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Culture of the Bay Scallop, *Argopecten irradians*, in Virginia

MICHAEL CASTAGNA

INTRODUCTION

In recent years there has been an increased interest in the development of marine aquaculture or mariculture. Techniques for growing many traditional species, such as oysters and quahogs, have been developed, and considerable effort has also been made to test the feasibility of culturing new, less traditional species (Loosanoff and Davis, 1963; Iversen, 1968; McNeil, 1970; Price and Maurer, 1971; and Milne, 1972). This paper reviews the natural history of the bay scallop, *Argopecten irradians* Lamarck, and presents a review of the Virginia Institute of Marine Science's (VIMS) continuing research on this species which began in 1968.

The bay scallop has several characteristics well suited for mariculture. It is fast growing, easy to condition and spawn, and is relatively hardy throughout all life history stages. Most important, it has a good market demand and commands high prices. Many species are biologically amenable to mariculture, but economics dictate the use of gourmet species which command high prices to defray high costs of culture.

Only adductor muscles of scallops are utilized. Yields vary, but approximately 1-1 1/4 bu of scallops produces 1 gal (9 lb) of adductor muscle. The price of shucked scallops rose to $38 per gal (for adductor muscles) in 1973, or over $4.20 per lb, certainly qualifying scallops as a gourmet food.

Utilization of shell and viscera would not significantly change the price or the demand. A mechanical
shucking and eviscerating machine developed for the calico scallop fishery along the southeast coast of the United States could be used on bay scallops (Webb and Thomas, 1971). This would markedly reduce manpower and cost problems associated with hand shucking.

Bay scallops retain the ability to swim at all sizes, making it necessary to confine them in suitable enclosures. Although this necessity increases expenses, it is partially compensated by reducing the cost of harvesting expenses.

NATURAL HISTORY

The natural history of the species has been described by Belding (1910), Wells (1927), Gutsell (1930), Loosanoff and Davis (1963), Sastry (1965), and Castagna and Duggan (1971). Bay scallops in the mid-Atlantic area spawn from mid-April through early September (Chanley and Andrews, 1971). Spawning in New England occurs when water temperatures reach 22-26°C (Belding, 1910). Although the scallops are hermaphroditic, self-fertilization is uncommon in nature (Belding, 1910; Gutsell, 1930). They usually release sperm first, followed by eggs (Loosanoff and Davis, 1963), which encourages cross-fertilization. Fertilized eggs develop into straight-hinge veligers in a few hours, and the larvae are planktonic for about 5-8 days. Longer larval periods are common when environmental conditions are less than optimum. The total length of the straight-hinge stage ranges from 85 μm minimum to 140 μm maximum (Chanley and Andrews, 1971).

Juveniles attach by byssal threads to eelgrass or other epibenthic support. They usually maintain attachment until 20-30 mm size is reached, after which most scallops drop to the bottom. Marine plants or other suitable cover is quite important to scallops. Small scallops (under 10 mm) do not survive well when exposed to silt. By attaching to the leaves or stems of submerged plants, they grow large enough to survive the more rigorous existence and greater exposure to silt on the bottom. Further, grass beds reduce current velocities. Work by Kirby-Smith (1972) indicates that scallops grow faster in slow currents. Maximum growth rates were achieved in 1-5 cm/sec, and a flow volume of 4 liters/hr/scallop the slowest current velocities tested. Scallops apparently retain their ability to form byssal attachment throughout their lives, but are seldom found attached when fully grown. They are active swimmers at all sizes and apparently use this ability to avoid predators such as starfish and crabs. Davis and Marshall (1961), studying the filter feeding of bay scallops, found an abundance of benthic and tychopelagic diatoms in the stomachs. They considered this an indication that much of the food is microflora, detritus, bacteria, and organic matter that is common in the water immediately adjacent to the bottom.

The bay scallop has a relatively high pumping rate, probably correlated with its rapid rate of growth. The average rate for small scallops, 38-44 mm in length, was 3.26 liters/hr. The larger scallops, 64-65 mm in length, averaged 14.72 liters/hr, with a maximum rate of 24.4 liters/hr (Chipman and Hopkins, 1954).

The average lifespan is about 12-16 mo with a few individuals surviving to 18 mo and rarely even to 24 mo (Belding, 1910). The scallop, typical of animals with short life cycles, exhibits great fluctuations in abundance.

MATERIALS AND METHODS

The procedures used by VIMS scientists for conditioning and spawning scallops and handling larvae were similar to those used by Loosanoff and Davis (1963). Stocks of spawners were collected from the seaside of Eastern Shore and from North Carolina. Scallop stocks were grown in pens and floats built of plastic screen stretched over wooden frames. Measurements of scallops were from hinge to lip. Seawater used in the laboratory was pumped from an adjacent creek by cast-iron pumps. All pipes and containers were plastic or glass. The seawater used for larvae and early juveniles was clarified by centrifugation in a Sharples1 clarifier, Type AS-14, or a Westfalia separator, Model KDD 605. The average salinity for

1Reference to trade names does not imply endorsement of commercial products by the National Marine Fisheries Service, NOAA.
the experimental area was 29.5 °/00
with seasonal temperatures ranging
from 3 to 28°C.

**CONDITIONING FOR SPAWNING**

The scallops were conditioned by
placing them in aerated standing sea-
water at temperatures of from 18 to
22°C for 3-6 wk depending on food,
temperatures, and the initial gonadal
condition of the scallops (Castagna
and Duggan, 1971). The conditioning
was usually done on scallops taken
from ambient-temperature seawater,
which dropped as low as 3°C in
winter. While held in standing water,
the scallops were fed mixed algal
cultures. The maturation of the gonads
could be seen by holding the valves
slightly open. The gonad is a tri-
angular bulbish organ lying along-
side the adductor muscle. When ripe,
it is usually a red-orange color (often
covered by a black epithelium). The
testis comprises the white anterior
border of the gonad (Castagna and
Duggan, 1971).

**SPAWNING**

Spawning was accomplished by
placing one or two adult scallops in
a 1-liter Pyrex container filled with
filtered seawater. A number of these
containers were placed in a water
table. By flooding the water table
with hot or cold water, the scallops
were subjected to temperature changes
sufficient to induce spawning. Tem-
peratures of 24-26°C induced max-
imum pumping activity. Temperatures
were usually raised to 30°C for a
few minutes and then dropped back
to 24°C. Spawning usually took place
at 28-26°C.

A sperm suspension (either stripped
or spawned) was added to further
stimulate scallops to spawn. Various
chemical stimulants have been tested
with little or no success. Both sex
products are often released by the
same scallop but usually not simulta-
neously.

After spawning the scallop was
removed from the dish and the egg
suspension was poured through a
screen, to remove dirt and fecal ma-
terial ejected by the spawner, into a
calibrated container of filtered sea-
water. Eggs were counted by stirring
the contents of the container and sub-
sampling several 1-ml samples. An
estimate of the number of eggs was
made by averaging the counts and
multiplying by the total volume.

**FERTILIZATION**

Fertilization was initiated by add-
ing approximately 6 ml of sperm sus-
pension per liter of egg suspension.
Fertilization was nearly 100 percent
successful even when sperm and eggs
from the same individual were used.
The addition of too much sperm
suspension can cause larval deformi-
ities, probably due to polyspermy.

**DEVELOPMENT**

Survival and development were
usually enhanced by holding develop-
ing eggs above 20°C. Optimum tem-
perature for development appeared to
be 26-28°C. A minimum salinity of
22.5 °/00 was necessary for develop-
ment to straight-hinge stage. At near-
optimum temperature in 28-30 °/00 sa-
linity, the blastula stage was reached
in about 4 hr, trophophore stage in
8-12 hr, and straight-hinge stage in
16-24 hr. The embryonic stages pre-
ceding the straight-hinge stage were
most vulnerable to environmental
conditions, but with proper mainte-
nance approximately 60 percent sur-
vival can be expected. Larvae from
self-fertilized eggs usually appeared
normal in the F1 generation. Sub-
sequent generations often had larval
deformities and poor survival.

The larvae were grown in 60-liter
plastic containers. Three times a week
the water was siphoned from these
containers through a fine nylon screen

![Scallop in foreground (left) is spawning.](image)
to retain larvae. These were concentrated in calibrated containers of filtered seawater, subsampled, and counted by the same procedures previously described. Measurements of a small sample were taken using an ocular micrometer, and the general condition of the larvae was ascertained. The larvae were then redistributed to containers of clean filtered seawater containing food and, if necessary, antibiotics.

**LARVAL DENSITY AND LARVAL ENVIRONMENT**

Larval density, although not critical, influenced the success of a group of larvae. Since labor and space were often in short supply, it was tempting to crowd as many larvae into as few containers as possible. This practice increased the number of failures, perhaps by increasing chances of disease transmission or because of competition for food or space. To avoid these problems, cultures were started at maximum densities of 40 eggs per ml. As the larvae grew, their densities were reduced with each water change until densities of 5 per ml were reached when larvae were ready to set.

Aeration was not necessary for survival at the densities stated above. Gentle aeration enhanced growth rate and survival of late larval stages but made little or no difference in small or early larvae. Since scallop larvae set at a relatively small size, aeration was not used routinely.

**FOOD**

Several unicellular cultures of marine flagellates or diatoms were tried as larval food with varying degrees of success. In all trials, mixtures of two or more species worked better than one species. No artificial food mixture was found that gave comparable results.

Some successful species used were *Monochrysis lutheri*, *Isochrysis galbana*, *Phaeodactylum tricornutum*, *Dunaliella tertiolecta*, and *Nanochloris oculata*. Even though food was added, the water was changed periodically to cleanse cultures of metabolic wastes and dead larvae.

When raising large numbers of scallops (or any other cultured filter feeder), the logistics of growing sufficient unicellular algae become a serious problem. An excellent method of growing quantities of food is the solarium method, often referred to as the Glancy method. (Joseph Glancy, Sayville, N.Y. was the biologist responsible for introducing this method.) This method consists of clarifying and holding seawater in aerated vats in sunlight in a solarium or greenhouse. The stored water develops a bloom of diatoms and flagellates which can be used as food.

The greenhouse method was used successfully at VIMS. Seawater was run through an AS-14 Sharples clarifier, which spins the water at 15,000 rpm in an 8-in diameter tube exerting 13,200 × g. Essentially a clarifier separates heavier particles by centrifugal force instead of gravity. The clarified seawater was then stored in 4 × 8 × 4-ft fiberglassed plywood tanks in a solarium and was continuously gently aerated. The clarified seawater retains small diatoms, flagellates, and protozoans. Heavier and larger forms, including zooplankters and diatoms with dense or heavy tests, are left on the wall of the clarifier tube. When stored in a solarium, the water temperature in the large aerated ranks rises, and the small diatoms and naked flagellates reproduce in a bloom that eventually colors the water. Seawater treated in this manner was referred to as cultured water and was used as a medium in which to grow larvae and early juvenile stages. No additional food was required. The cultured water was normally held 24 hr before use. This was sufficient time for a bloom to occur. If stored water was not used in 48 hr, it was usually discarded, since new cultured water resulted in faster growth and better survival of the larvae. Fertilization or inoculation was not necessary to attain dense blooms of useful food organisms.

Mixed wild algal cultures that grow in this system (Glancy method) were better foods than any combination of unicellular algae tested. Growth and survival were usually better than in larvae fed unicellular cultures.

**LARVAL DISEASES, PREDATORS, AND COMPETITORS**

Diseases, predators, and competitors were controlled by maintaining clean conditions. No physical, chemical, or prophylaxis treatment was used routinely except when water temperatures were over 28°C. Then, water was subjected to ultraviolet
light treatment. This treatment is reviewed by Loosanoff and Davis, (1963).

The most common disease problem was bacillary necrosis. This was treated with streptomycin (50 mg per liter) or with a wide spectrum antibiotic such as chloromycetin or polycillin. Care was taken in estimating dosage since antibiotics often caused the larvae to stop feeding for several days, and overdoses caused mortalities.

Arthropods often appeared in the larval cultures. These were controlled with tetraethyl pyrophosphate. Four drops in 60 liters of culture would usually kill all arthropods in less than an hour. Obviously this is a potent chemical and should not be used indiscriminately. Arthropods were also removed by screening. This method was preferred over chemical control.

Protozoans often appeared as a symptom of bacterial contamination. They were controlled by reducing the number of bacteria with an antibiotic.

As always, labor and space were considered as in a commercially-oriented culture practice. Therefore, it was usually more expedient to discard poor or sick cultures and start over rather than attempting treatment.

**SETTING**

Setting took place in 5-7 days, depending on food, temperature, and probably other environmental and genetic factors. The most obvious indication of spat stage was attachment by byssal threads to the culture container. The early juveniles have a well-developed foot with a heel-like byssal gland. The shell measures 175-200 μ at metamorphosis (Chaney and Andrews, 1971). This period, when the scallops were undergoing metamorphosis, was probably the most critical, and often heavy mortalities occurred.

Through early metamorphosis or setting, the scallops were kept in clarified water or in slowly flowing raw seawater. At this time vertical surfaces for attachment were presented to the setting scallops. These were panels of wood, mylar, or fiberglass that the juveniles fastened to by their byssus. Juveniles apparently preferred vertical surfaces and most were found clinging to the sides of the containers or the panels. As food requirements increased, flowing raw seawater was introduced. A screen of suitable size was placed at the overflow to retain scallops that were sucked into the overflow pipe while swimming. Juveniles were held in this manner until they reached 10-13 mm size, large enough to stay in 1/4-in plastic screen.

When the juvenile scallops were moved into the field, they required confinement to prevent them from swimming away. A variety of enclosures were used. Floats anchored at the surface had severe fouling problems which reduced the flow of water. Additional problems of boat wakes and wave action, washing the scallops about in the floats and often causing a concentration in a corner with some loss due to smothering, were also encountered. Floats placed on the bottom had fewer problems but the scallops did not grow well.

The most successful growth and survival was in pens constructed of poles placed into the bottom with 1/2-in mesh plastic screen tacked around the outside of the poles. The pens were 10 ft square and 7 ft high. They were constructed in shallow subtidal areas.

Bay scallops grown in pens were brought to market size in 5-7 mo. Further, the adductor muscle was considerably larger than in scallops grown in floats. This may be due to
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LITERATURE CITED


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Crustacean Aquaculture in Middle America

HAROLD H. WEBBER

INTRODUCTION

This paper is designed to inform the reader regarding the technical and economic feasibility of establish­ing a profitable aquaculture venture in certain specific locations on the west coast of Central America.

The recommendations made here are predicated on the following basic premises:

1) The continuing paucity of high-value crustacean aquafoods in the expanding world markets demands that new sources of supply be developed.

2) An aquacultural production technology is maturing which will enable us to generate large volumes of shrimps at favorable cost.

3) The risks and rewards of a vertically integrated aquafood enterprise have been evaluated, and the business projections reveal an advantageous return on investment.

MARKETS

There exists a market for high-value crustacean aquafoods, including marine and freshwater shrimps, lobsters, and crabs, which is now unsatisfied and is likely to remain supply-constrained for the remainder of the century. This is a consequence in part of an increasing affluence in the highly developed industrial soci­eties in the north temperate latitudes. This elevated economic status