Assessment of the Performance of Stocked Northern and Florida Largemouth Bass and Their Progeny in Briery Creek Lake, Virginia

by

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(ABSTRACT)

This study examined the suitability of Florida largemouth bass
(Micropterus salmoides floridanus) for introduction into Virginia and
other mid-latitude waters by comparing the performance of northern (M. s.
salmoides), Florida, and hybrid largemouth bass in a 342 ha south-central
Virginia reservoir, Briery Creek Lake (BCL). Fingerling northern and
Florida largemouth bass were stocked into Briery Creek Lake in 1986,
following impoundment, and in 1987. Largemouth bass were collected for
genotypic and performance analyses in the autumn and spring beginning in
1989 and ending spring 1991. Electrophoretic analyses demonstrated that
hybrid largemouth bass (F₁ and F₂) dominated the 1987-1990 cohorts and
indicated that one or both founding stocks were genetically impure.
Comparisons of electroshock catch composition showed no survival advantage
for Florida largemouth bass (FLMB) age-1 and older and no differential
vulnerability to angling among the four presumptive genotypes of
largemouth bass in Briery Creek Lake. Age-0 FLMB proportions declined
over both winters (1989-1990 and 1990-1991) indicating relatively high
first-mortality in the thermal regime of Briery Creek Lake (3,875 annual
mean of heating degree days). Statistical comparisons of growth revealed
no consistent differences among the respective bass genotypes, although
survival and growth tended to be slightly higher for F₁ hybrid bass. The
average total length of largemouth bass in BCL was below the state’s
average by age three. Total lengths of age-0 F₁ and northern largemouth
bass (NLMB) were higher than FLMB and F₂ bass in October, perhaps as a
result of earlier spawning among NLMB and between the subspecies.

Relative weights of largemouth bass in BCL were generally below 95; and few significant differences in Wr were observed among the presumptive largemouth bass genotypes. The suboptimal condition (Wr) of largemouth bass in BCL coupled with the decline in growth and condition of bass with increasing age suggested inadequate prey abundance in Briery Creek Lake.

Overall, Florida subspecific alleles did not increase in BCL over time, but the population genetic composition shifted toward an F1 mixture in the 1990 year class; future generations of largemouth bass should be dominated by F1 individuals. Results of this study did not demonstrate substantial performance differences among northern and Florida largemouth bass, and their hybrids, except for poorer first-year survival of the Florida subspecies. Therefore, this study provides no support for the continued introduction of Florida largemouth bass in Virginia or other mid-latitude regions.
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Introduction

The Florida subspecies of largemouth bass (*Micropterus salmoides floridanus*) has been the subject of much study and controversy since its taxonomic recognition by Bailey and Hubbs (1949). Both the Florida and northern (*M. s. salmoides*) subspecies have been widely stocked outside their native ranges. Fishery managers and anglers have stocked the Florida subspecies of bass in more northerly waters, assuming that the rapid growth and high condition exhibited by bass in Florida and in other areas where Florida subspecific genes are expressed will give rise to trophy bass fisheries in these locations. However, little attention has been given to the possible genetic and ecological impacts of these stocking programs on indigenous largemouth bass populations.

The Florida largemouth bass occurs naturally only in peninsular Florida, from the southern tip of Florida to the Suwannee River drainage, including the St. John's River system in north-eastern Florida (Bailey and Hubbs, 1949). The northern-most point of the St John's River is located at approximately 30° 20'N latitude in Florida. Northern largemouth bass are endemic to the North America north and west of peninsular Florida and southern Canada. Intergrade
largemouth bass, resulting from the interbreeding of the subspecies, occur naturally in the areas of the subspecies' range overlap in Alabama, northern Florida, Georgia, and South Carolina.

Introductions of Florida largemouth bass into lakes in Texas and California have been followed by angler catches of largemouth bass weighing from 6.8–9.0 kg (15–20 lbs.) or more (Botroff and Lembeck 1978). The establishment of these trophy bass fisheries has stimulated the popularity of Florida largemouth bass introductions into lakes and reservoirs throughout much of the United States among anglers and fishery managers. One result of the many agency and private stockings of Florida bass has been a vast expansion of the intergrade zone of largemouth bass (Philipp et al. 1983; O’Bara et al. 1991).

In the wake of increasing fishing pressure, habitat degradation and other stresses on bass populations, anglers and fisheries management agencies regard the Florida largemouth bass as a possible tool for developing or maintaining quality sport fisheries. However, the perceived attributes of the Florida subspecies (lower vulnerability to angling, better survival and longevity, and more rapid growth than northern largemouth bass) may not be observed in some systems, which could prove economically and ecologically unattractive.
In most cases, the quality of the fisheries resulting from Florida largemouth bass stocking programs has not been adequately examined. Florida largemouth bass are expected to grow larger, and generally to prove less vulnerable to angling than northern largemouth bass (Bailey and Hubbs 1949; Botroff and Lembeck 1978; Inman et al. 1978; Smith 1978; Pelzman 1980; Wright and Wigtil 1980; Maceina et al. 1988). However, studies to compare performance of the two subspecies have produced inconsistent conclusions. For example, Nieman and Clady (1978) found that Florida largemouth bass exhibited faster growth than northern bass in the first year of life and Reiger and Summerfelt (1978) reported faster growth for Florida largemouth bass for ages one and two. Both studies were done in Boomer Lake, Oklahoma, which received heated effluent. Botroff and Lembeck (1978) reported substantially faster growth rates for Florida bass older than two years in two San Diego County, California reservoirs. In contrast, Zolcynski and Davies (1976) and Smith and Wilson (1980) reported superior growth of northern largemouth bass during the first year of life in Alabama and Tennessee. Inman et al. (1978) found that in Texas, intergrade largemouth bass demonstrated better growth after three years than either northern or Florida largemouth bass.

Other inconsistencies are apparent in performance of the subspecies concern survival, catchability, condition, and
thermal preferenda (Clugston 1964; Zolczynski and Davies 1976; Inman et al. 1978; Reiger and Summerfelt 1978; Cichra et al. 1982; Smith and Wilson 1982; Betsill et al. 1986). These studies, however, shared a common flaw: the genetic purity of test fish was not confirmed. Therefore, the results of these studies should be interpreted cautiously.

Accurate molecular genetic identification of largemouth bass subspecies and intergrades can be accomplished using known electrophoretic and histochemical staining procedures to observe subspecific genetic markers for largemouth bass. Electrophoresis and histochemical staining of aspartate aminotransferase and isocitrate dehydrogenase (AAT-B and IDh-B, respectively) and other isozyme loci can effectively distinguish the northern and Florida largemouth bass and their hybrids (Philipp et al. 1983; Williamson et al. 1986).

Only a few studies comparing performance among the subspecies and intergrades of largemouth bass have determined the genetic purity of the putative stocks. Philipp and Whitt (1991) investigated growth and survival of the largemouth bass subspecies and hybrids in central Illinois (latitude 40° 10'N). They found that the northern largemouth bass exhibited higher overwinter survival and second and third year growth than the Florida largemouth bass; F₁ hybrids were intermediate for both performance parameters. Florida largemouth bass (about 1.5 years old) were significantly shorter, had lower
relative weights, and were less susceptible to angling and seine capture than northern or hybrid largemouth bass in ponds in San Marcos, Texas (latitude 29° 50′N) (Kleinsasser et al. 1990). In both of these studies, a quasi-natural system was represented by the use of small ponds (0.04–0.48 ha, 2 m max. depth). Only one comprehensive report is available comparing performance of the northern and Florida subspecies of largemouth bass under typical field conditions, in this case a Texas reservoir (Maceina et al. 1988). They reported superior third year growth, a size-dependent fecundity advantage for Florida largemouth bass, and apparently higher survival rates for Florida and hybrid bass compared to northern bass in Aquilla Lake (latitude 31° 55′N). In general, the respective studies have yielded somewhat different results among northern and southern systems, indicating that Florida largemouth bass can thrive in the south but are maladapted to the cold winters in the north. It is not clear whether the Florida subspecies is suitable for establishment in Virginia and other mid-latitude (i.e., 32°–39°N) regions.

Certain performance traits of Florida largemouth bass might render the subspecies inferior relative to local northern largemouth bass stocks if the Florida bass is transplanted to a temperate environment. In Boomer Lake, Oklahoma, which received heated effluent, Rieger and
Summerfelt (1978) reported that survival was higher for northern largemouth bass over both winters during the 1974-76 study period. The relative survival rates were about 66% and 2% for the 1974-75 winter, and 100% and 55% over the 1975-76 winter for northern and Florida largemouth bass, respectively. In thermal bioassays, Cichra et al. (1982) found that the ratio of Florida to northern largemouth bass that died due to cold shock was more than 2:1. In a similar study, Guest (1982) reported that Florida bass were less tolerant of low temperatures or of rapid declines in temperature than northern largemouth bass. No northern largemouth bass died when exposed to temperatures of 1-4°C for 7-30 days, but the cumulative percentage mortality of Florida bass ranged from 13-100% in all four trials. Using genetically verified, pure subspecific individuals and hybrids, Carmichael et al. (1988) documented higher mortality among age-0 Florida and Florida(♀) X northern(♂) hybrid largemouth bass than among northern or the reciprocal hybrids in a laboratory experiment where temperature was reduced from 21°C to 1°C at a rate of 1°C/day. Philipp and Whitt (1991) provided convincing evidence concerning cold tolerance and winter survival of electrophoretically confirmed Florida, northern, and F₁ hybrid largemouth bass (ages 0-3) in central Illinois. In all eight comparisons of survival over the three winters from 1981-1984 in small (0.08 ha) ponds, northern largemouth bass exhibited
the highest percent survival and Florida largemouth bass the
lowest; survival of F1 hybrids was intermediate. Also, as
winter severity increased, a relatively higher percentage of
Florida largemouth bass died.

In addition to lower cold tolerance, Florida largemouth
bass appear more sensitive to handling stress than the
northern subspecies (Williamson and Carmichael 1986). The
extant evidence suggests that Florida largemouth bass differ
physiologically from northern largemouth bass, presumably as
a result of the respective subspecies having evolved in
geographically and climatically different habitats. Studies
demonstrating reduced tolerance of handling and cold stress
(and perhaps other traits of the Florida largemouth bass not
yet examined), may reduce the impetus for stocking the Florida
subspecies into northern and mid-latitude waters.

The Florida subspecies has been stocked into many areas
outside its native range, including lakes containing
indigenous populations of northern largemouth bass. The
subspecies interbreed in areas of contact (Pelzman 1980;
Philipp et al. 1983; Norgren et al. 1986; O’Bara et al. 1991;
Morizot et al. 1991), resulting in introgression into both
respective gene pools. After several generations, northern or
Florida parental forms may become less frequent, and hybrid
largemouth bass may become numerically dominant (Maceina et
al. 1988). Hybrid largemouth bass may demonstrate better
growth and survival than either pure forms. This "heterotic advantage" may explain the outstanding growth seen in the "Big Bass Belt" of northern Florida, southern Alabama, Georgia, and South Carolina, where trophy bass are frequently observed. However, the incorporation of new, maladaptive genes, such as reduced cold tolerance, may eventually break down locally adapted gene complexes and thereby reduce overall population productivity (Philipp et al. 1981).

Florida largemouth bass genes currently occur in the bass populations of a number of Virginia reservoirs (Philipp et al. 1983). However, no attempts have been reported to quantify the performance of the Florida subspecies and its hybrids with northern largemouth bass in Virginia or other mid-latitude areas within the United States. Briery Creek Lake, in south central Virginia, was impounded in 1986 and stocked with both subspecies of largemouth bass. This created a unique opportunity to study the performance and interactions of Florida and northern largemouth bass under field conditions.

The goal of this project was to evaluate the suitability of the Florida largemouth bass for stocking into Virginia waters by analyzing its relative performance and genetic contribution to the developing population of largemouth bass in Briery Creek Lake. Toward this goal, bass were collected on four dates over a two-year period and subjected to analysis. Specific objectives were:
1) to describe the genetic composition of the largemouth bass population of Briery Creek Lake within and among successive cohorts; and
2) to compare and evaluate the performance of subspecies and hybrids in stocked and subsequent year classes of bass in terms of survival, growth, condition, and vulnerability to angling among presumptive largemouth bass genotypes.
METHODS

Field Collections

Largemouth bass were collected from Briery Creek Lake by boat electroshocking during dusk and evening hours on one date each in early May of 1990 and 1991 and in mid October of 1989 and 1990. On each date, approximately 50 adult bass (TL >200 mm) were taken from each of three general areas of the lake (designated as upper, middle, and lower lake). In addition, approximately 100 juvenile bass (TL 75-180 mm) were removed on each collection date without reference to lake location.

A sample of 97 largemouth bass was caught by hook-and-line in late April of 1991 for analysis of catchability. These fish were captured over several days on a variety of surface and subsurface artificial lures throughout the lake. The size and genetic composition of the hook-and-line sample was then compared with the May 1991 electroshock sample, which was taken less than two weeks later.

Laboratory Procedures

Largemouth bass were stored on ice and immediately returned to the laboratory at Virginia Polytechnic Institute
and State University (VPI & SU), where they were processed within 24 hours of capture. Livers were removed, individually labeled, and stored at -60°C in small "Whirl-pac" plastic bags for subsequent electrophoretic analyses. Scales were taken from adults, and length, weight and collection date were recorded for each fish collected.

Scales of adult bass were digitized (via a FORTRAN program, VDGIF) to provide data on length from focus to successive annuli, which were used to back-calculate lengths at younger ages. A corrected Lee equation was used to back-calculate lengths at ages one, two and three:

\[ L_n = a + (S_n/S_c)(L_c-a) \]

where

- \( L_n \) = the total length of the fish at the time of formation of annulus \( n \);
- \( a \) = the intercept value of a body-scale length regression (functional);
- \( S_n \) = the scale measurement from focus to annulus \( n \);
- \( S_c \) = the distance from the scale focus to the anterior margin; and
- \( L_c \) = the total length of the fish at capture.

These back-calculated lengths served as performance parameters to compare age-specific growth rates among subspecies and intergrades of largemouth bass.

The relative weight (\( Wr \)) for each fish was computed as
\[ Wr = \frac{W}{Ws} \times 100 \]

where: \( W \) = the weight of the fish (in grams), and
\( Ws \) = a standard weight for largemouth bass (including both subspecies and hybrids) from the weight-length regression equation developed by Wege and Anderson (1979):
\[
\log_{10} Ws = -5.316 + 3.191 \times \log_{10} L_c.
\]
The relative weight (Wr) was chosen as opposed to condition factor (K or C) or other weight-length metrics to facilitate comparisons with other populations and between size groups (Anderson and Gutrueter 1983).

**Electrophoretic Procedures**

Horizontal starch-gel electrophoresis of homogenized liver tissue was employed to categorize individual fish as being northern largemouth bass (NLMB), Florida largemouth bass (FLMB), first generation cross (F₁), or second or later generation cross (F₂). Electrophoresis and histochemical staining have been proven to be much more reliable than meristic or morphometric techniques in distinguishing the subspecies and intergrades of largemouth bass (Philipp et al. 1983; Williamson et al. 1986; Philipp and Whitt 1991). Because a banding pattern on a gel can be used to infer the genotype of an individual fish (Utter and Aebersold 1987), the
term "phenotype" is used to describe the bands on a gel. The respective categories of largemouth bass above are, thus, presumed genotypes based on electrophoretic phenotypes.

Four isozymes active in the liver tissue of largemouth bass were used to classify individual fish as to their presumptive genetic identity. Philipp et al. (1983) demonstrated that the northern and Florida subspecies of largemouth bass have fixed allelic differences (i.e., each subspecies exhibits expression of only certain alleles) at two loci, aspartate aminotransferase (AAT-B, IUBNC 2.6.1.1) and isocitrate dehydrogenase (IDh-B, 1.1.1.42). The other two distinguishing loci used to provide additional data on Fx bass, galactose-1-phosphate uridyltransferase (Galt-B, 2.7.7.12) and superoxide dismutase (SOD-A, 1.15.1.1) exhibit a low degree of allelic overlap among parental strains. In a Florida subspecies hatchery stock electrophoretically examined by Williamson et al. (1986), the slow-migrating Galt-B allele, fixed in the northern subspecies, occurred at about 4% frequency. The fast-migrating, northern-subspecific SOD-A allele occurred at 20% frequency in the Florida stock. Use of Galt-B and SOD-A markers to distinguish Florida from northern bass would be expected to result in error rates of 4% and 20%, respectively. Histochemical staining procedures for AAT-B, IDh-B, Galt-B, and SOD-A followed Philipp et al. (1983) and Williamson et al. (1986).
Individual fish were classified as to subspecific genotype only on the basis of AAT and IDh phenotypes. Galt-B and SOD-A, which are not fixed for the respective largemouth bass subspecies, were used to provide additional data on largemouth bass regarding the relative frequencies of northern or Florida subspecific alleles (i.e. "Floridaness"). All four isoenzymes (AAT-B, IDh-B, Galt-B, and SOD-A) are dimeric, comprised of two protein subunits. "Pure" subspecific genotypes displayed allozyme-specific electrophoretic banding patterns due to the formation of two homodimeric and heterodimeric molecules from the respective protein subunits (Figure 1). Fish were classified as NLMB if only the slow migrating alleles were exhibited at both diagnostic loci (i.e., AAT-B\textsuperscript{1} and/or \(-B\), and IDh-B\textsuperscript{1}). Florida largemouth bass (FLMB) exhibited the faster migrating alleles at the AAT and IDh loci (i.e., AAT-B\textsuperscript{3} and/or \(-B\), and IDh-B\textsuperscript{3}). Individual fish were classified as being F\textsubscript{1} (first filial generation) if they exhibited both a fast and a slow migrating allele at both diagnostic loci (e.g., AAT-B\textsuperscript{1}/B\textsuperscript{3}, IDh-B\textsuperscript{1}/B\textsuperscript{3}). Second or later generation hybrids (F\textsubscript{x}) could demonstrate a variety of banding patterns on a collection of gels; these were individuals that were not classified as NLMB, FLMB, or F\textsubscript{1} fish (i.e., those which were not homozygous for either slow or fast migrating alleles at AAT-B and IDh-B loci, nor heterozygous for fast and slow alleles at both AAT-B and IDh-B
Figure 1. Electrophoretic banding patterns of allelic isozymes used to differentiate and classify largemouth bass as to presumptive genotype.
It should be noted that due to random recombination of genetic material at unlinked loci during meiosis, individuals that were actually $F_x$ may have been misclassified as NLMB, FLMB, or $F_1$; the availability of only two definitive markers (i.e. AAT and IDh) to differentiate the subspecies and intergrades increases the possibility of this type of error. Classification errors of this type would tend to inflate the number of parental and $F_1$ assignments at the expense of the $F_x$ category. The frequency of such error in this study was believed to be low, because when fish were reclassified into presumptive genotypes through the addition of Galt phenotypes to the analysis, only about 4% of the 835 fish examined were reassigned to different categories, equal to the 4% frequency of the slow Galt allele in Florida bass reported by Williamson et al. (1986).

Temporal trends in the frequencies of Florida subspecific alleles within the gene pool of the Briery Creek Lake population were assessed both within cohorts (two to four successive samples) and over cohorts (four successive year classes). This was done by estimating the percentage of Florida alleles in each group (i.e., sample or cohort) as well as for the $F_x$ subgroup in each cohort or sample. In each instance, the number of Florida alleles expressed in the set were divided by the total number of alleles examined. It was
assumed that fast alleles at AAT, IDh, and Galt loci (i.e., AAT-B3, AAT-B4, IDh-B3, and Galt-B2) were Florida subspecific alleles (i.e., these alleles were assumed with 100% confidence to have been contributed from a pure Florida subspecies). This assumption was made for simplifying and elucidating the possibility of trends in the frequencies of Florida subspecific alleles over time, even though Galt-B is only 96% fixed. However, in the case of SOD-A, the slow-migrating, Florida subspecific allele was assumed with 100% probability to have been contributed by a pure Florida bass, whereas the fast-migrating, northern subspecific allele was rated as having an 80% probability of having been contributed by a northern bass, and 20% probability of having been contributed by a Florida bass, based on the frequencies reported by Williamson et al. (1986).

Classification of individual bass as NLMB, FLMB, F1, or Fx formed the basis of the comparisons used to evaluate the relative success of northern and Florida largemouth bass subspecies and their progeny in Briery Creek Lake. With data on the presumed genotypic composition of electroshocking and hook-and-line samples from electrophoretic analyses, comparisons of the relative frequencies of fish of each presumptive genotype could be made to quantify potential differences in overwinter survival, catchability, persistence through time, relative spawning success, and introgression.
among the bass genotypes. In addition, comparative data on the relative weights and growth rates for largemouth bass categories were used to assess the overall success of stocking Florida largemouth bass into Briery Creek Lake.

**Statistical Analysis**

The frequencies of individuals in each genotypic category, NLMB, FLMB, $F_1$, and $F_x$, by area of the lake, sample, and year class were compared to quantify: (1) spatial segregation among presumptive bass genotypes; and (2) change in the genotypic composition of the population over time. Frequency changes in the presumptive genotypic distributions for various collections were observed to compare over-winter survival and catchability rates. Lengths of juvenile fish collected in the two fall samples were used to infer the respective subspecies' spawning periods. Back-calculated lengths of adult fish at different ages were used to provide a measure of growth rates among the different genotypic categories of bass. The relative weights (Wr) of largemouth bass genotypes were examined to further measure performance differences. Tests were also made to ascertain the genetic contribution of Florida largemouth bass to $F_x$ intergrades and to successive year classes. The significance level for all statistical tests was set at $P=0.05$ for Type I error.
Composition Analyses

Two general types of analyses were performed, catch composition of different groups and performance comparisons. Chi-square tests of homogeneity were employed to compare the composition, or the proportion of largemouth bass collected of each genotypic category, among: 1) locations in the lake; 2) successive samples (i.e., within cohorts); 3) among subsequent year classes; 4) two sets of fall/spring samples (for over-winter survival); and 5) electroshocking and hook-and-line samples (for catchability). If comparisons indicated significant differences (P<0.05) between four-category distributions, further chi-square tests on pooled or paired groups were performed.

Performance

Because within most comparisons, samples sizes were relatively small and unequal, data were not distributed normally, variances were very discordant, and the true distribution of the data was unknown, "distribution-free" non-parametric statistical procedures were used to test null hypotheses.

Relative performance of presumptive largemouth bass
genotypes was quantified by Kruskal-Wallis tests on: (1) growth rates (back-calculated lengths at ages one, two, and three); (2) relative weights (Wr) of genotypes (within year class and sample date); and (3) total length at capture for juvenile bass collected in October, 1989 and October, 1990. The Kruskal-Wallis test was also used to compare the total length at capture (irrespective of genotype) between electroshocking and hook-and-line samples. When significant differences were observed in growth, Wr, or total length at capture among the four bass categories, the Wilcoxon rank sum test was used to identify the source(s) of the difference.

The Kruskal-Wallis test and the Wilcoxon rank sum test were used to determine whether differences in growth existed at different ages for BCL bass in consecutive generations. Largemouth bass were pooled with respect to presumptive genotype and lengths of fish were compared among cohorts by age.

To determine whether Wr was affected by age of fish, data from bass were pooled with respect to genotype and compared among ages (or year classes) within each sample. If there was a relationship between Wr and age, those fish were omitted for the determination of seasonal impacts on Wr. Seasonal (May vs. October) differences in Wr were evaluated using the Wilcoxon signed rank statistic on fall and spring Wr median pairs within each year class, but pooled over genotypic
category to provide adequate sample sizes.

It should be pointed out that the Kruskal-Wallis analysis of variance test (analogous to parametric ANOVA) and the follow-up Wilcoxon rank sum test (an analog to parametric paired t-tests) involve ranking numerical values (e.g., for lengths and relative weights) from the smallest to the largest. Thus, if a group of numbers tend to be larger than another group, they will have, on average, higher ranks. Mean and median values usually parallel average ranks. However, means are sensitive to outlying values, and median values are less informative than the average ranks of values in describing the overall nature of the data. The average rank for a group of values characterizes the general magnitude of values relative to other groups of values within a particular test. Both average ranks and medians are discussed in subsequent sections.

**Florida Subspecific Contribution to Groups**

The frequency of Florida subspecific alleles present was used to provide an index of temporal shifts in northern and Florida subspecific allele frequencies among fish of successive year classes and samples (within year classes) for the group as a whole and for $F_x$ bass groups separately.
STUDY AREA

Briery Creek Lake (BCL) is a 342-ha impoundment located within the Briery Creek Wildlife Management Area in Prince Edward County near Farmville, Virginia. Map coordinates are 37° 12'N latitude and 78° 30'W longitude (Figure 2). The Wildlife Management Area was designed by the Virginia Department of Game and Inland Fisheries (VDGIF) to provide a public hunting and fishing area as well as a flood control lake. Briery Creek Lake is mesotrophic and contains a large amount of standing and submerged timber. Although the lake averages approximately 4 m in depth, there are large weedy flats with depths less than 0.75 m which serve as waterfowl areas (Kittrell 1990).

The reservoir was impounded in the winter of 1985-86, and the small pool which formed was treated with rotenone in the spring of 1986 prior to stocking. The lake was stocked in the spring of 1986 with 62,100 fingerling Florida largemouth bass and 17,500 northern largemouth bass, and again in 1987 with 65,000 and 22,000 Florida and northern largemouth bass, respectively. The Florida largemouth bass fingerlings were obtained from the Welaka National Fish Hatchery, Florida. Broodstock for this hatchery originated from the St. John's
Figure 2. Map of Briery Creek Lake, Prince Edward County Virginia.
River, which is the northeastern limit of the range of the pure Florida subspecies (Philipp et al. 1983). Northern largemouth bass were obtained from a hatchery operated by the Indiana Department of Natural Resources. Both hatchery stocks were thought by hatchery personnel to consist only of pure subspecies of largemouth bass, but no meristic, morphometric or genetic analyses were performed to verify this assumption prior to stocking.

In addition to largemouth bass, the VDGIF stocked bluegill (*Lepomis machrochirus*), redear sunfish (*L. microlophus*), channel catfish (*Ictalurus punctatus*), chain pickerel (*Esox niger*) and white and black crappie (*Pomoxis* spp.) between 1986 and 1989. The lake was opened to fishing on January 1, 1989, and a two-bass daily creel limit with a 45.7 cm minimum size limit went into effect for largemouth bass. Regulations for largemouth bass were changed January 1, 1990 to a 305-381 mm protected slot limit and five per day creel limit (Kittrell, 1990). Regulations were changed because VDGIF electrofishing surveys indicated a shortage of larger bass and a high abundance of intermediate (193-292 mm) and harvestable (293-430 mm) size bass, which dominated the fishery (Kittrell 1990).
Water temperature data were needed to quantify the exposure of the bass population to cold, which may affect Florida largemouth bass performance and survival (Philipp and Whitt 1991). Thermographs were installed by VDGIF personnel at approximately 3 m depth near the BCL dam. Water temperature was monitored continuously (i.e., recorded every hour) from December 11, 1989, until April 11, 1990 (120 days) and also from November 16, 1990 to May 24, 1991 (200 days).

Because water temperature data were available for only two winters since the lake’s impoundment in 1986, an alternative method was also used for estimating winter severity. United States Weather Bureau climate records for Farmville, Virginia, located about 8 km from Briery Creek Lake, were consulted. The number of heating degree days (HDD), defined as the difference (in degrees Fahrenheit) between average daily air temperature and 65°F (18.3°C), summed over days, was compared among winters.
RESULTS

Climatic Data

For the two sets of thermograph data, differences in winter severity are evident between the 1989-90 and 1990-91 winters (Figure 3). Water temperature did not fall below 6°C over the winter of 1990-91, but was less than 6°C for 36 consecutive days from mid-December 1989 to mid-January 1990. Also, the lake was covered with ice for the last two weeks of December, 1989. The duration of winter temperatures were similar for both years: water temperature was below 10°C on 101 and 118 days in the winters of 1989-90 and 1990-91, respectively.

The average annual HDD at Farmville (i.e., from October to May) is 3,875. For the winters since the lake was impounded:

<table>
<thead>
<tr>
<th>Winter</th>
<th>HDD</th>
<th>% Deviation from the Long-term Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-87</td>
<td>3917</td>
<td>+1.1%</td>
</tr>
<tr>
<td>1987-88</td>
<td>4556</td>
<td>+17.6%</td>
</tr>
<tr>
<td>1988-89</td>
<td>4485</td>
<td>+15.7%</td>
</tr>
<tr>
<td>1989-90</td>
<td>3920</td>
<td>+1.2%</td>
</tr>
<tr>
<td>1990-91</td>
<td>3568</td>
<td>~8.0%</td>
</tr>
</tbody>
</table>

By using this estimate (HDD) as an average number of days in
Figure 3. Hourly thermograph readings from Briery Creek Lake, winters of 1989-1990 and 1990-1991.
which heating for offices or homes might be used, it is evident that the winters of 1986-87 and 1989-90 were near the long-term mean for the region. The 1987-88 and 1988-89 winters were much colder, and the 1990-91 winter was warmer than average.

In central Virginia, the months of December, January, and February typically have the most severe cold weather. From the time BCL was first stocked (1986), the coldest months were January 1988 (30.4°F [-0.89°C] average air temperature) and December 1989 (28.0°F [-2.22°C] average air temperature). Average monthly air temperature was at least 35°F (1.67°C) in all other winter months from 1986-1991 (Figure 4).

**Genotypic Composition of the Largemouth Bass Population**

Over 900 largemouth bass were collected and analyzed for genotype and growth performance. However, 82 fish were discarded from the analysis due to lack of definitive scale/age data or to poor resolution of AAT or IDh isozyme phenotypes; most fish discarded were juveniles collected in May, 1990. Apparently, tissues became warm, thereby reducing enzyme activity and electrophoretic resolution.

Age determination from scales of BCL largemouth bass was complicated by the high frequency of regenerated scales and the presence of "false-annuli" on most of the scales (N.
Figure 4. Mean monthly air temperature at Farmville, Virginia, October-April 1986-1991.
Cunningham, VDGIF, personal communication). However, age of most fish could be determined by counting scale annuli.

In order to provide an adequate sample size, bass were pooled over sampling dates for the test of genotypic proportions among lake sections. There were no significant differences in the distributions of presumptive bass genotypes among upper, middle and lower sampling locations within the lake (P=0.601, Table 1). Because presumptive bass genotypes were found to be homogeneously distributed throughout the lake, data for fish from all collection sites were pooled in subsequent analyses.

Of the 836 fish for which genotypic data were observed, only one individual of the 1986 year class was collected. This individual was scored as heterozygous at both the AAT and IDh diagnostic loci and was, therefore, classified as an F₁ bass. Data from this individual were not considered in subsequent analyses.

All four largemouth bass genotypic categories (i.e., both pure subspecies, F₁, and Fₓ bass) were observed in the 1987 year class (Table 2). This was surprising because only pure Florida and northern largemouth bass genotypes were expected in the 1986 and 1987 year classes. If bass first spawned at age two, as is usual in Virginia populations (William Kittrell, VDGIF, personal communication), then F₁ hybrids were expected to first appear in 1988 and Fₓ hybrids in 1990.

30
Table 1. Numbers (percentage contribution) of four genotypic categories of largemouth bass collected from the lower, middle and upper sections of Briery Creek Lake, 1989-1991.

<table>
<thead>
<tr>
<th>Lake Section</th>
<th>NLMB</th>
<th>FLMB</th>
<th>F&lt;sub&gt;1&lt;/sub&gt;</th>
<th>F&lt;sub&gt;x&lt;/sub&gt;</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>14(9.6)</td>
<td>6(4.1)</td>
<td>104(71.7)</td>
<td>21(14.5)</td>
<td>145(100.0)</td>
</tr>
<tr>
<td>Middle</td>
<td>18(12.4)</td>
<td>10(6.9)</td>
<td>105(72.4)</td>
<td>12(8.3)</td>
<td>145(100.0)</td>
</tr>
<tr>
<td>Upper</td>
<td>13(8.9)</td>
<td>9(6.2)</td>
<td>105(71.9)</td>
<td>19(13.0)</td>
<td>146(100.0)</td>
</tr>
</tbody>
</table>
Table 2. Numbers of largemouth bass of presumptive genotypes for four year classes collected over four sampling dates, 1989-1991, from Briery Creek Lake, Virginia.

<table>
<thead>
<tr>
<th>Year Class</th>
<th>Presumptive Genotype</th>
<th>10-89</th>
<th>5-90</th>
<th>10-90</th>
<th>5-91</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>NLMB</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td>39</td>
<td>37</td>
<td>8</td>
<td>5</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>F₂</td>
<td>8</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>57</td>
<td>53</td>
<td>13</td>
<td>8</td>
<td>131</td>
</tr>
<tr>
<td>1988</td>
<td>NLMB</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td>74</td>
<td>63</td>
<td>58</td>
<td>30</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>F₂</td>
<td>12</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>98</td>
<td>85</td>
<td>81</td>
<td>45</td>
<td>309</td>
</tr>
<tr>
<td>1989</td>
<td>NLMB</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>16</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td>56</td>
<td>21</td>
<td>35</td>
<td>26</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>F₂</td>
<td>18</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>94</td>
<td>28</td>
<td>49</td>
<td>37</td>
<td>208</td>
</tr>
<tr>
<td>1990</td>
<td>NLMB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>F₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>187</td>
</tr>
</tbody>
</table>
Also, of the three bass genotypes anticipated in the 1988 cohort, Florida subspecies bass were expected to dominate, with just a few $F_1$ and even fewer pure northern subspecies of largemouth bass represented, as Florida and northern largemouth bass were stocked at a ratio of about 3:1 in 1986. Assuming random mating and no differential mortality or emigration/immigration, about 9 of 16 bass pairings would be expected to be FLMB x FLMB. Under these assumptions, about 3 of 16 spawning pairs would be FLMB x NLMB (resulting in $F_1$ progeny), and approximately 1 of 16 would be NLMB x NLMB. However, approximately 80% of all individuals collected of the 1987-1989 year classes were $F_1$ or $F_2$ hybrids, with few representatives of either pure subspecies present in these cohorts.

**Intra-Year Class Genotypic Composition**

Frequencies of the presumptive genotypes within cohorts remained stable over time (i.e., among successive samples) for the 1987 year class ($P=0.879$), the 1988 year class ($P=0.784$), and the 1989 year class ($P=0.171$) (Table 2). Data from the October, 1990 and May, 1991 samples of the 1987 year class were pooled because of low sample sizes. A statistically significant difference ($P<0.001$) in genotypic composition occurred for the 1990 year class between October 1990 and May
1991 samples. This significant difference is described under the section "Overwinter Survival" below.

Trends in the frequencies of Florida subspecific alleles within year classes were examined for changes over time. No relationship between " Floridaness" and time (i.e., over successive samples) was observed for the 1987, 1988, or 1989 year classes (Figure 5). Frequencies of Florida subspecific alleles were generally about 0.50, but ranged from 0.425–0.523 among samples. It would not be possible to observe a trend in Florida subspecific contribution to the 1990 year class because only two samples were taken.

Similar observations were made on the frequency of Florida subspecific alleles to cohorts over time but only from fish classified as F. to determine if the genetic composition of this category of largemouth bass was changing over time within cohorts. Again, Florida subspecific allele frequencies fluctuated around 0.50 and no trends in frequencies were observed for the 1987, 1988, or 1989 year classes (Figure 6).

Inter-Year Class Genotypic Composition

Because genotypic distributions did not change over time within cohorts, data from different collection dates could be pooled for the 1987, 1988, and 1989 year classes. Comparisons of genotypic frequencies were then performed among these year
Figure 5. Frequencies of Florida subspecific alleles in successive samples for the 1987-1989 year classes.
Figure 6. Frequencies of Florida subspecific alleles among Fx-classified bass in successive samples of the 1987-1989 year classes.
classes (Figure 7). Relative frequencies of presumptive bass genotypes differed significantly (P=0.002) among the 1987, 1988, and 1989 cohorts. Pair-wise chi-square comparisons between year classes indicated that the 1987 and 1989 cohorts had similar distributions of bass genotypes (P=0.632). Both cohorts were characterized by low frequencies of NLMB and FLMB (0.06-0.13), a moderate number of $F_1$ fish (0.15-0.16), and a high frequency of $F_1$ bass (0.66-0.68). The genotypic composition of the 1988 year class differed greatly from that of the 1989 year class (P<0.0001) but was not statistically different from the 1987 cohort (P=0.064). The 1988 cohort contained higher percentages of NLMB and $F_1$ fish and lower proportions of $F_1$ and FLMB than either the 1987 or 1989 year classes (Figure 7).

To include genotype frequency data in the analysis from the two sample dates (i.e., 10-90 and 5-91) for the 1990 year class, which could not be pooled over the two sample dates, the other three year classes (1987, 1988, and 1989) were compared pair-wise to each sample of the 1990 year class (Table 3). Results indicated that presumptive genotype frequencies of both of the 1990 year class samples differed significantly from those of the previous three cohorts. Inspection of the frequencies of presumptive bass genotypes of the 1990 year class (October, 1990 sample) relative to those of the other cohorts revealed that the October 1990 sample had
Figure 7. Frequencies of presumed genotypes within 1987-1989 largemouth bass year classes in Briery Creek Lake.
Table 3. Chi-square statistics comparing frequencies of presumptive genotypes in the October 1990 and May 1991 samples of the 1990 year class versus those in the 1987-1989 year classes. All comparisons have three degrees of freedom.

<table>
<thead>
<tr>
<th>Year Class</th>
<th>October, 1990</th>
<th></th>
<th></th>
<th>May, 1991</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared</td>
<td>$X^2$</td>
<td>$P$</td>
<td></td>
<td>$X^2$</td>
<td>$P$</td>
</tr>
<tr>
<td>1987</td>
<td>50.2</td>
<td>&lt;0.001</td>
<td></td>
<td>22.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1988</td>
<td>114.2</td>
<td>&lt;0.001</td>
<td></td>
<td>61.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1989</td>
<td>50.5</td>
<td>&lt;0.001</td>
<td></td>
<td>27.4</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
proportionately fewer $F_1$ fish and relatively more FLMB and $F_x$ bass present (Table 2). The May, 1991 sample of the 1990 year class contained frequencies of NLMB and FLMB similar to the 1987, 1988, and 1989 year classes. However, the May, 1991 sample of the 1990 cohort also contained a much lower proportion of $F_1$ bass and a much higher proportion of $F_x$ fish compared to the 1987, 1988, and 1989 year classes. In all cohorts, proportions of NLMB collected remained fairly stable (from about 6 - 12 %).

No trends in the frequencies of Florida subspecific alleles among the successive year classes 1987-1990 were observed (Figure 8).

The $F_x$ fish were examined separately to determine if the hybrid and backcross components of the population exhibited greater or lesser frequencies of Florida subspecific alleles over successive year classes. No statistically significant relationship was observed ($P=0.3534$; Figure 8). Approximately 50% of the alleles scored for the 1987, 1988, and 1989 cohorts were classified as Florida subspecific alleles. The same was true for the three cohorts of $F_x$ bass.

**Over-Winter Survival**

Year classes were pooled and genotype frequencies were compared between fall and subsequent spring samples within age
Figure 8. Frequency of Florida subspecific alleles among successive collection dates for all bass of a cohort, and for $F_x$ bass alone.
groups to estimate differential survival among the presumptive genotypes. Significant overwinter survival differences were not observed for age-1 and older largemouth bass of different genotypes (Table 4). Genotypic proportions did, however, differ significantly (P=0.003) between fall and spring samples for age-0+1 largemouth bass. Therefore, the 1989 and 1990 year classes were examined separately.

Overwinter survival of juvenile largemouth bass representing the respective genotypic groups was assessed by comparing the composition of the 1989 year class in the October 1989 versus the May 1990 samples and the 1990 year class in the October 1990 versus the May 1991 samples. Survival of bass representing the respective bass genotypes showed a similar pattern in both winters. Frequencies of the respective genotypes within the 1989 cohort in the October 1989 and May 1990 samples were not statistically different (P=0.301), although sharp changes were evident (Figure 9). Failure to show statistical significance was attributable to the small size (N=28) of the May, 1990 sample which could be classified to presumed subspecific genotype. The frequency of Florida largemouth bass collected dropped dramatically between the October 1989 and May 1990 samples, declining from approximately 17% of the fish collected on October 1989 to about 4% of those collected in May 1990 (Table 2). The percentages of Fₙ bass and NLMB remained fairly stable between
Table 4. Numbers of presumptive genotypes of different age groups compared between autumn and the following spring. Year classes are pooled within age groups. All Chi-squares have three degrees of freedom.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Age 0 to 1</th>
<th>Age 1 to 2</th>
<th>Age 2 to 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall</td>
<td>Spring</td>
<td>Fall</td>
</tr>
<tr>
<td>NLMB</td>
<td>11</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>FLMB</td>
<td>48</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>F₁</td>
<td>74</td>
<td>62</td>
<td>109</td>
</tr>
<tr>
<td>F₂</td>
<td>44</td>
<td>47</td>
<td>16</td>
</tr>
<tr>
<td>N</td>
<td>177</td>
<td>132</td>
<td>147</td>
</tr>
<tr>
<td>X²</td>
<td>13.74</td>
<td></td>
<td>1.05</td>
</tr>
<tr>
<td>P</td>
<td>0.003</td>
<td></td>
<td>0.790</td>
</tr>
</tbody>
</table>
Figure 9. Change in the genetic composition of age-0 bass between October and May samples.
the two sampling periods, but the percentage of F₁ fish increased from about 60 % to 75 % over the 1989-90 winter (Table 2; Figure 9).

For the 1990 cohort, a significant difference (P<0.001) was observed between October 1990 and May 1991 samples. Again, a decline in the frequency of FLMB was observed over the winter of 1990-91. Approximately 39 % of the fish collected in October, 1990 were FLMB, compared to about 13 % of those collected in May, 1991 (Table 2; Figure 9). Also similar to results from the 1989-90 winter was the relative stability of the proportion of NLMB collected and an increase in frequency of F₁ fish. The overwinter survival of Fₓ fish, however, was not consistent. The proportions of Fₓ fish before and after their first winter were approximately equal in the 1989 cohort over but increased about 10 percentage points overwinter for the 1990 cohort (Figure 9).

Performance Comparisons

Performance of the four bass genotypic groups was compared in terms of annual growth, condition, spawning period, and vulnerability to angling. Results are described in terms of average ranks and medians.
Annual Growth Rates

Successive samples were pooled for cohort-specific back-calculated total length at age because genotypic composition did not differ among samples within the 1987-1989 year classes. The back-calculated lengths were compared for each age group among genotypic categories of bass within the 1987-1989 year classes. Lengths at capture were compared within the 1990 cohort. Of nine such comparisons (Table 5), four exhibited significant differences among presumptive genotypes in length at age. Of these four significant tests, length at age 2, 1989 year class should be regarded cautiously because only a single individual of the NLMB subspecies was represented.

1987 year class. Significantly different (P<0.05) lengths at age 2 were observed among presumptive largemouth bass genotypes in the 1987 year class (Table 5). Florida largemouth bass had the highest median length and average ranks of lengths at all three ages (Table 6). At age 2, northern (NLMB) bass were significantly shorter than F₁ bass (P=0.01), and F₅ individuals were smaller than F₁ individuals (P=0.041). The NLMB vs. FLMB length comparison, however, was not statistically significant (P=0.217) even though NLMB and FLMB had the lowest and highest average ranks of lengths at
Table 5. Median back-calculated total length (mm) at age of the four presumptive genotypes in the 1987, 1988, and 1989 year classes of largemouth bass in Briery Creek Lake. Number of fish in parentheses. Within cohorts, values in age columns followed by the same superscript are not significantly different.

<table>
<thead>
<tr>
<th>Year</th>
<th>Class</th>
<th>Genotype</th>
<th>Age 1</th>
<th>Age 2</th>
<th>Age 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>NLMB</td>
<td>110.1a</td>
<td>241.6b</td>
<td>267.7a</td>
<td>(7)</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>133.1a</td>
<td>255.1ab</td>
<td>304.7a</td>
<td>(10)</td>
</tr>
<tr>
<td></td>
<td>F1</td>
<td>109.8a</td>
<td>254.7a</td>
<td>283.1a</td>
<td>(80)</td>
</tr>
<tr>
<td></td>
<td>Fx</td>
<td>113.0a</td>
<td>242.2b</td>
<td>280.8a</td>
<td>(18)</td>
</tr>
<tr>
<td>1988</td>
<td>NLMB</td>
<td>120.2a</td>
<td>225.7b</td>
<td>268.4a</td>
<td>(32)</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>105.8a</td>
<td>232.2ab</td>
<td>285.3a</td>
<td>(13)</td>
</tr>
<tr>
<td></td>
<td>F1</td>
<td>120.8a</td>
<td>235.8a</td>
<td>282.9a</td>
<td>(192)</td>
</tr>
<tr>
<td></td>
<td>Fx</td>
<td>112.7a</td>
<td>227.3a</td>
<td>267.9a</td>
<td>(29)</td>
</tr>
<tr>
<td>1989</td>
<td>NLMB</td>
<td>114.2ab</td>
<td>228.7ab</td>
<td></td>
<td>(7)</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>107.1b</td>
<td>225.4b</td>
<td></td>
<td>(9)</td>
</tr>
<tr>
<td></td>
<td>F1</td>
<td>129.5b</td>
<td>248.1ac</td>
<td></td>
<td>(61)</td>
</tr>
<tr>
<td></td>
<td>Fx</td>
<td>117.0b</td>
<td>235.0abc</td>
<td></td>
<td>(9)</td>
</tr>
<tr>
<td>1990*</td>
<td>NLMB</td>
<td>145.5a</td>
<td></td>
<td></td>
<td>(8)</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>138.0a</td>
<td></td>
<td></td>
<td>(13)</td>
</tr>
<tr>
<td></td>
<td>F1</td>
<td>150.0a</td>
<td></td>
<td></td>
<td>(41)</td>
</tr>
<tr>
<td></td>
<td>Fx</td>
<td>143.5a</td>
<td></td>
<td></td>
<td>(42)</td>
</tr>
</tbody>
</table>

Table 6. Order, from greatest to least, for presumptive genotype-specific back-calculated lengths at age for 1987-1990 year classes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Class</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>FLMB&gt;(F_x)&gt;NLMB&gt;(F_1)</td>
<td>FLMB&gt;(F_1)&gt;(F_x)&gt;NLMB</td>
<td>FLMB&gt;(F_1)&gt;(F_x)&gt;NLMB</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>NLMB&gt;(F_1)&gt;(F_x)&gt;FLMB</td>
<td>(F_1)&gt;FLMB&gt;NLMB&gt;(F_x)</td>
<td>FLMB&gt;(F_1)&gt;(F_x)&gt;NLMB</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>(F_1)&gt;NLMB&gt;(F_x)&gt;FLMB</td>
<td>(F_1)&gt;(F_x)&gt;NLMB&gt;FLMB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990*</td>
<td>(F_1)&gt;(F_x)&gt;NLMB&gt;FLMB</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

age 2 for the 1987 year class, respectively (Table 6). The
failure to find statistical significance was a reflection of
the large variation of sample sizes and of variances within
the growth data (Walter Pirie, statistical
consultant/professor, VPI & SU, personal communication).
Median lengths for FLMB were about 17% greater than for NLMB
at age one and about 5% greater at two years of age. By age
three, 1987 cohort FLMB were about 12% longer than NLMB.

1988 Year Class. Total lengths of bass also differed
significantly (P<0.05) among presumptive genotypes at age two
for the 1988 year class. First generation (F_1) hybrids were
significantly larger than F_x (P=0.032) and NLMB individuals
(P=0.013) (Table 5). At two years of age, the median length
for F_1 bass was about four percent greater than the median
length for F_x and NLMB (Table 5). For this year class, FLMB
had the lowest average ranked lengths at age 1, the second
highest at age 2, and the highest average rank for lengths at
age three (Table 6). Length values of bass classified as F_x
were ranked lowest or second lowest at all three ages.

1989 Year Class. Statistically different lengths were
observed among presumptive genotypes at age 1 for the 1989
year class (p<0.005). Bass in the F_1 category were 18% longer
than FLMB (P=0.001) and 10% longer than F_x bass (P=0.013;
Table 5). Lengths of bass of different genotypes at age two were also significantly different ($P<0.025$), but only one NLMB fish was represented in the sample (Table 5). The $F_1$ fish were significantly larger ($P=0.004$) than Florida largemouth bass (Table 5). Florida bass lengths were ranked lowest among the other respective genotypic categories at ages one and two. Average ranks of lengths of $F_1$ bass were highest for ages 1 and 2, and $F_x$ bass lengths for this cohort were intermediate between $F_1$ and FLMB. Only one age 2 NLMB was collected, therefore the relative position of NLMB lengths at age 2 is unclear.

**1990 Year Class.** No significant difference in total length at capture among presumptive bass genotypes was observed for the 1990 year class (age 1') collected in May, 1991 (Table 5). Again, FLMB lengths were relatively short at an early age when ranked among length values of the other presumptive genotypic categories (Table 6).

**Patterns in Rank.** In eight of the nine age- and cohort-specific comparisons, $F_1$ bass had the highest or second highest average rank for lengths at different ages (Table 6). Also, in seven of the nine comparisons, growth of NLMB was ranked lowest or second lowest. Besides the consistently
highest growth for FLMB of the 1987 year class, which may be due to their larger size at stocking (see Discussion), lengths of FLMB tended to be shorter at age one for the 1988-1990 cohorts. The pattern of lengths of FLMB is unclear for these year classes at older ages. No consistent trends in lengths at age was apparent for Fx bass.

Comparison with Growth in Other Waters

Overall, growth for largemouth bass in Briery Creek Lake, expressed as the mean length attained by all largemouth bass pooled over all genotypes and cohorts, was satisfactory as compared to one and two year-old bass elsewhere in Virginia (Banach 1989; Table 7). Mean lengths of BCL bass at ages one and two (122.3 mm, and 241.0 mm, respectively) were similar to mean lengths of one and two year-old largemouth bass in other Virginia waters. However, the overall mean length attained by 118 age 3 bass collected from BCL (282.7 mm) is clearly below growth rates to age three in other Virginia systems.

As a lake ages, resources may begin to become limited, possibly resulting in reduced growth of subsequent generations of fish. Analysis of growth for consecutive generations in BCL did not clearly exhibit this pattern at ages one, two, or three. Results indicated that 1987 year class bass were significantly smaller at age one than 1988 (P=0.001) and 1989
Table 7. Mean back-calculated lengths at ages 1–3 for largemouth bass collected from Briery Creek Lake, and those reported by Banach (1989) representing the statewide average for Virginia, Piedmont region lakes, and mesotrophic lakes of Virginia.

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCL-1987</td>
<td>118.8</td>
<td>251.2</td>
<td>285.3</td>
<td>This Study</td>
</tr>
<tr>
<td>BCL-1988</td>
<td>123.0</td>
<td>234.8</td>
<td>278.5</td>
<td>This Study</td>
</tr>
<tr>
<td>BCL-1989</td>
<td>124.7</td>
<td>242.0</td>
<td>-</td>
<td>This Study</td>
</tr>
<tr>
<td>VA St. Avg.</td>
<td>125.5</td>
<td>238.5</td>
<td>314.7</td>
<td>Banach 1989</td>
</tr>
<tr>
<td>VA Piedmont</td>
<td>129.3</td>
<td>240.9</td>
<td>315.1</td>
<td>Banach 1989</td>
</tr>
<tr>
<td>VA Mesotrophic</td>
<td>117.7</td>
<td>226.4</td>
<td>301.3</td>
<td>Banach 1989</td>
</tr>
</tbody>
</table>
(P=0.0002) cohort bass (Table 8). The order of average ranks and median values for cohort lengths of one year-old largemouth bass was 1989>1988>1987. The pattern was different among age two bass in BCL. The average rank and median order for two year-old bass was 1987>1989>1988. At age two, 1987 fish were significantly larger than 1988 (P<0.001) and 1989 (P=0.019) bass; 1989 fish were significantly larger than 1988 cohort bass at age two (P=0.019). Largemouth bass lengths did not differ significantly at age three between the 1987 and 1988 year classes. No three year-old 1989 cohort bass were collected. Because scale annuli were not measured for 1990 year class bass, back-calculation of lengths was not possible.

**Relative Weight**

Relative weight values ranged from 55.95 to 200.89 for individual largemouth bass in Briery Creek Lake. The overall median Wr for Briery Creek Lake largemouth bass (pooled over genotype, sampling date, and year class) was 92.3. Only 120 of the 835 Wr values analyzed were greater than 100.00. Of these 120 values, 60 were F₁'s, 36 were Fₓ's, 21 were FLMB, and only 3 were NLMB. The distribution of these Wr values among genotypic categories was statistically different (P<0.005) from the Chi-square expected frequency distribution based on the observed proportions of the presumptive genotypes among
Table 8. Median length at ages 1-3 (sample sizes) for the year classes 1987-1989 for Briery Creek Lake largemouth bass, pooled over presumptive genotype. Medians representing lengths for the same age having the same letter are not significantly different.

<table>
<thead>
<tr>
<th>Year Class</th>
<th>Length Age 1</th>
<th>Length Age 2</th>
<th>Length Age 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>111.0&lt;sup&gt;a&lt;/sup&gt; (115)</td>
<td>250.5&lt;sup&gt;a&lt;/sup&gt; (115)</td>
<td>280.2&lt;sup&gt;a&lt;/sup&gt; (73)</td>
</tr>
<tr>
<td>1988</td>
<td>120.2&lt;sup&gt;b&lt;/sup&gt; (266)</td>
<td>234.0&lt;sup&gt;b&lt;/sup&gt; (202)</td>
<td>278.9&lt;sup&gt;b&lt;/sup&gt; (45)</td>
</tr>
<tr>
<td>1989</td>
<td>123.5&lt;sup&gt;b&lt;/sup&gt; (86)</td>
<td>243.9&lt;sup&gt;c&lt;/sup&gt; (37)</td>
<td></td>
</tr>
</tbody>
</table>
the 835 largemouth bass collected (Table 9). This was primarily due to a disproportionately low number of NLMB and \( F_1 \) largemouth bass and a relatively high number of FLMB and \( F_x \) largemouth bass having \( Wr \)s greater than 100.00 compared to what was expected.

The relative weights (\( Wr \)) of presumptive bass genotypes were compared within year classes by sampling date, resulting in 14 separate comparisons. Only two of the fourteen year class/sample comparisons, 1987/October 1989, and 1990/May 1991 samples, yielded significantly different \( Wr \) values among presumptive genotypes (Table 10). However, six of the fourteen comparisons were constrained by small sample size (only one or two fish in at least one genotypic category; Table 10). For the significant result for the 1987 year class (October 1989 sample), two of the six Wilcoxon pair-wise genotype comparisons yielded significantly different \( Wr \) values. The \( F_1 \) bass were in poorer condition than \( F_x \) fish (\( P=0.036 \)) and FLMB (\( P=0.012 \)). The \( Wr \) values for largemouth bass genotypic categories in the 1990 year class (May, 1991 sample) were significantly different (\( P=0.035 \)). Pair-wise comparisons within this group revealed that \( Wr \) values for \( F_x \) and FLMB were significantly higher than NLMB (\( P=0.008 \) and \( P=0.042 \), respectively).

When rank orders were compared, a general pattern became evident. In 10 of the 14 comparisons, FLMB had the highest or
Table 9. Observed and expected frequencies of Wr values greater than 100.00 per presumptive genotype of largemouth bass, in Briery Creek Lake.

<table>
<thead>
<tr>
<th></th>
<th>NLMB</th>
<th>FLMB</th>
<th>F₁</th>
<th>Fₓ</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>3</td>
<td>21</td>
<td>60</td>
<td>36</td>
<td>120</td>
</tr>
<tr>
<td>Expected</td>
<td>9.8</td>
<td>14.7</td>
<td>71.7</td>
<td>23.9</td>
<td></td>
</tr>
</tbody>
</table>
Table 10. Relative weights (Wr), and sample sizes (N) for age groups, for the four presumptive genotypes of largemouth bass from Briery Creek Lake within sample date for the 1987-1990 year classes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Class Date (Age)</th>
<th>NLMB</th>
<th>FLMB</th>
<th>F₁</th>
<th>Fₓ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>10-89* (2)</td>
<td>92.7 (5)</td>
<td>96.2 (5)</td>
<td>89.4 (34)</td>
<td>96.9 (8)</td>
</tr>
<tr>
<td></td>
<td>5-90 (3)</td>
<td>82.9 (3)</td>
<td>91.4 (3)</td>
<td>88.0 (37)</td>
<td>88.9 (10)</td>
</tr>
<tr>
<td></td>
<td>10-90* (3)</td>
<td>89.9 (1)</td>
<td>91.2 (2)</td>
<td>90.9 (8)</td>
<td>91.4 (2)</td>
</tr>
<tr>
<td></td>
<td>5-91 (4)</td>
<td>78.9 (1)</td>
<td>109.2 (1)</td>
<td>89.4 (5)</td>
<td>95.3 (1)</td>
</tr>
<tr>
<td>1988</td>
<td>10-89 (1)</td>
<td>88.9 (10)</td>
<td>93.7 (2)</td>
<td>91.7 (74)</td>
<td>89.4 (12)</td>
</tr>
<tr>
<td></td>
<td>5-90 (2)</td>
<td>91.0 (10)</td>
<td>92.3 (3)</td>
<td>93.3 (13)</td>
<td>90.3 (9)</td>
</tr>
<tr>
<td></td>
<td>10-90* (2)</td>
<td>83.9 (10)</td>
<td>91.0 (6)</td>
<td>88.4 (58)</td>
<td>91.5 (7)</td>
</tr>
<tr>
<td></td>
<td>5-91 (3)</td>
<td>87.0 (8)</td>
<td>99.2 (2)</td>
<td>90.2 (30)</td>
<td>86.4 (5)</td>
</tr>
<tr>
<td>1989</td>
<td>10-89 (0)</td>
<td>92.4 (4)</td>
<td>94.2 (16)</td>
<td>95.9 (56)</td>
<td>94.2 (18)</td>
</tr>
<tr>
<td></td>
<td>5-90 (1)</td>
<td>73.1 (1)</td>
<td>87.5 (1)</td>
<td>100.9 (21)</td>
<td>103.8 (5)</td>
</tr>
<tr>
<td></td>
<td>10-90 (1)</td>
<td>83.4 (6)</td>
<td>85.7 (4)</td>
<td>87.9 (35)</td>
<td>90.2 (4)</td>
</tr>
<tr>
<td></td>
<td>5-91 (2)</td>
<td>96.7 (1)</td>
<td>98.0 (5)</td>
<td>91.4 (26)</td>
<td>92.3 (5)</td>
</tr>
<tr>
<td>1990</td>
<td>10-90* (0)</td>
<td>94.5 (7)</td>
<td>94.6 (32)</td>
<td>94.1 (18)</td>
<td>94.1 (26)</td>
</tr>
<tr>
<td></td>
<td>5-91* (1)</td>
<td>90.7 (8)</td>
<td>96.1 (13)</td>
<td>93.2 (41)</td>
<td>97.4 (42)</td>
</tr>
</tbody>
</table>

* Samples having a significant Kruskal-Wallis test result.
second highest group of Wr values (Table 11). In 11 of the 14
genotype comparisons, NLMB Wr values were ranked lowest or
second lowest. No consistent patterns in Wr ranks were
evident for F₁ and F₅ bass.

To determine if condition of BCL bass differed between
seasons, bass were pooled over presumptive genotype and Wr
medians were compared between spring and fall samples. No
seasonal differences in the relative weight were observed for
largemouth bass collected in spring or fall samples from 1989-
1991 (Table 12).

The relative weight data for differences among age groups
was analyzed by pooling over presumptive genotypes within
samples. The youngest fish within a sample were consistently
in better condition than the older bass in the same sample
(Table 13). The highest median Wr values were observed among the 28
one year-old bass collected May 1990 (median Wr=100.7) and
among 104 age one bass collected May 1991 (median Wr=96.0).
All other median Wr values were below 96.0. Also, Wr values at age
were pooled over sampling date because there was no apparent
seasonal differences in Wr values. Age-0⁺ (juvenile, fall-
collected bass) and age-1 (May-collected yearlings) bass had
the two highest median values, 94.7, and 96.3, respectively.
Largemouth bass in Briery Creek Lake generally declined in
condition with increasing age (Figure 10). Younger (age-0⁺-1)
bass are clearly in better condition than are older largemouth
Table 11. Order, from greatest to least, for the average ranks of Wr values for genotypic categories within sample date and year class, and significance level for the Kruskal-Wallis test result.

<table>
<thead>
<tr>
<th>Year Class</th>
<th>Sample Date</th>
<th>Order of Average Rank Values</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>10-89</td>
<td>FLMB&gt;Fₓ&gt;F₁&gt;NLMB&gt;FLMB</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td></td>
<td>5-90</td>
<td>Fₓ&gt;F₁&gt;FLMB&gt;NLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>10-90</td>
<td>FLMB&gt;NLMB&gt;F₁&gt;Fₓ</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>5-91</td>
<td>FLMB&gt;Fₓ&gt;F₁&gt;NLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td>1988</td>
<td>10-89</td>
<td>FLMB&gt;F₁&gt;Fₓ&gt;NLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>5-90</td>
<td>FLMB&gt;F₁&gt;Fₓ&gt;NLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>10-90</td>
<td>FLMB&gt;F₁&gt;Fₓ&gt;NLMB</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>5-91</td>
<td>FLMB&gt;F₁&gt;NLMB&gt;Fₓ</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td>1989</td>
<td>10-89</td>
<td>F₁&gt;Fₓ&gt;FLMB&gt;NLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>5-90</td>
<td>Fₓ&gt;F₁&gt;FLMB&gt;NLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>10-90</td>
<td>Fₓ&gt;F₁&gt;NLMB&gt;FLMB</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>5-91</td>
<td>FLMB&gt;NLMB&gt;Fₓ&gt;F₁</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td>1990</td>
<td>10-90</td>
<td>NLMB&gt;FLMB&gt;F₁&gt;Fₓ</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>5-91</td>
<td>Fₓ&gt;FLMB&gt;F₁&gt;NLMB</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
Table 12. Fall (October 1989 and October 1990) versus spring (May 1990 and May 1991) sample median Wr values, number collected in parentheses, and the Wilcoxon signed rank statistic P-value.

<table>
<thead>
<tr>
<th>Year</th>
<th>Comparison</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Oct. 89 vs. May 90</td>
<td>Oct. 90 vs. May 91</td>
<td>P-value</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>92.0(57) 88.3(53)</td>
<td>89.9(13) 91.7(8)</td>
<td>&gt;0.10</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>93.0(85) 91.0(98)</td>
<td>88.1(81) 89.8(45)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>95.1(94) 100.7(28)</td>
<td>87.9(49) 92.5(37)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>94.5(83) 96.0(104)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 13. The order of average ranks of Wr values at age and the significant (P<0.05) Wilcoxon test results of Wr among age pairs for each sampling date.

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Average Rank Order Of Wr For Ages</th>
<th>Significant Wilcoxon Test Pairs Among Ages</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 89</td>
<td>$0^+ &gt; 1^+ &gt; 2^+$</td>
<td>$0^+ &gt; 1^+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$0^+ &gt; 2^+$</td>
</tr>
<tr>
<td>May 90</td>
<td>$1 &gt; 2 &gt; 3$</td>
<td>$1 &gt; 2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1 &gt; 3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$2 &gt; 3$</td>
</tr>
<tr>
<td>October 90</td>
<td>$0^+ &gt; 3^+ &gt; 2^+ &gt; 1^+$</td>
<td>$0^+ &gt; 1^+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$0^+ &gt; 2^+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$0^+ &gt; 3^+$</td>
</tr>
<tr>
<td>May 91</td>
<td>$1 &gt; 2 &gt; 4 &gt; 3$</td>
<td>$1 &gt; 2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$2 &gt; 3$</td>
</tr>
</tbody>
</table>

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Figure 10. Age-specific Wr, pooled over genotype, for largemouth bass in Briery Creek Lake.
bass in Briery Creek Lake.

Spawning Period

The use of daily growth rings on bass otoliths for determination of hatch time/spawning period was not possible because in many cases, otoliths for age-0 bass collected in October were found to have more than 120 rings. Age identifications of fish with this many otolith rings would have confidence intervals too wide for precise estimates of spawning dates. Spawning periods of the four presumptive bass genotypes were, therefore, compared indirectly from total lengths of age 0 bass collected in October 1989 and October 1990. This approach embodies the assumption that growth of largemouth bass for the first year of life proceeds at the same daily rate (mm/day) for each presumptive genotypic category.

A significant difference (P<0.05) in total lengths of bass among the respective genotypes was observed in data from the collection made in October, 1989 (Table 14). The order of average ranks of presumptive genotype lengths was NLMB>F₁>Fₓ>FLMB. Pair-wise comparisons of genotype-specific lengths revealed that FLMB were significantly shorter than F₁ and NLMB (P=.0005 and P=.016, respectively). Median lengths of FLMB were about 25 % less than those of NLMB.
Table 14. Median total lengths (mm) for age-0+ 1989 and 1990 cohort bass of each genotypic category collected October 1989 and October 1990 from Briery Creek Lake. Number of fish in parentheses. Medians followed by the same letter are not significantly (P<0.05) different.

<table>
<thead>
<tr>
<th>Year Class</th>
<th>Presumptive Genotype</th>
<th>Total Length (Sample Sizes)</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>NLMB</td>
<td>140.0&lt;sup&gt;b&lt;/sup&gt; (4)</td>
<td>P&lt;0.005</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>105.0&lt;sup&gt;a&lt;/sup&gt; (16)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td>124.5&lt;sup&gt;b&lt;/sup&gt; (56)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fₓ</td>
<td>117.5&lt;sup&gt;ab&lt;/sup&gt; (18)</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>NLMB</td>
<td>100.0&lt;sup&gt;a&lt;/sup&gt; (7)</td>
<td>P&gt;0.10</td>
</tr>
<tr>
<td></td>
<td>FLMB</td>
<td>99.5&lt;sup&gt;a&lt;/sup&gt; (32)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td>112.0&lt;sup&gt;a&lt;/sup&gt; (18)</td>
<td></td>
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<tr>
<td></td>
<td>Fₓ</td>
<td>104.0&lt;sup&gt;a&lt;/sup&gt; (26)</td>
<td></td>
</tr>
</tbody>
</table>
Test results for total length differences of presumptive bass genotypes collected October, 1990 were not statistically significant. The order of average ranks for this group was $F_1 > NLMB > FLMB > F_x$. For both years, FLMB and $F_x$ fish had the two lowest average ranks for total length at capture.

**Vulnerability to Angling**

There was no statistically significant difference ($P=0.38$) in the genotypic composition between the April 1991 hook-and-line sample and the May 1991 electroshock sample of bass from Briery Creek Lake (Figure 11). Florida largemouth bass contributed about six percent less to the lure-caught fish than to the electroshocking sample (nine versus three percent of the sample), and $F_1$ bass were slightly more abundant in the hook-and-line sample than among the electroshocked fish (76% versus 68%).

Length-at-capture comparisons between hook-and-line and electroshock samples indicated some degree of gear selectivity. The median length of fish caught by hook-and-line using artificial lures was about nine percent higher than of those sampled by electroshocking equipment; (295 mm vs. 268 mm). This difference was highly significant ($P<0.001$) when bass were pooled across genotypes for gear comparisons.
Figure 11. Comparison of catch composition from hook-and-line and electrofishing samples of largemouth bass from Briery Creek Lake, spring 1991.
DISCUSSION

Thermal Regime of Briery Creek Lake

Largemouth bass in Briery Creek Lake are exposed to a greater degree of winter severity and temperature variation than occur at more southerly latitudes. Florida bass in their native range typically encounter fewer than 300 heating degree days (HDD) annually. In Aquilla Lake, Texas, only 1°18'N of the northernmost population of pure Florida bass described by Philipp et al. (1983), Florida bass appeared to demonstrate higher survival than northern bass, once past their first winter (Maceina et al. 1988). However, it is important to note that the northern bass were native to a lotic system (Aquila and Hackberry creeks), not the lentic environment created by the Aquilla Lake dam. In central Illinois (40°04'N), which had a 10-year annual average HDD of 2,934, NLMB consistently exhibited superior cold tolerance/overwinter survival than FLMB in small ponds (Philipp and Whitt 1991). Bass in BCL (mean annual HDD=3,875) were exposed to colder weather than in central Illinois.

Thermograph data revealed relatively long periods of low water temperature in BCL. During the 1989-90 winter (3,920 HDD), there were 59 consecutive days during which the water
temperature was less than 10°C, and 31 consecutive days during which temperatures were less than 5°C. Carmichael et al. (1988) reported that Florida largemouth bass had high mortality (48% vs. 0% for the northern subspecies) in a bioassay in which fish were maintained at about 22°C for five days, after temperature was reduced from 22°C by about 1°C per day. The minimum temperature recorded in BCL over the two winters was 3.3°C and averaged less than 4°C for 14 consecutive days from late December, 1989 to January 4, 1990. Both laboratory and field studies suggest that the winter thermal regime of Briery Creek Lake would result in higher mortality on Florida bass than on northern bass.

The 1989–90 winter was only 1.1% colder than average in terms of average annual HDD for nearby Farmville, Virginia. There were about 8.0% fewer HDD than normal from October, 1990 through May, 1991. Water temperatures were less than 10°C for 71 consecutive days but did not drop below 5°C over the 1990–91 winter. These two seasons demonstrate the variability in water temperature to which fish were exposed in BCL.

Genotypic Composition

Largemouth bass were sampled from accessible littoral areas near the dam (lower), about midway up the lake (middle), and around the upper convergence of the three major creek
arms. Statistically equivalent proportions of presumptive genotypes were found among the sampling locations, indicating that bass were well mixed among those areas sampled. Betsill et al. (1986), in a largemouth bass telemetry study in two small Texas impoundments, found no differences in the selection of water depth, type of cover, water temperature, or dissolved oxygen between northern and Florida subspecies of largemouth bass. However, Reiger and Summerfelt (1978) reported higher seine capture rates of Florida versus northern bass in the thermal plume of Boomer Lake, Oklahoma, during one winter but no difference in a second, warmer winter. Additional electrofishing and seine samples indicated differences in thermoregulatory behavior between the subspecies; Florida bass sought warmer water than northern bass. However, genetic purity of bass stocks was not determined in either study. Koppelman et al. (1988) found no differences in final preferred temperatures among electrophoretically confirmed NLMB, FLMB, and F1 bass. There was no indication of habitat segregation among subspecies and intergrades of largemouth bass in Briery Creek Lake, at least among the size range of largemouth bass collected.

There were few large bass in electroshocking samples taken from Briery Creek Lake. Only one bass of the 1986 year class was collected. Most of the fish collected were from age-0 to just a few months away from laying down the third
scale annulus. Out of 836 bass, 111 three-year-olds (i.e., had three scale annuli), and eight four-year-olds were collected. No age five bass were captured. In an annual electrofishing survey independently conducted by the Virginia Department of Game and Inland Fisheries (VDGIF) in April, 1990, only one of 48 bass collected was four years of age, and no five year-old bass were captured (Kittrell 1990). The paucity of older bass could be due to selective harvest of large bass by anglers in compliance with the 45.7 cm minimum size limit imposed by the VDGIF in 1989. However, only 296 largemouth bass (average weight=1.22 kg) were harvested among more than 12,000 anglers contacted March 1 through December 31, 1989 by the VDGIF's creel census personnel (Kittrell 1990). The modest harvest along with length-frequency data from VDGIF electroshocking surveys prompted the VDGIF to change fishing regulations in 1990 from the 45.7 cm minimum size to the current 30.5-38.1 cm slot, five-per-day creel limit. The apparent shortage of larger, older bass (>45.7 cm) could also, in part, be due to inadequate sampling. The electric potential of the shocking probes is produced by a loud, gas-powered generator in the boat. Large, experienced bass may effectively elude the boat electroshocker amidst the abundant cover in the lake. Alternatively, growth and survival of older bass may be hindered by a lack of available, appropriately-sized forage. Poor growth and condition of
adult BCL bass was substantiated in this study and is discussed subsequently relative to genotypic performance. Currently, the VDGIF is considering candidate soft-rayed forage species for introduction into BCL.

Isozyme phenotypes at AAT-B and IDh-B loci indicated that the single bass of the 1986 year class sampled was an F₁. In 1986 and 1987, BCL was stocked with Florida and northern largemouth bass at a ratio of more than 3:1. Only 11 fish of the 131 collected from the 1987 cohort were classified as FLMB; most (80%) were F₁ or Fₓ hybrids. If stocked year classes were genetically pure, substantial spawning must have occurred in 1987 between 1986 stocked fish and possibly also with bass immigrating from natural populations residing within the Briery Creek Lake drainage. Tributaries inaccessible to the rotenone treatment applied prior to stocking in 1986 may have contained significant numbers of bass. However, to account for the relatively large proportion (16%) of 1987 year class fish classified as Fₓ, immigrating bass must have possessed characteristics of both subspecies' genome. Philipp et al. (1983) demonstrated that largemouth bass from three lakes in Virginia contained both northern and Florida subspecific alleles; they listed Virginia as one of the states comprising the current intergrade zone between northern and Florida populations of largemouth bass.

Another, perhaps more likely, explanation for such high
frequencies of $F_1$ and $F_x$ bass and the low frequency of FLMB in the 1987 year class is genetic impurity of one or both hatchery stocks used to stock BCL. It is possible that the northern largemouth bass received from Indiana were contaminated with Florida alleles. Although Philipp et al. (1983) did not examine bass sampled from Indiana waters, largemouth bass from adjacent states (Illinois, Kentucky, and Michigan) did not exhibit Florida subspecific alleles at diagnostic loci. Genetic impurity of the Florida bass stock is more likely because hatchery broodstock originated from bass taken from the St. John's River, Florida, which is the northeastern dividing line between populations of pure Florida largemouth bass and the intergrade zone (Bailey and Hubbs 1949; Philipp et al. 1983). Other comparative studies of northern and Florida largemouth bass which detected genetic impurity of stocks have indicated FLMB as the source (Busack 1989; Gilliland and Whitaker 1989; Maceina et al. 1988). Electrophoretic examination was not performed on broodstock of either the Indiana or Florida hatcheries.

Intra-Year Class Composition

Because the 1987 year class contained both first and later generation bass hybrids, all four genotypic categories could be tracked over all (1987-1990) cohorts. The relative
frequencies of FLMB, NLMB, F₁, and Fₓ genotypes did not change significantly over successive samples for the 1987, 1988, or 1989 year classes. Samples for these cohorts consisted of about 16-18% parentals (NLMB and FLMB) and about 82-84% hybrids (F₁ and Fₓ). The first sample, taken in October, 1989, contained both 1987 (age 2+) and 1988 (age 1+) year class bass. Survival of presumptive genotypes from ages 0-1 is not known for these cohorts. However, samples of the 1989 year class represented fish from ages 0+ to 2+. Overwinter survival of fish age 0+ to 1 year old (i.e., between the October, 1989 and May, 1990 samples) of the 1989 year class was not statistically different among bass types due to the small size of the May 1990 sample (see Overwinter Survival discussion below). Gilliland and Whitaker (1989) reported statistically similar genotypic proportions of bass between ages 0 and 2 years in Oklahoma reservoirs. However, Maceina et al. (1988), found that proportions of Florida subspecific alleles increased relative to NLMB within each of four successive generations of bass in Aquilla Lake, Texas, and that the percent of FLMB and hybrids in electroshocking samples also tended to increase over time (within a cohort) relative to northern largemouth bass. The similar proportions of presumptive genotypes in successive samples of the 1987, 1988, and 1989 cohorts indicated no differential survival of adult (age 1 and older) largemouth bass in BCL. This was also
evident by the lack of a temporal pattern in frequencies of Florida subspecific alleles. The percentage of Florida subspecific alleles per sample within year classes did not change in a consistent direction over successive sampling periods regardless of whether all bass of the sample were considered or just the $F_x$ bass.

The study by Maceina et al. (1988) was very similar to the present study in terms of design, but the results were not directly comparable. Maceina et al. (1988) observed consistent increases in Florida subspecific allele frequencies among successive generations of largemouth bass in Aquilla Lake, Texas, reaching about 50% for the 1986 year class in 1986 and 1987. However, Aquilla Lake was stocked with a total of about 500,000 age-0 Florida bass (376/ha) from 1982 through 1985. No northern bass were stocked in Aquilla Lake, but colonization came from the resident lotic stock of northern bass. Upon impoundment of Aquilla Lake, the receiving NLMB population faced large influxes of genetically different competitors as well as a new, lentic habitat.

Briery Creek Lake was stocked in only two years with both subspecies of largemouth bass. The apparent contamination of one or both sources of stocked fish and the relatively stable frequency of Florida subspecific alleles in successive cohorts implies that the population was rather well mixed from the beginning in terms of northern and Florida subspecific
alleles. The lack of a trend in the frequencies of subspecific alleles within cohorts in Briery Creek Lake indicates that the inter-specific hybrids present were not being selected out of the BCL population. If there was a selective advantage to either subspecies' genome, it would take more generations for a shift in the gene pool to high frequencies of the alleles specific to either subspecies to be realized.

**Inter-Year Class Composition**

Estimates of the percentage contribution of Florida subspecific alleles to the allele frequencies of successive year classes fluctuated around 50%, but showed no trend for either the year class considered as a whole (i.e., all fish of the cohort, pooled over genotypes and sampling dates) or for the $F_x$ component of the population alone. However, the distributions of genotypes differed among year classes, but in no apparent temporal pattern. The 1988 cohort was characterized by lower frequencies of $F_x$ and FLMB and higher frequencies of $F_1$ and NLMB relative to the 1987 and 1989 year classes. Presumptive genotypic distributions of both samples of the 1990 year class, which were statistically different from each other, differed significantly from those of 1987, 1988, and 1989 cohorts. The most striking difference for the
1990 year class concerns the sharp decline in the proportions of FLMB over the 1990-91 winter. Neither the frequency of Florida subspecific alleles nor the frequency of adult FLMB increased in successive year classes, suggesting no survival advantage for "Floridaness" in this system for fish past their first growing season and winter.

The expected increase in the relative frequency of F, bass, resulting from F, fish interbreeding with NLMB, FLMB, and other F, bass, was exhibited in the 1990 cohort. No dramatic shifts in the frequency of NLMB was observed among all four year classes; NLMB comprised about 6-13% of all bass collected over the 1987-90 cohorts. In contrast, Maceina et al. (1988) reported that in successive year classes of Aquilla Lake bass, Florida bass increased in and northern bass declined in frequency, suggesting that Florida bass had a survival advantage.

**Overwinter Survival**

First-winter mortality did appear to have a substantial effect on the FLMB genotypic class in Briery Creek Lake. However, significant differential survival was not observed for largemouth bass experiencing their second, or third winter in Briery Creek Lake. Juvenile Florida largemouth bass appear more sensitive to low temperatures than juvenile northern or
hybrid largemouth bass in BCL which is similar to the results reported by Philipp et al. (1991) in Illinois.

Unfortunately, sample sizes were too small to allow rejection of the null hypothesis of equal distributions between spring and fall samples of the 1989 cohort using the chi-square test of homogeneity. Nonetheless, FLMB declined sharply in frequency between October and May samples for both the 1989 and 1990 year classes. Also, F₁ genotype frequencies increased over both winters, suggesting that although the limited cold tolerance of FLMB negatively affected their overwinter survival ability, the overall genomic heterozygosity of F₁ bass was an advantage in coping with the variable thermal environment of BCL. Philipp and Whitt (1991) reported consistently higher winter survival rates of NLMB compared to FLMB in small ponds in central Illinois and indicated that the survival rate of FLMB was more dependent on winter severity than were survival rates of the other genotypes. They also found overwinter survival of F₁ bass, NLMB(♀) x FLMB(♂), to be as high or nearly as high as that of NLMB in seven of eight trials. The reciprocal F₁ cross, NLMB(♂) x FLMB(♀), demonstrated slightly lower survival than the other F₁ hybrid in seven of eight trials. However, survival of both F₁ crosses was higher than FLMB in all eight trials in the Illinois study.

The 1989-90 winter was about average for BCL in terms of
the number of heating degree days (3920), but the winter of 1990-91 was warmer than normal (about 8.0% fewer HDD). For FLMB to demonstrate significantly poorer overwinter survival during the relatively mild 1990-91 winter season supports the hypothesis that Florida bass will suffer disproportionate first year mortality in most Virginia waters. The observed survival advantage of F₁ largemouth bass would not be expected to benefit the BCL bass population as a whole because the frequency F₁ bass should decrease in later year classes. Rather, as the population moves toward a mixture of northern and Florida alleles, that is, toward an Fₓ genotypic composition, first-year overwinter survival will be less predictable; the percentage of Fₓ bass was relatively stable over the 1989-1990 winter, but increased by about 9% over the 1990-1991 winter. It could take many generations of selection before detrimental genes or gene combinations become uncommon.

**Performance**

A decade ago, Philipp et al. (1981; 1983) surveyed 90 largemouth bass populations across the United States electrophoretically and found latitudinal clines in allele frequencies and regionally distinct subpopulations of largemouth bass. Hallerman et al. (1986) and Norgren et al.
(1988) also documented separate subpopulations of largemouth bass over a particular geographic region. Philipp et al. (1981) cautioned that latitudinal clines in allele frequencies and genetic differences among geographically unique populations of bass were most likely the result of natural selection and that transplanting largemouth bass from one area of the country into waters already containing native largemouth bass could disrupt the gene pool of the receiving stock. This would likely result in reduced overall productivity of the composite population.

Similar surveys of salmon and trout populations have also indicated genetically unique stocks, both within and among different watersheds (e.g., Stahl 1987; Grant 1987; Altukhov and Salmenkova 1987). Latitudinal clines in allele frequencies have also been documented for several other fish species (Johnson 1977; Powers and Place 1978; Place and Powers 1979). Although allelic clines can be established by nonselective gene flow following contact of previously separated populations which experienced genetic drift (Kimura and Ohta 1971; Ohta and Kimura 1971; Aspinwall 1974), differing thermal conditions of the various regions inhabited by largemouth bass is inferred to be at least partly causal of the observed clines (Philipp et al. 1981). For example, Hines et al. (1983) reported differential thermal kinetic behavior of two allozymes (MDh-B¹ and MDh-B²), for which distinct
latitudinal clines of allele frequencies were observed among populations of northern and Florida largemouth bass. In Briery Creek Lake, realization of performance potential between the two genetically distinct subspecies of bass depends on the adaptability of one or both subspecies' genomes to the Briery Creek Lake environment. In BCL, subspecific genomes are both separated (in the parentals) and combined (i.e., in hybrids), providing a comparative assessment of subspecies and intergrade performance in terms of growth, condition, spawning period, and vulnerability to angling.

**Growth**

In Briery Creek Lake, growth differences were not striking among the four presumptive genotypes of largemouth bass. There was an overall tendency, albeit weak, for F1 bass to exhibit higher growth rates compared to the other bass genotypes. However, results of statistical length-at-age comparisons within year classes among the presumptive genotypes of largemouth bass were not consistent and were compromised by large variances in lengths and unequal sample sizes.

For the stocked year class of 1987, FLMB had the highest average ranked lengths at one, two, and three years of age. A possible explanation for the greater lengths exhibited by
FLMB of the 1987 year class is that stocked FLMB were larger or stocked earlier than NLMB, thereby conferring a growth advantage to the Florida subspecies. In both years, 1986 and 1987, FLMB were larger (about 2.5-4.0 cm TL) and stocked earlier (about three weeks) than NLMB, which were about 2.0 cm long at the time of stocking (A.L. LaRoche, VDGIF, personal communication). Spring electroshocking samples taken by the VDGIF approximately one month after stocking in 1986 indicated a bimodal length distribution for largemouth bass. However, fall 1986 electroshocking samples indicated that largemouth bass were then approximately the same size, averaging about 18 cm (A. L. LaRoche, VDGIF, personal communication). Maceina et al. (1988) reported that early-hatching bass tended to attain larger size through the first growing season than late-hatching bass in Aquilla Lake, Texas. They also found a positive correlation between average daily growth rate and age and that the smaller age-0 fish were in poorer condition and less likely to survive their first winter. Maceina and Isley (1986) found a shortage of prey for the smaller age-0 fish in Aquilla Lake, providing an explanation for size-related growth rate differences. An analogous situation could have occurred in BCL because stocked FLMB were slightly larger than stocked NLMB. The smaller fish may not have grown as well and remained smaller at the end of the growing season.

The relative lengths for FLMB of different ages were not
consistent in subsequent year classes. At age one, 1988 cohort FLMB had the lowest median length and average rank for lengths when compared among the other presumptive genotypes. Florida bass were ranked second largest at age two, and exhibited the highest median and average rank for lengths at three years of age for the 1988 year class. This suggests that FLMB were smaller at age one, but caught up and even surpassed NLMB in later years. Several authors have reported higher growth rates of NLMB relative to FLMB in early (ages less than two) years. Isley et al. (1987) and Williamson and Carmichael (1990) reported higher first year growth for northern bass compared to F₁ hybrids and Florida bass in Texas. Northern largemouth bass were found to achieve greater age-1 lengths than Florida bass in California reservoirs (Botroff and Lembeck 1978), and in ponds in Tennessee (Smith and Wilson 1982), Alabama (Zolcynski and Davies 1976), and Florida (Clugston 1964). In some of these studies, FLMB size and growth at older (i.e., >one year old) ages was reported to exceed that of NLMB from 10-30% (Maceina et al. 1988; Botroff and Lembeck 1978; Inman et al. 1978). The 1988 year class appeared to exhibit this growth pattern in BCL, but differences in lengths were not statistically significant at ages one or three. However, lengths attained by FLMB remained the least among the presumptive genotypes for the 1989 year class at one and two years of age. The F₁ bass for the 1989
cohort demonstrated the greatest lengths at ages one and two when ranked among the other bass categories.

Overall, F1 bass demonstrated a propensity for superior growth in Briery Creek Lake. Lengths at age 1 for F1 bass were ranked first or second highest (i.e., on average) in eight of the nine growth comparisons. The overall tendency of F1 bass to exhibit higher growth rates in BCL is not surprising. Reports of increased "trophy" catches in waters following the introduction of Florida bass (Botroff and Lembeck 1978; Pelzman 1980; Robb 1991) implies the possibility of higher growth potential for bass containing both northern and Florida subspecific genes.

Several studies appear to corroborate the growth advantage for Florida and hybrid largemouth bass. Inman et al. (1978) reported that F1 largemouth bass had the best growth after three years in Cain Lake, Texas. Kleinsasser et al. (1991) found that the Florida(♀) X northern(♂) hybrid were the largest after one year in Texas ponds compared to the reciprocal cross and the pure parental (NLMB and FLMB) forms. Other authors have reported better growth for Florida bass. Reiger and Summerfelt (1978) reported significantly higher growth for two year-old Florida bass compared to northern bass in Boomer Lake, Oklahoma. Wright and Wigtil (1982) reported greater growth and growth potential for Florida bass three years of age than F1 hybrid and northern bass in Dripping
Spring Lake, Oklahoma. Maceina et al. (1988) reported that female Florida largemouth bass had a size-dependent fecundity advantage due to larger size attained by three years of age. Growth studies of the subspecies and hybrids indicating superior growth for F₁ bass or FLMB, coupled with development of trophy fisheries following Florida largemouth bass introductions (Botroff and Lembeck 1978; Pelzman 1980), provide persuasive evidence that genes or genic combinations of the Florida subspecies can be associated with higher growth rates when compared to northern bass in some warmer environments. However, whether the growth advantage afforded by the presence of Florida largemouth bass genes will persist and outweigh possible negative traits, such as reduced handling or cold tolerance, remains uncertain for Briery Creek Lake. Any advantages offered by Florida largemouth bass and F₁ hybrid bass may be transient because as bass continue to interbreed, both presumptive genotypes will become less frequent and the population will inevitably shift towards an Fₓ-dominated composition. Therefore, the focus of genotypic comparisons shifts from the parental and F₁ bass to the relative performance of Fₓ hybrids in Briery Creek Lake.

In seven of nine comparisons of Briery Creek Lake bass, lengths at age of NLMB were ranked lowest or second lowest relative to the other three presumptive bass genotypes, all of which exhibit some percentage of Florida subspecific alleles.
However, it is important to note that the northern largemouth bass stocked into Briery Creek Lake were not of local origin. Therefore it is not appropriate to unequivocally conclude that stocking Florida largemouth bass will confer superior growth characteristics to bass populations in Virginia relative to native northern bass stocks. It is possible that had BCL been stocked with northern largemouth bass of local origin, results could have been different.

Annual growth rates through age two in BCL were generally near the Virginia state average, but lagged below the mean by age three. The poor growth demonstrated by older BCL bass appears at least partly due to a lack of available forage. Although there have been angler reports of gizzard shad (*Dorosoma petenense*), and golden shiners (*Notemigonus chrysoleucas*) have occasionally surfaced during electroshock samples, the primary and most abundant food items for largemouth bass in BCL are bluegill (*Lepomis macrochirus*) and other sunfishes. Electroshock catch rates of intermediate (91-140 mm) and harvestable-sized (<140 mm) bluegill were poor (Kittrell 1990), implying heavy predation on bluegill fingerlings. False annuli occurred frequently on scales (i.e., on about 40% of the scales) of adult bass collected from BCL, possibly resulting from a "food crunch" (Jearld 1983).
Relative Weight

As for growth, significant differences in relative weights among presumptive genotypes of largemouth bass in Briery Creek Lake occurred infrequently. However, largemouth bass classified as FLMB and $F_1$ tended to exhibit higher $W_r$ values than NLMB and $F_x$ largemouth bass. Of the 14 age/date comparisons made, six were not valid due to low sample sizes. Of the remaining eight comparisons, FLMB, $F_1$, and $F_x$ bass ranked highest or second highest in relative weight in five, and NLMB ranked lowest or second lowest in seven of the eight trials.

Other studies have yielded contrasting results for length-weight relationships for largemouth bass of different size or age categories. Smith and Wilson (1982) found that northern largemouth bass were in better condition than Florida bass after six months in Tennessee ponds. Maceina and Murphy (1988) reported higher relative weights for NLMB compared to FLMB between 101 and 300 mm TL in Aquilla Lake, Texas. Kleinsasser et al. (1990), however, found the Florida(♂) X northern(♂) cross to be significantly heavier than either parentals or the reciprocal cross after two years in Texas ponds. Wright and Wigtil (1982) reported that FLMB had the highest mean and median lengths and weights compared with NLMB and hybrids after three years growth in an Oklahoma pond.
Similarly, Botroff and Lembeck (1978) reported higher mean weights of FLMB of a given size or age-class compared to F1 and northern bass in California reservoirs. However, Philipp and Whitt (1991) found northern largemouth bass to consistently demonstrate superior condition in central Illinois.

In Briery Creek Lake, only 14.4% of Wr values exceeded 100, the standard for largemouth bass in good condition. The distribution of the high Wr values among genotypes did not conform to the chi-square expected distribution based on the overall genotypic proportions of bass collected from BCL: numbers of NLMB with high Wr values were less and numbers of FLMB were higher than expected. Values of Wr between 95 and 100 are generally considered satisfactory for largemouth bass in late summer or early fall (Wege and Anderson 1979). In BCL, Wr for bass pooled over genotype did not differ significantly between spring and fall samples. Largemouth bass in BCL are lighter for given lengths relative to the upper 75th percentile of largemouth bass from Midwestern ponds reported by Wege and Anderson (1979) and were in progressively poorer condition as they aged.

The pattern of declining relative weight with age paralleled the growth rate pattern. In Briery Creek Lake, forage is apparently adequate to support the young-of-the-year, but as the fish age, food availability becomes severely
limiting. The shortage of forage, especially for adult bass, may also be responsible for the lack of distinct and consistent growth and relative weight differences among different largemouth bass genotypes in Briery Creek Lake. That is, potential growth differences among the respective genotypes may not have been realized in absence of abundant, available forage in BCL.
**Spawning Period**

Young-of-the-year northern and $F_1$ largemouth bass were generally longer at capture than Florida and $F_x$ bass in BCL. It was not possible to determine whether these length differences were due to different spawning periods between the subspecies. Some authors have indicated that Florida bass spawn earlier than northern bass (Chew 1975; Botroff and Lembeck 1978) while others report the opposite (Isley et al. 1987).

Maceina et al. (1988) found from examination of otoliths that juvenile $F_1$ bass were older, on average, than northern bass, and that northern bass were older than Florida bass in Aquilla Lake. This indicated that, early in the spawning season, some Florida bass spawned with the northern subspecies in the Texas reservoir. They also found that early-hatching fish grew faster and were larger at the end of the growing season than late-hatching bass. If this growth differential occurred in BCL, the disparity in total length of age-0 bass would still reflect differences in spawning period. Maceina and Isley (1986) reported that the smaller juvenile bass in Aquilla Lake were confronted by a prey shortage and were, therefore, less likely to survive their first winter than the larger, early-hatched bass.
In Briery Creek Lake, results appeared parallel to the Aquilla Lake study, but data were much less definitive. Juvenile F₁ and northern bass were longer at capture in both October samples; the F₁ presumptive genotype increased in frequency overwinter relative to the other bass genotypes; northern bass frequencies remained fairly stable over both winters; but the frequencies of Florida bass declined sharply. This suggests that F₁ bass, and possibly NLMB, had a survival advantage early in life because they were longer towards the end of the growing season and appropriate-sized forage may have been more available. However, the relative weights of age-0 Florida bass in October tended to be higher than those of northern bass and F₁ hybrids, indicating that differential starvation may not account for the overwinter frequency shift in presumptive genotypes. The lower cold tolerance of Florida bass, either of itself or in combination with the size disadvantage, was believed to be the principal source of differential first-winter survival. The inconsistent overwinter survival pattern exhibited by Fₓ bass invokes concern for the success of future year classes in Briery Creek Lake.

**Vulnerability to Angling**

Several authors have reported that Florida largemouth
bass are less vulnerable to angling than their northern counterpart. Reiger et al. (1978) reported that in Oklahoma ponds (0.1 ha, max depth=1.2 m), 43 of 47 (91.5%) of northern bass were captured by lures or live bait compared to 20 of 36 (58.3%) Florida bass captured; subspecific identity was not electrophoretically confirmed. Zolcynski and Davies (1976) found that Florida bass in similar-sized ponds were more difficult to catch. They also observed that the Florida fish were more wary and usually headed for deeper water when fishing activity began. Botroff and Lembeck (1978) reported that the mean size and annual harvest of largemouth bass by anglers more than doubled three years after the introduction of Florida bass into El Capitan Reservoir, California. However, factors such as increased effort or fishing gear improvement were not included in the analysis. In contrast, Inman et al. (1978) found no differences in vulnerability to angling among the subspecies and F₁ hybrids in Cain Lake, Texas. However, stock purity was not electrophoretically confirmed in any of the above studies. Kleinsasser et al. (1990), using genetically verified northern, Florida, and reciprocal F₁ crosses, reported that northern largemouth bass were significantly more vulnerable to angling than the Florida subspecies in Texas ponds. They also noted higher wariness of Florida bass and that the small test ponds, devoid of cover, may not have been an accurate test of angling.
susceptibility among subspecies. Florida bass within BCL showed no significant differential susceptibility to either electroshocking or angling gear.

However, it is possible that the overall low number of Florida bass represented in angling and electroshocking samples was a result of lower catchability or increased wariness of the Florida subspecies to both gears. This would imply that the electrofishing samples taken were not representative of the bass population in Briery Creek Lake. Although this explanation of the low occurrence of Florida bass in samples can not be proven false, it seems unlikely given the concordance of VDGIF creel survey and electrofishing data on the size distribution of BCL bass (Kittrell, 1990). If there are substantial numbers of old and/or large bass residing in sections of BCL, they are not regularly captured by fishermen or game officials.
SUMMARY AND CONCLUSIONS

1. The winter thermal regime of Briery Creek Lake (average 3,875 heating degree days) is more severe than reported in other comparative studies of largemouth bass genotypes. Minimum winter water temperatures in BCL are frequently near the reported thermal tolerance limits of Florida bass.

2. Briery Creek Lake was stocked with both Florida and northern largemouth bass fingerlings in 1986 and 1987. However, only one 1986 year class bass was captured in four whole-lake electroshocking samples for this study, which began in October, 1989.

4. Genotypic frequency distributions were not significantly different among the upper, middle, and lower sections of the lake sampled. Largemouth bass subspecies and intergrades were not segregated in those areas of BCL which were electrofished.

5. Hybrid (F₁ and F₂) bass dominated the 1987 through 1990 year classes, indicating impurity of one or both founding stocks, rapid colonization by largemouth bass resident in
the Briery Creek watershed, or a combination of these factors.

6. There were no significant differences in the distributions of presumptive genotypes of largemouth bass in successive samples of 1987-1989 year class bass. Differential mortality was not observed for age-1+ and older largemouth bass in Briery Creek Lake.

7. The percentage of Florida subspecific alleles for all bass as well as F₅ bass considered separately remained stable over successive samples for the 1987, 1988, and 1989 cohorts. For these cohorts, survival from October 1989 through May 1991 was not influenced by the relative "Florianeness" of age-1+ and older bass.

8. Proportions of presumptive genotypes of largemouth bass did not change in a consistent direction among the 1987, 1988, or 1989 cohorts. Neither subspecies nor hybrid bass consistently became more or less frequent in the successive year classes 1987-1989.

9. The frequencies of Florida subspecific alleles did not differ among the 1987-1989 cohorts or among the F₅ bass of these cohorts, indicating no differential survival advantage for largemouth bass carrying Florida
subspecific genes after age 1.

10. Both the October 1990 and the May 1991 samples of the 1990 year class differed from the 1987, 1988, and 1989 cohorts in having proportionately fewer \( F_1 \) bass and more \( F_x \) bass. The expected shift of the bass population in BCL towards a predominantly \( F_x \) composition in later generations occurred for the 1990 year class.

11. First-year survival over the 1989-90 and 1990-91 winters was not consistent for \( F_x \) bass; however, proportions of \( F_1 \), NLMB, and FLMB did change in a consistent pattern. Over both winters, proportions of \( F_1 \) bass increased, northern bass proportions remained relatively stable, and Florida bass proportions declined.

12. Of a total of nine growth rate comparisons within year classes, only four exhibited significant differences in lengths at age among the four presumptive genotypes of largemouth bass. Backcalculated lengths were statistically different among presumptive bass genotypes at age one for the 1989 cohort, and for two year-old bass of the 1987, 1988, and 1989 cohorts. Generally, \( F_1 \) bass growth was relatively high and growth of northern bass low. Growth rates of FLMB and \( F_x \) bass were inconsistent,
but $F_x$ bass lengths were not ranked highest among any of the year class/age comparisons.

13. Overall, growth of largemouth bass in Briery Creek Lake was near the Virginia state average for one and two year-old largemouth bass but lagged precipitously behind by age three. The reduced growth for older fish suggests a prey shortage for larger bass in Briery Creek Lake.

14. The overall median Wr for largemouth bass in Briery Creek Lake was 92.3. Largemouth bass in BCL were usually not in what is considered "good" condition (i.e., Wr>100). Of the 120 Wr values greater than 100.0 in BCL, disproportionately few were northern largemouth bass.

15. Although six of the fourteen statistical comparisons of Wr among presumptive genotypes of largemouth bass were compromised by small samples, a trend was apparent. Relative weight values for northern largemouth bass in BCL tended to rank low compared to the other genotypic categories of bass.

16. Relative weights of BCL bass declined with age, paralleling the trend in growth rates. No seasonal differences were observed among spring- and fall-
collected bass in Briery Creek Lake.

17. In Briery Creek Lake, age-0+ northern and F₁ bass tended to be longer in the fall collections than either the Florida or F₂ bass, possibly reflecting earlier spawning dates or heterotic performance.

18. No significant difference in susceptibility to angling was observed among the four genotypic categories of largemouth bass in Briery Creek Lake.

Conclusions

Florida largemouth bass did not substantially outperform northern bass in Briery Creek Lake. Size attained at later ages and the condition of Florida bass were marginally better, but significant and consistent patterns of superior performance were not demonstrated by bass of the Florida subspecies. Vulnerability to angling appeared to be proportional to the abundance of each of the four presumptive genotypes present. Florida bass also exhibited poorer first-winter survival than northern bass and hybrids in the thermal regime of BCL, in agreement with the findings of Philipp and Whitt (1991) in central Illinois ponds.

Hybrid bass dominated the Briery Creek Lake population
from 1987 through 1990. While \( F_1 \) hybrids demonstrated superior growth and overwinter survival, \( F_x \) hybrids did not. Performance of \( F_x \) hybrids was more similar to that of the northern subspecies in BCL, despite the fact that \( F_x \) bass averaged in excess of 40\% Florida subspecific alleles. The future bass population in BCL is likely to be dominated by \( F_x \) fish, which will more closely resemble the northern bass parent if Florida genes are maladaptive. The net effect of the introgression of Florida subspecific alleles into the northern bass gene pool does not appear to be a positive contribution to improving the largemouth bass fishery in BCL.

However, Briery Creek Lake was less than an ideal test case. Genetic impurity of one or both founding stocks limited the ability to study the rate of introgression, but did facilitate comparisons of performance beginning with the 1987 year class. The low number of "pure" northern and Florida subspecific individuals collected weakened statistical tests of genotype-specific performance. Therefore, inferences on growth, condition, survival, and vulnerability to angling were rendered somewhat less conclusive. Another factor which probably interfered with the study's results was the shortage of prey in BCL. If forage were more abundant, perhaps potential growth differences would have been realized.

The situation in Briery Creek Lake is dynamic and further, periodic study is needed. It is apparent from the
last sample of bass taken from BCL that the genotypic composition is not at equilibrium, and forage is still limited. If conditions improve and the available prey supply/predator ratio increases, growth differences may become more evident. Also, potential performance differences not exhibited by one to three year-old bass could be exhibited by older individuals, particularly in a situation with limited food. Therefore, the prey base should be monitored and samples of older largemouth bass should be analyzed for subspecific alleles and growth rate to track BCL fishery trends.

In order to further illuminate the success or failure of stocking Florida bass in BCL, additional study is needed. Vulnerability to angling needs to be assessed over a longer period and under various conditions. To get an accurate estimate of spawning date, juvenile fish should be collected earlier in the summer, electrophoretically analyzed, and their otolith rings counted. It would also be informative to have an electrophoretically characterized sample of resident bass within the Briery Creek Lake drainage and to have allele frequency data on the respective founding broodstocks.

The Briery Creek case study provides no support for the introduction of Florida bass into other Virginia waters. Virginia's winter thermal regime spans a wider range than that at BCL. Minimum winter air temperatures range from -9.4°C in
the southeastern tidewater areas to -23°C in the western mountains; temperatures in the vicinity of BCL reach -20°C. Trophic conditions, water quality, and habitat also vary widely among reservoirs. It is therefore, possible, that Florida bass and their hybrid progeny would perform better in some other Virginia impoundments. At least 15 public fishing lakes throughout Virginia have been stocked with the Florida subspecies of largemouth bass since the mid 1970s (A. L. LaRoche III, VDGIF, personal communication). Electrophoretic surveys of the present genetic composition of these and other mid-latitude populations in which Florida bass have been stocked would describe the persistence of Florida subspecific genes over time and permit examination of factors which contribute or limit success. For some of these waters, data on bass populations may be adequate to compare the performance (e.g., growth, harvest, standing stock) of the population both before and after stocking Florida largemouth bass.

A more definitive understanding of the merits of stocking Florida bass in Virginia and other mid-latitude waters would result from such an analysis. In its absence, the Briery Creek Lake experience should serve to discourage other introductions of Florida bass into Virginia waters and similar latitudes.
LITERATURE CITED


Pelzman, R. J. 1980. Impact of Florida largemouth bass, Micropterus salmoides floridanus, introductions at
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VITA

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