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UPPER TEMPERATURE TOLERANCES OF SUMMER AND WINTER ACCLIMATIZED *Rangia cuneata* OF DIFFERENT SIZES FROM PERDIDO BAY, FLORIDA

In shallow, oligohaline bays, seasonal temperature ranges may be great; at times, temperatures will approach the tolerance of animals. In Perdido Bay, Florida (site of the present study), extremes in water temperature (taken just above the sediments) ranged from 4 °C in winter to 39 °C in summer. The dominant macroinvertebrate in this bay is the clam, *Rangia cuneata* (unpublished data). *Rangia* is also dominant in many oligohaline bays along the east and gulf coasts of North America (Hopkins and Andrews, 1970). Similar to Perdido Bay, these bays may have large annual and daily fluctuations in temperature (Ladd, 1951; Fairbanks, 1963).

Recent workers have measured the temperature tolerance of larvae and embryos of bivalves including *Rangia* (Cain, 1973; Wright *et al.*, 1983), but the temperature tolerance of adult *Rangia* is unknown. The purpose of this paper is to measure the upper lethal temperature in adult *Rangia cuneata* of different sizes and in different seasons.

MATERIALS AND METHODS

Two different types of temperature experiments were run. In the first type (Type I), animals were placed in water at 30°C (temperature of 0 deaths in preliminary experiments) and the temperature was raised 2°C every 12 hours. The percent mortality occurring after each 12 hr segment was recorded.

In the second type of experiment (Type II), animals were placed in water of

30, 32, 34, 36, 38 and 40°C (temperatures not run concurrently) for 3 days or until all animals were dead. Mortality was recorded in 12 hr increments.

For all experiments, animals were collected by hand from a subtidal sand beach in Perdido Bay, Florida (30°, 24' N; 87°, 24' W) and held at room temperature (25°C) until the next day when the experiment started. Three different size groups of animals (small, medium and large) with 10 animals per group were placed in 2 l of water each. Wet weights, including shell, for each size group were: 9.9-10.8 g (length ~ 10 mm) for small; 14.8-15.6 g (length ~ 34 mm) for medium; 23.6-26.2 g (length ~ 40 mm) for large. Air was bubbled in each experimental vessel throughout the experiment. Water, taken from the bay (salinity 2-4 ppt), was renewed in the experimental vessels every 12 hours with water of the proper temperature.

Temperature tolerances were measured in August, 1983 (average monthly water temperature - 30°C; range - 28 to 39°C) on summer acclimatized animals and in January and February, 1984 (average monthly water temperature - 12°C; range 4 to 15°C) on winter acclimatized animals. The criterion for death was gaping, as gaping animals returned to water at room temperature never recovered.

Experiments were run in duplicate. Duplicate experiments were not significantly different (paired t-tests ≥ 0.14) and values were pooled giving 20 animals for each size and temperature combination. Values were plotted on isometric paper to obtain three variable graphs.

RESULTS

When temperatures were raised slowly (Type I experiment), the

temperature at which over 50% of the animals died (LD_{50}) was 40°C for small and medium summer animals and 38°C for large summer animals. Winter acclimatization produced a 2°C change in the upper temperature limit. The LD_{50} temperature was 38°C for medium winter animals and 36°C for small and larger winter animals. Small animals were proportionally more sensitive in winter than in summer to high temperature.

There was very little variation in LD_{50} 's between replicates (not true replicates). All replicates had the same LD_{50} except one large, winter animal group (the LD_{50} was 34°C instead of a combined value of 36°C). In the medium summer animals, 30% of the animals died at 38°C in one replicate and 20% in the other replicate. There was a 100% death at 40°C in both groups. In the large summer animals, 30% (LD_{30}) died at 36°C in both replicates and 70% of the animals (LD_{70}) died at 38°C in one replicate and 40°C in the other.

In general, the death of summer animals was low until the lethal temperature was reached. Winter animals began dying at lower temperatures with no sudden jump in deaths at the LD_{50} temperature.

The same pattern of temperature tolerance with size emerges in 3 day or shorter (Type II) exposure to 'sublethal' temperatures. Medium size animals were more resistant to high temperatures than were large or small animals in both winter and summer (Figures 1 and 2). All size animals were more tolerant in summer than in winter (Figure 2). Winter animals began dying at 36 hours for temperatures above 30°C, whereas summer animals lived for 3 days with no death until 36°C.

Comparison of the two types of temperature experiments indicates that increased exposure to elevated

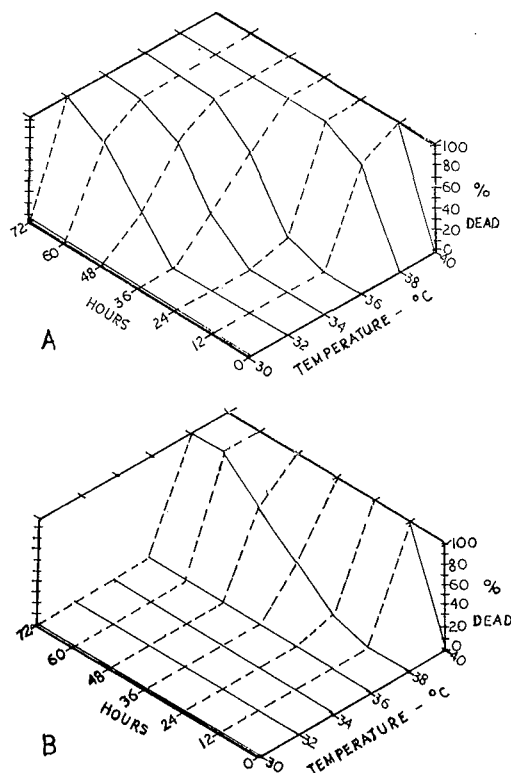


Figure 1. Percent mortality versus temperature and time for winter acclimatized *Rangia cuneata* of large size (A) and medium size (B). $N = 20$ for each temperature (duplicate samples combined).

temperature produces greater mortality. The upper lethal temperatures for medium summer animals in Type I experiments was 40°C, whereas in Type II experiments, the lethal point was 38°C.

Animals in the field were exposed to lethal temperatures (39.5°C) for brief periods (probably less than 12 hours) during hot, calm summer days.

DISCUSSION

These experiments have shown that *Rangia cuneata* in summer can withstand temperatures of 38-40° for at least 24 hours. Temperatures of 38-40°C lasting longer than 24 hours have never been recorded in Perdido Bay by the author. Summer animals, however began dying at 36°C, especially larger (older) animals. This loss of tolerance to high

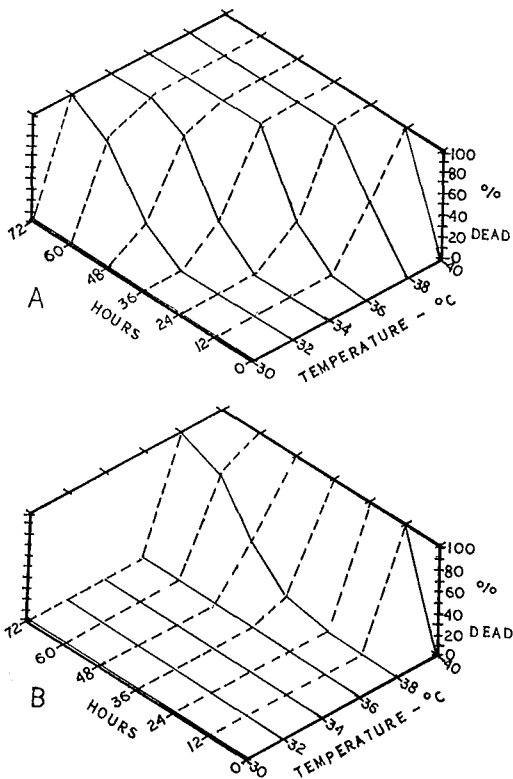


Figure 2. Percent mortality versus temperature and time for small *Rangia cuneata* which were winter acclimatized (A) and summer acclimatized (B). N = 20 for each temperature (duplicate samples combined).

temperatures could be one explanation for the greater mortality of larger (older) animals. In a population census done in September 1983, where both living and dead animals/shells were counted, the number of dead small, medium and large animals comprised 14, 13, and 27% of the living small, medium and large groups respectively. In addition, prolonged effects of elevated temperatures may include reduced fecundity and well-being, and increased parasitism and consequent mortality (Vernberg and Vernberg, 1963). Effects due to lowered levels of dissolved oxygen are probably not a factor in mortality, since *Rangia* is extremely tolerant of anoxia (maximum of 6.5 days alive at 0 ppm O_2 , unpublished data).

Comparison of adult and larval

stages of *Rangia* indicates that the larval stages are more sensitive to elevated temperatures. At salinities used in the present study (2-4 ppt), survival was < 5% for embryos and < 50% (average) for straight-hinge larvae at 32°C (Cain, 1973). All temperatures above 35°C were lethal to larvae (Cain, 1973). Environmental and genetic differences may exist between the more northern *Rangia* population from which embryos and larvae were raised and the southern population of the present study.

Thermal tolerances of adult intertidal molluscs have been reviewed by Newell (1964). As pointed out by Read (1967), one problem with many lethal temperature studies is that animals may withstand elevated temperatures for short periods (1 hr) but longer exposure results in death. Hence, thermal tolerance limits in the literature may be unrealistically high. As with the present study, Read (1967) found for the bivalve *Lima scabra*, increasing mortality with increasing exposure time. Temperatures higher than 33°C were detrimental to *L. scabra*. In the present study, temperatures of 32°C (winter) and 36°C (summer) began producing mortalities in all size animals. However, if the exposures were less than 24 hours, temperatures as high as 38°C were not lethal.

Acclimatization of upper thermal limits occurred in *Rangia* (this study) and in *L. scabra* (Read, 1967). Read (1967) found a 0.2 to 0.3°C increase in the lethal limit per degree rise in environmental temperature over a winter-summer difference of 3 to 4°C. For *Rangia*, there was a 2°C difference between thermal limits of winter and summer medium animals. The difference between summer and winter average temperatures in Perdido Bay is 18°C (12°C in winter and 30°C in summer, unpublished), giving a 0.1°C increase in the lethal limit for each

°C increase in environmental temperature. Acclimatization results should be viewed with some caution. Winter animals that are taken from very cold water (12°C) and placed in 25° (room temperature) and then 30°C water (beginning experimental temperature) probably suffer some shock. In unpublished oxygen consumption data, there was a seven-fold increase in uptake of oxygen between winter *Rangia* at ambient temperature (~ 12°C) and winter clams at 25°C, even after a 24 hour waiting period.

SUMMARY

1. Temperatures of 40°C for small and medium and 38°C for large summer animals were lethal in short-term experiments.
2. Over 3 days, temperatures of 32°C (winter) and 36°C (summer) began producing mortalities.
3. There was a 2°C difference in thermal limits between summer and winter animals.

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