests that the transplantation of juvenile bay scallops ~ 1 month before the commencement of spawning activity could be an important method of achieving successful spawning in a desired area.

The confirmed spawning of the transplanted scallops, coupled with the high survival of these individuals between the time of planting and the time of initial spawning (when roughly 33,000 - 40,000 scallops are calculated to have been present at the planting site) verified that the major goal of this project was achieved. Further spawning after the apparent start in late May - early June probably occurred at least through July.

VIII.3. Settlement and Growth of Scallops in Spat Collectors

Extensive settlement of scallops in spat collectors was first noted on 5 August 1994. A total of 2152 seed were obtained from just 3 spat collector units during the August and September samplings (Table 1). Spat collectors also had fairly heavy sets of *Anomia*

simplex, *Crepidula sp.*, *Arca transversa* and presumably *Dyspanopeus sayi*. The latter species was present in moderate numbers, but the sizes of the largest crabs (~ 20 mm carapace width) was considerably larger than the mesh size of the onion bags and thus it was apparent that the crabs had settled in the collectors as larvae and then grew to the sizes observed. While it can be assumed that the crabs preyed on at least some scallops in the collectors, as evidenced by remains of broken shells, we can't know the extent of the predation or the effect on the observed size-frequency distribution of scallops. Nevertheless, it is clear that extensive settlement of scallop larvae occurred in the collectors and substantial growth (up to a mean size of ~ 28 mm) occurred by 30 September.

Table 1. Numbers and sizes of juvenile bay scallops obtained from spat collectors which were initially deployed on 23 June 1994 at the Red Cedar study site in Flanders Bay, New York. Scallop sizes were determined from a subsample of n individuals on a given date; SD = standard deviation.

<u>Sampling Date</u>	<u>Collector #/Bag Position</u>	<u>Total # Scallops</u>	<u>Scallop Height (mm)</u>		<u>n</u>
			<u>Mean</u>	<u>SD</u>	
5 Aug 1994	#1/top	272	7.2	1.6	79
26 Aug 1994	#2/top	661	15.5	3.4	55
	#2/bottom	267	16.7	3.1	59
16 Sep 1994	#1/top	18	22.2	5.3	18
	#1/bottom	349	23.5	4.2	100
30 Sep 1994	#3/top	296	28.8	3.3	71
	#3/bottom	289	28.1	4.6	70

While we can only speculate on the source of the scallop larvae which settled on the spat collectors at the Red Cedar site, two lines of evidence can be followed which would suggest that at least some of the scallop spat resulted from the spawning of the transplanted scallops at the Red Cedar site. The model of larval dispersion which was developed by Siddall *et al.* (1986) for the Peconic Bays suggested that larvae originating in Flanders Bay had a high likelihood of remaining in that system. Our surveys of various sites and their respective scallop abundances in Flanders Bay during Fall 1993, and the decline in scallop populations which we observed at the Red Cedar site, suggest that there were very low scallop concentrations in this area in Spring 1994. It is likely, therefore, that the stock of transplanted scallops at the Red Cedar site represented the largest ($>30,000$) and most concentrated (~ 7 scallops/m²) group of scallops which was present at the time when spawning occurred in late May/early June. It is then not

unlikely that the transplanted scallops produced a significant proportion of the larvae which existed in the water column in Flanders Bay prior to metamorphosis and settlement.

Even though the high numbers of scallop seed caught in the spat collectors suggests that there were ample larvae in the water column during summer 1994, our dive surveys at the Red Cedar site through September and also in late December 1994 revealed only one juvenile scallop. This lack of seed on the bottom may have resulted from low levels of larval settlement on the bottom, poor survival of juveniles after settlement, or possible mass movement of juveniles off the Red Cedar site. The latter possibility, however unlikely, should not have led to a virtual absence of seed at the site. The fact that high numbers of seed were found in the spat collectors suggests that low levels of settlement on the bottom were also rather unlikely. Poor survival of juveniles after larval settlement seems a more likely possibility. Similar accounts of high numbers of scallop seed in spat collectors and a virtual absence of juveniles on the bottom were also noted in the West Neck Creek system ~ 4 km to the east during Summer 1994 (C. Smith, unpubl. data).

In an effort to determine if survival after settlement did occur in Flanders Bay, a survey was conducted in March, 1995. This survey utilized commercial dredges that were deployed at 40 stations throughout Flanders Bay in areas known to possess scallops in the past. Each sampling consisted of fishing the dredges in a circular pattern for one circular turn of the boat. Of the 40 stations covered juvenile scallops which would have possibly been offspring of what was planted in this project were found at 4 of the stations. Although juvenile scallops were found at few stations this was a very positive sign in light of the limited dredging time at each station. Also, the pattern of bay scallop population recovery seen in the eastern Peconics indicates that reestablishing relatively small concentrations of spawner scallops can lead to large recovery soon thereafter. Thus, this relatively small number of scallops is consistent with this project's goal of establishing spawning populations of scallops in the western Peconic system. The budget for this project was not sufficiently large to conduct electrophoretic genetic studies that might have more definitively identified these juveniles as offspring of our spawner sanctuary plantings. It was also extremely unlikely that sufficient genetic variation would have been present to separate natural and planted spawner scallop contributions to the standing stock of juveniles.

VIII.4. Comparison of Natural vs Hatchery-Reared Scallops - Hallock Bay Experiment

VIII.4a. Survival and Growth of Scallops in Pearl Nets

Survival of both small and large natural scallops was very high during the period from 21 March - 28 July 1994, but survival of hatchery-reared scallops during this period appeared to have been somewhat lower (Fig. 12). However, a comparison of slopes of the regression lines for these plots revealed that there were no statistically significant

differences ($p > .05$).

Shell growth of scallops of the three groups held in pearl nets exhibited different patterns (Fig. 13). Very little growth occurred in the large natural scallops. Shell growth of small natural scallops was slight between 21 March and 15 June; after this the rate of shell growth increased and by 28 July, the mean size of the sampled small natural scallops was 47.2 mm. Hatchery-reared scallops showed little shell growth between 15 April and 15 June 1994, but as with the small natural scallops an increased rate of growth was evident after this date. The mean height of hatchery scallops was 46.7 mm on 28 July 1994, which was very similar to that of the small natural scallops. Slow shell growth is common in *Argopecten irradians irradians* immediately prior to spawning, but usually increases after spawning (Belding, 1910; Tettelbach, 1991). This pattern was evident with the hatchery-reared and small natural scallops, but not with the large natural scallops.

VIII.4b. Spawning of Scallops Held in Pearl Nets

Temporal patterns of spawning appeared to be fairly similar in the small and large natural, and hatchery-reared scallops held in pearl nets (Figs. 14,15,16). All three groups showed a significant (t-tests, all $P < .01$) drop in gonad index and gonad dry weight 2 and 15 June 1994. The hatchery scallops also showed a small decline in gonad weight between 20 May and 2 June, but a slight rise in gonad index occurred during this period. Analysis of histological sections suggested that spawning of hatchery-reared scallops may have just begun by 2 June, at which time 3 of 10 sampled scallops seem to have shed some sperm. One of the large natural scallops sampled on 2 June seems to have shed some sperm by this date, but it appeared that spawning of the small natural scallops commenced between 2 and 15 June. All of the 15 June scallops from each of the three sampled groups ($n=10$) had released sperm, but only one of these scallops (from the hatchery-reared group) appears to have released eggs by this date. The majority of spawning in all three groups thus occurred after 15 June. Examination of the continuous temperature record (Fig. 17) during this period reveals that the water temperature ranged from 15.2-23.7 C. The most rapid water temperature increase during this period (from 15.2-19.6 C) occurred between 0730-1530 hrs on 3 June.

For the scallops of the three groups, gonad weights were highest in the large natural scallops and lowest in the hatchery scallops on 2 June, paralleling the differences in shell height of the three groups. This was expected on the basis of earlier work examining the relationship between shell size and gonad weight (Bricelj *et al.* 1987; Barber and Blake, 1991). However, the maximum mean values for gonad index (on 2 June) of the three groups were remarkably similar: 35.37, 35.15, and 35.76 for large natural, small natural, and hatchery scallops, respectively (Figs. 14,15,16). This strongly suggests that reproductive investment of each of the three groups of scallops held in pearl nets was very similar.

VIII.4c. Comparison of Spawning Patterns of Natural Population Scallops with Those Held in Pearl Nets

Temporal changes in gonad weights and gonad indexes (Figs. 18,19) as well as histological analyses for natural scallops at the pearl net site and dredging site in Hallock Bay, suggest that spawning commenced between 2 and 15 June 1994. The possibility that spawning at the dredging site began before 2 June can not be ruled out, however, because no samples were taken prior to that date. The maximum mean gonad index (36.96 on 2 June) for the natural scallops at the pearl net site was similar to that of the scallops held in pearl nets. The mean gonad index for the natural scallops at the dredging site on 2 June (44.50) was significantly (t-test, $p < .05$) higher than that for the natural scallops at the pearl net site. The three highest gonad index values for individual scallops (61.15, 55.35, 54.02) were all obtained at the Hallock Bay dredge site on 2 June.

Comparison of gonad weights of scallops from the natural populations at both the pearl net and dredging sites versus large natural scallops held in pearl nets (Figs. 15,18,19) shows that gonad weights were consistently lower on any given sampling date for the latter group even while shell heights were the same. This provides further evidence that growth of the scallops in pearl nets was stunted.

Handwritten notes at the top of the page include:
- A circle containing "1 to 20" and "scallops" with a circled "3" next to it.
- A circle containing "summary" and "recruits" with "list" written below it.
- An arrow pointing from the second circle to a larger circle containing "recruits" and "list".
- To the right, "15 from the" and "recruits of success" are written, with "recruits" circled below.

IX. PROJECT SUMMARY/CONCLUSIONS

- Approximately, 37,500 hatchery-reared scallops (average size = 25-28 mm), obtained from the Town of East Hampton Shellfish Hatchery, were planted South of Red Cedar Point in Flanders Bay on 19 November 1993.
- Density of the scallops planted in Fall 1993 declined from 9.70/m² to < 1/m² during the next month; by March 1994, it appeared that no planted scallops had survived through the winter.
- >50,000 scallops, the great majority being natural seed collected from Northwest Harbor in late April/early May, were transplanted to the Red Cedar site in Spring 1994.
- It is estimated that ~ 33,000 - 40,000 transplanted scallops spawned between 25 May - 9 June 1994 in Flanders Bay, as revealed through dive surveys and laboratory analyses of reproductive condition.
- These results demonstrated that scallops could be transplanted from a natural population to another area ~ 1 month before the anticipated date of spawning and thus serve as an effective means of achieving successful spawning in a desired location.
- Approximately, 1900 scallop seed were collected between 5 August and 30 September 1994 on spat collectors deployed at the Red Cedar planting site; it is likely that the scallops transplanted in Spring 1994 contributed to this recruitment; virtually no juvenile scallops were found on the bottom at the planting site.
- Scallops in natural populations in Hallock Bay commenced spawning at roughly the same time (late May/early June) as natural and hatchery-reared scallops held in pearl nets at the same location, suggesting that temporal reproductive patterns of hatchery-reared scallops planted in the field are not different from those of natural scallops.

Handwritten signature: "William J. Davis"

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FLANDERS BAY - SCALLOP RESEEDING

-FALL 1993-

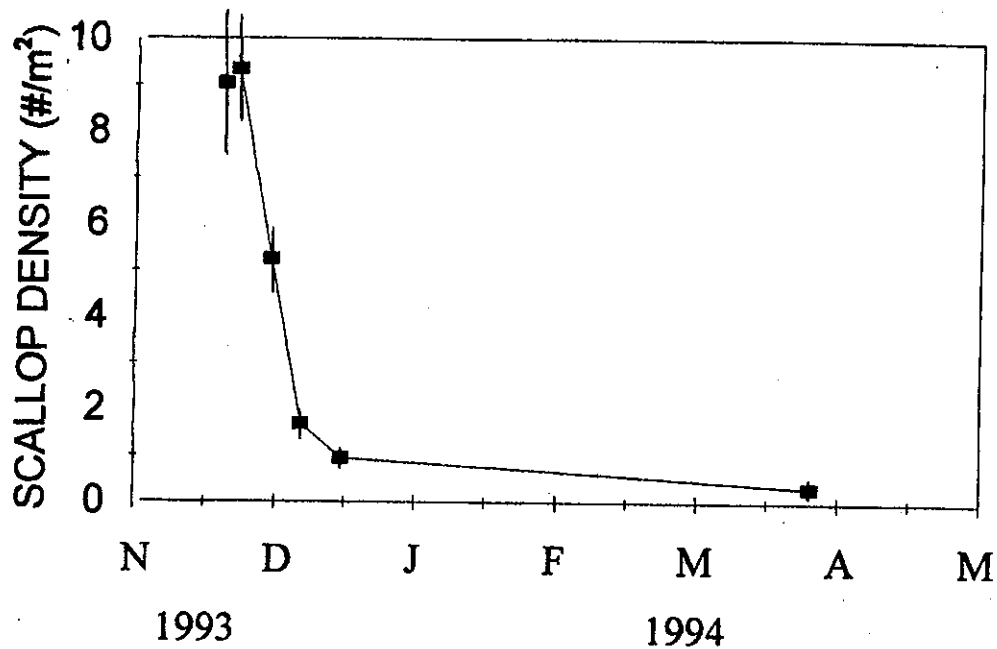


Fig. 7. Density of scallops at the Red Cedar site in Flanders Bay, New York, following the transplant of hatchery-reared scallops on 19 November 1993. Data points are mean density \pm 1 S.E. Calculated densities include natural scallops which, at the time of planting, were estimated to be present at a density of $\leq 0.8/m^2$.

FLANDERS BAY - SCALLOP RESEEDING

-SPRING 1994-

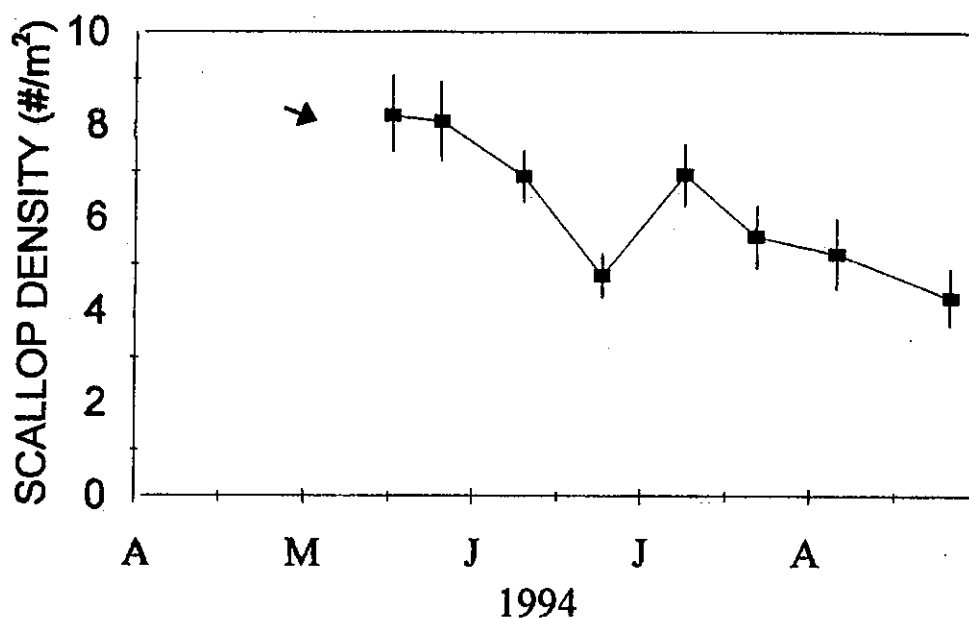


Fig. 8. Density of scallops at the Red Cedar site in Flanders Bay, New York, following the transplant of natural scallops from Northwest Harbor in late April/early May, 1994 (planting period is signified by the arrow). Data points are mean density \pm 1 S.E.

FLANDERS BAY

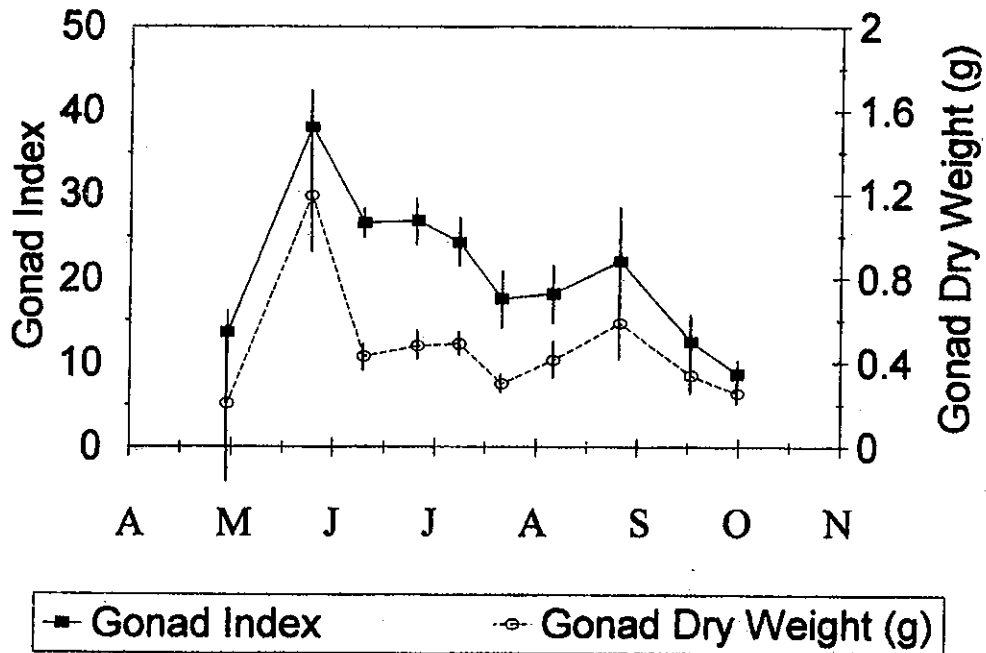


Fig. 9. Temporal changes in Gonad Index and Gonad Dry Weight of scallops transplanted to the Red Cedar site in Flanders Bay, New York. The initial values were obtained from a sample of scallops collected in Northwest Harbor at the time when transplants were initiated in late April 1994. Data points are mean \pm 1 S.D.

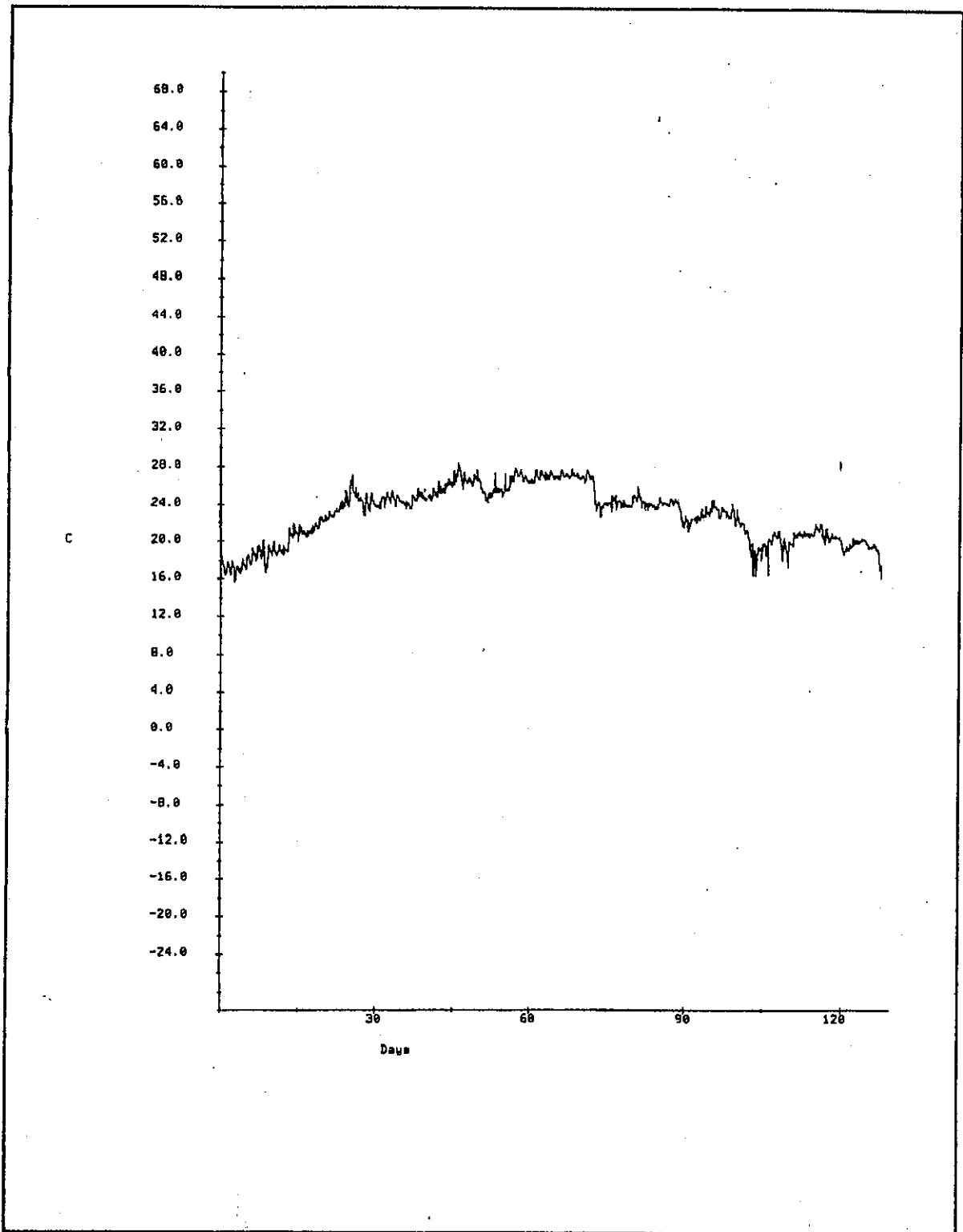


Figure 10. Water temperature at the Red Cedar site 25 May - 30 September 1994.

NORTHWEST HARBOR

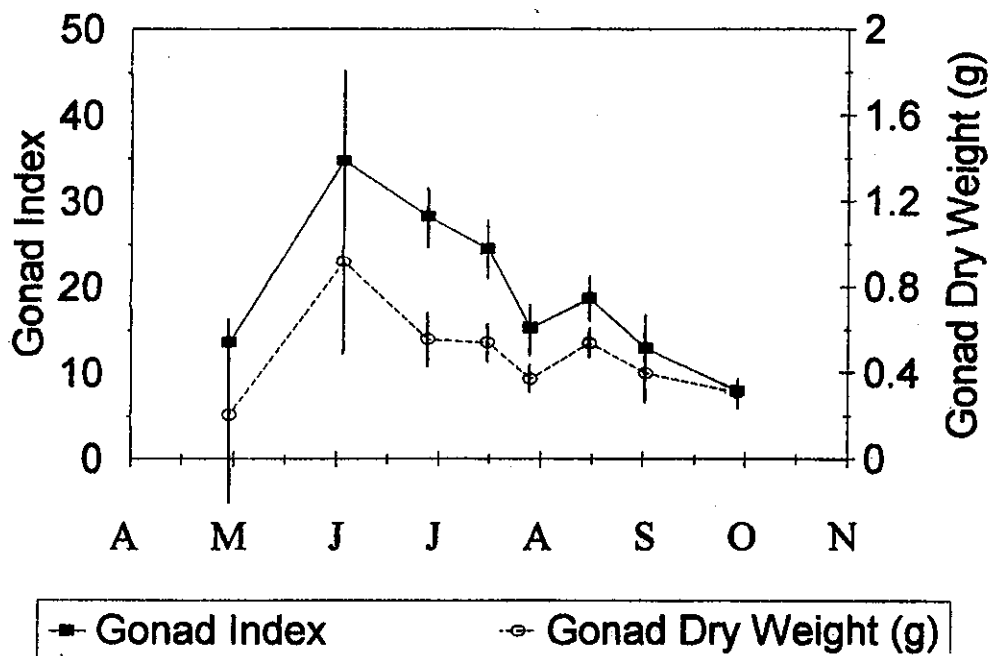


Fig. 11. Temporal changes in Gonad Index and Gonad Dry Weight of scallops from a natural population in the SE corner of Northwest Harbor, an area from which scallops were collected for transplantation to the Red Cedar site in Flanders Bay, New York. Sampling period = 29 April - 28 September 1994. Data points are mean \pm 1 S.D.

PEARL NET SCALLOPS

-SURVIVAL RATE-

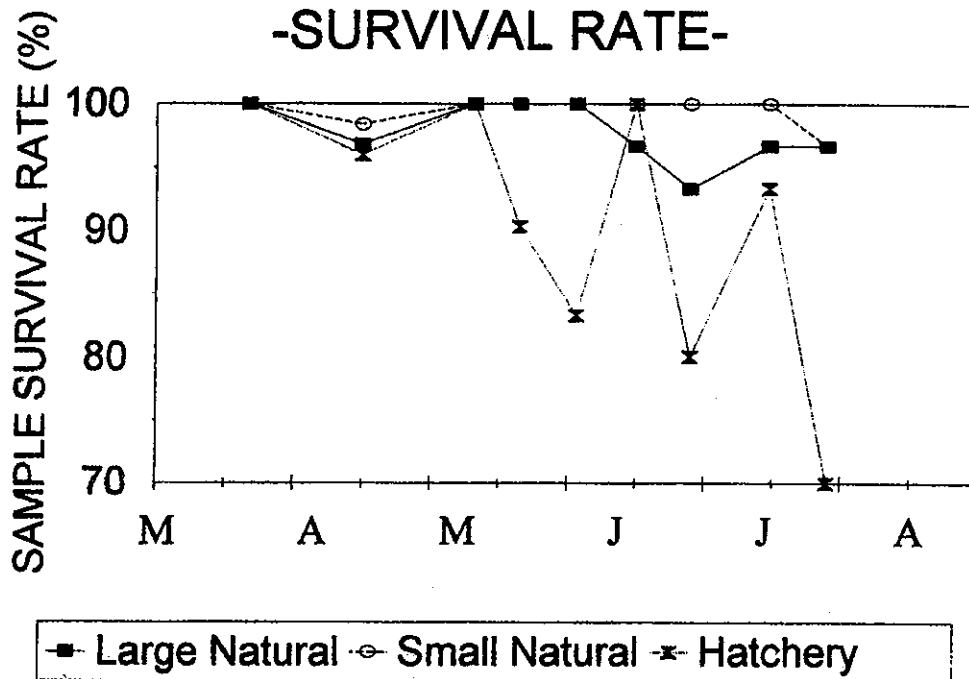


Fig. 12. Survival rates of large natural, small natural, and hatchery-reared scallops held in pearl nets at Hallock Bay, New York between 21 March - 28 July, 1994. Data points represent the % survival of scallops in a sample of a given group on a particular date. n = 124-125 for 15 April ; n = 30-31 for all other dates.

PEARL NET SCALLOPS

-GROWTH RATE-

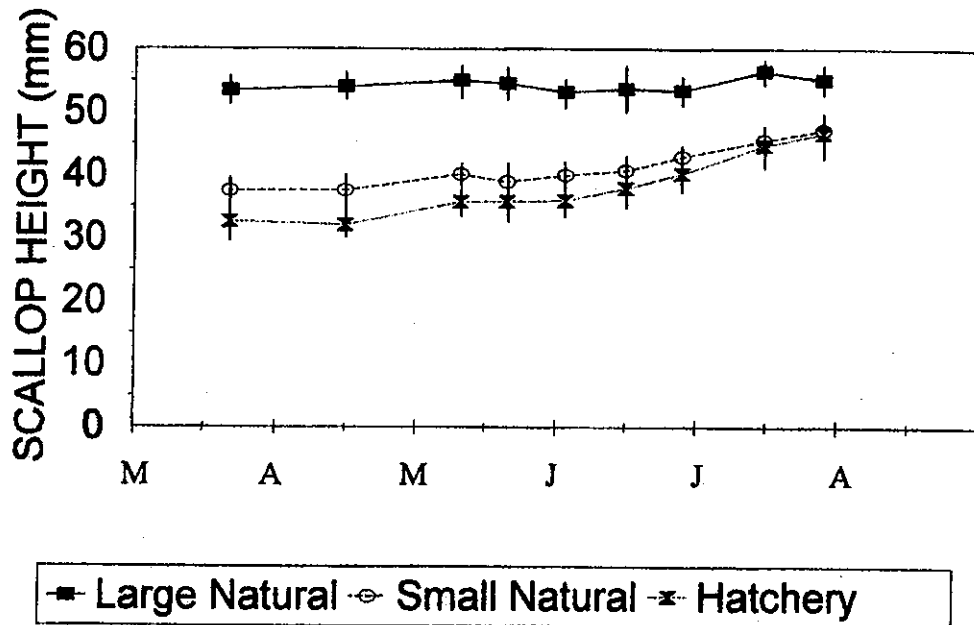


Fig. 13. Growth rates of large natural, small natural, and hatchery-reared scallops held in pearl nets at Hallock Bay, New York between 21 March - 28 July, 1994. Data points represent the mean shell height \pm 1 S.D. for a given group of scallops on a particular date.

PEARL NET SCALLOPS

-SMALL NATURAL-

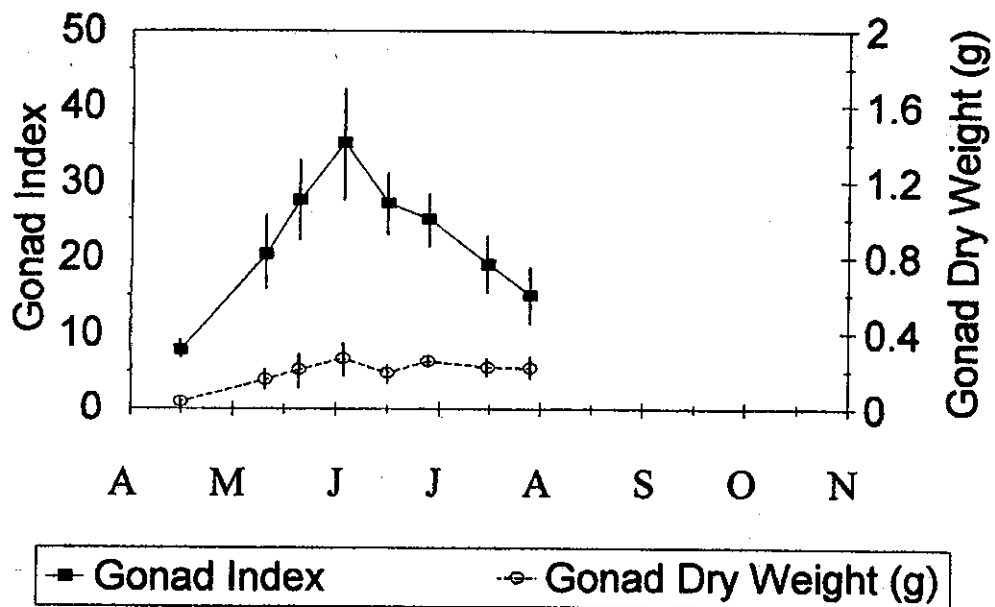


Fig. 14. Temporal changes in Gonad Index and Gonad Dry Weight of small natural scallops held in pearl nets at Hallock Bay, New York between 21 March - 28 July, 1994. Data points are mean \pm 1 S.D.

PEARL NET SCALLOPS

-LARGE NATURAL-

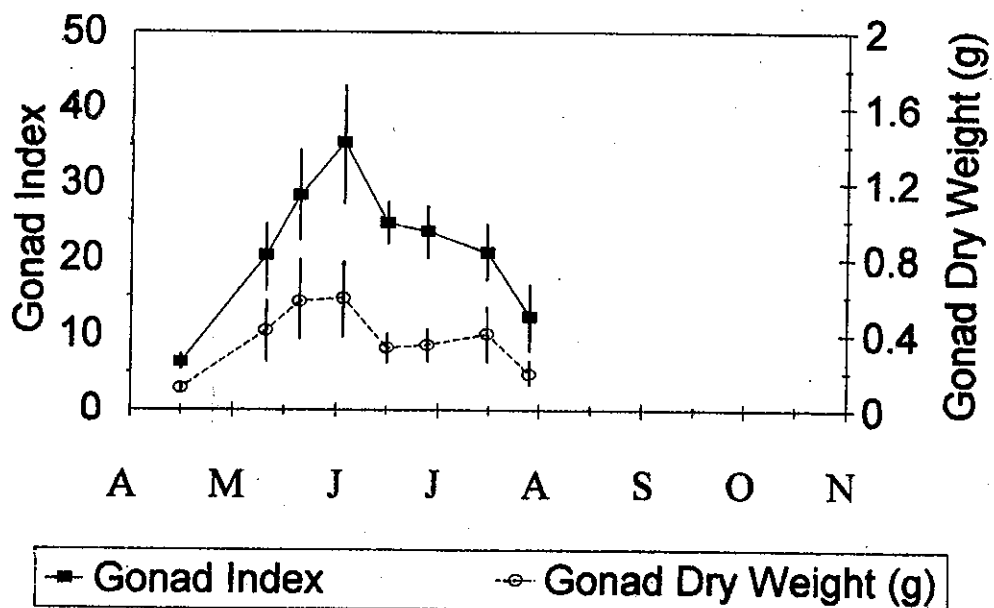


Fig. 15. Temporal changes in Gonad Index and Gonad Dry Weight of large natural scallops held in pearl nets at Hallock Bay, New York between 21 March - 28 July, 1994. Data points are mean \pm 1 S.D.

PEARL NET SCALLOPS

-HATCHERY-REARED-

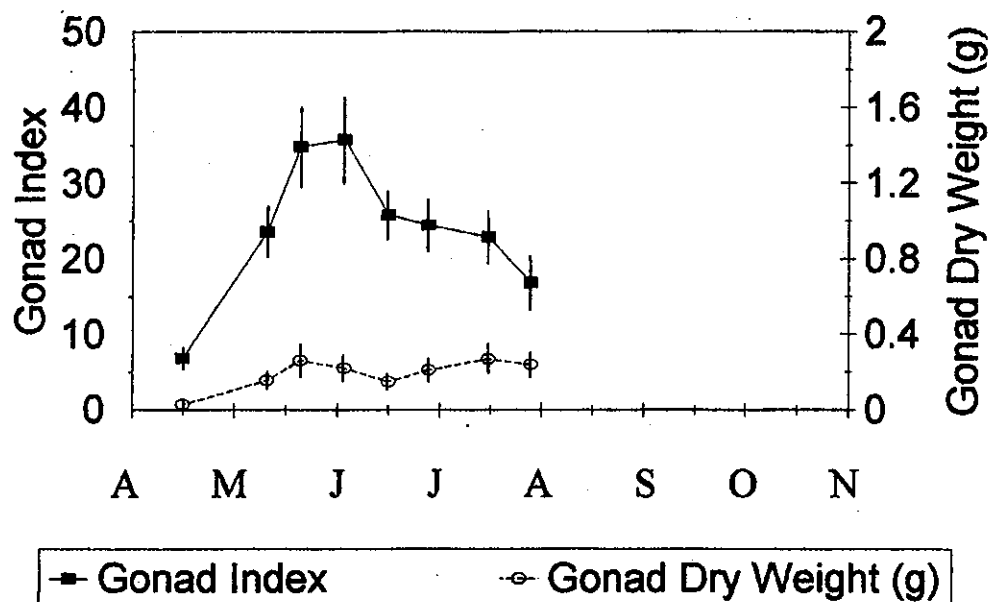


Fig. 16. Temporal changes in Gonad Index and Gonad Dry Weight of hatchery-reared scallops held in pearl nets at Hallock Bay, New York between 21 March - 28 July, 1994. Data points are mean \pm 1 S.D.

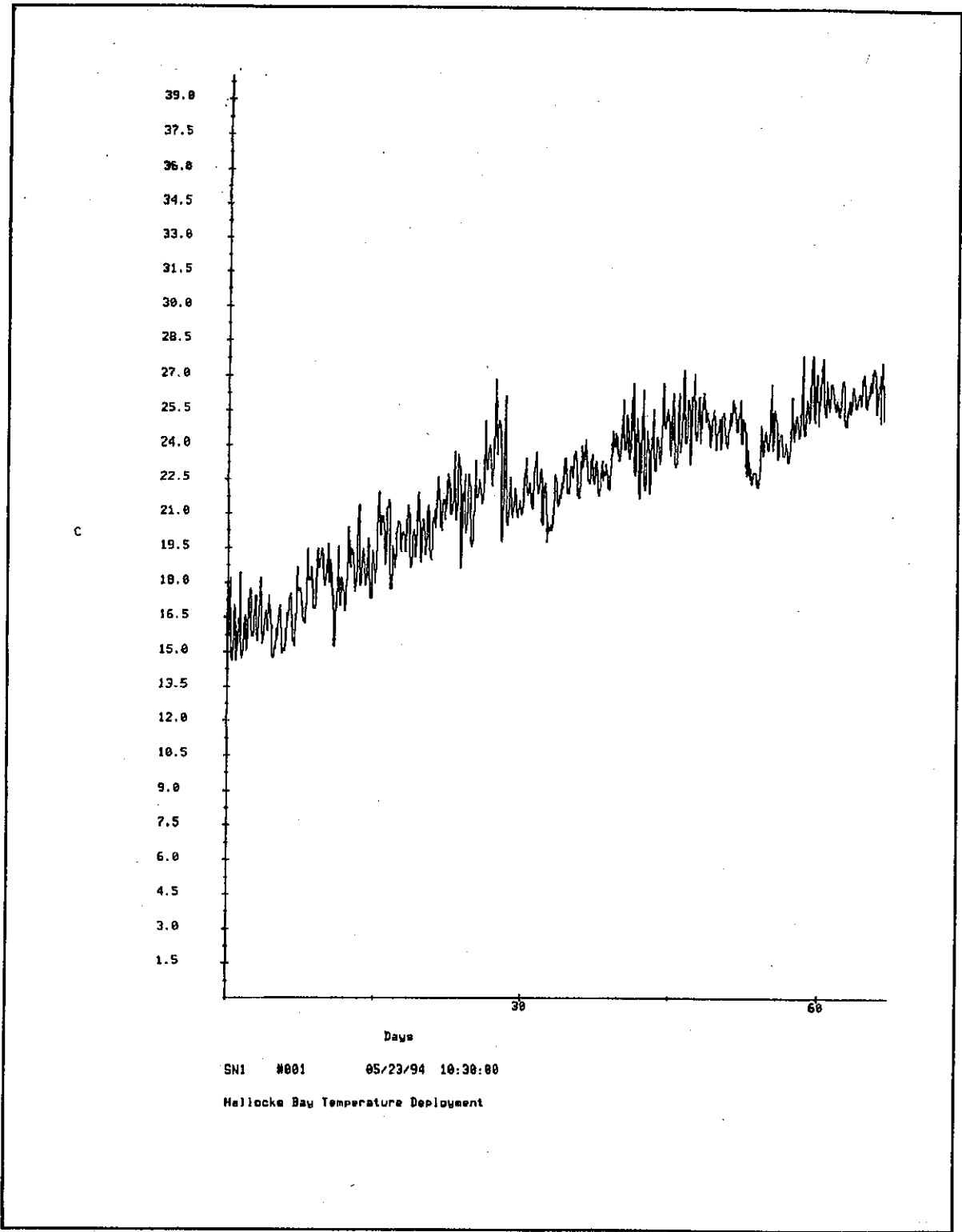


Figure 17. Water temperature at the Halloks Bay site 23 May - 28 July 1994.

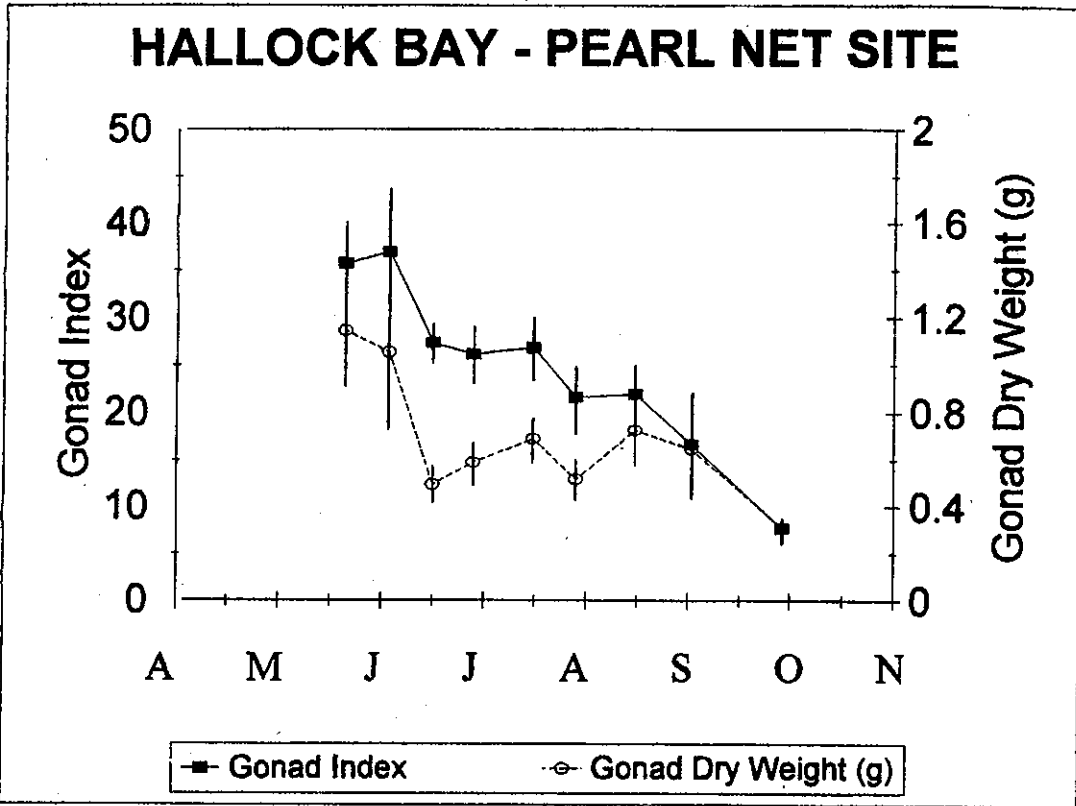


Fig. 18. Temporal changes in Gonad Index and Gonad Dry Weight of scallops from a natural population at the pearl net site in Hallock Bay, New York, 20 May - 28 September 1994. Data points are mean \pm 1 S.D.

HALLOCK BAY - DREDGE SITE

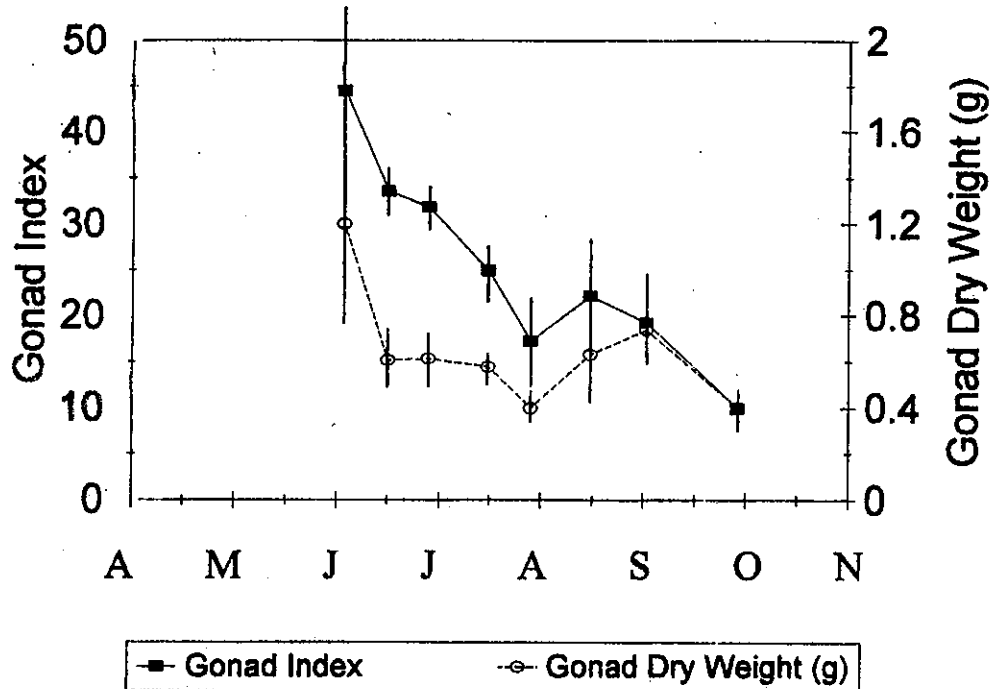


Fig. 19. Temporal changes in Gonad Index and Gonad Dry Weight of scallops from a natural population in northern Hallock Bay, New York, an area from which scallops were collected for use in pearl net experiments. Sampling period = 2 June - 28 September 1994. Data points are mean \pm 1 S.D.

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