Preferred temperature of the mexican native cichlid *Cichlasoma istlanum* (Jordan and Snyder, 1899)

Temperatura preferida del cíclido nativo mexicano *Cichlasoma istlanum* (Jordan and Snyder, 1899)

Jorge Luna-Figueroa[1],
Fernando Díaz[2]
and Sonia Espina[3]

[1]Laboratorio de Acuicultura, Centro de Investigaciones Biológicas. Universidad Autónoma del Estado de Morelos (UAEM). Av. Universidad 1001, Colonia Chamilpa. 62210 Cuernavaca, Morelos, México.
[2]Departamento de Acuicultura, Biotecnología Marina, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE). Kilómetro 107 Carretera Tijuana-Ensenada, Baja California, México.
[3]Laboratorio de Ecofisiología, Departamento de Biología. Facultad de Ciencias, Universidad Nacional Autónoma de México (UNAM). México D.F. 04510.

Luna-Figueroa, J., F. Díaz and S. Espina. 2003. Preferred temperature of the mexican native cichlid *Cichlasoma istlanum* (Jordan and Snyder, 1899). *Hidrobiológica* 14 (4): 271-275.

ABSTRACT

Preferred temperature of juvenile *Cichlasoma istlanum* was 2.1ºC higher ($p < 0.05$) than that of adults, which had a preferred temperature of 30.5ºC. The thermal preference of juveniles and adults did not differ between day and night. Adult's tolerance interval was 33.0% wider than that of the juveniles in reference to higher and lower avoided temperature. The estimated optimum growth temperature for juveniles was 31.6ºC and for adults was 29.5ºC. These results are relevant to optimize the aquacultural practices of *C. istlanum* in Morelos México; due to the differences in preferred temperature of juveniles and adults it could decreases cannibalism and competition for food between both age groups of the "mojarra".

Keywords: Preferred temperature, juvenile adults, avoided temperatures, "mojarra".

RESUMEN

La temperatura preferida por juveniles de *Cichlasoma istlanum* fue 2.1ºC mayor ($p < 0.05$) que la de los adultos, quienes prefirieron una temperatura de 30.5ºC. La preferencia térmica de ambos estadíos no difirió entre el día y la noche. El intervalo de tolerancia térmica considerando las temperaturas evitadas inferiores y superiores en los adultos de *C. istlanum* fue 33% mayor que en los juveniles. La temperatura óptima de crecimiento estimada para los juveniles fue de 31.6ºC y para los adultos de 29.5ºC. Estos resultados permiten optimizar las prácticas de cultivo de *C. istlanum* en Morelos, México, ya que las diferencias en las temperaturas preferidas entre los juveniles y adultos, permiten suponer que no habrá competencia intra específica en la columna de agua.

Palabras clave: Temperatura preferida, juveniles y adultos, temperaturas evitadas, mojarra.

INTRODUCTION

Fishes are well adapted to environmental temperature that they experience, leading to similarities in ecological responses to temperature (Magnuson *et al.*, 1979). For most fish species the preferred temperature is primarily a function of recent thermal history or thermal acclimation state of the individual. However the relationship between preferred temperature and acclimation temperature varies markedly among species, ranging from direct to inverse proportionality (Kelsch and Neill, 1990).

Thermoregulatory behaviour is an activity coordinated by the central nervous system, and therefore gives as result the preference to an optimum temperature environment. The preferred temperature represents the thermal space in which the processes that control the fish activity are effective and their performance efficiency is therefore increased and optimized (Brett, 1956; Prosser & Nelson, 1981; Kelsch & Neill, 1990; Jobling, 1994). Fish select their temperatures in proportion to their amount of metabolic power available for growth, activity, reproduction and other functions (Kelsch and Neill, 1990; Bryan *et al.*, 1990; Kelsch, 1996).

The Mexican "mojarra" *Cichlasoma istlanum* (Jordan and Snyder, 1899) is an endemic species of the Balsas and Amacuzac rivers, located in the state of Morelos, México. *C. istlanum* is an important resource in the local fishery, mojarra are important to local human population like food resources. In the last few years the catch as well as the overall size of these organisms has decreased at an alarming rate and it seems to be attributed to indiscriminate catch (Danko, 1991). Research on the environmental and nutritional requirements during the different developmental stages of the Mexican "mojarra" *C. istlanum* is required in order to improve our knowledge with regard to the culture of these organisms.

Therefore, as a first step to gathered that knowledge, it is essential to establish the optimum temperature to promote growth and overall health in *C. istlanum*. The goal of this study was to determine the final preferendum, theoretical optimum growth temperature as well as the temperatures avoided by two ontogenetic stages in the Mexican "mojarra".

MATERIAL AND METHODS

The fish were caught in the Amacuzac River, state of Morelos, México. The juveniles (N = 30) had a length of 2.65 – 5.05 cm and a body mass of 2.00–3.31 g whereas the adults (N = 30) had a length of 10–12 cm and a body mass of 10-20 g. They were held in the laboratory at the field collected temperature of 28 ± 1°C in four 500 L reservoirs with a photoperiod of 12:12 h light: darkness with 30 min transition periods between them. Animals were acclimatized to this new condition for three weeks. Physicochemical characteristics of the water were 6 to 8 mg/L O_2, hardness 150 mg/L of $CaCO_3$ and pH 8.1. Animals were fed with trout commercial pellet food (45% crude protein) supplied daily at 10% wet weight. During the maintenance phase of *C. istlanum*, no mortality was recorded amongst juveniles nor adults.

To determine the preferred and avoided temperatures we used a horizontal gradient of 300 cm of length and 20 cm of diameter, with 15 segments as described by Díaz *et al*. (2000). A thermoregulator Neslab (model HX 100) was connected at one extreme for cooling, and a 1000 W heater was placed at the other extreme to generate a stable and linear 11 to 38°C temperature gradient ($y = 9.32 + 1.94x$; where x = segments of gradient and y = temperature on the segments of gradient). In each compartment an air stone was placed to maintain the oxygen concentration at 5.6 to 12.1 mg/L eliminating the effect of vertical thermal stratification. The water depth was 9 cm and to maintain high water quality the trough-refilling rate was of 9.6-10.8 L/h.

Juveniles (N = 30) and adults (N = 30) of mojarra were tagged individually (Ruiz & Villalobos, 1991). Animals were starved for the 24 h period before testing. Ten tagged organisms were introduced to the gradient in the segment, which have the same acclimation temperature. Three replicates for each trial were done. Fish observation were made from reflections in a mirror oriented at a 45° angle, recorded hourly during 24 hours, and temperature was measured with digital thermometers that were distributed equidistant along the gradient. Prior to these recordings the organisms were maintained two hours in the trough to reduce the stress caused by handling. The photophase had a light intensity of 0.29×10^{16} quanta sec^{-1} cm^{-2} and a scotophase of 0.04×10^{16} quanta sec^{-1} cm^{-2}. The theoretical temperature for optimal growth in juveniles and adults of the Mexican "mojarra" was calculated using Jobling's (1981) equation ($y = 1.05x - 0.53$ were x = optimum temperature for growth and y = preferred temperature).

The information was processed by box plot Tukey (1977) Exploratory Data Analysis, to test homoscedasticity of the data we used a Bartlett's test with the computing program Sigma-Stat. Inc. In order to know if there were significant differences in the preferred temperature during diel cycles, and between juvenile and adult *C. istlanum*, the one-way analysis of variance was applied (Zar, 1999).

RESULTS

The preferred temperature median value of the juvenile "mojarra" at the day phase was of 32.5°C; for the night phase was of 32.0°C. No significant differences ($P > 0.05$) in the tem-

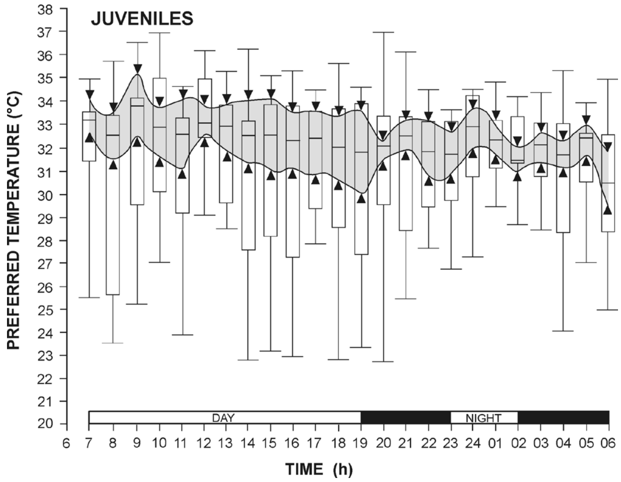

Figure 1. Preferred temperature of juveniles of the Mexican "mojarra" *Cichlasoma istlanum*. The shaded zone, limited by triangles, represents the 95% confidence interval of the median. The clear bars involve 50% of the organisms distribution.

perature preference of the juveniles during both phases of the cycle were assessed. Final thermal preferendum of juvenile of *C. istlanum* had a range of 30.5-33.7ºC with a median value of 32.6ºC (Figure 1). The preferred temperature of the adult during day and night phase was 31.0 and 30.2ºC respectively. There were no significant differences ($P > 0.05$) in the preferred temperature of the adults between day and night phases of the cycle. The preferred temperature range of the adult "mojarra" was in the 29.2 to 32.6ºC interval with a median value of 30.5ºC (Figure 2).

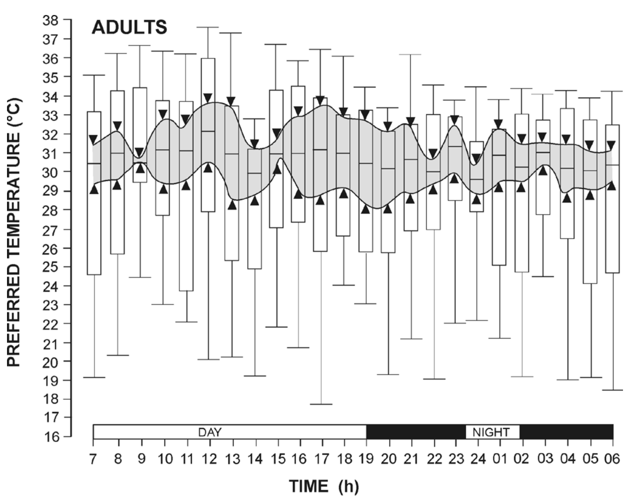

Figure 2. Preferred temperature of adults of the Mexican "mojarra" *Cichlasoma istlanum*. The shaded zone, limited by triangles, represents the 95% confidence interval of the median. The clear bars involve 50% of the organisms distribution.

When comparing the preferred temperature determined for juveniles and adults with ANOVA a significant differences ($P < 0.05$) were found between the median values during the 24 h cycle. Figures 1 and 2 show the preference of the juveniles for higher temperatures (2.1ºC; $p < 0.05$) in comparison to adults.

The theoretical optimum growth temperature calculated for the juvenile "mojarra" was at 31.6ºC and for the adults at 29.5ºC. The difference between the preferred temperature and the optimum growth temperature was only of 1.0ºC for both stages of the Mexican "mojarra". The juveniles of this species avoided temperatures lower than 22.7ºC and higher than 37.6ºC. The adults avoided temperatures lower than 17.5ºC and higher than 37.3ºC. The thermal tolerance zone was 33% higher in the adults (19.8ºC) than in the juveniles (14.9ºC).

DISCUSSION

When both stages of *C. istlanum* were placed in a thermal gradient, the fish distribute in accordance with the presumed effect of the temperature on surplus power capacity (Bryan *et al.*, 1990). According to Fraenkel and Gunn (1961) Mexican "mojarra" used an orthothermokinesis orientation mechanism. This implies that swimming velocity changed in response to temperature gradient, which enabled them to rapidly reached temperatures that enhance maximum metabolic scope. Then, the fish will remain within a relatively narrow temperature range that is juveniles were placed in 30.5 to 33.7 and adults of 29.2 – 32.6ºC, reducing swimming speed at that temperature. Therefore temperature selection by fishes appeared to be a process of preferred temperatures that maximize their available power (Kelsch & Neill, 1990; Bryan *et al.*, 1990; Kelsch, 1996).

This preference results in age segregation in the water column, reflecting a partition of the habitat. With regard to this, Giattina and Garton (1982) suggests four hypotheses for unifying concepts in the study of the thermoregulatory behaviour of fish: (1) The final preferendum of temperature is a characteristic response of each species that can be modified by non-thermal factors as age, availability of food, season and pathological conditions; (2) The partition of the habitat generated by thermoregulatory behaviour is an intra and inter-specific segregation measure to reduce cannibalism and competition; (3) The preferred temperature can reflect thermal optima for certain physiological processes; and (4) Fish generally avoid thermal extremes before these become lethal in order to choose for more favorable conditions that serve as thermal refuge.

In the absence of physiological studies, the ontogenetic changes in the final preferendum, observed in this study may correspond to the hypotheses number two which is similar to other species. Thus McCauley and Read (1973) observed in the *Perca flavescens* (Mitchill, 1814) a difference of 2.3–3.3ºC in preferred temperature between juveniles and adults. During the year the juvenile alewife *Alosa pseudoharengus* (Wilson, 1811) preferred 25ºC while the adults preferred 16ºC (Otto *et al*., 1976). In the yellow bullhead *Ictalurus natalis* (Lesueur, 1819) Reynolds and Casterlin (1978) reported that the preferred temperature of juveniles was of 28.8ºC and adults preferred 27.6ºC. Casterlin and Reynolds (1982) demonstrated that in *Pseudopleuronectes americanus* (Jordan and Gilbert, 1880) there were differences between the physiological responses to temperature depending on the age. The partitioning of aquatic environment among species and life stages along temperature gradients can be viewed to convey survival value for individuals and populations. Spatial segregation results in utilization of different food resources and, it minimizes predator-prey interaction (Coutant, 1987). It would be considered also as an adaptative response since it could decreases cannibalism and competition for food between both age groups of the "mojarra" *C. istlanum*.

Comparing the thermal preference from both juvenile and adult Mexican "mojarra" within their optimum growth temperature, was calculated at a difference of 1ºC. Kellog and Gift (1983) reported higher differences (2.0ºC) for *Morone saxatlis* (Walbaum, 1792), *Morone americana* (Gmelin, 1789) *Ictalurus catus* (Linnaeus, 1758) and *Notropis hudsonius* (Clinton, 1824) between the final preferendum and the optimum growth temperature. The relationship between thermoregulatory behaviour and the optimum growth temperature proposed by McCauley and Casselman (1981) proved that the fish farmer could use age-specific temperature information as a guide for selecting rearing temperatures that favor maximum growth as a fulfillment in both stages of the Mexican "mojarra".

The avoided temperatures intervals by *C. istlanum* were wider in the adults than in juveniles. Our results suggest that the higher and lower temperatures avoided by these organisms in the thermal gradient, reflect the limit of the thermal tolerance area, which includes the final preferendum zone. Therefore, the preference and avoided responses are of great importance with regard to thermoregulatory behaviour, which influences the mobility and distribution of these organisms (Cherry *et al*., 1975; Giattina & Garton, 1982).

The tolerance and thermal preference data can be used to determine the fitness of the culture sites. The tolerance to living at high temperatures intervals is a characteristic that both *Cichlasoma urophthalmus* (Günther, 1862) and *C. istlanum* share with thermophilic African cichlids (Martinez-Palacios *et al*., 1993). Due to this characteristic the mentioned species have high potential for culture in tropical areas. In this sense it is recommended that before selecting places based for fish aquaculture, the behavioural responses of the endemic species should be considered. Several authors refer that the thermal preference zone represents the area in which a species would inhabit, and consequently culture would be successful in the geographical sites where the final preferendum determined in aquatic organisms occurs regularly (Martínez-Palacios *et al*., 1996; Beitinger and Fitzpatrick 1979; Jobling 1981; Giattina and Garton 1982; Jobling 1994 and Wedemeyer 1996). It should be noted that the results of this study are relevant for optimizing the culturing of *C. istlanum*, in Morelos, México with regard especially to the differences in preferred temperature of juveniles and adults, due to the fact that this allows us to assume that there will be no intra-specific competition in the culture ponds.

REFERENCES

BEITINGER, T. L. & L. C. FITZPATRICK.1979. Physiological and ecological correlates of preferred temperature in fish. *American Zoologist* 19: 139-329.

BRETT, J. R. 1956. Some principles in the thermal requirements of fishes. *The Quarterly Review Biology* 31: 75-86.

BRYAN, J. D., S. W. KELSCH & W. H. NEILL. 1990. The maximum power principle in behavioral thermoregulation by fishes. *Transactions of the American Fisheries Society* 119: 611-621.

CASTERLIN, M. E. & W. W. REYNOLDS. 1982. Thermoregulatory behaviour and diel activity of yearling winter flounder *Pseudopleuronectes americanus* (Walbaum). *Environmental Biology of Fishes* 7:177-180.

CHERRY, D. S., K. L. DICKSON & J. JR. CAIRNS. 1975. Temperatures selected and avoided by fish at various acclimation temperatures. *Journal of the Fisheries Research Board of Canada* 32: 485-491.

COUTANT, C. C.1987. Thermal preference: when does an asset become liability? *Environmental Biology of Fishes* 18: 161-172.

DANKO, D.1991. *Cichlasoma (Parapetenia) istlanum* (Jordan and Snyder 1899). *Journal of American Cichlid Association* 143: 10-12.

DÍAZ, F., M. A. DEL RIO PORTILLA, E. SIERRA, M. AGUILAR & A. D. RE ARAUJO. 2000. Preferred temperature and critical thermal maxima of red abalone *Haliotis rufescens*. *Journal of Thermal Biology* 25: 257-261.

FRAENKEL, G. S. & D. L. GUNN, 1961. *The orientation of animals*. Dover Publications, New York, USA. 376 p.

GIATTINA, J. D. & R. R. GARTON.1982. A graphical model of thermoregulatory behaviour by fishes with a new measure of eurythermality. *Canadian Journal of Aquatic Science* 39: 524-528.

JOBLING, M.1981. Temperature tolerance and the final preferendum –rapid methods for the assessment of optimum growth temperatures. *Journal of Fish Biology* 19: 439-455.

JOBLING, M. 1994. *Fish Bioenergetics*. Chapman and Hall, London. 309 p.

KELSCH, S. W. & W. H. NEILL. 1990. Temperature preference versus acclimation in fishes selection for changing metabolic optima. *Transactions of the American Fisheries Society* 119: 601-610.

KELSCH, S. W. 1996.Temperature selection and performance by bluegills: Evidence for selection in response to available power. *Transactions of the American Fisheries Society* 125: 948-955.

KELLOG, R. L. & J. J. GIFT. 1983. Relationship between optimum temperatures for growth and preferred temperatures for the young of four fish species. *Transactions of the American Fisheries Society* 112: 424-430.

MAGNUSON, J. J., L. B. CROWDER & P. A. MEDVICK. 1979. Temperature as an ecological resource. *American Zoologist* 19: 311-343.

MARTÍNEZ-PALACIOS, C. A., C. CHAVEZ SANCHEZ & M. A. OLVERA NOVOA. 1993. The potential for culture of the American cichlid with emphasis on *Cichlasoma urophthalmus*. *In:* MUIR J. E. & R. J. ROBERTS (Eds.). *In Recent Advances in Aquaculture IV*. Blackwell Scientific Publications. Oxford. pp. 193-232.

MARTÍNEZ-PALACIOS, C. A., L. G. ROSS & V. H. SÁNCHEZ-LICEA. 1996. The tolerance to salinity, respiratory characteristics and potential for aquaculture of the Central American cichlid, *Cichlasoma synspilum* (Hobbs, 1935). *Aquaculture Research* 27: 215-220.

MCCAULEY, R. W. & L. A. A. READ. 1973. Temperature selection by juvenile and adult yellow perch (Perca flavescens) acclimated to 24ºC. *Journal of the Fisheries Research Board of Canada* 30: 1253-1255.

MCCAULEY, R. M. & J. M. CASSELMAN. 1981. The final preferendum as an index of the temperature for optimum growth in fish. *In:* K. TIEWS (Ed.). Proceedings of World Symposium on Aquaculture in Heated Effluent Recirculation Systems II. Berlin, pp. 81-93.

OTTO, R. G., M. A. KITCHELL & O. J. RICE. 1976. Lethal and preferred temperatures of the alewife *(Alosa pseudoharengus)* in lake Michigan. *Transactions of the American Fisheries Society* 104: 96-106.

PROSSER, C. L. & D. O. NELSON. 1981. The role of nervous systems in temperature adaptation of poikilotherms. *Annual. Review of Physiology* 43: 281-300.

REYNOLDS, W. W. & M. E. CASTERLIN. 1978. Ontogenetic change in preferred temperature and diel activity of the yellow bullhead, *Ictalurus natalis. Comparative Biochemistry and Physiology* 59A: 409-411.

RUIZ, C. G. & R. M. VILLALOBOS. 1991. A simple technique for making a streamer-type fish tag. *Northern American Journal of Fisheries and Management* 11: 475-476.

TUKEY, J. W. 1977. *Exploratory Data Analysis*. Addison Wesley, Massachusetts. 688 p.

WEDEMEYER, G. A. 1996. *Physiology of Fish in Intensive Culture Systems.* Chapman and Hall, New York. 232 p.

ZAR, J. H. 1999. *Biostatistical analysis.* Prentice Hall. New Jersey. 663 p.

Recibido: 6 de febrero de 2003.

Aceptado: 29 de julio de 2003.