Refining Shrimp Culture Methods: The Effect of Temperature on Early Stages of the Commercial Pink Shrimp [1]

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INTRODUCTION

Temperature has been thought to be the most important factor in the marine environment (Günter, 1957; Hedgepeth, 1957; Moore, 1958; Morowitz, 1968). Moreover, tropical species appear to be particularly sensitive to their upper temperature limits as it becomes increasingly apparent that certain of these organisms live within a few degrees of their upper limit during the summer months. This was first seen by Mayer, 1914, and has recently been discussed for a few species (Thorhaug, 1969, 1970 and 1971; Moore, in press). One very important application of the study of temperature limits is to aid mariculture efforts to find optimum and safe ranges for rearing of the delicate larval forms and to devise methods which will allow the larvae to grow rapidly but not approach the lethal limits. The first stages of aquaculture of the pink shrimp, *Penaeus duorarum*, have been successfully carried out by Idyll, Tabb and Yang, 1970; Ewald, 1965; and Cook, 1969. The next step after these basic methods is refining various aspects of rearing of larvae to produce a maximum yield. Since one of the most important factors for rate of growth as well as survival is temperature (Zein-Eldin and Griffith, 1966) we examined the temperature limits of stages from newly hatched nauplii through juvenile shrimp.

METHODS

The more than 2,000 experimental specimens of *Penaeus duorarum* were obtained from the University of Miami mariculture facility at Turkey Point, Florida. They were hatched from females captured on commercial shrimp grounds and spawned in the laboratory.

The specimens were reared according to the methods of Idyll et al (1970) and, when the appropriate larval stages were reached, transported to our laboratory (1 hour away) under optimum conditions of aeration and temperature control.

The instrument used to produce the temperature array was a polythermostat, which is basically an aluminum bar, precision bored to fit tubes (Thorhaug, 1969). It is heated at one end and cooled at the other with mercury thermoregulators so that the precision is ± 0.01C. The temperature range examined for most of the experiments was 10 to 40C with about 1 degree C between tubes, which range is that of environmental interest in the tropics. Oxygen was provided by bubbling air through pipettes fitted into the tubes by

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corks. Salinity was 31 parts per thousand (o/oo). Feeding was administered according to Idyll et al (1970). Conditions in general were kept at an optimum for the larvae so that temperature would be the important variable, since stress in one factor often combines with a second stress factor to cause less tolerance of temperature. It should be emphasized that these results were at a series of sustained temperatures and therefore are not necessarily consistent with fluctuating temperature limits, but rather show danger points to be avoided.

Measurements of lethal limits all contain one particularly poorly defined criterion: i.e., what is death for the individuals in question? Since biology offers us no precise general definition, we chose an empirical definition as follows: death of an organism occurred when no movement could be observed microscopically for 3 minutes even when the specimen was prodded. Discoloration or opaqueness often accompanied this. At higher temperatures disintegration occurred within a short time. This empirical criterion was selected after consultations with experts with long experience dealing with shrimp larvae; our definition proved workable.

RESULTS

The results of these experiments were surprising, especially for the first larval stage of the nauplii. The limits in all the larval stages examined occurred abruptly and the difference between all alive and all dead often was within only 1 to 2C which would indicate more abrupt limits than had been expected.

The newly-hatched nauplii from females collected in the field were able to metamorphose successfully into the protozoea only between 24 to 25 and 30.5

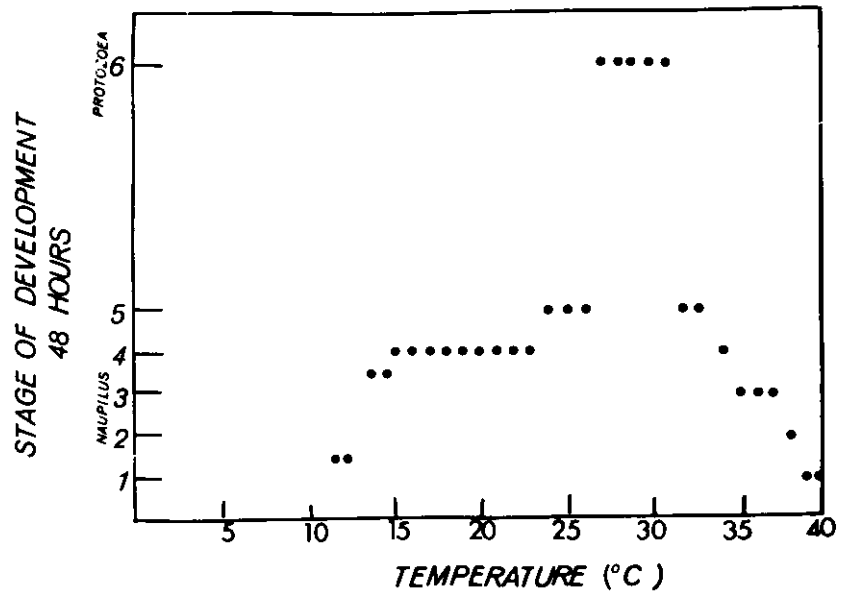

Fig. 1 Stage of development versus temperature for the commercial pink shrimp *Penaeus duorarum*. Each point represents 18 shrimp.

to 31.5C (as seen in Fig. 1 where each dot represents 18 organisms) which is a narrow range. Interestingly, the first few hours were marked by vigorous swimming activity in the tubes up to 37C, which might appear to be that of a vigorous population. After ten hours the ability to survive above 33 to 34C had severely lessened (Fig. 2). The shrimp at the lower end were alive by our criteria of movement, but they sat on the bottom and had very weak movement, which may well indicate that for shrimp at this stage they were not normal. One might also note in this experiment as well as the later stage experiments that cannibalism was markedly greater at temperatures just sublethally. This is a behavioral pattern which has been noted by mariculturists also. The optimum temperature used by Idyll et al (1970) (27 to 28C) then, is a real and necessary optimum. In the Turkey Point hatchery this is controlled by room air conditioners. It would plainly be better to control temperature as accurately as finances allow in this critical stage.

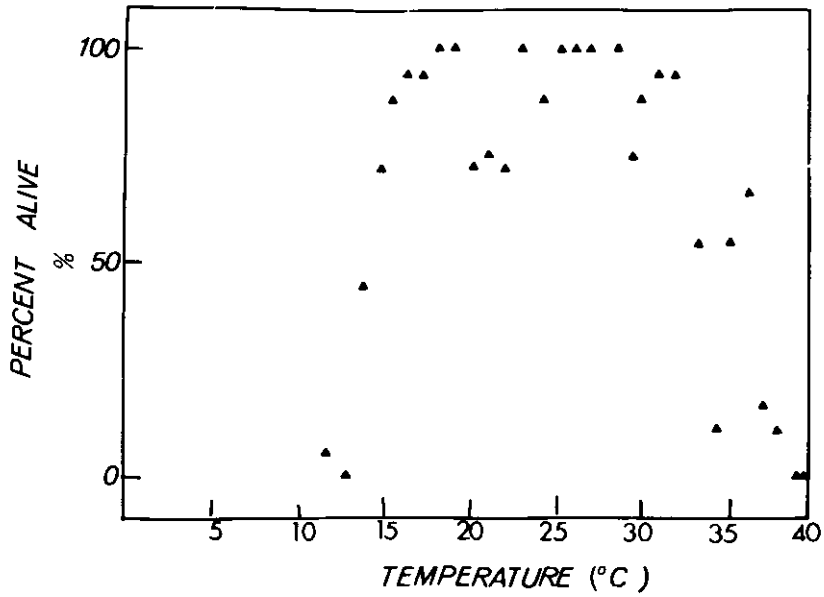

Fig. 2. *Penaeus duorarum* nauplii, percentage survival versus temperature after 10 hours.

The first protozoeal stage appeared to be much hardier with respect to lethal limits temperature than were the naupliar. After an 18 hour exposure (this stage lasts 18 to 24 hours) all organisms above 37 to 37.8C had died, while those below this temperature remained surprisingly active (Fig. 3 where each point represents 10 organisms). It should be emphasized that the time period used is an equilibrium time. During the first few minutes death will occur at the very hot temperatures. Finally, an equilibrium period is reached in many organisms, after which all those organisms which are going to die have died and the rest remain alive (Thorhaug, 1969; Bader, Roessler and Thorhaug, 1970). Of course, with regards to the shrimp larvae, these time periods are necessarily restricted by

the time for each larval stage, whereas in some of our algal work we can keep the specimens alive for months. Unfortunately, we are still in the process of obtaining the precise lower limit for each larval stage. However, this probably is not important to the mariculturist since higher temperatures cause faster growth and development.

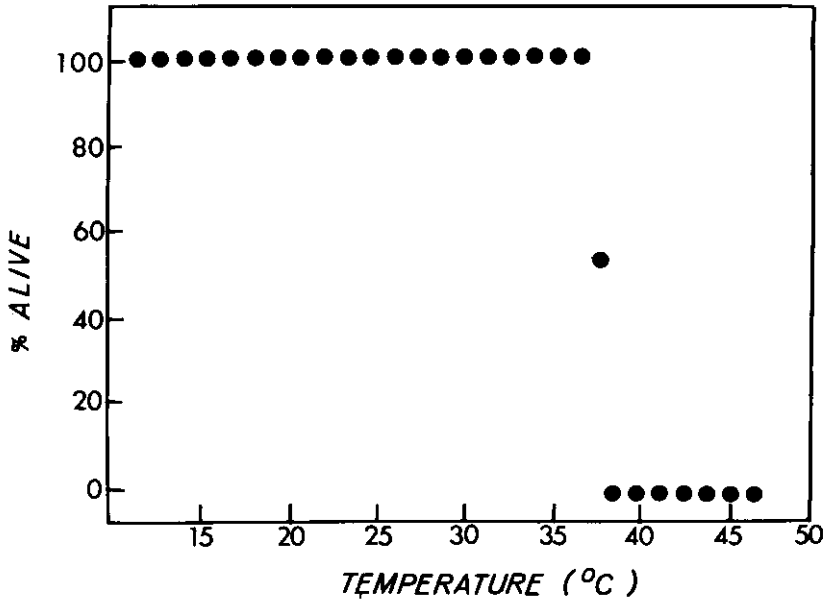

Fig. 3 *Penaeus duorarum* first protozoea. Percentage survival versus temperature. Each point represents 10 organisms.

The third protozoeae were not able to live above 35.7 to 36.7C after 22 hours (this stage is 18 to 24 hours in duration). Figure 4 represents 12 organisms per point.

The mysis stage was not able to develop to the postlarval or survive above 36.9 to 37.4C or below 14.6C as seen in Figure 5 where each point represents 12 organisms.

The first postlarva had very similar lethal limits of 36.8 to 37.8C (Fig. 6 where each point represents 12 organisms.) The "safe" limit was up to 33.5C for this stage.

One should note that these are sustained, not fluctuating temperatures, however, the temperature is similar to those environmentally derived temperatures (Jones et al, 1970).

DISCUSSION

The obvious warning from these results is that the mariculturist rearing pink shrimp must keep strict watch on the temperature of the water in which his specimens are kept, especially during mid-day in the summer when temperatures in a small body of water such as culture tanks may well reach temperatures near those discussed in the results.

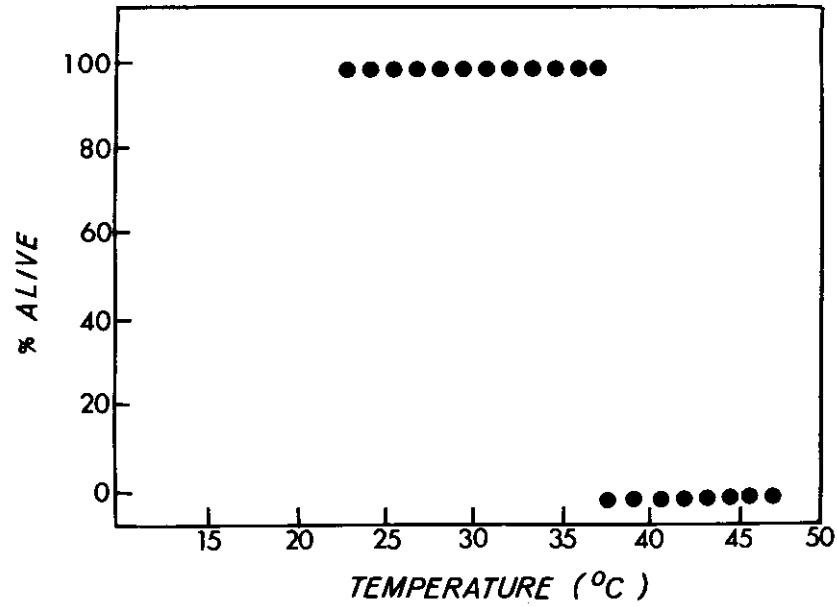

Fig. 4. *Penaeus duorarum* third protozoea. Percentage survival versus temperature. Each point represents 12 organisms.

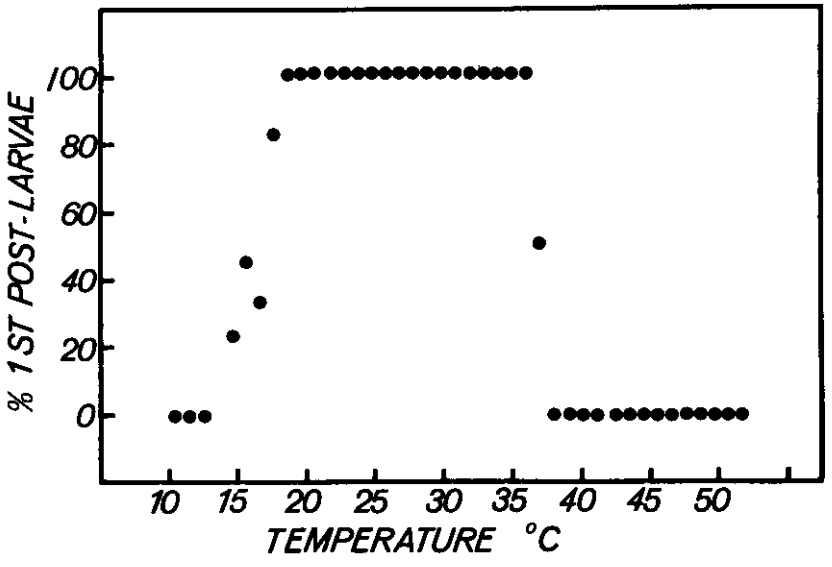

Fig. 5. *Penaeus duorarum* mysis development to postlarval stage. Percentage survival versus temperature. Each point represents 12 organisms.

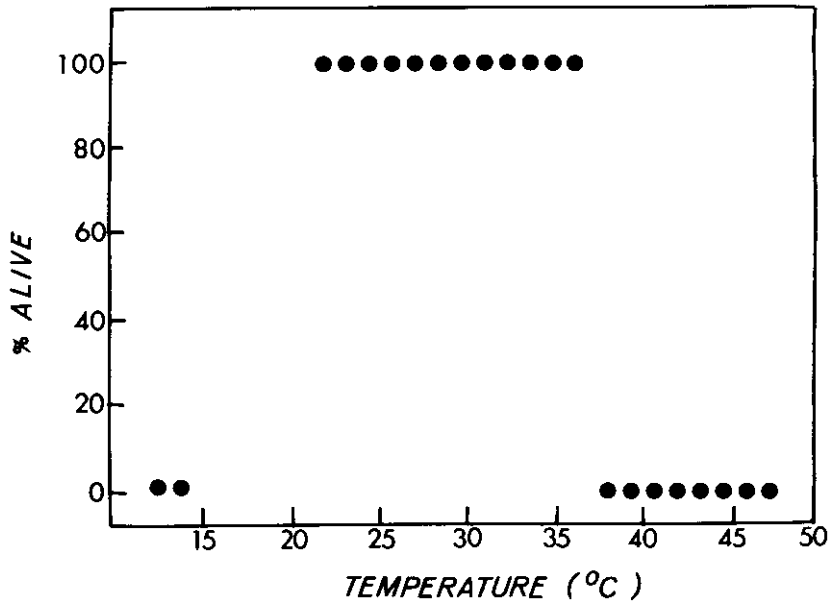

Fig. 6. *Penaeus duorarum,* lethal limits of the first postlarval stage. Each point represents 12 organisms.

We deduce from these results that newly-hatched nauplii are more delicate than the later stages. An expensive, but effective, method of controlling temperature for the napuliar stage of Idyll et al (1970) is to hold them in large 20 metric ton tanks indoors with room air-conditioning maintaining the temperature at 27 to 29C, which would appear to be the optimum temperature. One should be very careful that the temperature does not exceed 30.5C for any considerable length of time (for instance, several hours). This temperature would be well within mid-day temperatures of a shallow tropical pond or enclosed bay not protected from summer insolation.

There will be two problems depending on the location of the mariculture facility. The first will be that sub-tropical locations will have to keep the shrimp warm and thus use the natural heating of the sun. Second, tropical regions may run the risk of the water getting too warm thus approaching the upper lethal limits; in this case, protection from the sun will be necessary. Summer sun in some parts of the sub-tropics may also heat pools so that problems of maintaining 27-29C temperatures may be the same as in the tropics.

If indoor control of the first stage is impossible, our suggestion is that a greenhouse could be built with either a glass or, more economically, a heavy plastic "bubble" top. This could be cut in the form of a circle and enclosed with such simple materials as sand. A compressor could be used to pump this up. The heat from the compressor might also be added to the greenhouse. If this included fans in four directions, it would be simple to keep cool air coming in and hot air pushed out to cool the greenhouse in the middle of the day. This would allow cooling and heating.

A second out-of-doors alternative for the tropics where the lower temperatures would not be important would be to shade the ponds with a reflecting roof or canopy suspended about 4 to 10 feet above the pond in such a way that wind could enter and cause cooling by evaporation, thus the sun would not cause heating above the thermal limit. Prudent use of prevailing breeze or breezes plus fans could aid in evaporative cooling.

Of course, estuarine culture pen situations where one has the ability to cool or heat by regulating gates for the water flowing into or out of the mariculture area would not require the above devices. One should keep in mind in all these methods that the first stage is by far the most delicate.

The later stages from protozoeae to adult are able to withstand temperatures safely up to 33 to 35C. In fluctuating temperature situations they may well be able to withstand 36C for several hours. The basic problem is to regulate the temperature so that growth will be fastest (thus requiring fewer days to mature) and size greatest. The expense of keeping the shrimp at optimum temperatures will have to be weighed against the amount of labor to care for the shrimp for a longer period of time and the lower yield when temperatures become lethal or near lethal and many specimens die. For instance, at 20C organisms are less active, feed less actively, and do not appear as hardy from the protozoeae to the juvenile. If temperatures were to be ideally controlled, one might advise 27 to 29C in the first (nauplii) larvae and 27 to 30C fluctuating (day-night) for optimum growth and feeding for the later stage.

The above temperatures correlate well with the work of others (Lindner and Cook, 1968) using several species.

ACKNOWLEDGMENTS

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