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The Reproductive Cycle of the Bay Scallop, *Argopecten irradians irradians* (Lamarck), in a Small Coastal Embayment on Cape Cod, Massachusetts[1]

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ABSTRACT: The spawning activity of the bay scallop *Argopecten irradians irradians* (Lamarck) was monitored from May through September in a small embayment on Cape Cod, Massachusetts and compared with changes in hydrographic conditions. Spawning activity of bay scallops began in May and continued through July with some minor activity occurring during August and September. Activity was most closely related to changes in ambient temperature and occurred predominantly before the summer maximum temperature was recorded. As temperatures declined in the late summer and early fall, increased gametogenic activity was evident. A longer period of spawning activity was observed than was previously reported for New England waters.

Introduction

The bay scallop, *Argopecten irradians* (Lamarck), comprises an important part of the fishery activities on the east coast of the United States. In 1978 U.S. bay scallop landings were valued at $4.2 million with Massachusetts being the leading producing state (U.S. Dept. of Commerce, 1979). Because of its economic importance to coastal communities, an understanding of the dynamics of bay scallop populations is necessary for protection and for effective management of the fishery.

The bay scallop is found primarily in protected bays from New England to the Gulf of Mexico (Gutsell 1930); the subspecies *A. irradians irradians* is restricted in distribution from Maine to Long Island, New York (Clarke 1965). Bay scallops are hermaphroditic and highly fecund, but spawn only once during their relatively short life span (1.5–2.0 years). The development of gonadal material and subsequent successful spawning are controlled by both endogenous and exogenous factors, with temperature and nutritional status being of prime importance. Spawning of bay scallop populations in New England waters has been reported to occur when seawater temperatures range from 20–24 °C (Belding 1931) and is generally induced during the early summer as temperatures are still rising to the annual maximum (Gutsell 1930) and coincident with phytoplankton blooms (Sastry 1966, 1968). According to early reports (Belding 1910, 1931; Gutsell 1930; Marshall 1960) spawning of bay scallop populations in southern New England should occur during June and July. A detailed investigation of gonadal development and the duration of the spawning activity of the bay scallop, however, has not been conducted previously.

In the summer of 1979 a study was initiated in Waquoit Bay, a small embayment on the south shore of Cape Cod, Massachusetts, to investigate the reproductive cycle and early growth and development of bay scallop populations. This paper reports the gonadal development and spawning activity

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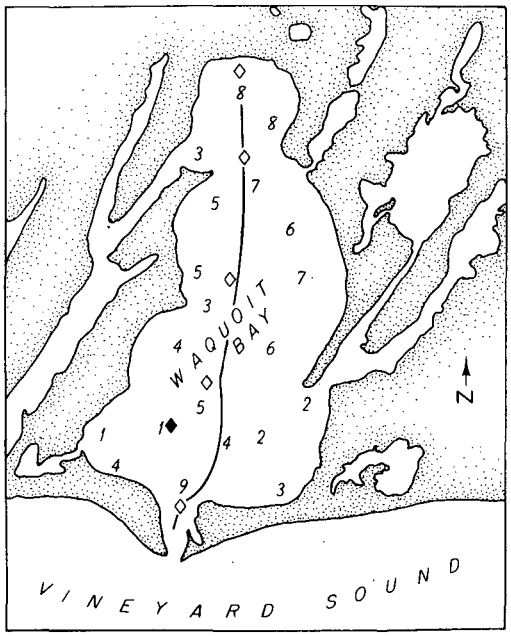

Fig. 1. Map of Waquoit Bay (depths in feet). Solid line denotes location of channel; ◇—sampling station, ◆—sampling station and location of scallops collected for gonad sampling.

of adult bay scallop populations within this small embayment.

Materials and Methods

Waquoit Bay is a long shallow (0.3–2.7 m in depth) body of water covering approximately 1600 acres on Cape Cod, Massachusetts. It is approximately 1 mile in length from the mouth to its head and the mouth of the bay is located on Vineyard Sound (42°35′N, 70°32′W). The bay has a silty-sandy bottom and a dredged channel that runs up the center (Fig. 1). At six locations along the length of the bay water temperature, salinity, dissolved oxygen and pH were measured with a Hydrolab Model 8100 Water Quality Unit for the duration of the study. From May 22, 1979 through September 18, 1979, 5 to 10 scallops were taken weekly at the same location to determine gametogenic activity in the adult bay scallop population. The gonad, a conspicuous organ that lies near the adductor muscle, was then dissected from the animal and placed in Bouin's fixative. After 48 h in fixative the gonads were rinsed for 6 h in running tap water and then placed in 70% alcohol.

The gonads were embedded with paraffin and 6 μm thick sections were made with a microtome. The sections were stained with Delafield's hematoxylin and counterstained with eosin Y (Humason 1962). Slides of gonads thus prepared were examined with a light microscope and classified according to the level of gametogenic activity. Gonad development and reproductive patterns of bivalve molluscs have been previously described by Brousseau (1978), Coe and Turner (1938), Quayle (1942), Merrill and Burch (1960), Ropes and Stickney (1965), Sastry (1963) and Shaw (1964).

The following criteria were used for classifying the stages of activity in the testicular portion of the gonad: *Early Active*—follicles increasing in number and expanding with spermatogonia and spermatocytes present; *Late Active*—spermatids predominating in the center of the lumen; spermatocyte numerous, while spermatozoa may be present; *Ripe*—spermatozoa predominating in the gonad; spermatozoa joined by their heads and the tails pointing toward the center of the lumen in the gonad (Fig. 2A); *Partially Spawned*—bundles of sperm separating and the follicles beginning to empty from the center of the lumen to the lumen wall of the gonad (Fig. 2B); *Spent*—the follicles empty with few residual sperm in the center of the lumen and occasional spermatogonia lining the follicle wall of the gonad (Fig. 2C).

The following criteria were used for staging the ovarian portion of the gonad: *Early Active*—oogonia arising from stem cells seen along follicle wall, oocytes attached to the follicle wall and their nuclei appearing darker than the surrounding cytoplasm; *Late Active*—oocytes having nuclei lighter than the cytoplasm, many of the oocytes still attached to the follicle wall; *Ripe*—the oocytes tightly packed within the follicles with most lying free of the lumen of the gonad (Fig. 3A); *Partially Spawned*—the follicles beginning to empty and residual oocytes appearing in the gonad (Fig. 3B); *Spent*—lumen empty with few residual ova, developing oogonia present on the follicle walls of the gonad (Fig. 3C). Gametogenic activity of the ovarian and testicular portions of the gonad

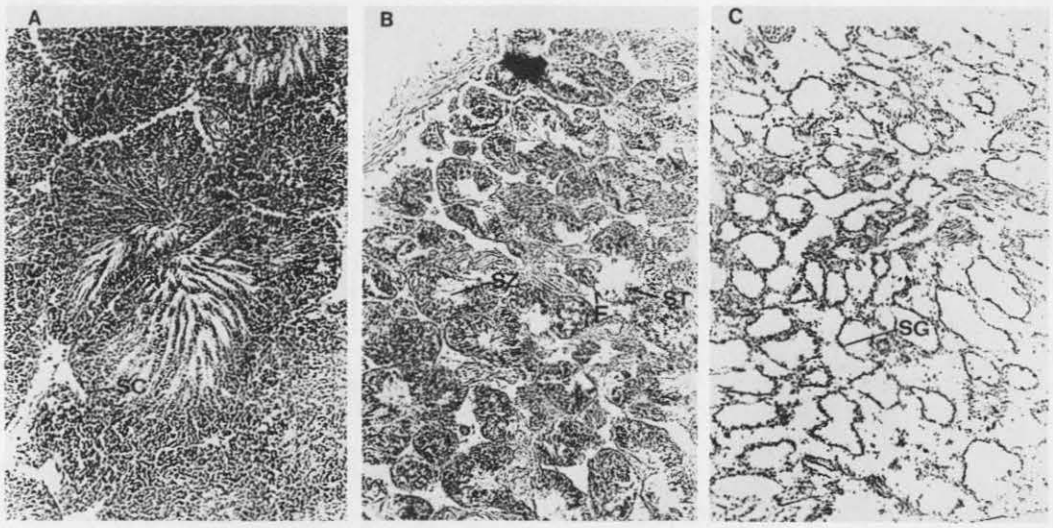

Fig. 2. a. Ripe male portion of gonad exhibiting the accumulation of ripe sperm (SZ) in the center of the follicle surrounded by spermatids (ST); spermatocytes (SC) line the follicle (F) wall; 400×. b. Partially spawned male portion of gonad; note the emptying of spermatozoa (SZ) from the follicle; 100×. c. Spent male portion of the gonad exhibiting empty follicles with spermatogonia (SG) lining the follicle walls; 200×.

was compared to the hydrographic conditions within the bay.

Results and Discussion

Hydrographic conditions of Waquoit Bay during the greater portion of sampling period are presented in Table 1. The ranges of temperature, salinity and dissolved oxygen encompass optimum values for growth and reproduction (Robert 1978). As the gonad matures the black membrane on its surface usually beings to disappear, and the

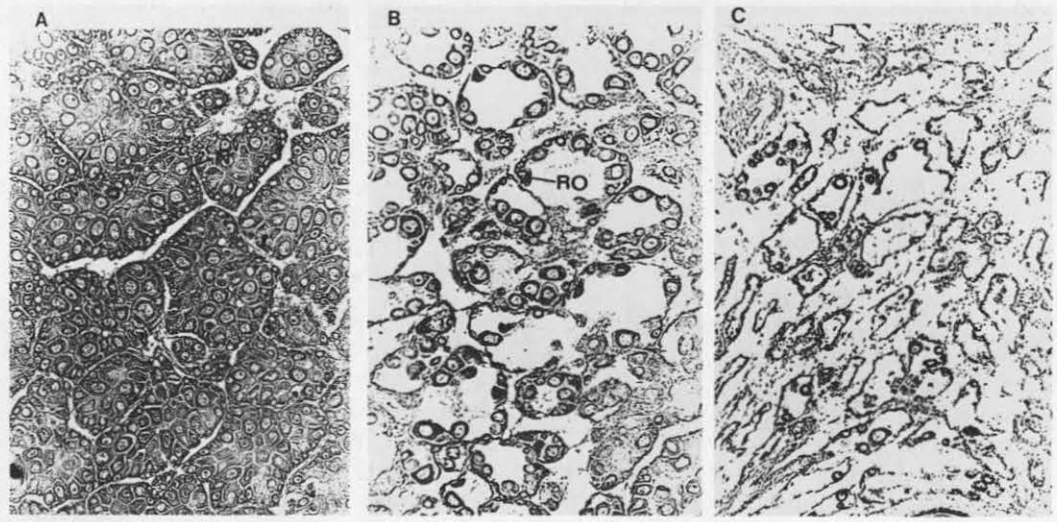

Fig. 3. a. Ripe female portion of gonad; note oocytes (N) tightly packed within the follicle; 200×. b. Partially spawned female portion of the gonad; note the nearly empty follicles and the presence of residual oocytes (RO) undergoing cytolysis; 200×. c. Spent female portion of the gonad exhibiting empty follicles and deterioration of the remaining oocytes and follicle walls; 200×.

TABLE 1. Summary of physical and chemical data for Waquoit Bay during the summer of 1979.

Date	T °C	Salinity ‰	Dissolved Oxygen ppm	pH
6-21-79	19.9	33.7	7.4	8.1
6-26-79	20.6	33.7	7.6	8.2
7-3-79	24.0	31.3	7.8	8.2
7-10-79	21.3	32.9	6.7	8.2
7-19-79	25.3	31.7	8.0	8.2
7-24-79	25.1	31.5	5.6	8.0
8-2-79	29.0	28.7	8.8	8.1
8-7-79	26.5	30.2	8.6	8.2
8-16-79	20.1	33.2	7.4	8.1
8-23-79	21.1	31.5	8.2	8.2
8-28-79	24.0	30.9	7.8	8.1
9-7-79	23.0	31.1	5.7	7.9

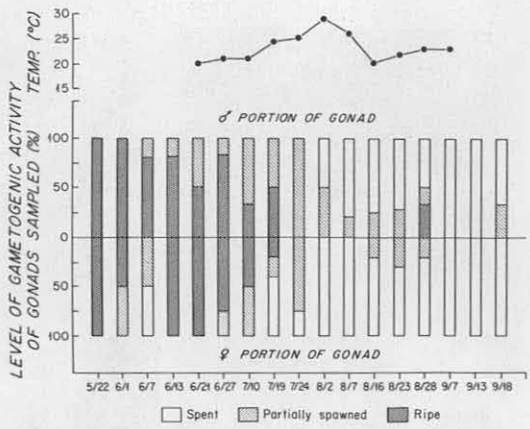

Fig. 4. Gametogenic activity of *Argopecten irradians* in Waquoit Bay, 1979.

testicular portion becomes increasingly large and cream-colored whereas the ovarian portion also becomes larger and orange-red in color. The first gonad sample taken on May 22 appeared ripe by gross examination. During July an increasing portion of the gonads become watery and tan-colored as reported by Sastry (1966). During August many gonads appeared in the spent condition.

These macroscopic examinations coincided with the microscopic examinations of gonadal material. By May 22 the testicular portions contained ripe spermatozoa. The spermatozoa predominated and spermatids and spermatocytes were also present. Ripe oocytes were tightly packed in the ovarian follicles. During June and July increasing numbers of gonads were in a partially spawned condition as spermatozoa emptied from the center of the lumen to the lumen wall and ovarian follicles began to empty. In the partially spawned condition degenerate ova appeared and new germ cells began to develop on the follicle walls. Increasingly towards the end of July and beginning of August, gonads began to appear in the spent condition; follicles appeared empty except for the occasional presence of spermatogonia in the male follicle and oogonia in the female follicles.

Evidence of gametogenic activity decreased after August 2 although some ripe and partially spawned bay scallops were found during August and September. The most noticeable change in gametogenic activity occurred with the August 2 sample in which all of the ovarian portions were in the spent condition and half of the testicular portions were spent. Gametogenic activity was most closely correlated with temperature (Fig. 4); the August 2 sampling date coincided with the summer thermal maximum of 29 °C. During late August and September the temperature declined and there was some evidence of gametogenic activity at this time. The regression equations for the relationship of gametogenic activity and temperature before the summer thermal maximum is reached are as follows.

Male $Y = 0.06X - 0.78$
$r = 0.72$, 4 d.f.,

Female $Y = 0.10X - 1.86$
$r = 0.90$, 4 d.f.;

where, Y = the proportion of the population with partially spawned or spent gonads;
X = temperature (°C)

It is apparent that spawning of bay scallop populations begins in May and continues through July, with some minor activity occurring during August and September. Belding (1931) reported that spawning of bay scallop populations in Massachusetts occurred between June 15 and August 15 when seawater temperature exceeded 18 °C. The data reported in the present study agree with those of Belding (1931) for the temperature

of first spawning, but a longer season for spawning activity was observed in this study than reported previously.

Spawning activity of bay scallop populations occurred predominantly before the summer maximum temperature was recorded. After the summer maximum temperature was reached most of the gonads appeared spent, thus emphasizing the importance of temperature in stimulating spawning as reported in the literature. Sampling of bay scallops for gonadal examination ceased with the September 18 sample as there was no indication from the literature or experience in the field to suggest that sampling should continue. It is evident from preliminary observations, however, that spawning may take place during the autumn when warmer than normal temperatures prevail and may explain the appearance of 1–5 mm juveniles in early November (G. Souza, Shellfish Master, Falmouth, MA, pers. commun.). Further investigation of this phenomenon is warranted.

Acknowledgment

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