ABSTRACT

BACHELER, NATHAN MITCHELL. Ecology of bigmouth sleepers (Eleotridae: *Gobiomorus dormitor*) in a Puerto Rico reservoir. (Under the direction of Dr. Richard L. Noble.)

The bigmouth sleeper *Gobiomorus dormitor* is an eleotrid species found in southern Florida and Texas, along the Atlantic coast of Central and South America, and the Caribbean Islands. This species is important in terms of recreational and consumptive fishing, and conservation. Bigmouth sleepers are harvested by anglers in parts of their range, while in Florida hydrological changes, habitat loss, and reduced water quality have reduced the species' already small geographical distribution, necessitating conservation measures. There is a paucity of data regarding the biology of bigmouth sleepers, but accurate knowledge of this species' ecology and behavior is crucial to effective conservation and management plans. Although bigmouth sleepers typically inhabit lotic habitats, they have been found in four reservoirs in Puerto Rico. In Carite Reservoir, abundance and size data indicate that habitat is suitable habitat for bigmouth sleepers, and the presence of a diversity of size classes of sleepers suggests that either in-reservoir reproduction or significant recruitment to the reservoir from an outside source is occurring. This research was initiated to evaluate the likelihood of each, and to learn more broadly about bigmouth sleeper ecology. Population biology, diet, and reproduction of bigmouth sleepers in Carite Reservoir were examined between 1999 and 2001. Many sizes of bigmouth sleepers were collected during this study, ranging from 25 to 400 mm TL. The estimated total population size in 2000 and 2001 was 1,783 and 3,353 fish, respectively. Daily growth rate of tagged fish ranged from –0.08 to 0.10 mm/day, and was negatively correlated with length of fish at marking. Diet of small bigmouth sleepers (50 – 100 mm TL) mainly consisted of insects, whereas larger fish primarily preyed upon fish and freshwater crabs. Sexual dimorphism of bigmouth sleepers was evident in the anatomy of their urogenital papillae; these differences developed at sizes as small as 50 mm TL and persisted throughout the year. Reproduction was seasonal, with the highest gonadosomatic indicies occurring in May and June and the lowest in January and February. The smallest mature male observed was 159 mm TL, while the smallest mature female was 179 mm TL. Size frequency distributions of oocytes in female ovaries during the reproductive season typically fell into two size groups, a group of primary oocytes (< 0.20 mm) and one group of maturing oocytes (> 0.20 mm). The largest oocytes observed were 0.70 mm from a 270-mm female. Fecundity was negatively correlated with date, suggesting batch spawning. Fecundity was relatively high (mean = 140,836) and was positively correlated with female body weight. Results of this research not only provide managers and conservationists a better understanding of bigmouth sleepers in Puerto Rico reservoirs, but also contribute to the knowledge of this species' ecology throughout its range.

ECOLOGY OF BIGMOUTH SLEEPERS (ELEOTRIDAE: *GOBIOMORUS DORMITOR*) IN A PUERTO RICO RESERVOIR

by

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PERSONAL BIOGRAPHY

Nathan Mitchell Bacheler was born on March 23, 1975, in Sault Ste. Marie, Michigan, to William Burgess and Pamela Ann Bacheler, and is two years older than his only sibling, Daniel Case Bacheler. A large part of his childhood was spent fishing, hiking, and camping with family and friends in this northern Michigan town. He graduated from Sault Area High School in 1993 with an interest in pursuing an undergraduate degree in the sciences. Nathan enrolled at Grand Valley State University in 1993 and graduated from there in 1997, majoring in Biology with an emphasis in aquatic and fisheries science. After taking time off to travel in Costa Rica, he entered North Carolina State University to work with Dr. Richard Noble on fish in Puerto Rico commencing in the summer of 1999.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

Ubiquitous hydrological alterations such as dam construction and associated water diversion, exploitation of groundwater aquifers, stream channelization, and intercatchment water transfer are producing global-scale effects on the environment (Rosenberg et al. 2000). One group of organisms that can be negatively affected by such alterations is fishes. Indeed, human alteration of aquatic habitats is now the most commonly cited cause of declines in fish populations (Helfman et al. 1997). Possibly the most detrimental alterations for native fishes are river barriers such as dams because they can dramatically alter the physical aspects of rivers, which in turn may cause large-scale changes in fish assemblages in these areas (Postel 1998). Rivers rich in native species are often replaced after dam building by introduced fishes that come to dominate the community composition (e.g., Martinez et al.1994, Holmquist et al. 1998).

Sleepers (family Eleotridae) are a group of euryhaline fishes found in tropical coastal areas throughout the world (Dickson et al. 1998), and should be sensitive to dam construction because many sleeper species often use streams as migration pathways. One poorly-known species of eleotrid, the bigmouth sleeper *Gobiomorus dormitor* (Figure 1), inhabits tropical and subtropical coastal freshwater streams in the Caribbean islands, southeastern Florida, southern Texas, and south along the Atlantic slope of Central and northern South America (Gilmore 1992). Bigmouth sleepers have suffered detrimental effects of dams in many places, such as Florida (Gilmore 1992) and Puerto Rico (Holmquist et al. 1998); declines in abundance or local extirpations of bigmouth sleepers are a serious conservation problem. In addition,

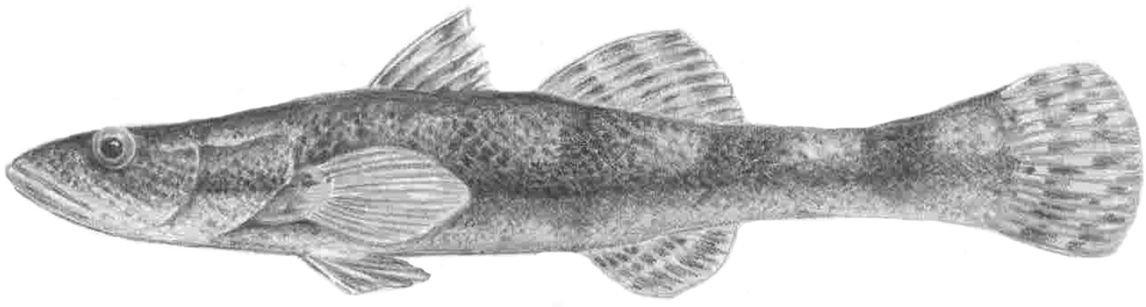

Figure 1. Adult bigmouth sleeper, *Gobiomorus dormitor*.

fishermen harvest bigmouth sleepers in many areas (e.g., Puerto Rico; Corujo 1989, Corujo 1999), so this species is also valuable in terms of recreation and food for local communities.

There is a paucity of data regarding the biology of eleotrids in general (Dickson et al. 1998) and bigmouth sleepers in particular (Winemiller and Ponwith 1998). Previous researchers (e.g., Darnell 1955, Nordlie 1981, Winemiller and Ponwith 1998) have recommended more research into this fish’s reproduction, ecology, and behavior. The ecology of bigmouth sleepers must be clearly understood if management and conservation plans are to be successful.

Very little published information regarding the ecology of bigmouth sleepers exists, but those studies that have documented habits of this species vary widely with regard to migration pattern, diet, and life history. For instance, early researchers in Panama noted that sleepers were commonly found in brackish and freshwater lowland streams and should therefore be considered euryhaline (Hildebrand 1938, Gunter 1942, 1956). Later research in Mexico and Costa Rica found that bigmouth sleepers are catadromous; they live in rivers but migrate to downstream brackish waters and lagoons for reproductive purposes, and migrate back into rivers post-reproduction (Darnell 1962, Kelso 1965, Nordlie 1981, Winemiller and Ponwith 1998). Only two studies have examined bigmouth sleeper reproductive ecology and behavior by direct means (McKaye 1977, McKaye et al. 1979). Contrary to previous studies, these researchers found that bigmouth sleepers can reproduce in natural lakes and are not dependent upon brackish water for reproduction.

Bigmouth sleepers in Puerto Rico

The bigmouth sleeper is one of only five native fish species in Puerto Rico that rely upon freshwater streams for a large portion of their lives (Hildebrand 1935, Erdman 1976, 1984). No empirical data have been collected on the reproductive pattern and migration of bigmouth sleepers in Puerto Rico rivers. Erdman (1976, 1984) suggested that bigmouth sleepers are catadromous and spend most of their lives in fresh water, but migrate to the sea to spawn. More recent river work by Holmquist et al. (1998) indicates that salt water might be essential for the life cycle completion of most of the Puerto Rico riverine macrofauna.

Like in other parts of the bigmouth sleeper's range, the riverine ecosystems in Puerto Rico have suffered the consequences of human manipulation. Many of the island's rivers and streams are dammed for irrigation, hydroelectric, drinking water, and flood control purposes, and no rivers currently have working fish passage devices installed (Benstead et al. 1999). There are 22 major reservoirs with a surface area over 100 hectares in Puerto Rico, which are believed to be unsuitable habitat for native river fishes (Erdman 1984). After the construction of the first four dams on the island, only three species of native fishes (bigmouth sleeper *Gobiomorus dormitor*, mountain mullet *Agonostomus monticola*, and the river goby *Awaous tajasica*) were able to enter these reservoirs, but none was able to establish reproducing populations (Erdman 1984). The occasional occurrence of adult native fauna in man-made lakes lacking spillway discharge on the island has been attributed to input of juveniles into the reservoirs by fishermen rather than by larval survival in freshwater (Holmquist et al. 1998).

Surveys of Puerto Rico reservoirs

Recent creel and gillnet surveys conducted by the Puerto Rico Department of Natural Resources have occasionally documented the presence of bigmouth sleepers in reservoirs in Puerto Rico (e.g., Rivera 1976, Corujo 1989). Furthermore, islandwide reservoir electrofishing for the Puerto Rico Department of Natural and Environmental Resources between 1992 and 2001 revealed bigmouth sleepers in four reservoirs in Puerto Rico (Churchill et al. 1995, Neal et al. 1999, Neal et al. 2001). Virtually nothing is known about the migration patterns, population size, habitat preferences, and life history characteristics of bigmouth sleepers in these novel systems. If successful reproduction and recruitment by bigmouth sleepers is possible in reservoirs or rivers without need for seaward reproductive migration, it would have enormous implications for managing the species for recreational purposes, and also for the implementation of successful conservation measures in areas where bigmouth sleepers are threatened or extirpated.

Comprehensive electrofishing by personnel of North Carolina State University (Churchill et al. 1995, Neal et al. 1999) revealed apparent bigmouth sleeper populations in some reservoirs in Puerto Rico. In these studies, 13 major reservoirs in Puerto Rico were electroshocked at least one time between 1992 and 2001. Before 1996, bigmouth sleepers were present in 4 reservoirs: Carite, Patillas, Guajataca, and Lucchetti (Table 1). After 1996, however, bigmouth sleepers were found in only two reservoirs, Carite and Patillas, and appear to have disappeared completely from Lucchetti and Guajataca Reservoirs. Carite Reservoir had by far the highest bigmouth sleeper catch-per-unit effort (CPUE; here, number of fish electroshocked per 1 hour

Table 1. Catch-per-unit-effort (fish/hour) and sizes of bigmouth sleepers from electrofishing samples in Puerto Rico reservoirs, 1992-2001 (from Churchill et al. 1995, Neal et al. 1999, Neal et al. 2001).

Reservoir	Fish/hour	Size
Carite	21.96	25 – 400 mm
Patillas	0.80	> 450 mm
Lucchetti (pre-1995)	Rare	320 – 560 mm
(post-1995)	0	-
Guajataca (pre-1996)	Rare	Juveniles and Adults
(post-1996)	0	-
All other PR reservoirs	0	-

shocking time), 21.96, while Patillas CPUE was only 0.80. If fish were caught before 1996 in Lucchetti and Guajataca Reservoirs, it was only rarely (Churchill et al. 1995). In addition, bigmouth sleepers collected in Carite Reservoir consistently ranged in size from 25 to 400 mm TL, while only large (>300 mm TL) adults were collected in Patillas and Lucchetti Reservoirs. Juvenile bigmouth sleepers were rarely captured in Guajataca Reservoir prior to 1995, but disappeared from samples after that time (Ashe et al. 1998).

From 1999 to 2001, research was conducted at Carite Reservoir to investigate factors in sportfish productivity (Neal et al. 2001). Complementary to and in conjunction with research efforts of that project, I was able to periodically obtain data on a variety of aspects of bigmouth sleeper biology and ecology.

Project Goals

Abundance and size data indicated that Carite Reservoir is suitable habitat for bigmouth sleepers, and the presence of a diversity of size classes of sleepers suggests the occurrence of either successful reproduction in the reservoir or recruitment to the reservoir from an outside source. To evaluate the likelihood of each, and to learn more broadly about bigmouth sleeper ecology, this research was initiated in Carite Reservoir. Results of this research will give managers and conservationists a better understanding of bigmouth sleepers in Puerto Rico reservoirs, while also increasing our knowledge of this species in general.

This thesis is divided into three manuscripts. Chapter 2 describes basic but important population characteristics of bigmouth sleepers in Carite Reservoir:

population abundance, size structure, and length-weight relationships. Chapter 3 provides a quantitative description of the diet of bigmouth sleepers in Carite Reservoir, in particular the ontogenetic shift in prey utilization. Chapter 4 elucidates some reproductive characteristics of bigmouth sleepers important to fisheries managers, such as sexual dimorphism, reproductive seasonality, length-at-maturity, and fecundity. Discussion and synthesis of these dimensions of bigmouth sleeper biology, as well as direction for future research, are discussed in Chapter 5.

REFERENCES

Ashe, D.E., T.N. Churchill, R.L. Noble, and C.G. Lilyestrom. 1998. Temporal variability in the littoral fish community of a Puerto Rico reservoir. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 52.

Benstead, J.P., J.G. March, C.M. Pringle, and F.N. Scatena. 1999. Effects of a low-head dam and water abstraction on migratory tropical stream biota. Ecological Applications 9: 656-668.

Churchill, T.N., R.L. Noble, J.E. Gran, and A.R. Alicea. 1995. Largemouth bass recruitment in Lucchetti Reservoir. Final Report. Federal Aid in Sportfish Restoration Project F-16, Study 2. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1989. Reservoir sportfish survey. Annual Report. Federal Aid in Sportfish Restoration Project F-16, Study 1. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1999. Puerto Rico Freshwater Fisheries Investigations. Project F-16.11, Study 8: Toa Vaca, Carite, Patillas, Cidra, Guayo, and Guayabal reservoirs creel survey. Puerto Rico Department of Natural and Environmental Resources.

Darnell, R.M. 1955. Nocturnal terrestrial habits of the tropical gobioid fish *Gobiomorus dormitor*, with remarks on its ecology. Copeia 1955: 237-238.

Darnell, R.M. 1962. Fishes of the Rio Tamesi and related coastal lagoons in east-central Mexico. Publications of the Institute of Marine Sciences at the University of Texas 8: 299-365.

Dickson, H., H.D. Hoese, and R.H. Moore. 1998. Fishes of the Gulf of Mexico: Texas, Louisiana, and adjacent waters, second edition. Texas A&M Press, College Station, Texas.

Erdman, D.S. 1976. Spawning patterns of fishes from the northeastern Caribbean. Contr. Agro. Pesq. Puerto Rico Department of Agriculture 8: 1-36.

Erdman, D.S. 1984. Exotic fishes in Puerto Rico. Pages 162-176 *in* W.R. Courtenay, Jr., and J.R. Stauffer, Jr. Distribution, biology, and management of exotic fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Gilmore, R.G. 1992. Bigmouth sleeper, *Gobiomorus dormitor*. Pages 105-111 *in* C.R. Gilbert, editor. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, Florida.

Gunter, G. 1942. A list of the fishes of the mainland of North and Middle America recorded from both fresh water and sea water. American Midland Naturalist 28: 305-326.

Gunter, G. 1956. A revised list of euyhaline fishes of North and Middle America. American Midland Naturalist 56: 345-354.

Helfman, G.S., B.B. Collette, and D.E. Facey. 1997. The diversity of fishes. Blackwell Science, Malden, Massachusetts.

Hildebrand, S.F. 1935. An annotated list of fishes of the fresh waters of Puerto Rico. Copeia 1935: 49-56.

Hildebrand, S.F. 1938. A new catalog of the fresh water fishes of Panama. Field Museum of Natural History, Chicago, Zool. 22(4): 217-359.

Holmquist, J.G., J.M. Schmidt-Gengenbach, and B.B. Yoshioka. 1998. High dams and marine-freshwater linkages: effects on native and introduced fauna in the Caribbean. Conservation Biology 12: 621-630.

Kelso, D.P. 1965. A contribution to the ecology of a tropical estuary. Master's Thesis, University of Florida, Gainesville, Florida.

Martinez, P.J., T.E. Chart, M.A. Trammell, J.G. Wullschleger, and E.P. Bergersen. 1994. Fish species composition before and after construction of a main stem reservoir on the White River, Colorado. Environmental Biology of Fishes 40: 227-239.

McKaye, K.R. 1977. Competition for breeding sites between the cichlid fishes of Lake Jiloa, Nicaragua. Ecology 58: 291-302.

McKaye, K.R., D.J. Weiland, and T.M. Lim. 1979. Comments on the breeding biology of *Gobiomorus dormitor* (Osteichthyes: Eleotridae) and the advantage of schooling behavior to its fry. Copeia 1979: 542-544.

Neal, J.W., R.L. Noble, N.M. Bacheler, M. McGee, and C.G. Lilyestrom. 2001. Freshwater sportfish community investigation and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Neal, J.W., R.L. Noble, C.G. Lilyestrom, T.N. Churchill, A.R. Alicea, D.E. Ashe, F.M. Holliman, and D.S. Waters. 1999. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. Journal of Fish Biology 18: 97-110.

Postel, S.L. 1998. Water for food production: Will there be enough in 2025? BioScience 48: 629-637.

Rivera-Gonzales, J. 1976. Relationship between the population dynamics and environmental water quality data of four fisheries in Puerto Rico. Dingell-Johnson Project F-4-10 Final Report. Puerto Rico Department of Natural and Environmental Resources.

Rosenberg, D.M., P. McCully, and C.M Pringle. 2000. Global-scale environmental effects of hydrological alterations: introduction. BioScience 50: 746-751.

Winemiller, K.O., and B.J. Ponwith. 1998. Comparative ecology of eleotrid fishes in Central American coastal streams. Environmental Biology of Fishes 53: 373-384.

CHAPTER 2

POPULATION BIOLOGY

INTRODUCTION

The sleepers (family Eleotridae) are a group of diadromous euryhaline fishes found in tropical coastal habitats throughout the world (Dickson et al. 1998). Despite the well-documented life histories of diadromous fishes in temperate regions, the life history of tropical diadromous fishes (e.g., sleepers) have received little attention (Winemiller and Ponwith 1998). One species of eleotrid, the bigmouth sleeper *Gobiomorus dormitor,* is a riverine species found throughout the Caribbean, southeastern Florida, southern Texas, and south along the Atlantic slope of Central and northern South America (Lindquist 1980, Gilmore 1992) (Figure 1). This species is important in terms of recreation and conservation. Bigmouth sleepers are harvested by anglers in parts of their range (Corujo 1989, Corujo 1999), while in Florida hydrological changes, habitat loss, and reduced water quality have reduced the species' already small geographical distribution, necessitating conservation measures (Gilmore 1992, Musick et al. 2000). Accurate knowledge of this species' ecology and behavior is crucial to effective conservation and management plans.

The literature regarding bigmouth sleeper reproduction is sparse and conflicting, yet has large conservation and management implications. Early studies in Panama and Mexico noted that sleepers were commonly found in brackish and freshwater lowland streams and should therefore be considered euryhaline (Hildebrand 1938, Gunter 1942, 1956). Later research in Mexico and Costa Rica found that bigmouth sleepers are catadromous; they live in rivers but migrate to downstream brackish waters and lagoons for reproductive purposes, and migrate back into rivers post-reproduction (Darnell 1962, Kelso 1965, Nordlie 1981, Winemiller and Ponwith

Figure 1. Distribution of bigmouth sleepers, *Gobiomorus dormitor* (from Gilmore 1992).

1998). Only two studies, in Lake Jiloa, Nicaragua, have examined reproductive ecology and behavior of bigmouth sleepers directly (McKaye 1977, McKaye et al. 1979). Contrary to the previous studies on bigmouth sleeper reproduction, McKaye and coworkers found that bigmouth sleepers can reproduce in natural lakes and are not dependent upon seawater for reproduction.

In Puerto Rico, bigmouth sleepers are one of only five native freshwater fishes (Hildebrand 1935), all of which are riverine and thought to be diadromous (Erdman 1976, 1984, Holmquist et al. 1998). Thus, the Puerto Rico freshwater fishes, including the bigmouth sleeper, would seem to require unimpeded migration pathways between the river and the sea for successful reproduction.

Many of the island's rivers and streams are dammed for irrigation, hydroelectric production, drinking water, and flood control purposes, and none of these have fish passage devices (Holmquist et al. 1998). There are 22 major reservoirs of Puerto Rico over 100 hectares in surface area, all of which are believed to be unsuitable environment for native river fishes (Erdman 1984). After the construction of the first four dams on the island, only three species of native fishes, the bigmouth sleeper *Gobiomorus dormitor*, mountain mullet *Agonostomus monticola*, and river goby *Awaous tajasica*, were reported as able to enter reservoirs, but none established reproducing populations (Erdman 1984). Holmquist et al. (1998) noted that all native freshwater fish species of Puerto Rico are obligated to access ocean water from rivers for reproduction. The occasional reports of native stream fishes in man-made lakes lacking fish passage devices in Puerto Rico are probably better explained by the input of juveniles into the reservoirs by fishermen than by larvae being produced and surviving in freshwater (Holmquist et al. 1998). If successful reproduction by bigmouth sleepers is possible in reservoirs without need to migrate to the sea, it would have implications for both the management of the species for recreational angling, and also for the implementation of successful conservation measures elsewhere in areas where bigmouth sleepers are threatened or extirpated.

Bigmouth sleepers have occasionally been recorded in creel and gillnet surveys of Puerto Rico reservoirs (e.g., Rivera 1976, Corujo 1989). Islandwide reservoir electrofishing for the Puerto Rico Department of Natural and Environmental Resources (Churchill et al. 1995, Neal et al. 1999, Neal et al. 2001) between 1992 and 2001 revealed bigmouth sleepers in four reservoirs in Puerto Rico. There are no published reports besides these that have recorded bigmouth sleepers upstream of a dam. Each of the reservoirs sampled by electrofishing had low bigmouth sleeper catch rates, except Carite Reservoir. Since Carite Reservoir is the first known abundant population of bigmouth sleepers above a dam, there is a complete lack of knowledge regarding all aspects of this species' biology in this type of environment. It was unknown if bigmouth sleepers were somehow escaping the reservoir for reproductive purposes, or whether bigmouth sleepers are in some situations opportunistic and able to survive and reproduce in lacustrine environments.

The unusually large population of bigmouth sleepers in Carite Reservoir prompted a closer look at the population characteristics in this novel and unique type of lacustrine environment. In this chapter, I examine several important and useful parameters of bigmouth sleeper population biology in Carite Reservoir: the population size and structure, growth rates, tag retention rates, and length-weight relationship.

Whereas bigmouth sleepers are popular sport fish, insight into the biological mechanisms that allow for successful survival and possible reproduction in reservoirs could hold a key for managing this species for recreational fishing. Also, further biological information could give conservation biologists the tools to predict the persistence or extinction probabilities for this species in areas where it is vulnerable.

STUDY SITE

Bigmouth sleepers were investigated from January 2000 to June 2001 in Carite Reservoir, a 124-hectare impoundment located near the town of Cayey, in mountainous south-central Puerto Rico (Figure 2). The reservoir is situated at 18°04’N and 66°05’W at an elevation of 543.6 m above sea level. Annual rainfall in the region is 210 cm, and the average temperature is 23.5°C (Carvajal-Zamora 1979). Carite Reservoir was impounded in 1913 by construction of an earthen dam on the La Plata River (Erdman 1984). It is one of the oldest reservoirs in Puerto Rico, built primarily for irrigation of sugar cane (Erdman 1984.) Today the reservoir provides water and electricity to meet the demands for domestic, industrial and agricultural purposes in the area. The Carite Reservoir drainage area is 21.2 km^2 and is comprised mainly of forest (Carvajal-Zamora 1979). Carite Reservoir is one of the least productive reservoirs in Puerto Rico (Carvajal-Zamora 1979), and as a result, catch rates of all fishes in the past have been consistently low (Neal et al. 2001). The water level fluctuated 4 m during this study (Figure 3), which is far less than the extreme fluctuations observed in other reservoirs on the island (e.g., up to 17 m annually in Lucchetti Reservoir; Neal et al. 1999). Maximum depth in Carite Reservoir is 19.5 m,

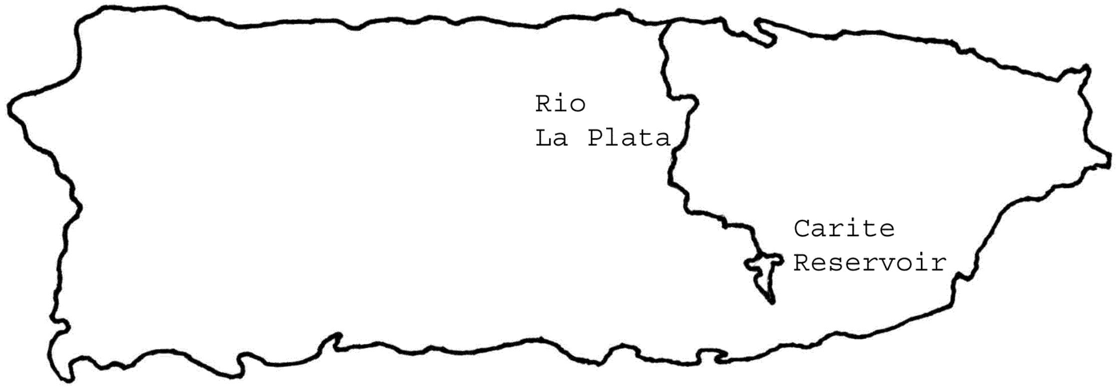

Figure 2. Map of Puerto Rico showing Carite Reservoir and the Rio de La Plata.

Figure 3. Water level (in m above sea level) observed in Carite Reservoir from January 2000 to June 2001. Data courtesy of the United States Geological Survey.

and average depth is 10 m at full pool (Carvajal-Zamora 1979). Water quality was assessed monthly between March and June 2001 (Table 1). Surface measurements were taken during daylight hours at one site near the dam. Also, water temperature and dissolved oxygen profiles were taken from the same site as above on 6 April 2001 (Table 2).

METHODS

Population Structure and Size

A Lincoln-Petersen population estimate with the Chapman's modification was used to estimate adult (> 200 mm TL) and total bigmouth sleeper population size in Puerto Rico reservoirs in the winters of 2000 and 2001. Fish were collected by boom electrofishing the entire shoreline, using 3 - 4 A and 60 pps DC, during both a marking and a recapture period. All fish were measured for total length (mm TL) during the marking and recapture period, and most fish (73%) were weighed to the nearest gram (g) during the marking period only. Bigmouth sleepers over 200 mm were marked with a pelvic fin clip, while individuals less than 200 mm received an anal fin clip. To differentiate between years, left pelvic fin clips were used in 2000 and right clips were used in 2001. Recapture efforts were made approximately 4 weeks following the marking period. Using the number of individuals in 10-mm length intervals, a length frequency distribution for bigmouth sleepers was created for each of the four collection periods.

Table 1. Water chemistry in Carite Reservoir, Puerto Rico. Measurements were taken at the surface of the water near the dam during daylight hours.

Date	**03/01/01**	**04/06/01**	**05/05/01**	**6/14/01**	**MEAN**
pH	7.5	8.7	8.3	8.8	8.3
Alkalinity (ppm)	85	70	110	75	85
Conductivity ($mS.m^{-1}$)	80	90	80	70	80
Clarity (m)	1.9	2.1	0.9	1.2	1.5
Dissolved Oxygen (mg/L)	7.9	8.3	7.7	8.6	8.1
Temperature (°C)	23.2	26.0	25.6	28.0	25.7

Table 2. Water temperature and dissolved oxygen profile for Carite Reservoir, Puerto Rico, taken near the dam on 6 April 2001.

Depth (ft)	**Temperature**	**Dissolved O_2 (mg/L)**
0	26.0	8.3
2.5	25.9	8.5
5.0	25.9	8.5
7.5	25.8	8.5
10.0	25.7	8.5
12.5	25.7	8.3
15.0	25.4	5.8
17.5	24.1	5.0
20.0	24.0	2.3
22.5	23.2	1.5
25.0	22.9	0.6
27.5	22.8	0.4
30.0	22.8	0.4
32.5	22.7	0.3
35.0	22.6	0.2
37.5	22.6	0.2
40.0	22.6	0.2

Growth

During the marking period (January) of 2000, all bigmouth sleepers captured longer than 150 mm TL were also tagged with an individually-numbered anchor tag. Individuals 150 – 200 mm TL were tagged with FF-94 Fine Fabric Anchor Tags (Floy Tag & Manufacturing, Inc., Seattle, Washington) using a Dennison #10312 Mark II Fine Fabric Tagging Gun (Avery Dennison, Framingham, Massachussets). Sleepers longer than 200 mm TL were tagged with FD-94 Floy Anchor Tags using a Dennison #08945 Mark II Regular Tagging Gun. Tagging procedures followed those described by Dell (1968) and Wydoski and Emery (1983). Each anchor tag was inserted at a 45-degree angle under the dorsal fin, penetrating far enough into the fish that the T-bar interlocked with the skeleton. Each tagged fish greater than 200 mm TL during the marking period was given a left pelvic fin clip, and individuals 150 – 200 mm TL were given an anal fin clip, so an estimation of a tag retention rate was possible. Tagged fish were recaptured during the recapture period (after 4 weeks) and at various other times throughout the year. Each tagged fish recaptured was again measured and weighed, allowing for calculation of growth rates.

Length-Weight Relationship

Most fish (73%) caught during the marking period in 2000 and 2001 were weighed, so a length-weight relationship was created based on these fish. The length-weight relationship was developed in the form $\log_{10} W = \log_{10} a + (b * \log_{10} TL)$, in which W = wet weight in g and TL = total length in mm.

Statistical Analyses

All analyses were performed using parametric statistics. Significance was accepted at the $\propto \leq 0.05$ level.

RESULTS

Population Structure and Size

The four primary sampling efforts totaled 65.1 hours of electrofishing and produced 907 bigmouth sleepers. Range of bigmouth sleepers captured was 33 – 399 mm TL in 2000 and 35 – 385 mm TL in 2001 (Figure 4). Most fish captured in 2000 were between 240 – 360 mm TL, while in 2001 the majority of fish captured were between 80 – 180 mm TL. Distinct cohorts appear to exist in the length-frequency distribution of the 2001 samples, unlike the 2000 sample where distinct cohorts are less apparent.

Total and adult (> 200 mm TL only) population size of bigmouth sleepers in Carite Reservoir was estimated in the winter of 2000 and again in the winter of 2001 (Table 3). Overall, total population size was estimated at 1,783 (± 921) individuals in 2000 and 3,353 (± 1,788) in the following year, 2001. No statistically significant difference was detected between years (Standard Normal Test: $Z = -0.78$; $p > 0.05$). Adult (>200 mm TL) bigmouth sleeper population size was 1,405 (± 795), and 1,349 (± 769) in 2000 and 2001, respectively. Adult populations were not significantly different in the two years (Standard Normal Test: $Z = 0.05$; $p>0.05$).

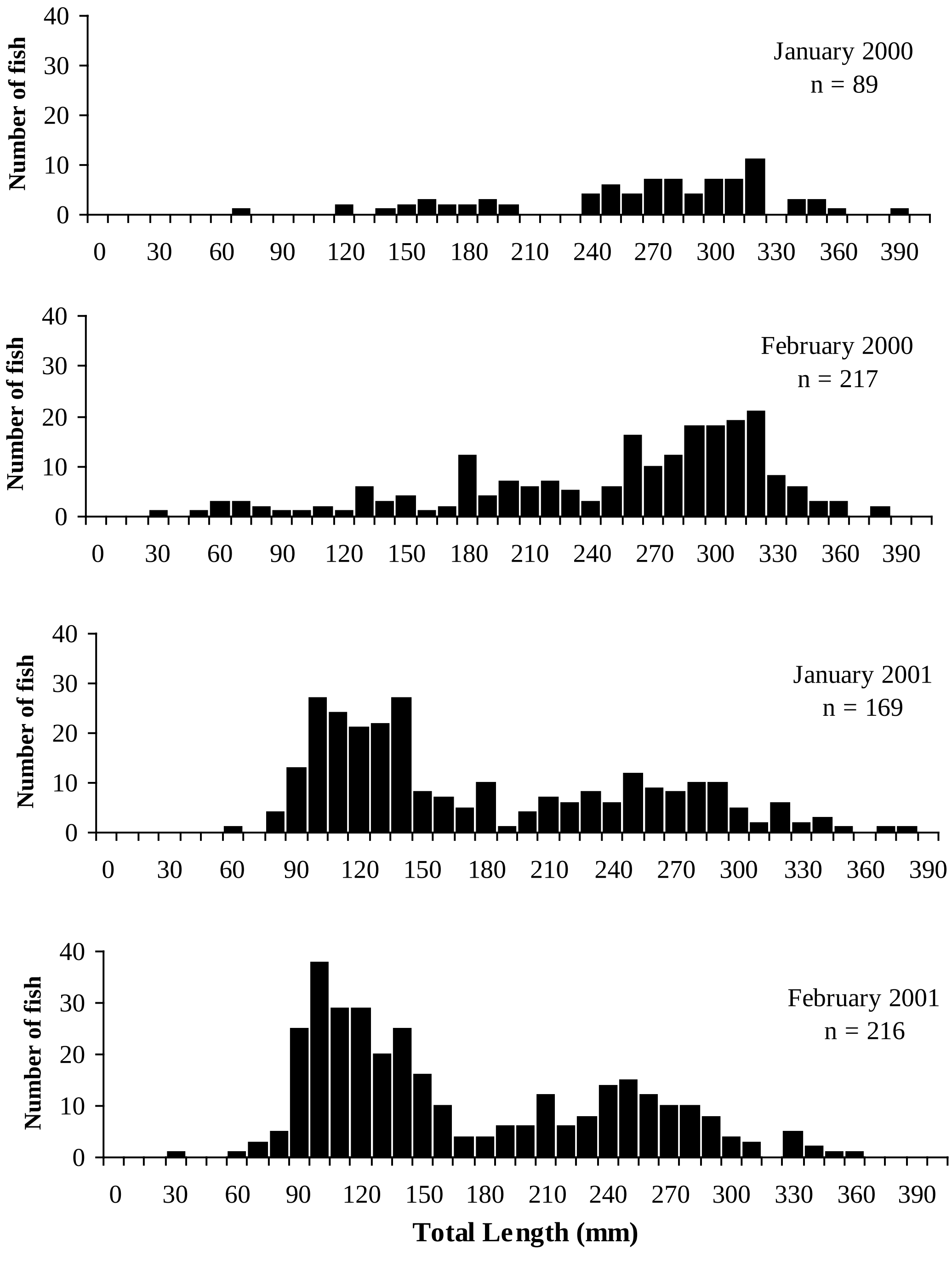

Figure 4. Length frequencies of bigmouth sleepers in Carite Reservoir captured during the marking and recapture periods of 2000 and 2001.

Table 3. Population estimates for bigmouth sleepers in Carite Reservoir in 2000 and 2001.

Date	Population	Marked	Captured	Recaptured	Pop. Size	95% CI
2000	All Fish	89	217	10	1,783	± 921
2000	Adults Only	73	170	8	1,405	± 795
2001	All Fish	169	216	10	3,353	± 1,788
2001	Adults Only	102	117	8	1,349	± 769

Growth

Of the 86 bigmouth sleepers (range = 158-399 mm TL; mean = 277.4 mm TL) tagged in January 2000, 14 tagged fish were recaptured (range = 180-366 mm TL; mean = 282.0 mm TL). These fish were at large for 25 to 167 days (mean = 50.2 days). Individual daily growth rate ranged from –0.08 to 0.10 mm/day. Growth rate was negatively correlated with length of fish at marking ($p = 0.027$; Figure 5); i.e., larger fish grew more slowly over the study period than smaller fish. Growth rate was not correlated with days at large ($p = 0.97$; Figure 6). Due to the size-specific growth rates observed, growth rates were calculated for three size classes of bigmouth sleepers. Fish 100 - 199 mm TL had the highest daily growth rate (mean = 0.07 mm/day, sd = 0.051), which was followed by fish 200 - 299 mm TL (mean = 0.03, sd = 0.022), and fish larger than 299 mm TL (mean = -0.01, sd = 0.039) (Figure 7).

The low growth rate observed from tagging data corresponded with change in the length-frequency distribution data. In 2001, when samples produced well-defined subcohorts, size distributions changed negligibly between the marking and recapture periods, a time period of approximately 28 days. This also suggests very low individual growth rates during this time period.

In addition to the 14 tagged fish that were recaptured, three marked fish were recaptured missing a tag. The tag retention rate was dependent upon the number of days the fish was at large in the reservoir (Figure 8). All fish recaptured up to 3 months after tagging lost no tags (n = 12), while only one fish had lost its tag between 3-12 months after tagging (n = 3). Both fish recaptured 12 months after tagging had lost their tags.

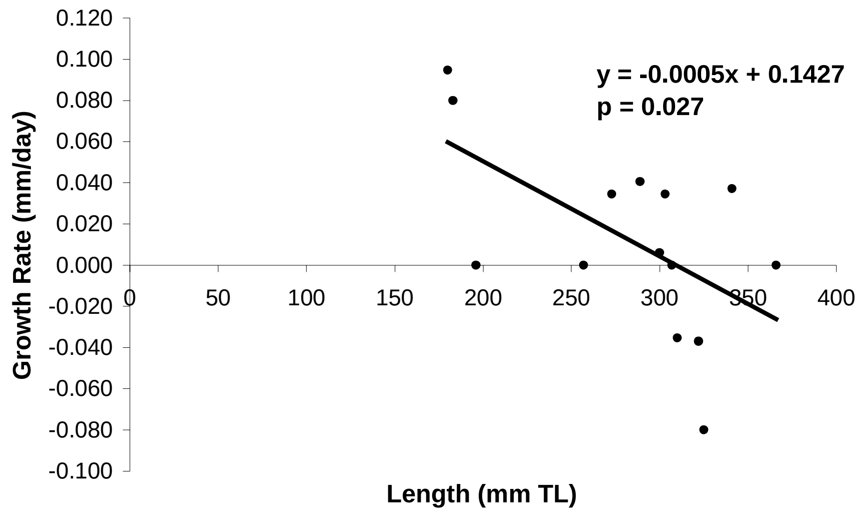

Figure 5. Relationship between daily growth rate and total length at marking of bigmouth sleepers in Carite Reservoir, 2000.

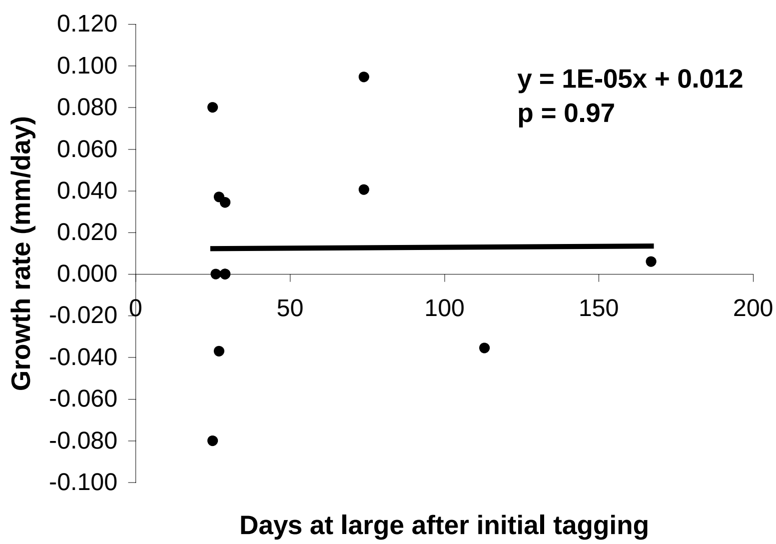

Figure 6. Relationship between daily growth rate and the number of days at large after the initial tagging of bigmouth sleepers in Carite Reservoir in 2000.

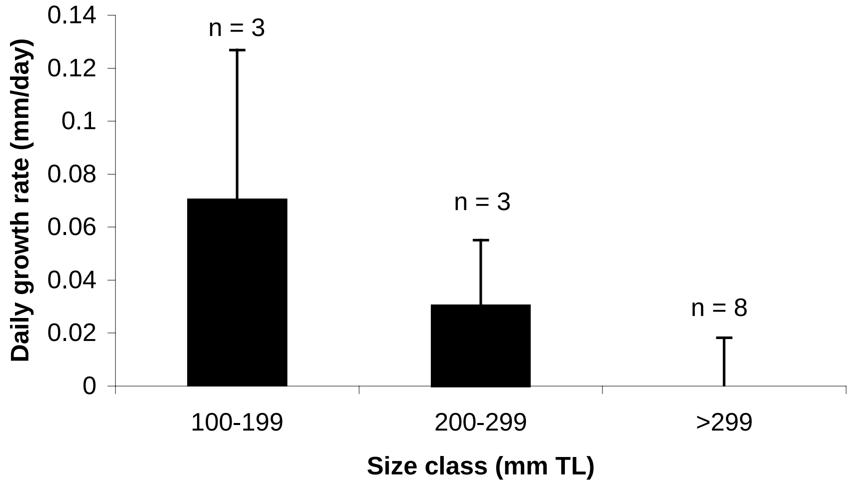

Figure 7. Daily growth rate observed by different size classes of bigmouth sleepers in Carite Reservoir in 2000. Error bars signify the 95% confidence intervals.

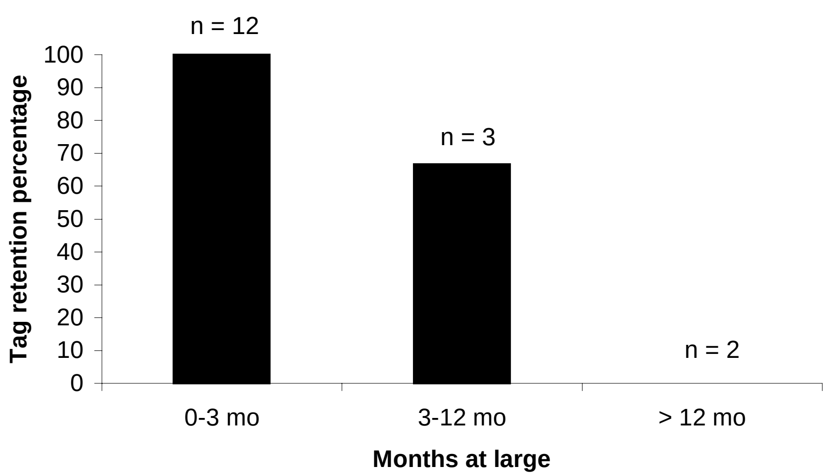

Figure 8. Anchor tag retention by bigmouth sleepers in Carite Reservoir with dorsally-located anchor Floy tags, 2000.

Tag retention rate was significantly different (Difference of Proportions Test: $Z = 2.07$, $p < 0.05$) between 0 - 3 months and 3 - 12 months at large, and also significantly different (Difference of Proportions Test: $Z = 3.74$, $p < 0.05$) between 0 - 3 months and greater than 12 months at large. No significant difference was observed in the tag retention rate between fish at large 3 - 12 months and those at large greater than 12 months (Difference of Proportions Test: $Z = 1.49$; $p > 0.05$).

Length-weight relationship

A total of 188 fish were collected, measured, and weighed during the population marking periods in the winters of 2000 and 2001 in Carite Reservoir. A pooled length-weight relationship was constructed based on these fish (Figure 9). The equation for the length-weight relationship was $y = 2.88\,x – 4.86$, and the $r^2 = 0.980$.

DISCUSSION

Bigmouth sleepers of varying sizes were collected in Carite Reservoir between 1999 and 2001, ranging from 33 to 399 mm TL. It appears that small bigmouth sleepers are rare in Carite Reservoir when boom electrofishing gear is the only sampling technique used. Boom electrofishing, however, has been shown to have an inherent size selectivity bias towards larger fish (Jackson and Noble 1995). A handheld electrofishing unit was used periodically in Carite Reservoir between 1999 and 2001 to accomplish other project objectives, and juvenile bigmouth sleepers were frequently found in these samples, often as small as 25 mm TL. Whereas most

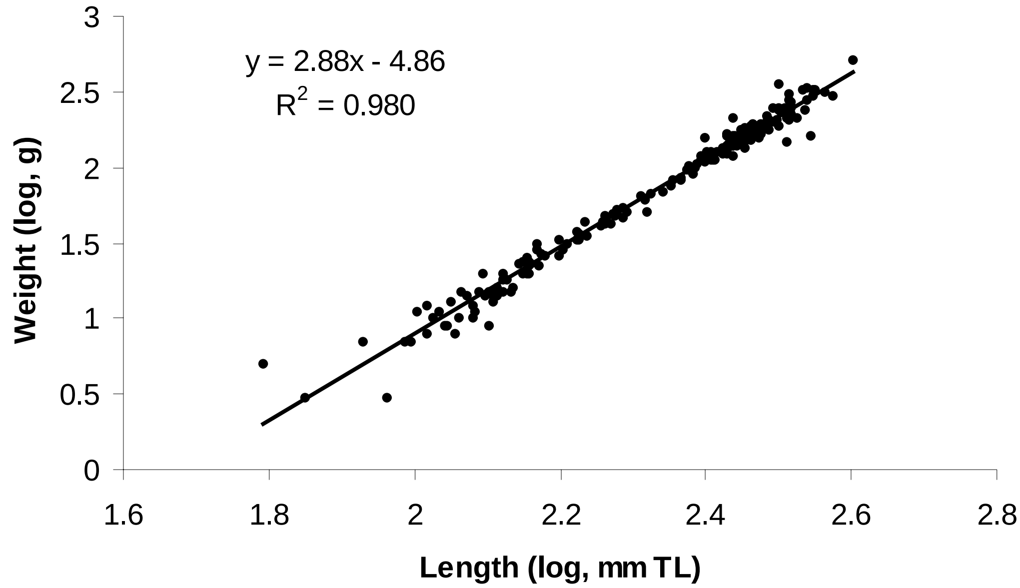

Figure 9. Length-weight relationship of bigmouth sleeper *Gobiomorus dormitor*, based on a total of 188 fish collected in the winters of 2000 and 2001 in Carite Reservoir.

bigmouth sleepers collected in 2000 were large fish (240 – 360 mm TL), most fish collected in 2001 were between 80 – 180 mm TL. This suggests that either the collection technique improved for small fish between years or that more small fish were present in Carite Reservoir in 2001.

The intent of the population estimates was to acquire an estimate of the population size of bigmouth sleepers in Carite Reservoir, and in this regard the population estimates were successful. Close agreement occurred between estimates of adult bigmouth sleepers in the 2 years, and the higher total estimate in 2001, was consistent with the larger numbers of small fish in 2001. Confidence intervals around the population estimates for bigmouth sleepers in Carite Reservoir in this study were very large. Inefficient capturing methods that prevented the capture of a sufficiently large proportion of the population, complemented by high water levels and associated inundated cover, were the primary causes. The population size of bigmouth sleepers in Carite Reservoir is large and possibly larger than the populations of largemouth bass or peacock bass, the two other primary piscivores in the lake (Neal et al. 2001). However, total adult bigmouth sleeper biomass in 2001 was only 186 kg or 1.5 kg/ha, compared to 3.18 kg/ha for largemouth bass (Neal et al. 2001).

The recovery of only 14 tagged fish limited the precision of the growth estimates from tagging in this study. It does appear, however, that the daily growth rate is extremely low compared to other species of fishes in the Puerto Rico (e.g., largemouth bass; Neal et al. 1999). Low productivity in Carite Reservoir may limit bigmouth sleeper growth. Also, these estimates are based solely on winter and spring growth (≤ 167 tags at large), so they may represent average growth characteristics of these seasons. Seasonal growth patterns of bigmouth sleepers could be a factor in the observed growth rates; e.g., energy may be used in gonadal growth for reproductive purposes during winter and spring instead of using it for somatic growth, and rapid growth could occur late in the year. Alternatively, bigmouth sleeper growth may occur in spurts following the reproductive periods of other fishes as prey would become temporarily abundant. Whereas bigmouth sleepers lost tags in this study when at large longer than 6 months, further tag retention studies on bigmouth sleepers should evaluate tagging methods and areas of the fish to be used for tagging. Increased duration of tag retention would improve future studies on seasonal growth patterns of bigmouth sleepers.

Bigmouth sleepers can complete their life cycle when restricted to fresh water in Lake Jiloa, Nicaragua (McKaye 1977, McKaye et al. 1979), yet appear to be catadromous in river-lagoon systems (Kelso 1965, Nordlie 1981, Winemiller and Ponwith 1998). Only in Puerto Rico, though, have bigmouth sleepers been reported to inhabit man-made reservoirs, but this phenomenon likely occurs elsewhere given the opportunistic nature of the species (Nordlie 1981).

The evidence suggesting that bigmouth sleepers reproduced in Carite Reservoir in Puerto Rico is extensive. First, bigmouth sleepers have been reported in Carite Reservoir since it was first studied in 1976 (Rivera 1976), but they likely occurred there much earlier, possibly since the reservoir's construction in 1913. Second, islandwide electrofishing efforts during the 1990's have continuously produced a wide range of sizes of bigmouth sleeper in Carite Reservoir, often less than 30 mm TL. Only larval fish have not been collected, but electrofishing biases towards larger individuals, and no larval collection techniques were employed. Third, the dam impounding Carite Reservoir is a large earthen type, and its spillway rarely overflows as high water extraction rates for drinking water in nearby areas occur. Downstream migration may occur during rare large rainstorms, but upstream migration into the lake over the dam would seem to be impossible for any bigmouth sleeper. There are also three dams downstream from Carite Reservoir, two 10 m in height and one 40 m in height (Holmquist et al. 1998), that fish would need to migrate past to reach Carite Reservoir from the ocean. No bigmouth sleepers have been collected in La Plata Reservoir, the first major obstacle to upstream migration on the La Plata River system (Neal et al. 1999, Neal et al. 2001). Though researchers have found bigmouth sleepers in terrestrial situations, never was any fish observed more than a few feet from the water's edge (Darnell 1955, Kelso 1965). Migration over land by bigmouth sleepers should not be considered a plausible explanation for the presence of this species in Carite Reservoir. Furthermore, downstream portions of the Rio de La Plata were electrofished in the spring of 2001, and these efforts produced no bigmouth sleepers, but introduced fishes (e.g., Mozambique tilapia *Oreochromis mossambica* and redbreast sunfish *Lepomis auritus*) were abundant. It is improbable that bigmouth sleepers in Carite Reservoir are completing their life cycles by migrating downstream for reproductive purposes and then back up into Carite Reservoir.

An alternative hypothesis is that bigmouth sleepers are reproducing in rivers, but instead of migrating downstream they migrate upstream out of Carite Reservoir. Carite Reservoir is a tropical headwater reservoir, and, characteristic of these types of reservoirs, Carite Reservoir has a few rivulets draining into it that are small and ephemeral. Though flow into Carite Reservoir surely does occur, not once during the spring of 2001 was water observed draining into Carite Reservoir from these ephemeral rivers. Water level data reveal a constant decrease during the spring and summer (see Figure 3), the time of year when bigmouth sleepers should be reproducing (McKaye 1977). Large rainstorms are likely necessary for the rivulets to flow, but if flow occurred it would be in short, pulsed events of less than 2 days in duration and therefore not conducive for bigmouth sleeper reproduction. Bigmouth sleepers are a biparental, guarding fish species, and the time needed for courting, egg laying, and guarding is at least 4 days (McKaye et al. 1979). Furthermore, reproduction has never been found to occur in rivers. No tributary flowing into Carite Reservoir should be considered suitable bigmouth sleeper reproductive habitat.

The evidence points to Carite Reservoir as being the primary spawning habitat used by bigmouth sleepers in this study. Bigmouth sleepers can reproduce in fresh water (McKaye 1977, McKaye et al. 1979) and appear to be flexible in the types of environments used for reproduction. No other hypotheses, such as birds or fishermen stocking this species into the reservoir, can account for the large population sizes observed in Carite Reservoir during this study.

Reservoir reproduction by bigmouth sleepers does not seem to be widespread, however. Three other reservoirs in Puerto Rico contained bigmouth sleepers in the early 1990's, but the species was extirpated from Lucchetti and Guajataca Reservoirs in the mid-1990's and has not been found since. Patillas Reservoir only contained one large adult in 2000, so these few remaining fish may also disappear soon. The reasons why Carite Reservoir is suitable bigmouth sleeper habitat, while all other reservoirs in

Puerto Rico are not, deserves research attention. Factors such as biotic interactions, available habitat, or other abiotic conditions could all be important to bigmouth sleeper reproduction and survival. If important factors could be identified that would enhance bigmouth sleeper survival and reproduction, managers could use this information to manage other reservoirs in Puerto Rico for native bigmouth sleepers. Radio telemetry could further explanations for bigmouth sleeper population sustainability in reservoirs, but bigmouth sleepers have been found to lose implanted transmitters (Appendix A). Information presented here will assist managers and conservationists in enhancing bigmouth sleeper populations in Puerto Rico and elsewhere.

REFERENCES

Carvajal-Zamora, J.R. 1979. Ecological survey of lakes. Final Report. Project F-4, Study 11. Puerto Rico Department of Natural and Environmental Resources, San Juan.

Churchill, T.N., R.L. Noble, J.E. Gran, and A.R. Alicea. 1995. Largemouth bass recruitment in Lucchetti Reservoir. Final Report. Federal Aid in Sportfish Restoration Project F-16, Study 2. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1989. Reservoir sportfish survey. Annual Report. Federal Aid in Sportfish Restoration Project F-16, Study 1. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1999. Puerto Rico Freshwater Fisheries Investigations. Project F-16.11, Study 8: Toa Vaca, Carite, Patillas, Cidra, Guayo, and Guayabal reservoirs creel survey. Puerto Rico Department of Natural and Environmental Resources.

Darnell, R.M. 1955. Nocturnal terrestrial habits of the tropical gobioid fish *Gobiomorus dormitor*, with remarks on its ecology. Copeia 1955: 237-238.

Darnell, R.M. 1962. Fishes of the Rio Tamesi and related coastal lagoons in east-central Mexico. Publications of the Institute of Marine Science of the University of Texas 8: 299-365.

Dell, M.B. 1968. A new fish tag and rapid, cartridge-fed applicator. Transactions of the American Fisheries Society 97: 57-59.

Dickson, H., H.D. Hoese, and R.H. Moore. 1998. Fishes of the Gulf of Mexico: Texas, Louisiana, and adjacent waters, second edition. Texas A&M Press, College Station, Texas.

Erdman, D.S. 1976. Spawning patterns of fishes from the northeastern Caribbean. Contr. Agro. Pesq. Puerto Rico Department of Agriculture 8: 1-36.

Erdman, D.S. 1984. Exotic fishes in Puerto Rico. Pages 162-176 *in* W.R. Courtenay, Jr., and J.R. Stauffer, Jr. Distribution, biology, and management of exotic fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Gilmore, R.G. 1992. Bigmouth sleeper, *Gobiomorus dormitor*. Pages 105-111 *in* C.R. Gilbert, editor. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, Florida.

Gunter, G. 1942. A list of the fishes of the mainland of North and Middle America recorded from both fresh water and sea water. American Midland Naturalist 28: 305-326.

Gunter, G. 1956. A revised list of euyhaline fishes of North and Middle America. American Midland Naturalist 56: 345-354.

Hildebrand, S.F. 1935. An annotated list of fishes of the fresh waters of Puerto Rico. Copeia 1935: 49-56.

Hildebrand, S.F. 1938. A new catalog of the fresh water fishes of Panama. Field Museum of Natural History, Chicago, Zool. 22(4): 217-359.

Holmquist, J.G., J.M. Schmidt-Gengenbach, and B.B. Yoshioka. 1998. High dams and marine-freshwater linkages: effects on native and introduced fauna in the Caribbean. Conservation Biology 12: 621-630.

Jackson, J.R., and R.L. Noble. 1995. Selectivity of sampling methods for juvenile largemouth bass in assessments of recruitment processes. North American Journal of Fisheries Management 15: 408-418.

Kelso, D.P. 1965. A contribution to the ecology of a tropical estuary. Master's Thesis, University of Florida, Gainesville, Florida.

Lindquist, D.G. 1980. Bigmouth sleeper, *Gobiomorus dormitor*. Page 784 *in* D.S. Lee, C.R. Gilbert, C.H. Holcutt, R.E. Jenkins, D.E. McAllister, J.R. Stauffer, Jr., editors. Atlas of North American Freshwater Fishes. NC State Museum of Natural History, Raleigh, NC.

McKaye, K.R. 1977. Competition for breeding sites between the cichlid fishes of Lake Jiloa, Nicaragua. Ecology 58: 291-302.

McKaye, K.R., D.J. Weiland, and T.M. Lim. 1979. Comments on the breeding biology of *Gobiomorus dormitor* (Osteichthyes: Eleotridae) and the advantage of schooling behavior to its fry. Copeia 1979: 542-544.

Musick, J.A. and seventeen coauthors. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25: 6-30.

Neal, J.W., R.L. Noble, N.M. Bacheler, M. McGee, and C.G. Lilyestrom. 2001. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Neal, J.W., R.L. Noble, C.G. Lilyestrom, T.N. Churchill, A.R. Alicea, D.E. Ashe, F.M. Holliman, and D.S. Waters. 1999. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. Journal of Fish Biology 18: 97-110.

Rivera-Gonzales, J. 1976. Relationship between the population dynamics and environmental water quality data of four fisheries in Puerto Rico. Dingell-Johnson Project F-4-10 Final Report. Puerto Rico Department of Natural and Environmental Resources.

Winemiller, K.O., and B.J. Ponwith. 1998. Comparative ecology of eleotrid fishes in Central American coastal streams. Environmental Biology of Fishes 53: 373-384.

Wydoski, R., and L. Emery. 1983. Tagging and marking. Pages 215-237 *in* L.A. Nielson and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, MD.

CHAPTER 3

DIET

INTRODUCTON

Eleotrids (family Eleotridae) are among the world's most widely distributed teleost fishes, found in oceanic, brackish fresh waters of tropical and subtropical regions of the world (Nelson 1976). Although frequently collected in scientific samples, little attention has been given to many aspects of their ecology.

One poorly-known species of eleotrid, the bigmouth sleeper *Gobiomorus dormitor*, is a riverine species found throughout the Caribbean, southeastern Florida, southern Texas, and the Atlantic slope of Central and northern South America (Lindquist 1980, Gilmore 1992). Bigmouth sleepers have been found in wide range of habitats, including rivers (Darnell 1962, Winemiller and Ponwith 1998, Holmquist et al. 1998), lagoons (Kelso 1965, Nordlie 1981), natural lakes (McKaye 1977, McKaye et al. 1979), and reservoirs (Rivera 1976, Corujo 1989, Churchill et al. 1995, Neal et al. 1999, Chapter 2). The few previous studies pertaining to the reproduction of this species suggest that they are catadromous or amphidromous in rivers (Darnell 1962, Kelso 1965, Nordlie 1981, Winemiller and Ponwith 1998). In some instances, however, they have been able to successfully reproduce in a natural lake in Nicaragua (McKaye 1977, McKaye et al. 1979) and in a reservoir in Puerto Rico (Chapter 2).

Feeding habit is one aspect of the biology of bigmouth sleepers for which little information exists. Hildebrand (1938) reported that bigmouth sleepers, "feed on crustaceans, fishes, water beetles and apparently any other aquatic animal life of suitable size." He further stated that, "they make quick excursions, if hunger prompts them, to seize almost any animal of suitable size that comes near."

Quantitative analysis of diet by Nordlie (1981), based on a sample of five fish, concluded that shrimps, and to a lesser extent fish, comprised the entire bigmouth sleeper diet in Tortuguero Lagoon in Costa Rica. Follow-up work by Winemiller and Ponwith (1998), sampling in Tortuguero Lagoon and its associated rivers, found that the breadth of diet of bigmouth sleepers was much wider than that reported by Nordlie (1981). Bigmouth sleepers preyed on items such as microcrustaceans, shrimps, aquatic insects, terrestrial arthropods, mollusks, worms, and at least four species of fish (Winemiller and Ponwith 1998). Darnell (1955) reported that, of seven bigmouth sleepers examined from a headwater stream in Mexico, three contained no food, two contained fish, one had aquatic insects, and one had a large tarantula and several unidentified arthropods. No information regarding the diet of bigmouth sleepers in natural lakes or reservoirs have been published.

Bigmouth sleepers have been occasionally been recorded in creel and gillnet surveys of Puerto Rico reservoirs (Rivera 1976, Corujo 1989), but diet has never been quantitatively assessed in these systems. The objective of this study, therefore, was to document the feeding habits of bigmouth sleepers in a Puerto Rico reservoir. This study complements and expands the small body of literature regarding the diet of bigmouth sleepers, and will provide useful information to managers in Puerto Rico or elsewhere who require these data to make informed management decisions.

STUDY SITE

Bigmouth sleepers were investigated from October 1999 to October 2001 in Carite Reservoir, a 124-hectare impoundment located near the town of Cayey, in mountainous south central Puerto Rico. Information regarding the physical characteristics of Carite Reservoir can be found in Chapter 2. Eleven species of exotic fishes besides the native bigmouth sleepers are regularly found in Carite Reservoir: largemouth bass *Micropterus salmoides*, peacock bass *Cichla occe1laris,* channel catfish *Ictalurus punctatus,* white catfish *Ameiurus catus,* redbreast tilapia *Oreochromis rendalli,* Mozambique tilapia *Oreochromis mossambica*, redbreast sunfish *Lepomis auritus*, bluegill *Lepomis macrochirus*, mosquitofish *Gambusia affinis*, threadfin shad *Dorosoma petenense,* and redear sunfish *Lepomis microlophus* (Neal et al. 1999). Other available prey in the lake consists of microcrustaceans, a freshwater crab *Epilobocera sinuatifrons*, and aquatic insects.

METHODS

Bigmouth sleepers were collected using two electrofishing methods. Larger fish were targeted using a boom-mounted electrofishing unit with 3 - 4 A and 60 pps DC employed for daytime sampling. In 1999 and 2000, all adult fish (≥ 200 mm TL) were collected, measured for total length (TL, mm), and weighed (g) in the field. Stomach samples from adult bigmouth sleepers were obtained using esophageal tubes (Van Den Avyle and Roussel 1980) and preserved in 70% ethanol prior to the release of the fish. In 2001, all fish were euthanized using an anesthetic (MS-222) overdose and kept on ice until processing the next day. Each fish was measured for total length (TL, mm) and weight to the nearest 0.01 g, and stomachs were dissected.

Over the period 27 October 1999 - 15 October 2000, juvenile fish were targeted using nighttime electrofishing efforts with a 260-volt DC delivered via hand held probe (Jackson and Noble 1995). All bigmouth sleepers were euthanized and retained on ice as detailed above. In the laboratory, each fish was measured for total length and weight to the nearest hundredth of a gram. Stomachs were dissected from all juvenile fish and preserved in 70% ethanol until stomach contents processing occurred.

Stomach samples from all adult and juvenile fish were processed within 2 days of collection. Contents were examined in the laboratory under a binocular microscope at 10X and identified to the lowest recognizable taxon. Results are presented as percent frequency of occurrence, i.e., the proportion of fish with food that contained a given prey.

RESULTS

Five hand held and 11 boom electrofishing efforts produced 61 and 269 bigmouth sleepers, respectively. Bigmouth sleepers ranged from 50 to 384 mm TL (Figure 1). More adults were collected than juveniles.

Overall, 74.5% of all bigmouth sleeper stomachs were empty. However, the percentage of empty stomachs differed by length class. Of all small fish (< 100 mm TL) examined, 17.4% had empty stomachs, while all length groups greater than 100 mm TL had a much higher frequency of empty stomachs (Figure 2).

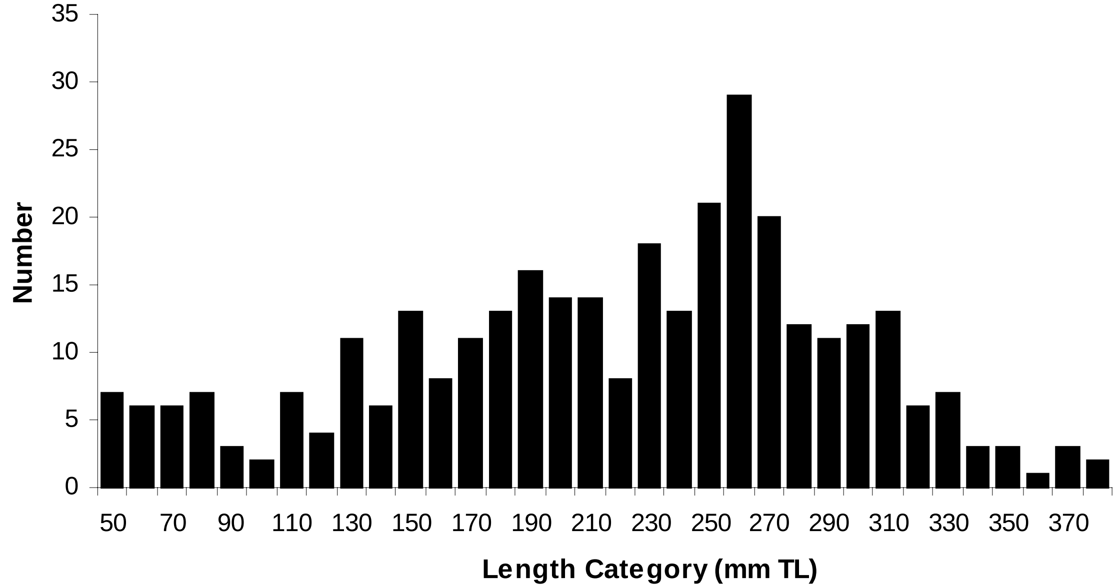

Figure 1. Length frequencies of bigmouth sleepers from Carite Reservoir examined in this study, 1999 - 2001.

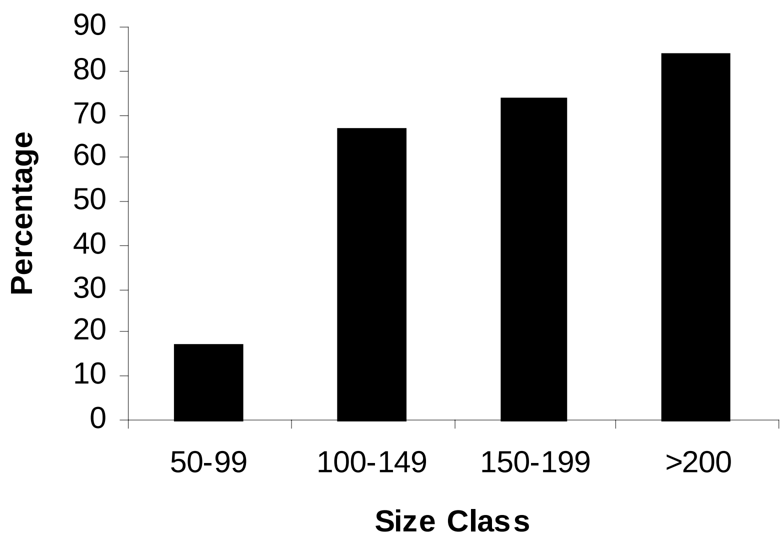

Figure 2. Percentage of empty stomachs for four size classes of bigmouth sleepers in Carite Reservoir, 1999 - 2001.

The frequency of occurrence of prey items also differed by length class, showing an ontogenetic shift in feeding ecology as fish grew (Figure 3). The degree of piscivory increased with size from 8.3% in small juveniles (50 – 100 mm TL), exceeding over 60% for all larger fish. Insects were the most common prey type for small juveniles (96%), but the frequency of insects decreased as size increased. Crabs were not observed in the stomachs of fish less than 150 mm TL, but were occasionally observed in the stomachs of fish between 150 and 200 mm TL (6.3%) and became frequent in fish greater than 200 mm TL (26.5%). Ostracods were consumed by smaller fish (< 150 mm TL) but not by larger ones.

The average weight of prey items found in the stomachs of bigmouth sleepers increased as length of bigmouth sleepers increased (Figure 4). The average weight of prey items for bigmouth sleepers 50 – 99 mm TL was 0.04 g, but increased to 3.73 g for bigmouth sleepers greater than 200 mm TL. In other words, small bigmouth sleepers fed primarily upon small prey, whereas large bigmouth sleepers switched to primarily larger prey items.

Threadfin shad was by far the most common piscine prey item, found in 67.6% of all bigmouth sleeper stomachs containing fish (Figure 5). Largemouth bass (10.8%), bigmouth sleepers (8.1%) and bluegill (8.1%) were also found frequently. One redbreast sunfish and one *Gambusia* spp. were also found in bigmouth sleeper stomachs.

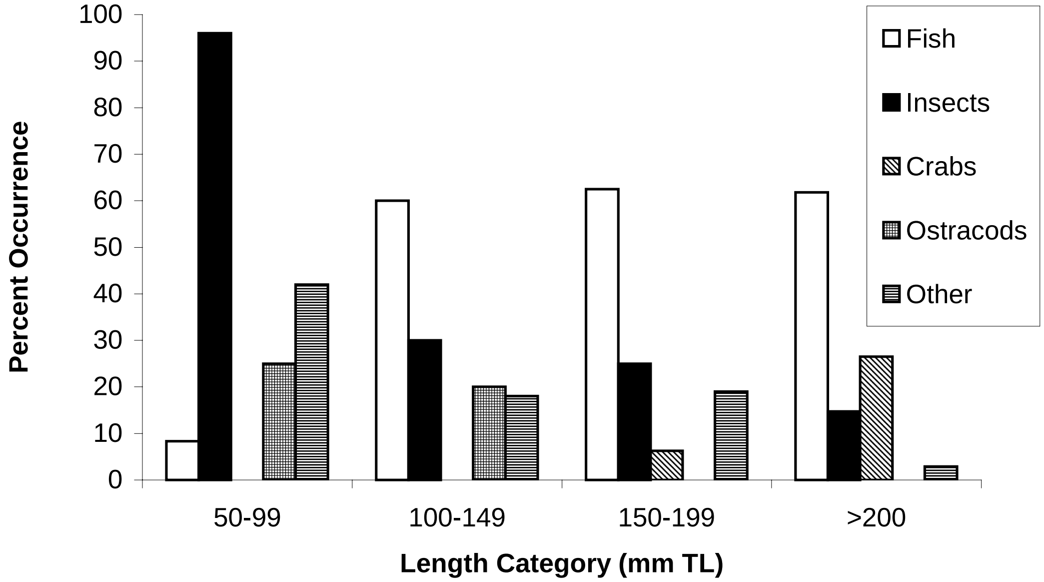

Figure 3. Ontogenetic shifts in prey utilization by bigmouth sleepers in Carite Reservoir, 1999 - 2001. Percent occurrence is presented for fish containing food.

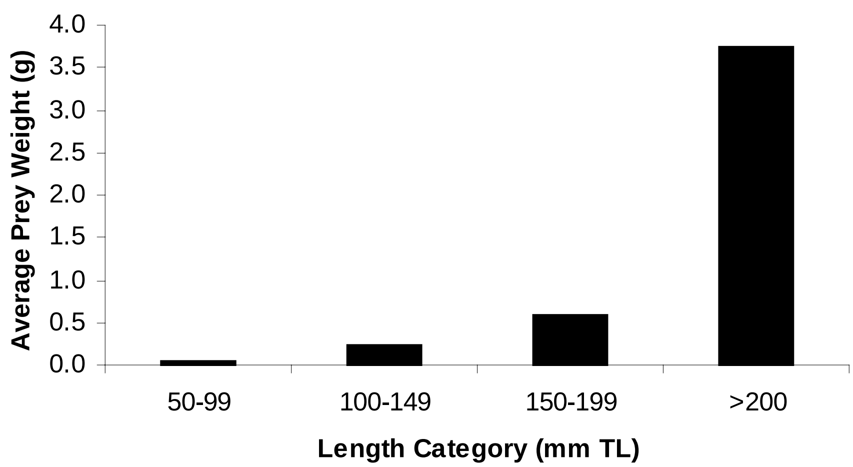

Figure 4. Average weight of prey items found in the stomachs of bigmouth sleepers in Carite Reservoir, 1999 – 2001.

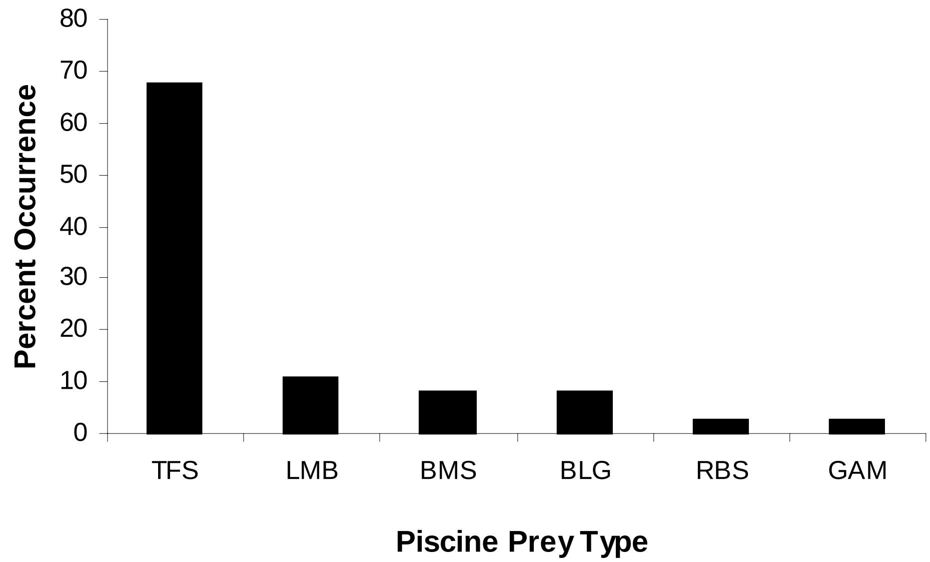

Figure 5. Percent occurrence of piscine prey items in stomachs of bigmouth sleepers in Carite Reservoir, 1999 - 2001. Percent occurrence is calculated as the number of stomachs containing a certain prey type divided by the number of stomachs containing fish. Threadfin shad (TFS) was most common, followed by largemouth bass (LMB), bigmouth sleepers (BMS), bluegill (BLG), redbreast sunfish (RBS), and mosquitofish (GAM).

DISCUSSION

Bigmouth sleepers are native to streams in Puerto Rico, but occur in some reservoirs as well (Rivera 1976, Corujo 1989, Churchill et al. 1995, Neal et al. 1999). Stream ecosystems in Puerto Rico are dominated by shrimps (March et al. 1998), which have been reported to be an important component of bigmouth sleeper diet (Nordlie 1981, Winemiller and Ponwith 1998). Despite freshwater shrimp prevalence in freshwater streams in Puerto Rico, they do not often occur in reservoirs (Holmquist et al. 1998). As such, the diets of bigmouth sleepers reported in this study were very different from those reported by Nordlie (1981) and Winemiller and Ponwith (1998) in a shrimp-dominated system. Whereas shrimps and to a lesser extent fish were the major diet items of bigmouth sleepers from previous studies, fish (mainly threadfin shad), insects, freshwater crabs, and ostracods (a small microcrustacean) were the most frequent prey items in this study. Also, this is the first study to document cannibalism in bigmouth sleepers.

Ontogenetic shifts in diet of bigmouth sleepers have only previously been examined by Winemiller and Ponwith (1998), and they found that small bigmouth sleepers fed on shrimp, but shifted to feeding on a combination of shrimp and fish at larger sizes. An ontogenetic shift in the diet of bigmouth sleepers was also evident in this study. Small bigmouth sleepers feed primarily on small items such as insects and ostracods, but larger individuals switched to feeding on food items such as fish and freshwater crabs. No shrimp was observed in the stomach of a bigmouth sleeper in this study. Instead, small bigmouth sleepers fed on aquatic insects (Odonata, Diptera, Hemiptera), terrestrial insects (Hymenoptera), and ostracods in Carite Reservoir.

Observed ontogenetic shifts in diet of bigmouth sleepers may be related to time of collection if diel feeding patterns occur, because most juveniles were collected during evening hours and adults were primarily collected during the day. However, the adults that were collected at night had very similar prey items as adults collected during the day (e.g., fish and crabs), and juveniles collected during the day also contained mainly insects and ostracods like the juveniles collected at night. Ontogenetic differences in prey selection does not appear to be related to time of collection, but is rather due to size differences only.

Other researchers (Hildebrand 1938, Darnell 1955, Winemiller and Ponwith 1998) considered bigmouth sleepers to be highly opportunistic in prey diversity, and this study verifies those earlier findings. Bigmouth sleepers ate a wide variety of food items in this study, including at least six species of fish, three orders of aquatic insects (Odonata, Diptera, and Hemiptera), terrestrial insects (Hymenoptera), and crustaceans (ostracods and freshwater crabs). In addition, on 20 October 2001, a lizard head, most likely that of a gecko, was found in the stomach of a 174-mm bigmouth sleeper.

Other small but important prey items may have gone undetected in this study. For instance, microcrustacea such as zooplankton are presumably significant for bigmouth sleepers smaller than 50 mm TL, but our sampling methods prevented us from collecting these small individuals. More research is necessary on the diets of small bigmouth sleepers (less than 50 mm in length) because it is at this life stage that bigmouth sleepers may have the most specific feeding preferences, and it may be these small sizes that are most vulnerable to ecological changes.

REFERENCES

Churchill, T.N., R.L. Noble, J.E. Gran, and A.R. Alicea. 1995. Largemouth bass recruitment in Lucchetti Reservoir. Final Report. Federal Aid in Sportfish Restoration Project F-16, Study 2. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1989. Reservoir sportfish survey. Annual Report. Federal Aid in Sportfish Restoration Project F-16, Study 1. Puerto Rico Department of Natural and Environmental Resources.

Darnell, R.M. 1955. Nocturnal terrestrial habits of the tropical goboid fish, *Gobiomorus dormitor,* with remarks on its ecology. Copeia 1955: 237-238.

Darnell, R.M. 1962. Fishes of the Rio Tamesi and related coastal lagoons in east-central Mexico. Publications of the Institute of Marine Science of the University of Texas 8: 299-365.

Gilmore, R.G. 1992. Bigmouth sleeper, *Gobiomorus dormitor*. Pages 105-111 *in* C.R. Gilbert, editor. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, Florida.

Hildebrand, S.F. 1938. A new catalog of the fresh water fishes of Panama. Field Museum of Natural History, Chicago, Zool. 22(4): 217-359.

Holmquist, J.G., J.M. Schmidt-Gengenbach, and B.B. Yoshioka. 1998. High dams and marine-freshwater linkages: effects on native and introduced fauna in the Caribbean. Conservation Biology 12: 621-630.

Jackson, J.R., and R.L. Noble. 1995. Selectivity of sampling methods for juvenile largemouth bass in assessments of recruitment processes. North American Journal of Fisheries Management 15: 408-418.

Kelso, D.P. 1965. A contribution to the ecology of a tropical estuary. Master's Thesis, University of Florida, Gainesville, Florida.

Lindquist, D.G. 1980. Bigmouth sleeper, *Gobiomorus dormitor*. Page 784 *in* D.S. Lee, C.R. Gilbert, C.H. Holcutt, R.E. Jenkins, D.E. McAllister, J.R. Stauffer, Jr., editors. Atlas of North American Freshwater Fishes. NC State Museum of Natural History, Raleigh, NC.

March, J.G., J.P. Benstead, C.M. Pringle, and F.N. Scatena. 1998. Migratory drift of larval freshwater shrimps in two tropical streams, Puerto Rico. Freshwater Biology 40: 261-273.

McKaye, K.R. 1977. Competition for breeding sites between the cichlid fishes of Lake Jiloa, Nicaragua. Ecology 58: 291-302.

McKaye, K.R., D.J. Weiland, and T.M. Lim. 1979. Comments on the breeding biology of *Gobiomorus dormitor* (Osteichthyes: Eleotridae) and the advantage of schooling behavior to its fry. Copeia 1979: 542-544.

Neal, J.W., R.L. Noble, C.G. Lilyestrom, T.N. Churchill, A.R. Alicea, D.E. Ashe, F.M. Holliman, and D.S. Waters. 1999. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Nelson, J.S. 1976. Fishes of the world. A Wiley-Interscience Publication. John Wiley, New York, New York.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. Journal of Fish Biology 18: 97-110.

Rivera-Gonzales, J. 1976. Relationship between the population dynamics and environmental water quality data of four fisheries in Puerto Rico. Dingell-Johnson Project F-4-10 Final Report. Puerto Rico Department of Natural and Environmental Resources.

Van Den Avyle, M.J., and J.E. Roussel. 1980. Evaluation of a simple method for removing food items from a live black bass. Progressive Fish-Culturist 42: 222-223.

Winemiller, K.O., and B.J. Ponwith. 1998. Comparative ecology of eleotrid fishes in Central American coastal streams. Environmental Biology of Fishes 53: 373-384.

CHAPTER 4

REPRODUCTION

INTRODUCTION

The bigmouth sleeper *Gobiomorus dormitor* is a fish species in the family Eleotridae, a group of poorly understood euryhaline fishes found in tropical coastal streams throughout the world (Dickson et al. 1998). Bigmouth sleepers are found in southern Florida, southern Texas, the Atlantic slope of Central and northern South America, and in the Caribbean Islands (Gilmore 1992) (Figure 1). The few previous studies pertaining to the reproduction of this species suggest that they are catadromous or amphidromous (Darnell 1962, Kelso 1965, Nordlie 1981, Winemiller and Ponwith 1998). In some instances, however, they have been able to successfully reproduce in a natural lake in Nicaragua (McKaye 1977, McKaye et al. 1979) and in a reservoir in Puerto Rico (Chapter 2).

Studies of the ecology of Puerto Rico native freshwater fishes are limited (but see Erdman 1976, Holmquist et al. 1998), yet effective management of fish for recreational angling and conservation purposes requires comprehensive species-specific ecological information. Bigmouth sleepers are one of only five native fishes that spend most of their lives in freshwater in Puerto Rico (Hildebrand 1935, Erdman 1976, 1984), and are the primary native freshwater fisheries resource (Corujo 1999). Furthermore, as in Florida (Gilmore 1992, Musick et al. 2000), the combined threat of habitat loss due to stream barriers and water quality degradation in Puerto Rico may necessitate conservation measures (Holmquist et al. 1998). An improved understanding of the life history of bigmouth sleepers will aid in identifying the biotic

Figure 1. Distribution map of bigmouth sleepers, *Gobiomorus dormitor* (from Gilmore 1992).

and abiotic requirements and constraints of the species, which may facilitate better management or conservation strategies. In Puerto Rico, bigmouth sleepers inhabit rivers (Erdman 1976, 1984; Holmquist et al. 1998), but they have also been found in four man-made reservoirs on the island (Rivera 1976, Churchill et al. 1995, Neal et al. 1999). Furthermore, evidence supports the claim that bigmouth sleepers are successfully spawning in at least one reservoir, Carite Reservoir (Chapter 2). Although aspects of the life history of bigmouth sleepers have been reported previously (e.g., McKaye 1977, McKaye et al. 1979, Winemiller and Ponwith 1998), the life history of the species in man-made reservoirs has not been examined. The paucity of reproductive information on bigmouth sleepers in general, combined with the complete lack of knowledge of reservoir populations, has prompted a closer look at this reproducing population of bigmouth sleepers in a Puerto Rico reservoir.

The objective of this study was to determine significant reproductive traits of bigmouth sleepers in Carite Reservoir, specifically those that could have management or conservation importance. These include morphological differences between the sexes, reproductive seasonality, length at maturity, fecundity, and oocyte sizes.

STUDY SITE

From October 2000 to October 2001 bigmouth sleepers were examined in Carite Reservoir, Puerto Rico. Carite Reservoir is a 124-hectare impoundment located in the south central mountains of Puerto Rico, near the town of Cayey (Figure 2). The reservoir is situated at 18°04’N and 66°05’W at an elevation of 543.6 m above sea level. Annual rainfall in the region is 210 cm, and the average temperature is 23.5°C

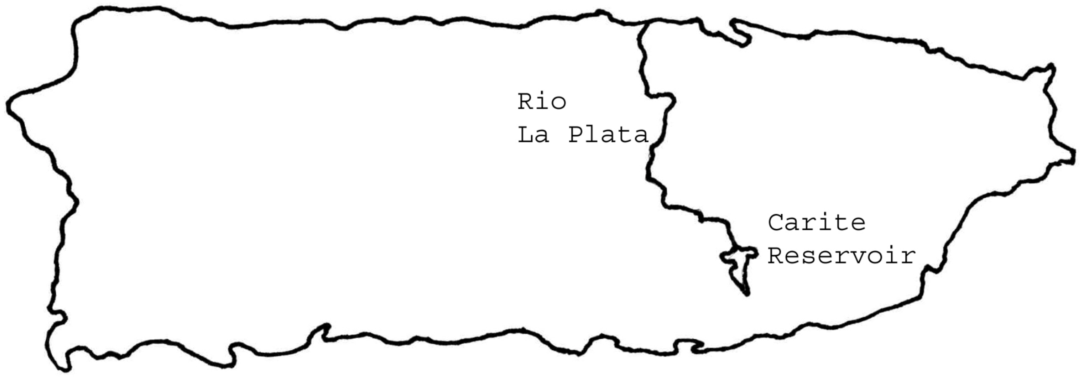

Figure 2. Location of Carite Reservoir and the La Plata River, Puerto Rico.

(Carvajal-Zamora 1979). Surface water temperature during part of this study (January – June 2001) fluctuated between 21.5 – 28.0° C. Carite Reservoir is one of the oldest reservoirs in Puerto Rico, having been constructed in 1913 (Erdman 1984). The earthen dam is located on the headwaters of the La Plata River, and was built primarily as water storage for the irrigation of sugar cane (Erdman 1984.) Today the reservoir provides water and electricity to meet the demands for domestic, industrial and agricultural purposes in the Guayama area. The Carite Reservoir drainage area is 21.2 km^2 and is comprised mainly of forest (Carvajal-Zamora 1979). The water level fluctuated approximately 4 m during the study (Figure 3), far less drastic than the extreme fluctuations in other reservoirs on the island (e.g., up to 17 m annually in Lucchetti Reservoir; Neal et al. 1999). Maximum depth in Carite Reservoir is 19.5 m, and average depth is 10 m at full pool (Carvajal-Zamora 1979).

METHODS

Sampling Procedure

Bigmouth sleeper specimens were collected eight times between 14 October 2000 and 20 October 2001, in Carite Reservoir. Bigmouth sleepers were captured using boom electroshocking (3 – 4 A and 60 pps DC current) along the shoreline of the reservoir during daylight hours. All fish were immediately euthanized by anesthetic (MS-222) overdose and placed on ice until processing, which took place 3 - 6 hours after collection. In the laboratory, each fish was measured to the nearest millimeter total length (TL) and weighed to the nearest 0.01 gram (g).

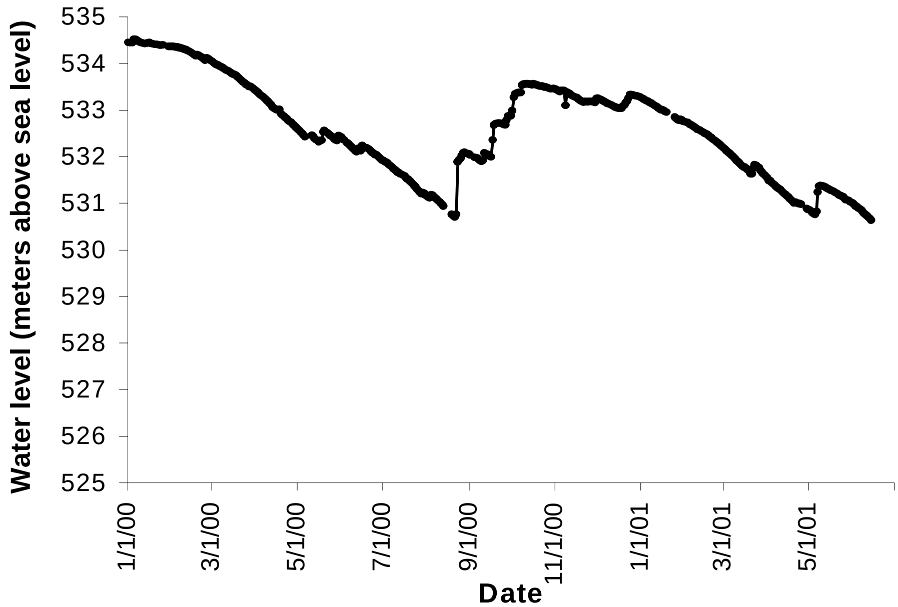

Figure 3. Water level (in m above sea level) in 2000 and 2001 in Carite Reservoir, Puerto Rico. Data courtesy of the United States Geological Society.

Sexual Dimorphism

Since there are not any obvious coloration differences between male and female bigmouth sleepers, the urogenital papillae was examined as a potential sexual dimorphic characteristic. Size and shape of the urogenital papillae have found to be good sexually dimorphic characters in some fish species (Thresher 1984). The urogenital papillae of all sizes of bigmouth sleepers were examined year-round to determine if there are persistent visible differences between the sexes. Verification of gender was made by direct gonad observation.

Size differences between male and female bigmouth sleepers may exist. To investigate if differences occur between the sexes in body size or shape, two length-weight relationships were formulated and compared during this study, one for male and one for female bigmouth sleepers. The length-weight relationships were developed in the form $\log_{10} W = \log_{10} a + (b * \log_{10} TL)$, in which W = wet weight in g and TL = total length in mm.

Gonadosomatic Index

Individuals were dissected, the gonads were removed from each fish and weighed to the nearest 0.01 g, and stomach contents were removed and weighed. The gender of each fish was noted by gonadal examination. The gonadosomatic index (GSI), an index of relative maturity stage, was calculated for each fish using the following formula:

GSI = gonad weight / (body weight – stomach contents weight) * 100

Length-at-maturity

A maximum nonreproductive gonad state was computed for both males and females based upon the highest GSI values observed during the nonreproductive season. A male or female was considered mature if it had a GSI value higher than the highest GSI value observed during the nonreproductive season. The smallest mature male and female collected during the study was considered the length at which sexual maturation occurs in Carite Reservoir.

Oocyte Diameters

Immediately after ovaries were weighed, subsamples of eggs from ripe females were taken from the ovaries and measured. Diameters of oocytes from each female were measured to 0.01 mm using an ocular micrometer on a dissecting scope. Oocytes smaller than 0.20 mm were designated as primary oocytes and those larger than 0.20 mm were considered maturing oocytes. Only maturing oocytes were analyzed in this study. To test for positional differences of oocyte sizes, 25 eggs were taken from the anterior, medial, and posterior region of the ovary (n = 75 total oocytes per fish) to make positional comparisons of oocyte size. Measurement was accomplished according to West (1990), orienting the follicle axis parallel to the micrometer.

Fecundity Estimates

Fecundity, defined here as the total number of maturing oocytes in the ovary (i.e., excluding primary oocytes), was estimated for each ripe female (GSI value > 1), based upon a 0.05 g sample of maturing oocytes from the ovaries. Fecundity for each female was then estimated using the following formula:

Fecundity = number of oocytes in 0.05g sample * ovary weight in grams * 20

Statistical Analyses

All analyses were made using parametric statistics. Significance was accepted at the $\propto \leq 0.05$ level.

RESULTS

During the study, 248 bigmouth sleepers were collected, consisting of 131 females and 117 males. Their length and weight information is given in Table 1. Male and female total length was found to be only marginally different (Student's t-test; $t = 1.95$; $df = 246$; $p = 0.052$), but the difference in weight of male and female was significant ($t = 2.40$; $df = 246$; $p = 0.017$). That is, females collected in this study tended to be only marginally longer than males, but weighed significantly more.

Table 1. Size information for female and male bigmouth sleepers collected between October 2000 and October 2001 in Carite Reservoir.

		Females	**Males**	**Total**
Sample Size		131	117	248
Length (mm TL)	Range	51-336	42-360	42-360
	Mean	232.5	217.9	225.6
	St. Dev.	57.7	59.2	58.7
Weight (g)	Range	1.0-363.0	0.6-301.0	0.6-363.0
	Mean	110.1	89.6	100.5
	St. Dev.	66.5	68.0	67.8

Sexual Dimorphism

Examination of 18 fish on the first sampling period (October 2000) revealed obvious morphological differences between bigmouth sleeper males and females in the anatomy of the urogenital papillae (Figure 4). Further sampling revealed that these differences were noticeable throughout the year and in all sizes of fish. Thereafter, each fish was classified before dissection as either male (n = 112; 42 – 360 mm TL) or female (n = 118; 51 – 336 mm TL) based on papilla structure, and verified by gonadal dimorphism after dissection. Examination of papilla using the naked eye alone always yielded correct classification of gender for fish greater than 100 mm TL. For smaller fish, a dissecting microscope was necessary, but even then discrimination of sex was always possible using papilla structure. Males have a long, thin papilla that appears laterally segmented, and the genital pore is a small circular dot on its posterior end. Females, in contrast, have a round papilla whose posterior edge appears to be covered in small bristles. Also, females have a more anterior genital pore that appears to be partially overlapped by a hinged cover.

The length-weight relationship was not significantly different between males and females in slope ($t = 0.77$, $df = 1$, $p > 0.05$) or intercept ($t = 0.79$, $df = 1$, $p > 0.05$). In other words, one sex did not weigh more at any given length than the other, and the similarity in weight between the sexes was consistent over the entire length range of fish collected.

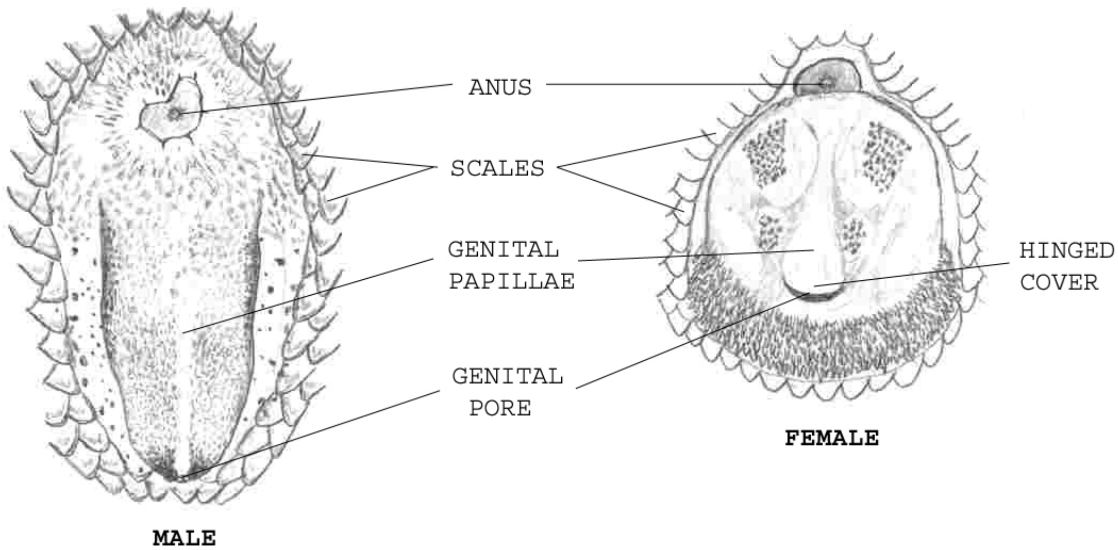

Figure 4. Anatomical structure of the male and female urogenital papillae of the bigmouth sleeper (drawing by J.W. Neal).

Gonadosomatic Index

GSI values were considerably higher for females (mean = 1.64) than for males (mean = 0.34) in Carite Reservoir. Average GSI values for males (Figure 5) and females (Figure 6) were quite variable throughout the year and indicated a cycle of reproductive development. Average GSI for males and females was low in January and February, higher in April, peaked in May and June, and decreased in October. When body size-specific GSI values were plotted across the reproductive season, no differences were evident, suggesting that larger individuals are not reproducing earlier than smaller ones, or vice-versa.

Length-at-maturity

Individual GSI values during the nonreproductive season (January - February) were always less than 0.3 for males and 1.0 for females (see Figures 5, 6), so these values were used as baseline values to which individuals could be compared for assessment of maturity. The smallest male with a GSI higher than 0.3 was a 159-mm TL male with a GSI of 0.46 captured on 20 October 2001 (Figure 7). The smallest female with a GSI higher than 1.0 was a 178-mm TL female with a GSI of 1.54 captured on 11 June 2001 (Figure 8).

Oocyte Diameters

Oocyte diameters were measured for 40 female bigmouth sleepers ranging in size from 178 – 328 mm TL (April – June 2001). Typical frequency distributions of oocytes in female ovaries during the reproductive season fell into two size groups:

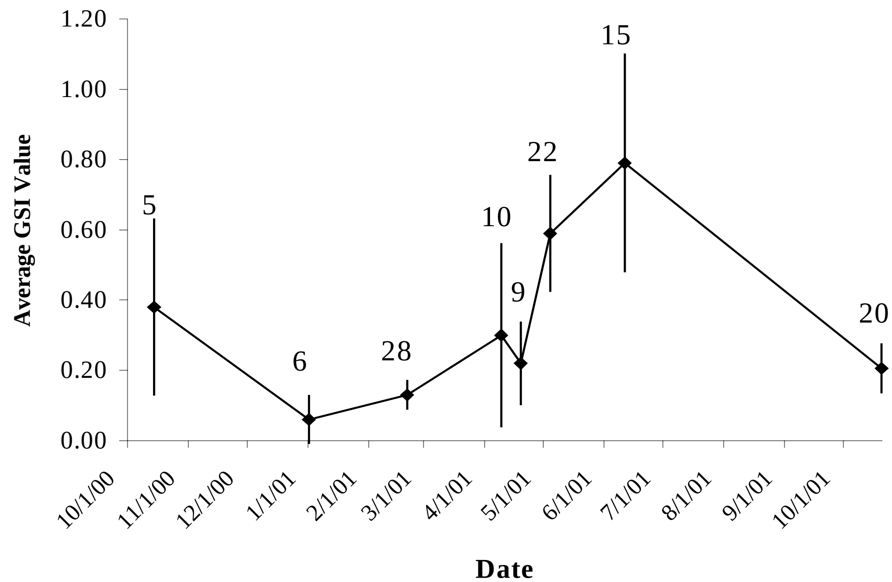

Figure 5. Average gonadosomatic index for male bigmouth sleepers from October 2000 to October 2001 in Carite Reservoir. Sample sizes are denoted above each sampling period.

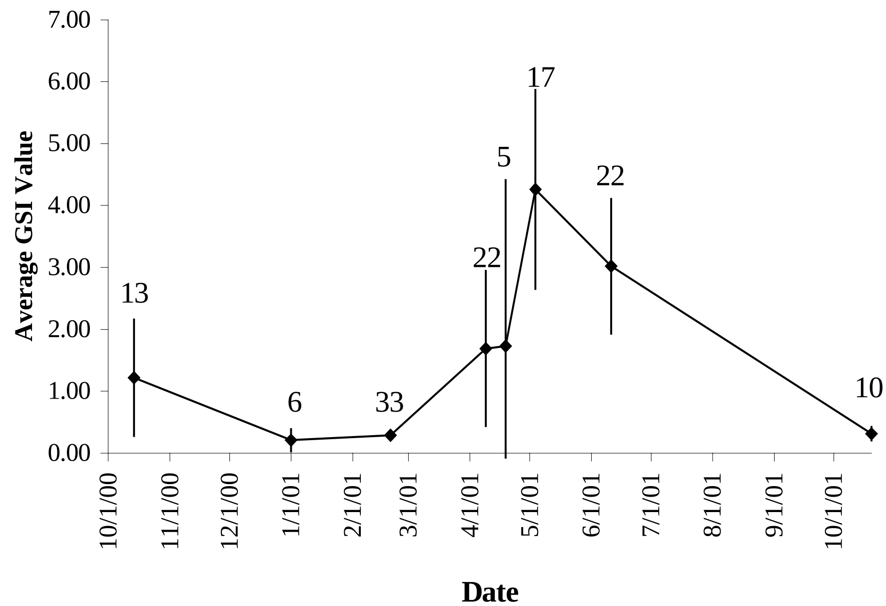

Figure 6. Average gonadosomatic index for female bigmouth sleepers from October 2000 to October 2001 in Carite Reservoir. Sample sizes are denoted above each sampling period.

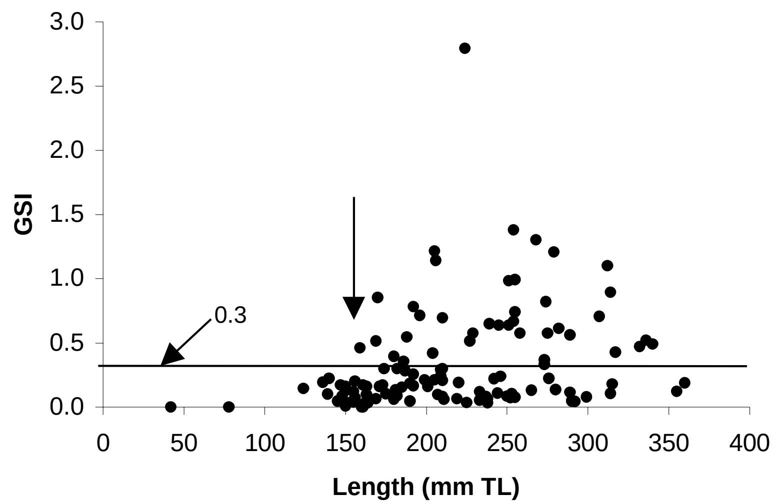

Figure 7. Gonadosomatic index for each male collected during this study (all seasons combined). Baseline nonreproductive GSI values were always below 0.3 for males. The shortest male considered mature is a 159-mm male with a GSI value of 0.46, denoted by the vertical arrow.

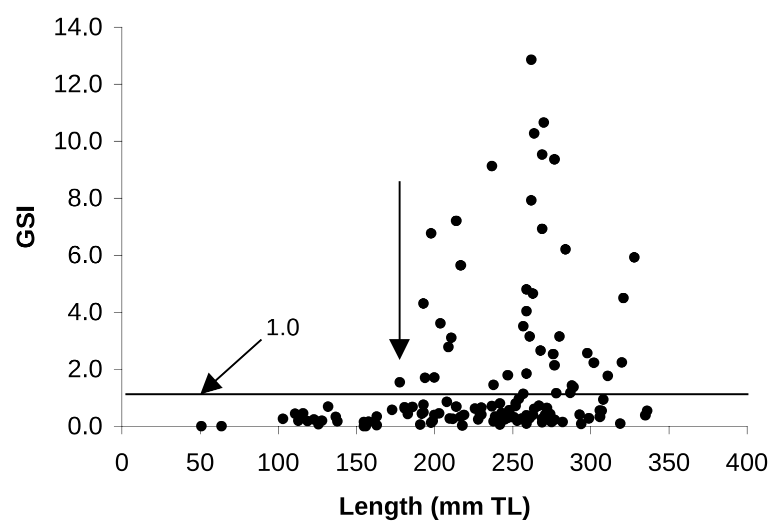

Figure 8. Gonadosomatic index for each female collected during this study (all seasons combined). Baseline nonreproductive GSI values were always below 1.0. The shortest female considered mature is a 178-mm female with a GSI value of 1.54, denoted by the vertical arrow.

primary oocytes (< 0.20 mm) and maturing oocytes. As examples, the frequency distributions of eggs from three randomly chosen females, one from each sampling period during the reproductive season, are shown in Figure 9. Larger oocytes, 0.66 – 0.70 mm diameter, were observed in 5 females. Only a marginally significant difference occurred in oocyte diameters among positions within the ovary (ANOVA; $F = 3.04$; $df = 2$; $p = 0.054$), so all fecundity estimates were made using a medial portion of each ovary only.

Fecundity Estimates

Forty female bigmouth sleepers had GSI values greater than 1.0, so these fish were used in the fecundity analyses. Fecundity ranged from 15,423 – 419,136 (mean = 140,836, sd = 110,200) for female bigmouth sleepers in this study, but there was a negative relationship between fecundity and date ($t = 2.42$; $df = 39$; $p < 0.05$; Figure 10). No difference in mean fecundity was evident between the 9 April and 4 May samples ($t = 0.18$; $df = 19$; $p = 0.43$), but the 11 June fecundity estimates were significantly lower than those found on 9 April ($t = 1.94$; $df = 24$; $p = 0.03$) and 4 May ($t = 2.45$; $df = 31$; $p = 0.01$), suggesting that partial spawns had occurred. Consequently, only the 9 April and 4 May samples were used in the analysis of fecundity verses female body weight. There was a positive relationship between fecundity and female body weight ($R^2 = 0.38$; $t = 3.38$; $df = 19$; $p = 0.003$; Figure 11).

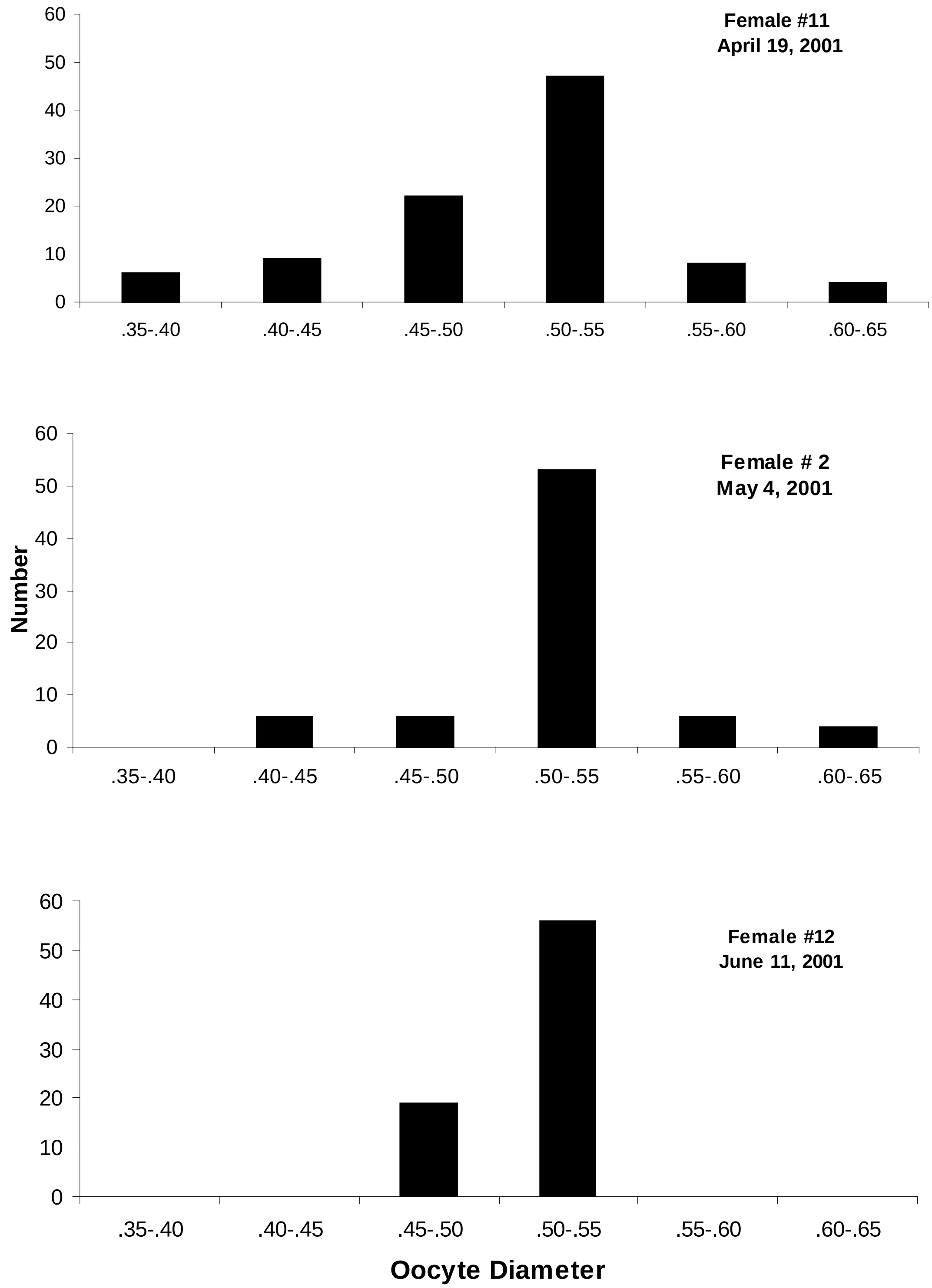

Figure 9. Oocyte diameter length frequency for randomly selected female bigmouth sleepers during the reproductive season (April- June) in 2001.

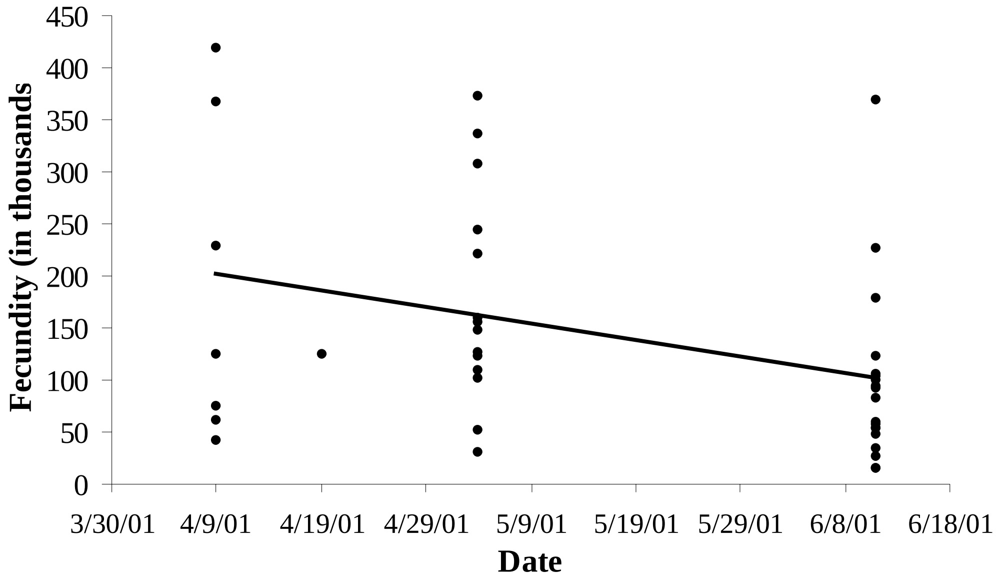

Figure 10. Relationship between fecundity of female bigmouth sleepers and date of capture in Carite Reservoir, 2001.

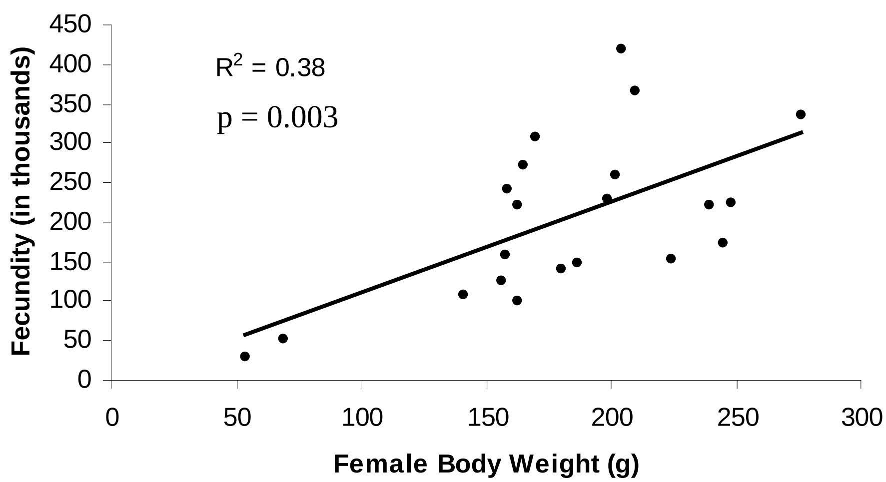

Figure 11. Relationship between fecundity and female body weight of bigmouth sleepers in Carite Reservoir, 2001.

DISCUSSION

This is the first study to document a suite of reproductive characteristics of bigmouth sleepers simultaneously in one system. In general these results agree with the previously documented reproductive ecology of bigmouth sleepers, but there are some notable exceptions to, and many expansions upon, the earlier works.

Determination of sex in most species of fishes is difficult based on external characteristics and may even be impossible outside of spawning periods. One method that has proven to be successful in some species is examination of the fine structure of the urogenital papillae (Thresher 1984). Bigmouth sleepers in this study differed considerably in the anatomy of their urogenital papillae, and these differences developed at a very small size and persisted throughout the year.

The gonadosomatic index (GSI) showed that reproduction of bigmouth sleepers was seasonal in Carite Reservoir, with the highest GSI values occurring in May and June. Reproduction seemed to be possible by at least a segment of the population during a 2 month window (May-June), but the reproductive window may be much larger than observed in this study, as no sampling was done during the months of July through September. GSI values for male and female bigmouth sleepers in these months would have helped to better define the breeding season. Sampling efforts at shorter time intervals would help to precisely define bigmouth sleeper spawning periodicity.

Spawning seasonality of bigmouth sleepers in Carite Reservoir was similar to previous findings in a lagoon and a natural lake. Kelso (1965) reported collecting gravid bigmouth sleeper females in Tortuguero Lagoon, Costa Rica, in May. McKaye

(1977) surveyed Lake Jiloa (a natural lake in Nicaragua) year-round and found 90% of all bigmouth sleeper nests in May and only 10% in April. In contrast, Winemiller and Ponwith (1998) found some individuals in Costa Rica with ripe or ripening gonads during each of the 10 months of their study (March – December). They also found small juveniles (15 – 30 mm) in nearly every monthly sample, suggesting year-round reproduction by at least some population segments. Reproductive seasonality in Carite Reservoir was seasonal, with the highest GSI values occurring between April and June. Also, in both October samples, a very small proportion of individuals were ripe or ripening. However, no ripe fish were found in January or February. In addition, small bigmouth sleepers were frequently captured in year-round sampling efforts in Carite Reservoir (Chapter 2, Neal et al. 2001), indicating a prolonged spawning season by adults or very slow growth rates as juveniles, or both.

The length-at-maturity of bigmouth sleepers has not been previously examined. The length at which individuals of a species mature probably varies by individual and should instead be considered as a range of lengths over which individuals mature. That could be further examined histologically. Since histological techniques were not utilized in this study, the smallest individual with a GSI greater than the maximum nonreproductive GSI was considered the length at which bigmouth sleepers mature. Males appear to mature at a slightly smaller size than females.

Winemiller and Ponwith (1998) reported a maximum oocyte diameter of 0.35 mm for bigmouth sleepers from Tortuguero Lagoon, Costa Rica. The maximum oocyte diameter for bigmouth sleepers in Carite Reservoir, in contrast, was 0.70 mm. Although this discrepancy could result from failure of Winemiller and Ponwith (1998) to collect female bigmouth sleepers before they were fully ripe (with advanced oocytes), their collection of ripe fish over a long season indicates that oocyte sizes differ between these two systems. Different oocyte diameters also suggest that either this trait is phenotypically or genetically variable, or that these two populations may be different subspecies or species. Further comparisons of ripe bigmouth sleeper oocyte sizes or genetic information among systems should be conducted to resolve this discrepancy.

Ripe or ripening female bigmouth sleepers in Carite Reservoir had one group of primary oocytes (< 0.20 mm) and one group of developing oocytes (0.20 – 0.70 mm). Oocytes of 0.50 – 0.55 mm diameter were the most common for ripe females, yet eggs larger than 0.55 were rarely found. This suggests that female bigmouth sleepers typically release eggs of this size class (0.50 - 0.55 mm) during reproduction.

The number of maturing oocytes (> 0.20 mm) in the ovary is one of many ways to estimate fecundity. The estimated fecundity found in this study is likely not the same as the number of eggs laid by a female at one reproductive event. McKaye et al. (1979) found female bigmouth sleepers laid approximately 4,000 – 6,000 eggs in a single oval mass 30 cm in length. They also report, though, that bigmouth sleepers are capable of producing multiple broods in a relatively short period of time, and in one instance a female produced two broods separated by only 6 to 7 days. Female bigmouth sleepers in Carite Reservoir also may raise multiple broods throughout a reproductive season, but the oocyte length frequencies from individual fish did not show evidence of multiple batches of oocytes simultaneously developing in the ovaries. Either bigmouth sleepers can produce eggs from primary oocytes extremely quickly, or instead bigmouth sleepers only lay a portion of their eggs at any one reproductive event. Lower fecundity estimates late in the spawning period suggest that batch-spawning occurred. Consequently, the 11 June sample was not used in the fecundity versus female body weight analysis due to the likely underestimation of fecundity during this time period.

The use of radio telemetry to monitor the movements of fishes can provide useful information about the species' reproductive ecology (Winter 1996). To identify bigmouth sleeper spawning movements and areas in Carite Reservoir, 25 bigmouth sleepers were implanted with radio transmitters in 2000, released into Carite Reservoir, and located weekly. However, bigmouth sleepers lost all implanted transmitters due to probable incision rupture, death, or transintestinal expulsion, thereby precluding the collection of this information (Appendix A).

Winemiller (1989) categorized some South American fishes into three life history categories, and it may be beneficial to classify bigmouth sleepers in this same framework for comparative reasons. The "equilibrium" strategy, similar to the "K-strategy" proposed by Pianka (1970), is characterized by long generation times, large investment in individual offspring, delayed maturation, aseasonal reproduction, and prolonged breeding. The two other life history characteristics divide many of the traits comprising Pianka's (1970) "r-selected" organisms. Those fishes with short generation time, low fecundity, and minimal investment per offspring is known as the "opportunistic" strategy. Last, cyclic reproduction, relatively long generation times, large clutches, and small investment per offspring characterize the "seasonal" strategy. Bigmouth sleepers in Carite Reservoir are clearly seasonal strategists by this classification, reproducing in the spring and summer and producing extremely large clutches with very small oocytes. Without similar data for estuary-dependent populations, it is unclear whether this is a characteristic of the species or an adaptation to being land-locked in a freshwater reservoir.

REFERENCES

Carvajal-Zamora, J.R. 1979. Ecological survey of lakes. Final Report. Project F-4, Study 11. Puerto Rico Department of Natural and Environmental Resources, San Juan.

Churchill, T.N., R.L. Noble, J.E. Gran, and A.R. Alicea. 1995. Largemouth bass recruitment in Lucchetti Reservoir. Final Report. Federal Aid in Sportfish Restoration Project F-16, Study 2. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1999. Puerto Rico Freshwater Fisheries Investigations. Project F-16.11, Study 8: Toa Vaca, Carite, Patillas, Cidra, Guayo, and Guayabal reservoirs creel survey. Puerto Rico Department of Natural and Environmental Resources.

Darnell, R.M. 1962. Fishes of the Rio Tamesi and related coastal lagoons in east-central Mexico. Publications of the Institute of Marine Science of the University of Texas 8: 299-365.

Dickson, H., H.D. Hoese, and R.H. Moore. 1998. Fishes of the Gulf of Mexico: Texas, Louisiana, and adjacent waters, second edition. Texas A&M Press, College Station, Texas.

Erdman, D.S. 1976. Spawning patterns of fishes from the northeastern Caribbean. Contr. Agro. Pesq. Puerto Rico Department of Agriculture 8: 1-36.

Erdman, D.S. 1984. Exotic fishes in Puerto Rico. Pages 162-176 *in* W.R. Courtenay, Jr., and J.R. Stauffer, Jr. Distribution, biology, and management of exotic fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Gilmore, R.G. 1992. Bigmouth sleeper, *Gobiomorus dormitor*. Pages 105-111 *in* C.R. Gilbert, editor. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, Florida.

Hildebrand, S.F. 1935. An annotated list of fishes of the fresh waters of Puerto Rico. Copeia 1935: 49-56.

Holmquist, J.G., J.M. Schmidt-Gengenbach, and B.B. Yoshioka. 1998. High dams and marine-freshwater linkages: effects on native and introduced fauna in the Caribbean. Conservation Biology 12: 621-630.

Kelso, D.P. 1965. A contribution to the ecology of a tropical estuary. Master's Thesis, University of Florida, Gainesville, Florida.

McKaye, K.R. 1977. Competition for breeding sites between the cichlid fishes of Lake Jiloa, Nicaragua. Ecology 58: 291-302.

McKaye, K.R., D.J. Weiland, and T.M. Lim. 1979. Comments on the breeding biology of *Gobiomorus dormitor* (Osteichthyes: Eleotridae) and the advantage of schooling behavior to its fry. Copeia 1979: 542-544.

Musick, J.A. and seventeen coauthors. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25: 6-30.

Neal, J.W., R.L. Noble, N.M. Bacheler, M. McGee, and C.G. Lilyestrom. 2001. Freshwater sportfish community investigation and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Neal, J.W., R.L. Noble, C.G. Lilyestrom, T.N. Churchill, A.R. Alicea, D.E. Ashe, F.M. Holliman, and D.S. Waters. 1999. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. Journal of Fish Biology 18: 97-110.

Pianka, E.R. 1970. On r- and K-selection. American Naturalist 100: 592-597.

Rivera-Gonzales, J. 1976. Relationship between the population dynamics and environmental water quality data of four fisheries in Puerto Rico. Dingell-Johnson Project F-4-10 Final Report. Puerto Rico Department of Natural and Environmental Resources.

Thresher, R.E. 1984. Reproduction in reef fishes. TFH Publications, Inc. Ltd. Neptune City, New Jersey.

West, G. 1990. Method of assessing ovarian development in fishes: a review. Australian Journal of Marine and Freshwater Resources 41: 199-222.

Winemiller, K.O. 1989. Patterns of variation in life history among South American fishes in seasonal environments. Oecologia 81: 225-241.

Winemiller, K.O., and B.J. Ponwith. 1998. Comparative ecology of eleotrid fishes in Central American coastal streams. Environmental Biology of Fishes 53: 373-384.

Winter, J.D. 1996. Advances in underwater biotelemetry. Pages 555-590 *in* B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd Edition. American Fisheries Society, Bethesda, Maryland.

CHAPTER 5

DISCUSSION AND SYNTHESIS

SIGNIFICANCE AND DIRECTIONS FOR FUTURE RESEARCH

These results indicate that Carite Reservoir is a suitable environment for bigmouth sleepers *Gobiomorus dormitor* to complete their entire life cycle. This study was the first to document successful within-reservoir bigmouth sleeper reproduction. Unfortunately, unsuccessful tag retention precluded radio-telemetry necessary to define spawning movements and areas. Other explanations of bigmouth sleeper presence in Carite Reservoir, such as introductions by fishermen or birds, or reproductive migration out of and back into Carite Reservoir, are not supported with evidence. However, based on the islandwide surveys of Puerto Rico reservoirs by Churchill et al. (1995) and Neal et al. (1999), Carite Reservoir may be the only reservoir in Puerto Rico where successful reproduction has occurred in the last decade, though juvenile bigmouth sleepers were found in low numbers Guajataca Reservoir before 1996. The reasons for the presence of exclusively large adults in three other reservoirs in Puerto Rico have not been considered. Continuation of islandwide reservoir assessments is necessary to validate the limited populations in Puerto Rico reservoirs.

This study was the first to determine many important ecological characteristics of bigmouth sleepers. Growth rates for bigmouth sleepers have not been previously examined, but these results for Carite Reservoir indicate very low growth rates in low-productivity systems. Anchor tag loss, though negligible within 3 months of tagging, was high for fish after 3 months at large and should be an important factor to consider in future tagging and growth studies. Population size was estimated in Carite

Reservoir; although less precise than intended, this was the first measure of population abundance ever completed on bigmouth sleepers. Sexual dimorphism was discovered and described. The fine structure of the urogenital papillae differed between the sexes of bigmouth sleepers. Length-at-maturity was also determined, occurring earlier in males than females. Fecundity decreased as the reproductive season progressed, and was positively related to female weight.

Other parameters were examined in this study to compare with previous work on bigmouth sleepers in other environments. Spawning seasonality of bigmouth sleepers, April to at least June in this study, is more prolonged than the season reported by Kelso (1965) and McKaye (1977). However, no individuals were ripe or ripening in the winter months, contradictory to the results of Winemiller and Ponwith (1998). Examining fish at smaller intervals for gonad development would increase the precision of the results reported here.

Others (Darnell 1955, Nordlie 1981, Winemiller and Ponwith 1998) quantitatively assessed the diet of bigmouth sleepers in rivers and lagoons, but this study was the first to assess diet in a reservoir. Bigmouth sleepers fed primarily on small prey items such as insects and ostracods while small, then shifted their diet to include mainly larger items such as fish and freshwater crabs (*Epilobocera* spp.) as they grew. Threadfin shad (*Dorosoma petensense*) was the most common piscine prey. Studies on the extent to which indirect or direct competition exists between the three primary piscivores in Carite Reservoir (bigmouth sleepers, largemouth bass *Micropterus salmoides*, and peacock bass *Cichla ocelaris*) should shed light on the unique community dynamics here.

Radio telemetry was perceived to be a useful technique to study bigmouth sleeper habitat, movement, and reproduction in Carite Reservoir. Consequently, 25 fish were implanted with radio transmitters, released into Carite Reservoir, and located weekly (Appendix A). However, tags were lost from fish and discovered on shore when water level had dropped in Carite Reservoir. Evaluation of alternative tagging methods, or different transmitter coating types, should occur before any future study attempts to use radio telemetry to study bigmouth sleepers.

The occurrence of a sustaining population of bigmouth sleepers in Carite Reservoir is encouraging since this species has suffered severe habitat loss throughout its geographical range by the construction of dams (Gilmore 1992, Holmquist et al. 1998), but the occurrence of a sustaining population in Carite Reservoir is encouraging. This study, the previous work done by the Puerto Rico D.N.E.R. (Rivera 1976, Corujo 1989), and islandwide assessments by Churchill et al. (1995) and Neal et al. (1999) suggest that bigmouth sleepers can persist in some reservoirs. The implications of this are many. If factors can be identified that allow for bigmouth sleeper survival and successful reproduction in Carite Reservoir, managers could actively manipulate other reservoirs to comply with these conditions. Not only would enhancing the population size of bigmouth sleepers in areas where they are threatened or extirpated be a conservation success, but it could also help to diversify reservoir fisheries and promote a native fisheries resource.

REFERENCES

Churchill, T.N., R.L. Noble, J.E. Gran, and A.R. Alicea. 1995. Largemouth bass recruitment in Lucchetti Reservoir. Final Report. Federal Aid in Sportfish Restoration Project F-16, Study 2. Puerto Rico Department of Natural and Environmental Resources.

Corujo, I.N. 1989. Reservoir sportfish survey. Annual Report. Federal Aid in Sportfish Restoration Project F-16, Study 1. Puerto Rico Department of Natural and Environmental Resources.

Darnell, R.M. 1955. Nocturnal terrestrial habits of the tropical gobioid fish *Gobiomorus dormitor,* with remarks on its ecology. Copeia 1955: 237-238.

Gilmore, R.G. 1992. Bigmouth sleeper, *Gobiomorus dormitor*. Pages 105-111 *in* C.R. Gilbert, editor. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, Florida.

Holmquist, J.G., J.M. Schmidt-Gengenbach, and B.B. Yoshioka. 1998. High dams and marine-freshwater linkages: effects on native and introduced fauna in the Caribbean. Conservation Biology 12: 621-630.

Kelso, D.P. 1965. A contribution to the ecology of a tropical estuary. Master's Thesis, University of Florida, Gainesville, Florida.

McKaye, K.R. 1977. Competition for breeding sites between the cichlid fishes of Lake Jiloa, Nicaragua. Ecology 58: 291-302.

Neal, J.W., R.L. Noble, C.G. Lilyestrom, T.N. Churchill, A.R. Alicea, D.E. Ashe, F.M. Holliman, and D.S. Waters. 1999. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. Puerto Rico Department of Natural and Environmental Resources.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. Journal of Fish Biology 18: 97-110.

Rivera-Gonzales, J. 1976. Relationship between the population dynamics and environmental water quality data of four fisheries in Puerto Rico. Dingell-Johnson Project F-4-10 Final Report. Puerto Rico Department of Natural and Environmental Resources.

Winemiller, K.O., and B.J. Ponwith. 1998. Comparative ecology of eleotrid fishes in Central American coastal streams. Environmental Biology of Fishes 53: 373-384.

APPENDIX A

USING RADIO TELEMETRY FOR BIGMOUTH SLEEPERS *Gobiomorus dormitor* (ELEOTRIDAE): A CAUTIONARY NOTE

Bigmouth sleepers *Gobiomorus dormitor* are an eleotrid species found in tropical coastal streams in southern Florida, southern Texas, the Atlantic slope of Central and northern South America, and in the Caribbean Islands (Gilmore 1992). I was interested in obtaining diel, weekly, and seasonal movement information about bigmouth sleepers in a Puerto Rico reservoir, a novel bigmouth sleeper reproductive environment (Chapter 2). This species was thought to be a prime candidate for telemetry study because their movement and migration patterns are poorly understood, they had not been previously studied using radio telemetry methods, and they attain a relatively large adult size. Two months after implanting fish, however, very little additional movement by individuals was detected. A few months later most transmitters were found on shore when water levels had dropped considerably. It is suspected that either fish died, the incisions ruptured, or the tags were lost by transintestinal expulsion (e.g., Summerfelt and Mosier 1984, Chisholm and Hubert 1985, Marty and Summerfelt 1986, 1990, Baras and Westerloppe 1999). The purpose of this note is to document the surgical methods used to implant bigmouth sleepers with transmitters, describe the initial movements and habitat associations of the telemetered fish, comment on the tag loss observed, and discuss the possible mechanisms that could explain this phenomenon.

This study took place between May 2000 and May 2001 in Carite Reservoir, a highly dendritic 124-hectare impoundment located in the south central mountains of Puerto Rico, near the town of Cayey. Surface water temperature over this study fluctuated from 21.5 – 28.0° C, and the water level fluctuated approximately 4 m.

Bigmouth sleepers were collected by electrofishing (60 pps DC, 3 – 4 A) on 17 May 2000 and 14 October 2000; efforts resulted in the collection of 10 and 15 bigmouth sleepers of sufficient sizes, respectively. Fish were 245 to 353 mm TL (mean = 305.5) and weighed 112 to 300 g (mean = 200.3). Surgical procedures were conducted 0 – 2 hours after collection. All fish were placed into a large holding tank in preparation for surgical implantation of transmitters. Model 2I-RC transmitters, manufactured by Holohil Systems, Ltd. (Carp, Ontario, Canada), were used for their long operating time (1 year) and light weight (7 – 8 g in air). Transmitters were encapsulated in an inert waterproof epoxy and operated at a frequency range of 150.050 MHz to 150.849 MHz, at 36 pulses per minute. Winter (1983, 1996) suggested that, as a general rule, transmitters should weigh no more than 2% of the body weight of a fish in air; however, transmitters in this study weighed 2.2% to 7.0% of the bigmouth sleeper body weight due to small average adult size of fish and large battery size in the transmitters. Brown et al. (1999) found no swimming performance differences in juvenile rainbow trout when transmitter weight was extended to 6-12% body weight, although changes in behavior were not evaluated. Whether large transmitter size had an effect on bigmouth sleeper behavior or survival in this study is not known.

After capture, fish were individually anesthetized in 19 L of oxygenated water containing 10 mg/L tricaine methanosulfonate (Finquel MS-222), which was buffered by baking soda to keep the pH near 7. Anesthesia occurred in 1-4 minutes. Each fish was measured (TL; mm), weighed (g), injected with 10 ml/kg oxytetracycline (an antibiotic that reduces risk of infection) through the dorsal lymphatic duct, and placed on a surgery table. Anesthetic water was constantly administered through the gills using a hand pump.

Radio transmitters were implanted surgically into the abdominal cavity of each fish according to procedures modified from Hart and Summerfelt (1975) and Waters (1999). Before and between surgeries all equipment and transmitters were sterilized using 3% Nolvasan solution and rinsed with sterile saline solution. Scales were removed and Betadine was applied to a small ventral area anterior to the anus. A small incision was started with a scalpel and extended with blunt-edged surgical scissors to a length of approximately 2 cm. One transmitter was inserted into the abdominal cavity of each fish. To guide the antenna, a 16-guage needle was inserted through the skin between the incision and the anus and the antenna was pulled through the abdominal wall. This ensures proper healing of the incision without abrasion from the antenna. To close the incision, sutures were made at 3-mm intervals with a 000 atraumatic cutting needle and 2-0 Maxon absorbable sutures. Average surgery time was 5 minutes.

Fish were returned to the large holding tank post-surgery and were allowed to recover. Recovery of bigmouth sleepers, characterized by the return of equilibrium and normal swimming behavior, took 3 to 15 minutes in this study. Each fish had fully recovered before release. The fish captured on May 17 were not released at their site of capture due to imminent bad weather, and were instead released at the surgery site. Fish implanted on 14 October were released in two groups, each near their site of capture.

Tracking was completed once every 4 - 18 days between 13 January 2001 and 5 May 2001, and in addition, fish were located every 3 hours for a 24 hour period once a month during this same time period. An STR_1000 automatic scanning receiver and three-element hand-held yagi receiving antenna (Lotek Engineering, Ontario, Canada) were used to locate each fish. Starting at the boat ramp, the boat was driven parallel to the shoreline as the antenna was rotated, scanning for a signal. When a signal was detected, the boat was maneuvered in that direction until a fish was located. Verification of each location was determined by rotating the antenna 360 degrees until no difference in signal strength was determined. If time permitted, the entire shoreline was searched. For each fish located, its position on a lake map was recorded with its GPS coordinates in decimal degrees using a Garmin GPS 12 unit. The time, depth, substrate, structure, distance from shore, and region of lake were also noted.

The first systematic locating session occurred on 13 January 2001, and 17 of the 25 telemetered fish were found (68%). The eight unheard transmitters were never found in the remainder of the study. Distances moved by individuals from the release site varied considerably, ranging from 5 to 1,450 m (mean = 159.7 m; sd = 339.5 m; Figure 1). Fish were found at a mean depth of 1.2 m (sd=0.71) and a mean distance offshore of 9.1 m (sd=18.1). All fish were found over a clay substrate. Most fish were found within 1 m of structure (n=15), but some were not (n=2). If fish associated with structure, it was submerged branches (80%) or vegetation (20%).

After January 13, movement was detected in only three fish, and the distances each fish moved during the 4 – 18 d intervals were always less than 10 m. No

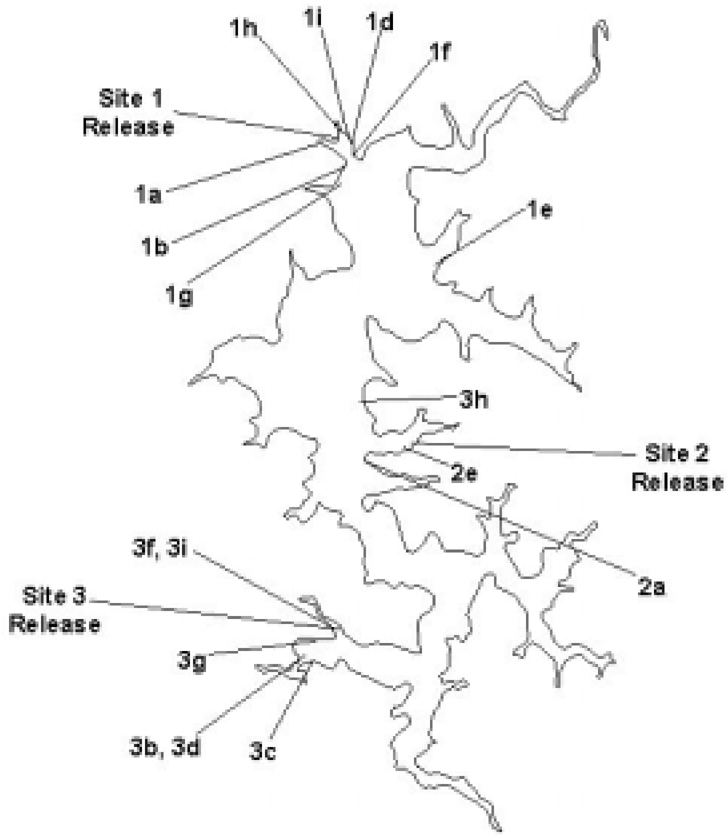

Figure 1. Release sites of 25 telemetered bigmouth sleepers and the locations where 17 fish were located during the first tracking session in Carite Reservoir, 13 January 2001. Ten fish were released from site 1, six from site 2, and nine from site 3. Each number-letter combination represents the location of a unique fish: the number represents the site from which it was released, and the letter represents the order of the fish within each release.

movement by fish was detected after 30 March 2001. Water levels dropped 4 m throughout the spring, so that by the end of April it was suspected that some transmitters were on land. By the end of April, there were nine remaining transmitters being heard in Carite Reservoir, and most of these were being detected on land. Consequently, a small section of a paper clip was used in place of the antennae to reduce the audible detection range. Transmitters could then only be heard in a radius of approximately 1 m. Using this method, six of the nine transmitters that were still functioning were found exposed on land.

There are three possibilities that could explain these events: fish mortalities, rupture of the incision, or transintestinal expulsion. First, it is possible that fish died during the study. Although oxytetracycline was used to prevent infection, it is possible that incisions became seriously infected, the fish died, and their tags remained on the bottom after the carcasses decomposed. Also, the behavior of tagged fish may have been negatively affected by the presence of the transmitter in its abdominal cavity, exposing them to increased predation threat (e.g., ospreys) or reduced feeding opportunities. However, bigmouth sleepers are demersal and cryptic (McKaye 1977, Nordlie 1981) and not expected therefore to be greatly affected behaviorally by the presence of internally-implanted transmitters.

A second possibility is that transmitters were shed due to a rupture of the incision (e.g., Marty and Summerfelt 1986, Lucas 1989). For this to have occurred, the surgical material or procedure would need to have been faulty, creating an open passage for the transmitter to exit through the abdominal wall of the fish. My experiences in the tagging of other species suggests that this is unlikely. In the spring of 2000, 12 largemouth bass (*Micropterus salmoides*) were implanted using identical transmitters and surgical techniques as those used for bigmouth sleepers in this study. Two telemetered largemouth bass were recaptured 2 and 6 weeks after surgery and were healing or had healed well. These fish were located periodically for 20 weeks with no apparent negative physical or behavioral effects caused by the transmitters. Nevertheless, flathead catfish incisions have failed to heal (Bill Pine, pers. comm.). Flathead catfish, which are scale-less, also commonly associate with cover, which could exacerbate suture abrasions. Likewise, bigmouth sleepers may be prone to suture rejection, or the sutures may have been caught and torn on the dense cover in which the fish live. It was unfortunate that no bigmouth sleepers were recaptured during routine intensive shoreline boom electrofishing during the spring of 2001 to verify whether surgical procedures were faulty.

A third possibility that could explain the observed tag loss by bigmouth sleepers is transintestinal expulsion. Transintestinal expulsion of transmitters by fish has been documented by others for African catfish *Heterobranchus longifilis* (Baras and Westerloppe 1999), channel catfish *Ictalurus punctatus* (Summerfelt and Mosier 1984, Marty and Summerfelt 1986, 1990) and rainbow trout *Oncorhynchus mykiss* (Chisholm and Hubert 1985). Usually, transintestinal expulsions were associated with the formation of a capsule that adhered to the intestine, probable rupture of the intestinal wall close to the stomach, the passage of the tag into the lumen of the pyloric intestine, and its expulsion through the anus by peristalsis. Factors known to affect transintestinal explusion are transmitter coating (Helm and Tyus 1992) or the size of the fish relative to tag size (Baras and Westerloppe 1999).

I considered myself to be well-trained in the surgical procedure and had past success using identical surgical techniques with largemouth bass (e.g., no largemouth bass died or were found to suffer ruptured incisions). Before conducting telemetry studies on bigmouth sleepers in the future, preliminary studies should be conducted to identify the processes by which bigmouth sleepers can lose tags, and to mitigate these transmitter losses by evaluating alternative methods. External tagging methods also may be a good alternative to internal tagging of bigmouth sleepers. Holding tank studies are recommended for such evaluations.

REFERENCES

Baras, E., and L. Westerloppe. 1999. Transintestinal expulsion of surgically implanted tags by African catfish *Heterobranchus longifilis* of variable size and age. Transactions of the American Fisheries Society 128: 737-746.

Brown, R.S., S.J. Cooke, W.G. Anderson, and R.S. McKinley. 1999. Evidence to challenge the "2% Rule" for biotelemetry. North American Journal of Fisheries Management 19: 867-871.

Chisholm, A.M., and W.A. Hubert. 1985. Expulsion of dummy transmitters by rainbow trout. Transactions of the American Fisheries Society 114: 766-767.

Gilmore, R.G. 1992. Bigmouth sleeper, *Gobiomorus dormitor*. Pages 105-111 *in* C.R. Gilbert, editor. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, Florida.

Hart, L.G., and R.C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*Pylodictis olivaris*). Transactions of the American Fisheries Society 104: 56-59.

Helm, W.T., and H.M. Tyus. 1992. Influence of coating type on retention of dummy transmitters implanted in rainbow trout. North American Journal of Fisheries Management 12: 257-259.

Lucas, M.C. 1989. Effects of implanted dummy transmitters on mortality, growth and tissue reaction in rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Biology 35: 577-587.

Marty, G.D., and R.C. Summerfelt. 1986. Pathways and mechanisms for expulsion of surgically implanted dummy transmitters from channel catfish. Transactions of the American Fisheries Society 115: 577-589.

Marty, G.D., and R.C. Summerfelt. 1990. Wound healing in channel catfish by epithelialization and contraction of granulation tissue. Transactions of the American Fisheries Society 119: 145-150.

McKaye, K.R. 1977. Competition for breeding sites between the cichlid fishes of Lake Jiloa, Nicaragua. Ecology 58: 291-302.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. Journal of Fish Biology 18: 97-110.

Summerfelt, R.C., and D. Mosier. 1984. Transintestinal expulsion of surgically implanted dummy transmitters by channel catfish. Transactions of the American Fisheries Society 113: 760-766.

Waters, D.S. 1999. Spawning season and mortality of adult largemouth bass (*Micropterus salmoides*) in a tropical reservoir. Master's thesis. North Carolina State University, Raleigh, North Carolina.

Winter, J.D. 1983. Underwater biotelemetry. Pages 371-395 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Winter, J.D. 1996. Advances in underwater biotelemetry. Pages 555-590 *in* B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd Edition. American Fisheries Society, Bethesda, Maryland.