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ECOLOGY OF THE ALLIGATOR GAR, *ATRACTOSTEUS SPATULA*, IN THE VICENTE GUERRERO RESERVOIR, TAMAULIPAS, MÉXICO

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ABSTRACT—We provide the first ecological account of the alligator gar, *Atractosteus spatula*, in the Vicente Guerrero Reservoir, Tamaulipas, México. During March to September, 1998, the local fishery cooperative captured more than 23,000 kg of alligator gar from the reservoir. A random sample of their catch was dominated by males, which were significantly smaller than females. Males and females had similar weight-length relationships. Relative testicular weight varied little seasonally, but relative ovarian weight showed a strong seasonal pattern that indicated peak spawning activity during July and August. Body condition of both sexes also varied in a pattern consistent with late summer spawning. Fishing for alligator gar virtually ceased from October to February, when nonreproductive individuals were presumed to move offshore to deeper water. Alligator gar fed primarily on largemouth bass, *Micropterus salmoides*, and less frequently on other fishes. The gillnet fishery for alligator gar in the reservoir appears to be based primarily on individuals that move into shallow, shoreline areas to spawn. Males probably remain in these habitats longer than females. The dominance of largemouth bass in the alligator gar diet reflects this centrarchid's high occurrence in littoral habitats of the reservoir, and the diet of alligator gar inhabiting deeper habitats of the reservoir could be different.

RESUMEN—Son aportados por primera vez algunos aspectos ecológicos del catán, *Atractosteus spatula*, en la represa de la Presa Vicente Guerrero, Tamaulipas, México. El trabajo fue desarrollado durante el período de marzo-septiembre de 1998, en el cual las cooperativas pesqueras locales capturaron más de 23,000 kg de catán de la represa. La captura estuvo dominada por machos, los cuales fueron más pequeños que las hembras. Ambos sexos registraron una relación peso-longitud similar. El peso relativo de los ovarios mostró un fuerte patrón estacional no asi el peso relativo de los testículos, los cuales exhibieron poca variación estacional. En ambos sexos el coeficiente de condición varió mensualmente, indicando un pico de actividad de desove durante julio-agosto. La pesca de catán disminuyó virtualmente de octubre a febrero, cuando el catán no se reproduce y se presume que migra de la zona litoral hasta los sitios más profundas de la represa. El catán se alimentó principalmente de la lobina negra, *Micropterus salmoides*, y en menor porcentaje de otros peces. La pesca de catán con redes agelleras en esta represa, se confina a individuos que se desplanza las zonas litorales someras en donde ocurre el desove. Los machos probablemente permanecen más tiempo en estos hábitats que las hembras. La dominancia de la lobina negra en la dieta del catán refleja la alta incidencia del centrárquido en hábitats litorales de la represa, siendo la dieta del catán de aguas profundas de la represa probablemente diferente.

The alligator gar, *Atractosteus spatula*, is widely distributed in rivers and lakes of the Mississippi River drainage from the lower Missouri and Ohio rivers to the Gulf Coast from the Econfina River, Florida to Veracruz, México (Suttkus, 1963; Álvarez del Villar, 1970; Wiley, 1976; Lee and Wiley, 1980; Page and Burr, 1991). In spite of its ancient phylogenetic history, comparatively little ecological research has been conducted on the gar family, Lepi-

sosteidae. In part, lack of interest in gars stems from their perceived lack of value as a fishery resource in North America, and the belief that these predators reduce populations of more desirable species (Scarnecchia, 1992). In contrast, the alligator gar is highly valued as a food fish in northeastern Mexico, where the species is known as the catán. Alligator gar is an important food fish consumed by at least 100 families in the municipality of Padilla, Tamaulipas (Porras-Escamilla, 1998). Until now, no studies have been conducted on Mexican populations of the alligator gar. Here we report findings from a 7-month study of population structure, reproductive seasonality, and diet of the alligator gar in the Vicente Guerrero Reservoir in central Tamaulipas, México.

MATERIALS AND METHODS—*Study Area*—The study was conducted in the Vicente Guerrero Reservoir, which is located within the Gulf coastal plain between 23°45′ and 24°05′N and 98°40′ and 98°57′W, ca. 54 km northeast of Ciudad Victoria, Tamaulipas. The reservoir was constructed in 1971 by the Secretaría de Recursos Hidráulicos to provide irrigation water for 42,000 ha of cropland, as well as recreation. The reservoir has a maximum depth of 62 m and a capacity of 5.28×10^9 m^3. Its main tributaries are the Purificación, Pilón, Grande, and Corona rivers. The region receives an average annual rainfall of 700 to 800 mm, with heaviest precipitation during summer. Average annual temperature is 24 to 26°C (Secretaria de Programación y Presupuesto, 1983).

Sampling—Monthly samples of alligator gar from Vicente Guerrero Reservoir were obtained from commercial catches from the Villa de Padilla Fishery Production Cooperative Society during 2 periods (March through September 1998 and April through July 1999). Fishing effort by the cooperative was 17 days (March), 18 days (April), 22 days (May), 16 days (June), 11 days (July), 18 days (August), and 17 days (September), with nearly equal effort expended each day. We surveyed their total catch 1 to 4 days per month during 1998 for a total of 15 survey days. Our survey effort during 1999 was lower, and was directed at supplying more samples for morphometric and dietary analyses. Commercial fishermen used gillnets of 15 cm bar mesh, 3 m in height by 150 to 600 m in length. Nets were set at ca. 1800 h with an effective fishing time of 12 h. Gillnetting was concentrated around the following regions of the reservoir: La Retama, Las Islas, La Cortina, Barretas, Ebano, El Toro, La Garrapata, El Guayabo, Islas de en Medio, El Melón, Río Corona, Río Pilón, Mogote, Santa Ana, and Enramadas.

In the field, each specimen was measured for total length (TL), interorbital distance, total weight, and weights of consumable meat and gonads. Fishermen frequently clean their catch in the field, and the latter measurements were made for calculation of conversion equations to aid future research. Length was measured with a metric tape and fish measuring board to the nearest 1 cm, or with calipers to the nearest 1 mm; weights were measured with a spring balance to the nearest 1 g, or for larger quantities with a DETECTO series MCS dial balance to the nearest 28 g. Gonads and digestive tracts were preserved in 10% formalin and transported to the laboratory for examination.

Data Analysis—To examine variation in body condition, the relationship between weight and $\log_{10}$TL was estimated by using linear regression. Differences in the weight-length relationship of males and females were examined by means of analysis of covariance. Size at sexual maturity of each sex and reproductive activity were estimated based on macroscopic examination of gonads and calculations of the gonadosomatic index (GSI): $100 \times$ (gonad weight/body weight). Gonads were classified as 3 stages (Rossemblum et al., 1987): immature (categories I–IV), mature (V–VI), and spent. Sex was not determined in 25 cases in which gonads were immature.

Following Lagler (1956), diet was evaluated using the descriptors of prey frequency of occurrence (*%F*), number (*%N*), and volume (*%V*). In addition, George and Hadley's (1979) index of relative importance (*RI*) was calculated for each prey item:

$$RI_i = \frac{(\%F_i + \%N_i + \%V_i)100}{\sum_{i=1}^{n} (\%F_i + \%N_i + \%V_i)}$$

where n is the number of prey categories. In George and Hadley's study, weight was used in place of volume.

RESULTS—The number of alligator gar that we obtained each month was a function of variation in our survey effort and the ability of fishermen to catch fish with gillnets (the latter is a function of fish density and movement in littoral habitats). Expressed on a per-survey-day basis, monthly catch-per-unit effort for alligator gar showed no seasonal trend (4.0–March, 13.0–April, 9.5–May, 13.5–June, 6.0–July, 13.0–August, and 11.0–September). Few gar were caught after September, and fishing activity for this species nearly ceased from November until the following spring. Because few specimens are caught in gillnets at the traditional nearshore fishing places during the late fall and winter, local fishermen presume that the fish

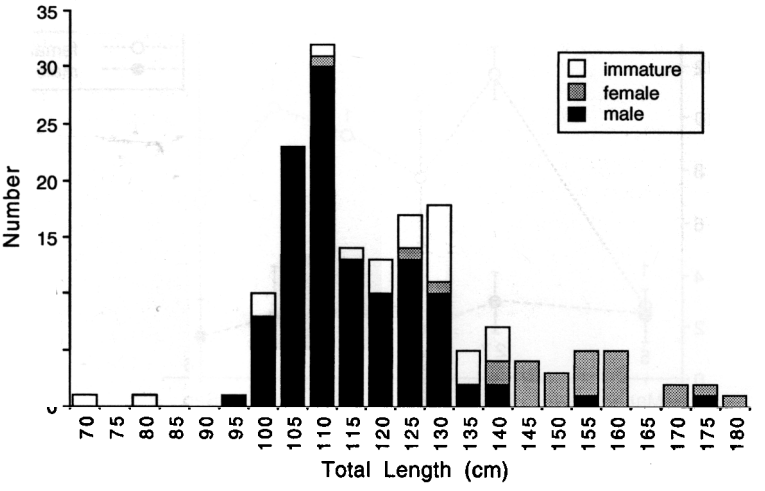

FIG. 1—Size frequency distribution by sex of alligator gar from Vicente Guerrero Reservoir, Tamaulipas, México, 1998 to 1999 (n = 163).

move offshore to deeper regions of the reservoir. During 1998, biomass of alligator gar per survey day by month was: 48.3 kg (March), 143.9 kg (April), 97.9 kg (May), 158.1 kg (June), 72.9 kg (July), 167.0 kg (August), and 256.0 kg (September).

With r^2 = 0.96, the regression equation describing the relationship between total length and interorbit distance was TL = 10.668 (ID) + 27.0. We converted data for total biomass (kg) of alligator gar meat harvested each month by the cooperative to the total weight (kg) of whole fish harvested using the following conversion equation obtained by regression analysis of meat (lacking skin and viscera) versus whole body for 121 gar: $W_{\text{total body}} = 0.268 + 1.863W_{\text{meat}}$ (r = 0.975, $P < 0.0001$, n = 121). The total monthly harvest of gar by the cooperative was: 2,015 kg (March), 3,130 kg (April), 7,315 kg (May), 3,157 kg (June), 1,072 kg (July), 1,294 kg (August), and 5,513 kg (September).

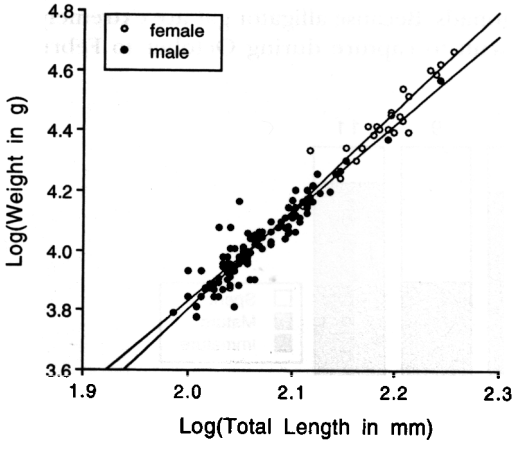

FIG. 2—Regressions of weight (log body weight in g) versus total length (log TL in cm) for male (n = 115) and female (n = 25) alligator gar from Vicente Guerrero Reservoir, Tamaulipas, México, 1998 to 1999. Regression equation for females is $\log(W) = 3.330 \log(L) - 2.863$; for males $\log(W) = 2.951 \log(L) - 2.077$.

Total length of alligator gar ranged from 97 to 180 cm. Our samples were dominated by males (male = 115, female = 25, immature = 25), and males were significantly smaller than females (t-test$_{\text{two-tailed}}$, $P < 0.0001$, Fig. 1). On average, females weighed 5.4 kg more than males. The minimum size of maturation for males was 95 to 100 cm TL, and for females was 125 to 130 cm TL. The weight-length relationships for males and females were not significantly different (ANCOVA, $P > 0.05$, Fig. 2), with a common regression equation: $\log_{10}W = 3.176(\log_{10}L) - 2.540$, where W is expressed in g, and L as cm TL (r^2 = 0.94).

During March to September 1998, mean GSI of males showed low temporal variation (1.53 to 2.91), but mean GSI of females significantly increased from 2.8 in March to 11.7 in April. Mean GSI of females was relatively high

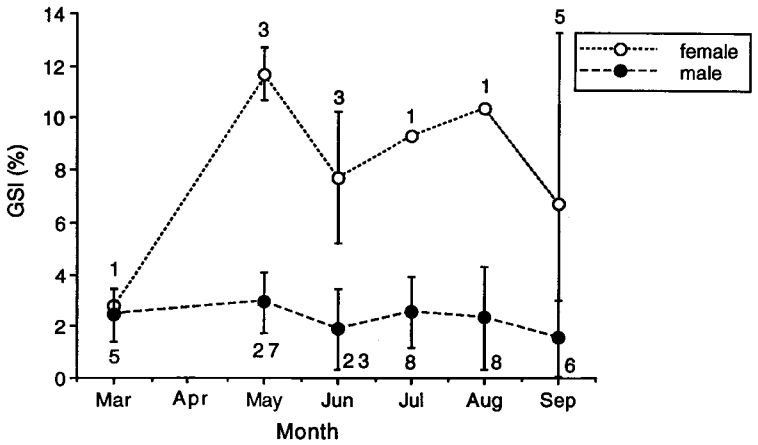

FIG. 3—Monthly variation in mean gonadosomatic index (bars = ±1 *SD*) for male (n = 77) and female (n = 14) alligator gar from Vicente Guerrero Reservoir, Tamaulipas, México, 1998.

throughout the summer and declined during September (Fig. 3). The percentage of mature gonads increased from a minimum of 25 during March to a maximum of 87 during July (Fig. 4). No spent gonads were detected during March, and low percentage of spent gonads was observed during May to July and September (no gonad data were obtained for April). Thirty-seven percent of gar gonads were spent during August, thus indicating the peak spawning period for this species in Vincente Guerrero Reservoir.

Fishes were the only prey identified from alligator gar stomachs. By all measures (% frequency, numerical abundance, % volume, index of relative importance), largemouth bass (*Micropterus salmoides*, local name is lobina negra) was the predominant prey in stomachs (Table 1). Though of less importance, shads (*Dorosoma cepedianum* and *D. petenense*), cichlids (*'Cichlasoma' cyanoguttatum*), and catfish (Ariidae) also were consumed.

DISCUSSION—Alligator gar captured from littoral habitats of Vicente Guerrero Reservoir were mainly adults with either mature or spent gonads. Because alligator gar are extremely difficult to capture during October to February,

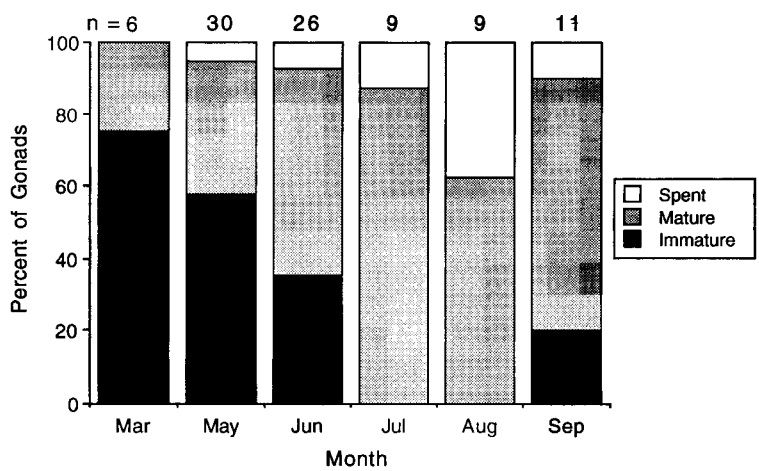

FIG. 4—Monthly percentages of immature, mature, and spent gonads (male and female) in alligator gar from Vicente Guerrero Reservoir, Tamaulipas, México, 1998 (n = 91).

TABLE 1—Frequency of occurrence, numerical percentage, volumetric percentage, and index of relative importance for 4 prey taxa taken from stomachs of 60 alligator gar from Vincent Guerrero Reservoir (n examined = 138, n empty = 78).

Prey taxon	% Frequency	% Number	% Volume	Relative importance
Micropterus salmoides	51.5	50.0	78.0	59.8
'Cichlasoma' cyanoguttatum	15.7	12.8	8.4	12.3
Dorosoma spp.	12.9	20.9	6.4	13.4
Ariidae	1.4	1.2	0.9	1.2
Unidentified fish	18.5	15.1	6.3	13.3

we presume that these individuals move from limnetic habitats of the reservoir to littoral habitats for spawning. We found little published information on spawning behavior of the alligator gar. May and Echelle (1968) collected two juvenile alligator gar in an arm of Lake Texoma, Oklahoma–Texas, the first documentation of reproduction by this species in a reservoir. Suttkus (1963) reported that *Lepisosteus* species spawn adhesive eggs in shallow areas with 1 to 4 males joining a single female, and all departing soon afterward. A recent study of the spotted gar (*Lepisosteus oculatus*) revealed seasonal movement into seasonally inundated littoral regions of the Atchafalaya River swamps in Louisiana (Snedden et al., 1999). The fact that male alligator gar greatly outnumbered females in the commercial catch (ratio females to males = 1:7.6) suggests that males remain in the littoral zone longer than females. By remaining within a spawning habitat, these males might be able to fertilize the clutches of several females in succession.

Female alligator gar are larger than males, a pattern also observed for longnose gar, *Lepisosteus osseus,* from reservoirs in Missouri (Netsch and Witt, 1962) and Kansas (Klaassen and Morgan, 1974). The overall size range of Vicente Guerrero Reservoir alligator gar was larger than that obtained by Suttkus (1963) for a sample of 21 alligator gar in Lake Ponchartrain, Louisiana (41 to 147 cm TL). Slope of the weight-length relationship for Vicente Guerrero Reservoir alligator gar indicated positive allometric growth.

Given the high correlations we obtained for relationships between weight of harvested meat and total body weight, between body weight and TL, and between TL and interorbital distance, future investigators will be able to estimate the size of whole fish based on measurements of heads found in the field or meat delivered to markets. For example, 7 kg of meat corresponds to a fish weighing approximately 12.8 kg and measuring 145 cm TL. Given that our best estimates of stocks currently come from the commercial catch, such conversions will be necessary to obtain adequate descriptions of alligator gar stocks.

Monthly changes in the gonadosomatic index and percentages of mature and spent gonads indicated a summer spawning period with a peak during August. By comparison, the spawning period of alligator gar in Louisiana is from April to June (Suttkus, 1963). Based on documentation of early life stages, Echelle and Riggs (1972) estimated *A. spatula* in Lake Texoma, Oklahoma–Texas, spawn from January to September. Evidence of spawning (spent gonads) was observed in Vicente Guerrero Reservoir only during June to September, so that alligator gar captured from March through May might have been individuals that moved into littoral habitats in search of potential sites for spawning. Since at lower latitudes the lengthening of photoperiod during spring occurs earlier, and annual temperature variation is lower, it would be reasonable to assume that, within a species, spring spawning dates would be advanced and duration of the reproductive period would be longer (Hubbs, 1985). Although the longer reproductive period (relative to data summarized in Suttkus, 1963) of the lower-latitude population of alligator gar in Vincente Guerrero Reservoir follows this assumption, initiation of spawning was actually later in central Mexico (24°N) than in either Louisiana (30 to 33°N) or Lake Texoma (Lat. 34°N), a topic that deserves additional study.

Largemouth bass, the most important food

and sportfish in the reservoir, is the primary prey of alligator gar from littoral zones of the reservoir in summer. Because we do not have diet data for alligator gar from other regions of the reservoir and for other periods of the year, it currently is not possible to estimate overall consumption of largemouth bass by alligator gar. Catfish were a minor dietary component, and all material we identified from alligator gar stomachs were ariids. Normally estuarine inhabitants, ariid catfish have increased in abundance within the reservoir, and ariids now outnumber freshwater ictalurid catfishes in this system (F. J. Garcia de León, pers. obser.). Most alligator gar stomachs were empty, a common finding in studies of large piscivores. Additionally, high frequency of empty stomachs probably was influenced by immobilaztion in gillnets for up to 12 h. Smaller prey would have digested faster, which could have biased our dietary findings toward larger prey. Other studies have found alligator gar feeding on gamefish, mullet (*Mugil cephalus*), crabs, and water birds (Suttkus, 1963).

Currently, the alligator gar population of Vincente Guerrero Reservoir does not appear to be highly vulnerable to overfishing, because commercial fishing is confined to 7 months of the year and takes mostly males. The large females, which are critical for maintaining recruitment, were captured in much lower numbers in this study. If one assumes a 1:1 sex ratio, most females are avoiding capture by the commercial fishery on an annual basis. Because the species is long-lived, a relatively low level of successful recruitment should be able to maintain a relatively stable population in the reservoir. On the other hand, if the sex ratio is naturally skewed toward domination by males, our catch data would justify concern if escape of spawners from the fishery was low. Clearly, more field data are needed to serve as the foundation for a basic model of alligator gar population dynamics in this system.

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