Temporal Variability in the Littoral Fish Community of a Puerto Rico Reservoir

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Abstract: Electrofishing the littoral zone of Lucchetti Reservoir, Puerto Rico, from 1992 through 1997 indicated dynamic changes in fish community structure, despite consistent annual water level regimes. Nine species of fish, including 2 cichlids, 2 centrarchids, and 2 ictalurids, were collected. Relative abundance varied significantly over seasons and years for most species. One species, the bigmouth sleeper (*Gobiomorus dormitor*), may have become extirpated during the period and 1 new species, armored catfish (*Liposarcus multiradiatus*), became established. Adult largemouth bass (*Micropterus salmoides*) varied nearly 3-fold in density and 1.5-fold in biomass over 5 years, as estimated by mark-recapture. Despite annual variability in community structure and prey base composition, relative weights of adult largemouth bass were consistently close to 100. Although more variable than typical southeastern reservoirs, Lucchetti Reservoir is capable of supporting a productive largemouth bass fishery.

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After an initial period of post-impoundment instability, a general stabilization of reservoir communities and productivity characterizes North American reservoirs (e.g., Kimmel and Groeger 1986). Although water level fluctuations (Ploskey 1986) and poorly developed predator-prey interactions (Noble 1986) contribute to year

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class variability, species composition for a reservoir remains relatively consistent after the immediate post-impoundment dynamic period, in large part due to eventual dominance by generalists (e.g., Jackson et al. 1991).

Puerto Rico has a paucity of freshwater fish species, thus reservoir fish communities have developed through introductions of exotic species from a broad geographic range (Erdman 1984). Although 63 species of fish have been identified from fresh waters of Puerto Rico (Williams and Williams 1994), only 13 have been found routinely in reservoirs on the island during project assessments. Most of Puerto Rico's 28 reservoirs, which serve as sources for hydroelectric production, irrigation, and municipal water supply, are located in the mountainous regions of the island, and are subject to extreme water level fluctuations in response to pronounced seasonal rainfall regimes.

From 1992 to 1997, an intensive study of the fish community of Lucchetti Reservoir was conducted to establish a scientific basis for fishery management (Churchill et al. 1995). To understand predator-prey relationships of juvenile largemouth bass, routine characterization of the littoral community was conducted. The objectives of this paper are to describe the seasonal and annual variability in the littoral community, and to relate variability in adult largemouth population characteristics to the changes in littoral composition.

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Methods

Lucchetti Reservoir is a 108-ha impoundment that lies in the mountain region of southwest Puerto Rico. The basin is located in a subtropical moist forest with an annual mean precipitation of 198 cm. The watershed comprises 6.66 km^2 of mainly agricultural land. Lucchetti Reservoir was constructed in 1952 and serves mainly as a storage impoundment to provide water to the arid Lajas Valley region. The reservoir is connected via a series of underground aqueducts to storage impoundments at higher elevations.

The reservoir consists of 4 embayments corresponding to river confluences that feed into it. Maximum depth at the spillway (174 m above sea level) is 54 m. Retention time has been calculated at 0.66 years, an above average value for Puerto Rico reservoirs (Perez-Santos 1994). The shoreline has a slope of >45% with rock and clay substrates. Perez-Santos (1994) described the reservoir as eutrophic. Annual water level fluctuations of >10 m occur seasonally in response to rainfall regime, resulting in changes in habitat that are consistent from year to year.

Field sampling was conducted from March 1992 through March 1998. Shoreline electrofishing using a hand-held 260-volt, direct current unit (Jackson and Noble

1995) was conducted every 3 weeks from 1992 through the end of 1994. From July 1995 through 1997, electrofishing was limited to sampling at 6-week intervals. Five representative fixed sites selected prior to the study were maintained throughout the sampling period. Sites were chosen with regard to the most common habitat types consisting of shaded rocky areas of the reservoir and were dispersed so that all sites were at least partially accessible during periods of low water level. Approximately 22% of the shoreline was electrofished at the 5 sites when the water level was at pool. The percentage of shoreline sampled increased with lower water levels.

Littoral fish community composition characteristics of primarily juvenile fishes were obtained through nighttime electrofishing efforts. Each site was electrofished for 30 minutes or until 75 fish had been randomly collected, exclusive of threadfin shad (*Dorosoma petenense*). All fishes were identified to species and enumerated. Percent relative abundance for commonly-occurring species was compared for seasonal and annual differences using analysis of variance and test of least significant difference. $P < 0.05$ was accepted as the significance level for all tests. Data were not transformed because extreme values were found to be consistent among various seasons for the dominant species. To better illustrate changes in relative abundance through seasons, only years that were not significantly different were used in seasonal analyses.

Adult largemouth bass population size was estimated by mark-recapture each winter from 1994 through 1998. Largemouth bass were collected by means of a boom-mounted electrofishing boat using 240-volt, pulsed direct current. The entire shoreline was electrofished and all largemouth bass ≥250 mm total length (TL) were marked by a pelvic fin clip. Fins clipped were alternated from year to year. Total lengths (mm) were recorded for all largemouth bass captured and weights (g) were recorded for a representative sample. Approximately 1 month post-marking, a recapture effort was conducted by electrofishing. For recapture, sites were chosen systematically around the shoreline and shocking continued until enough largemouth bass ≥250 mm had been captured to yield a population estimate with a precision of approximately ± 25% (Robson and Regier 1964). Relative weights (Anderson 1980) were calculated for largemouth bass captured during the marking period.

Results

Lucchetti Reservoir is a dynamic system in regard to seasonal and annual changes in relative abundances of species. Also, fish community structure displayed changes with the loss of 1 species and the introduction of another. Sampling revealed 9 fish species present consistently for at least part of the study (Table 1). An introduction of a new species, armored catfish, to the reservoir was discovered in June 1996 and it has been observed regularly since then. Conversely, the bigmouth sleeper, which had occurred in samples regularly from the onset of the study, was not observed after April 1997. All other species were present throughout the study. Largemouth bass, bluegill (*Lepomis macrochirus*), redbreast tilapia (*Tilapia rendalli*), and Mozambique tilapia (*Tilapia mossambica*) all displayed significant changes in relative

Table 1. Mean percent overall abundance of species present in Lucchetti Reservoir, 1992–1997. P = present, but not enumerated. R = rare (<1%).

Common name	Scientific name	Mean % overall relative abundance
Bluegill	*Lepomis macrochirus*	34.84 ± 3.06
Redbreast tilapia	*Tilapia rendalli*	33.40 ± 3.04
Largemouth bass	*Micropterus salmoides*	15.19 ± 1.96
Mozambique tilapia	*Tilapia mossambica*	15.18 ± 1.89
Channel catfish	*Ictalurus punctatus*	1.02 ± 0.16
Threadfin shad	*Dorosoma petenense*	P
Armored catfish	*Liposarcus multiradiatus*	R
Bigmouth sleeper	*Gobiomorus dormitor*	R
Marbled bullhead	*Ameiurus nebulosus marmoratus*	R
Green swordtail	*Xiphophorus helleri*	R
Western mosquitofish	*Gambusia affinis*	R

abundance both annually and seasonally. Channel catfish (*Ictalurus punctatus*) and marbled bullhead (*Ameiurus nebulosus marmoratus*), however, did not show any significant seasonal changes in relative abundance but varied significantly among years.

Largemouth bass is the dominant predator in Lucchetti Reservoir and contributes to littoral samples primarily as young. Relative abundance varied significantly among years ($P < 0.001$) as well among seasons ($P = 0.002$), when catches of young largemouth bass sometimes dominated the catch. In 1996, y-o-y largemouth bass dominated the samples comprising 48% of the catch. Similar abundances occurred in spring, summer, and fall, whereas winter samples had a much lower representation of largemouth bass (Fig. 1).

Bluegill abundance differed among years ($P = 0.02$) with a range of percent contribution to the total species composition of 18% in 1992 to 62% in 1995. Years 1993 and 1994 were similar in bluegill relative abundance ($P = 0.95$). Summer (Jun–

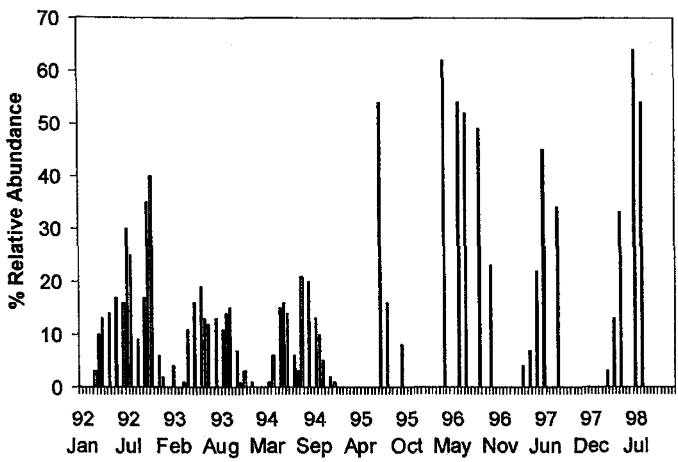

Figure 1. Percent relative abundance of largemouth bass in littoral samples, Lucchetti Reservoir, 1992–1998.

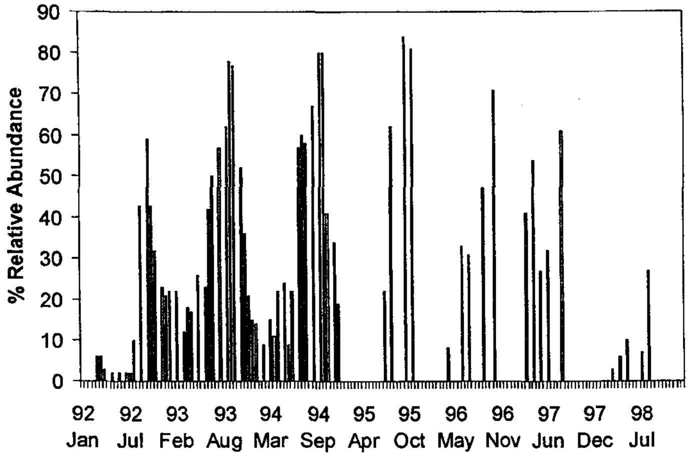

Figure 2. Percent relative abundance of bluegill in littoral samples, Lucchetti Reservoir, 1992–1998.

Aug) and fall (Sep–Nov) were found to have similar abundance ($P = 0.61$) and had the highest abundance of bluegill, while winter (Dec–Feb) and spring (Mar–May) were similar ($P = 0.87$) with a significantly lower abundance of bluegill (Fig. 2).

Redbreast tilapia relative abundance also differed among years ($P < 0.001$). Years 1992 and 1993 had similar relative abundances ($P = 0.24$) of redbreast tilapia and 1994–1997 were also similar to each other ($P = 0.06$). Overall, redbreast tilapia relative abundance decreased after 1992 with a range of 53% in 1992 to 9% in 1996 (Fig. 3). Only 1992 and 1993 were used to show seasonal changes in regards to relative abundance since not all seasons from 1995–1997 were sampled. Changes in

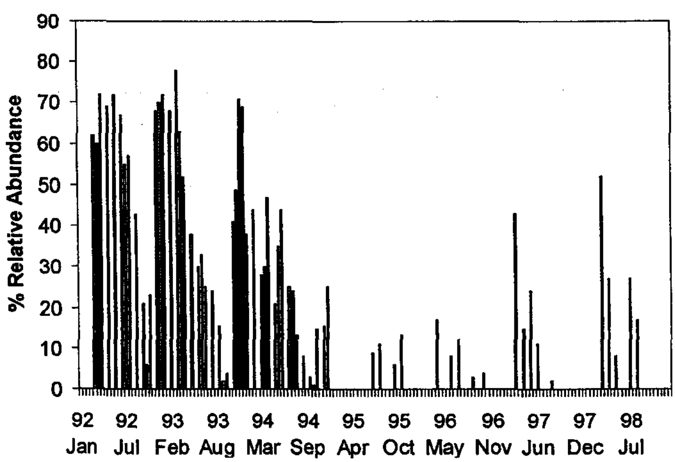

Figure 3. Percent relative abundance of redbreast tilapia in littoral samples, Lucchetti Reservoir, 1992–1998.

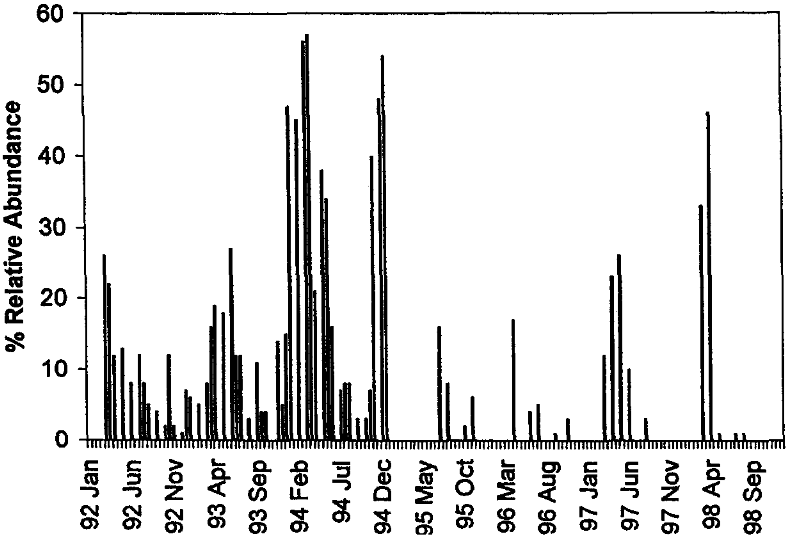

Figure 4. Percent relative abundance of Mozambique tilapia in littoral samples, Lucchetti Reservoir, 1992–1998.

abundance were found to occur seasonally ($P < 0.001$), with the fall having significantly fewer redbreast tilapia than the winter–summer period ($P = 0.44$).

Mozambique tilapia relative abundance remained fairly constant through the study (Fig. 4). All years had similar annual abundances ($P = 0.41$) of Mozambique tilapia except 1994, which had a significantly higher relative abundance. For 1992 and 1993, analysis of seasonal variations in relative abundance indicated that winter, summer, and fall were all similar ($P = 0.21$), while spring Mozambique tilapia abundance was significantly greater.

Both channel catfish and marbled bullheads comprised a small portion of the electrofishing samples. Relative abundance changed for both channel catfish ($P = 0.04$) and marbled bullhead ($P = 0.004$) from 1992 through 1997. Channel catfish relative abundance ranged from <1% in 1995 to 2% in 1994, while marbled bullheads ranged from 0.0% from 1995 through 1997 to <1% in 1992. No seasonal variation in relative abundance was apparent for either species. Although marbled bullheads did not occur in any of the nighttime electrofishing samples after 1994, they were routinely observed during largemouth bass population estimates and in angler creels.

Bigmouth sleeper abundance declined dramatically over the study. In 1992, 40 specimens were collected in the 14 samples. Catches in 1993 and 1994 declined to only 12 and 6 individuals, respectively, in 17 samples annually. Only 2 bigmouth sleepers were collected thereafter, the last in April 1997. Likewise, bigmouth sleepers disappeared from other fishery surveys and angler creels in Lucchetti Reservoir. However, it was reported that anglers continued to catch bigmouth sleepers routinely below the dam (Victor Rodriguez, PRDNER, pers. commun.).

In 1993 a single adult specimen of armored catfish was found in a nighttime

Table 2. Adult largemouth bass population estimates ± 95% confidence intervals (CI), Lucchetti Reservoir, 1994–1998.

Date	Population estimate ± CI	*N*/ha	Kg/ha	Total biomass (kg)
Jan 1994	6,564 ± 1,571	61.3	36.4	3,894.8
Jan 1995	3,846 ± 678	35.9	17.4	1,861.8
Jan 1996	11,875 ± 2,454	111.0	38.4	4,108.8
Jan 1997	8,670 ± 1,120	81.0	25.0	2,675.0
Feb 1998	9,670 ± 2,360	90.4	40.4	4,322.8

electrofishing sample. Specimens were found again in June 1996, and they were captured routinely thereafter. During March 1998, several juvenile (<35mm TL) armored catfish were collected for the first time.

Samples also yielded both western mosquitofish (*Gambusia affinis*) and green swordtail (*Xiphophorus helleri*) in very small numbers (<10) throughout the course of the study. Threadfin shad, which were not sampled quantitatively because they are a limnetic rather than a littoral species, were collected in all samples since the onset of the study with the exception of September 1994, when only 21 fish of all species were collected.

Adult (≥250 mm TL) largemouth bass population estimates varied approximately 3-fold in number and over 2-fold in biomass over the 5 years (Table 2). Because growth of young bass is rapid, most reach 250 mm TL and maturity as yearlings. Only in 1997, following a strong 1996 year class, were there substantial numbers of bass <250 mm TL in January. These smaller fish (200–249 mm TL), estimated by ratio, contributed an additional 5,429 individuals (7.2 kg/ha) to the 1997 population. However, mean relative weights ranging from 92.7 to 103.4 were found for all sizes of bass and all years that population estimates were conducted.

Discussion

Relative abundance of each species was dynamic from year to year and among seasons. Species composition also changed over time with 1 species extirpated and another introduced. Samples typically were dominated by juvenile tilapias and largemouth bass early in the year, and by bluegill late summer and fall. This trend closely follows the reproduction cycles of these species.

Threadfin shad, although not quantitatively sampled, were continually present, and at times, when schools were inshore at night, they were equal in abundance to all littoral species combined. At other times, they comprised a small proportion of inshore fishes. In addition, tilapias were probably underrepresented in the samples. Cichlid fishes are less susceptible to direct current and pulsed direct current than centrarchids (Holliman 1998). Nevertheless, the rather constant water temperatures likely resulted in a uniform bias over the annual cycle, thereby allowing the definition of seasonal and annual trends in relative abundance for tilapia species.

Substantial annual variation in juvenile and adult largemouth bass occurred, with little impact on the relative abundance of other species. Year class size of y-o-y largemouth bass is difficult to assess, as hatching occurs over an extended period, and rapid growth rates lead to early-hatched fish becoming unavailable to the sampling gear before late-hatched fish become available (Gran 1995, Churchill et al. 1995). Nevertheless, only in 1996 were young bass abundant enough to apparently suppress prey supplies, leading to reduced density-dependent growth rate of juveniles, as indicated by a large number of age-1 fish <250 mm TL. However, relative weights of adult largemouth bass were approximately 100, indicating high prey availability for mature bass.

Alicea (1995) indicated that prey-sized bluegills (100 mm TL) were uncommon in Lucchetti Reservoir in 1992, but occurred continually in samples from 1993 to 1994. As bluegill became a more dominant species in the reservoir, the percentage of juvenile largemouth bass with empty stomachs declined from 17% and 16% in 1992 and 1993 to only 9% in 1994. The high condition of adult bass at all densities suggests that they may be more flexible in prey utilization than juveniles.

Extreme differences in population size from year to year are consistent with a stock comprised of few year classes, variable recruitment and high mortality rate (Ricker 1975). Rapid growth of young bass (1 mm/day) leads to recruitment at age 1, generally at a length of ≥250 mm. High mortality of adult largemouth bass results in the stock being comprised primarily of age-1 and -2 fish (Churchill et al. 1995); consequently, annual variations in recruitment have a strong impact on adult population size and total predatory biomass. Therefore, management should be directed at stabilizing recruitment and harvest rates.

Nevertheless, variability in adult bass stock seems to have relatively little impact on littoral community structure. Limited examination of adult largemouth bass food habits (Churchill et al. 1995) indicated that threadfin shad and tilapia were the primary diet items. Stancil et al. (1997) document that threadfin shad spawn throughout the year in Lucchetti Reservoir, providing a continuous prey base. However, since threadfin shad and tilapia were utilized in similar proportions, it is unlikely that shad provide a buffer against exploitation of littoral prey resources.

Alicea et al. (1997) found that redbreast tilapia displayed annually consistent seasonal trends in size for fish <100 mm TL. Although presence of fish 20–40 mm TL throughout the year indicated some continual spawning, sizes of prey increased from early to late in the year, consistent with the relatively fewer individuals of redbreast tilapia in the fall. Likewise, they found that Mozambique tilapia exhibited significantly higher numbers early each year.

Stability of the littoral community may be more subject to changes in species composition. During the 6 years of this study, bigmouth sleepers vanished and armored catfish became established. Bigmouth sleeper, a catadromous predatory species that is native to Puerto Rico freshwater systems, occurs commonly in reservoirs. In Lucchetti Reservoir, it has never comprised >1% of the annual littoral sample (Churchill et al. 1995). The disappearance of bigmouth sleepers from the reservoir remains unexplained. Only large (>300 mm TL) specimens were collected when they were present, suggesting that no recruitment was occurring. It is unlikely that the species, which is an estuarine-dependent and therefore catadromous reservoir fish, had been landlocked since construction of Lucchetti Reservoir in 1952. Recruitment, therefore, would occur only via invasion of the reservoir by juveniles, either upstream over the dam or downstream via the aqueduct system, fed by reservoirs that also would need to be invaded from downstream. Such recruitment could be expected to be erratic, so depletion might occur as adults are subject to natural and fishing mortality.

The sudden appearance of armored catfish can probably be attributed to the release of aquarium fish into the reservoir, watershed, or aqueduct system. Armored catfish, which were uncommon on the island 5 years ago, can now be found in most Puerto Rico reservoirs. It is apparent that this population is established and growing in size, as armored catfish nest cavities can be readily observed in the clay banks of the reservoir during low water periods. Its impact on the fish community of Lucchetti Reservoir remains to be determined.

Mosquitofish and green swordtail were also periodically collected in Lucchetti Reservoir, but always at low densities. Mosquitofish occur commonly on the island, but their success in Lucchetti Reservoir is likely limited by steep shorelines and fluctuating water levels. The presence of green swordtail may be attributed to release by anglers using them as bait or discards from aquaria.

Whether community fluctuations in Lucchetti Reservoir are characteristic of Puerto Rico reservoirs is uncertain. Only Guajataca Reservoir, a 310-ha impoundment of northwest Puerto Rico, has been sampled regularly. Churchill et al. (1995) indicated that the fish community composition of Guajataca Reservoir is more erratic than that of Lucchetti Reservoir. Annual assessment is underway on a representative sample of Puerto Rico reservoirs to obtain data for comparisons to Lucchetti Reservoir.

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