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ECOLOGY OF THE MAYAN CICHLID, *CICHLASOMA UROPHTHALMUS* GÜNTHER, IN THE ALVARADO LAGOONAL SYSTEM, VERACRUZ, MEXICO

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ABSTRACT The Mayan cichlid, *Cichlasoma urophthalmus*, has a wide distribution in southeastern Mexico where it inhabits rivers and coastal lagoons. In the Alvarado lagoonal system, Veracruz, it is distributed towards the north in Camaronera Lagoon. The Mayan cichlid shows an affinity for oligohaline to mesohaline sites with submerged vegetation, well-oxygenated, deep, and transparent water. The major abundance and biomass of this species was obtained during December to February. The diet of Mayan cichlids consists principally of plant detrital material and algae. Length-frequency distribution shows 2 size classes during both the dry and rainy seasons, corresponding to reproductive fish and young of the year; during the nortes season there is only one modal size class of fish between 60–100 mm SL. Individuals with developed gonads are found throughout the year, although most reproductive adults are found between April and December. The highest Gonadosomatic Index (GSI) values coincided with the peak in reproductive activity between May and July. The fecundity ranged from 1,556–3,348 eggs/female, and there was no relationship between female size and fecundity.

RESUMEN El cíclido maya, *Cichlasoma urophthalmus,* tiene una distribución amplia en el sureste de México, donde habita ríos y lagunas costeras. En el sistema lagunar de Alvarado, Veracruz, esta especie se distribuye hacia el norte principalmente en la Laguna Camaronera. Esta especie muestra afinidad por sitios oligohalinos y mesohalinos con vegetación sumergida, bien oxigenados, profundos y de aguas transparentes. La mayor abundancia y biomasa de *C. urophthalmus* fue obtenida durante Diciembre a Febrero. La dieta del cíclido maya consistió principalmente de detritus vegetal y algas. La distribución frecuencia-longitud mostró dos clases de talla durante las temporadas de secas y lluvias, correspondientes a individuos reproductores y menores de un año; durante la temporada de nortes se encontró solo una clase de talla modal entre 60–100 mm LS. Los individuos con gónadas desarrolladas se encontraron a lo largo del año, aunque los adultos más reproductivos se encontraron entre Abril y Diciembre. El valor más alto del Índice Gonadosomático (IGS) coincidió con el pico de actividad reproductiva entre Mayo y Julio. La fecundidad se registró entre 1,556–3,348 huevos/hembra y no hubo relación entre la talla de las hembras y su fecundidad.

INTRODUCTION

The family Cichlidae is of freshwater origin with about 1300+ species worldwide (Nelson 1994). Members of this family are notorious for their capacity to colonize diverse habitats such as rivers, estuaries, lakes and coastal lagoons, representing a notable adaptation to a wide range of physical, chemical and biological environmental variables. The genus *Cichlasoma* comprises 118 species from the New World (Alvarez del Villar 1970, Astorqui 1971, Kullander 1983, 2004). At least 39 species are found in Mexico, where *Cichlasoma* is the most diverse genus of the freshwater ichthyofauna (Alvarez del Villar 1970). The Mayan cichlid, *Cichlasoma urophthalmus*, occurs in fresh and brackish waters of the Atlantic watersheds from the Rio Coatzacoalcos basin southward through Mexico, including the Yucatan Peninsula and Isla Mujeres, into Belize, Guatemala, Honduras and Nicaragua (Miller 1966, Martínez-Palacios and Ross 1992, Greenfield and Thomerson 1997).

The Mayan cichlid has been recorded in the State of Veracruz in the southern Gulf of Mexico (GOM) in the Pánuco, Sarabia, Chachalacas, Papaloapan, Coatzacoalcos, and Achotal Rivers. In the Alvarado lagoonal system, 3 genera and at least 7 species of cichlids have been reported, with the Mayan cichlid being the species with highest abundance and greatest ecological importance among the freshwater species of the system (Chávez-López 1998). Mayan cichlids have been reported in river-lagoonal systems associated with Términos Lagoon, Campeche (Amezcua-Linares and Yáñez-Arancibia 1980). They have also been reported from the Champotón River basin, Campeche, the Grijalva-Usumacinta River basin, Tabasco, the Yucatan Peninsula and Isla Mujeres in Quintana Roo (Miller 1966, Reséndez-Medina 1981, Caso-Chávez et al. 1986, Martínez-Palacios 1987), and on barrier reefs in Belize (Greenfield and Thomerson 1997).

In Mexico, the Mayan cichlid is exploited commercially in the artesanal fishery and has a potential for aquaculture in freshwater areas (Miller 1966, Martínez-

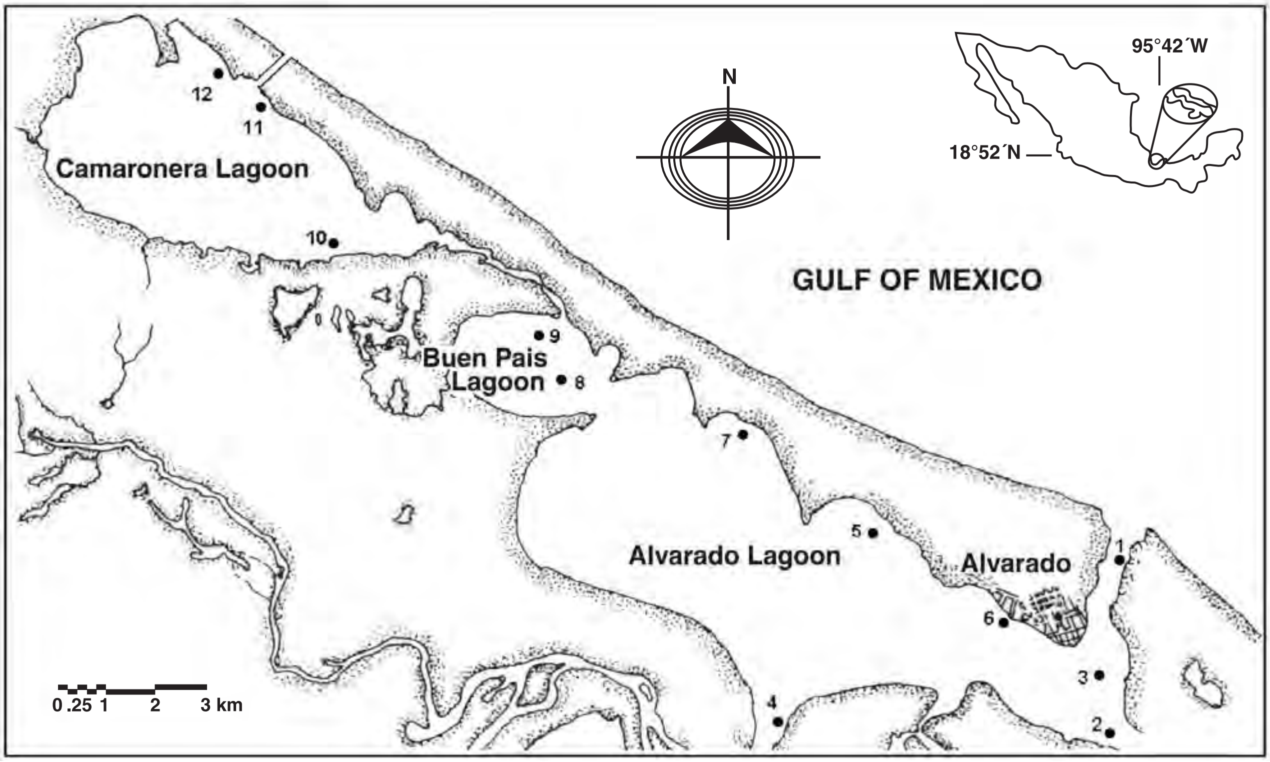

Figure 1. Sampling stations during June 2000–July 2001 in the Alvarado lagoonal system, Veracruz, Mexico. Inset map shows approximate geographic location of the study area.

Palacios and Ross 1992, Ross and Beveridge 1995). In the local markets, it has been preferred over introduced species such as tilapias, and the price was 20–40% higher than that for introduced species in Campeche (Résendez-Medina 1981), where this species has been sold along with marine species.

It has been shown that the Mayan cichlid is extremely adaptable throughout its range and that aspects of its life history vary depending on environmental conditions; for example, see Loftus (1987), Martínez-Palacios et al. (1990), Martínez-Palacios and Ross (1992), Faunce and Lorenz (2000), Faunce et al. (2002), and Bergmann and Motta (2004). The purpose of the present study is to provide additional information on the biology and reproduction of Mayan cichlids in the Alvarado lagoonal system in Veracruz, Mexico.

MATERIALS AND METHODS

Field collections and processing of specimens

Mayan cichlids were collected on 12 dates from June 2000 to July 2001 at 12 stations in the Alvarado lagoonal system, Veracruz, Mexico (Figure 1). Physicochemical data taken at each station included depth (cm), Secchi transparency (cm), salinity (psu), temperature (°C), dissolved oxygen (mg/l), and turbidity (NTU); percent submerged aquatic vegetation (SAV) cover was estimated visually. For analysis, monthly collections were divided into seasons following Raz-Gusmán et al. (1992), where the dry season was March through June, the rainy season was July through October, and the nortes season was November through February.

Fish were captured at each station using a single haul of a 30 m long x 2 m high seine constructed with 6.35 mm mesh. Total area sampled with each seine haul was 756.25 m^2. Fish were fixed in 10% buffered formalin and also injected in the abdominal cavity in the field to retard the digestive process. Fish were washed in fresh water after one week in formalin and then stored in 70% ethanol. Species identification followed Alvarez del Villar (1970) and Reséndez-Medina (1981). Each fish was measured to the nearest mm standard length (SL), weighed (WW) to the nearest g, and the gonads were removed and weighed to the nearest 0.1 g. Seasonal feeding of Mayan cichlids was determined by analyzing the stomach contents of 35 fish from each season. Stomach contents were separated to the lowest taxonomic level possible, weighed (0.01g) and analyzed according to the gravimetric method (Hyslop 1980).

Gonadal maturity classes were established by extracting a 1 mm thick portion of the ovaries or testes. Semi-permanent preparations were examined microscopically to determine the class of gonadal development following Murphy and Taylor (1990). The Gonadosomatic Index (GSI) was determined using the formula GSI = [gonad weight/(total wet weight – gonad weight)/100]. The total number of vitellogenic oocytes (> 0.42 L x 0.30 W mm) in the ovaries of mature females (87 mm–146 mm SL, 28.6–66.7 g) were counted to estimate fecundity.

Statistical Analysis

The relationships between SL and WW of male and female Mayan cichlids and between fecundity and female SL and weight were examined using linear regression analyses. A regression of GSI vs. body weight was used to verify that GSI was an appropriate index of spawning preparedness. The GSI data were arc sine transformed and then compared by gender across months with ANOVA. If a significant *F*-value was determined, pairwise Sidak tests were used to separate mean values. A Mann-Whitney U-test was used to compare each of seven physicochemical variables between stations with and without Mayan cichlids. Diet was compared among seasons using the Bray-Curtis similarity coefficient C_Z, with 0 = most dissimilar diets and 1 = identical diets (Marshall and Elliott 1997). Differences in length-frequency distributions among seasons were compared with pairwise Kolgomorov-Smirnov 2-sample Chi-square tests.

The relationship between the physicochemical variables and Mayan cichlid abundance was also examined using Principal Component Analysis (PCA) in a 2 step procedure (Peterson and VanderKooy 1997). First, the stations were ordered based on the seven physicochemical variables with PCA of the correlation matrix, with varimax rotation to maximize the loading results. A Scree Test was used to determine the number of components, and standardized scores of the factors were plotted for each station/month period against the meaningful components. Second, these station/month coordinates were coupled with the abundance of the Mayan cichlid for that specific collection station. Any variable with a correlation ≥ 0.50 was considered when interpreting a component. All calculations were made using SPSS software (Versions 10.0 or 11.5, Chicago, IL) and the results were considered significant if $P < 0.05$.

RESULTS

Abundance

Mayan cichlids were captured in 59 of 128 collections (46.1%) from the 12 stations in the Alvarado lagoonal system. The frequency of capture was similar among the stations except for the Blanco River station (# 4), where the Mayan cichlid was taken during only 4 of 12 collections, and in the estuarine zone of Papaloapan River (stations 1–3) where the species was not collected.

Adult Mayan cichlids ranged from 87 to 146 mm SL and had the greatest abundance in Camaronera Lagoon (*n* = 672, representing 52.7% of the total fish caught) and in the Aneas, Arbolillo, and Buen Pais stations (# 6,7,8,9) on the internal margin of the barrier separating the lagoon from the ocean. Abundance was greatest between November to February (nortes season) and lowest in April. Mayan cichlids were most abundant at stations containing SAV (Table 1); such as stations 10 and 11 in Camaronera Lagoon (*n* = 639, 49.4%), stations 8 and 9 in Buen Pais Lagoon (*n* = 200, 15.2%), and at the Arbolillo station (# 7) in Alvarado Lagoon (*n* = 216, 16.4%).

Habitat Relationships

The Mayan cichlid showed affinity for mesohaline stations, which were most common during the nortes and dry seasons and least common in the low salinity rainy sea-

TABLE 1

Abundance of *Cichlasoma urophthalmus* expressed as a percentage of the individuals collected, as percentage in stations with < 50% coverage with submerged aquatic vegetation (SAV), as percentage in stations with about 50% coverage with SAV, and as a percentage in stations with > 50% coverage with SAV. Sampling stations correspond to stations on Figure 1.

	Sampling Stations												
	12	11	10	9	8	7	5	6	4	2	3	1	TOTAL
Overall abundance	3.3	32.4	17.0	15.2	7.4	16.4	0.5	6.3	1.5				100.0
Stations with													
SAV < 50%	3.3				0.5	15.4	0.4	4.3	1.5				25.4
SAV = 50%		0.8	16.9					1.2					18.9
SAV > 50%		31.6	0.1	15.2	6.9	1.0	0.1	0.8					55.7

TABLE 2

Comparison of physicochemical factors ($\bar{x} \pm s$) between habitats with with and without *Cichlasoma urophthalmus*. Significant difference* ($P < 0.05$) determined by a Mann-Whitney U test.

Parameter	All stations	Stations with *C. urophthalmus*	Stations without *C. urophthalmus*
Submerged Vegetation (%)*	41.35 ± 34.47	57.24 ± 30.59	30.12 ± 32.74
Depth (cm)	99.11 ± 82.90	83.36 ± 30.96	110.25 ± 104.00
Secchi transparency (cm)	43.9 ± 21.93	45.11 ± 16.35	43.05 ± 25.22
Salinity (psu)*	5.72 ± 5.70	7.13 ± 5.32	4.72 ± 5.79
Dissolved Oxygen (mg/l)*	9.39 ± 1.76	9.72 ± 1.70	9.16 ± 1.77
Temperature (°C)	27.8 ± 2.92	27.96 ± 2.92	27.7 ± 2.94
Turbidity (NTU)	17.35 ± 14.86	15.63 ± 10.63	18.6 ± 17.20

son. Stations with Mayan cichlids exhibited greater SAV ($Z = 4.42$, $P < 0.001$), higher salinity ($Z = 3.16$, $P < 0.001$), and slightly higher dissolved oxygen ($Z = 1.78$, $P = 0.076$) than stations without Mayan cichlids (Table 2). There were no differences among the other variables measured (all $P > 0.05$). The SAV was composed mainly of *Ruppia maritima* with various percentages of the algae *Gracillaria verrucosa* and *Rhizoclonium hieroglyphicum* in Camaronera and Buen Pais Lagoons; other stations with SAV had only beds of *R. maritima.* There were no statistically significant differences in temperature, depth, transparency, and turbidity between stations where Mayan cichlids were present vs absent ($P > 0.05$; Table 2), but Mayan cichlids tended to occur at shallower and less turbid stations (Table 2).

The PCA analysis extracted 3 axes that accounted for 66.26% of the total variation in the physicochemical data (Table 3). The first component represents transparency (+), salinity (+), dissolved oxygen (+) and turbidity (-). The second component represents SAV (-) and depth (+), and the third component represents water temperature (+). The analysis indicates that stations of shallow depth, greater SAV (*Ruppia maritima*) cover, high salinity, high dissolved oxygen, high transparency, and low turbidity had the greatest numbers of Mayan cichlid captured (Figure 2). These stations were located in Camaronera Lagoon, usually during the nortes and dry seasons.

TABLE 3

Physicochemical variables correlated with the 3 principal components with eigenvalues > 1. The percent of variance explained by each component is in parenthesis. Variables with correlations > 0.50 are used in identifying the components.

	PC-I (30.15%)	PC-II (20.07%)	PC-III (16.04%)
Depth (cm)	0.084	0.858	0.121
Submerged Vegetation (%)	0.185	– 0.660	0.376
Secchi transparency (cm)	0.683	0.414	0.191
Salinity (psu)	0.737	– 0.192	0.008
Dissolved Oxygen (mg/l)	0.688	– 0.093	– 0.350
Temperature (°C)	0.018	– 0.039	0.902
Turbidity (NTU)	– 0.753	– 0.067	– 0.155

Size Distribution

Length-frequency histograms were constructed for each season (Figure 3). There were clear bimodal size distributions for the rainy season (20–40 mm and 101–120 mm SL) as well as the dry season (1–40 mm SL and 81–120 mm SL), indicating numerous small Mayan cichlids. In contrast, the highest frequencies in the nortes season corresponded to 60–100 mm and 120–160 mm SL, with no small fish being collected. Comparison of SL size distributions among seasons, pooled by gender, indicated that there was no significant difference between dry and rainy seasons ($Z = 1.322$, $P = 0.061$) or between rainy and nortes seasons ($Z = 0.685$, $P = 0.737$). However, the dry and nortes season SL size distributions were different ($Z = 1.958$, $P = 0.001$).

Log_{10} SL vs $\log_{10}$ WW for all females was significant ($F = 1600.59$, $r = 0.94$, $P < 0.001$, $n = 210$) and explained by $\log_{10} \text{WW} = –1.460 + 2.984 \log_{10} \text{SL}$. For males, $\log_{10}$SL vs $\log_{10}$ WW was significant ($F = 1938.99$, $r = 0.96$, $P < 0.001$, $n = 168$), and explained by $\log_{10} \text{WW} = –1.240 + 2.752 \log_{10} \text{SL}$.

Diet

The Mayan cichlid was predominately herbivorous in the Alvarado lagoonal system (Table 4), with a total of 19 food types identified. All fish had plant material in the stomach, and the percentages varied by season from a low of 74.41% in the dry season to a high of 98.3% in the

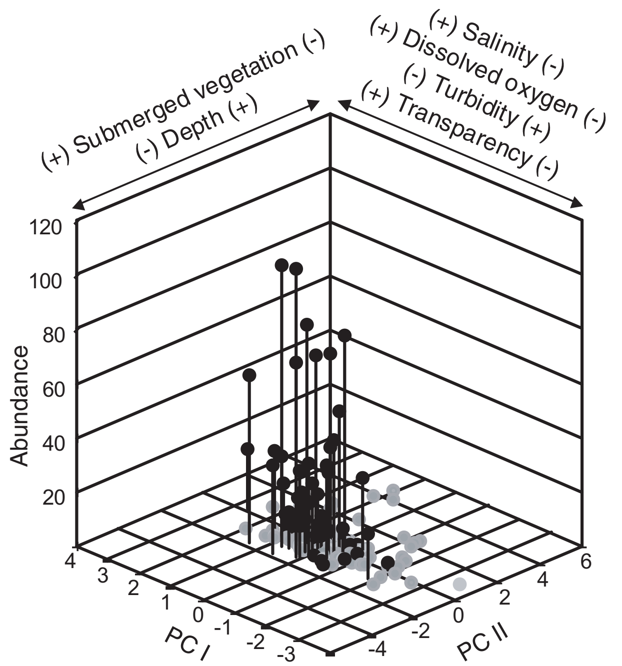

Figure 2. Three-dimensional plot of the stardardized factor scores for the stations and months of collection and the abundance of *Cichlasoma urophthalmus* arranged on principal components I and II based on seven physicochemical variables. Black lollypops are where Mayan cichlids were collected, whereas gray lollypops are where no Mayan cichlids were collected.

nortes season. Mayan cichlids supplemented its herbivorous diet with 18 other food types (2.12% of the diet) in the rainy season, 4 other food types (1.83% of the diet) in the nortes season, and 6 other food items (26.6% of the diet) in the dry season. The dry season diet was unique in that it was composed of a number of animal taxa, particularly mollusks (20.1%), crustaceans (3.75%) and fish scales (2.07%). The diets of Mayan cichlid were most similar between the rainy and nortes seasons ($C_Z = 0.9816$), There was reduced diet similarity between the rainy and dry seasons ($C_Z = 0.6716$) and between the nortes and dry seasons ($C_Z = 0.6705$).

Reproduction

Males, females, and juvenile Mayan cichlids were found in all collections in the Alvarado lagoonal system. Overall, the sex ratio of mature individuals was 1.16:1 (female:male). Gonadal recrudescence was first observed in individuals > 100 mm SL in April, although individuals as small as 60 mm SL showed gonadal development in July.

A comparison of GSI and gonad-free wet weight for females ($r^2 = 0.107$, $P < 0.001$, $n = 314$) and males ($r^2 = 0.068$, $P < 0.001$, $n = 247$) showed that while there is a significant, positive relationship between GSI and body weight, GSI explains $\leq 10.7\%$ of the variation in weight. Thus, GSI can be used as an index of spawning preparedness for this species. Female GSI varied significantly across sampling dates ($F_{11,314} = 12.177$, $P < 0.001$). The GSI indicates maximal ovarian development from May–July, with a GSI peak in May (Figure 4). Elevated GSI values were also seen in June–July 2000, verifying that maximal female reproductive activity occurs at the end of the dry season (May–June). However, there was a small peak in female GSI in December. The highest GSI values in May and June corresponded to females 120–160 mm SL. In contrast, male GSI values were significantly different over time ($F_{11,247} = 3.062$, $P < 0.001$) and showed much greater variability over the season than did those of females (Figure 4). Male GSI peaks occured in May–July in both years and in January 2001, similar to peaks seen in females. The large variation in GSI most likely indicates that individuals were in all stages of gonadal development each month, suggesting a protracted reproductive season.

During all months, individuals with undifferentiated and immature or regressed (stage I) ovaries were collected, and these individuals made up the majority of the females collected (Figure 5). Fish with ovaries in stages II and III were captured from May–July and December–February, while reproductive individuals (stage IV) were captured from May–July and December, with the greatest percentages found in June and July in both 2000 and 2001 (Figure 5).

Females ranging from 87–145 mm SL had fecundity

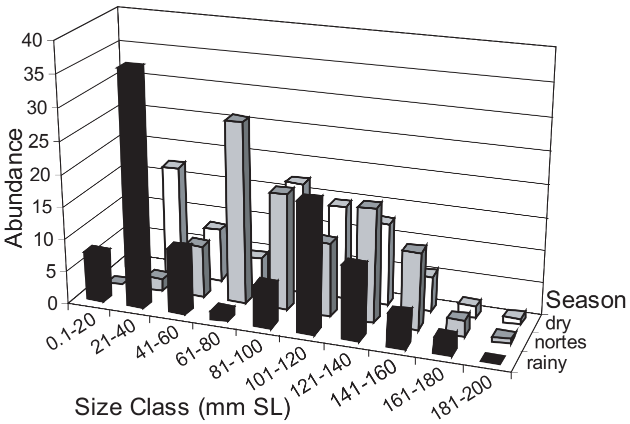

Figure 3. Size distribution of *Cichlasoma urophthalmus* by season in the Alvarado lagoonal system, Veracruz, Mexico. Dry season was March through June; the rainy season was July through October; and the nortes season was November through February.

TABLE 4

Seasonal diet composition (% weight) of *Cichlasoma urophthalmus* in Alvarado lagoonal System.

Food items	Rainy season	Nortes season	Dry season
Plant organic matter	97.28	98.17	67.16
Fish scales	0.62	0.54	2.07
Algae	0.58	0	0.48
Tanaidacea	0.57	0	0
Ruppia maritima	0.48	0.20	5.77
Annelids	0.13	0	0
Crustacea	0.10	0.084	3.75
Insects	0.074	0	0.67
Nematodes	0.06	0	0
Molluscs	0.048	0.99	20.10
Animal organic matter	0.016	0	0
Hydrobiidae	0.007	0	0
Amphipoda	0.005	0	0
Isopoda	0.002	0	0
Diptera	0.001	0	0
Fish eggs	0.001	0	0
Acari	0.0002	0	0
Fisaria sp.	0.0001	0	0
Cladocera	0.0001	0	0

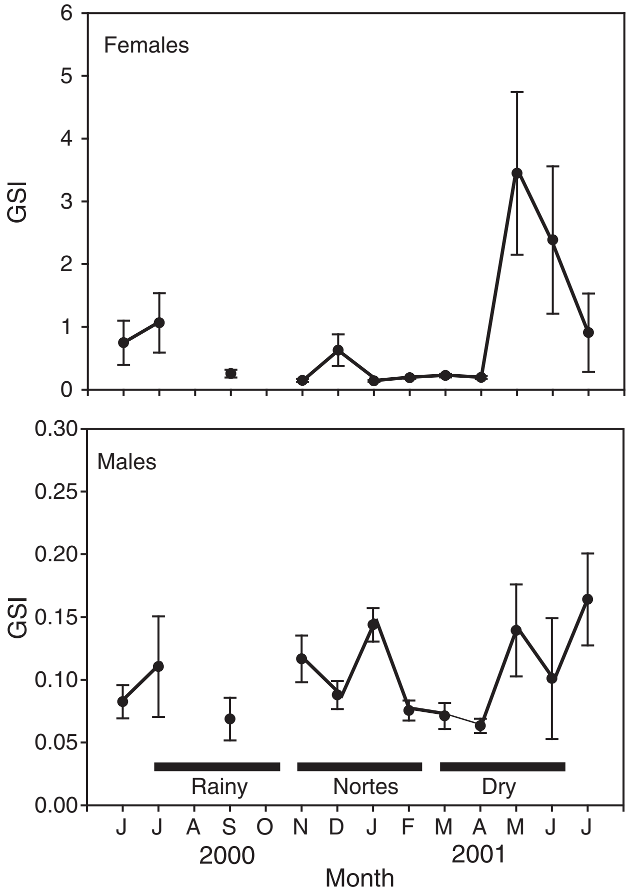

Figure 4. Plot of the gonadosomatic index (GSI; $\bar{x} \pm s_{\bar{x}}$) by month of female (n = 314) and male (n = 247) *Cichlasoma urophthalmus* from the Alvarado lagoonal system, Veracruz, Mexico. No collections were made in August and October 2000.

values from 1,556 to 3,348 eggs/female. There was no correlation between fecundity and SL of females (Fecundity = 1,916.92 + 2.780 SL; r = 0.0835, n = 14, P = 0.74), as small females often had a greater number of oocytes compared with large females.

DISCUSSION

Mayan cichlids were closely associated with habitat characterized by SAV and salinities between 3 and 13 psu in the Alvarado lagoonal system. This explains why the majority of the Mayan cichlids collected were taken in the nortes season and greater abundance was observed in Camaronera and Buen Pais Lagoons. Mayan cichlids were absent from the three Papaloapan River stations that have zero or low salinity throughout the year. The results of the present study agree with Caso-Chávez et al. (1986), who reported a greater number of Mayan cichlids in zones influenced by the ocean and with the presence of seagrass in Terminos Lagoon, Mexico. Mayan cichlids are also reported to have the greatest abundance in salinities up to 25 psu in the Mexican Caribbean (Martínez-Palacios and Ross 1992) and Florida (Faunce and Lorenz 2000). In fact, water temperature and salinity are not likely to limit their range in non-native habitat types in south Florida except in really cold winters, because at 25 °C, salinity tolerance is > 37 psu (Stauffer and Boltz 1994).

There were 2 size class distributions of the Mayan cichlid documented in the Alvarado lagoonal system. During the nortes season, mainly pre-adults and adults (61–160 mm SL) were captured, as has been reported in other Mexican locations (Caso-Chávez et al. 1986, Martínez-Palacios and Ross 1992). In contrast, the size class distribution was bimodal during the dry season, representing both juvenile recruits (10–20 mm SL) and reproductive adults (81–120 mm SL). The bimodal pattern shifted to larger sizes in the rainy season, with fish between 40–60 mm SL being most numerous, followed by a cohort of fish between 140–160 mm SL. We propose 2, non-exclusive explanations for the lack of larger Mayan cichlids collected in our study. First, the populations may suffer from overfishing as has been documented in the Celestún Lagoon, Mexico (Martínez-Palacios and Ross 1992); the minimum commercial size for this species in the Alvarado lagoonal system is 150 mm SL. Second, larg-

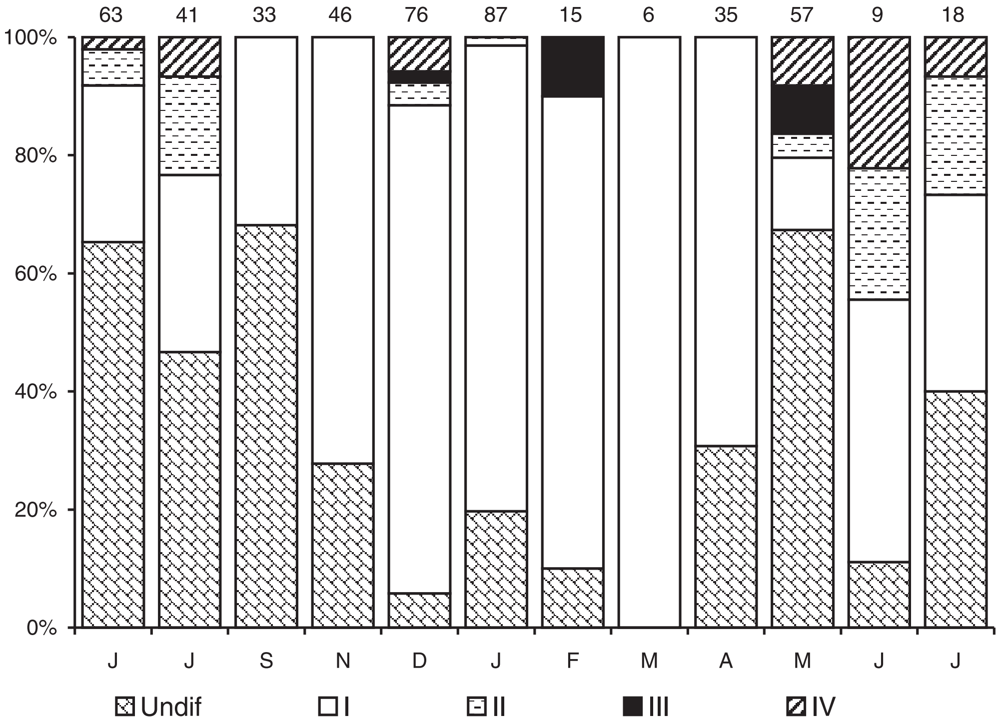

Figure 5. Monthly ovarian classes of *Cichlasoma urophthalmus* in the Alvarado lagoonal system, Veracruz, Mexico. Individual sample sizes by month are provided above each histogram. No collections were made in August and October 2000.

er fish have been shown to migrate to deeper water habitats in Florida systems (Faunce et al. 2002), and we suggest our inability to collect larger Mayan cichlids is due in part to our shallow water sampling techniques and we used relatively small seines. In fact, we did not collect individuals in spawning or post-spawning condition during this study, which may suggest that Mayan cichlids select other sites in the lagoonal system or immediately offshore to complete their reproduction. For example, Mayan cichlids have been observed breeding in seawater over sand on the barrier reef behind St. George Cay (Greenfield and Thomerson 1997), a different habitat type than those sampled in the Alvarado lagoonal system. Mayan cichlids with large ($\bar{x}$ = 1.72 mm) diameter oocytes were captured in Celestún Lagoon, Mexico, where mean salinity ranged from 16–24 psu (Martínez-Palacios and Ross 1992); these diameters are much higher than any value measured in the Alvarado lagoonal system.

The diet of Mayan cichlids was principally herbivorous but varied seasonally, most likely in response to prey availability. Although plant material was the main food item, diet in the dry season was composed of a considerable portion of crustaceans, insects, and mollusks, similar to findings by Chávez-Lopez (1998). Mayan cichlids collected in *Thalassia testudinum* grassbeds in Terminos Lagoon, Mexico, were mainly ingesting plant and detrital matter, with sponges and cirripeds as incidental food (Caso-Chávez et al. 1986). In contrast, Mayan cichlids (96–200 mm SL) in the Celestún Lagoon, Mexico, were classified as carnivorous, feeding mainly on small invertebrates (palaemonid and penaeid shrimp) with little algae or seagrass (Martínez-Palacios and Ross 1988). Finally, Bergmann and Motta (2004), based on diet and trophic morphology, indicated that Mayan cichlids in southern Florida were generalists, feeding on fish and snails, and that being generalist and opportunistic feeders enhanced its colonization success in non-native environments.

It appears the reproductive season is more prolonged in coastal Mexican lagoons, likely caused by factors such as temperature and day length (Noakes and Balon 1982, Munro et al. 1990). Although Mayan cichlids have a protracted reproductive period in the Alvarado lagoonal system, we found females with mature eggs only between May and July. Caso-Chávez et al. (1986) reported that reproductive activity was maximal in June and no reproductive females were collected after September in Terminos Lagoon, Mexico. Martínez-Palacios and Ross (1992) indicated that the reproductive season began in mid-April and ended by mid-November in the Yucatan Peninsula. In contrast, the reproductive season in Florida appears to occur only in April and May (Loftus 1987, Faunce and Lorenz 2000). The reproductive season in

Mexico (Martínez-Palacios and Ross 1992) stopped when temperatures dropped below 24 °C, from late-November to March, whereas in Florida, reproduction stopped in October at 23 °C (Faunce and Lorenz 2000). In the Alvarado lagoonal system, we did not find mature females in the coldest months of the year (January and February) when water temperature had decreased to 23 °C.

Our data are comparable with all other reports that sexual maturation occurs by 100 mm SL in Mayan cichlids. In the Yucatan Peninsula, Mexico, the minimum size for female maturity is 102 mm SL, enabling females to reproduce during their first spring as they approach their first birthday (Martínez-Palacios and Ross 1992). Females in Terminos Lagoon, Mexico, reached sexual maturity at 60 mm SL (Caso-Chavez et al. 1986). We also found mature females as small as 60 mm SL but only in July toward the end of the reproductive season. In contrast, Mayan cichlids from northern locations in Florida reach 50% sexual maturity at 127.2 mm SL (Faunce and Lorenz 2000), suggesting there may be latitudinal variation in size at maturity as reported for other cichlid species (Turner and Robinson 2000).

Surprisingly, we found no relationship between female size and fecundity for Mayan cichlids in the Alvarado lagoonal system, although a significant positive relationship has been previously reported for this species in Celestún Lagoon, Mexico (Martínez-Palacios and Ross 1992). The small sample size for fecundity estimates may contribute to the lack of a significant relationship. Even when a significant relationship is seen between fish size and fecundity, size explains only 33% of the variation in fecundity (Martínez-Palacios and Ross 1992). Nonetheless, the range of fecundity values we obtained overlap the low end of the range reported by Martínez-Palacios and Ross (1992; 2085–6615 ova/female, 113–198 mm SL) and were based on smaller fish (87–146 mm SL) than those in the Yucatan.

Camaronera Lagoon, the northern part of the system, had the highest salinity between April and June (dry season), when the majority of reproductive activity occurs and when nest construction and parental care occurs in Florida populations (Faunce and Lorenz 2000). The rainy season begins in July and the salinity decreases to 5 psu in this zone as the water levels begin to increase. This coincides with the termination of parental care and the migration of juveniles to other areas to find lower salinity and warmer temperatures (34 °C in Alvarado Lagoon). In the lower salinities common during the rainy season, juveniles are in an almost isotonic aquatic medium at salinities which facilitate the best growth of Mayan cichlids < 1 year old (Martínez-Palacios et al. 1990). Furthermore, the abundance of adults decreases in the shallow areas of the lagoonal system during the rainy season, suggesting they may move to deeper areas with higher salinities.

In spite of the wide distribution of Mayan cichlids in the southeast of Mexico, until now little was known regarding the state of natural populations. Some populations of Mayan cichlids that inhabit cenotes (sinkholes) in the Yucatan Peninsula are considered species of special concern in Mexico (Diario Oficial de la Federación 2002). However, Mayan cichlids were suggested as a native aquaculture resource in Mexico, with presumed lack of a negative effect on native biodiversity (Ross and Beveridge 1995). In contrast, Mayan cichlids are one of the most abundant exotic species established in southern Florida (Trexler et al. 2000), where they severely impact native substrate spawners like largemouth bass (*Micropterus salmoides*), warmouth (*Lepomis gulosus*), and spotted sunfish (*L. punctatus*) through nest building, habitat alteration, and egg predation. Since Mayan cichlids outnumber native species in northern Florida Bay, more research is needed on community level impacts in brackish water. Thus, a greater understanding of the life history of the species in low salinity systems in its native range may aid management of introduced populations in south Florida.

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