Diet and Movement of Largemouth Bass and Butterfly Peacocks in La Plata Reservoir, Puerto Rico

Craig G. Lilyestrom, *Puerto Rico Department of Natural and Environmental Resources, Marine Resources Division, San Juan, PR 00906*

Timothy N. Churchill, *North Carolina State University, Department of Zoology, Raleigh, NC 27695*

Abstract: Diet and telemetry studies were conducted in La Plata Reservoir, Puerto Rico, to investigate potential interactions between largemouth bass (*Micropterus salmoides*) and butterfly peacocks (*Cichla ocellaris*). Partitioning of food resources between the 2 species was evident and consistent over several size classes. Interspecific differences were observed in home range size, diel movement, and habitat preference during telemetry studies conducted on adults for up to 250 days. Maximum activity for both species corresponded with periods of elevated food consumption. Although the current studies were restricted to 1 reservoir, low overlap in diet and habitat preference indicates ecological compatibility in tropical reservoir systems.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 50:192-200

Largemouth bass and peacock cichlids (*Cichla* spp.) are morphologically similar predators that evolved in temperate North America and tropical South America, respectively. Introductions of peacock cichlids to freshwater systems containing largemouth bass have been highly successful in Florida and Hawaii, with no apparent negative biological interactions and a high economic benefit to surrounding areas (Devick 1972*a*, Shafland 1995). In Florida, 2 species of peacock cichlids, the butterfly peacock (*C. ocellaris*) and the speckled peacock (*C. temensis*), have proven efficient at reducing excess tilapia (*Tilapia* spp.) production while providing excellent, self-sustaining sport fisheries (Shafland 1995).

Butterfly peacock introductions into Puerto Rico's reservoirs have had mixed success since the species was imported from Colombia in 1967 (Erdman 1984). Several failures to establish have been recorded, and most island reservoirs where they have been stocked with existing largemouth bass populations remain numerically dominated by the latter (Corujo Flores 1989). Liberal daily bag limits of 12 large-

mouth bass and 8 butterfly peacocks were implemented in 1984 for all reservoirs, but the effects of these regulations have not been thoroughly evaluated. Both species are popular sport fishes although there has been some controversy among anglers over the effects of butterfly peacocks on fish communities.

We hypothesized that interspecific competition may be responsible for the poor performance of 1 species or the other in Puerto Rico reservoirs. Potential for food competition was investigated by comparing diets for 3 size classes. Movement of adults of both species was evaluated over time to determine potential overlaps in habitat use and feeding periods. Telemetric studies have not been previously conducted on butterfly peacocks or largemouth bass in Puerto Rico.

Funding for this study was provided under Federal Aid in Sport Fish Restoration Project F-30 of the Puerto Rico Department of Natural and Environmental Resources (PRDNER). We wish to thank Pedro Quiñones and Gilberto Oliveras of PRDNER for their unwavering support in the field and laboratory. Thanks are also extended to Paul Shafland, Kirk Winemiller, and a third anonymous reviewer for their suggestions for improving this manuscript.

Methods

La Plata Reservoir, Puerto Rico, a 390-ha impoundment, was selected for this study because it supports quality fisheries for both largemouth bass and butterfly peacocks. It is the island's largest reservoir and contains a high degree of habitat complexity. Like most reservoirs in Puerto Rico, La Plata has steep shores and narrow littoral margins along exposed shoreline reaches of the old river bed. Embayments are shallow and sedimented and heavily colonized in places with water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). Water quality conditions and temperature vary little throughout the year despite fluctuations in water level and rapid flushing rates (Tilly and García-Sais 1987).

Sampling for largemouth bass and butterfly peacock diet studies was performed by shoreline electrofishing using a boom-mounted, direct-current shocking unit. Stomach contents were removed from live fish using acrylic tubes and preserved in formalin (Van Den Avyle and Roussel 1980). Fish and insects were identified and enumerated, and prey volume was estimated by water displacement. Indices of diet diversity (Shannon-Weiner H), food item dominance (d) and affinity (I) were calculated to describe diet composition (Calliet et al. 1986). Indices of relative importance (IRI) were calculated with pooled information on volume, number, and frequency of each food item to estimate overall importance in the diet (Calliet et al. 1986).

Adult largemouth bass (N = 9, 382–540 mm total length, TL) and butterfly peacocks (N = 9, 301–400 mm TL) were collected from La Plata Reservoir by shoreline electrofishing and lightly anesthetized prior to surgical implantation of ultrasonic telemetry tags commencing in July 1993. Ultrasonic tags (Model CT-82-2, Sonotronics, Inc.) that weighed 8 g and operated at a nominal frequency of 75.0 kHz were inserted into a 30- to 40-mm incision on 1 side of the ventral midline posterior to the pelvic fins. Tags were labelled with the name, address, and telephone number of the

principal investigator. The public was informed of the study via mailings, fliers, radio, and word of mouth. Anglers were advised to release tagged fish upon capture.

Fish tracking was performed from July 1993 to June 1994 when a severe drought caused water levels to fall dramatically and the reservoir became inaccessible. Attempts were made to locate fish 2 to 3 times each week during randomly selected morning and afternoon hours. No trips were made to locate fish until 7 days after release to prevent bias due to unusually large movement patterns during the first week post-surgery observed in other studies (Peterson 1975, Warden and Lorio 1975, Winter 1977). The entire reservoir basin was covered in each tracking effort until all tagged fish were accounted for. However, if a given fish was not located in 3 subsequent trips, it was assumed to have been harvested.

Location of fish was determined by triangulation and line of sight to shoreline features. After each fish was located with hydrophones, water depth was recorded from a depth finder and notes were made regarding surface habitat at the site. Colored flagging was used to identify sites when necessary, and all locations were mapped at a scale of 1:5,800. The number of times each species was observed at a particular habitat type was tested using Loglikelihood (chi-square) analysis. Calculation of habitat electivity indices was not performed due to variability in percentage of vegetative surface coverage present over the study period.

Home ranges were calculated assuming that butterfly peacocks and largemouth bass are exclusively littoral. Individual home ranges were presented as shoreline lengths between the 2 most distant observations. An observation curve was calculated and home range considered stable when its length did not increase by more than 5% for every 5 observations (Odum and Kuenzler 1955).

Diel tracking was performed on selected tagged fish during 24-hour periods in August 1993 (warm water period) and January 1994 (cool water period). Two fish of each species were followed during August and 1 of each species during January. Minimum and maximum surface water temperatures recorded at La Plata Reservoir during the tracking period were 23.7 C during January and 29.8 C during August. Diel movements were measured as straight-line distances on maps between locations noted every 2 hours.

Results

Diet

Feeding periodicity differed somewhat between species with respect to the volume of food found in stomachs (Fig. 1). Largemouth bass had 2 distinct feeding periods, 1 from 0800 to 1000 hours and another from 1700 to 2000 hours. Most largemouth bass stomachs collected between 1200 and 1600 hours were empty or contained well-digested food.

Butterfly peacock food volumes reflected a short period of feeding activity at 0900 hours. However, a main feeding period was identified between 1300 and 1700 hours when most butterfly peacock stomachs contained undigested food items. This period corresponded with the period when largemouth bass were least active.

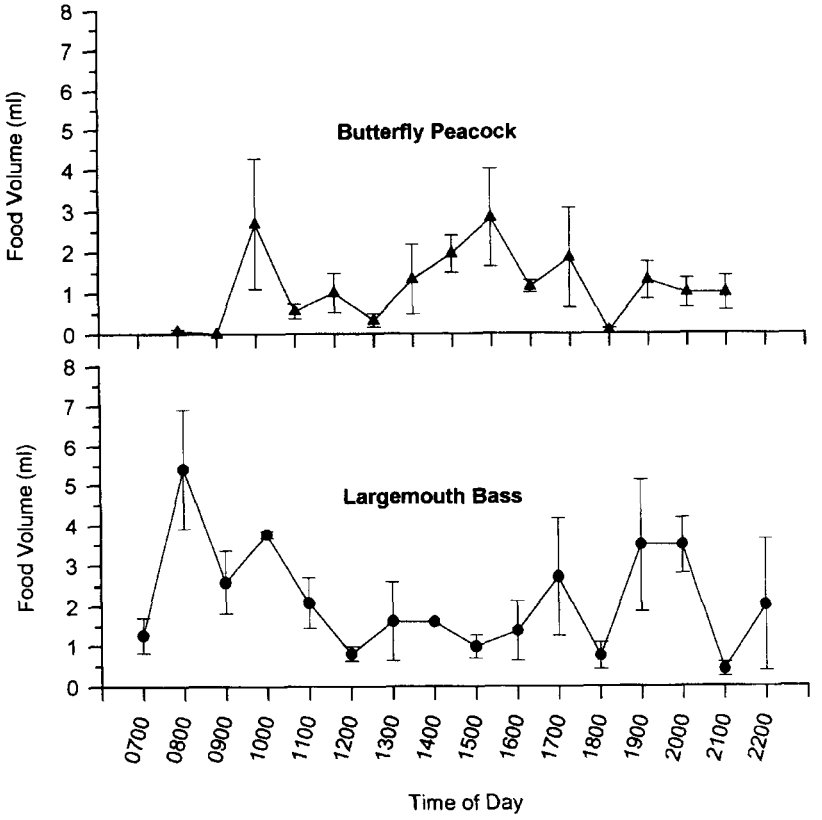

Figure 1. Diel feeding periodicity of largemouth bass and butterfly peacocks in La Plata Reservoir, Puerto Rico, based on mean food volume (with SE bars) found in stomachs.

The diet of largemouth bass ≤150 mm was dominated by threadfin shad (*Dorosoma petenense*) followed by tilapia (*Tilapia* spp.) fry and unidentified fish remains (Table 1). Other items of minor importance included western mosquitofish (*Gambusia affinis*), prawns (*Macrobrachium* sp.), and aquatic insects. The diet of butterfly peacocks ≤150 mm was dominated by tilapia fry; 83% of individuals contained this food item. Threadfin shad, aquatic insects, fish remains, and tilapia fingerlings were of lesser importance.

Threadfin shad were approximately 4 times as important in the diet of largemouth bass 151–300 mm. Tilapia fingerlings, prawns, aquatic insects, and largemouth bass fingerlings (cannibalism) were also detected in stomachs. Medium-sized butterfly peacocks in the same size range consumed tilapia fry most frequently. Tilapia was more than twice as important as threadfin shad in the diet of butterfly peacocks. Tilapia fingerlings, sunfish (*Lepomis* spp.) fingerlings, and unidentified fish remains were also present, but were of minor importance.

Diets of the largest size class (≥300 mm) were similar for both species, with

Table 1. Dietary index values used to describe trophic relationships between largemouth bass and butterfly peacocks in La Plata Reservoir, Puerto Rico. All values were calculated using both prey item frequency and volume (in parentheses). Only *IRI* values >100 are presented.

			Diet indices			
Size class (mm)	*N*	Food item	Relative importance *IRI*	Diversity *H*	Dominance *d*	Similarity *I*
			Largemouth bass			
<151	67	Threadfin shad	2,807	1.80 (1.53)	0.23 (0.28)	
		Tilapia fry	761			
		Fish remains	693			
151–300	249	Threadfin shad	4,896	1.31 (1.11)	0.39 (0.53)	
		Tilapia fry	1,169			
		Fish remains	337			
>300	93	Threadfin shad	4,873	1.50 (1.51)	0.36 (0.30)	
		Tilapia fingerlings	777			
			Butterfly peacock			
<151	23	Tilapia fry	14,456	0.55 (1.67)	0.78 (0.25)	
151–300	109	Threadfin shad	2,036	0.55 (1.67)	0.78 (0.25)	
		Tilapia fry	4,844			
>300	22	Threadfin shad	2,972	0.55 (1.67)	0.78 (0.25)	
		Tilapia fingerlings	768			
		Largemouth bass fingerlings	336			
		Guppies	228			
		Tilapia fry	162			
		Sunfish fingerlings	146			
			Interspecific			
<151						0.49 (0.64)
151–300						0.65 (0.68)
>300						0.29 (0.71)

threadfin shad the dominant food item. Feeding in this size range appeared to be more opportunistic, and *IRI* values for tilapia fry, tilapia fingerlings, largemouth bass fingerlings, guppies (*Poecilia reticulata*), and sunfish fingerlings all exceeded 100.

Diet diversity indices calculated for each species indicated that the diet of largemouth bass was more diverse than that of butterfly peacocks for all size classes (Table 1). Lizards, terrestrial insects, and snails were encountered only in largemouth bass diet, thus contributing to higher diversity values ($H \geq 1.30$). The butterfly peacock diet was numerically dominated by 1 or a few food items (usually tilapia fry) across all 3 size classes as reflected by low diversity index values ($H = 0.55$) and high dominance index values ($d = 0.78$). Interspecific trophic differences determined volumetrically were small, although butterfly peacocks generally appeared more specialized than largemouth bass.

Movement

Important interspecific differences were observed in the following habitat association categories in La Plata Reservoir: brush, floating vegetation [water lettuce, water

hyacinth, and dense-flower smartweed (*Polygonum densiflorum*)], inundated trees and stumps, rock, and other [including common bamboo (*Bambusa vulgaris*) stands, inundated grasses, and no cover] ($\chi^2 = 37.62$, $P \leq 0.001$). Largemouth bass tended to associate with floating vegetation and butterfly peacocks with flooded trees and stumps (Table 2). Largemouth bass located near the dam, where floating vegetation extended across the reservoir, were occasionally found far from shore beneath heavy mats of water hyacinth and water lettuce. Differences in mean depth preference were also detected between the 2 species (*t*-test, $P = 0.0001$, df = 456). Mean depth (with SE) for butterfly peacock observations ($N = 264$) was 3.2 ± 0.14 m and for largemouth bass ($N = 194$) was 4.1 ± 0.16.

Home ranges calculated for butterfly peacocks were nearly 3 times larger than those calculated for largemouth bass. Mean linear home ranges ($4{,}769 \pm 750$ m for butterfly peacocks and $1{,}746 \pm 750$ m for largemouth bass) differed significantly (*t*-test, $P = 0.0116$, df = 16). Values ranged from 1,680 to 11,312 m for butterfly peacocks and from 577 to 4,032 m for largemouth bass. No significant relationship was observed between length of home range and total length of fish. Home range and habitat association observations were collected for up to 250 days.

Diel movements of 2 adult largemouth bass monitored at 2-hour intervals indicated that they were more active during the warmwater period (Tables 3, 4). Highest activity generally corresponded with dawn and dusk during August, although 1 individual moved much more than the other. Low activity levels were observed throughout the day for 1 largemouth bass during the January 1994 monitoring. Butterfly peacocks exhibited little activity during either period, but moved slightly more in January than in August. Minor movement (2400–0200 hours) was observed for the 2 fish monitored during August 1993, and for the 1 individual tracked in January 1994. No observations were made from 0400 to 0800 hours for either species during January 1994, which prohibited evaluation of early morning movement.

Disappearance of tagged fish was a problem throughout the study. Four largemouth bass and 4 butterfly peacocks were confirmed captured, and their tags returned by anglers. These tags were inserted into other fish. Two largemouth bass and 3 butterfly peacocks that disappeared from the reservoir probably were harvested by anglers. One individual of each species ceased movement after a time and was presumed dead. Only 3 fish were active at the end of the study period.

Table 2. Proportional use (%) of major habitat association categories by transmitter-tagged largemouth bass ($N = 221$ observations) and butterfly peacocks ($N = 282$ observations) in La Plata Reservoir, Puerto Rico.

Habitat association	Largemouth bass	Butterfly peacock
Brush	14	13
Floating vegetation	58	34
Flooded trees/stumps	20	37
Rocks	3	7
Other	5	9

Table 3. Diel movement of largemouth bass (LMB) and butterfly peacocks (BP) (m/minute) during August 1993 in La Plata Reservoir, Puerto Rico. Total lengths were as follows: LMB No. 1 = 540 mm; LMB No. 2 = 440 mm; BP No. 1 = 302 mm; BP No. 2 = 301 mm.

	LMB		BP	
Time period	No. 1	No. 2	No. 1	No. 2
1200–1400	0.000	0.000	0.000	0.000
1400–1600	3.025	0.260	0.000	0.000
1600–1800	1.100	0.470	0.000	0.000
1800–2000	0.130	0.000	0.000	0.000
2000–2200	5.160	0.490	0.000	0.000
2200–2400	1.870	0.000	0.000	0.000
2400–0200	2.420	0.000	0.350	0.000
0200–0400	1.880	0.000	0.000	0.000
0400–0600	0.000	0.000	0.000	0.000
0600–0800	4.640	0.570	0.000	0.000
0800–1000	0.920	0.000	0.000	0.000
1000–1200				

Table 4. Diel movement of largemouth bass (LMB) and butterfly peacocks (BP) (m/minute) during January 1994 in La Plata Reservoir, Puerto Rico. Total lengths were as follows: LMB No. 3 = 439 mm; BP No. 3 = 400 mm.

Time period	LMB No. 3	BP No. 3
1200–1400	0.150	0.220
1400–1600	0.810	0.410
1600–1800	0.470	0.000
1800–2000	0.210	0.000
2000–2200	0.210	0.000
2200–2400	0.170	0.000
2400–0200	0.210	0.000
0200–0400	0.000	0.140
0400–0600		
0600–0800		
0800–1000	0.290	0.940
1000–1200	0.530	0.390

Discussion

Results of this study suggest that largemouth bass and butterfly peacocks occupy different niches in La Plata Reservoir. While there is some overlap in diet, largemouth bass tend to be more opportunistic foragers, whereas butterfly peacocks select tilapia fry, at least up to 300 mm. Based on item frequency, interspecific diet overlap (I = 0.65) was highest for the intermediate size class.

Competition for similar food resources occurs only when resources are limited on a spatial or temporal scale. Redbreast tilapia (*T. rendalli*) and Mozambique tilapia (*T. mossambica*) comprise a large proportion of La Plata Reservoir's fish biomass and are abundant in all areas of the reservoir (Lilyestrom et al. 1994). Both tilapia and threadfin shad have been reported to spawn multiple times each year in Puerto Rico reservoirs making them continuously available for predators of all sizes (Churchill et al. 1995).

Although diel monitoring was limited and variable for both species, La Plata Reservoir largemouth bass appeared to feed mainly during morning and evening hours, and butterfly peacocks during afternoon. The volume of food in stomachs and the number of identifiable food items had their highest values following periods of observed maximum activity for both species. These findings support the conclusions of Devick (1972*a*, 1976) and Shafland (1995) that the 2 species partition food resources.

Biotelemetric observations of habitat preferences corroborated Devick's (1972*b*) contention that butterfly peacocks generally inhabit shallower areas and different types of cover than largemouth bass. Butterfly peacocks generally moved longer distances than largemouth bass which may be related to their tactic of pursuing forage fishes as opposed to the ambush tactic used by largemouth bass (Erdman 1969). One butterfly peacock moved the entire length of the reservoir basin several times.

Adult largemouth bass occupied smaller home ranges than butterfly peacocks, suggesting that the latter had a greater ability to utilize more of the reservoir's spatial resources. Largemouth bass daily activity periods during both warm and cool water monitorings were nearly identical to those reported in a Florida study (Mesing et al. 1981). The lack of a relationship between home range length and fish size reported by Mesing and Wicker (1986) in Florida may have been due to the narrow length ranges of both species tagged in this study.

Syntopic stocking of these 2 species should be successful in Puerto Rico, especially in large waters with habitat complexity similar to that found in La Plata Reservoir. Past failures of butterfly peacocks to establish in Puerto Rico reservoirs containing largemouth bass may have been due to other factors such as insufficient numbers stocked, water level effects, or overharvest. Further studies are needed to address factors affecting recruitment and angler effects on both species in Puerto Rico.

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