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Growth, Survival, and Site Fidelity of Florida and Intergrade Largemouth Bass Stocked in a Tropical Reservoir

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Abstract.—Differential performance of genetic strains of largemouth bass *Micropterus salmoides* is an important management consideration. In Puerto Rico, largemouth bass are widely stocked without attention to which stock is the superior genetic stock for island reservoirs. We simultaneously stocked fingerling Florida largemouth bass *M. s. floridanus* and intergrade (hybrids of Florida and northern largemouth bass *M. s. salmoides*) largemouth bass at four sites within Lucchetti Reservoir, Puerto Rico. Recapture efforts 24–26 d following stocking revealed no differences in initial growth or survival. Dispersion from stocking sites varied among sites and between groups at two sites and for all sites pooled; Florida largemouth bass were significantly more mobile after stocking. Relative abundance of each group was similar at age 1, but Florida largemouth bass accounted for 76% of the catch at age 2 and 100% at ages 3 and 4. Initial growth rate was rapid for both groups (1.25 mm/d) until about 275 mm total length, but growth slowed to 0.25 mm/d by age 1 and was only 0.06 mm/d after age 2. Mean relative weight (W_r) of intergrade largemouth bass was significantly higher than that of Florida largemouth bass at ages 1 and 2 during the spawning season (although the Florida groups' W_r remained at nearly 100). Because Florida largemouth bass displayed greater longevity, we recommend future stockings to use only this subspecies in Puerto Rico.

Genetic variation of largemouth bass *Micropterus salmoides* is an important management consideration because of widespread range expansion through extensive stocking programs (MacCrimmon and Robbins 1975), as well as differential performance of genetic strains (Pelzman 1980). Bailey and Hubbs (1949) recognized two subspecies, northern *M. s. salmoides* and Florida *M. s. floridanus*, and described superior growth of the Florida subspecies. Introductions of the Florida largemouth bass have proceeded under the assumption that this subspecies will exhibit superior growth rate and longevity, as well as lower vulnerability to angling (Kleinsasser et al. 1990), and hence provide larger fish than existing bass stocks (Pelzman 1980).

Conflicting reports support and discredit the proposed superiority of Florida largemouth bass. Researchers have concluded that Florida largemouth bass in their native environment demonstrate superior growth to trophy size because of longer growing season and other favorable environmental factors (Chew 1975), which may or may not be experienced when these fish are introduced elsewhere. Bottroff (1967) found, however, that Florida largemouth bass performed better in California than the northern subspecies. Johnson and Graham (1978) found no differences in growth rates of the two subspecies up to age 3, but noticed higher growth rates of Florida largemouth bass at ages 4 and 5. In Texas ponds, F_1 hybrids (female Florida × male northern subspecies) were heavier at comparable lengths than either parental subspecies or the reciprocal F_1 hybrids (female northern × male Florida subspecies; Kleinsasser et al. 1990).

Most studies comparing northern and Florida largemouth bass have focused on growth and condition (e.g., Wright and Wigtil 1982; Rudd 1985; Williamson 1986; Isely et al. 1987; Maceina and Murphy 1988; Philipp and Whitt 1991). In addition, a number of studies have addressed stress reaction (Williamson and Carmichael 1986), thermophysiological differences and overwintering mortality (e.g., Cichra et al. 1982; Guest 1985; Parker et al. 1985; Philipp et al. 1985a, 1985b; Fields et al. 1987; Koppelman et al. 1988), and angling vulnerability (Stevenson 1973; Johnson 1975; Zolczynski and Davies 1976; Inman et al. 1978; Rieger and Summerfelt 1978; Kleinsasser et al. 1990). Many of these reports conflict, however. The inconsistencies might have resulted from the lack of persuasive data on genetic identity (Philipp et al. 1991). A method for accurately identifying the percent contribution of the two subspecific genomes was unavailable before use of starch gel electrophoresis (Philipp et al. 1981, 1983).

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In Puerto Rico, largemouth bass have been stocked widely since their initial successful introduction in 1946 (Erdman 1984), and most reservoirs contain populations with alleles of both the Florida and northern subspecies. The intergrade is not a subspecies, but a hybrid form of the two subspecies which have interbred for many years. Intergrade largemouth bass in Puerto Rico are characteristically small and short-lived, few exceeding 400 mm total length (TL) and 3 years of age (Ozen and Noble 2000; Neal et al., in press). Conversely, populations of Florida largemouth bass frequently yield larger and presumably older fish in the two reservoirs in Puerto Rico containing the Florida subspecies exclusively (Churchill et al. 1995; Neal et al. 1999).

Hatchery capabilities for fingerling largemouth bass production in Puerto Rico are limited. Optimal use of those limited resources to supplement reservoir populations will depend on stocking the genetic group that is best suited to the local conditions for growth and survival. If the reported differences in population structure among Puerto Rico reservoirs are a result of genetic differences, then fisheries managers may be able to increase growth and longevity by manipulating genetic composition. We evaluated which genetic group, Florida or intergrade, is better suited for stocking into reservoirs in Puerto Rico. We simultaneously stocked equal sizes and numbers of both genetic groups in Lucchetti Reservoir, and monitored growth, condition, movement, and relative survival of each.

Study Site

Lucchetti Reservoir is a 108-ha impoundment in the mountain region of southwestern Puerto Rico. The lake basin is located in a subtropical moist forest having a mean annual precipitation of 198 cm (Churchill et al. 1995). The Lucchetti Reservoir watershed is composed of 6.7 km^2 of largely agricultural land that has been developed from the tropical forest landscape. The original capacity of the lake at spill level (174 m above sea level) was 20.4 million m^3. The maximum depth is 22.2 m (Neal et al. 1999), and retention time is 0.66 years, an above-average value for Puerto Rican reservoirs (Pérez Santos 1994).

Lucchetti Reservoir is characterized by steeply sloping shorelines with a mixture of rock and clay substrates representing several distinct habitat types. This reservoir has been categorized from mesotrophic (Pérez Santos 1994) to eutrophic (Cham and Carvajal-Zamora 1981) on the basis of nutrients, physical limnology, chlorophyll *a*, and phytoplankton biomass. Water transparency typically ranges from 0.5 to 2.1 m. The lake is divided into four embayments, two major and two minor arms, corresponding to its four primary tributaries. High annual variability in largemouth bass populations and prey base composition have been reported (Ashe et al. 2000), although abundant prey are available year-round (Alicea et al. 1999; Stancil et al. 1999). The largemouth bass population in Lucchetti Reservoir is composed of intergrade largemouth bass.

The Puerto Rico Department of Natural and Environmental Resources (DNER) maintains a management station providing the public a paved access ramp, shoreline fishing access areas, picnic area, and camping facilities. The Puerto Rico Electric Energy Authority is responsible for reservoir operations, and DNER is responsible for its living resources.

Methods

Florida and intergrade largemouth bass fingerlings were stocked into Lucchetti Reservoir at a rate of about 13 bass/ha for each genetic group. All individuals were tagged with binary-coded wire microtags that indicated date of stocking, stocking site, and genetic status. On April 17–18, 1997, we stocked 353–360 Florida largemouth bass (mean TL = 54.0 mm, N = 100, SE = 0.48) and 352–357 intergrades (mean TL = 55.0 mm, N = 100, SE = 0.44) at each of four sites located within separate embayments of the reservoir. A subsample of 30 fish from each group was sent to the Illinois Natural History Survey in Champaign, Illinois, for genetic verification of the group assignments.

Allozyme extraction was performed on liver tissue following the methods described by Philipp et al. (1983), and vertical starch gel electrophoresis was performed to determine protein phenotypes at three genetic indicator loci. The diagnostic loci examined were *AAT-B* (enzyme commission [EC] number 2.6.1.1; IUBMBNC 1992), *IDHP-B* (EC 1.1.1.42), and *MDH-B* (EC 1.1.1.37). Our Florida largemouth bass showed only 3 alleles: *AAT-B*3* and **4* and *IDHP-B*3*. The intergrade populations demonstrated a mixture of Florida and northern subspecies alleles (*AAT-B*1,* and *IDHP-B*1*; Table 1). The MDH-B locus was used secondarily to help determine the degree of intergradation, *MDH-B*2* indicating the Florida subspecies. The intergrades showed a preponderance of Florida subspecific al-

TABLE 1.—Allele frequencies of three major diagnostic loci for genetic groups of Florida and intergrade (hybrids of northern and Florida largemouth bass) largemouth bass stocked into Lucchetti Reservoir, Puerto Rico, in April 1997.

Genetic group	N	AAT-B*			IDHP-B*			MDH-B*	
		*1	*3	*4	*1	*3	*4	*1	*2
Florida	30	0.000	0.733	0.267	0.000	1.000	0.000	0.000	1.000
Intergrade	30	0.117	0.200	0.683	0.000	1.000	0.000	0.050	0.950

lele forms at all three loci, pure Florida alleles occurring at *IDHP-B**.

We used electrofishing, performed 24–26 d following the stocking, to assess the initial growth, survival, and movement of each genetic group. The entire shoreline of the reservoir was electrofished at night using a 260-V, DC, hand-held probe (Jackson and Noble 1995); juvenile largemouth bass were measured for TL (mm), weighed (g), and checked for microtags. Microtagged fish were identified using a Northwest Marine Technologies Field Sampling Detector (FSD-I). If a fish was tagged, it was retained for tag removal; all other largemouth bass were released alive. Locations of capture of all largemouth bass were recorded.

Microtagged juvenile and adult largemouth bass also were collected periodically through July 2001 with additional littoral electrofishing using either the hand-held probe for young bass up to 130 mm TL or pulsed DC via a boom shocker for larger fish. In these samples, microtagged bass were measured, weighed, and retained for tag removal. Date and capture location for each recapture were recorded.

We used relative weight (W_r; Wege and Anderson 1978) to index condition of stocked largemouth bass. We compared W_r of each genetic group during each of the first 3 years at large (age 0 to age 2). Movement distances following stocking were assessed by the "shortest possible distance" method and geographic information system. This method measured the straight-line distance between the stocking and recapture sites without crossing land. We used t-tests to compare growth, condition, and movement distances between groups and analysis of variance (ANOVA) to compare growth and movement among sites. Differences in the number of recaptures at age were analyzed using the Kruskal–Wallis H-test. All tests were two sided at $\alpha = 0.05$.

Results

Sampling 24–26 d after stocking produced 339 juvenile largemouth bass, of which 154 were microtagged. Catch per unit effort was 20.1 fish/h for stocked largemouth bass and 24.1 fish/h for those spawned in the wild. We recaptured 5.4% of the microtagged bass originally stocked, and the recapture rate was similar for both groups (Table 2). Relative abundance of each group remained similar at age 1 (52% Florida versus 48% intergrade, Figure 1). By age 2, Florida largemouth bass accounted for 76% of recaptured largemouth bass; after age 3, only Florida largemouth bass were collected. We observed no difference in relative susceptibility of either group to our gear during the first 2 years, so we believe that the disappearance of intergrade largemouth bass during the third year represented differential mortality of this group. The distributions of recapture ages were significantly different ($H_1 = 7.51$, $P = 0.006$), and

TABLE 2.—Summary statistics for intergrade (subspecific hybrids of Florida and northern largemouth bass) and Florida largemouth bass at stocking and for fish recaptured 24–26 d after stocking into Lucchetti Reservoir, Puerto Rico.

Genetic group	Number stocked	Number recaptured	Percent recaptured	Total length at stocking (mm)	Total length at recapture (mm)	Daily growth rate	
						Mean	SE
Intergrade	1,417	76	5.4	55.0	86.1	1.23	0.051
Site 1	352	12	3.4	55.2	87.4	1.29	0.179
Site 2	353	30	8.5	56.8	84.6	1.11	0.075
Site 3	355	17	4.8	52.8	85.1	1.29	0.069
Site 4	357	17	4.8	54.9	89.1	1.37	0.109
Florida	1,425	78	5.5	54.0	85.4	1.26	0.039
Site 1	357	12	3.4	54.9	86.6	1.27	0.128
Site 2	353	30	8.5	53.6	84.6	1.24	0.059
Site 3	355	18	5.1	55.6	86.2	1.22	0.064
Site 4	360	18	2.8	52.0	85.3	1.33	0.123

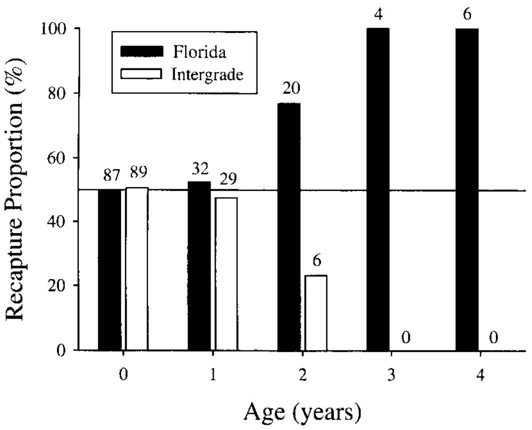

FIGURE 1.—Relative composition of recaptured Florida and intergrade (hybrids of northern and Florida largemouth bass) largemouth bass in Lucchetti Reservoir, Puerto Rico, following stocking in April 1997. The numbers above the bars are the number of recaptures, and the 50% line represents a 1:1 recapture ratio.

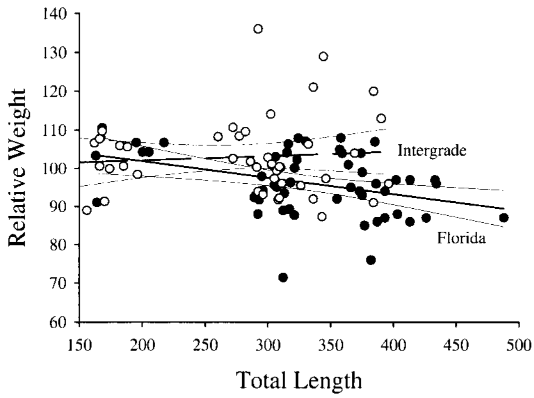

FIGURE 3.—Relationship of relative weight (g) to total length (mm) for Florida (solid circles) and intergrade (i.e., hybrids of northern and Florida largemouth bass; open circles) largemouth bass stocked April 17–18, 1997, in Lucchetti Reservoir, Puerto Rico. Thicker lines are regression lines for the relative weight–total length relationship; thinner lines are 95% confidence limits.

Florida largemouth bass were the longer-lived subspecies.

Growth rate of stocked largemouth bass during the first 26 d at large was 1.25 mm/d, and mean growth rates of Florida and intergrade fish did not differ significantly (t_{152} = 0.177, P = 0.86, Table 2). Growth rates calculated for largemouth bass stocked at each of the four stocking sites did not differ significantly ($F_{3,153}$ = 1.50, P = 0.216). By age 1, growth slowed to 0.25 mm/d, and growth rate was only 0.06 mm/d after fish reached age 2 (Figure 2).

For fish under 225 mm TL, relative weight was not significantly different between the two genetic groups (age 0; Figure 3), but after largemouth bass reached 275 mm TL, intergrade largemouth bass

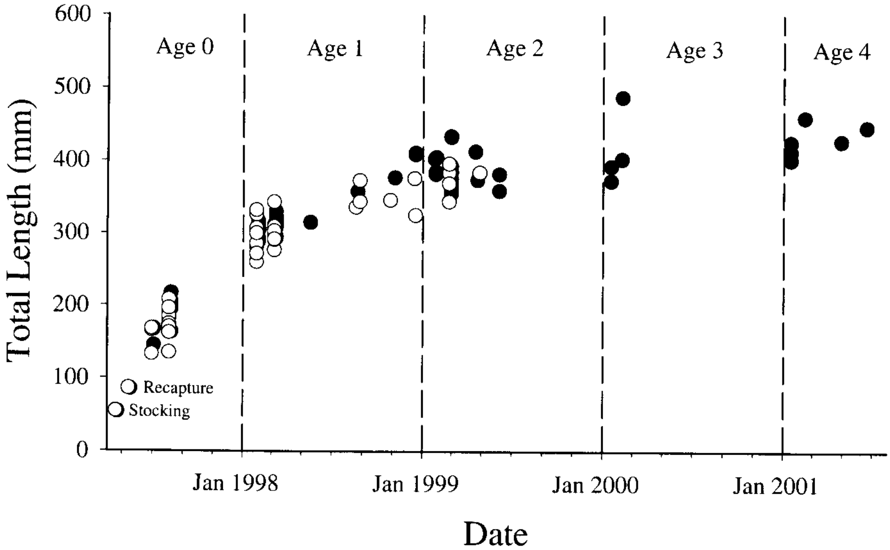

FIGURE 2.—Growth in total length (mm) of Florida (solid circles) and intergrade (i.e., hybrids of northern and Florida largemouth bass; open circles) largemouth bass in Lucchetti Reservoir, Puerto Rico, following stocking on April 17–18, 1997. First data pair indicate the mean size at stocking (N = 100 for each group), the second pair indicate the mean size at recapture 24–26 d later (N = 78 Florida; N = 76 intergrade), and all other points are individual recaptures. Ages of recaptures were determined using a January 1 hatch date.

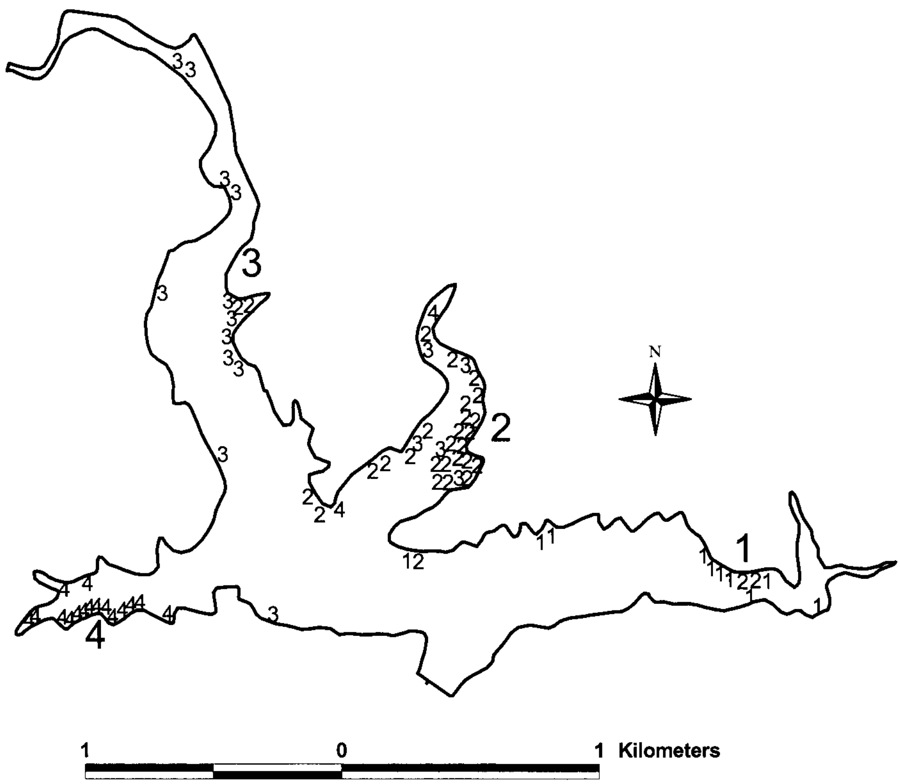

FIGURE 4.—Locations of microtagged Florida largemouth bass when recaptured 24–26 d after initial stocking in Lucchetti Reservoir, Puerto Rico. Large numerals represent the four initial stocking sites, and small numerals indicate recapture location for individual largemouth bass (as numbered according to their initial stocking site).

were significantly higher in condition than Florida largemouth bass (age 1; $t_{52} = -2.55$, $P = 0.007$). At age 2, the condition measures became even more disparate, Florida largemouth bass exhibiting a mean W_r of 96 versus 109 for intergrades ($t_{20} = -2.68$, $P = 0.007$). Of the age-2 and older largemouth bass recollected, 68% were males. Unfortunately, we did not determine sex of recaptures until age 2. Although we had no data on sex ratio at stocking, we assumed it was 1:1.

Movement during the 24–26 d immediately after stocking differed for each group (Figures 4, 5; $t_{146} = -2.27$, $P = 0.024$). Florida largemouth bass, moving an average of 368.4 m (SE = 51.0 m), tended to relocate 115 m farther from the initial stocking site than intergrade fish, which moved an average of 233.2 m (SE = 33.7 m). Movement also varied among sites (Figure 6). Fish relocated the shortest distances from sites 2 and 4, and the greatest distances from site 3 ($F_{3,144} = 3.22$, $P = 0.025$). Site 1 had intermediate movement distances.

Discussion

Genetic constitution of an individual largemouth bass determines its potential fitness. Some genotypes are more suited for the inhabited environment than others and exhibit improved performance (Philipp and Whitt 1991). Thus, introduction of largemouth bass outside of their native environments may result in reduced fitness, manifested in reduced growth, survival, or reproductive capacity. In Puerto Rico, largemouth bass are not native. Most island reservoirs contain intergraded populations, but recent evidence suggests advantages of stocking the Florida subspecies (Neal et al. 1999). Whereas all island reservoirs contain populations with high frequencies of Florida alleles, stocking pure Florida fish will not genetically contaminate reservoir populations.

In our study, we stocked offspring of these two groups simultaneously into the same reservoir to evaluate performance. Genetic analyses confirmed that our Florida largemouth bass contained only

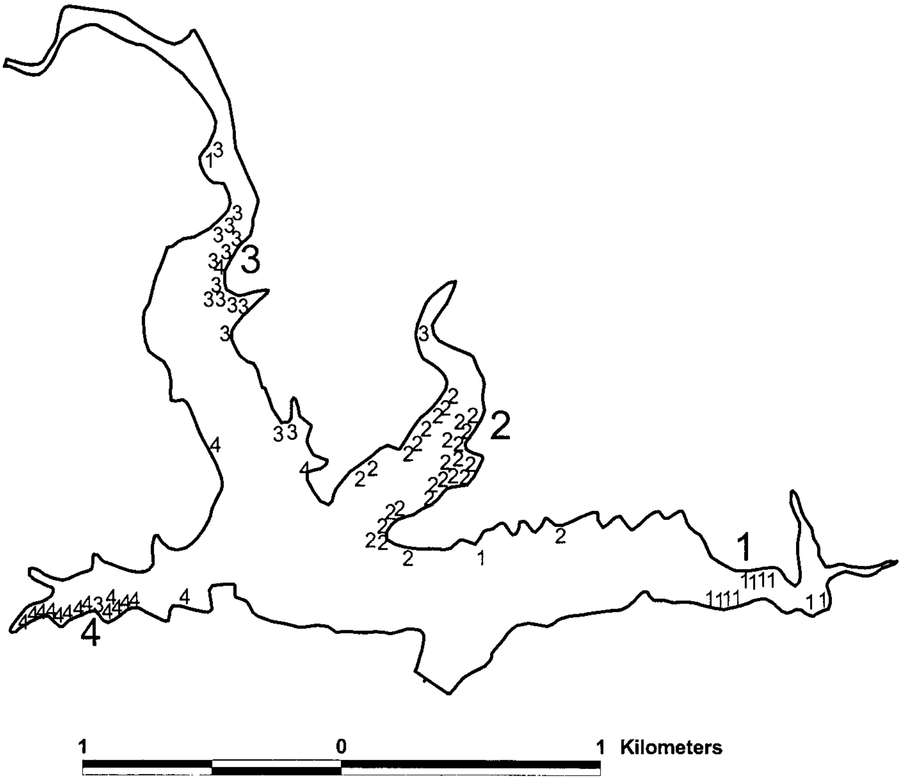

FIGURE 5.—Recapture locations of microtagged intergrade largemouth bass (i.e., hybrids of northern and Florida largemouth bass) 24–26 d after initial stocking in Lucchetti Reservoir, Puerto Rico. Large numerals represent the four initial stocking sites, and small numerals indicate recapture location for individual largemouth bass (as numbered according to their initial stocking site).

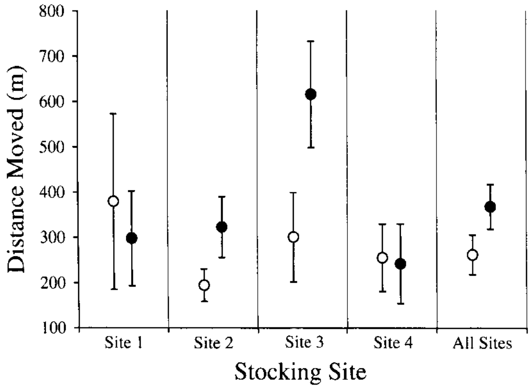

FIGURE 6.—Mean minimum distance from stocking site of intergrade (i.e., hybrids of northern and Florida largemouth bass; open circles) and Florida (solid circles) largemouth bass fingerlings captured 24–26 d after stocking in Lucchetti Reservoir, Puerto Rico. Error bars are standard errors.

Florida subspecies alleles. The intergrade group contained some northern subspecies alleles, but was characterized by a large percentage of Florida subspecies alleles. Growth rates and survival until sexual maturity were similar for both groups, but survival after sexual maturity appeared to favor pure Florida largemouth bass, which accounted for 76% of the recaptures at age 2 and 100% of the recaptures at ages 3 and 4.

Annual mortality of adult intergrade largemouth bass in Lucchetti Reservoir may exceed 50% (Waters 1999; Neal and Lopez-Clayton 2001), and few fish survive to age 3 (Neal et al., in press). Annual fishing mortality from recreational harvest and tournament catch and release is 27–29% and accounts for more than half the overall mortality (Waters 1999; Neal and Lopez-Clayton 2001). Because pure Florida largemouth bass are less susceptible to angling than largemouth bass containing northern subspecies alleles (Kleinsasser et al. 1990), the disappearance of intergrades in Lucchetti Reservoir following their second year at large may have been in part related to greater vulnerability to angling.

Initial growth was rapid for both genetic groups, but slowed considerably after maturity to only 0.06 mm/d after age 2. Ozen and Noble (2000) applied the von Bertalanffy growth equation to data from our genetic groups combined and found an asymptotic length (L_∞) of 404.4 mm, a growth coefficient (k) of 1.44, and t_0 of 0.21. Mean von Bertalanffy growth parameters for 648 largemouth bass populations from 34 states reported by Beamesderfer and North (1995) included $k = 0.21$ and $L_\infty = 635$ mm. This indicates that largemouth bass in Puerto Rico grow much faster to adulthood but do not reach the body sizes attained in the contiguous United States.

Because growth rates did not differ between groups, size-classes were similar, enabling comparison of relative weight by age-class. The differences in mean W_r of Florida and intergrade largemouth bass were apparently due to condition differences in spring. Most of our sampling was conducted during the spawning season, and these data weighted our analyses. We found no significant differences in mean W_r during fall and winter seasons. The difference in condition may have been related to gonadal development, although our experimental design did not address this question. Further research focusing on reproductive investment of these two groups in Puerto Rico is warranted.

A surprising difference between the genetic groups in our study was the tendency of Florida largemouth bass to relocate greater distances from the original stocking sites. We found no evidence in the literature that suggested greater mobility of this subspecies. Movement can influence growth and survival, so movement (and hence genetic composition) is an important factor to consider for supplemental stocking. The availability of appropriate habitat for certain life stages may be critical to recruitment (Gilliam and Fraser 1987; Schlosser 1995), and young largemouth bass demonstrate strong habitat preferences (Irwin et al. 1997). The ability to move to preferred habitat may provide a competitive advantage to Florida largemouth bass in some situations. However, no immediate advantages in juvenile growth and survival were apparent in this study.

The rapid growth to adulthood and the short life span of largemouth bass in Puerto Rico is unusual and, at present, without explanation. Our results suggest that in the future Florida largemouth bass should be stocked in Puerto Rico reservoirs when stocking is employed as a management tool. This genotype disperses more widely and has equal growth to intergrade largemouth bass but lives at least 2 years longer. Although slow growth after age 2 precludes growth to trophy size, these fish do remain in the fishery longer.

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