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REARING THE BAY SCALLOP, *AEQUIPECTEN IRRADIANS* [1]

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ABSTRACT

Bay scallops, Aequipecten irradians, *collected from various bays along the Eastern Shore of Virginia and from Bogue Sound, North Carolina, were conditioned and spawned in the laboratory, out of their normal spawning period. A thermal stimulus of 21-27°C was used to stimulate spawning, and larvae set in 10-19 days using cultured algae as food.*

Juvenile scallops were held in plastic trays in the laboratory for one week, then moved to outdoor tanks with flowing, unfiltered seawater. They remained there until they were about 2 mm in width, then moved to plastic screened wooden floats in the field where they reached an average minimum market size (50 mm) in 12-13 months.

Mortality of larvae, early post-set scallops and adults is described.

The bay scallop appears to be amenable to mariculture. The biological feasibility of rearing bay scallops from egg to market size has been established.

INTRODUCTION

The Bay scallop, *Aequipecten irradians*, contributed $11,962,000 to the United States fishery between 1960-67 (Lyles, 1969), ranking in value among bivalve mollusks behind oysters, clams and sea scallops.

The bay scallop was the source of a small fishery along the seaside of the Eastern Shore of Virginia before the disappearance of the eelgrass in the early 1930's. Lyles (1969) indicates an average of 888,333 lb was taken from Virginia waters (not necessarily limited to Eastern Shore waters) between 1920-1932 contributing a yearly average of $102,666 to the state's fishery.

In spite of its commercial value, little attention has been given to rearing the bay scallop to market size. Belding (1910), in discussing its artificial propagation in Massachusetts waters stated, "It would be impossible to raise the young embryos in sufficient numbers for commercial hatching." He further stated, "There is but one way now known of artificially aiding the scallop industry, i.e., by transplanting in the fall the abundant set from exposed places to the deeper water before the 'seed' is killed by the winter."

Since Beldings work with the bay scallop, Wells (1927) was able to spawn and raise the larvae past the setting stage thus providing the initial step for its culture. Loosanoff and Davis (1963) described the methods to condition, spawn and raise the larvae to metamorphosis. Turner and Hanks (1960) and Sastry (1966) substantiated the feasibility of conditioning the bay scallop out of season.

At the Eastern Shore Laboratory of the Virginia Institute of Marine Science, investigations into rearing bay scallops began in 1968. This species was believed suitable for mariculture for a number of reasons:

1. Most important, this species has a high market value necessary to support a mariculture operation.
2. Markets and consumer acceptability were established.
3. Natural scallop populations fluctuate due to year class failures (Belding, 1910). Culture techniques could stabilize the supply and make it possible to develop new markets.
4. Hatchery techniques of conditioning, spawning and rearing bay scallop larvae

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had been successfully demonstrated.

5. Rapid growth to market size is characteristic of this species (12-17 months in Massachusetts waters, Belding, 1910; 10 months in more favorable North Carolina waters, Gutsell, 1928), and growth rate could probably be increased by selection of brood stock (Loosanoff and Davis, 1963).
6. Automatic shucking devices used for the calico scallop, *Argopecten gibbus*, could, with little or no modifications, be adapted for the bay scallop, alleviating labor and other problems inherent to hand shucking operations.

MATERIALS AND METHODS

Description of Area and Procurement of Brood Stock

All scallops were reared at the Wachapreague Laboratory, with the exception of those used in a preliminary study to determine the feasibility of using pens for holding scallops to market size. Floats were held in Finney Creek near the laboratory. Tidal amplitude is 1.2-1.5 m. Temperatures ranged from −1.1-29.8°C and salinities from 21.4-32.5‰ from November 1969 to October 1970. Surface current data from August to October 1970 averaged 19.3 cm/sec. Scallops in floats were covered with 7.5-13 cm of water.

The pen was set up on a tidal flat in Assateague Channel. Temperature, salinity and current were about the same as in Finney Creek. Tidal amplitude is about 1.2 m. The scallops were always covered with at least 30.5 cm of water.

Initial brood stock consisted of 66 adult scallops collected from Metomkin, Burton, Swash and Hog Island bays along the Eastern Shore peninsula of Virginia, and from Bogue Sound, North Carolina, from October through December 1967. Scallops for the study of the feasibility of using pens were reared by a hatchery on Long Island and sent to Virginia on 9 July 1970.

Conditioning Procedures

Conditioning was accomplished by holding 6-10 scallops in fiberglass boxes (60 x 45 x 13 cm) with approximately 20 liters of raw, standing seawater. Water was changed three times per week, and scallops were fed one liter of a mixture of algal solution per day. After about a week at 18°C, temperatures were raised to 20-22°C for 3-8 weeks. Conditioning was carried out in December and January.

Gonadal condition was checked in live animals by grasping a gaping scallop with thumb and forefinger, the flesh of the fingers acting as wedges between the valves. With the valves slightly opened, the gonad could be observed as a slightly bulbous, triangular structure lying anterior to and partially encircling the adductor muscle. The bay scallop is a functional hermaphrodite (Belding, 1910; Gutsell, 1930) with the testis comprising the anterior border of the gonad running from near the ventral tip to the dorsal base where it becomes slightly enlarged. The ovary occupies the more posterior portion.

When ripe, the ovarian portion becomes reddish-orange, and the testis cream-colored, although a black pigmented epithelium sometimes obscures the initial color change of the former.

Spawning Procedures

When gonads appeared ripe, spawning procedures were begun using methods described by Loosanoff and Davis (1963). Spawners were placed in 2 liter glass finger bowls or 1.5 liter pyrex dishes and stimulated to spawn by raising the water temperature from ambient to 27-30°C. Occasionally a sperm suspension was needed to stimulate spawning.

Fertilization sometimes occurred simultaneously with spawning, when an individual scallop released both sperm and eggs. More often, only one sex product was released by an individual scallop. As soon as spawning occurred, adults were removed from the spawning dishes and the ova in each dish were fertilized with approximately 2 ml of sperm suspension. Care was taken to introduce only a small amount of sperm suspension since high densities of spermatozoans were suspected of causing a high percent of deformed larvae.

Larval Rearing Procedures

Fertilized eggs were passed through a 153 μ nylon screen to remove clumps of fecal and tissue matter and collected in calibrated containers. They were then counted using methods described by Loosanoff and Davis (1963) and placed in 20 gal polyethylene garbage cans at a density of 1-2 million per 60 liters of seawater (17-34 per ml). Temperatures of larval cultures ranged from 20-28°C during the larval period.

The water was changed three times a week by siphoning water and larvae through nylon screens. These were constructed by fusing nylon screen to a 10 cm section of a 30 cm diameter plexiglass tube with 1, 2 dichloroethane. The mesh size of the screen was increased as the larvae grew. At each water change the larvae were concentrated on screens and washed into calibrated containers for subsampling and counting. This procedure allowed observation of growth, condition, mortality, setting, bacterial activity and effects, if any, of competitors, predators or saprophytes. Measurements were made on the first 10 larvae found in

a randomly chosen microscopic field, using an ocular micrometer. Decisions were made at that time on the disposition of the larvae (how many per container or tray), and the larvae were redistributed to containers.

As larvae grew, the number per can was decreased until there were approximately 200,000 per can (4/ml). At this density the larvae measured 148-216 μ (all measurements of larvae and scallops refer to the height or distance from umbo to ventral edge) and were starting to set.

Seawater used during the conditioning, spawning and immediate postset period was pumped from Finney Creek, cleared of particulate matter by a Westfalia Clarifier, model KDD 605 (Centrico, Inc., Englewood, N. J.) and treated with ultra-violet light. Unicellular cultures of *Monochrysis lutheri*, *Phaeodactylum tricornutum* or *Dunaliella tertiolecta* were fed to the conditioning scallops and the larvae throughout their 10-19 day larval period, at the rate of 1 liter per day. A mixture of two or three species was generally used. Occasionally, as a supplement to the above food, seawater filtered through a 15 μ dacron bag filter was added at a rate of 16 liters per 60 liter water change.

Nursery Procedures

Once the larvae had set, they were moved to plastic photographic trays (55 x 67 x 10 cm) at a density of approximately 200,000 per tray. They were left for about a week to allow them to grow before being moved to wooden outdoor tanks (2.5 x 0.61 x 0.1 m) with unfiltered flowing

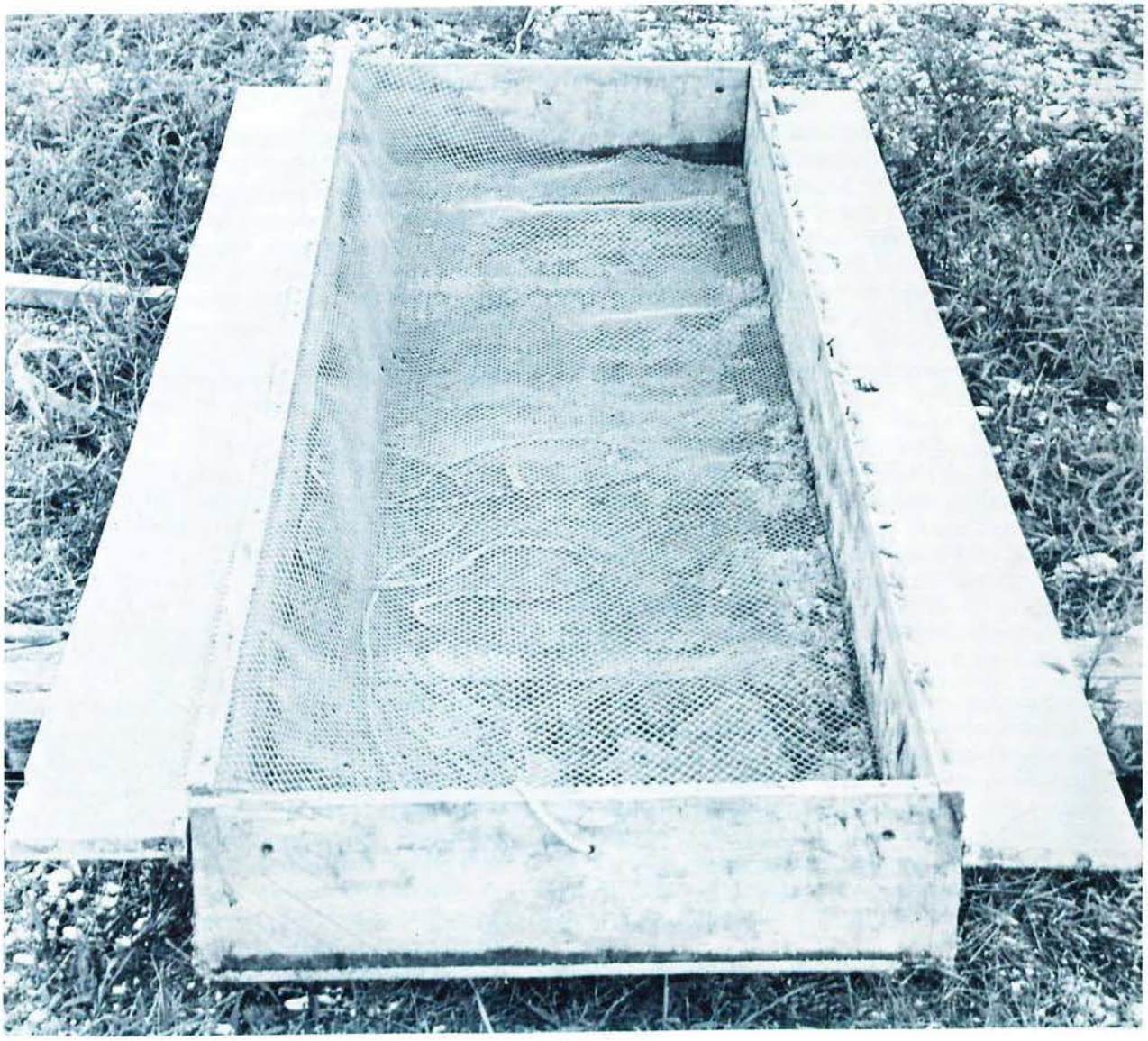

FIG. 1. *Floats used to hold scallops until market size.*

seawater. These tanks were constructed of three-quarter inch (1.9 cm) plywood and painted with an epoxy coating. A maximum of 500,000 scallops could be placed in each tank.

Initially, when 2 mm in height (after about 2-3 weeks during the warmer months), scallops were moved to wooden, rectangular floats 210 cm long, 61 cm wide, and 15 cm deep (Fig. 1). These were constructed of three-quarter inch (1.9 cm) pine boards and covered top and bottom with fiberglass window screen (16 mesh per inch) or plastic netting. Subsequent observations indicated that it was possible to hold them in the tanks until 10 mm in height before being moved to floats. This eliminated using floats covered with the two smaller mesh screens and reduced the unit effort.

In approximately 12-13 weeks the scallops measured about 25 mm in height and had been moved from floats with window screen to ones with large plastic netting (mesh size, 16 x 22 mm). They remained here until market size (50-65 mm).

The pen, used in the preliminary study mentioned above, was constructed of hardware cloth (12.5 mm mesh) tacked to poles that had been pumped into the bottom to give an area 10' x 10' x 6'. The scallops rested on the relatively hard mud-sand bottom. They averaged 16.1 mm on 9 July 1970, the start of the experiment. They were placed in a quarter inch hardware cloth cage until 14 August when they were large enough (24 mm in height) to be released into the 1/2 inch mesh 10' x 10' x 6' pen. On 24 November 1970, they were collected using dip nets.

RESULTS AND DISCUSSION

Utilizing 66 adult scallops collected in 1967, three filial generations have been produced. The progeny have been used as brood stock and for other studies related to the mariculture of the bay scallop. The initial group of 66 adults was successfully conditioned and stimulated to spawn as early as February. Despite bi-weekly efforts, spawning during February, March and early April was infrequent; however, by mid-April when the gonads appeared more fully developed, spawning was stimulated quite easily and as frequently as twice a week.

Although self-fertilization is believed to be uncommon in nature (Belding, 1910; Gutsell, 1930), it was a common occurrence in the laboratory. The larvae obtained by self-fertilization in the laboratory appeared normal, and, in fact, one isolated scallop spawned hermaphroditically for nine weeks during the late summer and early fall of 1968 producing nine groups of larvae that displayed normal growth, setting and survival. By either method, fertilization was quite successful, leaving less than an estimated 1% of each group of eggs unfertilized.

The fertilized eggs reached the straight hinge stage in 18-28 hr at temperatures between 20-28°C (with faster development occurring at higher temperatures). The larvae averaged 73.27 μ in height at straight hinge stage, and usually doubled in size in 5 days with temperatures over 20°C and with adequate food. The percent of fertilized eggs that reached setting ranged from 2.4-7.8% (average 5%). This represents, at best, a rough estimate due to the difficulty in counting set larvae. The losses were probably due to several factors; disease (Tubiash and Chanley, 1963; Loosanoff and Davis, 1963) and zooplankton predators or competitors which passed through the filter system. The authors suspect a large number of pelecypod larvae would never reach the setting stage due to generic deficiency. Larvae normally began setting in 10-19 days, with most occurring in 10-14 days. One group set in six days. Soon after setting, the scallops formed a firm byssal attachment.

During the early post-setting period to 2 mm in height, mortalities often reduced the number of live scallops by an estimated 50-80%. This high post-set mortality often occurs with pelecypods (Loosanoff and Davis, 1963). During metamorphosis the nutritional needs of the scallops may change, requiring a different food than the type available; this could directly or indirectly contribute to this mortality. Smothering may also contribute to the mortalities. Matthiessen and Toner (1966), culturing bay scallops in Massachusetts waters, found little mortality associated with metamorphosis. They estimated that of the 14-28% mortality occurring at this time approximately 5% could be attributed to mechanical loss due to the cleaning of trays.

Scallops from 2 mm in height to market size suffered an estimated 50% mortality. The sides and screened bottoms of the floats frequently became fouled with hydroids, algae, tunicates and mud. This fouling undoubtedly reduced circulation in the floats and probably had an adverse affect on growth and survival. Also, in the area where the floats were being held, a strong tidal flow, possibly combined with boat traffic, often caused the scallops to become washed to one side or end of the float, which, along with the fouling, caused the float to tip in the water. If the float was not righted many scallops died, apparently from smothering.

It is believed that improved handling techniques could reduce mortalities occurring between 2 mm and market size. Putting stabilizing wings on the floats (Fig. 1) has helped to alleviate the tipping.

Moving the floats to an area with less current and less boat traffic, using a deeper float so scallops are below the surface, submerging floats, chemically treating floats to prevent fouling, or using a different method for holding scallops may improve survival during this period.

Growth and Mortality of Scallops Held in Floats

F_1 and F_2 generation scallops (total of 10,652) were placed in floats in November 1969 and monitored for growth and mortality until November 1970. Data collected from one group of F_2 generation scallops (3 months old in November 1969), held at a density of 44/ft^2, is typical for scallops held in surface floats in the Wachapreague area (Figs. 2 and 3).

Growth from December 1969 to April 1970 was negligible, while the average growth rate from May 1970 through August 1970 (Fig. 2) was 7.0 mm/month.

Growth and temperature data (Fig. 2) indicate that maximum growth occurs above 10°C. Observations, however, have indicated that growth (measured as the height of the scallop) decreases as the scallop approaches 50 mm. This is shown in Fig. 2 where, between August and November 1970, the growth rate has decreased even though temperatures were above 10°C. Density of scallops in the float may also have had an affect on growth of the larger scallops.

Assuming minimum market size to be 50 mm (Belding, 1910), a few F_2 scallops were marketable in approximately 11 1/ 2 months. However, a mean size of 50 mm was not reached until about the 13 month (Fig. 2) mainly due to a lack of growth during the winter months (1969-1970).

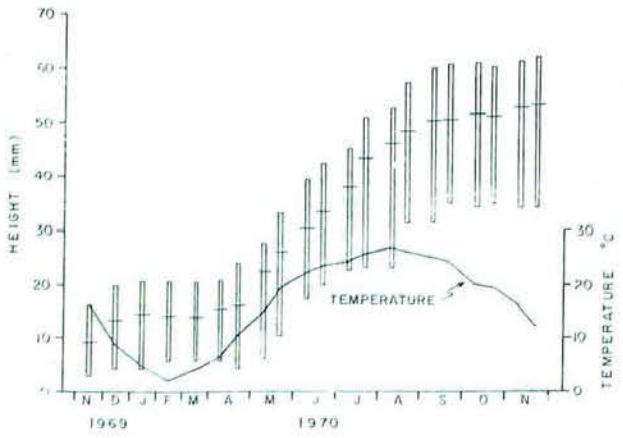

FIG. 2. *Average monthly growth and range of F_2 scallops reared in floats from November 1969 through November 1970. Scallops spawned August 1969.*

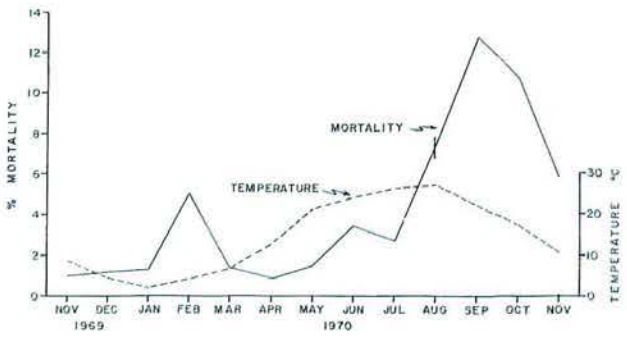

FIG. 3. *Average monthly mortality for F_2 scallops reared in floats from November 1969 through November 1970. Scallops spawned August 1969.*

This suggests that if in the experimental area scallops were spawned in January, February, and March and moved to natural waters by the end of April and averaged 10.0-15.0 mm by the end of May, they would be market size in October (8-10 months). Improved handling techniques and/or genetic improvement may reduce even more the time it takes to reach market size. Adjusting the spawning schedule will allow marketable scallops to be available at most any time of the year. However, methods for holding scallops may have to be adjusted during the winter months due to the danger of ice. Surface floats during the winter are not adequate where ice is common.

Growth of scallops held in the pen from July to November 1970 averaged 8.3 mm/month. Scallops grew from 16.1 mm to 57.4 mm, going from egg to market size in 6 months.

Average monthly mortalities (Fig. 3) generally remained below 7% from November 1969 to November 1970. The increase in mortality noted in February is attributed to sub-zero temperatures and ice in January. The increase from June through September is believed due to two factors: a general physical decline of the animals and overcrowding. Disease, parasites, and factors mentioned earlier may have influenced mortality. However, senescence, referred to by Belding (1910), was probably the more important factor. Belding mentions that this period of physical decline begins at 18 months and nearly eliminates each year class by the 26 month. Mortality of F_1 scallops began to increase at the tenth month (Fig. 3). Confinement in floats and high summer temperatures possibly weakened them so the period of physical decline began earlier. Gutsell (1930) also noted that only a few scallops reached 2-years of age, but stated that "development of sexual products in preparation for a second spawning began and continued normally until

death intervened." This, he states, "suggests not death from old age but from some pathologic factor." Some scallops, when spawning in the laboratory, discharge pieces of gill tissue, suggesting that spawning itself could be responsible directly or indirectly for some deaths and poor condition. Sastry (1966) mentions that of all the scallops examined throughout the reproductive period in North Carolina waters, those in spawning condition were least tolerant to all test temperatures (10, 20, 25 and 30°C). The decrease in mortality in October and November 1970 (Fig. 3) is believed due mainly to decreasing temperature resulting in a decrease in metabolic activity.

Although much work remains, mainly the determination of optimum densities and optimum depth for holding scallops in floats, the biological feasibility of rearing the bay scallop from egg to market size has been established. Optimization of all procedures is necessary, as well as further study of methods for holding scallops from about 10 mm to market size.

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