# Age, Growth, and Movement of 2 *Morone* Hybrids in the Apalachicola River System, Florida

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*Abstract*: Mitochondrial DNA (mtDNA) markers were used to distinguish 2 *Morone* hybrid reciprocal crosses, palmetto bass (*Morone saxatilis* female × *M. chrysops* male) and sunshine bass (*M. chrysops* female × *M. saxatilis* male), in Lake Seminole and the Apalachicola River, Florida. Individual sunshine bass survived to age 6 and weighed up to 5.9 kg, representing the oldest and largest specimens of this hybrid cross collected from a wild natural system. Hybrids moved downstream >125 km, through 2 dams, to the Apalachicola River. Palmetto bass demonstrated a greater tendency than sunshine bass to emigrate from Lake Seminole to the Apalachicola River. Movement differences are discussed and related to inheritance of maternal spawning traits which may effect hybrid fisheries within or below reservoirs.

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Striped bass *(M. saxatilis)* × white bass *(M. chrysops)* $F_1$ hybrids have been stocked throughout the southeastern United States to control shad (*Dorosoma* spp.) and create sport fisheries (Bayless 1968, Ware 1974, Crandall 1978). Palmetto bass were used exclusively in most state hybrid stocking programs except in Florida and Georgia. Since 1987, these 2 states have stocked sunshine bass to augment palmetto bass introductions because striped bass female brood stock were often limited and utilized primarily for striped bass production. Since 1989, several states, including Mississippi, Kentucky, North Carolina, South Carolina, and Oklahoma have produced sunshine bass (Am. Fish. Soc., Southern Div., Striped Bass Comm. meeting minutes, 1993).

Previous *Morone* hybrid evaluations focused on comparisons to prior striped bass introductions (Logan 1968, Bishop 1968, Williams 1970, Kinman 1987) or establishment of new fisheries (Borkowski and Synder 1982, Young 1984, Yeager 1985). Morello (1984) used sunshine bass to establish an urban fishery in Lake Osborne, Florida. Other studies failed to report which hybrid cross was stocked or evaluated (Keefer 1981, Champeau 1984, Ebert et al. 1987). Initial pond studies reported that smaller sunshine bass fry exhibited lower survival to phase I (25–50 mm total length, TL) compared to palmetto bass (Bishop 1968, Bayless 1972). Moss and Lawson (1982) reported that palmetto bass were more easily produced than sunshine bass. In contrast, Ware (1974) and Yeager (Fla. Game and Fresh Water Fish Comm. [FGFC], pers. commun.) reported good survival (46% and 49%, respectively) of sunshine bass fry to phase I, provided grow-out ponds were well fertilized and zooplankton populations were maintained.

From 1975 to 1984, phase I palmetto bass stocked into Lake Seminole, Florida-Georgia, created an excellent fishery in the Apalachicola River tailwater (Young 1984). FGFC recognizes angling achievement by awarding Big Catch Citations to fishers catching trophy-size hybrids ≥ 3.7 kg. From 1982 to 1990, several trophy palmetto bass were caught annually during spring creel surveys in the trailrace. In 1985, Florida's state record *Morone* hybrid, weighing 7.4 kg., was caught in Lake Seminole (FGFC, unpubl. data).

In 1987, phase I sunshine bass were first introduced into Lake Seminole to replace palmetto bass because the limited numbers of female striped bass available in Florida and Georgia were directed to striped bass restoration programs. Since palmetto bass introductions had created a successful fishery in the upper Apalachicola River, Florida fish managers were concerned about long-term survival and growth of sunshine bass in the Apalachicola-Chattahoochee-Flint (ACF) river system. In anticipation of changing to sunshine bass introductions, Florida co-stocked tagged phase II (203–254 mm TL) palmetto bass and sunshine bass into Lake Seminole in 1985 and 1986 to evaluate growth, relative survival, and movement. These evaluations were unsuccessful because tag returns were almost negligible 12 months after stocking.

Wirgin (1987) demonstrated that restriction fragment-length polymorphism (RFLP) analysis of mitochondrial DNA (mtDNA) can be used to distinguish fixed differences in mtDNA genotypes among all 4 North American *Morone* species. Since mtDNA is almost always transmitted uniparentally in vertebrate organisms, RFLP analysis of mtDNA provides an efficient means to trace the maternal lineage of individual fish. Single restriction enzyme digests can be used to unequivocally distinguish mtDNA genomes of striped bass and white bass. In effect, RFLP analysis of mtDNA provided a means of marking all hybrids stocked into the ACF as sunshine bass or palmetto bass. These genetic marks are lifelong and overcome the complications associated with physical handling and tagging large numbers of small fish.

The objectives of this study were to compare co-stocked sunshine bass and palmetto bass and determine whether sunshine bass would live as long, grow to trophy size (qualify for the Big Catch Program), and exhibit similar downstream migration to maintain the quality hybrid fishery in the Apalachicola River trailrace. This inves-

tigation focused on Lake Seminole and the upper Apalachicola River since the tailwater hybrid fishery is dependent upon reservoir stocking and hybrid movement out of the lake.

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## Methods

Lake Seminole, a shallow 15,182-ha run-of-river reservoir, was formed by Jim Woodruff Lock and Dam (JWLD) in 1957 at the confluence of the Flint and Chattahoochee rivers near Chattahoochee, Florida. The Apalachicola River originates at the tailwater discharge from Lake Seminole, and extends 171 km to Apalachicola Bay. Mean monthly discharge is approximately 700,000 liters/sec (U.S. Army Corps Eng. 1986). During the January–May rainy season, a number of flood gates are continuously opened. The Chattahoochee River is influenced by discharge from Walter F. George Lake (Lake Eufaula), an 18,500-ha mainstream storage reservoir, located in southwest Georgia, approximately 125 km upstream of Lake Seminole. Water releases from Walter F. George Lake normally occur through hydropower turbines, although flood gates are opened periodically to discharge excess water and mitigate depressed dissolved oxygen in the tailwater.

During 1988, 500,000 each of sunshine bass and palmetto bass were stocked into Lake Seminole (Table 1). Previously, 250,000 palmetto bass were released in 1986, and 249,000 sunshine bass in 1987. No hybrids were stocked into Lake Seminole during 1985, 1989, or 1990. During this study, palmetto bass were also stocked upstream in Walter F. George Lake by GDNR.

We attempted to sample and analyze mtDNA from 25 hybrids from the 1988 year class at ages 1, 3, 4, and 5. Hybrids were collected in Lake Seminole during November and December 1989, March 1991, and December 1991 and 1992. Three floating experimental gill nets, 2.3 m deep and 48 m long with mesh sizes ranging from 32 to 203 mm stretched, were set at dusk and fished overnight. Nets were fished for 1–2 nights, depending on the number of fish collected. Hybrid samples were

**Table 1.** Numbers of palmetto bass and sunshine bass stocked into Lake Seminole, Florida-Georgia, Walter F. George Lake, Georgia, 1986–1988.

| | Lake Seminole | | Walter F. George Lake | |
|---|---|---|---|---|
| Stocking year | Palmetto bass | Sunshine bass | Palmetto bass | Sunshine bass |
| 1986 | 250,000 | 0 | 450,000 | 0 |
| 1987 | 0 | 249,000 | 900,000 | 0 |
| 1988 | 500,000 | 500,000 | 900,000 | 0 |

taken in the Apalachicola River below JWLD to evaluate downstream movement through the dam and supplement Lake Seminole samples. Apalachicola River samples were collected in the upper 10 km of the river during December 1989, January–March 1991, and March 1993 by nighttime electrofishing (pulsed direct current) and during creel surveys.

*Morone* $F_1$ hybrids were distinguished from their parents using meristic and morphometric traits (Bayless 1972; Harrell 1984; Kerby 1979, 1980; Waldman 1986). Hybrids were separated from striped bass using lateral line scale counts and by their deeper body, smaller head, shorter and broader caudal region, and head slope (more of an acute angle). Hybrids were distinguished from white bass by a single tooth patch on the tongue (Bayless 1972). However, phenotypic characters of *Morone* hybrid reciprocals often overlap (Bayless 1972; Kerby 1979, 1980) and exhibit considerable variation (Harrell and Dean 1987) making it difficult, if not impossible, to distinguish sunshine bass from palmetto bass without genetic analyses.

Livers were removed from each hybrid, immediately put on wet ice or quick-frozen in a slurry of dry ice and ethyl alcohol, stored at −15 C, and shipped to the laboratory on dry ice for mtDNA analysis. RFLP analysis of mtDNA was used to distinguish between palmetto bass and sunshine bass. Hybrid identification was determined using mtDNA markers as described by Wirgin et al. (1992). Total DNA was isolated from hepatic tissue using C-Tab buffer (Saghai-Marood et al. 1984) as described by Wirgin et al. (1990). All DNAs were digested with the restriction enzymes *Ava* I and *Hind* III for 3–6 hours at 37 C. DNA fragments were electrophoretically separated overnight in 1.0% horizontal agarose gels and were visualized by Southern blot analysis (Southern 1975). Membranes were prehybridized and hybridized at 65 C, over night, to highly purified mtDNA (probes) prepared from a single striped bass liver. All probe DNAs were $^{32}$p radiolabeled by nick translation (Rigby et al. 1977) and washed 3 times. Final wash conditions for membranes were 1.0 × SSC/0.1% SDS for 60 minutes at 65 C. Membranes were exposed to x-ray film with intensifying screens for 1–3 days at −80 C. Mitochondrial DNA genotypes were categorized as striped bass (palmetto bass maternal parent) or white bass (sunshine bass maternal parent) for each individual fish based on results from the 2 restriction enzymes. In all cases, both enzymes provided congruent results in identifying the maternal ancestry of individuals.

Each hybrid was weighed (g) and measured (mm) for TL. Otoliths (sagittae) were removed and ages determined as described by Snyder et al. (1983). Since fish were sacrificed for aging, hybrids from the 1986 and 1987 year classes, at ages 5–7, were included in the data sets to establish longevity and supplement growth information. Mean TLs and weights were calculated for sunshine bass and palmetto bass at ages 1, 3, 4, 5, 6, and 7 and compared with Student's *t* tests.

Movement of hybrids from Lake Seminole to the Apalachicola River was evaluated by comparing percentages of the 1988 year class of sunshine bass and palmetto bass collected from the lake and river at ages 1, 3, and 5 using chi-square analysis (Sokal and Rohlf 1981). A second data set containing all hybrids with mtDNA analysis, was also analyzed since equal numbers of both hybrids were stocked into Lake Seminole from 1987 through 1988. We expected that the sample frequencies of each

hybrid cross would be similar for the lake and river if there was equal survival after stocking, no natural hybridization, equal gear vulnerability, and no behavior or movement differences.

## Results

Between 1 November 1989 and 31 March 1993, 126 *Morone* hybrids were collected from Lake Seminole ($N = 57$) and the Apalachicola River ($N = 69$) and analyzed for mtDNA markers (Table 2). Palmetto bass ($N = 84$) outnumbered sunshine bass ($N = 42$) by a 2:1 ratio during the study, even though equal numbers were stocked from 1986 to 1988. The total number sampled included 10 fish from the 1986 year class and 16 from the 1987 year class. Of the 28 hybrids sampled at age 1, 15 were sunshine bass and 13 were palmetto bass indicating similar survival 18 months after stockings. Ten of the 16 hybrids from the 1987 year class were genetically identified as palmetto bass, even though this hybrid cross was only stocked into Walter F. George Lake during that year. The appearance of these palmetto bass precluded our ability to successfully evaluate relative survival of the 2 hybrid crosses.

### Age

A total of 38 age-5 and -6 hybrids were collected from December 1991 to March 1993. Of these, 14 were sunshine bass from the 1987 and 1988 year classes, demonstrating longevity of this hybrid cross (Table 2). Palmetto bass survived to age 7, as documented from otolith analysis of hybrids from the 1986 year class ($N = 4$). As expected, sunshine bass were not collected from the 1986 year class since they were not stocked that year.

### Growth

Mean total lengths and weights of sunshine bass and palmetto bass were not significantly different ($P > 0.05$) at ages 1, 3, 4, 5 and 6 (Fig. 1). Lake Seminole and Apalachicola River data were pooled because of small sample sizes for individual age classes. By age 5, both sunshine bass and palmetto bass achieved the desired Big Catch qualifying size with mean weights > 3.7 kg. The largest sunshine bass captured measured 682 mm TL and weighed 5.9 kg at age 5, while 13 others (ages 5 and 6) weighed 3.7–5.7 kg. The largest palmetto bass collected measured 679 mm TL and weighed 6.5 kg at age 7 and 31 others, ages 5–7, weighed 3.8–6.2 kg.

### Movement

Among the 1988 year class hybrids sampled, palmetto bass demonstrated more downstream movement than sunshine bass. At ages 1, 3, and 5, palmetto bass comprised 75%–85% of the hybrids collected from the Apalachicola River ($N = 61$), while they consistently made up < 50% of the Lake Seminole ($N = 39$) samples (Fig. 2). The percentages of sunshine bass and palmetto bass were significantly different ($P < 0.20$) for age-1 hybrids in Lake Seminole samples and age-3 and -5 hybrids in Apalachicola River samples (Fig. 2).

**Table 2.** Percent of sample and total number ($N$) of palmetto bass and sunshine bass collected from Lake Seminole, Florida-Georgia, and the Apalachicola River, Florida, 1989–1993.

| Date | Hybrid | Lake Seminole | Apalachicola R. | Combined Total |
|---|---|---|---|---|
| | | 1988 year class | | |
| | | age 1 | | |
| Nov–Dec 89 | Palmetto | 25% (4) | 75% (9) | 46% (13) |
| | Sunshine | 75% (12) | 25% (3) | 54% (15) |
| | | age 3 | | |
| Mar 91 | Palmetto | | 86% (31) | 86% (31) |
| | Sunshine | | 14% (5) | 14% (5) |
| | | age 4 | | |
| Dec 91 | Palmetto | 42% (5) | 67% (2) | 47% (7) |
| | Sunshine | 58% (7) | 33% (1) | 53% (8) |
| | | age 5 | | |
| Dec 92–Mar 93 | Palmetto | 46% (5) | 80% (8) | 62% (13) |
| | Sunshine | 54% (6) | 20% (2) | 38% (8) |
| | Total | (39) | (61) | |
| | | 1987 year class | | |
| | | age 6 | | |
| Dec 92–Mar 93 | Palmetto | 50% (5) | 83% (5) | 63% (10) |
| | Sunshine | 50% (5) | 17% (1) | 37% (6) |
| | | 1986 year class | | |
| | | ages 5–7 | | |
| Dec 92–Mar 93 | Palmetto | 100% (8) | 100% (2) | 100% (10) |
| | Sunshine | | | |
| | | All Year Classes | | |
| | | ages 1–7 | | |
| Dec 89–Mar 93 | Palmetto | 47% (27) | 83% (57) | 76% (84) |
| | Sunshine | 53% (30) | 17% (12) | 24% (42) |
| | Grand total | (57) | (69) | (126) |

The observed differences in movement between sunshine bass and palmetto bass from the 1988 year class persisted when older fish (ages 5–7) from the 1986 and 1987 year classes were included in the analysis (Fig. 3). Even though equal numbers of the 2 hybrid crosses were stocked into Lake Seminole between 1986 and 1988, palmetto bass made up a disproportionate and significantly ($P < 0.20$) higher percentage (83%) than expected of all hybrids collected from Apalachicola River samples ($N = 69$). Conversely, sunshine bass represented an expected 53% ($N = 30$) of Lake Seminole samples ($N = 57$), despite the immigration of some fish from the 1987 year class of palmetto bass from Walter F. George Lake.

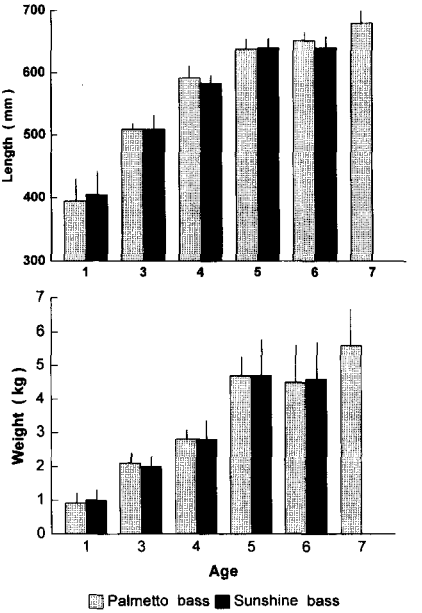


**Figure 1.** Mean total length, weight, and age of palmetto bass and sunshine bass collected in Lake Seminole, Florida–Georgia, and the Apalachicola River, Florida, 1989–1993. Vertical lines represent 2 SE.

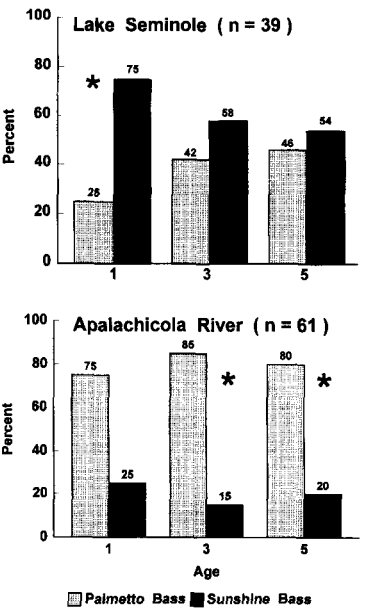


**Figure 2.** Percent of palmetto bass and sunshine bass (1988 year class) collected in Lake Seminole, Florida–Georgia, and the Apalachicola River, Florida, 1989–1993. Significant (*, $P < 0.2$) differences are indicated for chi-square analysis.

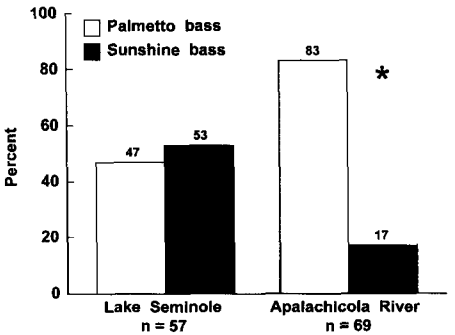


**Figure 3.** Percent of palmetto bass and sunshine bass (all year classes) collected in Lake Seminole, Florida–Georgia, and the Apalachicola River, Florida, 1989–1993. Significant (*, $P < 0.2$) differences are indicated for chi-square analysis.

## Discussion

This study is the first field evaluation to document the longevity and growth of sunshine bass in a large natural system. Mitochondrial DNA markers were a viable long-term genetic marker to unequivocally identify sunshine bass introduced into Lake Seminole without the technical difficulties associated with conventional tags such as handling mortality, tag loss, or reduced growth.

Mitochondrial DNA analysis of analysis of 1987 year class fish identified palmetto bass, not stocked into Lake Seminole, which compromised the ability to complete a performance evaluation of these reciprocal hybrids. The appearance of 1987 year class palmetto bass was attributed to emigration from Walter F. George Lake, rather than natural hybridization. Mesing et al. (1990) reported that in 1985, 667,000 palmetto bass were stocked into Walter F. George Lake, while no *Morones* were stocked into Lake Seminole or the Apalachicola River. Monthly standardized nighttime electrofishing samples were conducted from May 1985 to March 1986 to collect y-o-y *Morones* from sandbars in the Chattahoochee River, Lake Seminole, and the Apalachicola River from JWLD to Apalachicola Bay. Sampling methodologies for y-o-y *Morones* were similar to Van Den Avyle and Higginbotham (1979) who reported that y-o-y white bass, hybrids, and striped bass preferred sand habitats at night in Watts Bar Reservoir, Tennessee. Naturally-reproduced y-o-y striped bass were collected throughout the Apalachicola River system from July to December, but y-o-y hybrids were not observed until December, following a flood event in the watershed. After floodgates at Walter F. George Lake and Lake Seminole were opened in December, y-o-y hybrids were collected from Lake Seminole to Apalachicola Bay. Analysis of mtDNA from these hybrids confirmed they were palmetto bass, the same cross stocked into Walter F. George Lake. Y-o-y hybrids should have been collected concurrently with y-o-y striped bass from July through November, had successful natural *Morone* hybridization occurred in the system. Therefore, the appearance of y-o-y hybrids from Lake Seminole to Apalachicola Bay, in the ab-

sences of stocking, was probably the result of emigration from an upstream reservoir.

Longevity of sunshine bass (age 6) and palmetto bass (age 7) was similar and both crosses lived to the maximum age possible during the time span of this study. Other investigators (Williams 1970, Germann and Bunch 1983, Snyder et al. 1983, and Champeau 1984) have documented hybrid (presumably palmetto bass) survival to age 5 and older; however, survival of sunshine bass to that age has not been previously reported.

Sunshine bass in the Lake Seminole and Apalachicola River system attained weights that qualify for Florida's Big Catch Program (≥ 3.7 kg). The largest sunshine bass collected weighed 5.9 kg at age 5. In 1985, the Florida state record hybrid (palmetto bass) weighed 7.4 kg and was caught in Lake Seminole. Ware (1974) reported an 8.2-kg palmetto bass (age 8 or 9) caught in Norris Reservoir, Tennessee, while Ott and Malvestuto (1981) reported hybrids (presumably palmetto bass) to 9.0 kg in Clarks Hill Reservoir, South Carolina. Germann and Bunch (1983) reported the world record hybrid (cross not reported) caught in the Savannah River, Georgia, in 1982 weighed 9.2 kg. Because several large sunshine bass weighing ≥3.7 kg were observed during our study, fish managers should not avoid stocking phase I sunshine bass in lieu of palmetto bass based on concerns over longevity or growth.

Movement of hybrids downstream through flood gates may be common, but it is not well documented in the literature. Young (1984) first reported that stocking palmetto bass into Lake Seminole established a successful fishery in the Apalachicola River below the reservoir. Mesing et al. (1990) provided evidence of age-0 palmetto bass downstream movement of 296 km. This investigation demonstrated that palmetto bass migrated considerable distances downstream, moving > 125 km, from Walter F. George Lake to the upper Apalachicola River, through 2 dams. Sunshine bass also exhibited downstream movement, but not to the extreme displayed by palmetto bass. The results of this investigation further illustrate that downstream movements of age-0 and adult *Morone* hybrids should be considered when stocking open systems which could result in hybrids entering waters where they are not intended.

During our study, palmetto bass outnumbered sunshine bass in Apalachicola River samples, while sunshine bass numbers were similar to palmetto bass in Lake Seminole collections, even though palmetto bass emigrated from an upstream reservoir. We hypothesize that movement differences observed during this investigation may be attributed to behavioral traits of the maternal parents of sunshine bass (white bass) and palmetto bass (striped bass). Hines (1976) reported that rainbow trout *(Oncorhynchus mykiss)* × steelhead (term applied to ocean-run rainbow trout) hybrids migrated to the ocean, a characteristic of parental steelhead. Johnson et al. (1988) reported that the biology of walleye *(Stizostedion vitreum)* × sauger *(S. canadense)* hybrids more closely resembled that of the walleye (female) parent. Kerby (1979, 1980) reported some meristic and morphometric characters of *Morone* hybrid crosses (palmetto bass and Virginia bass, *M. saxatilis* × *M. americana*) were generally intermediate, while others skewed towards one parent or the other.

Typically white bass spawning occurs prior to striped bass spawning in the same areas depending on water temperatures (Kerby and Harrell 1990). In the ACF, white

bass are collected and spawned in state hatcheries during February and March, while striped bass are collected and spawned in late March and April for the production of sunshine bass and palmetto bass, respectively. Although both *Morone* species exhibit upstream spawning migrations, white bass begin these movements earlier than striped bass. If sunshine bass inherit spawning tendencies of white bass (maternal parent), then these hybrids may leave the open water areas of Lake Seminole, located near flood gates, and migrate upstream 4–6 weeks in advance of palmetto bass. Therefore, fewer sunshine bass would remain in Lake Seminole and be affected by high water discharges into the Apalachicola River during late winter and spring. As a result, fewer sunshine bass would be observed in the Apalachicola River and higher numbers would occur in lake Seminole. Conversely, if palmetto bass exhibit striped bass behavior, their upstream migrations would not occur until mid-March or April. Therefore, palmetto bass would be more susceptible than sunshine bass to water discharges during late winter and spring flood events.

Results of this study documented long-term survival and excellent growth of sunshine bass to a trophy size (≥ 3.7 kg). Relative survival and growth of these *Morone* hybrids should be further investigated within a closed system. Movement patterns suggest a potential behavioral difference between palmetto bass and sunshine bass during spring and these differences may be related to their maternal spawning traits. Evidence of maternal influence on behavior of these hybrid crosses should be further investigated, possibly with a radio telemetry study.

## Management Implications

Based on our results, sunshine bass can attain Florida Big Catch qualifying weight within 5 years. Also, *Morone* hybrid cross selection may influence the numbers of fish available for downstream tailwater fisheries dependent upon upstream reservoir stocking programs, type of reservoir, and the timing of water releases. In the case of the Apalachicola River hybrid fishery, Florida fisheries managers will stock palmetto bass when available, since the Apalachicola River population is dependent upon hybrids discharged from Lake Seminole. In contrast, Georgia managers may prefer to continue stocking sunshine bass, since their observed growth was similar to that of palmetto bass through age 6, and sunshine bass exhibited a greater tendency to remain within Lake Seminole. These differences in behavior should be considered when managers are developing tailwater or reservoir fisheries for *Morone* hybrids.

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