Research Report

Studies on the effects of water temperature on the sexual development of adult Olympia oysters, *Ostrea lurida*

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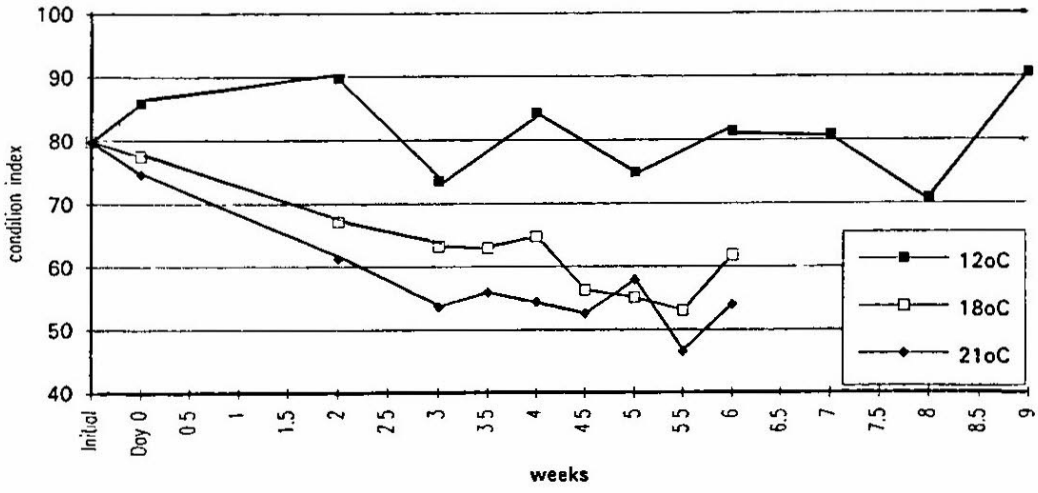
Ostrea lurida (Carpenter), is the native oyster of the Pacific Coast of United States where it is commonly called the Olympia or Californian oyster. This species is a larviparous or brooding bivalve which means that fertilization takes place inside the female mantle cavity where larvae are brooded for a period of 8 to 12 days. During this brooding period, due to the formation of the shell, the larvae go from a white color in the first 3 to 4 days to a black color in the last 3 days,just before being released. These fully mature larvae are commonly called "black sick" larvae. During the 1800s and the early years of this century, oyster farmers in Puget Sound, Washington, were able to maintain a successful fishery and meet the market demands. However, this oyster's production has suffered a dramatic decrease since those early years; from 2.5 million pounds (1250 tonnes) in 1910 to barely 5 thousand pounds (2.5 t) in 1990. Overfishing, lack of recruitment, freezing temperatures, and especially pollution were important causes of the decline in the now decimated populations.

Based on other oyster species like the Pacific (*Crassostrea gigas*), or the European (*Ostrea edulis*) oysters, the most apparent method for restoring the decimated stocks is through artificial rearing in hatcheries. Therefore, the main objective of this work was to examine gametogenesis and larval production at three water temperatures under constant hatchery conditions by monitoring and collecting data in these 5 categories: condition index, number of brooding oysters, number of larvae released, sexual phases, and gonadal index. The water temperatures were 12, 18, and 21°C, which cover the observed natural temperature range from initiation of growth and gametogenesis in the early spring months to subsequent spawning.

Material and Methods

In January 1992, adult Olympia oysters were brought to the lab when the seawater temperature was 8°C. At this point, an initial sample was taken. Three groups of 300 oysters for each



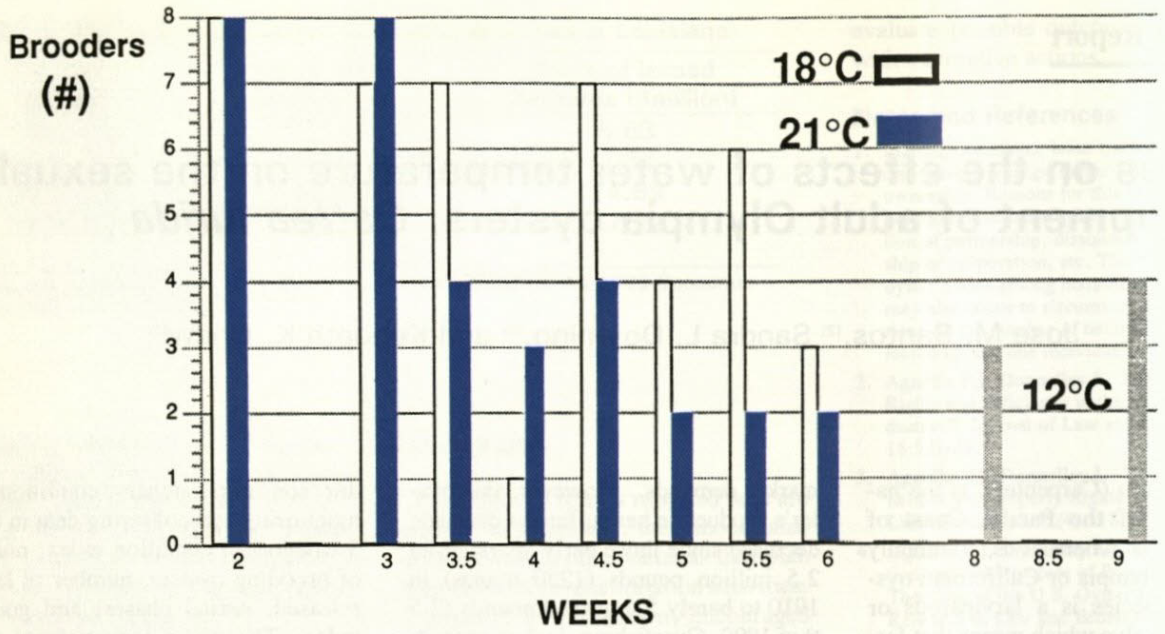


Figure 2. Number of brooding oysters in the three temperature groups.

temperature were randomly selected. Each temperature group was then divided into three and placed in experimental tanks at a density of 100 individuals per tank. Water temperature in the tanks was increased 2°C/day. On Day 0, the 3 temperature groups were at their respective temperatures and a sample for each group was taken. The next samples were taken at week 2. After that, samples were taken 1/week for the 12°C group for a period of 9 weeks, and because of rapid development, 2/week for both 18 and 21°C groups for a period of 6 weeks. Throughout the experiment, rearing conditions in all tanks were kept constant: static system with a strong aeration, type and amount of algae (a mixture of *Chaetoceros gracilis*, *Skeletonema costatum*, *Thallasiosira pseudonana*, and *Rho-*

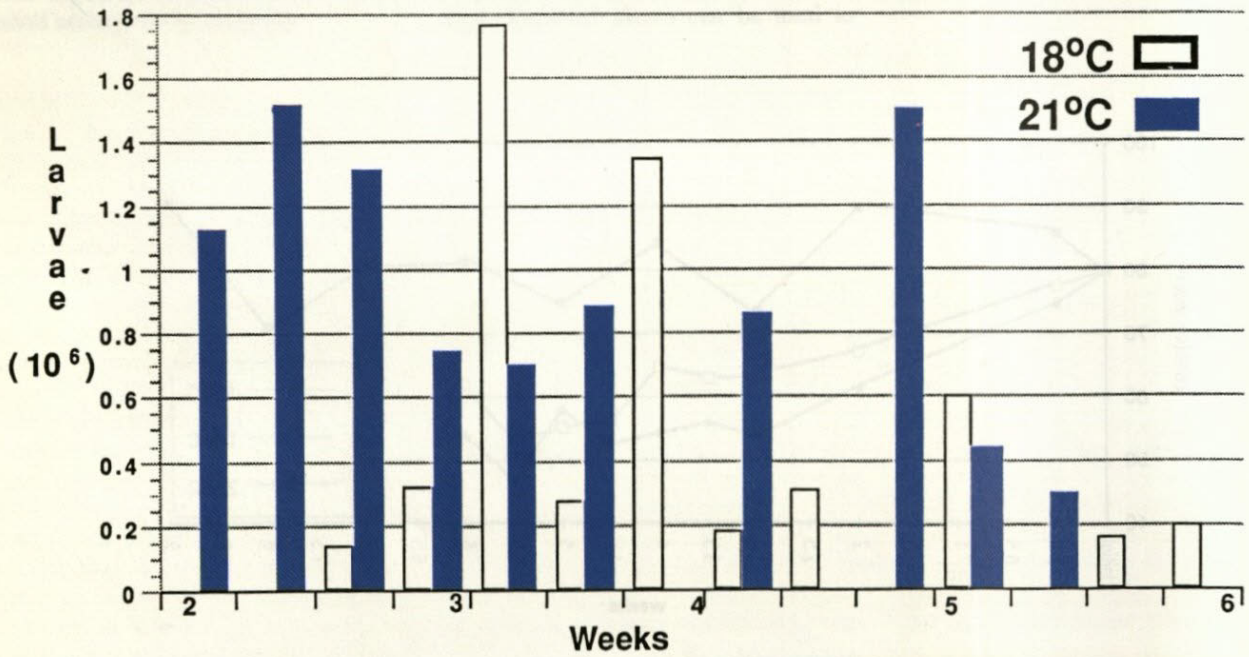


Figure 3. Number of released larvae in the three temperature groups.

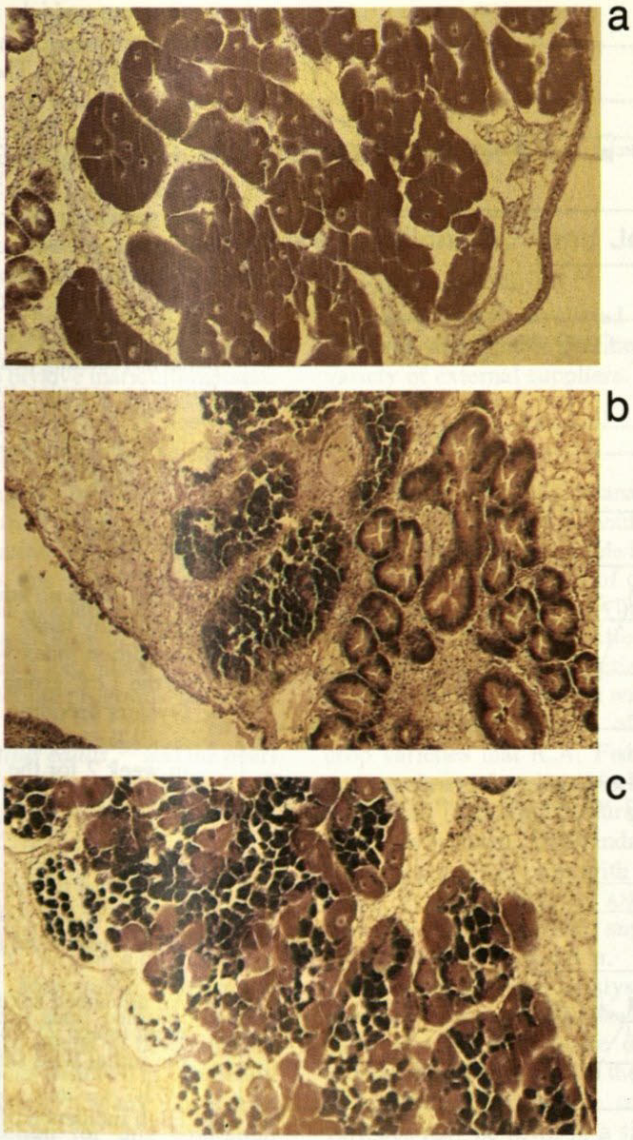


Figure 4. Sexual phases observed in the adult *Ostrea lurida*. All three individuals are in the early active stage (2) of development. a) Female phase with the follicles containing oocytes; b) male phase with the follicles containing spermatids along the walls and sperm balls in the centers; c) ambisexual phase with the follicles containing oocytes as well as spermatids and sperm balls.

damonas sp. at 500 M cells/oyster/day), and stocking density (1.5 l.x oyster).

In each sample, 36 oysters were taken: half of these for determining condition index, and the other half for histological analysis. Condition index was calculated based on the formula: C.I=(dry meat weight/internal shell cavity vol.) x 1000. For the histological analysis, 5 stages were defined and ranked as follows: inactive (0), spent (1), early active (2), late active (3), ripe (4), and brooding or partially spawn (5). For ambisexuals, they were staged and ranked separately for each sex.

Results and Discussion

Survival

During the 9 weeks of experiment, there was no mortality in any of the temperature groups.

Condition Index

The 12°C group maintained a more constant and higher condition index level than the 18 and the 21°C groups (Fig 1). In contrast at both 18 and 21°C, there was a rapid decrease after the initial sample. This probably reflects the different amounts of energy used for reproduction by the three groups.

Number of brooding oysters

From week 2 to the end of the sampling at 6 weeks, there were a high number of brooding oysters in the 18 and 21°C (Fig.2). There were more brooders in the 18 than in the 21°C group (Table 1). Oysters in the 21°C group were brooding "black sick" larvae in the second week of experiment compared to the 18°C group (week 3) or the 12°C group (week 9) which indicates they had faster gonadal development. This might explain their decrease in condition indices especially when one considers that the 12°C group, which only had a slightly decreasing condition index, only had brooders in the last week (9) of the experiment.

Larval release

Not only was the 21°C group the first one to release larvae to the water, but it also was the group that released the highest number. This fact supports the hypothesis that the brooding period is shorter in the oysters at 21°C. There were two release peaks in the 21°C group (weeks 2.5 and 5), and one peak in the 18°C group (week 3.5) (Fig.3). It is interesting to note that the total number of released larvae by oysters at 21°C was twice that number produced at 18°C while the total number of brooding larvae was twice as high in the 18°C group: the result was that overall (brooded plus released), both groups produced approximately 15 million larvae.

Sexual phases

Three distinct patterns were found throughout the experiment in all three temperatures: predominantly female, predominantly male, and strongly ambisexual (Fig.4 a-c). In addition to these distinct patterns, it is important to mention that no ambisexuals were found in the initial sample taken from nature in January. Throughout the experiment,

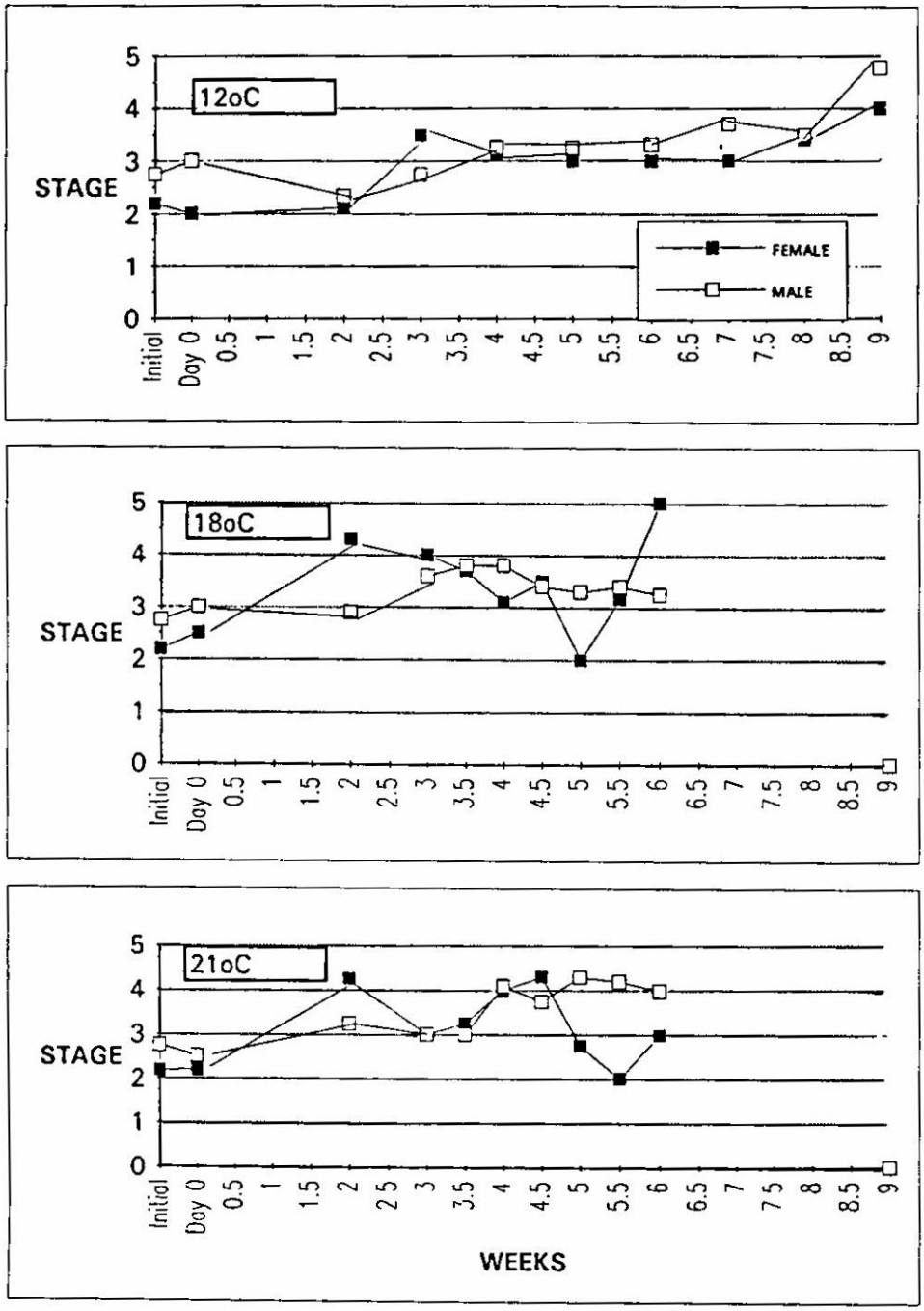


Figure 5. Gonadal index of *Ostrea lurida* males and females for the three temperature groups.

all temperature groups exhibited the three phases in similar proportions.

Gonadal index

Throughout the 9 weeks of sampling, the gonadal index for the 12°C group gradually increased for both the males and females (Fig 5). There was a male spawning peak at week 9. Although a few brooding oysters were found in the 12°C group at week 8 (Fig.2), the population mean for the females never reached the level of ripeness (stage 4). This sexual development followed a similar pattern to the one expected in nature. On the other hand, the effect of increased temperature can be seen in the 21°C group which reached two female spawning peaks, at weeks 2 and 4.5 (Fig.5). The 21°C group also had faster sexual development than the 18°C group which had female spawning peaks at weeks 2 and 6 (Fig.5). These female spawning peaks agree with the larval release peaks (Fig.3). The sexual development in the males in both 18°C and 21°C groups seemed to follow similar patterns reaching peaks at week 4. Since no samples were taken in week 1, we may have missed a male peak as brooders were found during week 2.

Summary

- There were no adult mortalities in any tank.
- Condition index was highest in the 12°C group.
- Oysters brooding "black sick" larvae were found first in week 2 for the 21°C group, in week 3 in the 18°C, and in week 9 for the 12°C group.
- Number of larvae produced (brooded + released) at 18 and 21°C over the course of the experiment were similar, 15 million.
- An advanced sexual development (stage 2) was found in the initial wild sample (January).
- High incidence of ambisexuals were found throughout the experiment with no significant differences in proportions among the three temperature groups.
- The gametogenesis cycle of the 21°C group was the fastest:
  –Female spawning peaks in week 2 and 4.5 for the 21°C group, and in week 2 and 6 for the 18°C group;
  –Male spawning peaks in weeks 4 and 5.5 for the 21°C group, and in week 4 for the 18°C;
  –None was found for the 12°C.

Notes and References

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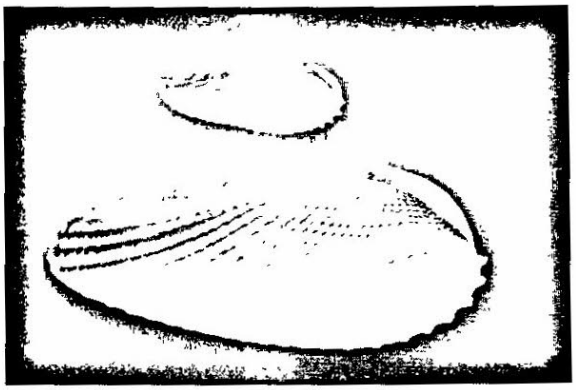

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Cover: *A harvest of hard clams from Atlantic Littleneck ClamFarms*
—photograph by Jack Alterman

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