Spatial and temporal distributions of young-of-year fish in Carite Reservoir, Puerto Rico

By

Michael Clinton Lloyd

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Wildlife, Fisheries, and Aquaculture
in the Department of Wildlife, Fisheries and Aquaculture

Mississippi State, Mississippi

May 2014

Spatial and temporal distributions of young-of-year fish in Carite Reservoir, Puerto Rico

By

Michal Clinton Lloyd

Approved:

Jason Wesley Neal
(Major Professor)

Robert Kröger
(Committee Member)

Eric D. Dibble
(Committee Member/Graduate Coordinator)

George M. Hopper
Dean
College of Forest Resources

Name: Michael Clinton Lloyd

Date of Degree: May 16, 2014

Institution: Mississippi State University

Major Field: Wildlife, Fisheries, and Aquaculture

Major Professor: J. Wesley Neal

Title of Study: Spatial and temporal distributions of young-of-year fish in Carite Reservoir, Puerto Rico

Pages in Study: 54

Candidate for Degree of Master of Science

Information regarding spatiotemporal trends in young-of-year (YOY) fish distributions gives managers insight into recruitment and ultimately adult population variability. In Puerto Rico, limited research has been conducted on YOY distributions with no studies addressing reservoir systems. A comparison of the efficacy of two sampling gears and an assessment of spatiotemporal distributions of YOY fish communities in a tropical reservoir were conducted. Diversity of catch between push nets and offshore light traps were similar, though species composition of catch was different between gears. Inshore light traps collected greater total numbers and diversities of the YOY fish community than offshore traps in spring and summer seasons. Catch per unit effort was greater in the spring for inshore traps whereas CPUE was greater in offshore traps in the fall. These results will allow managers to coordinate YOY fish sampling efforts for specific species with periods of peak abundance and preferred habitat.

DEDICATION

I would like to dedicate this thesis to my best buddy and companion, who has seen me through it all; my big burly boxer, Zeus.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to Cynthia Fox and Milton Munoz, for endless nights on the reservoir and for making this research possible, Dr. Wes Neal for giving me the opportunity to conduct this research, my committee members Dr. Jackson, Dr. Kröger and Dr. Dibble as well as colleges Karina Olivieri, Nick Peterson and Samuel Garcia. Special thanks to Zac Loman and Dr. Steve Miranda for guidance with statistical analysis. I would also like to thank the Puerto Rico Department of Natural and Environmental Resources, as well as, U.S. Fish and Wildlife Sport Fish Restoration for funding this project (SFR Project F-53R).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

YOUNG-OF-YEAR FISH IN PUERTO RICO RESERVOIRS

The first year of fish development is a critical period that is often poorly understood. During this period, ontogenetic changes occur rapidly as fish develop from endogenous feeding yolk-sac larvae to exogenous feeding pre- and post-flexon larvae through finfold absorption and fin ray development in juvenile fish (Kelso and Rutherford 1996). Combined, all of these early life stages can be considered young-of-year (YOY) fish (Ahlstrom et al. 1976; Hardy et al. 1978). Spatial and temporal distributions of YOY fish are an important consideration for understanding community structure and function of fish populations, and these factors are paramount to understanding recruitment variability in early life stages of fishes (Quist et al. 2004). By understanding spatial and temporal trends of YOY fish distributions in tropical reservoirs, managers can plan larval and juvenile fish sampling according to time of spawning and habitat use per species in which they are interested. In addition, YOY fish sampling can answer questions about ecological interactions among YOY fish and how these interactions are influenced by their environment. This knowledge can save management agencies both time and effort.

Young-of-year fish sampling has received a great deal of attention in recent decades as a tool for predicting recruitment success and year-class strength of cohorts within managed fish populations. Due to the heterogeneity of YOY fish distributions, sampling with even the least biased methods can produce great variability in population estimates (Cyr et al. 1992). Until recent years, YOY fish sampling was typically conducted primarily on a species-specific basis, making it difficult to integrate existing information on YOY fish ecology and its relationship to survival and recruitment (Miller et al. 1988). This is especially true in tropical reservoirs, as the research base on young-of-year (YOY) fish distributions within tropical reservoirs is limited.

In Puerto Rico, most larval fish studies have focused on estuarine (Stoner 1986; Cook et al. 2009) or stream environments (Holmquist et al. 1998; Neal et al. 2012). No prior research has addressed YOY fish sampling, production, or distributions in the reservoirs of Puerto Rico, with the exception of YOY Largemouth Bass *Micropterus salmoides* (Churchill et al. 1995; Ozen 2002). To address this knowledge gap, I compared YOY fish sampling techniques and assessed the seasonality and habitat use of YOY fish in tropical reservoirs. Additionally, I correlated water quality parameters to YOY fish distributions, to determine environmental factors that could influence YOY fish spatial and temporal distributions. Working under the hypothesis that YOY fish distributions are spatially and temporally heterogeneous by nature, the first objective of this study was to compare the relative selectivity of an active and a passive method of collecting YOY fish in Carite Reservoir, Puerto Rico. The second objective was to describe spatial and temporal trends in YOY fish distributions in Carite Reservoir. The third objective assessed spatial and temporal trends in YOY fish distributions in relation to water quality parameters in Carite Reservoir.

This thesis consists of this introductory chapter, two chapters to address the research objectives, and a synthesis chapter that includes management recommendations.

Chapter 2 explores the use of different types of YOY sampling gears in their ability to efficiently capture YOY fish in a tropical reservoir. Active bongo style push nets and passive larval light traps were used to address questions about gear sampling efficacy for the YOY fish community in limnetic habitats. Chapter 3 investigates seasonality and habitat use by the YOY fish community. Light traps were used to compare littoral and limnetic habitats within three reservoir basins through the course of a year. Abiotic factors were measured concurrently to assess potential influences to YOY fish distributions. The final chapter synthesizes the results of this study and proposes management recommendations and future research for YOY fish sampling in tropical reservoirs.

References

Ahlstrom, E.H., J.L. Butler, and B.Y. Sumida. 1976. Pelagic stromateoid fishes (Pisces, Perciformes) of the eastern Pacific: kinds, distributions, and early life histories and observations on five of these from the northwest Atlantic. Bulletin of Marine Science 26:285-402.

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-16-2. Puerto Rico Department of Natural and Environmental Resources.

Cook, B.D., S. Bernays, C.M. Pringle, J.M. Hughes. 2009. Marine dispersal determines the genetic population structure of migratory stream fauna of Puerto Rico: evidence for island-scale population recovery processes. Journal of the North American Benthological Society 28:709-718.

Cyr, H., J.A. Downing, S. Lalonde, S.B. Baines, and M.L. Pace. 1992. Sampling larval fish populations: choice of sample number and size. Transactions of the American Fisheries Society 112:280-285.

Hardy, J.D., G.E. Drewry, R.A. Fritzche, G.D. Johnson, P.W. Jones, and F.D. Martin. 1978. Development of fishes of the Mid-Atlantic Bight, an atlas of eggs, larvae, and juvenile stages, volumes 1-6. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-78/12.

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, W.E., and D.A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255-302 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Miller, T.J., L.B. Crowder, J.A. Rice, and E.A. Marschall. 1988. Larval size and recruitment mechanisms in fishes: toward a conceptual framework. Canadian Journal of Fisheries and Aquatic Sciences 45:1657-1670.

Neal, J.W., C.M. Adelsberger and S.E. Lochmann, 2012. A comparison of larval fish sampling methods for tropical streams. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4:23-29.

Ozen, O. 2002. Population dynamics of Largemouth Bass in Lucchetti Reservoir, Puerto Rico. Ph.D. dissertation, Zoology, North Carolina State University.

Quist, M.C., K. R. Pember and C.S. Guy. 2004. Variation in larval fish communities: implications for management and sampling designs in reservoir systems. Fisheries Management and Ecology 11: 107-116.

Stoner, A.W. 1986. Community structure of the demersal fish species of Laguna Joyuda, Puerto Rico. Estuaries 9:142-152.

CHAPTER II

COMPARISON OF ACTIVE AND PASSIVE YOUNG-OF-YEAR FISH SAMPLING GEARS IN A TROPICAL RESERVOIR

Introduction

Young-of-year (YOY) fish sampling can be conducted with active and passive sampling methods, each with a number of different gears. Active YOY sampling methods include seining, trawling, electrofishing, plankton net tows, and pumping (Kelso and Rutherford 1996). Though efficiency of these methods has improved greatly since the beginning of use in the early 1800's, some drawbacks to active sampling include the possibility of damaging larval specimens and high operational cost, including significant labor requirements and increasing fuel costs. Passive YOY fish sampling methods include drift sampling, activity traps, and light traps. Passive gears are less expensive and require less operational costs than active gears (Kelso and Rutherford 1996). However, passive gears are stationary and selective, requiring larvae to encounter the gear through normal activity or by attracting the specimens.

Push nets, similar to plankton tow nets, mounted to the bow of a boat and actively fished, can be used to effectively sample both limnetic and littoral larval fish communities (Claramunt et al. 2005). Compared to traditionally towed nets of the same size, push nets show higher efficiency and effectiveness in collecting YOY fishes (Claramunt et al. 2005; Overton and Rulifson 2007; Fryda et al. 2008). Light traps are a passive gear that has been described as "selective but useful devices" for sampling larval fishes (Doherty 1987). While light trap utility may be limited in determining associated YOY fish densities, they can be an effective means of determining species presence or absence and relative abundance (Niles and Hartman 2007). Furthermore, Neal et al. (2012) successfully used light traps to sample larvae in Puerto Rico streams, including larvae and juveniles of native fish species.

Due to the paucity of information regarding gear selectivity by YOY fishes within Puerto Rico reservoirs, this research was designed to determine the efficacy of push nets and light traps in sampling the YOY fish community in Carite Reservoir. This research aimed at setting the foundation of YOY fish sampling in Puerto Rico by evaluating gear selectivity and describing seasonality of YOY fish distributions within limnetic habitats of a tropical reservoir.

Methods

Study Site

Located in the mountainous south-central region of Puerto Rico, Carite Reservoir (18º04'N and 66º05'W) is a 124-ha impoundment on the La Plata River, formed by the construction of an earthen dam in 1913 (Figure 2.1). The reservoir elevation is 543.6 m above mean sea level at full pool. The drainage area of Carite Reservoir is comprised mainly of forest and encompasses 21.2 km^2 (Carvajal-Zamora 1979). Today Carite Reservoir provides water and electricity to meet the demands for domestic, industrial and agricultural needs in the area.

Sampling Gears

One active and one passive gear type was chosen for YOY sampling comparison. Light traps were used as the passive gear and push nets were used as the active gear. Light traps were chosen because of their previously reported success for sampling Puerto Rico fishes (Neal et al. 2012), and push nets were chosen based on higher efficiencies and ease of use by a two-member crew (Claramunt et al. 2005; Overton and Rulifson 2007). The selected light traps were modified quatrefoil traps (Aquatic Research Instruments, Hope, ID, USA) that consisted of an acrylic trapping assembly with an internal polycarbonate tube where the light source was located. The units were 30 × 30 × 25 cm (length-width-height) and had a 7-mm gap on all four sides to allow organisms inside the trap (Figure 2.2). YOY fish were collected at the bottom of the trap in a 250 µm mesh plankton sock. The light source inside was a submersible battery powered LED dive light. A battery-powered source of light was chosen over chemical light sticks due to diminishing luminance found in chemical light sticks for sample periods exceeding 1 h (Kissick 1993).

The push nets were paired 0.5 m diameter bongo-style plankton nets. Nets were composed of 200 µm mesh and measured 2 m in length. This mesh size was chosen for the possibility of catching yolk-sac larvae. The terminal end of the net was fitted with an 11-cm diameter removable PVC collection cup, also fitted with 200 µm mesh. The push-nets were deployed from a boom system 1.5 m off the bow of the boat, and approximately 1 m below the surface of the water. The boom was designed to allow the push-nets to be pulled from the water to empty the collection cups after a push sample was completed. Push net hauls were conducted at a speed of approximately 1 m/s, measured with a handheld GPS unit, in an attempt to preserve yolk-sac larvae (Colton et al. 1980; Claramunt et al. 2005). Colton et al. (1980) showed that sampling bongo-style push nets at slower towing speeds, which in turn lessens filtration pressure, increased undamaged yolk-sac larvae by almost fifty percent.

Pilot Study

When estimating larval and juvenile fish population abundances, it is important to be both accurate (unbiased) and precise (low variance; Cyr et al. 1992). Therefore, a preliminary study was conducted in December 2010 to determine the coefficient of variation (CV) for different time intervals of push net hauls. Push net hauls were conducted for time intervals of 1, 2.5, 5, 7.5, 10, and 15 min. The order in which the time intervals were sampled was chosen at random. Three replicates of each time interval were conducted throughout the night. Paired push nets were treated independently for each of the 18 hauls (N=36).

Young-of-year fish were only caught in 5, 10 and 15-min hauls. Of the 36 total replicates, a total of 8 larval fish were collected. Low catch rates were presumably due to time of year, which was likely outside of the spawning seasons of most species present. Though this is not a large number of larvae, standard error from the mean and CV were still possible. Duration of bongo-push net sampling was set at 10 minutes because the CV during the pilot study was less than 0.5 for 10 minute hauls (Figure 2.3; Cyr et al. 1992).

Larval Fish Collection

Young-of-year fish samples were collected from Carite Reservoir every other week over the course of one year (N= 26). The reservoir was stratified into three sections:

a lower section at the dam and two upper arms. Both gear types were sampled in limnetic habitats within each reservoir section. Limnetic sites were chosen in open water habitats greater than 25 m from shore, with a depth > 5 m.

Twelve sites were chosen *a priori* for gear comparison for limnetic habitats within each section of reservoir (Figure 2.4). Prior to each sampling event, two sites were randomly chosen in each section of reservoir for light trap sampling, and one site was chosen at random in each section for push net hauls.

Young-of-year fish collection was conducted at night for proper function of light traps and to reduce visual avoidance of push nets (Tischler et al. 2000; Fryda et al. 2008). Light traps were set at sunset (1800 h), and samples were collected at 6 h intervals, with first collection at midnight (0000 h) and final retrieval at sunrise (0600 h). One push net haul was conducted per section during each 6 h light trap set. GPS coordinates were recorded at the start and end of each haul to give a total distance traveled, allowing for an estimate of the total volume of water filtered through push nets.

Young-of-year fish were sacrificed, fixed in 10% formalin and returned to the field station for analysis (Kelso and Rutherford 1996). Specimens were counted, measured for total length and identified to the species using larval and juvenile taxonomic keys (Auer 1982; Wang and Reyes 2008). Various morphological (myomere and fin ray counts) and meristic (photophore and melanophore pigmentation) measurements were used to identify YOY fish (Fig. 2.5; Auer 1982).

Analysis

Frequencies of relative species composition of catch, species diversity using the Shannon-Wiener Index, and species evenness were compared to determine efficacy of sampling gears. Catch rates of light traps and push-nets could not be compared directly because the volume of water that light traps sample is unknown.

Relative species composition matrices were constructed by summing the total number of fish by species, caught by a particular gear, within each section of reservoir, by season. Total number of species was then divided by the total sum of fish caught by each gear, per section, per season. This resulted in matrices constructed of relative percent of fish species within each section of reservoir for each season. Biweekly samples were combined into four calendar seasons; spring (March-May), summer (June-August), fall (September-November) and winter (December-February).

Non-metric multidimensional scaling (NMDS) ordination based on Bray-Curtis similarities was used to visually depict similarities in relative percent frequency of species composition between gears and among seasons. Non-metric multidimensional scaling is an indirect gradient analysis that maximizes rank-order correlations between distance measures and distance in ordination space. Permutational multivariate analysis of variance (PERMANOVA) was used to determine differences between gears and seasons based on relative percentage of species compositions (R 2.15.1; R core development team 2013). Generalized linear mixed models were constructed to determine differences in diversity indices and evenness of catch between gears and among seasons and reservoir sections (SAS 9.2; SAS Institute, Cary, NC. USA).

Results

Light traps and push nets each collected a total of eight species of YOY fish in limnetic habitats. All sunfish (*Lepomis spp.)* were combined due to overlapping meristic and morphometric measurements of the genus. Push nets and light traps collected a total of 1,231 and 289 YOY fish respectively, from June 2011 to June 2012. Push nets sampled a total volume of 19,237 m^3 of water, averaging 64.3 ± 0.4 m^3 per net haul. Push net catches were dominated by Threadfin Shad *Dorosoma petenense*, comprising 94.2% of total catch, with Channel Catfish *Ictalurus punctatus* having the next largest percentage of total catch at 2.9% (Table 2.1; Figure 2.6). Light trap catches were dominated by Channel Catfish (76.8%) and Threadfin Shad (13.8%), which comprised approximately 90% of the total catch (Table 2.1; Figure 2.6).

Young-of-year fish communities showed strong groupings of gear types in the NMDS ordination (Stress: 0.0816; R^2 Axis 1: 0.7271 Axis 2: 0.1723; Figure 2.7). Push nets grouped tightly on axis 1 and axis 2 with axis scores ranging from 0.06 to 0.20 (range = 0.14) and -0.07 to -0.01 (range = 0.06), respectively. The tightness of the push net grouping shows similarity in species composition caught with this gear. Threadfin Shad had a 0.90 correlation with axis 1 in the positive direction that strongly influenced the push net grouping. Centrarchids (*Lepomis spp.* and Largemouth Bass *Micropterus salmoides*) only correlated 0.30 and 0.24 on axis 1, due to low numbers caught in either gear, but potentially influenced the push net grouping.

Light traps did not show as tight a group with axis scores ranging from -0.24 to 0.20 (range = 0.44) and -0.06 to 0.37 (range = 0.31) on axes 1 and 2, respectively. Channel Catfish had a strong correlation of 0.97 on axis 1 in the negative direction, and had a strong influence on light trap grouping. However, White Catfish *Ictalurus catus*, Redbreast Tilapia *Tilapia rendalli*, Tiger Barb *Puntius tetrazona* and Amazon Sailfin Catfish *Pterygoplichthys pardalis* also correlated with axis 1 in the negative direction (-

0.28, -0.24, -0.11, and -0.10, respectively). The multitude of species influencing light traps did not allow as tight a grouping as push nets.

Because NMDS ordination is a tool to visualize differences in YOY fish communities sampled with the different gears, PERMANOVA was used to determine actual differences in YOY fish sampled by the different gears. Although push nets and light traps sampled the same species, the relative frequency of species composition of catches differed between gears (pseudo-$F_{1,23} = 32.21$; $P < 0.001$) and among seasons (pseudo-$F_{3,23} = 4.29$; $P < 0.006$), validating the differences observed in the NMDS ordination.

Shannon-Wiener diversity indices also differed between gears ($F_{1,583} = 10.97$; $P < 0.001$), but showed no difference among seasons ($F_{3,8} = 3.36$; $P > 0.07$), reservoir sections ($F_{2,6} = 0.48$; $P > 0.64$) or when the effects of gear and season were combined ($F_{3,583} = 1.54$; $P > 0.20$). Post-hoc analysis using differences in least squared means indicated push nets had greater diversities than light traps during the summer ($P < 0.005$) and fall ($P < 0.013$; Figure 2.8). Light traps, however, consistently caught a greater variety of the larval fish community with post-hoc comparisons of least squared means indicating greater evenness for spring ($P < 0.001$), summer ($P < 0.001$) and winter ($P < 0.032$; Figure 2.9).

Discussion

Push nets and light traps successfully captured the same eight species, albeit in different proportions. Push nets collected almost four times the total number of YOY fish, although both gears had low diversities due to Threadfin Shad and Channel Catfish comprising over 90% of the total catch. Push nets almost exclusively collected Threadfin

Shad and less than 6% of the total catch was the remaining seven species. Diversities were greater for push nets compared to light traps in summer and fall seasons, but this could be attributed to 80% of light traps being empty during the summer and catch being comprised mostly of Channel Catfish in the fall.

Diversity in this study was much lower than reported in Neal et al. (2001), who sampled littoral fish communities in Carite Reservoir using boom-mount and hand-held electrofishing systems. Excluding lepomids, which were not identified to species, five of the seven species collected by these two gears represented only 45% of the non-lepomid species reported previously. There were six species collected in 2001 that were not found in the present study, Bigmouth Sleeper *Gobiomorus dormitor*, Mozambique Tilapia *Oreochromis mossambicus*, Butterfly Peacock Bass *Cichla ocellaris*, Southern Platyfish *Xiphophorus maculatus*, Western Mosquitofish *Gambusia affinis*, and Rosy Barb *Pethia conchonius*. Conversely, the current study collected two species that were not reported in the previous study, these species were Amazon Sailfin Catfish and Tiger barb. The discrepancies between the two studies were likely due to differences in life stage and habitat sampled, as the current study targeted exclusively YOY fishes in limnetic habitat. However, the absence of Amazon Sailfin Catfish and Tiger Barbs in 2001 may indicate that these two species have more recently colonized the reservoir.

Threadfin Shad are considered the principal prey species to sport fish in Puerto Rico reservoirs (Neal et al. 2011), and push nets were the clear choice for collecting this species. Push nets collected about 29 times more Threadfin Shad than light traps with considerably less effort. Furthermore, bycatch was much lower in push nets compared to light traps (5.9% versus 86.2%, respectively). Prchalová et al. (2012) reported similar findings when they compared frame trawls, an active gear, to gillnets, a passively fished gear. Although seasonal differences were not statistically significant for push nets, this was likely due to large variability in catch. Distinct trends of greater catch of YOY Threadfin Shad during the spring season that sequentially decreased through the following seasons were apparent, with an eight-fold decrease in absolute catch between spring and combined fall/winter seasons. These trends were similar to Neal and Prchalová (2012), who reported greatest abundances of larval shad in the spring in Puerto Rico reservoirs. Based on the findings of the current study, targeted sampling of Threadfin Shad YOY should utilize push nets during the spring for maximization of larval catch.

Light trap catches had greater species evenness in comparison to push nets, although their efficiency is limited to presence/absence of species because the numbers of YOY fish caught would not be sufficient for attempting abundance estimates (Doherty 1987). As with push nets, trends in light trap catch indicated greater numbers of YOY fish being caught in spring and summer seasons, concurrent with primary spawning seasons of many species. There is, however, an exception to these trends, with Channel Catfish catch peaking in both spring and fall seasons, with greatest abundances being caught during fall. This is inconsistent with the literature in that typically Channel Catfish start spawning earlier in the year (March) at lower latitudes and later in the year (July) at higher latitudes, but do not display more than one spawning season (Stevens 1959; Hubert and O'Shea 1991). Further discussion of this phenomenon is presented with spatiotemporal analyses in Chapter 3.

There are potential biases with sampling the YOY fish community with push nets. Visual avoidance of the gear has been determined to affect sizes of YOY fish captured with push nets (Brander and Thompson 1989; Hickford and Schiel 1999), and although samples were collected at night in attempt to lessen visual avoidance, targeted fish potentially possessed the ability to avoid the nets. Back filtration pressure within the nets could also contribute to possible gear bias. Large numbers of phytoplankton were often collected that potentially lessened filtration ability of the nets causing back pressure to build. A flow meter, mounted inside the mouth of the nets would provide greater accuracy of the volume of water filtered than my volumetric estimation method, as well as indicate if nets were filtering at their greatest capacity (Claramunt et al. 2005).

Both gears efficiently sampled different aspects of the YOY fish community within Carite Reservoir. Due to the style of gear (active or passive) and the proportions of the YOY fish community sampled, these two gears are not interchangeable. Selection and use of either of these gears should be based on the research goals and questions to be answered from fisheries managers in Puerto Rico. The use of both gears concurrently would give a more complete picture of YOY fish communities that inhabit limnetic habitats, as well as help to alleviate existing selectivity biases (Gregory and Powles 1988; Hickford and Schiel 1999). Due to the complexity of littoral habitat in Carite Reservoir, push net samples were only conducted in limnetic habitats of the reservoir. The next chapter investigates YOY habitat usage in limnetic and littoral habitats with the use of light traps.

Tables and Figures

Table 2.1 Total catch of young-of-year fish caught in light traps and push nets in limnetic habitats.

	Light Traps		Push Nets	
Taxon	**n**	**%**	**n**	**%**
Centrarchidae				
Micropterus salmoides	4	1.38	3	0.24
Lepomis spp.	1	0.35	15	1.22
Cichlidae				
Tilapia rendalli	8	2.77	1	0.08
Clupeidae				
Dorosoma petenense	40	13.84	1,159	94.15
Cyprinidae				
Puntius tetrazona	1	0.35	2	0.16
Ictaluridae				
Ictalurus punctatus	222	76.82	36	2.92
Ameiurus catus	4	1.38	1	0.08
Loricariidae				
Pterygoplichthys pardalis	9	3.11	14	1.14
All taxa	289		1,231	

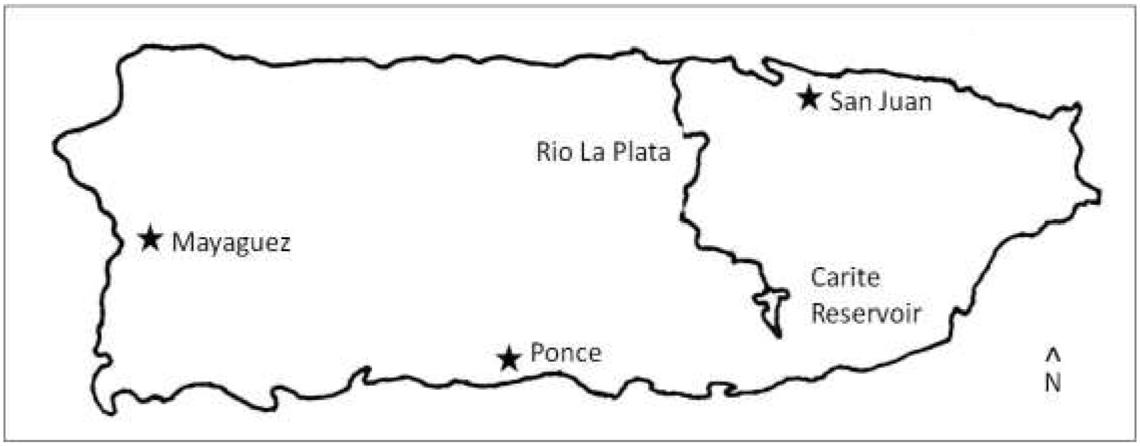

Figure 2.1 Location of Carite Reservoir on the La Plata River.

Figure 2.2 Modified quatrefoil light trap.

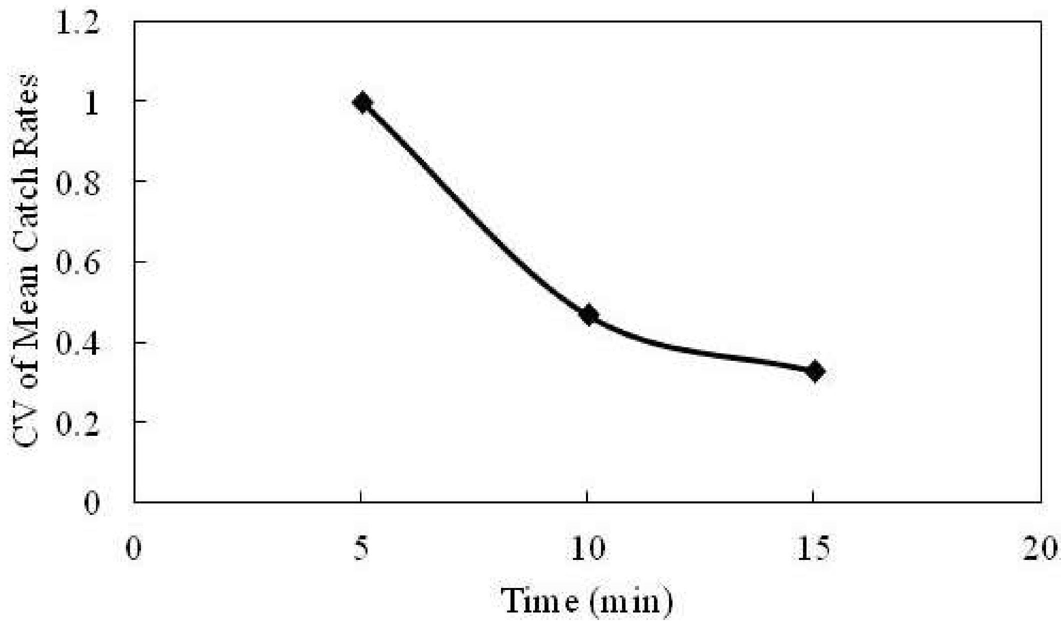

Figure 2.3 Coefficient of variation of mean catch rates of YOY fish for different tow durations of push nets.

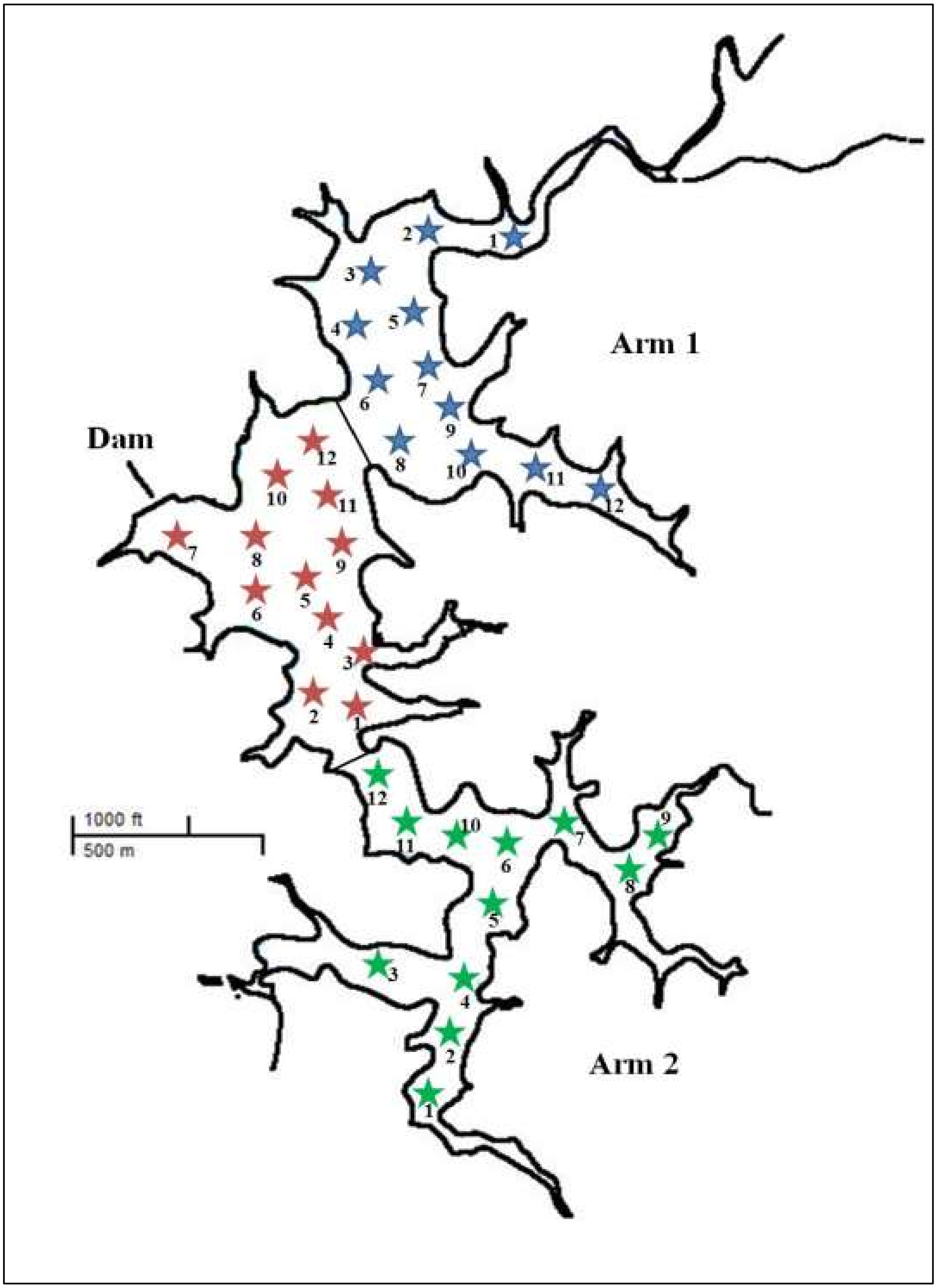

Figure 2.4 Limnetic sampling sites for sampling YOY fish community with light traps and push nets.

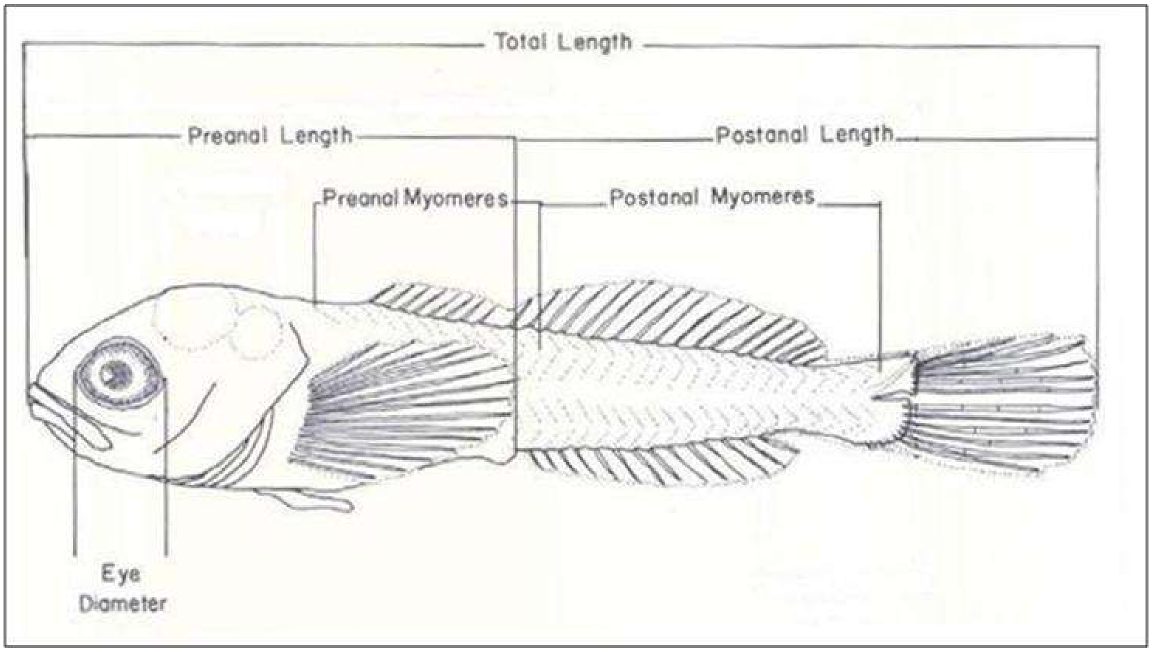

Figure 2.5 Diagrammatic representation of teleost larvae.

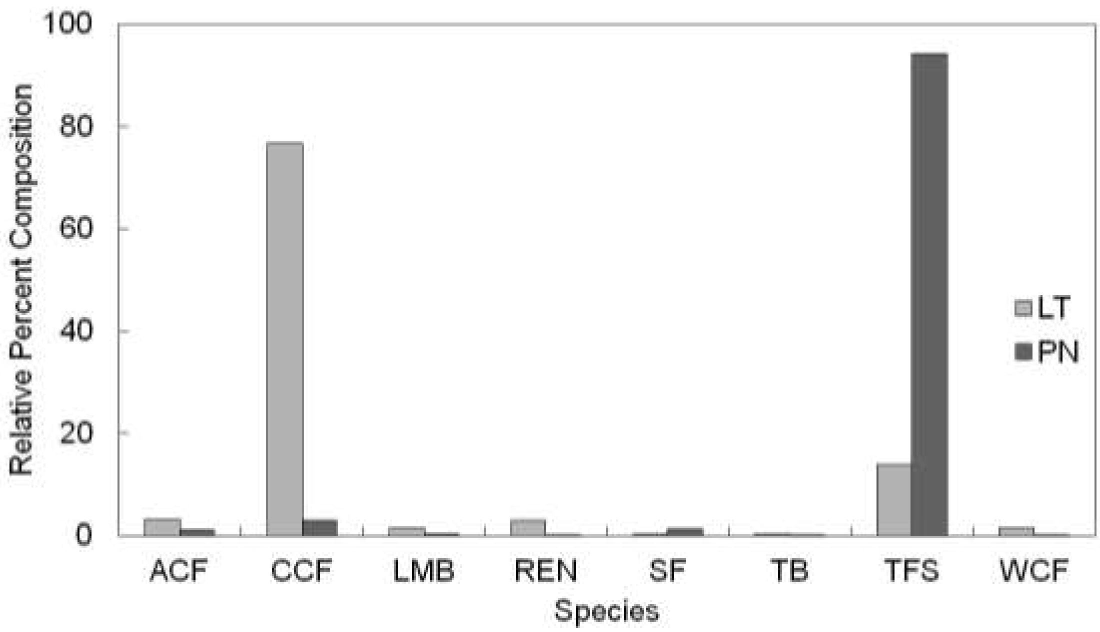

Figure 2.6 Relative percent composition of total catch from limnetic push nets and light traps.

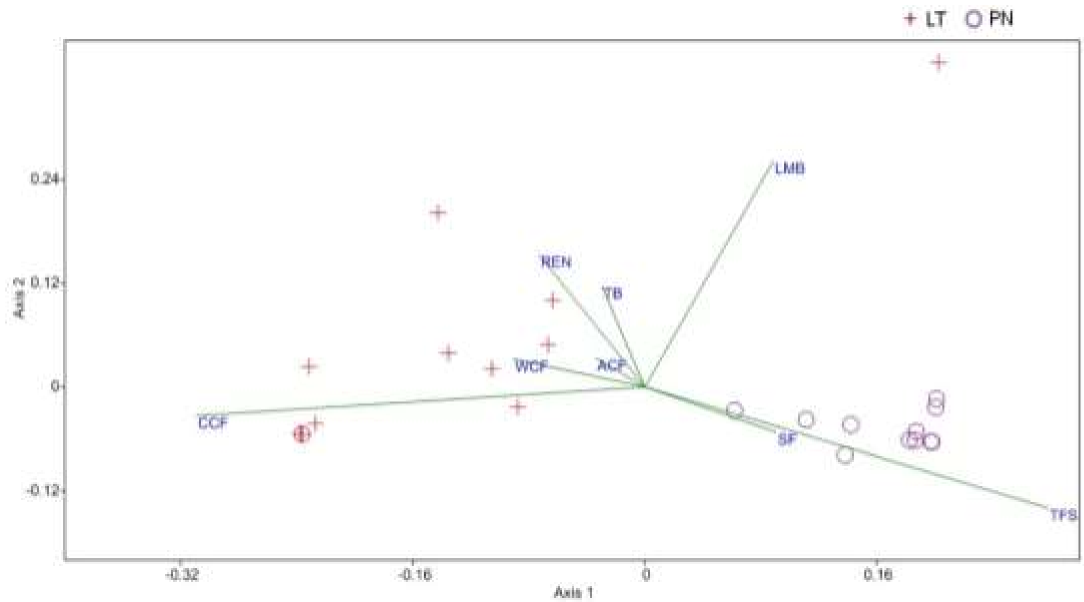

Figure 2.7 NMDS ordination of the relative percent composition of limnetic YOY fish communities sampled with light traps (circles) and push nets (crosses).

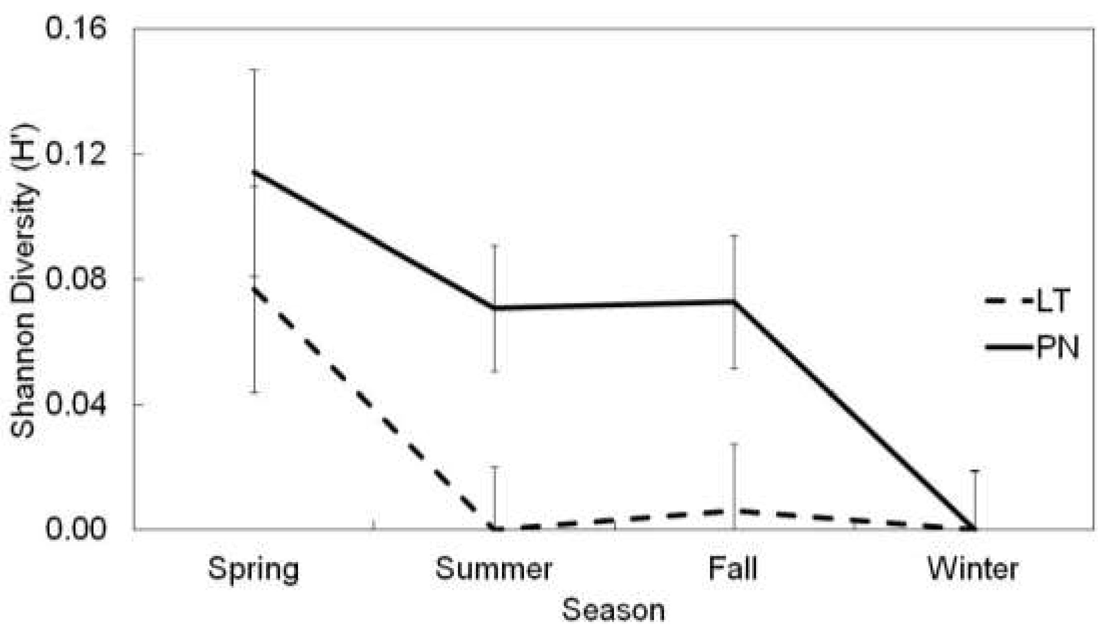

Figure 2.8 Mean ± S.E. diversity of limnetic YOY catch for light traps (LT) and push nets (PN).

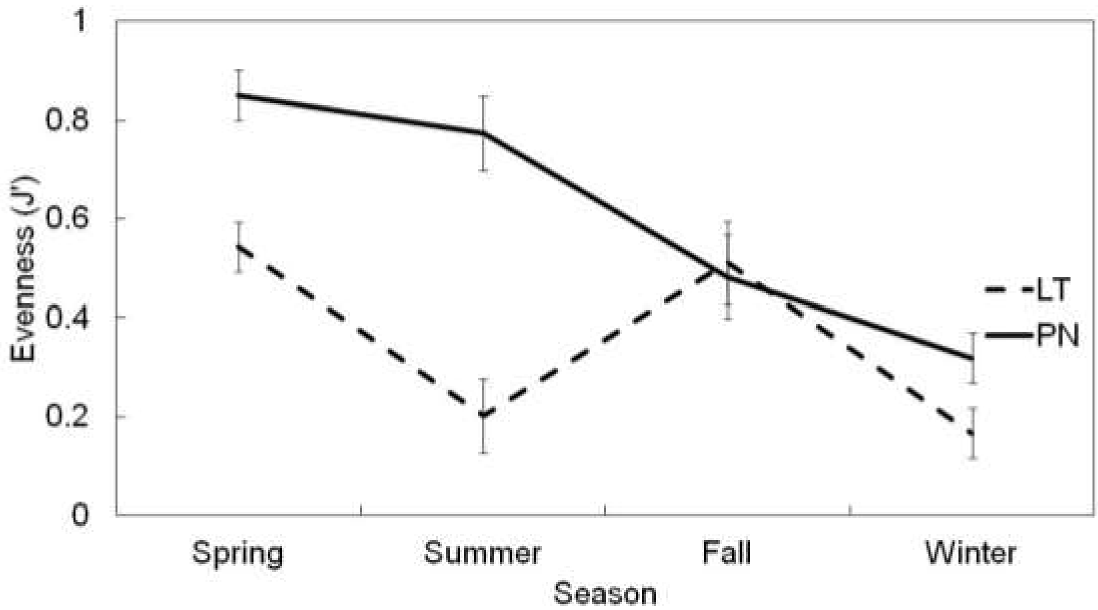

Figure 2.9 Mean ± S.E. evenness of limnetic YOY catch for light traps (LT) and push nets (PN).

References

Auer, N.A. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, Special Publication 82-3, Ann Arbor, Michigan.

Brander, K. and A.B. Thompson. 1989. Diel differences in avoidance of three vertical profile sampling gears by herring larvae. Journal of Plankton Research 11:775-784.

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.

Claramunt, R.M., D.E. Shoup, and D.H. Wahl. 2005. Comparison of push nets and tow nets for sampling larval fish with implications for assessing littoral habitat utilization. North American Journal of Fisheries Management 25:86-92.

Colton, J.B. Jr., J.R. Green, R.R. Byron, and J.L. Frisella. 1980. Bongo net retention rates as effected by towing speed and mesh size. Canadian Journal of Fisheries and Aquatic Sciences 37:606-623.

Cyr, H., J.A. Downing, S. Lalonde, S.B. Baines, and M.L. Pace. 1992. Sampling larval fish populations: choice of sample number and size. Transactions of the American Fisheries Society 112:280-285.

Doherty, P.J. 1987. Light-traps: selective but useful devices for quantifying the distributions and abundances of larval fishes. Bulletin of Marine Science 41:423-431.

Fryda, N.J., K.D. Koupal, and W.W. Hoback. 2008. Assessment of larval crappie (*Pomoxis* spp.) abundance and lengths in day and night push net collections from coves. Journal of Freshwater Ecology 23:529-535.

Gregory, R.S. and P.M. Powles. 1988. Relative selectivities of Miller high-speed samplers and light traps for collecting ichthyoplankton. Canadian Journal of Fisheries and Aquatic Sciences 45:993-998.

Hickford, M.J. and D.R. Schiel. 1991. Evaluation of the performance of light traps for sampling fish larvae in inshore temperate waters. Marine Ecology Progress Series 186:293-302.

Hubert, W.A. and D.T. O'Shea. 1991. Reproduction by fishes in a headwater stream flowing into Grayrocks reservoir, Wyoming. Prairie Naturalist 23:61-68.

Kelso, W.E., and D.A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255-302 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Kissick, L.A. 1993. Comparison of traps lighted by photochemicals or electric bulbs for sampling warmwater populations of young fish. North American Journal of Fisheries Management 13:864-867.

Neal, J.W., C.M. Adelsberger and S.E. Lochmann. 2012. A comparison of larval fish sampling methods for tropical streams. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4:23-29.

Neal, J. W. and M. Prchalová. 2012. Spatiotemporal distributions of Threadfin Shad in tropical reservoirs. North American Journal of Fisheries Management 32:929-940.

Neal, J.W., C.G. Lilyestrom, M. Muñoz-Hincapié, M. Prchalová, T. Jůza, M. Říha, and J. Kubečka. 2011. Threadfin shad prey production in tropical reservoirs, study 5. SFR Project F-53R Freshwater Sport Fish Management and Enhancement Final Report. Puerto Rico Department of Natural and Environmental Resources, San Juan.

Neal, J.W., R. L. Noble, C. G. Lilyestrom, N. M. Bacheler, and J. C. Taylor. 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.

Niles, J. M. and K. J. Hartman. 2007. Comparison of three larval fish gears to sample shallow water sites on a navigable river. North American Journal of Fisheries Management 27:1126-1138.

Overton, A. S., and R. A. Rulifson. 2007. Evaluation of plankton surface pushnets and oblique tows for comparing the catch of diadromous larval fish. Fisheries Research 86:99-104.

Prchalová, M., J.W. Neal, M. Munoz-Hincapie, T. Juza, M. Riha, J. Peterka and J. Kubecka. 2012. Comparison of gill nets and fixed-framed trawls for sampling Threadfin Shad in tropical reservoirs. Transactions of the American Fisheries Society 141:1151-1160.

Stevens, R.E. 1959. The white and channel catfishes of the Santee-Cooper Reservoir and tailrace sanctuary. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 13:203-219.

Tischler, G., H. Gassner and J. Wanzenbock. 2000. Sampling characteristics of two methods for capturing age-0 fish in pelagic lake habitats. Journal of Fish Biology 57:1474-1487.

Wang, J.C.S. and R.C. Reyes. 2008. Early life stages and life histories of Centrarchids in the Sacramento-San Joaquin River Delta System, California. Tracy Fish Facility Studies California.

CHAPTER III

SPATIOTEMPORAL TRENDS OF THE YOUNG-OF-YEAR FISH COMMUNITY IN A TROPICAL RESERVOIR

Introduction

Distributions of larvae and juvenile fish vary spatially and temporally in nature (Chambers and Trippel 1997). Duration of spawning season can vary from a few days to many months, and there can be seasonal variability of spawning intensity due to density independent factors such as rainfall, floods, and droughts (Kelso and Rutherford 1996). Furthermore, abiotic and biotic factors can have profound effects on the productivity of lentic systems and their biota, and these factors vary through space and time. These chemical and physical characteristics create the abiotic framework in which different species can survive, grow, and reproduce. All of these factors influence the decision making process of researchers and managers regarding when, where, and how to sample young-of-year (YOY) of individual fish species, and the community as a whole.

Temperature is a physical characteristic that limits where species can exist. Changes in water temperature, coupled with changes in other abiotic factors, such as hydrology, can induce certain fish species to spawn or influence the success of recruitment by YOY fishes (Kjesbu 1994; Nunn et al. 2007). Temperature can also limit growth or survival in YOY fishes, ultimately affecting recruitment success (Saksena et al. 1972; Uphoff 1989).

Another factor to consider is reservoir productivity as determined by nutrient availability. Productivity determines plant growth and, subsequently, biomass availability at higher trophic levels. Eutrophic conditions provide greater biomass of forage for planktivorous organisms (Gonzalez et al. 2010), and this energy can move via a 'bottom-up' effect, increasing biomass of organisms at higher trophic states (Allen et al. 1999). Conversely, excessively elevated nutrient input and associated trophic state can lead to water quality deterioration and reduced habitat suitability for many species (Smith et al. 1999; Boesch 2002).

A major source of mortality for fish during early life stages is predation (Kim and DeVries 2001; Legler et al. 2010), and faster-growing larvae may be better able to avoid predation and realize stronger recruitment success (Mills and Mann 1985). Date of hatch can affect larval growth rates and survival. Santucci and Wahl (2003) suggested that predation is an important mechanism regulating the recruitment success of young bluegill *Lepomis macrochirus*, and that fish spawned earlier in the season experienced higher mortality than those spawned later. Intraspecific and interspecific competition can greatly affect the survival and distributions of YOY fishes, as organisms share both space and resources within a system. Intense competition among YOY fishes can suppress prey populations, increasing variability in growth and survival of YOY fishes (Mittelbach 1988; Garvey and Stein 1998; Welker et al. 1994). Both predation risk and competitive interactions are regulated, in part, by hatching chronology and growth rates.

Fisheries managers need to have accurate information on spatial and temporal pattern of larval occurrence in order to better manage recruitment in fisheries. Young-of-year fish sampling can be conducted with active and passive sampling methods, and there are a number of different gears that are used for both methods. Active larval sampling methods include seining, trawling, electrofishing, plankton net tows, and pumping (Kelso and Rutherford 1996). Passive YOY sampling methods include drift sampling, activity traps, and light traps. Passive gears are less expensive and require less operational costs than active gears (Kelso and Rutherford 1996). However, passive gears are stationary and selective, requiring larvae to encounter the gear through normal activity or by attracting the specimens.

Despite the need for spatiotemporal information of YOY fishes, this life stage is rarely sampled and there is a paucity of information regarding distributions of YOY freshwater fishes in general. In tropical systems, these data are largely absent. Neal et al. (2012) compared larval sampling methods for Puerto Rico streams, but no directed larval sampling has occurred in Puerto Rico reservoirs. This study was designed to determine spatial and temporal trends in YOY fish community in Carite Reservoir, Puerto Rico. This research aimed at setting the foundation of YOY fish sampling in Puerto Rico by giving insight into habitat selectivity and seasonality of YOY fish distributions within littoral and limnetic habitats of a tropical reservoir.

Methods

Study Site

Carite Reservoir (18º04'N and 66º05'W) is a 124-ha impoundment that was constructed in 1913 on the La Plata River in the mountainous south-central region of Puerto Rico (Figure 2.1). The reservoir has an elevation of 543.6 m above sea level at full pool. The watershed of Carite Reservoir is comprised of mainly forest and encompasses

21.2 km² (Carvajal-Zamora 1979). Currently, Carite Reservoir provides water and electricity to meet the demands for domestic, industrial and agricultural needs in the area.

Carite Reservoir has historically been one of the least productive reservoirs in Puerto Rico, and catch rates of all fishes have been consistently low (Carvajal-Zamora 1979; Neal et al. 2001). Neal et al. (2001) found 14 fish species in Carite Reservoir, of which the Bigmouth Sleeper *Gobiomorus dormitor* was the only native species. Though populations of Bigmouth Sleeper have been documented in a few other reservoirs on the island, Carite Reservoir contains the only suspected land-locked reproducing population in Puerto Rico (Bacheler et al. 2004).

Sampling Gear

Light traps were used to sample the YOY fish community in littoral and limnetic habitats. Light traps were chosen because of their previously reported success for sampling Puerto Rico fishes (Adelsberger 2009). The selected light traps were modified quatrefoil traps (Aquatic Research Instruments, Hope, ID, USA) that consisted of an acrylic trapping assembly with an internal polycarbonate tube where a light source was located. The units were 30 × 30 × 25 cm (length × width × height), and had a 7-mm gap on all four sides to allow organisms inside the trap (Figure 2.2). Young-of-year fish were collected at the bottom of the trap in a 250-µm mesh plankton sock. The light source inside was a submersible battery powered LED dive light. A battery-powered source of light was chosen over chemical light sticks due to diminishing luminance found in chemical light sticks for sample periods exceeding 1 h (Kissick 1993).

Larval Fish Collection

Young-of-year fish samples were collected from Carite Reservoir once every two weeks over the course of one year (N= 26). The reservoir was stratified into three sections: a lower section at the dam and two upper arms. Littoral (inshore) and limnetic (offshore) habitats were compared within each section of the reservoir. Littoral habitat sites were chosen within 5 m of shore, at a water depth of ≤ 2 m (Vasek et al. 2006). Limnetic sites were chosen in open water habitats greater than 25 m from shore, with total depth > 5 m. Twelve sites were chosen *a priori* for each habitat type, within each section of reservoir for larval sampling (Figures 2.4 and 3.1). Prior to each sampling event, two sites were randomly chosen for each habitat type, in each section of reservoir for light trap sampling. Young-of-year fish collection was conducted at night for proper function of light traps (Tischler et al. 2000). Light traps were set at chosen sites at sunset (1800 h) and samples were collected at 6 h intervals, with the first collection at midnight (0000 h) and the final retrieval at sunrise (0600 h).

Young-of-year fish samples were sacrificed, fixed in 10% formalin and returned to the field station for analysis (Kelso and Rutherford 1996). Larvae were counted, measured for total length and identified to the species level using larval taxonomic keys (Auer 1982; Wang and Reyes 2008). Various morphological (e.g., myomere and fin ray counts) and meristic (e.g., photophore and melanophore pigmentation) measurements were used to identify larval fish (Fig. 2.5; Auer 1982). There are multiple periods to be considered in the early stages of fish development; from yolk-sac to pre- and post-flexon larvae through finfold absorption and fin ray development in juvenile fish. For this study, all of these stages are considered YOY fishes (Ahlstrom et al. 1976; Hardy et al. 1978).

Water Quality

In situ water quality parameters were measured concurrently with larval sampling. Dissolved oxygen (DO; mg L^{-1}), pH, specific conductivity (µS cm^{-1}), temperature (°C), and turbidity (NTU) measurements were collected at each sample location. Water quality parameters were collected with a Manta™ II Water Quality Multiprobe when each light trap was set and every 6 h throughout the night when light trap samples were collected. The water quality multiprobe was used to record water quality parameters at the surface and at 1 m depth at each light trap location.

Analysis

Young-of-year catch was compared between light traps set in the reservoir littoral and limnetic zones. Relative percent frequency of species composition, species diversity using Shannon-Wiener Index, and catch per effort were (CPUE) compared between the two habitats using mixed-effect models to determine habitat use by YOY fish. Percent frequency of species composition, species diversity and CPUE comparisons were also conducted temporally, providing insight into seasonality of YOY fish distributions between habitats.

Relative species composition matrices were constructed by summing the total number of fish by species, caught in either limnetic or littoral habitats, within each section of reservoir, by season. Total number of species was divided by the total sum of fish caught in each habitat, per section, per season. This resulted in matrices constructed of relative percent of fish species within each habitat and section of reservoir for each season. Samples were combined into four calendar seasons: spring (March-May), summer (June-August), fall (September-November) and winter (December-February).

Similarities in spatial and temporal species compositions were observed with the use of nonmetric multidimensional scaling (NMDS) of Bray-Curtis matrices. As an indirect gradient analysis, NMDS maximizes rank-order correlations between distance measures and distance in ordination space. Permutational multivariate analysis of variance (PERMANOVA) was conducted on relative species compositions and was used to validate differences in community abundances between habitats and among seasons as observed in the NMDS ordination. Shannon-Wiener diversity indices and catch per unit effort (log transformed) were fit to generalized linear mixed models to determine differences between habitats and among seasons and reservoir sections.

Water quality parameters were averaged per habitat within seasons. These data were combined with relative percent frequency matrices of the YOY fish community and analyzed with canonical correspondence analysis (CCA). Canonical correspondence analysis is a direct gradient analysis that ordinates species abundances based on environmental variables.

Results

Habitat Comparison

A total of 826 YOY fish were collected in the light traps with 537 in the littoral light traps and 289 in the limnetic light traps. Ten species were collected with littoral light traps, which was two more than were caught with limnetic traps (Table 3.1). Limnetic light trap catch was dominated by two species, Channel Catfish *Ictalurus punctatus* and Threadfin Shad *Dorosoma petenense*, comprising greater than 90% of total catch (76.8% and 13.8%, respectively; Figure 3.2). Littoral light trap catch was more evenly distributed among the YOY fish community with 90% of total catch being comprised of Redbreast Tilapia *Tilapia rendalli*, Largemouth Bass *Micropterus salmoides*, Amazon Sailfin Catfish *Pterygoplichthys pardalis*, Threadfin Shad and Tiger Barb *Puntius tetrazona* (39.5, 21.4, 12.7, 12.1 and 5.0%, respectively; Figure 3.2).

Young-of-year fish communities showed grouping of different habitats and seasons, mainly among limnetic traps in the NMDS ordination (Stress: 0.1382; R^2 Axis 1: 0.6298 Axis 2: 0.3655; Figure 3.3). Limnetic traps grouped more than littoral traps, indicating more similarity of the YOY fish collected. Spring and fall limnetic light traps grouped on axis 1 in the negative direction with a strong influence from Channel Catfish (-0.90). Spring littoral traps, as well as both littoral and limnetic traps set during summer, grouped on axis 1 in the positive direction. This group was influenced by a multitude of fish species. Redbreast Tipalia, Largemouth Bass, Amazon Sailfin Catfish and Western Mosquitofish *Gambusia affinis* all influenced this grouping on the positive first axis (0.74, 0.71, 0.57 and 0.32, respectively). Fall littoral traps showed some grouping on the second axis in the negative direction with an influence from Tiger Barbs (-0.59). Permutational multivariate analysis of variance of the relative percent composition of the larval fish community also supports the different groupings observed in the NMDS ordination. The larval fish community differed between habitats (pseudo-$F_{1,23}$ = 9.32; $P < 0.001$), among seasons (pseudo-$F_{3,23}$ = 5.88; $P < 0.001$), as well as when the effects of habitats and seasons are combined (pseudo-$F_{3,23}$ = 5.00; $P < 0.001$). Limnetic traps were strongly influenced by Channel Catfish in both spring and fall because this species made up greater than 76% of total catch. Littoral traps were highly influenced by Redbreast Tilapia and Largemouth Bass but did not group as tightly due to a greater species richness of the YOY community.

Shannon-Wiener diversity indices differed between habitats ($F_{1,583} = 29.54$; $P < 0.001$), among seasons ($F_{3,8} = 7.99$; $P < 0.009$) and when the effects of habitats and seasons are combined ($F_{3,583} = 7.53$; $P < 0.001$), but showed no difference among reservoir sections ($F_{2,6} = 0.70$; $P > 0.53$). Post-hoc comparisons of least squared means indicated that littoral light traps had greater diversity than limnetic light traps during both the spring ($P < 0.001$) and summer ($P < 0.001$) seasons (Figure 3.4). However, diversity was low and did not differ between habitats for fall and winter seasons ($P > 0.6$; 0.7, respectively).

Catch per unit effort differed between habitats for spring, summer and fall seasons. Littoral light traps had greater CPUE for spring and summer seasons ($P < 0.001$; < 0.002, respectively). However, limnetic catch rates were greater during the fall season ($P < 0.007$; Figure 3.5).

Water Quality

The results from the CCA indicate axis 1 had an eigenvalue of 0.2374 and explained 46.7% of the variability in the ordination of sites and species in relation to water quality parameters, whereas axis 2 had an eigenvalue of 0.1427 and explained only 28.1% of the variance in the ordination of sites and species, in relation to water quality parameters (Figure 3.6). Turbidity, pH and temperature correlated with sites and species ordinations on axis 1 in the negative direction (-0.60, -0.60 and -0.58, respectively). Dissolved oxygen (0.24) and specific conductivity (0.55) correlated with sites and species ordinations on axis 1 in the positive direction. As for axis 2, temperature, specific conductivity and dissolved oxygen negatively correlated with the ordination of sites and species on the axis (-0.18, -0.38 and -0.52, respectively), while pH and turbidity correlated with the ordination of sites and species in the positive direction (0.02 and 0.23, respectively).

Discussion

This research identified spatial and temporal trends of the YOY fish community in Carite Reservoir. Greatest abundances of YOY fish were caught during spring and summer within littoral habitats. Largemouth Bass and Redbreast Tilapia first appeared in littoral light traps late in the winter season. This is consistent with previous studies that indicate a prolonged period of spawning for Largemouth Bass in Puerto Rico reservoirs beginning as early as January (Ozen 2002; Neal 2003). Largemouth Bass numbers peaked during the spring season, whereas Redbreast Tilapia had greater abundances late in the spring and throughout the summer seasons. Both of these species are sought after as sport or food fish, and YOY Redbreast Tilapia are an important food source for YOY Largemouth Bass (Alicea et al. 1997). Thus, sampling for YOY of these species would be best conducted during spring and summer seasons within littoral habitats.

Amazon Sailfin Catfish were present primarily in the late spring and early summer months, indicating that this period is the likely spawning season. This species is considered invasive, therefore knowledge regarding different life history stages could prove useful in potential control efforts for the species (Bunkley-Williams et al. 1994). Due to later appearance in spring and summer, control via predation by piscivorous species presents an opportunity for management of this invasive species. Early spawned and faster growing piscivores, such as Largemouth Bass, would have the ability to consume YOY Amazon Sailfin Catfish as they are produced, lessening recruitment into the adult population.

Threadfin shad are considered a primary forage species in Puerto Rico reservoirs (Neal and Prchalova 2012), and were collected in light traps set in both littoral and limnetic habitats. However, the low total catch and relatively low percent composition of this species, combined with its mobility and schooling tendencies, reduces the utility of light traps for making inferences regarding population dynamics. Threadfin shad exhibit schooling behaviors within limnetic habitats and therefore a passive gear such as light traps may not be appropriate for sampling this species (Schael et al. 1995). The patchiness of shad distributions require schools to encounter the trap, whereas encountering schooling shad would have a higher probability with an active sampling gear (Prchalova et al. 2012), such as Bongo-style push nets (Chapter 2).

Channel Catfish catch peaked in both spring and fall seasons indicating two separate spawning periods during the year. The length distribution among all seasons was the same with catfish measuring between 15 – 20 mm, further indicating bimodal spawning. In temperate climates where Channel Catfish are native, these fish typically spawn once per year in late spring (Hubert 1999) when temperatures reach 21-29ºC, with 27ºC being considered optimal for spawning (Clemens and Sneed 1957; Walsh and Lindberg 1999). During this study, temperatures ranged from 20-29ºC over the course of the year. The water temperature reached its lowest value during late winter and began to rise in early spring, entering into the ideal spawning range for Channel Catfish. This increase into the spawning range could have initiated the first spawn and subsequent spring peak. Temperatures continued to increase gradually, and during late summer and fall, temperatures reached and remained at 27ºC across multiple sampling events. These temperatures coincided with the fall peak in YOY Channel Catfish. This may be the first report of bimodal spawning by this species, as no evidence of natural bimodal spawning by Channel Catfish was found in the literature.

Spatial patterns in YOY catch were only detected for comparisons of inshore versus offshore light traps, and no differences were detected between reservoir basins. However, the scale of this research was limited by cost of gear and manpower required to collect samples. Only two replicates per basin were collected for inshore and offshore habitats, limiting statistical power. Furthermore, variability between habitats and individual sampling stations likely masked any potential differences. These two factors could have led to Type II statistical error, in which an actual difference between basins would not be detected.

Despite lack of longitudinal differences, habitat differences were observed. Littoral traps caught greater numbers and exhibited greater diversities than limnetic traps and had 90% of total catch composed of Redbreast Tilapia, Largemouth Bass, Amazon Sailfin Catfish, Threadfin Shad, Tiger Barbs, and sunfish. Redbreast Tilapia, Largemouth Bass, and Amazon Sailfin Catfish are generally considered littoral species, which spawn in nest depressions or spawning cavities, so it was not surprising that abundance of YOY of these species were greatest inshore. Conversely, Channel Catfish dominated limnetic samples, accounting for nearly 77% of the total catch. However, this species is also cavity spawner (Hubert 1999). This suggests that YOY of channel catfish migrate from inshore spawning sites to offshore open water immediately after leaving parental production. Chapman (2000) noted that Channel Catfish YOY are guarded by the male for several days to several weeks, and then move to shallow water to begin feeding. Clearly, YOY of this species were not utilizing shallow littoral waters in this study, suggesting that they may employ a different life history stategy in tropical reservoirs. Further study is recommended.

Of the frequently collected species, only Threadfin Shad had similar catch between the two habitats. This was not surprising, as this schooling species appears equally at home in both littoral and limnetic environments (Neal and Prchalová 2012). *Dorosoma* species are generally positively phototaxic (Shelton and Stephens 1980), so they are attracted to light traps in both habitats. However, the low catch rates and high effort associated with light traps as compared to push nets (Chapter 2) and trawls (Prchalová et al. 2012), excludes this gear as a viable sampling technique for this species.

Littoral light traps provided valuable information on species presence/absence and perhaps relative abundance. Although NMDS groupings of littoral light traps were not as tight as groupings of limnetic traps, this was due to the greater diversities caught within littoral traps, which led to less similarity among sites in the ordination. Conversely, limnetic light traps grouped much tighter due to the predominance of Channel Catfish in catches. Although limnetic light traps successfully captured eight different species, only Channel Catfish were caught in great enough numbers to elicit the use of this gear in limnetic habitats.

Water quality tends to vary spatially within aquatic systems, offering an alternative means to analyze spatial trends. Water quality variables had limited effect on YOY fish distributions, though some inferences can be made. Channel Catfish, lepomids, and Tiger Barbs were influenced by turbidity, pH and temperature. The greater abundance of Channel Catfish in limnetic habitats potentially coincided with phytoplankton blooms or large suspended solids events, as evidenced by elevated turbidity. Greater turbidity could have given YOY Channel Catfish protection from predation (Miranda 1999), or it could have given the species an advantage during foraging activities (Daugherty and Sutton 2005). Redbreast Tilapia and Threadfin Shad were influenced by dissolved oxygen and conductivity, whereas the rest of the YOY fish community did not correlate with water quality variables.

Based on the results of this study, the following recommendations are suggested for using light traps to sample YOY fish in Carite Reservoir: 1) inshore light traps should be used to provide general community information and seasonality of YOY fish species, 2) offshore light traps have utility in characterizing Channel Catfish YOY dynamics, and 3) Threadfin Shad are most effectively sampled using active gears such as push nets or trawls. Although this research focused exclusively on this one reservoir, these recommendations should be applicable to other tropical reservoir systems with similar habitat, physicochemical, and fish community characteristics. Furthermore, this research detected interesting anomalies regarding Channel Catfish early life history, and further study is warranted to better understand these unique characteristics.

Tables and Figures

Table 3.1 Total catch and relative percent compostion of young-of-year fish caught with light traps set in littoral and limnetic habitats.

	Littoral		Limnetic	
Taxon	**n**	**%**	**n**	**%**
Centrarchidae				
Micropterus salmoides	115	21.42	4	1.38
Lepomis spp.	25	4.66	1	0.35
Cichlidae				
Cichla ocellaris	2	0.37	0	0
Tilapia rendalli	212	39.48	8	2.77
Clupeidae				
Dorosoma petenense	66	12.1	40	13.84
Cyprinidae				
Puntius tetrazona	27	5.03	1	0.35
Ictaluridae				
Ictalurus punctatus	11	2.05	222	76.82
Ameiurus catus	2	0.37	4	1.38
Loricariidae				
Pterygoplichthys pardalis	68	12.66	9	3.11
Poeciliidae				
Gambusia affinis	9	1.68	0	0
All taxa	537		289	

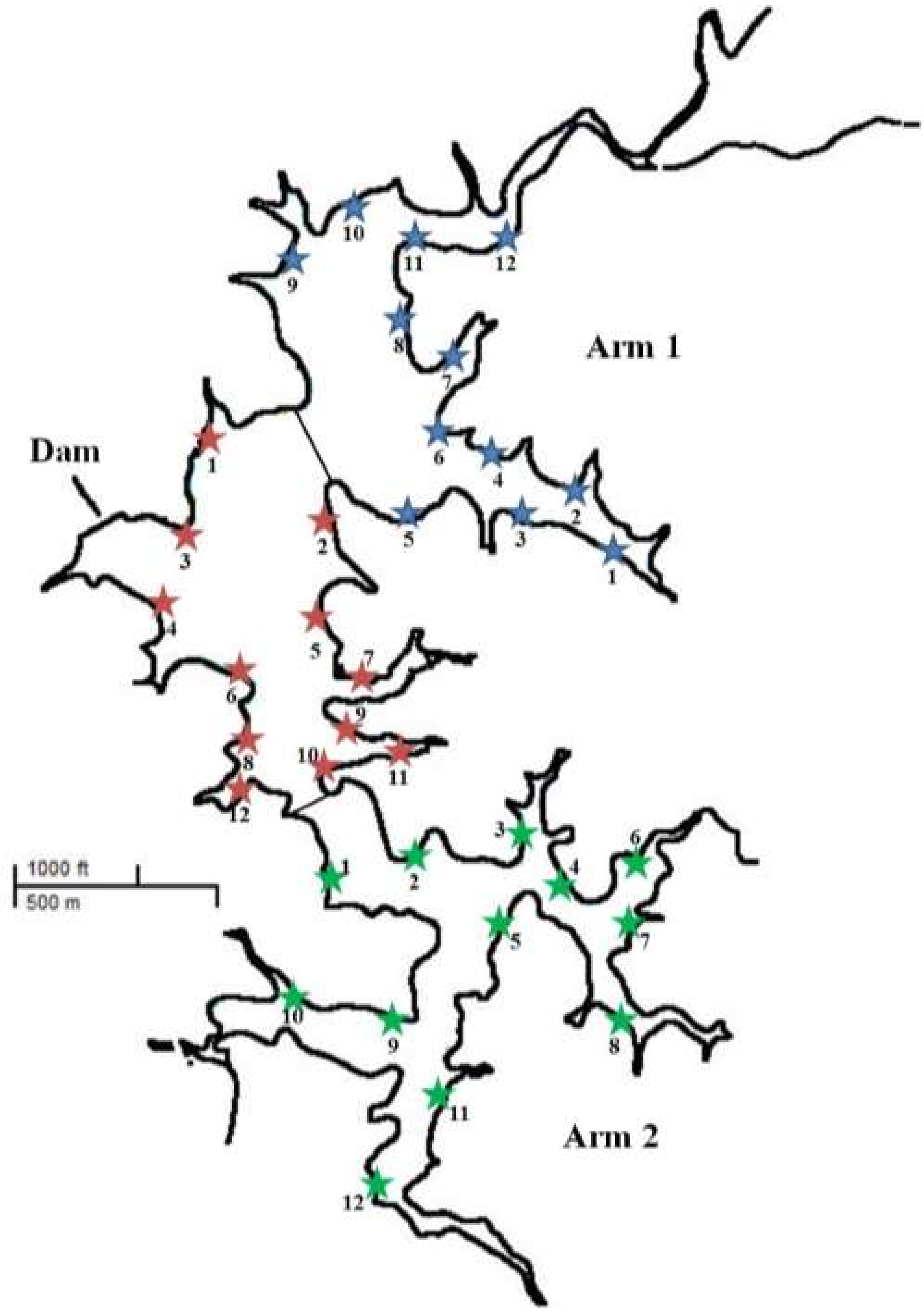

Figure 3.1 Littoral sampling sites for sampling YOY fish community with light traps.

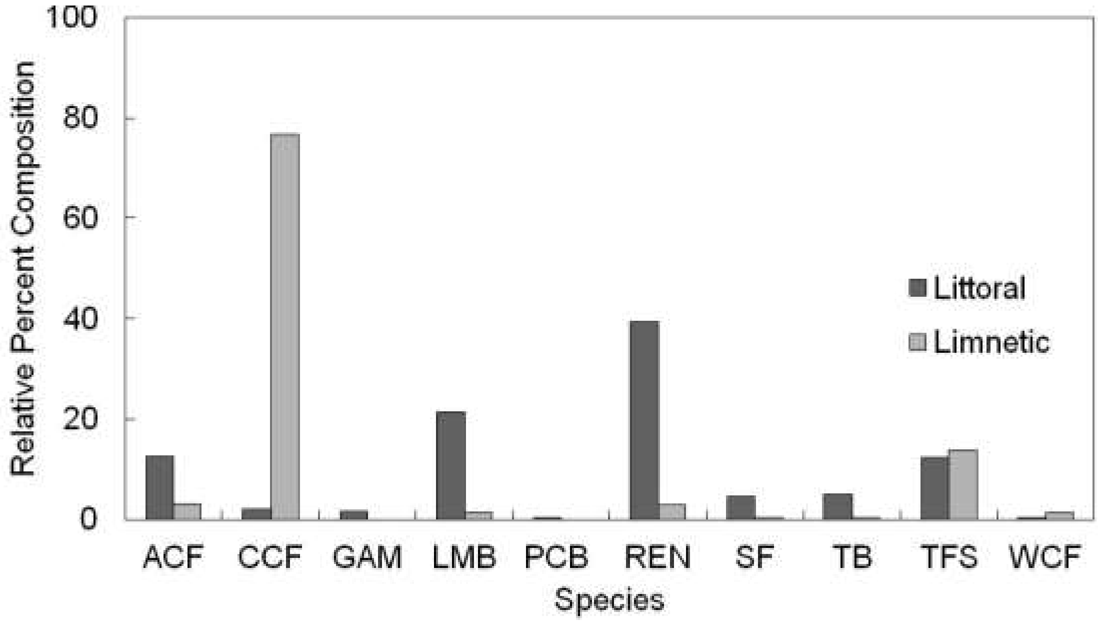

Figure 3.2 Relative percent composition of total catch from light traps set in both littoral and limnetic habitats.

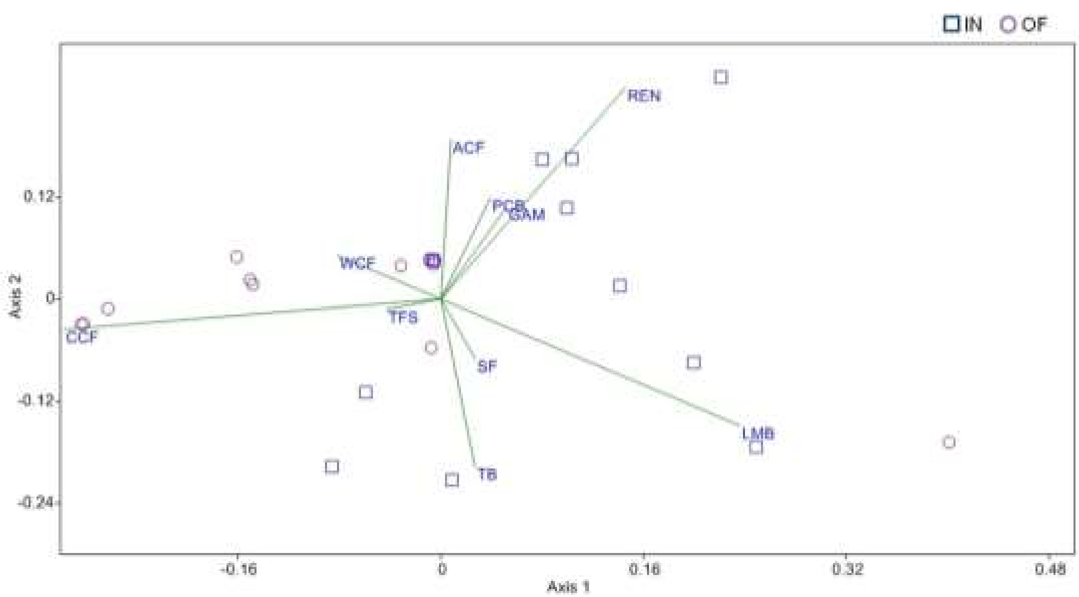

Figure 3.3 NMDS ordination of the relative percent composition of YOY fish communities sampled with light traps within littoral (diamonds) and limnetic (circles) habitats.

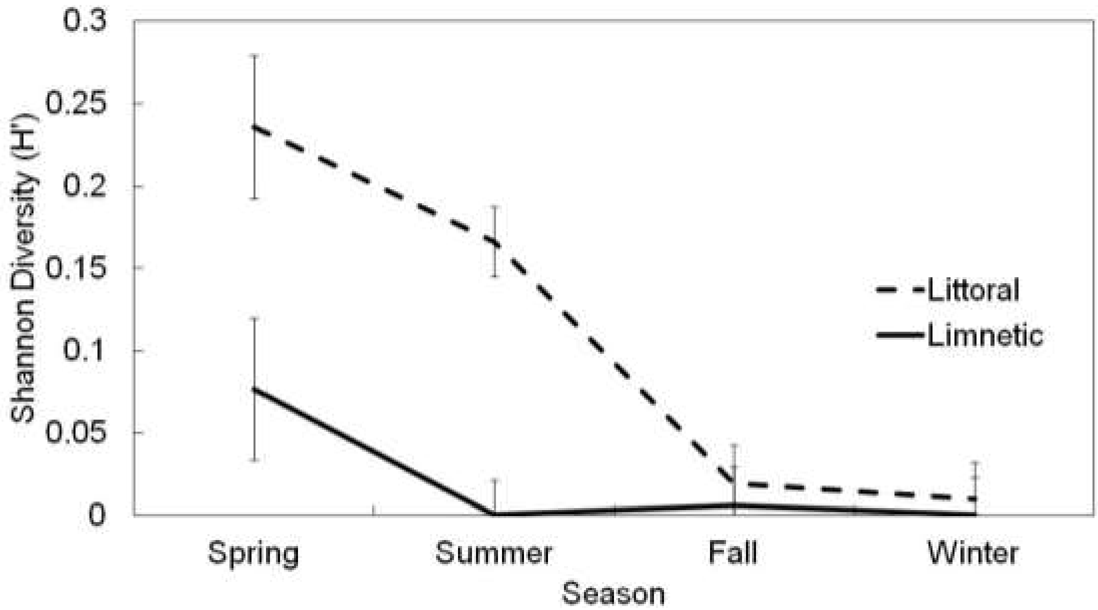

Figure 3.4 Mean ± S.E. diversity comparing littoral and limnetic YOY catch for light traps.

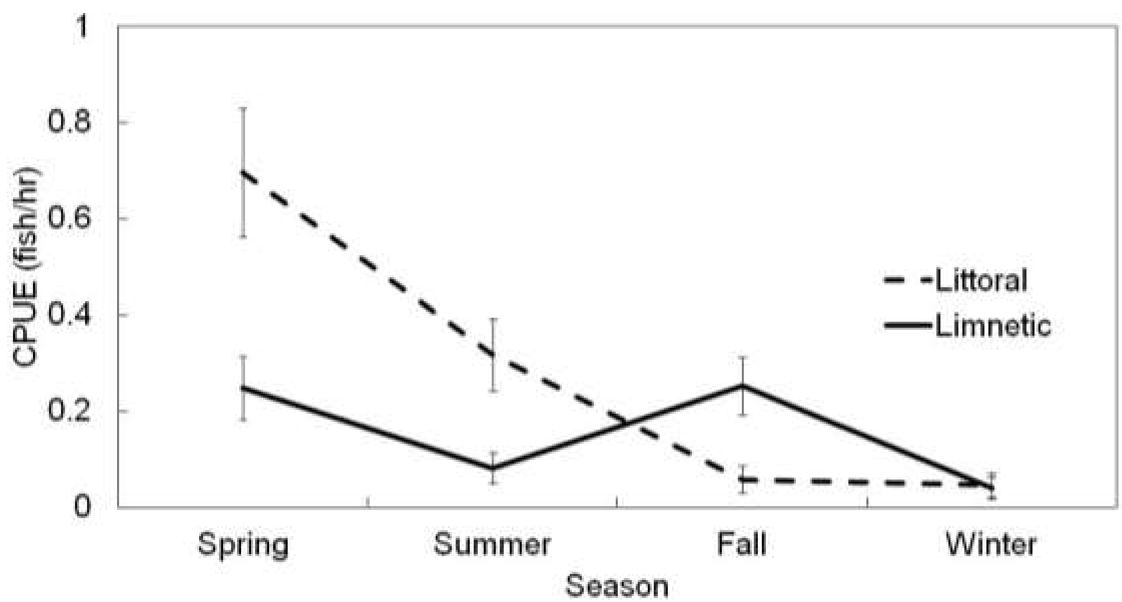

Figure 3.5 Mean catch per unit effort ± S.E. comparing littoral and limnetic YOY catch for light traps.

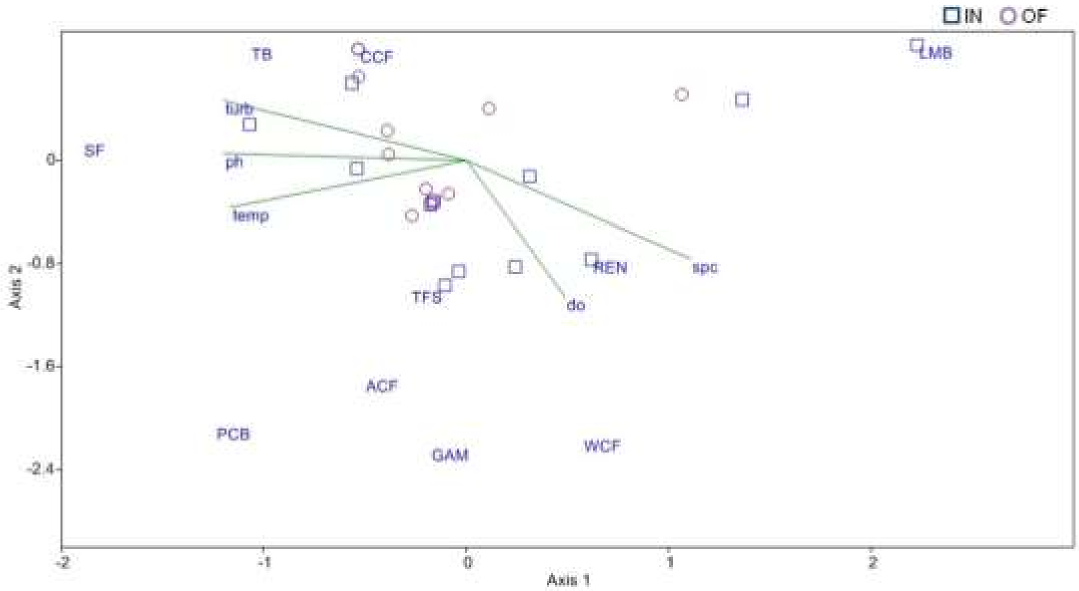

Figure 3.6 Canonical correspondence analysis of site (littoral [squares] and limnetic [circles]) and species matrices correlated with water quality parameters.

References

Adelsberger, C. 2009. Natural life history characteristics of bigmouth sleeper *Gobiomorus dormitor* in Puerto Rico Rivers. Master's thesis. University of Arkansas at Pine Bluff. Pine Bluff, Arkansas.

Ahlstrom, E.H., J.L. Butler, and B.Y. Sumida. 1976. Pelagic stromateoid fishes (Pisces, Perciformes) of the eastern Pacific: kinds, distributions, and early life histories and observations on five of these from the northwest Atlantic. Bulletin of Marine Science 26:285-402.

Alicea, A. R., R. L. Noble, and T. N. Churchill. 1997. Trophic dynamics of juvenile largemouth bass in Lucchetti Reservoir, Puerto Rico. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 51:149-158.

Allen, M.S., J.C. Green, F.J. Snow, M.J. Meceina, and D.R. DeVries. 1999. Recruitment of Largemouth bass in Alabama reservoir: Relations to trophic state and larval shad occurrence. North American Journal of Fisheries Management 19:67-77.

Auer, N.A. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, Special Publication 82-3, Ann Arbor, Michigan.

Boesch, D.F. 2002. Challenges and opportunities for science in reducing nutrient over-enrichment of coastal ecosystems. Estuaries 25:886–900.

Bunkley-Williams, L., E. H. Williams, J.R., C. G. Lilystrom, I. Corujo-Flores, A. J. Zerbi, C. Aliaume, and T. N. Churchill. 1994. The South American Sailfin Armored Catfish, *Liposarcus multiradiatus* (Hancock), a new exotic established in Puerto Rican fresh waters. Caribbean Journal of Science 30:90-94.

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.

Chambers, R. C., and E. A. Trippel. editors. 1997. Early life history and recruitment in fish populations. Springer, New York.

Clemens, H.P. and K.E. Sneed. 1957. The spawning of the channel catfish *Ictalurus punctatus*. U.S. Fish and Wildlife Service Special Science Report-Fish 219:1-11.

Chapman, F. 2000. Farm-raised Channel Catfish. University of Florida IFAS Extension (Online). Accessed December 4, 2013 at http://edis.ifas.ufl.edu/fa010.

Daugherty, D.J. and T.M. Sutton. 2005. Diel movement patterns and habitat use of Flathead Catfish in the Lower St. Joseph River, Michigan. Journal of Freshwater Ecology 20:1-8.

Garvey, J.E., and R.A. Stein. 1998. Competition between larval fishes in reservoirs: The role of relative timing of appearance. Transactions of the American Fisheries Society 127:1021-1039.

Gonzalez, M.J., L.B. Knoll, and M.J. Vanni. 2010. Differential effects of elevated nutrient and sediment imputs on survival, growth and biomass of a common larval fish species (*Dorosoma cepedianum*). Freshwater Biology 55:654-669.

Hardy, J.D., G.E. Drewry, R.A. Fritzche, G.D. Johnson, P.W. Jones, and F.D. Martin. 1978. Development of fishes of the Mid-Atlantic Bight, an atlas of eggs, larvae, and juvenile stages, volumes 1-6. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-78/12.

Hubert, W.A. 1999. Biology and management of channel catfish. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24:3-22.

Kelso, W. E., and D. A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255–302 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Kim, G.W. and D.R. DeVries. 2001. Adult fish predation on freshwater limnetic fish larvae: A mesocosm experiment. Transactions of the American Fisheries Society 130:189-203.

Kissick, L.A. 1993. Comparison of traps lighted by photochemicals or electric bulbs for sampling warmwater populations of young fish. North American Journal of Fisheries Management 13:864-867.

Kjesbu, O.S. 1994. Time of start of spawning in Atlantic cod (*Gadus morhua*) females in relation to vitellogenic oocyte diameter, temperature, fish length and condition. Journal of Fish Biology 45:719-735.

Legler, N.D., T.B. Johnson, D.D. Heath, S.A. Ludsin. 2010. Water temperature and prey size effects on the rate of digestion of larval and early juvenile fish. Transactions of the American Fisheries Society 139:868-875.

Mills, C.A., and R.H.K. Mann. 1985. Environmentally-induced fluctuations in year class strength and their implications for management. Journal of Fish Biology 27:209-226.

Miranda, L.E. 1999. Recreational catfish harvest in reservoirs in the USA. Fisheries Management and Ecology 6:499-513.

Mittlebach, G.G. 1988. Competition amoung refuging sunfish and effects of fish density on littoral zone invertebrates. Ecology 69:614-623.

Neal, J.W. 2003. Live fast and die young: On the growth and mortality of Largemouth Bass in Puerto Rico. Ph.D. dissertation, Zoology, North Carolina State University.

Neal, J. W., C. M. Adelsberger, and S. E. Lochmann. 2012. A comparison of larval fish sampling methods for tropical streams. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4:23-29.

Neal, J.W., R. L. Noble, C. G. Lilyestrom, N. M. Bacheler, and J. C. Taylor. 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. and M. Prchalova. 2012. Spatiotemporal distributions of Threadfin Shad in tropical reservoirs. North American Journal of Fisheries Management 32:929-940.

Nunn, A.D., J.P. Harvey, J.R. Britton, P.A. Frear and I.G. Cowx. 2007. Fish, climate and the Gulf Stream: the influence of abiotic factors on the recruitment success of cyprinid fishes in lowland rivers. Freashwater Biology 52:1576-1586.

Ozen, O. 2002. Population dynamics of Largemouth Bass in Lucchetti Reservoir, Puerto Rico. Ph.D. dissertation, Zoology, North Carolina State University.

Prchalová, M., J.W. Neal, M. Munoz-Hincapie, T. Juza, M. Riha, J. Peterka and J. Kubecka. 2012. Comparison of gill nets and fixed-framed trawls for sampling Threadfin Shad in tropical reservoirs. Transactions of the American Fisheries Society 141:1151-1160.

Saksena, V.P., C. Steinmetz, Jr., E.D. Houde. 1972. Effects of temperature on growth and survival of laboratory-reared larvae of the scaled sardine, *Harengula pensacolae* Goode and Bean. Transactions of the American Fisheries Society 4:691-695.

Santucci, V.J., Jr., and D.H. Wahl. 2003. The effects of growth, predation, and first-winter mortality on recruitment of bluegill cohorts. Transactions of the American Fisheries Society 132:346-360.

Schael, D.M., J.A. Rice and D.J. Degan. 1995. Spatial and temporal distributions of Threadfin Shad in a Southeastern Reservoir. Transactions of the American Fisheries Society 124:804-812.

Shelton, W. L., and R. R. Stephens. 1980. Comparative embryogeny and early development of threadfin and gizzard shad. Progressive Fish-Culturist 42:34-41.

Smith V.H., D. Tilman, and J. C. Nekola. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution 100:179-196.

Tischler, G., H. Gassner and J. Wanzenbock. 2000. Sampling characteristics of two methods for capturing age-0 fish in pelagic lake habitats. Journal of Fish Biology 57:1474-1487.

Uphoff, J. H. Jr. 1989. Environmental effects on survival of eggs, larvae, and juveniles of striped bass in the Choptank River, Maryland. Transactions of the American Fisheries Society 118:251-263.

Vasek, M., J. Kubecka, J. Matena, and J. Seda. 2006. Distribution and diet of 0+ fish within a canyon-shaped European reservoir in late summer. International Review of Hydrobiology 91:178-194.

Walsh, S.J. and W.L. Lindberg.1999. Catfish farming in Florida. University of Florida Institute of Food and Agricultural Sciences Extension circular 710. Florida Cooperative Extension Service, Gainesville, FL.

Wang, J.C.S. and R.C. Reyes. 2008. Early life stages and life histories of Centrarchids in the Sacramento-San Joaquin River Delta System, California. Tracy Fish Facility Studies California. Vol 42.

Welker, M.T., C.L. Pierce, and D.H. Wahl. 1994. Growth and survival of larval fishes: Roles of competition and zooplankton abundance. Transactions of the American Fisheries Society 123:703-717.

CHAPTER IV

SUMMARY

The YOY fish community in Carite Reservoir displayed heterogeneity both spatially and temporally. Young-of-year fishes were more abundant in the spring and summer, and exhibited decreasing trends through fall and winter for all species except Channel Catfish. Young-of-year fishes utilized littoral habitats with greater frequency than limnetic habitats. This study shows that light traps set in littoral and limnetic habitats give a more complete picture of the YOY fish community than push nets used in limnetic habitats alone. When compared to limnetic light traps, push nets caught greater diversities in the summer and fall, but diversities for both gears in limnetic habitats were low.

One potential bias with push nets was the possibility of back filtration pressure. The mesh size used on the push nets in this research was much smaller than most YOY fish sampling nets. This size (200 µm) was chosen to allow for the possibility of catching Bigmouth Sleeper yolk-sac larvae (~1 mm at hatch), but this mesh size likely created a back filtration pressure from within the nets. Back filtration pressure could potentially prevent specimen from filtering into the net. Without the use of a flow meter, it is impossible to determine the exact amount of water filtered through the nets or whether there was back pressure at the mouths of the nets. Whereas no Bigmouth Sleeper larvae were collected, this small mesh size was not necessary for sampling the larval fishes present. Thus, future studies should consider using push nets with mesh sizes of 250-300 μm that would reduce back pressure and should provide enhanced filtration without appreciable loss of smaller larvae.

Choice of sampling gear should be based on the question of interest to the fisheries manager. Littoral light traps caught the greatest species richness had greater diversities than light traps fished in offshore habitats; thus, these inshore sets represented a more complete picture of the fish community. However, limnetic light traps much more effectively sampled YOY Channel Catfish, suggesting that ictalurids might be underrepresented by inshore sampling alone. Conversely, limnetic-fished push nets caught greater total numbers of YOY fish, although catch was dominated by greater than 94% Threadfin Shad. Seasonal patterns must also be considered, and abundance of most species peaked in the spring or summer, although Channel Catfish exhibited a previously unreported bimodal distribution in larval abundance, with the greatest peak in fall. Therefore, managers must consider their objectives carefully when decide on which gear, singularly or in combination, that will be employed.

Based on these findings, recommendations for sampling larval fishes in Puerto Rico reservoirs are suggested in Figure 4.1. In general, bongo-style push nets should be used to answer questions regarding recruitment of prey species (e.g., Threadfin Shad) in offshore habitats. The greatest abundances of Threadfin Shad appeared during the spring; therefore, research aimed at estimating relative abundance of prey species in tropical reservoirs should focus sampling with push nets during the spring season. Light traps should be used to answer questions regarding littoral communities of YOY fish. Light traps set in littoral habitats caught a greater diversity of larval fish species; including species targeted for consumption (e.g., Cichlidae) as well as sport fish (e.g., Centrarchidae). Though numbers of YOY fish caught in light traps would make abundance efforts difficult, questions regarding timing of appearance and habitat usage can be answered with this gear. Limnetic light traps primarily caught Channel Catfish with peak abundances in both spring and fall, so sampling with this technique could be used or combined with littoral sampling if Ictalurids are of interest. Determination of both time of year and location to sample the larval fish community should be based on the species of larval fish in which the manager is interested. Centrarchidae and Cichlidae species would be best sampled during spring and early summer months with inshore light traps. Ictaluride sampling should occur in limnetic habitats and could effectively be sampled in the spring or fall months.

Only five species were collected in sufficient numbers to offer recommendations, and these are Largemouth Bass, Redbreast Tilapia, Amazon Sailfin Catfish, Channel Catfish, and Threadfin Shad. Other species, including important sport and food fish species such as sunfish, other tilapia species, Butterfly Peacock Bass, and Bigmouth Sleeper were either insufficiently sampled or not collected, and thus specific recommendations are not prudent. For species not collected during the study, it is not clear whether or not these species were present but not sampled, or if they were simply not available to be sampled. Regardless, more information on these species, particularly Bigmouth Sleeper and Butterfly Peacock Bass, is needed to better manage these important species.

This research was conducted in only one reservoir on the island of Puerto Rico. Though replication within the reservoir is sufficient to make claims about the seasonality and habitat usage of some YOY fishes in this reservoir, additional studies should be conducted in other reservoirs on the island. Altitude, temperature, reservoir usage, or trophic state of other reservoirs could potentially alter the spatial or temporal distributions of YOY fishes. Additionally, different fish species are present within reservoirs across the island and this has the potential to alter YOY fish distributions. Finally, this research exposed interesting life history characteristics of Channel Catfish that have not previously been reported. Further study of this species in Carite Reservoir and other island reservoirs would help clarify whether the observed bimodal spawning was only an anomaly, unique to Carite Reservoir, or if this altered life history strategy is characteristic of all populations in tropical reservoirs.

Tables and Figures

Table 4.1 Young of year sampling recommendations for Puerto Rico reservoirs.

Species	Season	Gear	Habitat
Largemouth Bass	Spring	Light Trap	Littoral
Redbreast Tilapia	Spring-Summer	Light Trap	Littoral
Amazon Sailfin Catfish	Spring-Summer	Light Trap	Littoral
Channel Catfish	Spring/Fall	Light Trap	Limnetic
Threadfin Shad	Spring-Summer	Push Net	Limnetic