Comparison of an Active and a Passive Age-0 Fish Sampling Gear in a Tropical Reservoir

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Abstract: Age-0 fish sampling is an important tool for predicting recruitment success and year-class strength of cohorts in fish populations. In Puerto Rico, limited research has been conducted on age-0 fish sampling with no studies addressing reservoir systems. In this study, we compared the efficacy of passively-fished light traps and actively-fished push nets for sampling the limnetic age-0 fish community in a tropical reservoir. Diversity of catch between push nets and light traps were similar, although species composition of catches differed between gears (*pseudo-F* = 32.21, df = 1,23, $P < 0.001$) and among seasons (*pseudo-F* = 4.29, df = 3,23, $P < 0.006$). Push-net catches were dominated by threadfin shad (*Dorosoma petenense*), comprising 94.2% of total catch. Conversely, light traps collected primarily channel catfish (*Ictalurus punctatus*; 76.8%), with threadfin shad comprising only 13.8% of the sample. Light-trap catches had less species diversity and evenness compared to push nets, consequently their efficiency may be limited to presence/absence of species. These two gears sampled different components of the age-0 fish community and therefore, gear selection should be based on research goals, with push nets an ideal gear for threadfin shad age-0 fish sampling, and light traps more appropriate for community sampling. The use of both gears concurrently would give a more complete picture of age-0 fish communities, as well as help to alleviate existing selectivity biases.

Key words: push nets, light traps, species diversity, NMDS

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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 age-0 fish (Ahlstrom et al. 1976, Hardy et al. 1978). Age-0 fish sampling is an important tool for predicting recruitment success and year-class strength of cohorts in fish populations. Variation in recruitment success and ultimately year-class strength can be affected by a multitude of factor including environmental conditions, changes in fish community composition, and gear selectivity (Allen and Hightower 2010).

Push nets, mounted to the bow of a boat and actively fished, can effectively sample both limnetic and littoral age-0 fish assemblages (Claramunt et al. 2005). When compared to traditionally towed nets of the same size, push nets are more efficient and effective at collecting age-0 fishes (Claramunt et al. 2005, Overton and Rulifson 2007, Fryda et al. 2008). Light traps are a passive gear described as "selective but useful devices" for sampling age-0 fishes (Doherty 1987). Although light traps are limited in determining age-0 fish densities, they can be an effective means of determining species presence or absence and relative abundance (Niles and Hartman 2007).

Knowledge of gear selectivity and differences in seasonal distributions of age-0 fish are important considerations for understanding community structure and function of fish populations, and these factors are paramount to understanding recruitment variability in early life stages of fish (Quist et al. 2004). Due to the paucity of information regarding gear selectivity for age-0 fishes within Puerto Rico reservoirs, this study was designed to determine the efficacy of push nets and light traps in sampling a reservoir age-0 fish community in Puerto Rico. The objective of this study was to lay the groundwork of age-0 fish sampling in Puerto Rico by increasing understanding of gear selectivity and seasonality of age-0 fish distributions within limnetic habitats of a tropical reservoir.

Study Site

Located in the mountainous south-central region of Puerto Rico, Carite Reservoir is a 124-ha impoundment on the La Plata River, formed by the construction of an earthen dam in 1913. The reservoir is situated at 1804 N and 6605 W at an elevation of 543.6 m above sea level at full pool. The 21.2-km^2 drainage area of Carite Reservoir is composed of mainly forest (Carvajal-Zamora 1979). Carite Reservoir provides water and electricity to meet the demands for domestic, industrial and agricultural needs in the area, and has light sport and consumptive fishing pressure. Generally, reservoirs in Puerto Rico are mesotrophic to eutropic and fish communities are primarily comprised of nonindigenous species (Neal et al. 2009). Although Carite Reservoir has historically been one of the least productive reservoirs in Puerto Rico (Carvajal-

Zamora 1979), it has a similar fish community to other reservoirs on the island, containing the most popular sportfish (Neal et al. 2001) and therefore provided a good starting point for reservoir age-0 fish sampling.

Methods

Light traps and push nets were used to sample age-0 fishes. 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 expected higher catch rates and ease of use by a two-member crew (Claramunt et al. 2005, Overton and Rulifson 2007). The light traps were modified quatrefoil traps (Aquatic Research Instruments, Hope, Idaho) that consisted of an acrylic trapping assembly with an internal polycarbonate tube where the battery-powered light-emitting diode light source was located. 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 units were $30 \times 30 \times 25$ cm (length-width-height) and had a 7-mm gap on all four sides to allow organisms inside the trap. Age-0 fish were collected at the bottom of the trap in a 250-µm mesh plankton sock.

The push nets were paired 0.5-m diameter bongo-style plankton nets. Nets were 2-m long and constructed of 200-µm mesh. This mesh size was chosen to allow capture of yolk-sac larvae. The terminal end of the net was fitted with an 11-cm diameter removable polyvinyl chloride 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, approximately 1 m below the surface of the water. The boom was designed to allow the push nets to be retrieved from the water to empty the collection cups after a sample was completed. Push net sampling was conducted at a speed of 1 m sec^{-1}, which has been found to be less damaging to yolk-sac larvae (Colton et al. 1980, Claramunt et al. 2005).

When estimating larval and juvenile fish abundances, it is important that estimates are 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. Results of this study indicated that 10-min samples provided the best tradeoff between sample CV and sample duration (Neal et al. 2014).

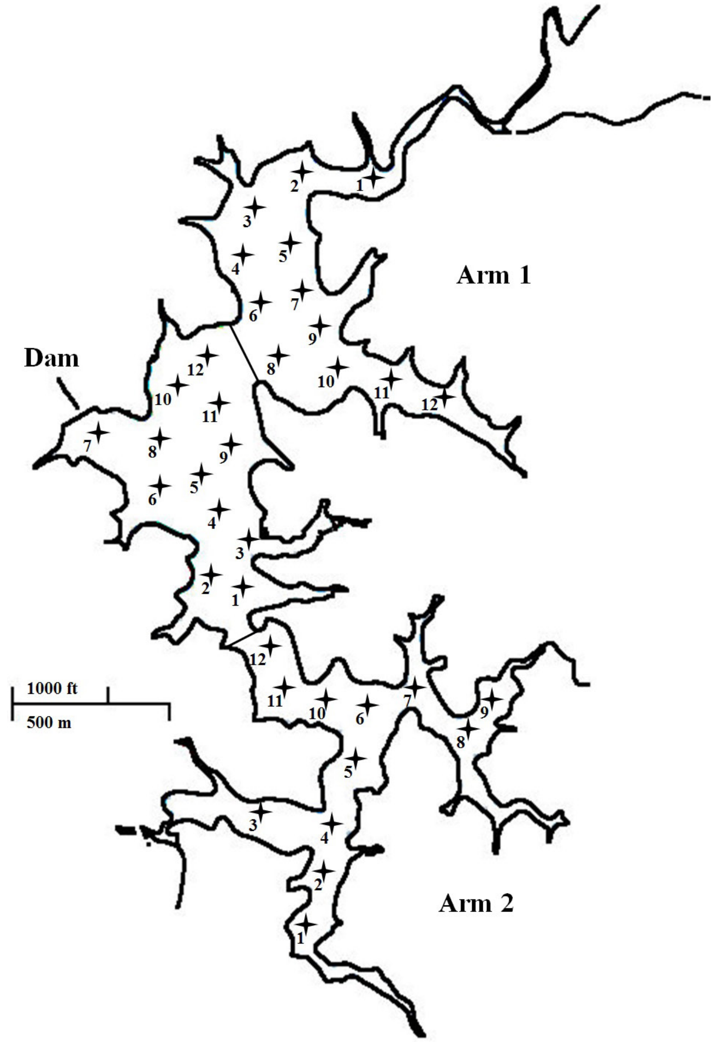

Figure 1. Limnetic sampling sites in Carite Reservoir, Puerto Rico.

Age-0 fish were collected from 26 biweekly samples taken from Carite Reservoir during one year. The reservoir was stratified into three sections: a lower section at the dam and each of two upper arms. Twelve sites were chosen for gear comparison *a priori* within each section of reservoir (Figure 1). Prior to each sampling event, sites were randomly chosen in each section of reservoir for light-trap sampling ($n = 2$), and push-net sampling ($n = 1$). Both gear types were deployed in limnetic habitats greater than 25 m from shore, with a depth >5 m.

All sampling 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 prior to sunset (approximately 1800 hours), and samples were collected at 6-h intervals with the final retrieval occurring just after sunrise (approximately 0600 hours). Puerto Rico is located just 18 degrees north of the equator, therefore day length varied by no more than 2 h during the course of the year. Thus, adjusting set and retrieve times of light traps across seasons was not necessary. One push-net sample was conducted per section during each 6-h light trap set.

Fish were sacrificed, fixed in 10% formalin, and returned to the field station for analysis (Kelso and Rutherford 1996). Specimens were counted and identified to the species using larval and juvenile

Table 1. Total catch (*n*) and relative percent composition of age-0 fish caught in light traps and push nets in limnetic habitats in Carite Reservoir, Puerto Rico, from June 2011 through June 2012.

	Push nets		Light traps	
Taxon	***n***	**%**	***n***	**%**
Largemouth bass (LMB)				
Micropterus salmoides	3	0.24	4	1.38
Sunfish (SF)				
Lepomis spp.	15	1.22	1	0.35
Redbreast tilapia (REN)				
Tilapia rendalli	1	0.08	8	2.77
Threadfin shad (TFS)				
Dorosoma petenense	1159	94.15	40	13.84
Tiger barb (TB)				
Puntius tetrazona	2	0.16	1	0.35
Channel catfish (CCF)				
Ictalurus punctatus	36	2.92	222	76.82
White catfish (WCF)				
Ameiurus catus	1	0.08	4	1.38
Amazon sailfin catfish (ACF)				
Pterygoplichthys pardalis	14	1.14	9	3.11
All taxa		1231		289

taxonomic keys (Auer 1982, Fujimura and Okada 2007, 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 fish larvae (Auer 1982, Margulies 1983). Reservoir fish communities in Puerto Rico are composed of primarily non-native species, requiring the need to use various larval and juvenile keys developed in other regions. All sunfish (*Lepomis* spp.) were combined due to overlapping meristic and morphometric measurements of the genus.

Catch rates of light traps and push nets could not be compared directly because light traps sample an unknown volume of water. As an alternative, frequencies of relative species composition of catch, species diversity using the Shannon-Wiener Index, Pielou's evenness and CV of total catch were compared to determine efficacy of sampling gears. Species diversity and evenness indices were computed using PAST version 2.14 statistical software (Hammer et al. 2001). 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. This technique is an indirect gradient analysis that maximizes rank-order correlations between distance measures and distance in ordination space. Because NMDS ordination is a tool to visualize differences in age-0 fish communities sampled with the different gears, permutational multivariate analysis of variance (PERMANOVA) was used to determine differences in species sampled between gears and seasons based on relative percentage of species compositions (R 2.15.1). This technique is generally more powerful than other resemblance-based permutation methods to detect changes in community structure (Anderson and Walsh 2013). Generalized linear mixed models were constructed to determine differences in diversity, evenness and CV of catch between gears and among seasons and reservoir sections (SAS Institute 2008). All common and scientific names of fishes caught in this study can be found in Table 1. All statistical tests were considered significant at $P \leq 0.05$.

Results

Light traps and push nets each collected a total of eight taxa of age-0 fish (Table 1). Push nets and light traps collected a total of 1231 and 289 age-0 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 sample. Push-net catches were dominated by threadfin shad, comprising 94.2% of total catch, with channel catfish comprising the next largest percentage of total catch at 2.9% (Table 1, Figure 2). Light-trap catches were dominated by channel catfish (76.8%), followed by threadfin shad (13.8%) (Table 1, Figure 2).

Age-0 fish samples showed strong grouping by gear type in the

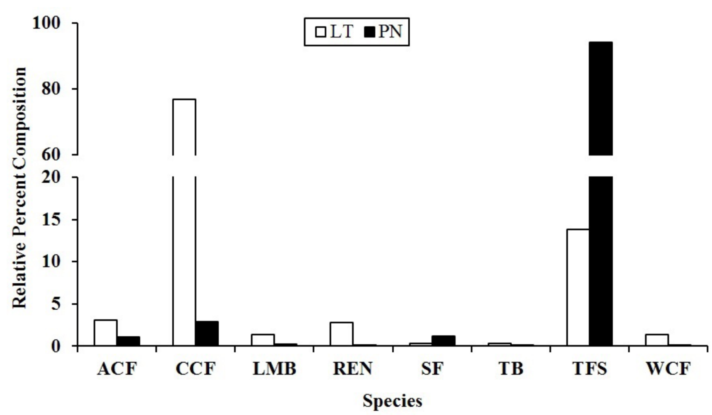

Figure 2. Relative percent composition of total catch from limnetic light traps (LT) and push nets (PN) from June 2011 through June 2012, in Carite Reservoir, Puerto Rico. Refer to Table 1 for abbreviations.

NMDS ordination (Stress: 0.08, R^2: Axis 1: 0.73 Axis 2: 0.17, Figure 3). Push nets grouped tightly on axis 1 and axis 2 with axis scores varying from 0.06 to 0.20 and −0.07 to −0.01, respectively. The tightness of the push-net grouping shows similarity in species composition caught with this gear. Threadfin shad relative percent frequency was highly correlated with axis 1 scores in the positive direction (r = 0.90) and strongly influenced the push-net grouping. Centrarchid (sunfish and largemouth bass) relative percent frequency only slightly correlated with axis 1 (r = 0.30 and 0.24, respectively) 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 varying from −0.24 to 0.20 and −0.06 to 0.37 on axes 1 and 2, respectively (Figure 3). Channel catfish relative percent frequency had a strong correlation with axis 1 in the negative direction (r = 0.97), and had a strong influence on light trap grouping. However, white catfish, redbreast tilapia, tiger barb and Amazon sailfin catfish also correlated with axis 1 in the negative direction (r = 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.

Although push nets and light traps sampled the same species, the relative frequency of species composition of catches differed between gears (*pseudo-F* = 32.21, df = 1, 23, $P < 0.001$) and among seasons (*pseudo-F* = 4.29, df = 3, 23 $P < 0.006$), validating the differences observed in the NMDS ordination. Shannon-Wiener diversity indices also differed between gears ($F = 10.97$, df = 1, 583, $P < 0.001$), but showed no difference among seasons ($F = 3.36$, df = 3, 8, $P > 0.07$), reservoir sections ($F = 0.48$, df = 2, 6, $P > 0.64$), and there was no interaction between gear and season ($F = 1.54$, df = 3, 583, $P > 0.20$). 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 4). Likewise, push nets also had greater species evenness than light traps in both summer ($P < 0.005$) and fall ($P < 0.005$, Figure 4) seasons. Coefficient of variation was not different between gears (F = 10.13, df = 1, 583, $P > 0.22$) or among seasons ($F = 9.28$, df = 3, 8, $P > 0.59$), although it was considerably large for both light traps (mean = 2.44 ± 0.62) and push nets (mean = 1.62 ± 0.37).

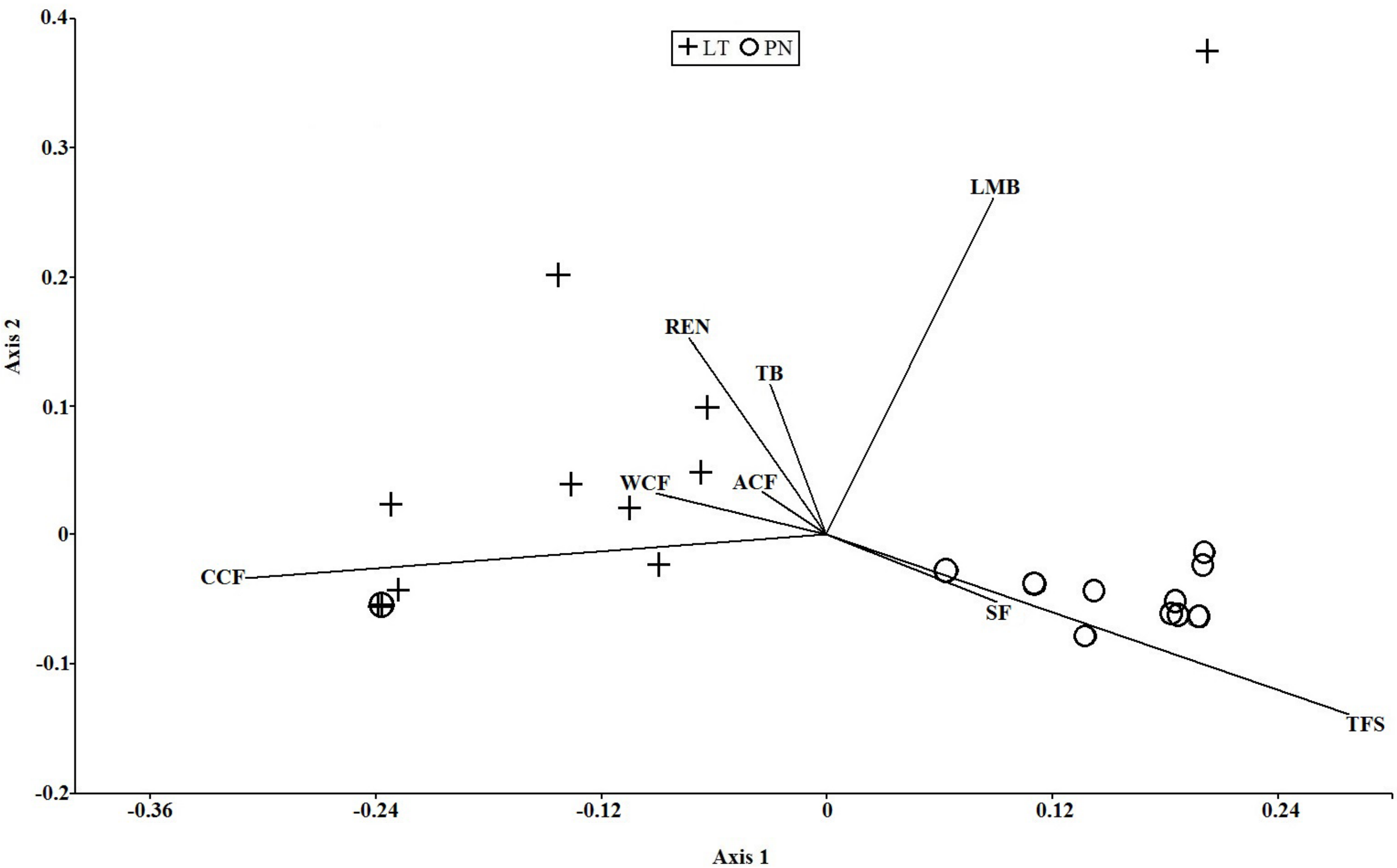

Figure 3. Nonmetric multidimensional scaling ordination of the relative percent composition of limnetic age-0 fish communities sampled with light traps (crosses) and push nets (circles) in Carite Reservoir, Puerto Rico, from June 2011 through June 2012 (Stress: 0.0816; R2 Axis 1: 0.7271 Axis 2: 0.1723).

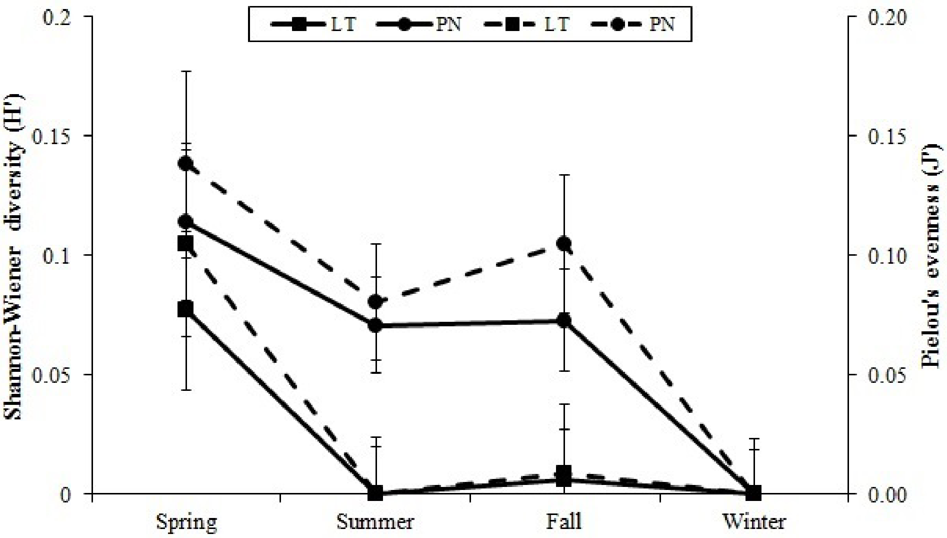

Figure 4. Mean (± SE) Shannon-Wiener diversity (solid line) and Pielou's evenness (dashed line) of limnetic age-0 catch in light traps (LT) and push nets (PN) in Carite Reservoir, Puerto Rico.

Discussion

Push nets and light traps successfully captured the same eight taxa, but in different proportions. Push nets collected almost fourfold more age-0 fish compared to light traps, but samples in both gears had low diversities due to a single species dominating the catch of each. Sample diversity and evenness was greater for push nets than light traps in summer and fall seasons, but this could be attributed to light traps being 80% empty during the summer and catch being composed mostly of channel catfish in the fall. Both gears exhibited large relative variability in catch, although no difference in CV was detected between gears or among seasons, CV trends for light traps were greater presumably due to the stationary nature of the light traps. By actively sampling, push nets can overcome factors that may affect catchability of age-0 fish, such as currents or swimming ability, and therefore show less variability in catch.

Diversity in this study was much lower than reported in Neal et al. (2001), who sampled adult and juvenile littoral fish communities in Carite Reservoir using boom-mounted and hand-held electrofishing systems. Excluding sunfish, which were not identified to species, five of the seven species collected in our study 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 Amazon sailfin catfish and tiger barb, which were not reported in the previous study. The discrepancies between the two studies were likely due to differences in life stage and habitat sampled, as the current study targeted exclusively age-0 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 of sport fishes in Puerto Rico reservoirs (Neal et al. 2011), and push nets were clearly more effective than light traps at indexing abundance of this species. Push nets collected about 29 times more threadfin shad than light traps with considerably less effort. Furthermore, total numbers of bycatch were much lower with push nets compared to light traps (5.9% versus 86.2%, respectively). Prchalová et al. (2012) reported similar findings in Puerto Rico reservoirs 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 age-0 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 fall/winter seasons combined. These trends were similar to Neal and Prchalová (2012), who reported greatest abundances of age-0 shad in the spring in Puerto Rico reservoirs. Based on the findings of the current study, targeted sampling of age-0 threadfin shad should use push nets during the spring and early summer.

Light trap samples had less species diversity and evenness in comparison to push nets and are therefore limited to presence/

absence of species since the numbers of age-0 fish caught would not be sufficient for attempting abundance estimates (Doherty 1987). As with push nets, trends in light trap samples indicated greater numbers of age-0 fish caught in spring, concurrent with primary spawning seasons of many species. However, channel catfish catch peaked in both spring and fall, with greatest abundances observed during fall. All catfish caught during this study were between 15–19 mm, indicating two separate spawning events. 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).

There are potential biases with sampling the age-0 fish community with push nets. Visual avoidance of the gear has been determined to affect sizes of age-0 fish captured with push nets (Brander and Thompson 1989, Hickford and Schiel 1999), and although samples were collected at night to lessen avoidance, targeted fish potentially possessed the ability to avoid the nets. Slow speeds (1 m sec-1) and back filtration pressure within the nets could also have contributed to possible gear bias. Total amount of water filtered by push nets was estimated using area of net mouth and distance traveled to simplify catch per unit effort computations; however, large numbers of phytoplankton were often collected that could have potentially lessened filtration ability of the nets causing back pressure to build. Catch rates were not compared in this study and lack of flow meters presumably did not greatly affect diversity estimates, however, a flow meter mounted inside the mouth of the nets would provide greater accuracy of the volume of water filtered as well as indicate if nets were filtering at their greatest capacity (Claramunt et al. 2005).

Both gears efficiently sampled different aspects of the limnetic age-0 fish community within Carite Reservoir. Due to the style of gear (active or passive) and the proportions of the age-0 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. As suggested by this research and others, the use of both gears concurrently would give a more complete picture of age-0 fish communities that inhabit limnetic habitats, as well as help to alleviate existing selectivity biases (Gregory and Powles 1988, Hickford and Schiel 1999).

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Literature Cited

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(3):285–402.

Allen, M. S. and J. E. Hightower. 2010. Fish population dynamics: mortality, growth, and recruitment. Pages 43–79 *in* W. A. Hubert and M. C. Quist, editors. Inland fisheries management in North America, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Anderson, M. J. and D. C. I. Walsh. 2013. PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: What null hypothesis are you testing? Ecological Monographs 83:557–574.

Auer, N. A. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, 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(2):423–431.

Fujimura, K. and N. Okada. 2007. Development of the embryo, larva and early juvenile of Nile tilapia *Oreochromis niloticus* (Pisces: Cichlidae). Developmental staging system. Development Growth and Differentiation 49:301–324.

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(4):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.

Hammer, O., D. A. T. Harper, and P. D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4:9.

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.

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.

Margulies, D. 1983. A preliminary guide to the identification of families of larval fishes occurring in the Ohio River. Ohio Journal of Science 83:135–138.

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

_____, R. Kröger, C. G. Lilyestrom, M. Muñoz, M. Prchalová, D. Lutz-Carillo, N. R. Peterson, M. C. Lloyd, K. Olivieri-Velázquez, C. N. Fox, and J. M. Bies. 2014. Freshwater sport fish management and enhancement. Puerto Rico Department of Natural and Environmental Resources, Federal Aid in Sport Fish Restoration, Final Report, Project F-53R, San Juan.

_____, C. G. Lilyestrom, and T. J. Kwak. 2009. Factors influencing tropical island freshwater fishes: species, status, and management implications in Puerto Rico. Fisheries 34:546–554.

_____, _____, 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.

_____, 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.

_____ and M. Prchalová. 2012. Spatiotemporal distributions of threadfin shad in tropical reservoirs. North American Journal of Fisheries Management 32:929–940.

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. Muñoz-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.

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

SAS Institute. 2008. Statistical analysis system for Windows (SAS 9.2). Cary, North Carolina: SAS Institute.

Stevens, R. E. 1959. The white and channel catfishes of the Santee-Cooper Reservoir and tailrace sanctuary. Proceedings of the Annual Conference of the 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. Vol 42.