Studies on the *Mytilus edulis* Community in Alamitos Bay, California III. The Effects of Reduced Dissolved Oxygen and Chlorinity Concentrations on Survival and Byssus Thread Formation

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(2 Text figures)

During the course of studying the ecology of the *Mytilus edulis* Linnaeus, 1758, community in Alamitos Bay, California (Reish, 1963, 1964a, 1964b) the senior author was interested in learning what biological or physical factors would limit or destroy the population. No animal was or has subsequently been observed to prey on *M. edulis* in this area. Ebling *et al* (1964) reported that crabs fed upon *M. edulis* in the laboratory and in suspended sea cages in English waters. An occasional crab, *Hemigrapsus oregonensis* (Dana, 1851), has been taken from mussel beds in Alamitos Bay, but it is not known whether or not it will feed upon it. No empty *M. edulis* shells have been observed with circular holes present as a result of radular drilling by snails.

A mass mortality of *Mytilus edulis* and associated organisms occurred in Alamitos Bay in 1962 following an extensive red tide bloom of the dinoflagellate *Gonyaulax polyhedra* Stein (Reish, 1963). It was not known if the mussels were killed directly by the accumulation of toxic material in the body or indirectly by the decrease of dissolved oxygen in the water.

The chlorinity of the sea water throughout the bay is that of normal sea water (19.2‰). Decreases in chlorinity in Alamitos Bay occur only following rains as the result of run-off from the surrounding area (Stone & Reish, 1965); however, the chlorinity returns to normal levels rapidly. It is not known whether or not these reduced chlorinities in Alamitos Bay are lethal to *Mytilus edulis*.

Two additional causes of community destruction may be cited. Large clumps of *Mytilus edulis* on floating docks may be dislodged by their own weight or by heavy waves and fall to the bottom. Dead mussel shells have been taken in bottom samples beneath these docks, but, of course, the cause of death was unknown. People utilize mussels as fishing bait.

Of the different possible causes of destruction to the mussels discussed above, two lend themselves to laboratory experimentation: reduced chlorinities and dissolved oxygen concentrations. The initial purpose, therefore, of this investigation was to determine the lethal limits of these two environmental factors on *Mytilus edulis* under controlled laboratory conditions. During the course of conducting the preliminary experiments, it was discovered that the production of byssal threads, which were used for attachment to the flask, was related to varying con-

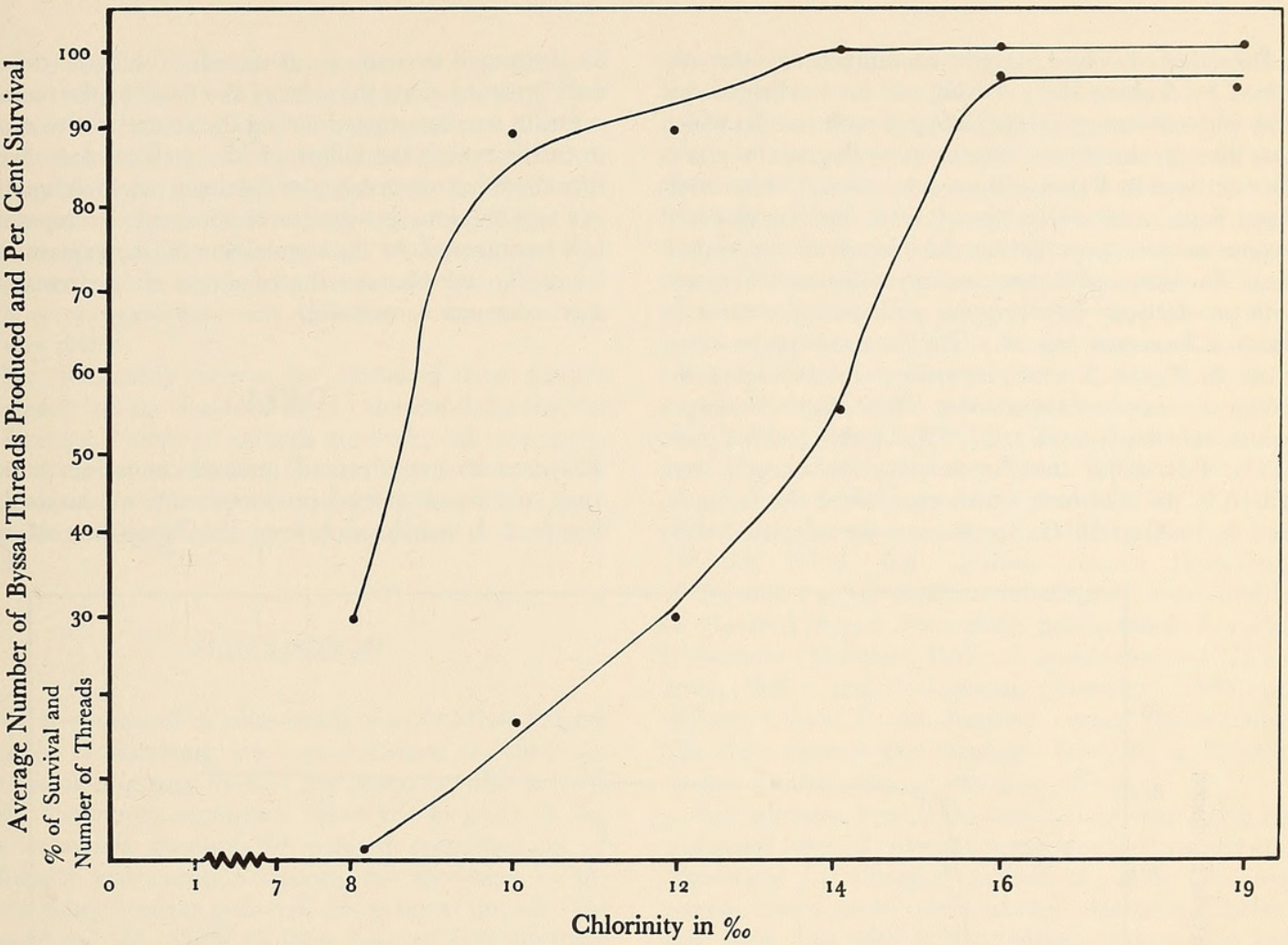

Figure 1

Survival and average number of byssal threads produced by *Mytilus edulis* under reduced concentrations of chlorinity during a 14 day period at 15°C to 16°C

centrations of chlorinity and dissolved oxygen. Therefore, it was possible not only to investigate the lethal concentrations of dissolved oxygen and chlorinity but also to ascertain intermediate levels of the condition of the animal by counting the number of byssal threads produced during the experimental period.

MATERIALS AND METHODS

Specimens of *Mytilus edulis* were collected from the boat floats in Alamitos Bay marina. They were cleaned of fouling organisms from the surface of the shells and all their byssal threads were cut. Only specimens measuring from 15 to 20 mm in width were used. Preliminary studies indicated these smaller sized mussels produced a greater number of byssal threads per unit time than larger ones, and since the gonads were immature, no spawning would occur during the course of the experiment. The specimens were then placed in aquaria in a cold bath with water temperatures of 15°C to 16°C. Specimens were left in the aquaria for 3 days. The specimens used in the experiments were cleaned again and the byssal threads cut. One specimen was placed in an Erlenmeyer flask with 150 ml of filtered sea water. Ten specimens were used for each concentration of dissolved oxygen and chlorinity. The animals were not fed during the course of the experiment.

Decreased chlorinities were made by adding an appropriate amount of distilled water. Chlorinities were determined by titrating with silver nitrate as outlined by BARNES (1959). The following chlorinity concentrations were used: 19.0 (control), 16.0, 14.0, 12.0, 10.0 and 8.0‰. The top was closed with a rubber stopper.

Decreased dissolved oxygen concentrations were obtained by flushing the overlying air in the Erlenmeyer flask with nitrogen gas through hypodermic needles which pass through the rubber stopper according to the procedure outlined by Reish & Richards (1966). Three additional flasks, each with a mussel, were used for dissolved oxygen measurement during the course of the experiment. The dissolved oxygen concentration was determined with an electrode following the procedure described by Reish & Richards (*op. cit.*). The dissolved oxygen values given in Figure 2 were determined by averaging the values measured within a series. These dissolved oxygen values were 4.5 (control), 2.1, 0.9, 0.6, 0.3, and 0.2 ppm.

The Erlenmeyer flasks containing the mussels were placed in the cold bath which maintained the temperature at 15°C to 16°C. Specimens were examined daily for death and to count byssal threads. The byssal threads were attached along the sides of the flasks by the mussels.

Death was ascertained during the course of the experiment by noting the failure of the shell to close. When this condition occurred, the specimen was left another day as a check to see whether or not tissue decomposition had commenced. At the termination of the experiments, which ran for 14 days, the condition of the remaining specimens was determined.

DATA

The data for the effects of reduced chlorinities on survival and byssal thread production are summarized in Figure 1. It can be seen from this figure that *Mytilus*

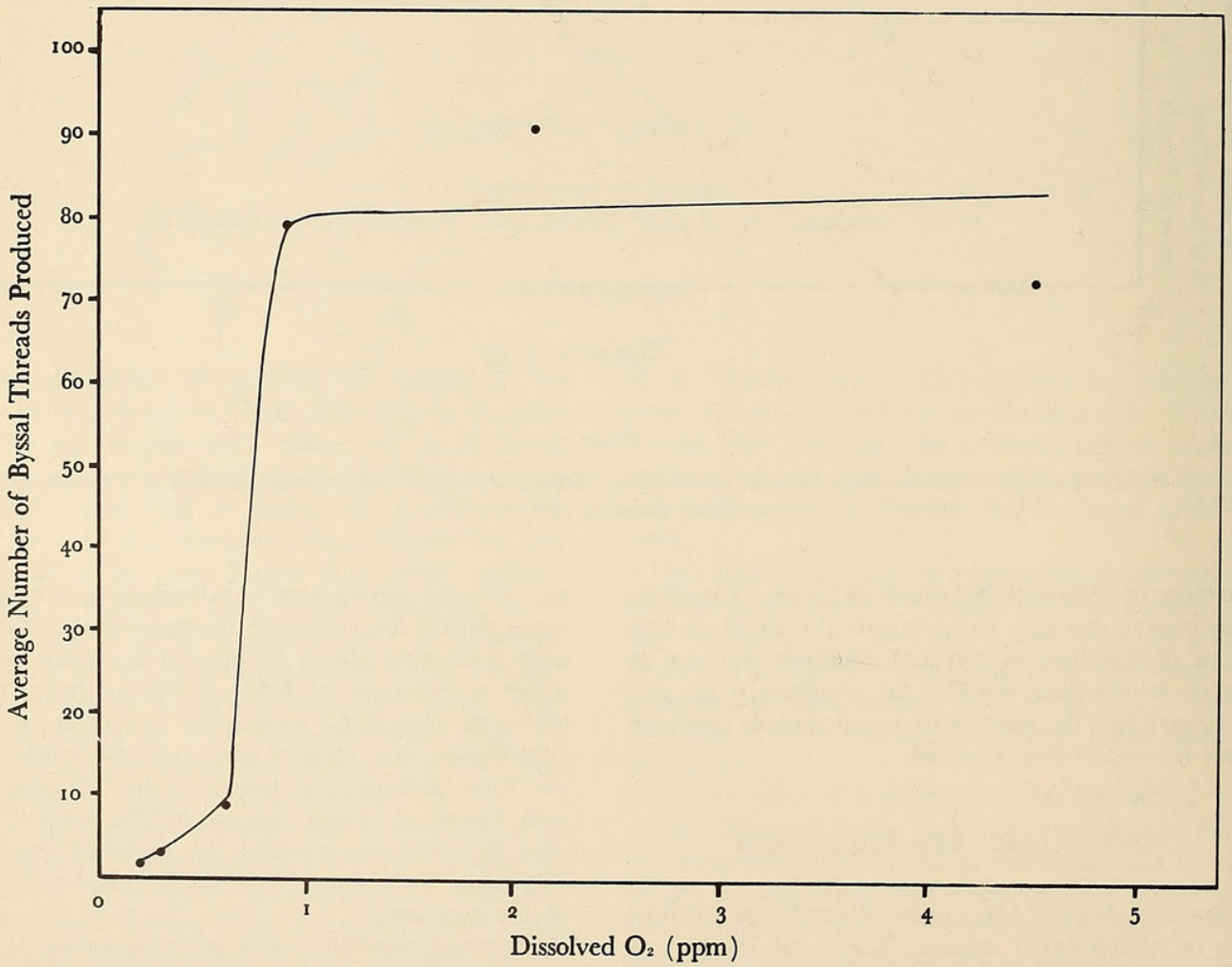

Figure 2

The average number of byssal threads produced by *Mytilus edulis* under reduced concentrations of dissolved oxygen during a 14 day period at 15°C to 16°C

edulis is capable of living for 14 days in chlorinities as low as 10.0‰. The 14 day median tolerance level (TL_m) is approximately 8.6‰. However, these data are of interest when compared to the production of byssal threads during this 14 day period. The number of threads formed decreased at chlorinities between 14‰ and 16‰. The number of byssal threads continued to decrease to 10‰. No threads were secreted by these mussels at 8‰, but 30% of the specimens were still alive at the end of the 14 day period.

The relationship between the number of byssal threads produced and the dissolved oxygen concentration is given in Figure 2. Nearly all animals survived at all concentrations of dissolved oxygen. The difference between the number of threads produced at 0.9 ppm and 0.6 ppm is striking: 80 per animal per 14 day period as compared to 9.

DISCUSSION

Small specimens of *Mytilus edulis* from Alamitos Bay are capable of surviving low concentrations of chlorinity and dissolved oxygen for a 14 day period at 15°C to 16°C under laboratory conditions. While the majority of the test organisms survived the reduced concentrations of chlorinity and dissolved oxygen, the specimens in the lower concentrations produced fewer byssal threads. The response of *M. edulis* in these lowered concentrations was similar; the two shells remained tightly closed most of the time. The shells of specimens in the controls of higher concentrations would be open.

Apparently *Mytilus edulis* is affected physiologically, as measured by byssal thread production, by chlorinities between 14‰ and 16‰, but is capable of surviving much lower levels. Chlorinities as low as 2.7‰ have been measured in Alamitos Bay (Stone & Reish, 1965). Since there are no rivers emptying into Alamitos Bay, recovery to normal chlorinities is rapid following the fresh water run-off from rain. If the rain falls over a week or more, which may occur some years, then the effects of this run-off could become an important survival factor to a population of *M. edulis*. It is of interest to note that populations of *M. edulis* occur in chlorinities of 8‰ in the Baltic Sea (Schlieper, 1955).

The survival of *Mytilus edulis* in a reduced dissolved oxygen environment under laboratory conditions has not been studied previously. During a red tide bloom of the dinoflagellate *Gonyaulax polyhedra* in Alamitos Bay in 1962 (Reish, 1963), the dissolved oxygen content of the water was lowered as a result of the decomposition of dead protozoans and other organisms. Dissolved oxygen concentrations as low as 0.1 ppm were measured, but it was unknown how long this low level persisted.

The relationship of byssal thread production in *Mytilus edulis* to altered environmental conditions has not been observed in the past. It seems logical to assume that the fewer number of threads secreted would reflect a lower metabolic rate. A reduced metabolic rate, as measured by oxygen consumption, was measured in mussels living in chlorinities below their range of tolerance (Bouxin, as reviewed by Kinne, 1964). Similar decreases in metabolic rate employing other measures of activity, but with a similar experimental procedure, have been noted in polychaetes (Reish, 1966) and in the wood-boring isopods *Limnoria* (Anderson & Reish, 1967). Four species of polychaetes, *Nereis grubei* (Kinberg, 1866), *Dorvillea articulata* (Hartman, 1938), *Neanthes arenaceodentata* (Moore, 1903), and *Capitella capitata* (Fabricius, 1780), failed to eat algae under sublethal concentrations of dissolved oxygen. Fecal pellet production in *Limnoria tripunctata* (Menzies, 1951), *L. quadripunctata* (Holthuis, 1949), and *L. lignorum* (Rathke, 1799), was directly related to the dissolved oxygen concentration. The daily egestion rate decreased markedly in dissolved oxygen concentrations of less than 2.0 ppm.

It is apparent from these data that *Mytilus edulis* can withstand lowered chlorinities and dissolved oxygen concentrations for extended periods of time. The shells remain closed under these altered conditions. Correlating these data with field conditions, it is evident that if lowered environmental conditions extend for only a short period of time, then *M. edulis* would be able to withstand these conditions by keeping its shells closed. If, on the other hand, reduced dissolved oxygen concentrations or chlorinities extend over a longer period of time, such as a week or two or more, then the survival factor for *M. edulis* would become critical. Since some knowledge of the limiting values of dissolved oxygen and chlorinity on *M. edulis* are now known under laboratory conditions, it would be of particular value to study more precisely the survival of *M. edulis* under adverse conditions in the field.

SUMMARY

1. The survival of *Mytilus edulis* under reduced concentrations of dissolved oxygen and chlorinity at 15°C to 16°C was studied under laboratory conditions.
2. The 14 day TL_m value for chlorinity was 8.6‰.
3. Nearly all specimens of *Mytilus edulis* lived for 14 days in reduced dissolved oxygen concentrations as low as 0.2 ppm.

4. The number of byssal threads produced was found to be directly related to concentration of chlorinity and dissolved oxygen. The number of threads produced decreased sharply between 14.0‰ and 16.0‰ chlorinity and 0.6 ppm and 0.9 ppm dissolved oxygen.

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