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Salinity and temperature tolerances of the green and brown mussels, *Perna viridis* and *Perna perna* (Bivalvia: Mytilidae)

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Abstract: Since the appearance of the green mussel, *Perna viridis*, in the Golfo de Paria in 1993, the habitat of the brown mussel, *Perna perna*, has been altered. *P. viridis* is driving out the *P. perna* mussel from its natural beds in La Esmeralda, Guatapanare and El Morro de Chacopata, Sucre State, and at the end of 1995 it appeared in Isla Margarita, Nueva Esparta State, Venezuela. For that reason, a study has been carried out to determine whether *P. viridis* from La Esmeralda has a higher tolerance and adaptability than *P. perna,* in terms of salinity and temperature. Low and high lethal temperatures were 6°C and 37.5°C for *P. viridis* and 3°C and 34.5°C for *P. perna*. Low and high lethal salinities were 0 and 64‰ for *P. viridis* and 8 and 54‰ for *P. perna*, respectively, indicating that the green mussel has wider thermohaline tolerance limits than the brown mussel. This may explain why *P. perna* has been displaced by *P. viridis* in less than three years.

Key words: Thermohaline tolerances, habitat alteration, distribution, tropical mussels, *P. viridis*, *P. perna*.

Temperature and salinity are among the most important environmental factors affecting abundance, availability and distribution of marine organisms. These factors affect the metabolic rates which may be reflected in the activity level of organisms. The overall range of sea surface temperature found in a particular location in the oceans is not high, with the average annual differences in the Atlantic and Pacific Oceans not exceeding 10°C. However, vertical temperature gradients in the Atlantic and Pacific Oceans are several orders of magnitude greater than sea surface temperature gradients. Temperature has been shown to limit geographical as well as vertical distribution of coastal and oceanic species. Salinity may involve changes in embryonic development depending on other environmental factors (Walsh *et al.* 1989).

Ecologically tolerance may be defined as a measure of how the change of an external factor may affect the organisms and their ability to adapt to such fluctuations. Tolerance has two components: a genetically determined capacity to withstand a certain range of parameters and a phenotypic capacity, named acclimation, to shift tolerance within this range as a result of previously experienced conditions (Segnini & Chung 1991, Segnini *et al.* 1993).

P. viridis is a mussel from Indo-Pacific Ocean where temperature ranges between 26 and 28°C (Penchaszadeh & Vélez 1996). *P. perna* is a sub-tropical mussel that colonized the Caribbean Sea several decades ago and established itself in Venezuelan coasts, where it formed natural beds, probably, favoured by the surge of sub-surface waters which have temperatures up to 21°C in the North-Oriental coast of Venezuela (Fukuoka 1971). *P. viridis* has been studied as indicator of pollution (Chidambaram 1991, Karunasagar & Karusanagar 1992, Prakash & Rao 1993, Rajagopal *et al.* 1994); as possible aquaculture species (Hanafi *et al.* 1988, Sreenivasan *et al.* 1989, Gallardo *et al.* 1992); distribution (Rylander *et al.* 1996) and as ecological monitor (Krishnakumar *et al.* 1990, Agard *et al.*1992).

This study presents the temperature and salinity tolerances and activity responses of *P. viridis* and *P. perna* to fluctuations which are fundamental to predict their behavior, occurrence or distribution.

MATERIALS AND METHODS

Mussels (*P. viridis* and *P. perna*) were collected from natural beds at La Esmeralda, Estado Sucre, Venezuela (10°40'35" N, 63°30'50" W). Mussels were brought to the laboratory, cleaned of epibiotic organisms and acclimatized for 15 days under laboratory conditions at 25°C (the same as the location where they were collected); the pH was between 7 and 8 and oxygen 90% saturation; 600 mussels (5-110 mm of total length, measured in antero-posterior direction) of each species were used. In each case, two replications and one control were carried out. They were placed in aquaria of 95 litres capacity, with a heater and temperature control (± 0.1°C). The seawater used was filtered to remove particles bigger than 1µm and treated 15 minutes in an UV filter.

To determine upper temperature tolerance limits (UTTL), water temperature was increased 1°C every day from the acclimation temperature. For the lower temperature tolerance limits (LTTL), the mussels were placed in a container (Frigid Unit Inc.) specially designed for that purpose and temperature was decreased by approximately 1°C per day.

For determination of critical thermal maximum and minimum (CTM), two organisms (30-48 mm total length) were taken at random; they were placed in a 5 l container with 2 l of seawater inside and an air stone with an aerating pump in order to provide oxygen, water circulation and uniform temperature. In the case of CTM (maximum), heaters were used to obtain three temperature increasing rates (0.2, 0.5 and 0.8°C per min, using one, two or three heaters, respectively). For these tests, five replicates of two mussels were used for each heating rate. In the case of critical thermal minimum, temperature was lowered at 0.5°C min using a cold bath obtained by adding ice cubes, regularly, to the bath. In this case, the contai-ner used had 1 l of water.

To determine CTM for higher and lower temperatures, the death criterion was the mussel opening the valves and not closing them. A mortality criterion was defined taking into account that stressed organism have their valves open, and when a metal bar is introduced into them, the mussel closes the valves quickly. In the case of lower temperature tolerance limits (LTTL), mussel was considered dead when the organism did not close the valves in 15 s.

For determination of low and high lethal salinity, concentration was modified in 2 ‰ every 2 days.

The organisms were not fed during the whole experimental period.

RESULTS

The results obtained from this study show that *P. viridis* has wider thermohaline tolerance limits than *P. perna*. None of the green mussels died at temperature below 33.5°C. At this temperature, *P. perna* had a 20% mortality rate. When the temperature rose to 34.5°C, the mortality rate was 50% for this species. For *P. viridis* it was 20% at 36.5°C and 50% at 37.5°C.

Critical thermal maximum (CTM), shown in Fig. 1, indicated that at the rate of 0,2°C/minute, the brown mussel (*P. perna*) died at 38.3°C and the green mussel (*P. viridis*) died at 40.8°C. At the rate of 0.5°C/minute, the brown mussel died at 39.6°C and the green mussel at 41.8°C. At the rate of 0.8°C/minute, the brown mussel died at 40.5°C and the green mussel at 43.1°C (Table 1).

TABLE 1

Critical thermal maximum (CTMax) and minimum (CTMin) for Perna perna *and* Perna viridis *at different heating and cooling rates*

Species	CTMax (°C/min)		
	0.2	0.5	0.8
Perna perna	38.3±0.26	39.6±0.99	40.5±0.54
Perna viridis	40.8±0.34	41.8±0.61	43.1±0.55
	CTMin (0.5 °C/min)		
Perna perna	2.4±0.08 ***		
Perna viridis	5.4±0.12 ***		

*** ($p < 0.01$)

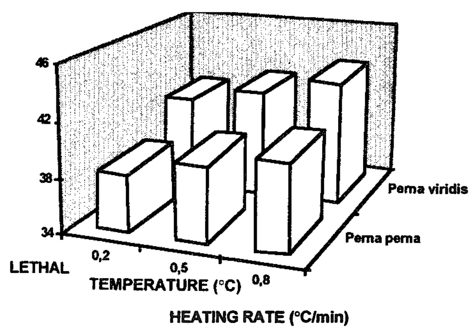

Fig. 1. Critical thermal maximum at three heating rates.

It is useful to notice that when the critical point was reached, the studied organisms extended its foot, to move in different directions until the mussel lay in the bottom of the container. Then they drew in its foot, and after a few seconds they opened the valves and died. For lower temperatures the foot was stuck to the bottom of the container but when the mussel was touched, it drew in the foot from the outside very slowly.

For lowering temperature, *P. viridis* had a 10% mortality rate at 7°C and 100% at 6°C. On the other hand, *P. perna* had a 2% mortality rate at 4°C and total death (100%) at 3°C.

The salinity effect is shown in Fig. 2. When the experimentation for lowering salinity was carried out *P. perna* showed a 15% mortality at 12 ‰ and 50% at 8 ‰. For *P. viridis* 2% mortality was found at 4 ‰ salinity. At 0 ‰ we observed 4% mortality. They were left in this condition and after 11 days the bioassay was terminated without any mortality (Table 2).

TABLE 2

High and low lethal temperature and salinity limits

Category	*Perna perna*	*Perna viridis*
UTTL(°C)	34.5	37.5
LTTL(°C)	3.0	6.0
HLS(%0)	54	64
LLS(%0)	8	0

UTTL: Upper temperature tolerance limits
LTTL: Lower temperature tolerance limits
HLS: High lethal salinity
LLS: Lower lethal salinity

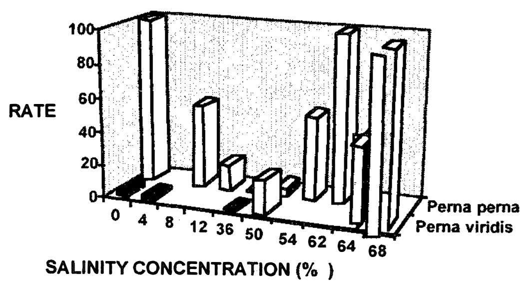

Fig. 2. Salinity tolerance of *Perna perna* and *Perna viridis*.

DISCUSSION

The critical thermal maximum (CTM) is a method used to provide information about tolerance of the organisms as a answer to environmental media in an ecological and physiological sense. Critical thermal maximum (minimum) determination is related to a fast and controlled heating or cooling of an organism from its acclimation or environmental temperature until the final point where the organism die.

For the three heating rates, the lower CTM value was obtained at the slow heating rate (0.2°C/minute) and the higher value at the higher rate. This indicates that external water temperature increases more quickly than internal body temperature not allowing an acclimation at the lowest heating rate used. These results do not agree with the definition given by Hutchison (1961) who suggested that heating rate should be in a magnitude that body temperature could be very close to the water temperature where the organisms are placed. Chung & Acuña (1981) reported similar results for *P. perna*.

For *P. perna* and *P. viridis* the CTM values always exceeded the UTTL values (Tables 1 and 2), the faster the rate of increasing temperature (0.2 to 0.8°C/min), higher the differences between CTM and the UTTL obtained. The results suggested that organisms could stand beyond the thermal tolerance zone at constant increase in temperature using CTM method for a while.

These results on salinity and temperature allow us to infer that these abiotic factors play an important role in the settlement of green mussel. Nowadays the green mussel has colonized habitats in La Restinga, hypersaline lagoon (58 ‰ salinity), Isla de Margarita, and on exposed rocks in shallow waters where during the day the temperature is very high (up to 40°C). *P. perna* has not been found in these places. Meanwhile, *P. perna* is found in deeper zones where the temperature is lower.

It is important to notice that the higher adaptability of the green mussel compared with the brown mussel, implies that *P. viridis* has been displacing *P. perna* from their habitat, and thus in a few years *P. viridis* may be the predominant species in all South American coasts (Penchaszadeh & Vélez 1996).

RESUMEN

Estudios recientes han informado de alteraciones del hábitat del mejillón marrón, *P. perna*, por el mejillón verde, *P. viridis*, desde su aparición en las costas del Golfo de Paria en 1993. En la actualidad *P. viridis* está desplazando al mejillón *P. perna* de sus bancos naturales en La Esmeralda, Guatapanare y El Morro de Chacopata, Estado Sucre, y a finales de 1995 apareció en la Isla de Margarita, Estado Nueva Esparta, Venezuela. Por esta razón se ha realizado un estudio para determinar si *P. viridis* tiene una mayor tolerancia y adaptabilidad que *P. perna*, en términos de salinidad y temperatura de ambas especies colectadas en La Esmeralda. Las temperaturas letales bajas y altas fueron 3°C y 34.5°C respectivamente, para *P. perna* y 6°C y 37.5°C para *P. viridis*. Salinidades letales bajas y altas fueron 8 y 54 ‰ para *P. perna* y 0 y 64 ‰ para *P. viridis*, respectivamente, indicando que el mejillón verde tiene una tolerancia termohalina mayor que el mejillón marrón. Estos resultados pudieran explicar porque *P. perna* ha sido desplazado por *P. viridis* en menos de tres años.

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