Journal of Shellfish Research, Vol. 2, No. 2, 177–181, 1982.

INFLUENCE OF REDUCED SALINITY ON THE ATLANTIC BAY SCALLOP *ARGOPECTEN IRRADIANS* (LAMARCK) AT VARIOUS TEMPERATURES

RENEE S. MERCALDO AND EDWIN W. RHODES
National Marine Fisheries Service
Northeast Fisheries Center, Milford Laboratory
Milford, Connecticut 06460

ABSTRACT The short-term effects of reduced salinities on bay scallops were investigated by exposing animals to salinities of 0, 5, 10, and 15 ppt for periods of 2, 6, 24, and 48 hours. The experiment was repeated during various times of the year at ambient seawater temperatures of 24°, 19°, 13°, 5°, 1°, and 0°C. Survival generally decreased for a given exposure time as the temperature increased. At 24°C total mortality occurred at salinities of 0 to 10 ppt after 6 hours. None of the animals at 19° and 13°C survived after 24 hours in 0 to 5 ppt. Bay scallops at 5°C exhibited total mortality after 24 hours of exposure at 0 ppt. The mean mortality was 30% or less after exposure to all time and salinity combinations at 1°C. Results at 0°C were inconclusive. In general, scallop survival in 15 ppt was 80% or better at each time and temperature. Mortality was greatest in combinations of low salinity (0, 5, 10 ppt) and high temperature (24°, 19°C). Response surface curves based on data were used to make predictions concerning scallop survival at salinities from 0 to 20 ppt and exposures up to 50 hours. These observations may explain mortalities in natural scallop populations during heavy freshets.

INTRODUCTION

Salinity and temperature are important environmental factors which influence the distribution and survival of many marine organisms (Vernberg et al. 1963). The bay scallop *Argopecten irradians* (Lamarck) has been observed in salinities ranging from as low as 10 ppt to as high as 38 ppt (Belding 1910, Gutsell 1931, Sastry 1961, Castagna and Chanley 1973, Duggan 1975). These bivalves are commonly found in high-salinity estuaries, bays, and inlets along the eastern and Gulf coasts of the United States (Belding 1910, Gutsell 1931, Duggan 1975). Heavy rainfall and freshwater runoff often expose scallops to greatly reduced salinities. Broom (1976) noted that bay scallops may suffer considerable exposure to freshets and low temperature because they are often found in shallow water areas. Gutsell (1931) maintained that heavy freshets can be very destructive and that severe cold weather, especially when accompanied by spring low tides, sometimes damaged scallop populations. Significant mortality among scallop populations has been observed during the spring and may be a result of these freshets.

Several observations on scallops and salinity have been reported. Sastry (1961) exposed scallops directly to lowered salinities, including 21, 14, 7, and 0 ppt for a 2-hour period. The animals remained active at 21 and 14 ppt and displayed no change in behavior. Although the scallops at 7 ppt initially closed their valves, they later opened them without extending their tentacles. No active water circulation could be observed. After 2 hours of exposure, all animals were returned to ambient (28 ppt) seawater where they resumed normal activity. Scallops submerged in distilled (0 ppt) water also survived but kept their valves tightly closed even after returning to ambient seawater.

Duggan (1975) examined the effects of gradual salinity reductions on bay scallops at temperatures between 10° and 15°C and 20° and 25°C. Animals at ambient (25 to 27 ppt) seawater were acclimated to 5 to 7 ppt over a 4-hour period by adding 5 ℓ of fresh tap or distilled water at 30-minute intervals. During submersion at 15 ppt, the scallops retracted their tentacles and partially closed their shells. No activity was observed during reductions below 15 ppt. The scallops resumed normal activity after being transferred into ambient seawater.

These experiments were designed to determine the relationship between low-salinity exposure, time, and temperature for bay scallops. This information is needed to explain observations on scallop distributions and mortalities in the natural environment and to permit better decisions on planting sites for bay scallops.

MATERIALS AND METHODS

All experiments were performed with hatchery-reared bay scallops between 10 and 30 mm in height. Fresh water for salinity dilutions was collected from a waterfall on the Wepawaug River, Milford, CT. Seawater was obtained from Milford Harbor and had a salinity between 25 and 28 ppt. Salinity determinations were made using hydrometers and Knudsen's tables. Salinities and temperatures were accurate to ± 1 ppt and ± 1°C. Tests were made at ambient seawater temperature with scallops that had been held in ambient seawater for at least 1 month. Experiments were performed in standing seawater in 10-ℓ polyethylene pans, each initially containing up to four groups of 10 scallops held in 88- × 88- × 50-mm plastic berry baskets with mesh liners. During a 3-hour period the salinities in the pans were reduced gradually by dilution to 15, 10, 5, or 0 ppt. The scallops remained at these salinities for 2, 6, 24, and 48 hours, respectively, before being reacclimated to ambient salinity at 5 ppt intervals over a 3-hour period. When ambient salinity was reached, the baskets were placed in flowing seawater for a 1- to 2-week observation period. Control groups at ambient salinity in standing seawater pans were removed at 2 and 48 hours and similarly placed in flowing seawater. The scallops were examined daily, and the dead bivalves removed. Animals were considered dead if they did not respond to tactile stimuli or display movement. Dead scallops were often found gaping widely with loose meats and a fetid odor. Darkening of the blue eyes usually took place and an absence of byssal threads and fecal material could be noted. The experiment was performed once at 19°, 13°, 5°, and 1°C and in duplicate at 24° and 0°C.

Survival data from these tests were used to construct response surface curves for each temperature (Figures 1 through 6). Data points for these curves were determined in the following manner: regression coefficients were estimated by a stepwise regression analysis (using a BMPOZR Program of the Biomedical Computer Programs at the University of California). The regression coefficients were fitted to a full quadratic equation with two variables, time and salinity, using a quadratic equation to give the points plotted in the response surface curves:

$$Y = K + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2$$

where $Y = \arcsin\sqrt{\%\ \text{survival}}$, K = a constant, X_1 = time, and X_2 = salinity. The number of animals which survived at each salinity, temperature, and time combination is reflected in these curves.

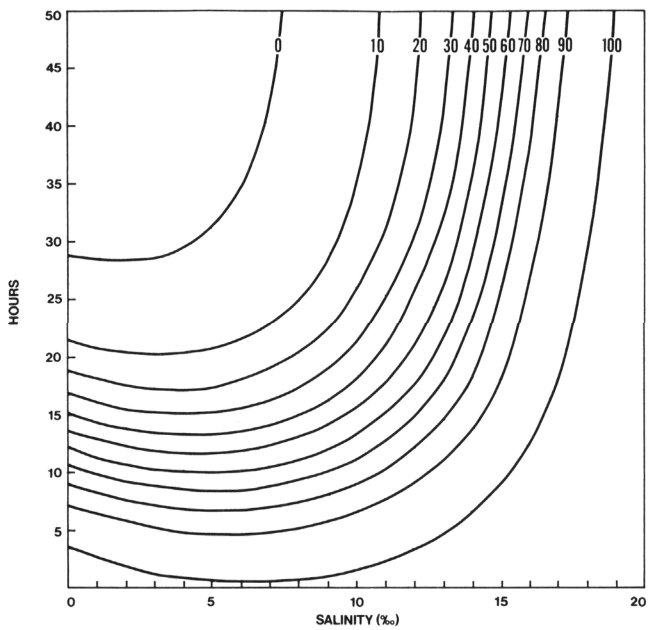

Figure 2. Response surface curve prediction of scallop survival at salinities between 0 and 20 ppt up to 50 hours at 19°C.

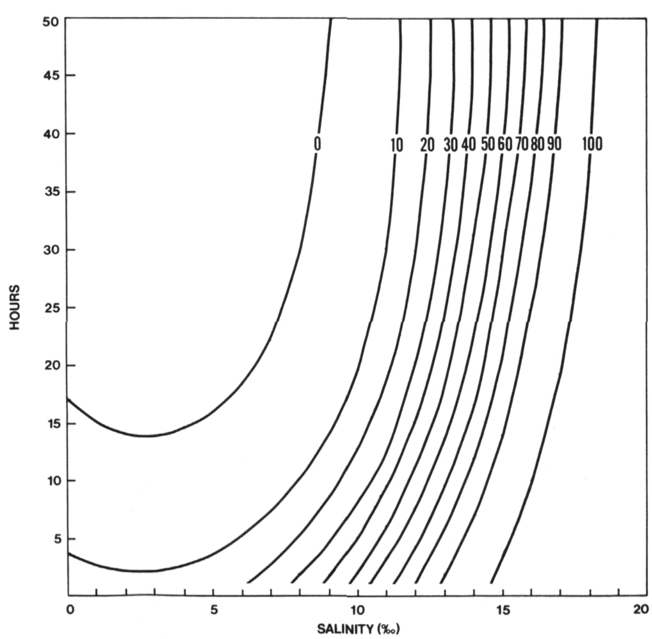

Figure 1. Response surface curve prediction of scallop survival at salinities between 0 and 20 ppt up to 50 hours at 24°C.

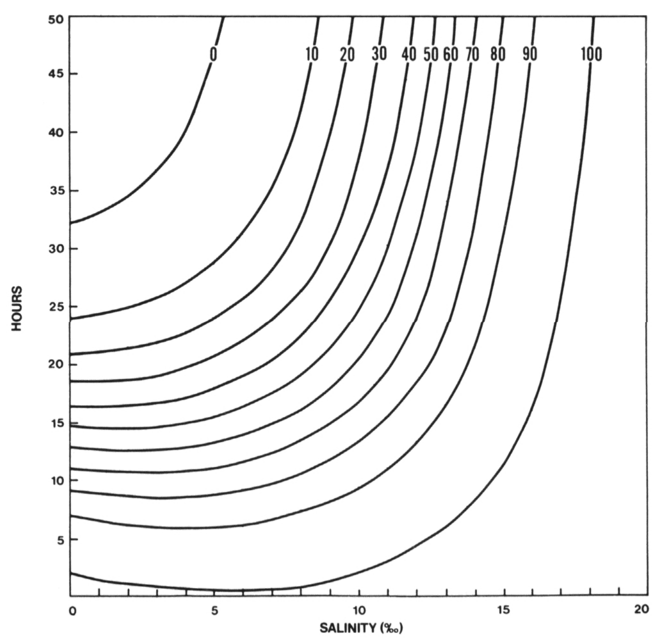

Figure 3. Response surface curve prediction of scallop survival at salinities between 0 and 20 ppt up to 50 hours at 13°C.

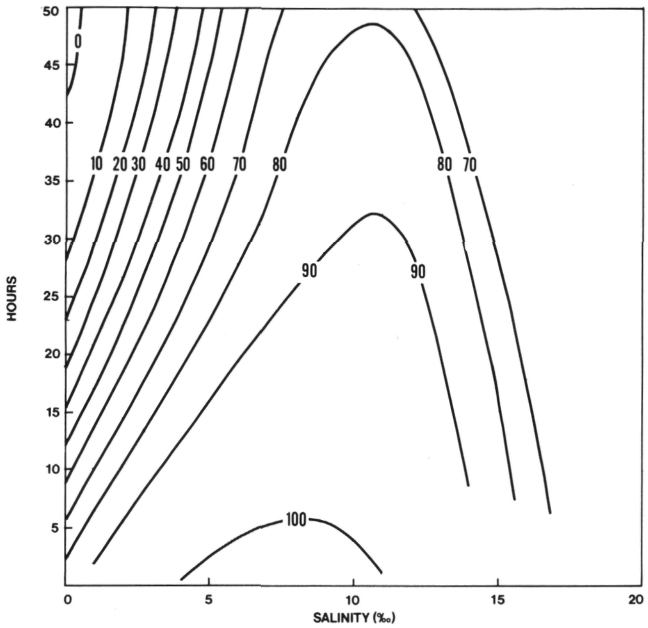

Figure 4. Response surface curve prediction of scallop survival at salinities between 0 and 20 ppt up to 50 hours at 5°C.

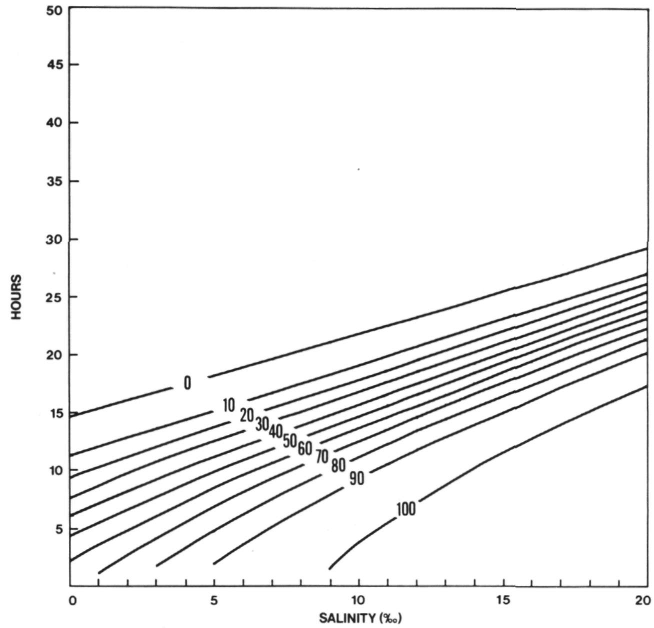

Figure 6. Response surface curve prediction of scallop survival at salinities between 0 and 20 ppt up to 50 hours at 0°C.

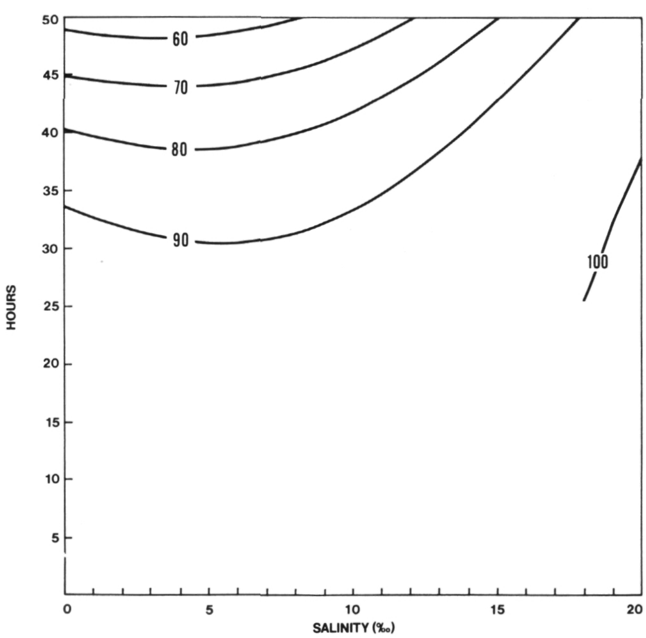

Figure 5. Response surface curve prediction of scallop survival at salinities between 0 and 20 ppt up to 50 hours at 1°C.

RESULTS

Scallops in duplicate experiments at 24°C experienced total mortality at 0 and 5 ppt when exposed for 5 hours or more, with ≤ 20% survival occurring at 2 hours. Fewer than 20% of the animals survived exposure for 6 hours or more at 10 ppt. No scallops were able to tolerate submersion at 10 ppt for 24 hours or more. Sixty percent survival or better occurred at 15 ppt for all time intervals (Table 1).

TABLE 1.

Survival of scallops exposed to salinities of 0, 5, 10, 15, and 28 ppt for time intervals of 2, 6, 24, and 48 hours at 24° and 19°C.

	24°C				24°C				19°C			
	Hours				Hours				Hours			
Salinity (ppt)	2	6	24	48	2	6	24	48	2	6	24	48
28	10	–	–	10	10	–	–	10	10	–	–	10
15	10	9	10	6	9	10	9	9	10	10	10	10
10	10	0	0	0	8	2	0	0	10	10	1	0
5	6	0	0	0	4	0	0	0	10	10	0	0
0	2	0	0	0	1	0	0	0	10	9	0	0

Ten percent mortality was found at 19°C in 0, 5, and 10 ppt up to 6 hours. Only one scallop survived submersion at 10 ppt for 24 hours, with no scallops enduring exposure for 48 hours. Total mortality occurred at 0 and 5 ppt for 24 hours or more. All of the animals tolerated 15 ppt for each of the time periods (Table 1).

Better than 90% of the bivalves survived in 0 and 5 ppt at 13°C up to 6 hours. No survival occurred at 24 hours or more. Mortality was 10% at 10 ppt up to 24 hours. Total survival occurred at 15 ppt for all the time intervals (Table 2).

At 5°C, 90% of the scallops tolerated submersion at 0 ppt up to 6 hours, while complete mortality occurred at ⩾ 24 hours at this salinity. Some survival occurred at 5 ppt for all of the time intervals with as many as 50% alive at 48 hours (Table 2).

TABLE 2.

Survival of scallops exposed to salinities of 0, 5, 10, 15, and 28 ppt for time intervals of 2, 6, 24, and 48 hours at 13°, 5°, and 1°C.

Salinity	13°C				5°C				1°C			
	Hours				Hours				Hours			
(ppt)	2	6	24	48	2	6	24	48	2	6	24	48
28	10	--	--	9	10	--	--	8	10	--	--	10
15	10	10	10	10	8	9	8	8	10	10	8	9
10	10	10	9	0	10	10	10	8	9	9	10	7
5	10	10	0	0	10	8	9	5	9	10	10	4
0	10	9	0	0	9	9	0	0	10	10	9	7

Some of the bivalves at 1°C survived at all the temperature-salinity combinations. At 0 and 10 ppt, 70% of the scallops tolerated exposure up to 48 hours. Survival at 5 ppt for 48 hours was 40%. At the other time intervals and salinities, 20% mortality or less was observed (Table 2).

During duplicate experiments at 0°C all of the animals at ⩾ 24 hours in 0 ppt died. Some survival occurred at ⩽ 6 hours in both groups with as few as 60% alive at 2 hours and 50% alive at 6 hours. Most scallops tolerated exposure to 5, 10, and 15 ppt at all time intervals; however, only 40% survival was found at 5 ppt for 48 hours. Unusual mortality occurred in the control groups at 0°C, with only 60% alive at 2 hours in one of the groups (Table 3).

TABLE 3.

Survival of scallops exposed to salinities of 0, 5, 10, 15, and 28 ppt for time intervals of 2, 6, 24, and 48 hours at 0°C.

Salinity	0°C				0°C			
	Hours				Hours			
(ppt)	2	6	24	48	2	6	24	48
28	9	–	–	10	6	–	–	10
15	10	10	9	8	9	10	7	10
10	7	9	9	7	8	6	7	8
5	8	8	6	5	8	8	9	4
0	6	5	0	0	7	9	0	0

Response surface curves for each temperature are presented in Figures 1 through 6. These curves are explained in the discussion. Raw survival data are listed in Tables 1 through 3.

DISCUSSION

Reduced salinity caused by heavy rainfall and ensuing runoff commonly occurs in estuaries inhabited by the bay scallop. These bivalves are able to tolerate exposure to low salinity for varying lengths of time, depending on the temperature.

Brief submersion in fresh water, for as little as 2 hours, is lethal to scallops at warmer temperatures (24°C). Animals at temperatures between 13° and 5°C can withstand exposure to 0 ppt for periods up to 6 hours. Scallops in cold water at 1°C can endure fresh water up to 48 hours. During experimentation, scallops at 0°C did not survive exposure to fresh water for periods > 6 hours. Winter mortality of laboratory-held scallops is not uncommon, and those used in this test may have been stressed from frequent handling and exposure to air temperature. It is possible that the combination of extreme temperature and low salinity created an intolerable environment for the bay scallop. Gunter (1961) stated that salinity is a limiting factor in the distribution of many marine organisms, especially at the lower extremes. However, excellent survival in these experiments at 1°C in fresh water suggests that scallops may tolerate exposure at 0°C in their natural environment during winter and early spring freshets and that the low survivals at 0°C and low salinities in these experiments are attributable to other factors. Significant mortality in the control supports this. Thus, in general, the bay scallops survived submersion in low salinity better at cooler temperatures. Vernberg et al. (1963) also found that specimens of cold-acclimated *Argopecten irradians* and *Modiolus modiolus* (Linné) were more resistant to low salinity than warm-acclimated individuals.

Other bivalves are also more resistant to low salinity at reduced temperature. Castagna and Chanley (1973) noted better tolerance to a range of salinities at cooler temperatures with the false angel wing *Petricola pholadiformis* (Lamarck). Loosanoff (1965) observed that the American oyster *Crassostrea virginica* (Gmelin) can survive periods of spring floods or heavy rains when the salinity of the water is greatly reduced. He noted that temperature is extremely important to this survival because the lower the temperature, the longer the oysters can tolerate low-salinity water. Galtsoff (1964) found that oysters conditioned slowly at low temperature and low salinity can endure prolonged situations of stress. Loosanoff (1948) observed that at temperatures between 8° and 12°C some adult and young oysters survived 70 days in fresh water, while all animals at temperatures between 22° and 26°C died within 13 days. Chanley (1958) studied the effects of reduced salinity on juvenile bivalves. He noted that several factors are of primary importance in determining how long animals can exist in salinities that are too low for indefinite survival.

These conditions include cooler water temperatures, larger animal sizes, and the ability of the bivalve to withdraw into a watertight shell.

In the present study, bay scallops exposed to salinities of 0, 5, and 10 ppt in warm seawater, initially closed their valves tightly. After several hours of submersion at salinities of ⩽ 10 ppt, the scallops opened their shells without extending their tentacles. As Duggan (1975) reported, scallops exposed to salinities of 15 to 16 ppt fully retracted their tentacles, closed their shells, and ceased all movement. He found that a few scallops did not close their shells completely but closed their mantle edges in what appeared to be an attempt to seal the body tissues from the changing environment.

Bay scallops can endure exposure to 15 ppt for at least 48 hours. Scallops in the control group and at 15 ppt for several hours displayed normal activity, including clapping, full extension of tentacles, and formation of byssal threads. None of the bivalves at ⩽ 10 ppt acted in a normal manner until they were returned to flowing ambient seawater.

Vernberg et al. (1963) tested the effects of temperature and salinity on excised gill tissue. Gill cilia of *Argopecten* were least resistant to lower salinity among those bivalves tested. They noted a reduction in gill ciliary activity at 18 ppt and a complete cessation of activity below 12 ppt. The response of the gill tissue corresponded with that of the whole animal.

Response surface curves, based on survival data and prepared for each temperature, suggest the probable results of exposure at salinities between 0 and 20 ppt for 50 hours. According to the curves, at 25°C 50% mortality can be expected between 10 and 15 ppt at exposure times as short as 2 hours (Figure 1). In 19°C such mortality should not occur until 16 hours at 10 ppt and 12 hours at 0 to 5 ppt (Figure 2). This trend continues at 13°C where exposure for 27 hours at 10 ppt and 15 hours at 0 to 5 ppt is necessary to cause a 50% mortality (Figure 3). At 5°C bay scallops are quite resistant to reduced salinity with 80% survival at 10 ppt for 48 hours and 50% survival expected at 42 hours in 5 ppt (Figure 4). However, survival in fresh water at 5°C is no longer than that occurring at 13° and 19°C. Salinity tolerance is greatest at 1°C, where 90% survival is predicted in exposures up to 30 hours and better than 50% survival in exposures up to 50 hours (Figure 5). The 0°C response surface curve reflects a reversal in the trend of increased tolerance to lower salinities as the temperature declines which is apparent from the experiments at 1°C and above (Figure 6). Because this curve and the raw data in Table 3 were probably influenced by other laboratory stress conditions that occurred during the 0°C tests, they may not accurately reflect the consequences of salinity exposures at this temperature.

The salinity-temperature-time experiments provide predictive information for determining whether heavy freshets will produce mortality in scallop populations. This information can explain the absence of scallops in estuaries fed by large rivers with heavy freshwater runoff. When planting bay scallops that are produced by aquacultural methods, it is important to select an estuarine area which is not subjected to frequent and extended exposure to lower salinity.

ACKNOWLEDGMENTS

The authors express their appreciation to John MacInnes for running the computer analysis of the survival data and producing the response surface curve points. We also thank Patricia Boyd, Patricia Goertz, Ronald Goldberg, and James Widman for technical help and Rita Riccio for editorial assistance.

REFERENCES CITED

Belding, D. L. 1910. A report upon the scallop fishery of Massachusetts, including the habits, life history of *Pecten irradians,* its rate of growth and other factors of economic value. *Spec. Rep., Comm. Fish. Game, Mass.* 150 p.

Broom, M. J. 1976. Synopsis of biological data on scallops *Chlamys (Aequipecten) opercularis* (Linnaeus), *Argopecten irradians* (Lamarck), *Argopecten gibbus* (Linneaus). *FAO Fish. Biol. Synop.* 114:44 p.

Castagna, M. & P. Chanley. 1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western mid-Atlantic coast. *Malacologia* 12:47–96.

Chanley, P. E. 1958. Survival of some juvenile bivalves in water of low salinity. *Proc. Natl. Shellfish. Assoc.* 48:52–65.

Duggan, W. P. 1975. Reactions of the bay scallop, *Argopecten irradians,* to gradual reductions in salinity. *Chesapeake Sci.* 16(4):284–286.

Galtsoff, P. S. 1964. The American oyster *Crassostrea virginica* Gmelin. *U.S. Fish Wildl. Serv. Fish Bull.* 64:480 p.

Gunter, G. 1961. Some relations of estuarine organisms to salinity. *Limnol. Oceanogr.* 6:182–190.

Gutsell, J. S. 1931. Natural history of the bay scallop. *Bull. U.S. Bur. Fish. Doc. No. 1100.* 46(1930):569–632.

Loosanoff, V. L. 1948. Survival, feeding and growth of oysters (*O. virginica*) in low salinities. *Anat. Rec.* 101(4):55.

_______ . 1965. The American or eastern oyster. *U.S. Fish Wildl. Serv. Circ.* 205:36p.

Sastry, A. N. 1961. Studies on the bay scallop, *Aequipecten irradians concentricus* Say, in Alligator Harbor, Florida. Tallahasse, FL: Florida State Univ. Available from: University Microfilms, Ann Arbor, MI; Publ. No. 61–01293. 125 p. Dissertation.

Vernberg, F. J., C. Schlieper & D. E. Schneider. 1963. The influence of temperature and salinity on ciliary activity of excised gill tissue of molluscs from North Carolina. *Comp. Biochem. Physiol.* 8:271–285.