Effects of Reservoir Drawdown on Available Habitat: Implications for a Tropical Largemouth Bass Population

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Abstract: In temperate reservoirs, habitat quality and availability can be vital to year-class formation of young largemouth bass. We assessed littoral habitat availability for largemouth bass in a tropical reservoir. Habitat characteristics (slope, substratum, and cover) were measured at 5 water levels (169, 170, 171, 172, and 173 m above mean sea level) at 15 30-m sites in Lucchetti Reservoir. Total structural habitat availability declined sharply at lower water levels, and both inundated terrestrial vegetation and woody debris were absent at the lowest water level examined. Coarse substrates (gravel, cobble, and boulder) were more common at higher water levels, and fine substrates (primarily clay) dominated at lower water levels. Annual catch rates of age-1 largemouth bass from 1993–2000 were significantly related to estimated mean structural habitat availability for the previous spawning season. Water level appears to affect largemouth bass population size partly through availability of habitat, presenting an opportunity for population management through habitat manipulations. Potential water level management protocols are discussed.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 55:156–164

Largemouth bass *Micropterus salmoides* populations in reservoirs are generally assessed and managed on a whole-impoundment scale, yet spatial variations in abundance within reservoirs are common (Summerfelt 1971, Siler et al. 1986, Annett et al. 1996, Irwin et al. 1997, Phillips et al. 1997). Distributions of largemouth bass often vary along longitudinal gradients in physical and biological characteristics (Soballe et al. 1992). Spatial differences in littoral habitat such as substrate, slope, and structure can influence distribution of spawning sites (Hunt et al. *in press*), prey abundance, and risk of predation (Kramer and Smith 1961, Savino and Stein 1982, Meals and Miranda 1991, Phillips et al. 1997). Hence, habitat composition and availability can have important impacts on largemouth bass population dynamics (Annett et al. 1996, Irwin and Noble 1996).

In temperate reservoirs, habitat quality and availability can be vital to year-class formation in young largemouth bass (Aggus and Elliot 1975, Meals and Miranda 1991, Irwin et al. 1997). Reservoir embayments with adequate juvenile habitat have been shown to exhibit larger year-classes than embayments with limited habitat (Phillips et al. 1997). Water level fluctuations can qualitatively and quantitatively change available habitat (Irwin and Noble 1996), and may impact year-class formation (Fisher and Zale 1991). Sammons and Bettoli (2000) found that strong largemouth bass year-classes were produced in years when the water level was at or over pool level during spring and summer in Normandy Reservoir, Tennessee. Thus, the potential exists to manage water levels during largemouth bass spawning and early juvenile stages to maximize recruitment.

In an 8-year study of Lucchetti Reservoir, Puerto Rico, Ozen (2002) found that water level variability during the spawning period directly influences age-1 recruitment to the fishable stock. Also, studies of adult movements (Lilyestrom and Churchill 1996, Waters 1999) as well as juvenile hatching periodicity (Ozen and Noble 2000) suggest that availability of spawning habitat in Lucchetti Reservoir is largely determined by water level. Whereas water level is highly variable in Puerto Rico, the relationship between water level and habitat availability may be crucial to recruitment for largemouth bass. In this study, we quantified changes in relative composition of available habitat (slope, structure, substrate) corresponding to water level fluctuations in Lucchetti Reservoir, Puerto Rico, and we compared mean available habitat during the spawning season to recruitment of age-1 fish the following year.

We thank the personnel of the Puerto Rico Department of Natural and Environmental Resources (DNER), Division of Marine Resources and Division of Reserves and Refuges. Additionally, numerous North Carolina State University employees assisted along the way. These include, but are not limited to T. Churchill, A. Alicea, D. Ashe, O. Ozen, G. Rodriguez-Ferrer, F. del Toro, and D. Mora-Pinto. Funding was provided through Federal Aid in Sport Fish Restoration under Puerto Rico DNER Projects F-16 and F-41-2 and through North Carolina Agricultural Research Service Project 06270.

Methods

Lucchetti Reservoir is a 108-ha impoundment in the mountain region of southwestern Puerto Rico. The area receives an average of 198 cm of rainfall annually and was originally tropical forest, although much of the landscape is now used for agriculture. Lucchetti Reservoir has been categorized from mesotrophic to eutrophic on the basis of nutrients, physical limnology, chlorophyll *a*, and phytoplankton biomass data (Puerto Rico Environ. Quality Bd. 1992, Tilly 1983, Churchill et al. 1995). The maximum depth is 22.2 m (Neal et al. 1999), but water levels can decline as much as 18 m (Fig. 1). The primary function of the reservoir is water storage for irrigation, but

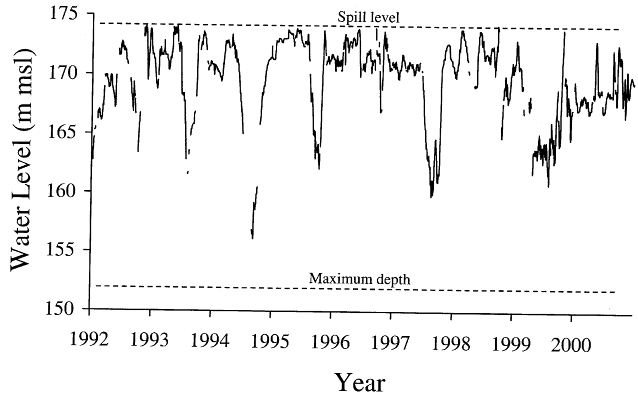

Figure 1. Water level in Lucchetti Reservoir, Puerto Rico, measured as meters above mean sea level (msl) for 1992–2000. The upper limit represents the level at which water spills over the dam, and the lower limit represents the maximum depth of the reservoir.

the creation of the Lucchetti Field Station and associated facilities has improved recreational access and increased reservoir popularity among boating anglers (Churchill et al. 1995).

We quantified microhabitat at 15 sites selected to be representative of the common habitat types based on slope, substrate, and structure. This was accomplished during a period of low water when 6 vertical meters of the littoral zone were exposed. At each site, we used horizontal line transects of 30-m length to measure microhabitat components available at 1-m depth contours from 169–173 m mean sea level (msl). This yielded 5 transects per site, each representative of the available habitat at water levels exceeding the respective transect level. For example, at a water level of 174 m msl (full pool), the habitat lying on the 173 m msl transect would be available.

For each transect, the composition of substrate and cover was determined by measuring the horizontal width of each habitat characteristic intersecting the 30-m transect line. We modified the habitat categories presented in Annett et al. (1996) to accommodate the specific habitat and morphological characteristics of Lucchetti Reservoir (Table 1). To categorize slope at each depth contour, we visually integrated along each transect the slope between the transect line and 1-m higher on the shoreline.

Changes in structural habitat availability with water level were assessed using nonlinear regression with a quadratic equation. This equation allowed prediction of available cover at any given water level. We estimated mean structural coverage available during the January–July spawning and nursery periods of 1992–1999 based on mean water levels. Catch rates of age-1 largemouth bass from 1993–2000 reported by Ozen (2002) were regressed on mean structural coverage estimates for the previous spawning period for each year (e.g., 1999 age-1 cohort vs. 1998 mean cov-

Table 1. Microhabitat characteristics recorded for 75 30-m transects in Lucchetti Reservoir, Puerto Rico. Habitat and substrate categories are modified from those presented in Annett et al. (1966) to be more characteristic of Lucchetti Reservoir.

Category	Description, particle diameter, or slope
Habitat structure	
Inundated vegetation	Attached vascular plants; grass, shrubs, small trees
Woody structure	Stumps, logs, woody debris, and root packs
Rocky structure	Any rock or group of rocks providing potential cover
Substrate	
Sand-clay-silt	<5 mm
Gravel	Rocks 5–65 mm
Cobble-boulder	Rocks >65 mm
Bedrock	Solid, embedded stone
Slope	
Shallow	<20 degree incline
Moderate	20–45 degree incline
Steep	>45 degree incline

erage). This allowed us to determine the relationship between recruitment and structural habitat availability.

Results and Discussion

Habitat data assessed at the 15 sites and 5 water levels indicated that percent total cover at a given depth contour decreased significantly as water level declined (Fig. 2; $F_{2,2} = 135$; $P = 0.007$). Total cover was abundant at 173 m msl, covering 93% of the shoreline (Fig. 3). The proportion of coverage dropped precipitously at lower water levels, with only 25% coverage by 169 m msl. Availability of inundated terrestrial vegetation experienced the most dramatic change, with total coverage decreasing from over 73% of the shoreline at 173 m msl to 0% at 170 m msl. Abundance of woody structure was greatest from 171–173 m msl, with almost no coverage at lower levels. Rocky cover was the only habitat type to show increasing occurrence at lower water levels.

Substrate was dominated by clay at all water levels (Fig. 4). The occurrence of clay was highest for 169 m msl and lowest for 173 m msl, and the same was true for bedrock. Both juvenile largemouth bass and nesting adults have been shown to avoid these substrate types (Annett et al. 1996). The percent coverage of both gravel and cobble-boulder substrates was highest at 173 m msl, and no cobble-boulder substrate coverage occurred at 169 m msl. These rocky substrata are important as largemouth bass nesting sites (Annett et al. 1996) and as structural cover for juvenile largemouth bass (Irwin et al. 1997). All observed trends in substrate with declining water level were weak, and none of the relationships were significant at $\alpha = 0.05$. Slope categories did not change significantly within the range of water levels examined.

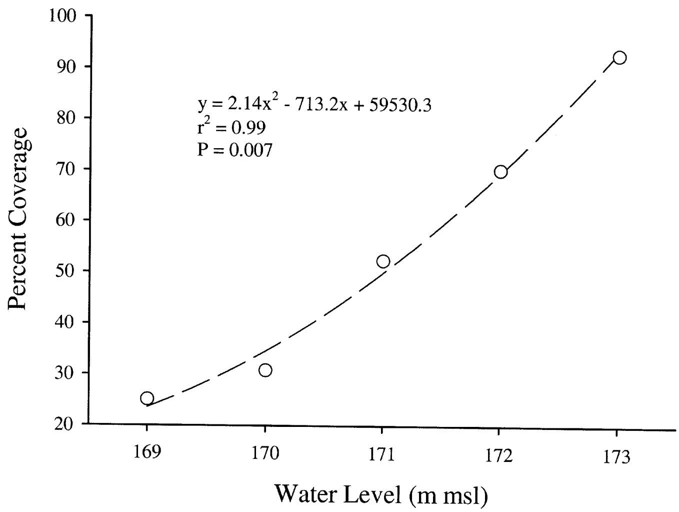

Figure 2. Relationship of percent coverage of structural habitat and water level for 169–173 m msl contour levels. A quadratic equation provided the best fit using nonlinear regression.

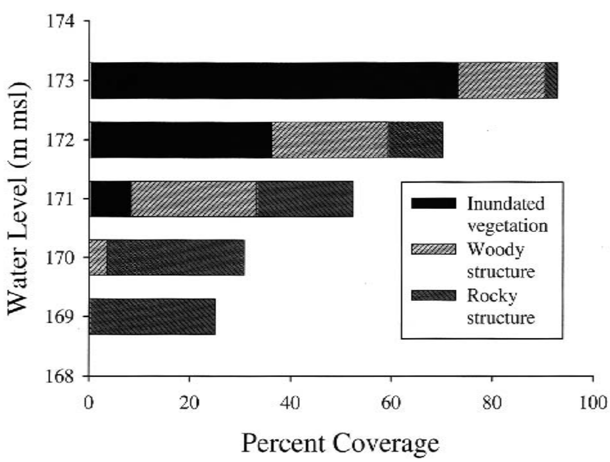

Figure 3. Structural habitat composition and mean percent coverage measured at 5 water levels at 15 sites in Lucchetti Reservoir.

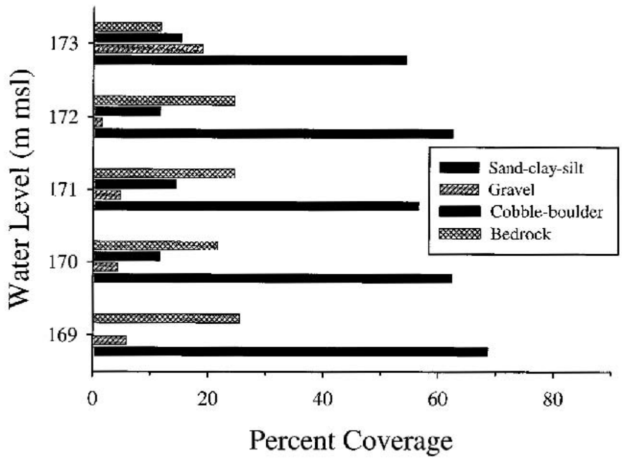

Figure 4. Mean percent coverage of substrate types measured at 5 water levels at 15 sites in Lucchetti Reservoir.

The differences in available structure over depth contours, particularly inundated vegetation, resulted from the normally cyclic pattern of water level. Reservoir level typically declined during the summer in preparation for the impending hurricane season, allowing vegetation to grow on the higher exposed shoreline first. When water level rose during the late fall and winter, this terrestrial vegetation was inundated, providing important habitat for largemouth bass. Largemouth bass spawning in Lucchetti Reservoir has been shown to occur exclusively in shallow, vegetated areas (Waters 1999). Also, juvenile largemouth bass prefer vegetative cover (Strange et al. 1982), which can reduce predation risk (Savino and Stein 1982) and may act as a substratum for prey items (Annett et al. 1996). The amount of inundated vegetation available for cover should be directly related to the duration and magnitude of the low water period.

Surprisingly, rocky cover increased in coverage at lower water levels. However, the occurrence of dense inundated vegetation at higher water levels may have biased our estimates of both woody and rocky cover. Our methodology, designed to prevent estimates of total coverage from exceeding 100%, assumed that only 1 structural component (i.e., inundated vegetation or woody debris, etc.) could occupy any given area. However, in many cases both rocks and woody material coincided with terrestrial vegetation. Although we made attempts to include these other habitat types, dense grass, weeds, and shrubs frequently concealed them. This was especially true for rocky cover, which was likely underestimated at higher water levels.

Water level characteristics during the spawning season in Lucchetti Reservoir account for much of the variation in recruitment of largemouth bass (Ozen 2002). Whereas water level determines habitat availability, it is likely that available habitat

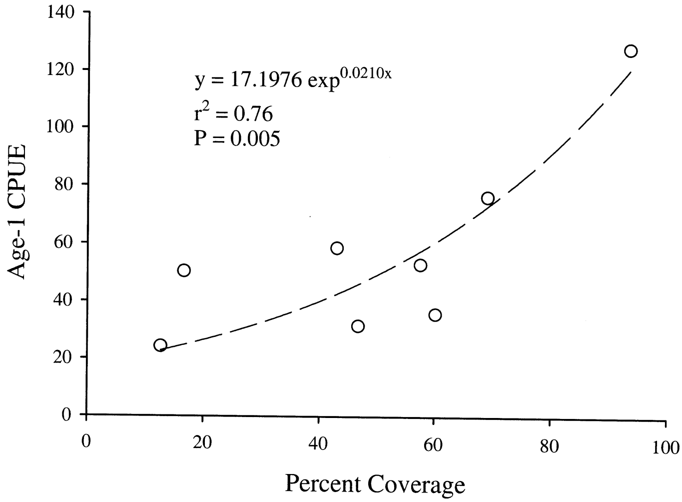

Figure 5. Estimated percent coverage of structural habitat (inundated vegetation, wood, and rock structure) at mean water level from January to June versus annual mean catch per effort of age-1 largemouth bass for 8 years. An exponential equation provided the best fit using nonlinear regression. Catch data were adapted from Ozen 2001.

is one of the key factors for successful recruitment. Most studies on the effects of water level fluctuations on fish populations have focused on recruitment processes, linking spawning success to water level variation (Zalewski et al. 1990, Kohler et al. 1993). Although sharp declines in water level can expose largemouth bass nests and cause nesting males to leave the spawning grounds (Waters 1999), prolonged periods of low water will likely affect recruitment via habitat availability for spawning and nursery (Ploskey 1986). In this study, we regressed annual age-1 largemouth bass catch rates from Ozen (2002) against estimated mean structural coverage during the previous spawning season (Fig. 5). There was a strong relationship between the two ($F_{1,6}$ = 19.0, P = 0.005), suggesting that structural cover is crucial to year-class formation in this reservoir.

Juvenile largemouth bass have been shown to prefer complex physical structure, especially areas including aquatic vegetation and woody debris (Annett et al. 1996). Since habitat is a primary factor regulating the distribution and abundance of age-0 largemouth bass (Irwin 1994), changes in habitat with water level fluctuations may impact populations of this species. We have shown that the abundance of complex physical habitat in Lucchetti Reservoir declines rapidly as water level decreases. In addition, previous research has shown that adult largemouth bass population size is controlled by water level during the spawning season (Ozen 2002), likely due to habitat availability. The importance of habitat to largemouth bass recruitment presents an opportunity for population management through habitat manipulations

(Irwin et al. 1997). Our results suggest that high recruitment is realized when structural cover, submerged vegetation in particular, is abundant. By moderately lowering water level during summer and fall, terrestrial vegetation can grow on exposed littoral substrates, thereby achieving conditions similar to those successfully used by Strange et al. (1982) to enhance juvenile habitat. Lowering water levels for a short duration also concentrates prey species for juvenile largemouth bass, allowing faster growth. When water level returns to near full pool in winter, the terrestrial vegetation is inundated as spawning commences. Maintaining a high, stable water level during the spring will allow nesting adults and juveniles to take full advantage of the habitat, maximizing year-class production and ensuring stable recruitment in this tropical reservoir.

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