SURVIVAL AND GROWTH OF CLAM AND OYSTER LARVAE AT DIFFERENT SALINITIES

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Adult clams (*Venus mercenaria*) and oysters (*Crassostrea virginica*) are found, both in areas where the salinity is almost oceanic, and in areas where it is low. There is little published information on the effects of salinity on the reproductive processes of the hard clam. Turner and George (1955) reported an experiment in which early larvae of *V. mercenaria* were introduced into the bottom of a glass tube in which layers of sea water of diminishing salinity were placed one above the other. The larvae swam upward, through the sharp gradients that separated the layers, with no loss in velocity until they had passed the boundary between the sea water at 20.0 parts per thousand and that at 15.0 p.p.t. In the latter their velocity decreased and they no longer moved upward. Instead, they swam in a circular pattern just above the interface. Turner, in a personal communication, reported rearing clam larvae to metamorphosis at salinities of 31.0, 28.0, 24.0 and 20.0 p.p.t. He reports, however, that he had a constant mortality in 20.0 p.p.t. until, by the tenth day, he had only about 20 per cent as many living larvae at this salinity as were still living at the higher salinities.

Since Korringa (1941) has reviewed the literature relating to the effects of salinity on several species of oysters, only those works dealing with American oysters will be mentioned here. Ryder (1885), Nelson (1921), Hopkins (1931), Loosanoff (1932) and other investigators have attempted to evaluate, from field data, some of the effects of salinity on various phases of oyster physiology. In addition, Loosanoff (1948, 1952) found experimentally that adult Long Island Sound oysters developed functional spermatozoa and fertilizable eggs at a salinity of 7.5 p.p.t. but that these eggs did not develop normally. In lower salinities gonad development was arrested. He found, however, in one experiment that Long Island Sound oysters, which were already ripe, spawned at salinities as low as 5.0 p.p.t. Butler (1949), in a study of oysters from upper Chesapeake Bay, concluded that gametogenesis was inhibited in 90 per cent of the surviving population until salinity levels rose to about 6.0 p.p.t.

Amemiya (1926) and Clark (1935) studied the salinity range for the development of fertilized eggs, of the American oyster, into shelled larvae. Both concluded that 14.5 or 15.0 p.p.t. was the lower limit for normal development and that 39.0 p.p.t was the upper limit. Amemiya, however, believed the optimum salinity for development was from 25.0 to 29.0 p.p.t., whereas Clark thought the optimum was at 23.0 p.p.t.

Nelson (1921), in New Jersey waters, observed active free-swimming larvae in salinities ranging from 5.17 to 28.80 p.p.t. From this and his observation that the adult oyster closed and refused to feed at salinities below 10.42 p.p.t.,

Nelson concluded that oyster larvae (p. 38) "may become accustomed to much lower densities than the adult animal will stand, and still remain active."

Prytherch (1934) studied the salinity limits for the attachment and metamorphosis of oyster larvae and found that they could attach in salinities from 5.6 to 32.2 p.p.t., but that beyond these limits (p. 71) "no setting occurred though many of the larvae crawled for periods of over four hours." Moreover, although (p. 71) "setting was accomplished with considerable regularity in salinities ranging from 9.0 to 29.0 p.p.t.," beyond these limits only a small percentage of the larvae was able to complete the process. He believed that the salinity range from 16.0 to 18.0 p.p.t. was optimum for setting.

In the present study we have re-investigated the effect of salinity on development of fertilized eggs of the American oyster, *C. virginica,* into shelled larvae to obtain quantitative data for estimating the relative percentage of eggs developing normally in different salinities. Similar studies were also made on eggs of the hard clam, *V. mercenaria.* In addition, we determined the effects of several lowered salinities on the survival and growth of free-swimming larvae of both clams and oysters after they had reached the straight-hinge stage.

Development of Fertilized Eggs at Different Salinities

Methods

Our laboratory tap water cannot be used, without treatment, to lower the salinity because it contains enough metallic ions, chiefly copper, to be toxic to developing eggs. In Experiment No. 1 we did use tap water to lower the salinity but added a chelator to bind up the excess metal ions. In Experiment No. 2 we used distilled water to dilute our usual sea water. This water was from a Stokes still that discharged into a tin-lined storage tank. In all subsequent experiments a Barnstead BD-2 demineralizer was our source of salt-free water, and this water was stored either in Pyrex carboys or polyethylene tanks.

High salinity water was obtained by evaporation of our sea water in polyethylene containers until the salinity was 44.52 p.p.t. This water was then stored in a Pyrex carboy until used in these experiments. The salinities tested in Experiment No. 3 were obtained by making appropriate dilutions of this high salinity water with our usual sea water (27.0 p.p.t.). In Experiment No. 4 all the salinities were obtained by diluting the high salinity water with demineralized water. The salinities tested in Experiment No. 5 were obtained by diluting our usual sea water with demineralized water.

The animals used in these experiments were spawned in the usual manner (Loosanoff and Davis, 1950; Davis, 1953). Fertilized eggs of both oysters and clams were thus obtained free of the body tissues and excessive sperm that may have affected the results of earlier workers, who used stripped eggs and sperm. For each experiment eggs from several females were pooled and an equal number of eggs was taken from this mixed lot to start cultures at each of the different salinities. All containers were then covered, to prevent loss of water by evaporation, and placed in the constant temperature bath at 23.0° C. Forty-eight hours later the contents of each culture vessel were screened and the number of normal straight-hinge larvae determined. Experimental errors, including transfer of the

eggs to the experimental culture vessels, recovery of the larvae and sampling, can probably account for differences of not more than ± 10 per cent in any individual experiment.

Salinity tolerance of developing eggs of V. mercenaria

Eggs of the hard clam of Long Island Sound can develop into normal straight-hinge larvae only within the relatively narrow salinity range of 20.0 to 32.5 p.p.t.

TABLE I

Comparison of the percentage of eggs, of oysters and clams, that develops to normal straight-hinge larvae in sea water of different salinities. Highest number developing to straight-hinge larvae from each spawning taken as 100 per cent. Experiments No. 3, No. 4 and No. 5 from same spawning

Salinity (in p.p.t.)	Eggs of Long Island Sound oysters		Eggs of Peconic Bay oysters			Eggs of Long Island Sound clams		
	Exp. No. 1	Exp. No. 2	Exp. No. 3	Exp. No. 4	Exp. No. 5	Exp. No. 3	Exp. No. 4	Exp. No. 5
44.5				0				
40.0				0				
35.0			56	29		0	1.0	
32.5			99	35		52	34	
30.0			92	78		54	84	
27.5				75			100	
Control* (26.0–27.0)	89	87	88	88	92	92	92	100
25.0				85			91	
22.5	100	100		94	100		80	84
20.0	90	82		84	76		21	16
17.5	79	91		58	63		0	0
15.0	64	73			48			0
12.5	<0.1	<0.1			18			0
10.0	0	0			0			0
7.5	0	0			0			0
5.0					0			0
2.5					0			0

* Control—Milford Laboratory sea water.

(Table I). At a salinity of 35.0 p.p.t. only one per cent or less of the eggs developed into shelled larvae, and at 17.5 p.p.t. none of the eggs developed into normal shelled larvae. Even at 20.0 p.p.t. only 16 to 21 per cent of the eggs developed into straight-hinge larvae and at 32.5 p.p.t. only 34 to 52 per cent reached this stage. Thus, the salinity range for practical work, extending from 22.5 to 30.0 p.p.t., is narrower than the biological or absolute range (20.0 to 32.5 p.p.t.). In our experiments, the optimum salinity for the development of clam eggs was about 26.5 to 27.5 p.p.t.

Salinity tolerance of developing eggs of C. virginica

Some eggs of Long Island Sound oysters, conditioned at 26.0 to 27.0 p.p.t., developed into normal straight-hinge larvae in salinities as low as 12.5 p.p.t. (Experiments No. 1 and No. 2, Table I, and Experiment No. 6, Table II). The highest percentage of normal straight-hinge larvae was obtained at a salinity of 22.5 p.p.t. The percentage of normal larvae obtained in salinities below 22.5 p.p.t. decreased progressively, in most experiments, with each successive decrease in salinity down to 15.0 p.p.t. Below 15.0 p.p.t. the percentage of normal larvae decreased abruptly and in a salinity of 12.5 p.p.t. less than 0.1 per cent of the eggs developed normally.

TABLE II

Comparison of the relative percentage of normal straight-hinge larvae obtained at salinities (a) from eggs of oysters from different areas at the same salinity and (b) from eggs of oysters from the same area at different salinities

	Oysters conditioned and spawned at 26.0–27.0 p.p.t.				Hodges Bar oysters that developed gonads at about 8.74 p.p.t.*		
					Oysters spawned in		
	Long Island Sound Exp. No. 6	Peconic Bay Exp. No. 7	Hodges Bar Exp. No. 6	Hodges Bar Exp. No. 7	7.5 p.p.t. Exp. No. 8	10.0 p.p.t. Exp. No. 8	15.0 p.p.t. Exp. No. 8
Control 26.0–27.0 p.p.t.	100	100	82	91	0	0	0
25.0 p.p.t.	99	86	80	94	0	0	0
22.5 p.p.t.	100	87	90	100	0	0	26
20.0 p.p.t.	100	86	100	91	7	26	72
17.5 p.p.t.	92	76	87	81	50	76	92
15.0 p.p.t.	37	58	60	45	48	100	100
12.5 p.p.t.	<0.1	13	1.4	11	83	92	89
10.0 p.p.t.	0	0	0	0	100	98	78
7.5 p.p.t.	0	0	0	0	99	96	72
5.0 p.p.t.	0	0	0	0	0	0	0
2.5 p.p.t.	0	0	0	0	0	0	0

* These oysters were kept, for four days prior to spawning, at the salinities at which they were induced to spawn.

Eggs of oysters from Peconic Bay, where the salinity may be as high as 31.0 p.p.t., showed about the same percentage developing in each of the lower salinities as did eggs of Long Island Sound oysters, except that a slightly higher percentage of these eggs developed at a salinity of 12.5 p.p.t. (Experiments No. 4 and No. 5, Table I, and Experiment No. 7, Table II).

In salinities above 22.5 p.p.t. the percentage of normal larvae again decreased progressively with each successive increase in salinity up to 35.0 p.p.t. Because of the comparatively high percentage of eggs that developed normally in 35.0 p.p.t., we suspect that at least a few eggs would have developed in 37.5 p.p.t. (not tested), although in 40.0 p.p.t. none developed normally.

The salinity tolerance of eggs of Maryland oysters from Hodges Bar, a low salinity area, differed only slightly from that of eggs of Long Island Sound oysters when both groups of parent oysters were conditioned at 26.0–27.0 p.p.t. (Experi-

ments No. 6 and No. 7, Table II). However, when Maryland oysters from the same area developed gonads in their native habitat, where the salinity was only 8.74 p.p.t. at the time they were collected, and were spawned in salinities of 7.5, 10.0 and 15.0 p.p.t., the eggs developed into normal straight-hinge larvae at 10.0 p.p.t., and larvae, normal in shape and only slightly smaller in size, developed at 7.5 p.p.t. (Experiment No. 8, Table II). Even at 5.0 p.p.t. many of the eggs developed into very early shelled stages before they died. The upper salinity limit for development of normal larvae from eggs of oysters which developed gonads and were spawned at low salinities was also appreciably lower than for eggs of oysters from the same area that developed gonads and were spawned at 26.0–27.0 p.p.t. None of the eggs produced at low salinities developed into normal larvae at salinities above 22.5 p.p.t.

Effect of Lowered Salinities on Growth of Larvae

Methods

To determine the effect of lowered salinities on growth of larvae we started with straight-hinge clam and oyster larvae 48 hours old. These larvae were obtained by spawning clams and oysters in sea water at our normal salinity (26.0–27.0 p.p.t.). Several 18-liter cultures of the eggs of each species were then set up in sea water at that salinity and permitted to develop for 48 hours. At the end of this period the larvae from all the cultures were collected on stainless steel screens to give a single combined culture of clam larvae and one of oyster larvae. The number of larvae per ml. in each combined culture was determined and appropriate volumes used to start duplicate cultures of clam larvae and duplicate cultures of oyster larvae at each of the salinities tested.

In both experiments the water in which the larvae were kept was changed every second day. Since the food used was grown in sea water of our normal salinity, it was added before the salinity was adjusted after a change of water. In the first experiment additional food was given to the cultures on the days between changes, as was our usual practice. The salinity could not be adjusted after this additional food was given, however, and it was found that this increased the salinity of the cultures appreciably. The increase in salinity, while only about 0.5 p.p.t. in cultures in which the nominal salinity was 22.5 p.p.t., was as much as 1.5 p.p.t. in cultures nominally at 10.0 p.p.t. and lower.

In the second experiment the salinities were maintained at the nominal level. About 1½ times the usual amount of food was given on the days when the water was changed and the salinity adjusted, but no additional food was given until the next change of water.

Effect on clam larvae

The results of the two experiments on clam larvae were in general agreement in that growth of larvae was comparatively good at salinities of 20.0 p.p.t. and higher (Fig. 1). In both experiments larvae were reared to metamorphosis at these salinities. In the first experiment there was no appreciable difference in growth of the larvae at 20.0 p.p.t., 22.5 p.p.t. and at our normal salinity (26.0–27.0 p.p.t.). However, in the second experiment, in which the salinities were controlled more care-

fully, the rate of growth of larvae decreased progressively at each successively lower salinity, as shown by the average size at each measuring period. At a salinity of 17.5 p.p.t., although growth of the clam larvae was significantly slower than at normal salinity, some larvae did reach metamorphosis. These larvae were sluggish and, apparently, more susceptible to disease than were larvae kept at higher salinities. Thus, even though some larvae reached metamorphosis, such a high mortality occurred during and immediately after setting that we were unable to follow their growth further.

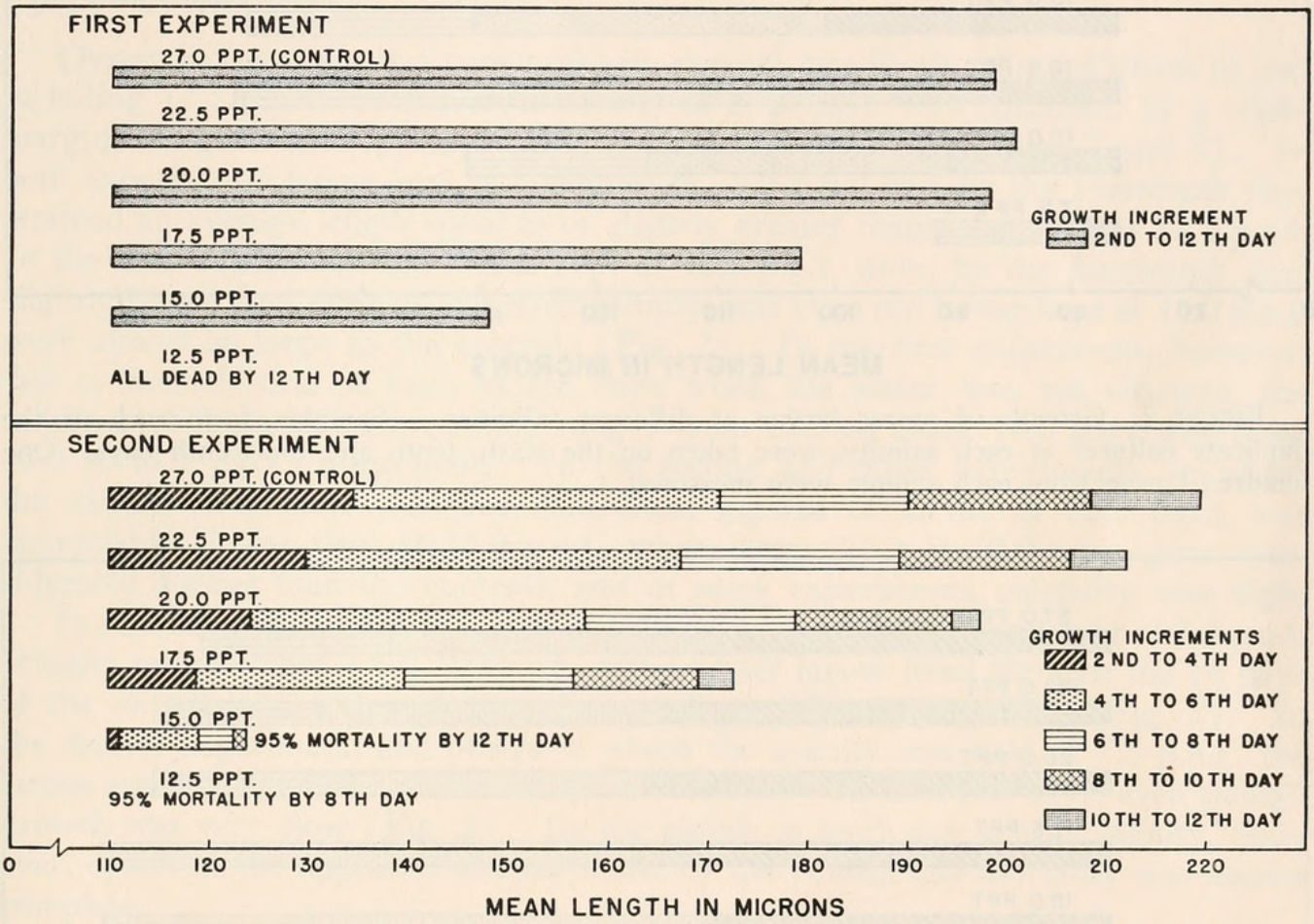

FIGURE 1. Growth of clam larvae at different salinities. Samples were taken and measurements made only at the beginning and termination of the first experiment. In the second experiment, salinities were more carefully controlled and samples, from each of the duplicate cultures at each salinity, were taken every second day. One hundred larvae from each sample were measured.

Clam larvae kept at a salinity of 15.0 p.p.t. grew even more slowly than those kept at 17.5 p.p.t. They were sluggish and susceptible to attack by protozoa, fungus and bacteria. In each experiment some larvae lived more than 12 days, but all died before reaching setting size.

At a salinity of 12.5 p.p.t., a few clam larvae survived for 10 or 12 days, but did not grow. In the second experiment, when samples were taken every two days, a slight but progressive decrease in size of larvae kept at this salinity was noted. In both experiments, it was observed that at salinities of 12.5 p.p.t. and lower, the shells of dead clam larvae were completely disintegrated in approximately 48 hours. The progressive decrease in size of larvae at 12.5 p.p.t., therefore, suggests that the shells, even of living larvae, were being slowly dissolved.

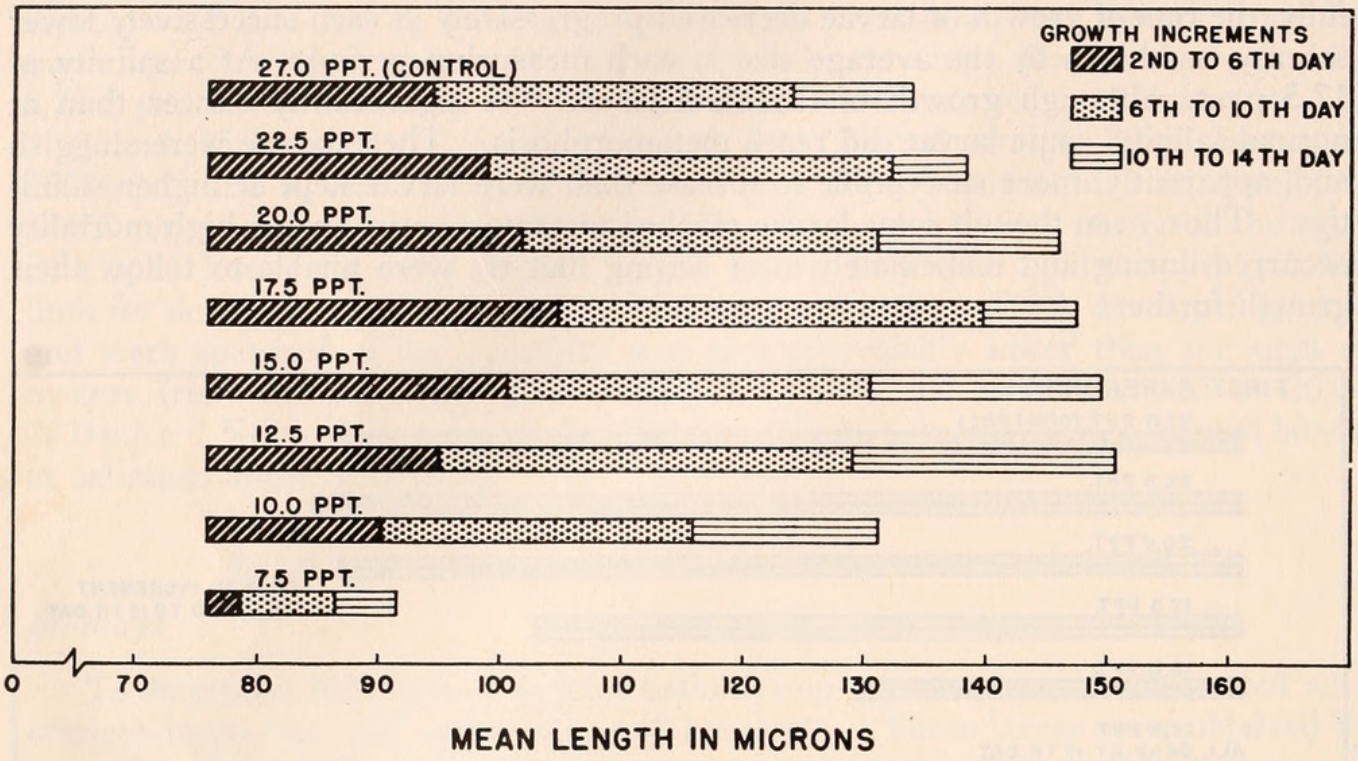

FIGURE 2. Growth of oyster larvae at different salinities. Samples, from each of the duplicate cultures at each salinity, were taken on the sixth, tenth and fourteenth days. One hundred larvae from each sample were measured.

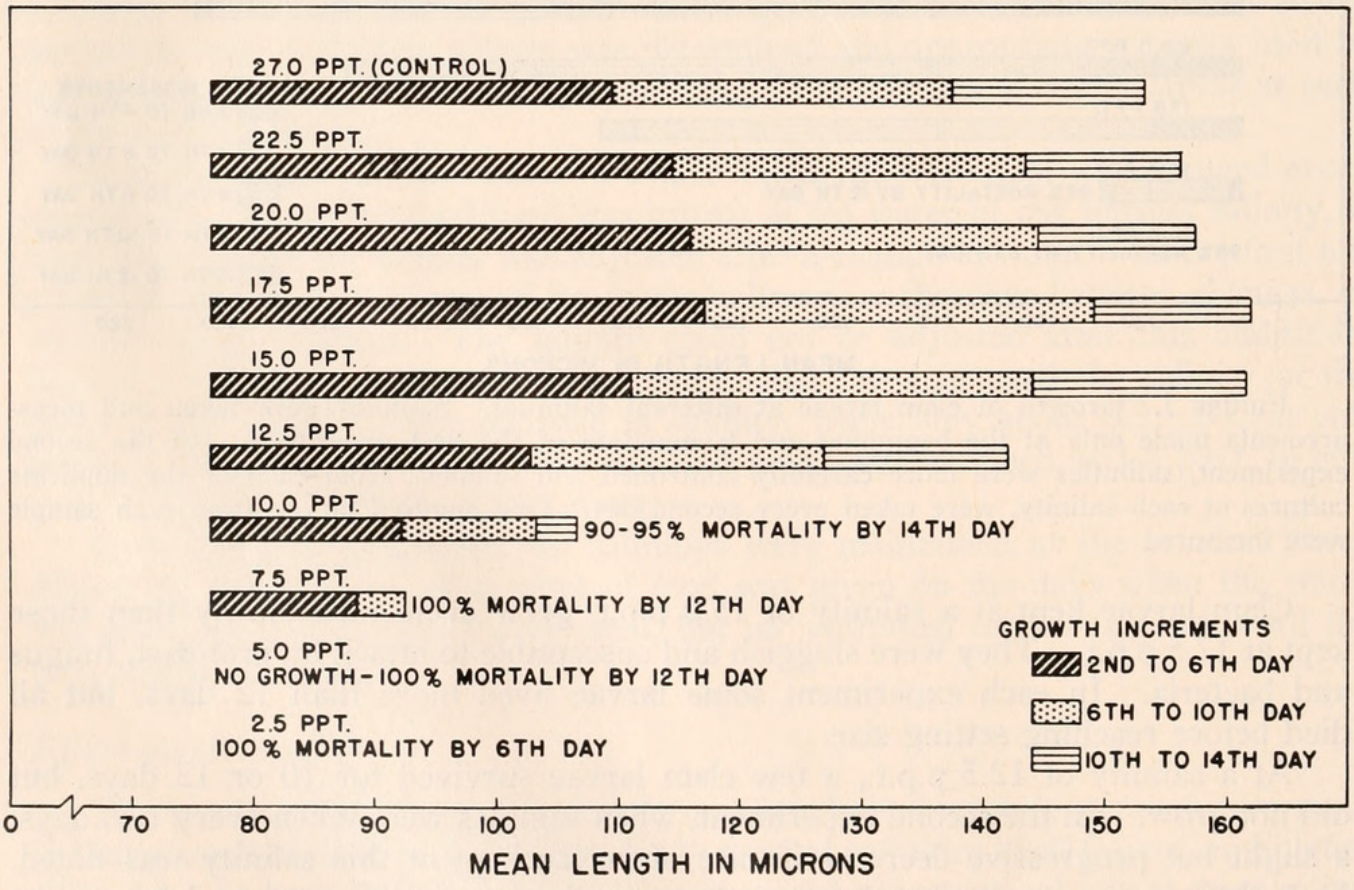

FIGURE 3. Growth of oyster larvae at different salinities. Salinities were more carefully controlled than in the previous experiment. Samples from each of the duplicate cultures at each salinity, were taken on the sixth, tenth and fourteenth days. One hundred larvae from each sample were measured.

At salinities of 10.0 p.p.t. or lower, clam larvae showed no growth and all were dead within six days.

The lower borderline salinity for clam larvae appears to be about 17.5 p.p.t. Clam larvae and set would probably survive and grow slowly at this salinity if all other conditions were nearly ideal, but would probably die if some other environmental factor were unfavorable. It would seem exceedingly doubtful that conditions in nature would ever be so favorable that clam larvae could survive, reach setting stage, and continue to grow at salinities of 15.0 p.p.t. or lower.

Effect on oyster larvae

Oyster larvae grew at a comparatively normal rate in all salinities down to and including 12.5 p.p.t. However, a salinity of 17.5 p.p.t. was optimum, by a slight margin, for growth of larvae at least through the tenth day (Figs. 2 and 3). In both experiments larvae kept in a salinity of 15.0 p.p.t. had, by the fourteenth day, attained an average length equal to or slightly greater than those kept at 17.5 p.p.t. In the first experiment the larvae kept at 12.5 p.p.t. were, by the fourteenth day, slightly larger than those at any other salinity, and even the larvae kept at 10.0 p.p.t. were almost as large as the controls (Fig. 2). In the first experiment, however, due to the addition of food on the days when the water was not changed, the salinities of these cultures actually ranged from 12.5 to about 14.0 p.p.t. and from 10.0 to 11.5 p.p.t., respectively. In the second and other experiments, in which the salinity was more carefully controlled, growth of larvae at 12.5 p.p.t. was appreciably slower than at 15.0 p.p.t., while larvae kept at 10.0 p.p.t. grew considerably slower than the controls, and in some experiments mortality was high.

In the first experiment, in which the salinity of the cultures nominally at 7.5 p.p.t. actually ranged from 7.5 to 9.0 p.p.t., some oyster larvae lived through the 14 days of the experiment, although growth was slow and mortality high (Fig. 2). In the second experiment, and others in which the salinity was held at 7.5 p.p.t., the larvae appeared to feed and seemed quite normal for the first few days, even though growth was very slow (Fig. 3). By the eighth to tenth day at this salinity, however, oyster larvae appeared moribund and by the twelfth day mortality was almost complete.

At a salinity of 5.0 p.p.t. oyster larvae appeared moribund within 48 hours. After four days almost all were completely dead, and in only a few could ciliary motion be detected.

Thus far, we have the results of only one experiment using larvae of oysters from low salinity areas in Maryland. While the results of a single experiment are not always reliable, this experiment indicated that when these oysters are conditioned at a salinity of 26.0–27.0 p.p.t. their larvae do not tolerate any lower salinities than do larvae from Long Island Sound oysters conditioned at the same salinity. As a matter of fact, in this experiment the optimum growth of the Maryland larvae was at 22.5 p.p.t., and the rate of growth decreased progressively with each successive decrease in salinity below this optimum.

Effect on older oyster larvae

The results of the above experiments, in which we started with straight-hinge larvae, could be interpreted as indicating that larger larvae (10 to 14 days old)

can grow as fast as or faster, at a salinity of 15.0 p.p.t. (or even 12.5 p.p.t. in the first experiment), than at 17.5 p.p.t. We believed, however, that this was because the larvae at 17.5 p.p.t., being larger at 10 days, were more severely handicapped by insufficient food. Davis and Guillard (in press) have shown that it requires approximately four times the quantity of food given these cultures to maintain maximal growth of larvae after they reach an average length of 140 μ, yet such a quantity of food would have handicapped the smaller or slower growing larvae at the other experimental salinities.

To test the above hypothesis in another experiment we determined the rate of growth of older larvae at salinities of 26.0–27.0 p.p.t. (control), 17.5, 15.0, 12.5, 10.0 and 7.5 p.p.t. A culture of oyster larvae, that had been reared to a mean length of 165 μ at normal salinity, was divided into six smaller cultures and one

TABLE III

Comparison of growth of older oyster larvae at different salinities. Measurements are in microns

	Control 26.0–27.0 p.p.t.	17.5 p.p.t.	15.0 p.p.t.	12.5 p.p.t.	10.0 p.p.t.	7.5 p.p.t.
Initial mean length	165.55	165.55	165.55	165.55	165.55	165.55
Length after 8 days at different salinities	206.30	214.00	203.05	205.75	186.80	175.49
Increase	40.75	48.45	37.50	40.20	21.25	9.94

of these was kept at each of the above salinities. Eight days later it was found that the larvae kept at 17.5 p.p.t. had grown the fastest, while there was very little difference in size between the controls and those kept at 15.0 or 12.5 p.p.t. (Table III). The larvae kept at 10.0 p.p.t., however, had increased in size only about one-half as much as the controls, and those kept at 7.5 p.p.t. had increased only about one-fourth as much as the controls.

These cultures were continued for several more days to get an indication of the setting rate of larvae in the different salinities. Those kept in 17.5 p.p.t. gave significantly more spat than any of the other cultures, but setting was also good at 15.0 and 12.5 p.p.t. A few spat were obtained at 10.0 p.p.t. but the larvae kept at 7.5 p.p.t. all died before metamorphosis.

DISCUSSION

Our experiments on the development of fertilized clam eggs indicate that even with a salinity as high as 22.5 p.p.t., the reproductive potential of clams may be reduced as much as 15 to 20 per cent. If the salinity is reduced to 20.0 p.p.t., the reproductive potential of clams is reduced 80 to 85 per cent and if the salinity over the spawning beds should be as low as 17.5 p.p.t., there appears to be no possibility of obtaining normal larvae.

Once clam larvae have attained the straight-hinge stage, we find, as did Turner (personal communication), that the larvae grow quite well at 20.0 p.p.t. but contrary to Turner's results we find no significant mortality at this salinity. Turner and George's (1955) observation that the larvae swam upward, the normal reaction, until they came into the sea water at 15.0 p.p.t. also appears significant. We find that at both 17.5 and 15.0 p.p.t. the larvae appear sluggish, grow slowly and suffer high mortality either prior to reaching setting stage (15.0 p.p.t.) or during metamorphosis (17.5 p.p.t.).

The minimum salinity at which a good percentage of clam eggs develops into straight-hinge larvae is 22.5 p.p.t. Once the larvae have attained this stage, however, they survive and grow well at a salinity as low as 20.0 p.p.t. Thus, as Loosanoff, Miller and Smith (1951) showed for the temperature requirements of eggs and larvae of *V. mercenaria,* the embryonic stages cannot tolerate as wide a range of salinities as can the larval stages. Similarly, Chanley (in press) found that small juvenile clams (1.8 to 3.6 mm. in length) survived for a month or more at 15.0 p.p.t. but died in salinities of 12.5 p.p.t. or lower, while larger juveniles (5.0 to 21.5 mm. in length) survived at 12.5 p.p.t.

Much additional research is needed to find the minimum salinities at which adult clams develop gonads, to find whether the salinity at which the parents develop gonads influences the salinity tolerance of the eggs and larvae, and to find whether races tolerant of low salinities exist or can be developed.

By comparison with the status of research on clams, the relation of salinity to the reproductive processes of oysters appears to be fairly well documented. Thus, the findings of Loosanoff (1948, 1952) and Butler (1949) appear to agree quite well that 6.0 to 7.5 p.p.t. is the minimum salinity for the development of gametes by the American oyster. Additional research is required, however, to determine more clearly the value of gametes produced at low salinities.

In general, our results on the development of fertilized eggs of oysters conditioned at a salinity of 27.0 p.p.t. are in close agreement with those of Amemiya (1926) and Clark (1935). However, possibly because of improvements in technique, use of larger cultures and repeated trials, or due to differences in the salinities at which the oysters developed gonads, we have been able to demonstrate that a few eggs of such oysters will develop normally at 12.5 p.p.t. or about 2.5 p.p.t. lower than found by earlier workers.

The very close agreement of the results of Amemiya (1926), Clark (1935), and ours with oysters conditioned at 26.0–27.0 p.p.t., researches so widely separated in time, space and populations sampled, suggested that the salinity tolerance of eggs of the American oyster was quite similar throughout the range of the mollusk. Preliminary tests with Maryland oysters from Hodges Bar, a low salinity area, that had been artificially conditioned at 27.0 p.p.t., appeared to confirm this suggestion. Additional research, however, showed that this was not true when these oysters developed gonads in their native habitat where the salinity was only 8.74 p.p.t. at the time the oysters were collected. When these oysters were spawned at salinities of 7.5, 10.0 or 15.0 p.p.t., comparatively normal larvae were obtained in a salinity as low as 7.5 p.p.t. It may be that eggs of oysters developing gonads at even lower salinities can develop at salinities below 7.5 p.p.t.

Additional research is needed to determine the value of larvae developing at

such low salinities. Will such larvae survive, grow and set? Will they grow and set at lower salinities than larvae developing at higher salinities?

Our observation that, once they have reached the straight-hinge stage, oyster larvae may live for some time at salinities as low as 5.0 p.p.t. suggests that the larvae Nelson (1921) reported swimming at a salinity of 5.17 p.p.t., and those observed by many other workers at low salinities, may simply be survivors of larval populations accidentally carried into these low salinities. Our observations, even of older larvae, at 10.0 p.p.t., indicate that growth at this salinity is extremely slow although a very few of the larvae kept at this salinity did set. Perhaps larvae from oysters that develop gonads at low salinities survive better and grow faster at salinities of 10.0 p.p.t. and lower than do larvae from oysters conditioned at 26.0–27.0 p.p.t. Otherwise, our observations on growth, coupled with Prytherch's (1934) observations on the setting of larvae at different salinities, would seem to suggest that oyster sets, occurring in areas where the salinity is only 10.0 p.p.t. or lower, are dependent upon larvae that grow almost to setting size at higher salinities and are carried to low salinity setting areas as practically fully mature larvae. Moreover, Chanley's results (in press) indicate that recently set spat, like the larvae, grow best at salinities near 17.5 p.p.t. and that growth is significantly retarded by salinities of 10.0 p.p.t. or lower. Unlike the larvae some of his spat grew slowly at a salinity of 5.0 p.p.t. although only about 40 per cent survived at this salinity.

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Summary

1. The optimum salinity for the development of straight-hinge larvae from eggs of clams from Long Island Sound is about 27.5 p.p.t.

2. The salinity range for development of eggs of these clams is from 20.0 p.p.t., at which salinity only 16 per cent to 21 per cent of the eggs develop, to 35.0 p.p.t., at which salinity only 1 per cent or less of the eggs develops normally.

3. The optimum salinity for growth of clam larvae after they reach the straight-hinge stage is 27.5 p.p.t. or higher, while 15.0 p.p.t. is the lowest salinity at which appreciable growth occurs, and 17.5 p.p.t. is the lowest at which we were successful in rearing clam larvae to metamorphosis.

4. Both the optimum salinity and the salinity range for the development of straight-hinge larvae from eggs of the American oyster appear to be governed by the salinity at which the parent oysters develop gonads.

5. The optimum salinity for the development of eggs of oysters from Long Island Sound, Peconic Bay, and Hodges Bar, Maryland was about 22.5 p.p.t. when these oysters developed gonads at a salinity of 26.0–27.0 p.p.t.

6. When Hodges Bar oysters developed gonads at a salinity of approximately 8.74 p.p.t. the optimum salinity for the development of their eggs was between

10.0 and 15.0 p.p.t. and appeared to be dependent upon the salinity at which the parent oysters were kept immediately prior to spawning.

7. The salinity range for development of normal straight-hinge larvae from eggs of these low salinity oysters was from 7.5 to 22.5 p.p.t., whereas the range for eggs from oysters conditioned at 26.0–27.0 p.p.t. was from 12.5 to above 35.0 p.p.t.

8. The optimum salinity for growth of larvae of Long Island Sound oysters, conditioned and spawned at 26.0–27.0 p.p.t., was 17.5 p.p.t.

9. The optimum salinity for growth of larvae of Hodges Bar oysters, conditioned and spawned at 26.0–27.0 p.p.t., appeared to be about 22.5 p.p.t.

10. It is still undetermined whether the optimum salinity for growth of larvae is influenced by the salinity at which the parent oysters develop gonads.

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