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Thermoregulatory Behavior of Red Sea Urchin *Strongylocentrotus* Franciscanus (Agassiz, 1863) and Purple Sea Urchin *Strongylocentrotus* Purpuratus (Stimpson, 1857) (Echinodermata: Echinoidea)

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Abstract: Thermoregulatory behavior of red sea urchin *Strongylocentrotus franciscanus* and purple sea urchin *S. purpuratus* was determined in a horizontal thermal gradient. The preferred temperature select by the red sea urchin was 17.5 ± 0.3 °C during the diurnal cycle and 16.8 ± 0.4 °C for the night. The purple sea urchin preferred temperature during daytime of 18.8 ± 0.2 °C and night was 17.4 ± 0.3 °C. For both species of sea urchin preferendum between day and night cycles were different ($P < 0.05$), the purple sea urchin preferred higher temperatures that red urchin, suggesting that *S. purpuratus* use thermoregulatory behavior as a mechanism of environmental segregation to avoid competition for space and food with red sea urchin.

Keywords: Preferred temperature, red sea urchin, purple sea urchin.

INTRODUCTION

Environmental temperature plays a vital role in determining when and where aquatic species may survive and prosper, such as ectotherms. Laboratory studies have shown that variations in temperature have an important effect on the physiological and biochemical rates at the level of the organism and affect its ability to survive, growth, and reproduction [1-3]. Temperature is a controlling and directive factor of the activity of aquatic species and therefore mobile species, such as sea urchins, exhibit different behavioral responses including thermal habitat selection and avoid lethal temperatures [4,5]. For many aquatic species a preferred temperature is a primary function of its recent thermal history or state of thermal acclimation [6].

Ectotherms have a capacity to cope with the changes in temperature that occur in the environment by selecting favorable habitats for using behavioural responses [4]. The preferred temperature represents a thermal interval in which the processes that control activity are not affected and their efficiency is therefore increased and optimized [7-9]. Fry [10] defines the final preferendum as the temperature around

which all individuals (of a given species) can congregate, regardless to previous thermal history before being placed in the gradient [11,12]. Jobling and Kellog [13,14] have shown that organisms select temperatures in proportion to quantity of metabolic energy necessary for maximize different biological processes such as metabolism, swimming speed, growth. Body temperature (Tb) is the most important ecophysiological variable that affects the function of ectotherms. Virtually all aspects of behavior and physiology of ectotherms are sensitive to Tb [15, 16]. The thermoregulatory behaviour is used by ectotherms to reduce the spatial and temporal impact of environmental temperature under Tb [15]. Thermal preference studies conducted in the laboratory propose a vital link in the environmental, physiological, and adaptive behavioral tactics used by aquatic organisms [17].

In the state of Baja California two types of sea urchins are commercially important, red *Strongylocentrotus franciscanus* (Agassiz 1863) and purple *Strongylocentrotus purpuratus* (Stimpson 1857). Red sea urchins are distributed from Alaska to Isla Cedros in Baja California México; this species is found between the intertidal zone and 50 meters in depth on rocky substrates [18,19]. Purple sea urchins *Strongylocentrotus purpuratus* have a wide biogeographic distribution that extend from southern Alaska to central Baja California México, this species are exposed to a wide range of environmental temperatures from 4 to 20 °C [20]. Coastal fishing represents an important factor in Baja California, providing 2,000 people with jobs directly and producing 7 million

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dollars per season in sea urchin gonad production. Red sea urchin populations have been subject to commercial exploitation since the seventies; according to [21] this resource is considered overexploited. This study is the first to evaluate the thermal preference of adult red sea urchins *Strongylocentrotus franciscanus* and purple sea urchins *S. purpuratus* to obtain an estimate of the optimum preferred temperature for growth and reproduction and thus evaluating the ability of the these organisms to adapt to different thermal regiments along the coast of Baja California and the potential impact of climate change.

MATERIAL AND METHODOLOGY

Strongylocentrotus franciscanus and *S. purpuratus* (with a range of 2.9- 8.6cm and 1.0- 8.6cm in test diameter) were collected by scuba diving at a depth of 5 to 10 meters at Campo Kennedy in Punta Banda, Baja California, México (31º 42.16´ Lat. N; 116º 40.9´ Long. W.). The organisms were kept 21 days in a laboratory in 200L reservoirs with a continuous water replacement system, with a salinity of 35‰, and a temperature of 16 ±1ºC, which were the conditions registered during the collection. The red and purple sea urchins were fed fronds of *Macrocystis pyrifera* Linnaeus (kelp) in accordance with [19].

Forty-eight hours prior to starting the sea urchins were marked with plastic tags with nylon string on the spines for individual identification. The preferred temperature experiments for both species of sea urchins were performed in a gradient as described by [22]. A Neslab Thermoregulator (model HX 150) was connected at one end of the gradient to cool the water. A 1000 watt heater was placed at the opposite side of the gradient, which was connected to a temperature controller (Moeller CI-K3-125-M) to warm the water, generating a stable gradient of 10º to 30ºC, ($y = 6.20+ 1.60x$, $r^2 = 0.98$ where x = segments of the gradient, y = temperature in each segment of the gradient). Twenty aeration stones were placed along the gradient to maintain a dissolved oxygen concentration of 5.8- 7.2mg L^{-1}, thus eliminating the stratification effect of the water column. The depth of the water column in the gradient was 9cm and to maintain a good quality of water the replacement rate was 10.0- 12.0L h^{-1}.

To determine the preferred temperature of the sea urchins the gravitational method described by [23] was used. Five sea urchins, of both species marked with individual labels, were introduced to the segment in the gradient where the water temperature was the same as temperature of acclimatization from where they came from. For each sea urchin 10 repetitions were performed (N = 50). The sea urchins were not fed 24h prior to the testing period to prevent interference due to diet [24,25]. During the day they were exposed to high light intensity of 0.55 x 10^{15} quanta sec^{-1}cm^{-2} and 0.10 x 10^{15} quanta sec^{1} cm^{-2} at night. Observations made on the number of sea urchins in the gradient segments were made by a mirror at a 45º angle and were recorded every hour of a 24h period. Temperature was also measured with digital thermometers, which were distributed equally along the gradient by matching each of the virtual segments.

Subsequent to the calculations of normality and homoscedasticity of the data the nonparametric test was applied by Mann-Whitney to determine differences in preferred temperature in both species of sea urchins exposed to the day and night light cycle [26]. To contrast the differences in the day and night preferendum of the sea urchin *S. franciscanus* and *S. purpuratus* the nonparametric test was applied by Kruskall-Wallis [26]. The data on the preferred temperature of both species of sea urchin were processed using exploratory data analysis and presented in parallel box plot [27].

RESULTS

Red sea urchins, *Strongylocentrotus franciscanus,* that were exposed to a day and night cycle in the gradient had a preferred temperature range of 17.5 ± 0.3 ºC during the day and 16.8 ± 0.4 ºC at night (Fig. **1**). Purple sea urchins, *S. purpuratus*, had a preferred temperature range of 18.8 ± 0.2 ºC during the day and 17.4 ± 0.3ºC at night (Fig. **2**). The interpreferenda interval transition for the red sea urchin was 0.7 ºC and as for the purple sea urchin 1.4 ºC, where the sea urchins began to displacement to move toward favorable physiological temperatures. There were significant differences in the preferred temperature in both species of sea urchin in the day and night cycle (P < 0.05) (Figs. **1** and **2**). When comparing through the nonparametric test of Kruskall-Wallis the day and night preferred temperature of the red sea urchins with obtained for the purple sea urchins significant differences were found (P < 0.05).

DISCUSSION

The temperature preferendum of both sea urchins were significantly different between the day and night cycles. In the case of fresh water snail *Helisoma trivolis,* Say [28] found a diel rhythm of preferred temperature at 17-18 ºC during the day cycle and 21-22 ºC during the night cycle. For the sea snail *Megastrea (Lithopoma) undosa* Wood [6] obtained a diel rhythm of preferred temperature. In other aquatic species such as *Amia calva* Linnaeus, *Procambarus spiculifer* Le Conte, *Procambarus clarkii* Girad [29-31] have also reported diel rhythms of preferred temperatures between both day and night cycles. This behavior can be explained by the hypothesis of bioenergetics proposed by [32] who suggests that the diel rhythms of preferred temperatures between the day and night favor the daily metabolic balance in aquatic ectotherms, this mechanism can be used by many organisms to preserve energy when food is limited in its habitat.

The preferred temperatures, for both species of sea urchin, are probable to be those that provide the greatest field of activity, and therefore a greater amount of energy available can be channeled to other functions such as scope for activity according to [10], reproduction, survival, and growth [12]. It has been reported by [33,34] that the optimum interval of temperatures for the feeding of *S. franciscanus* was 15.7 to 17.1 ºC. As for *S. purpuratus* [35] obtained that the embryonic development was carried out normally between the intervals of 13 to 20 ºC. Ulbricht [36] reported that the temperature coefficient (Q_{10}), for the red sea urchin *S. franciscanus* was 1.19 in a temperature interval of 15 to 18 ºC and 0.88 for *S. purpuratus* in a temperature interval of 18 to 21 ºC, which indicated that within these temperature interval the organism had a better adaptive responses to maintain homeostasis. Stated by [37,38] that the point where the Q_{10}

decreases in relation to acclimation temperature corresponds to the optimum temperature for growth and reproduction. A decrease in the value of Q_{10} indicated that the metabolism of the organisms is reduced and therefore there was a greater amount of energy available for the organism to allocate for different processes. These temperature ranges reported for different physiological processes in both species of sea urchin coincide with the thermal preferendum values stated by this paper for red and purple sea urchin. According to [13]

the analysis of data on thermal preference in different aquatic organisms indicates that the preferred temperature may be used as a fast method to determine the temperature required to promote maximum growth in both species of sea urchin.

Purple sea urchins *S. purpuratus* preferred higher temperatures than the red sea urchins *S. franciscanus.* Giattina *et al.*[5] suggested four hypotheses to unify the concepts in the study of behavioral thermoregulation in aquatic organ-
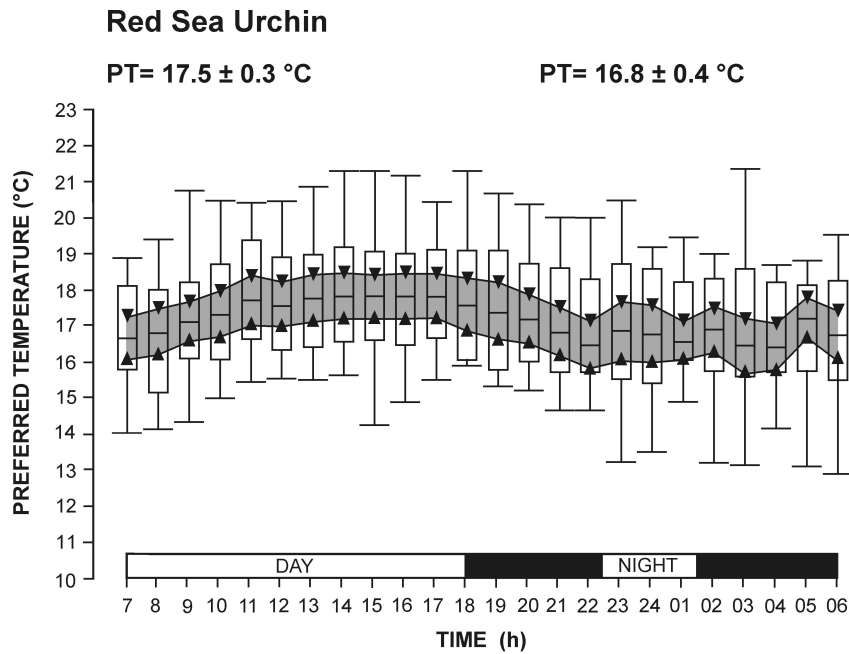
Red Sea Urchin

Fig. (1). Thermoregulatory behaviour of red sea urchin *Strongylocentrotus franciscanus* in a day-night cycle. The shadow zone bordered by triangles represents the 95% confidence interval of the median. The bars include 50% of the distribution and the vertical lines represent the quartiles.
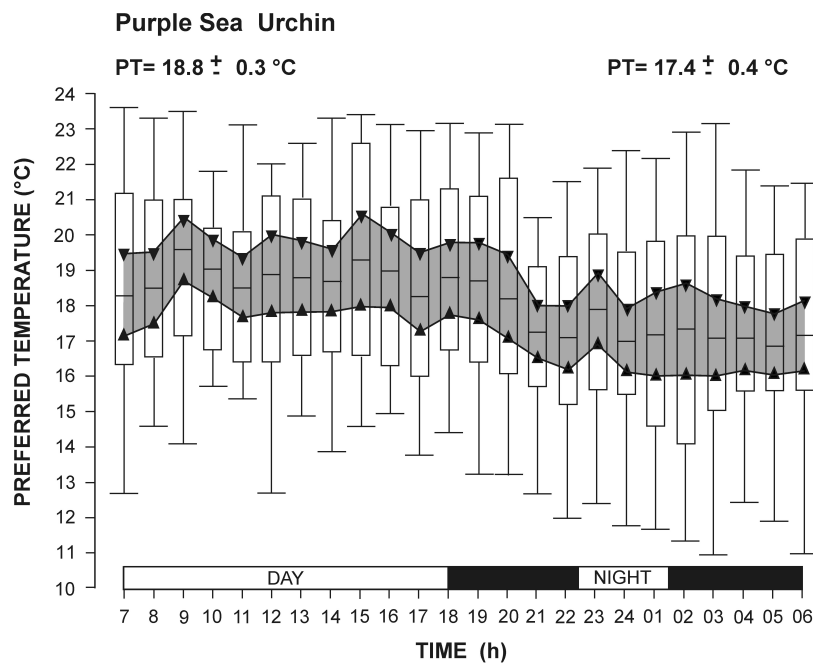
Purple Sea Urchin

Fig. (2). Thermoregulatory behaviour of purple sea urchin *Strongylocentrotus purpuratus* in a day-night cycle. The shadow zone bordered by triangles represents the 95% confidence interval of the median. The bars include 50% of the distribution and the vertical lines represent the quartiles.

isms: 1) the final thermal preferendum is a species-specific response to a temperature gradient but can be modified by non-thermal factors such as age, food availability, seasonality, and pathological condition; 2) partitioning of the habitat by thermoregulatory behavior is a measure of segregation both intra and interspecific that permits the reduction in cannibalism and competition; 3) the preferred temperature can reflect thermal optimum for certain biological processes and 4) generally aquatic organisms avoid thermal extremes before they turn lethal. Pearse [39] mention that the purple sea urchin competes with abalone and red sea urchins for space and food. Therefore the purple sea urchin according to what was stated by [5] use thermoregulatory behavior for environmental segregation to avoid competition for space and food against the red sea urchins which coincides with the second hypothesis and as mentioned by [40] that the purple sea urchins are distributed in the intertidal habitat, in contrast to juvenile red sea urchins which do it in the sub tidal. An interval of physical and biological factors such as preferred temperature, competition, and dietary preference vary in species and can lead to separation of the niche as reported in this paper for both species of sea urchin by thermoregulatory behavior.

Behavioral responses to temperature have an adaptive value physiologically and ecologically for the species. We have demonstrated that sea urchins, like arthropods and vertebrates, may have thermoregulatory behavior when they are placed in a temperature gradient. The distribution of animals on the temperature in their natural habitat may be the result of an active thermoregulatory behavior and not merely due to passive processes of differential survival.

This information is vital to determine the suitability of different areas for the cultivation of species such as sea urchins, meet environmental requirements to keep in captivity, and understand its distribution in addition to providing useful results to determine the effects of climate change on these species [20].

CONFLICTS OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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