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Relative Contribution of Stocked Minnow-Fed and Pellet-Fed Advanced Fingerling Largemouth Bass to Year-Classes in Crab Orchard Lake, Illinois

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Abstract.—Very little research exists concerning stocking pellet-reared versus minnow-reared, advanced fingerling largemouth bass *Micropterus salmoides* into fertile lakes. This project determined the relative contribution of stocked, advanced fingerlings (89–160 mm) reared on either fathead minnows *Pimephales promelas*, pelleted feed, or pellets followed by minnows to bass year-class strength. Bass were stocked at seven stations in Crab Orchard Lake, Illinois in summer1993–1996 and 1998. Electrofishing catch of all age-0 bass averaged 39.2 per hour and ranged from 18.7 to 73.9 per hour. Stocked bass contributed 16.0 percent of the age-0 fish collected (n = 1,623) during fall and 13.8 percent of the age-1 bass collected during spring (n = 843). Relative survival (RS) at age-0 favored minnow-reared bass by 1.3–16.2 to one over pellet-reared bass and was statistically significant ($p < 0.05$) in two of three years. Survival at age-0 favored bass sequentially fed the prepared diet and minnows with RS of 0.4–0.8, but was only statistically significant in one of two years. RS of age-1, minnow-reared bass was 1.5–4.1 times that of pellet-reared fish and statistically significant in all five years. Largemouth bass fed a minnow diet for 14 days prior to stocking will survive at least as well a minnow-reared bass through age-0, and both diets resulted in higher bass survival than with pellets alone. By age-1, however, survival favored bass reared on minnöws exclusively.

Introduction

Sport fisheries resources are essentially fixed and finite. Due in part to human population increase, disposable time, demographics, improved fishing equipment, and anglers' skill levels, pressure on these resources is increasing. In addition, the aging of reservoir habitats has reduced the availability of sportfish. Construction of new lakes and reservoirs no longer occurs at a significant rate, and many man-made lakes and reservoirs are more than 25 years old. Thus, the only way to maintain angler catch-per-unit effort at even the current level is through better management.

Biologists have several options to improve sport fisheries in lakes and streams. These include stocking, regulations, and habitat enhancement. Almost 19 million fingerling largemouth bass *Micropterus salmoides* are stocked annually in North America (Heidinger 1999). Although fingerling largemouth bass are commonly stocked to supplement natural recruitment (Boxrucker 1986), evaluations of this management technique are limited (Terre et al. 1993), and there are no generally accepted guidelines to gauge success of supplemental stocking.

Researchers have used a number of criteria to evaluate these stockings including the percent of stocked fish harvested, percent of stocked fish in the year-class, and cost:benefit ratios. Results have varied. McCammon and von Geldern (1979) stocked Lake Nacimiento with 200-mm tagged largemouth bass. Thirty-nine percent of these fish were harvested after four years. In Shasta Lake stocked fish constituted 50 percent of the largemouth bass population, and 15 percent of the stocked fish were harvested in two years. They concluded that largemouth bass maintenance stocking is not a profitable technique for large reservoirs. Marked largemouth bass (35–64 mm TL) stocked into two Oklahoma lakes at 448 and 446 bass per hectare made up 70 percent and 75 percent of their year-class after two growing seasons (Boxrucker 1986). After 15 months, 50-mm bass stocked at 20 fish per hectare into Lake Coronado, Arkansas constituted 33 percent of their size-class (Filipek and Gibson 1986). In Chatfield Reservoir, Colorado, Krieger and Puttman (1986) stocked 125-mm marked largemouth bass at 4–22 habitat hectare for three years. At age-2, 12 percent, 59 percent, and 59 percent of the recovered bass were marked. New York's Nassau Lake was stocked with 190-mm finclipped largemouth bass in 1966. The stocked fish comprised 42 percent, 36 percent and 18 percent of their cohort over the next three years

(Fieldhouse 1971). From 1988–1992, Buynak and Mitchell (1999) stocked Taylorville Lake in Kentucky with 107–114 mm finclipped largemouth bass at rates of 4–11 per hectare. In 1993 electrofishing samples indicated 24.5 percent of the total bass population were marked fish. This 5-year stocking program resulted in a cost to benefit ratio of 1:3.9 for the catch-and-release portion of the fishery from 1990 to 1995.

Other researchers have documented less or had mixed success from stocking largemouth bass fingerlings. Ryan et al. (1996) stocked Lake Conroe, Texas with 138-mm Florida bass *M. s. floridanus* at a rate of 2.8 fish per hectare and Lake Gladewater, Texas with 121-mm Florida bass at a rate of 8.8 fish per hectare. Based on electrofishing samples and genetic analysis, stocked bass comprised 0.0 percent, 5.0 percent, and 0.0 percent of their cohort in Lake Conroe and 4.5 percent, 6.7 percent, and 0.0 percent of their cohort in Lake Gladewater in the three years following stocking. Three Texas reservoirs were stocked by Terre et al. (1993) with 19–32 mm Florida × northern largemouth bass *M. s. salmoides*. Towns Reservoir was stocked the first year with 30 bass per hectare and the following year with 100 bass per hectare. Meredith Reservoir was stocked once with 94 fish per hectare, and Braunig Reservoir was stocked once with 200 fingerlings per hectare. Based on electrofishing samples and genetic analysis, stocked fish represented only one to seven percent of the total largemouth bass collected over the next four years in Towns Reservoir and 41–45 percent in the other two reservoirs. The authors indicated that Towns Reservoir had a history for the highest level of natural recruitment of the three reservoirs.

Various other hypotheses have been postulated to explain success or failure of supplemental stocking of fingerling largemouth bass. The size, number, stocking location, and quality of the bass stocked are all thought to contribute to the success rate (Heidinger 1999). In general, larger stocked fish have a higher survival rate than smaller fish. Larger fish also cost more to raise than smaller fish. Size-related overwinter mortality of age-0 largemouth bass has been demonstrated by some authors, but not others (see Garvey et al. 1998 for a review of the literature). There is some indication that the heaviest period of mortality for small bass may occur not in the winter, but during a critical period in mid-spring (Mick 1994).

Bennett (1962) recommended that corrective stocking rates should approach the carrying capacity of the water for that species. In general, unless natural recruitment is extremely limited, stocked largemouth bass cannot be expected to make up a large proportion of the population with very low stocking rates; however, as the numbers and size of stocked bass increase so does the cost of stocking. Also, as stocking rates are increased, there is a tendency for the percent return of the stocked fish and, therefore, the cost of stocking to increase (Buynak and Mitchell 1999). The maximum number of stocked fish in the lake may still occur at the highest stocking density.

Habitat (location) is thought to affect the survival of stocked largemouth bass (Noble et al. 1994). Because stocked bass are displaced fish, they initially do not have a home range and exhibit more movement than wild bass. If habitat quality is insufficient or food availability is limited, stocked bass may behave like wild bass and search for higher quality habitat (Noble et al. 1994; Savitz et al. 1983). This movement may increase their vulnerability to larger piscivors and could ultimately reduce or negate the contribution of stocked bass to the population.

One major concern that biologists have is with the quality of largemouth bass that have been reared on a prepared diet. If all costs are considered, it is probably cheaper to raise large quantities of advanced fingerling bass on a prepared diet than on minnows (Heidinger 2000). Most previous studies have used bass that have been reared on natural food. Esocids reared on pellets have been found to exhibit different behaviors than minnow-reared fish, which increased their susceptibility to predation (Wahl and Stein 1989). The behavioral differences included different spatial association and predator avoidance. Similar behavior patterns by pellet-reared bass would likely result in reduced survival. In addition, there is some concern that pellet-reared largemouth bass do not overwinter as well as bass reared on a natural diet (Isely 1981; Roem and Stickney 1989). To date, studies have not definitively compared the relative contribution between stocked pellet-reared versus minnow-reared, advanced fingerling largemouth bass.

One objective of this study was to assess the stocking of advanced fingerling largemouth bass into a large reservoir in terms of their relative contribution to year-class strength. A second objective was to evaluate the survival of bass fed pellets, minnows, or a combination of the two diets. The third object was to investigate the movement of the stocked bass.

Study Area

Crab Orchard Lake is an old (impounded in the 1930's), shallow (average depth = 2.1 m), fertile 2,819 ha reservoir located in southern Illinois. The lake elevation is 405 ft above sea level, and water levels fluctuate from 0.3 m below to 0.6 m above pool level. It has approximately 201.1 km of shoreline surrounded by hardwood and pine forests and some grassy meadows. Development around the lake consists of two marinas and several campsites. The lake is relatively fertile because of nitrogen and phosphate loading from the City of Marion's municipal wastewater treatment facility. Due to a hard clay pan and wind action, with the exception of emergent water willow *Dianthera americana* and a few coves with water lily *Nymphae* spp., there is very little aquatic vegetation in the lake. Siltation has created soft muck in areas covering about 25 percent of the lake. Average Secchi disk reading is approximately 0.31 m, and at least 2–3 mg/L oxygen is usually present to 3.5 m during the summer months.

Fish species composition is primarily *Lepomis* spp., *Morone chrysops*, *Ictalurus punctatus*, *Pylodictus olivaris*, *Pomoxis* spp., *Morone mississippiensis*, *Aplodinotus grunniens*, *Ictiobus* spp., *Cyprinus carpio*, *Dorosoma* spp., largemouth bass, and hybrid striped bass *Morone* spp. To minimize spillway loss of largemouth bass and other fish species, a 24-mm barmesh screen was installed on the spillway.

Methods

Marked largemouth bass fed two of three diets were stocked in each of five years (Table 1). Pellet-reared and minnow-reared bass were stocked concurrently in each of three years. Bass fed minnows and a combination of pellets and minnows were stocked in each of two years. Two groups of bass were stocked at the same seven stations in every year of the study to compare survival. Contributions of the stocked bass to year-classes were evaluated by electrofishing at 10 stations (Figure 1) in the first fall (age-0) and following spring (age-1) after stocking.

Bass fed minnows were raised in a 3.2-ha rearing pond with a catch basin within 100 m of Crab Orchard Lake. Forage consisted of the insects (terrestrial and aquatic), fathead minnows *Pimephales promelas*, and crayfish that inhabited the pond prior to stocking. Pellet-reared bass were fed BIO-Trainer and BIO-Diet in other Illinois hatchery rearing ponds. Bass fed the combined diet were also reared in Illinois rearing ponds, fed the same prepared diets as the pellet-reared bass until 10–14 days prior to stocking, and then fed minnows until stocking.

Each of the two groups of bass was usually marked by immersion in buffered 500-mg/L oxytetracycline (OTC) for six hours (Brooks et al. 1994) prior to stocking. Small (25-mm TL) largemouth bass were immersion marked and stocked into the 3.2 ha rearing pond. The fluorescent OTC marks for small fingerlings were located at about the 35th daily ring. The bass were fed minnows and reared to approximately 150-mm TL by Fish and Wildlife personnel prior to stocking. Pellet-fed bass were raised to approximately 150-mm TL and either fin clipped (1993) or held in hauling tanks and marked with OTC. Since the OTC ring on the otolith of pellet-fed bass is much farther away from the nucleus than the mark on the otolith of minnow-reared bass, the two groups of fish were easily distinguished.

Largemouth bass fingerlings (9,885–13,882) were stocked at seven stations in each of five summers over a six-year period between 1993 and 1998 in Crab Orchard Lake (Table 1). Total stocking densities ranged from 3.5/ha to 4.9/ha during the study. Both groups of bass were distributed among the seven stations. Numbers and sizes stocked were dependent on availability of pellet-reared bass and minnow-reared bass from the nursery pond; therefore, they were not stocked at the same rate at each station within or among years. Because Noble et al. (1994) suggested that bass should be stocked in areas where natural recruitment tends to be favorable, we determined the number of bass stocked at each of the seven stations through a combination of historical catch information and visual assessment of habitat including quality and quantity. Habitat quality assessments included macrophyte density for cover and forage, coves that provided protection from wave action, and availability of shallow areas that should have provided refuge for small bass from large piscivors.

Each fall and spring, bass were collected at Stations 1–7 (Figure 1) and at three additional stations (Stations 8–10). The bass were collected by electrofishing from a boat using a three phase, 240-V AC, 5,000-W generator connected to a balanced, six-electrode array (Novotny and Priegel 1974). Age-0 bass were sampled in late October of each year, and age-1 bass in the following spring. All bass were aged using saggittae otoliths (Heidinger and Clodfelter 1987). Effort at each station was limited to approximately one hour of pedal time or when 40 bass within the desired size range were collected per station. An unbiased sample that included 60 age-2 largemouth bass was collected in September 1996 by Fish and Wildlife Service (FWS)

Table 1. Dates and number of largemouth bass stocked at each of seven sites located at Crab Orchard Lake, Illinois during 1993–1998. The fish were marked with either fin clips (1993 pellet-reared) or oxytetracycline (all other groups) prior to stocking.

	Minnow reared				Pellet reared[a]			
	Date	*N*	Average total length	Range	Date	*N*	Average total length	Range
Cambria Neck		418				262		
Camp Ground		1,573				988		
Carterville		1,573				988		
Green Briar		418				262		
Spillway		835				524		
West End		1,573				988		
Wolf Creek		1,573				988		
Total stocked	8/7/93	7,963	141	117–178	8/16/93	5,000	134	108–162
Cambria Neck		200				190		
Camp Ground		1,350				1,160		
Carterville		1,350				1,390		
Green Briar		200				190		
Spillway		471				487		
West End		884				911		
Wolf Creek		1,350				1,390		
Total stocked	8/20/94	5,805	150	127–188	8/25/94	5,718	131	105–170
Cambria Neck		200				200		
Camp Ground		1,623				1,623		
Carterville		2,093				2,093		
Green Briar		200				200		
Spillway		79				79		
West End		653				653		
Wolf Creek		2,093				2,093		
Total stocked	8/19/95	6,941	139	120–200	8/31/95	6,941	128	89–162
Cambria Neck		181				345		
Camp Ground		498				2,326		
Carterville		1,279				2,326		
Green Briar		190				370		
Spillway						328		
West End						1,542		
Wolf Creek		1,279				2,326		
Total stocked	8/24/96	3,427	131	96–178	9/5/96	9,563	89	70–150
Cambria Neck		173				173		
Camp Ground		1,163				1,163		
Carterville		1,163				1,163		
Green Briar		173				173		
Spillway		512				405		
West End		652				759		
Wolf Creek		1,223				991		
Total stocked	8/5/98	5,059	142	103–165	9/9/98	4,827	160	126–193

[a]In 1994 and 1995 the fingerlings were initially reared on a prepared diet and then allowed to feed on live minnows for 14 days prior to stocking.

and Illinois Department of Conservation (IDNR) personnel in their general survey of the bass population in Crab Orchard Lake. Catch rates (CPUE) were assessed by number collected per hour of electrofishing. The rates were used to compare abundance among years and stations.

Percent contributions between two groups of bass were adjusted to depict contribution if numbers stocked at each station were equal between groups. The ratio of returns to number stocked for each food group at each station was multiplied by one half the total number stocked at each station, and that ratio was multiplied by the total number of stocked fish captured at each station. This allowed us to treat each station as a separate stocking when examining contribution since movement

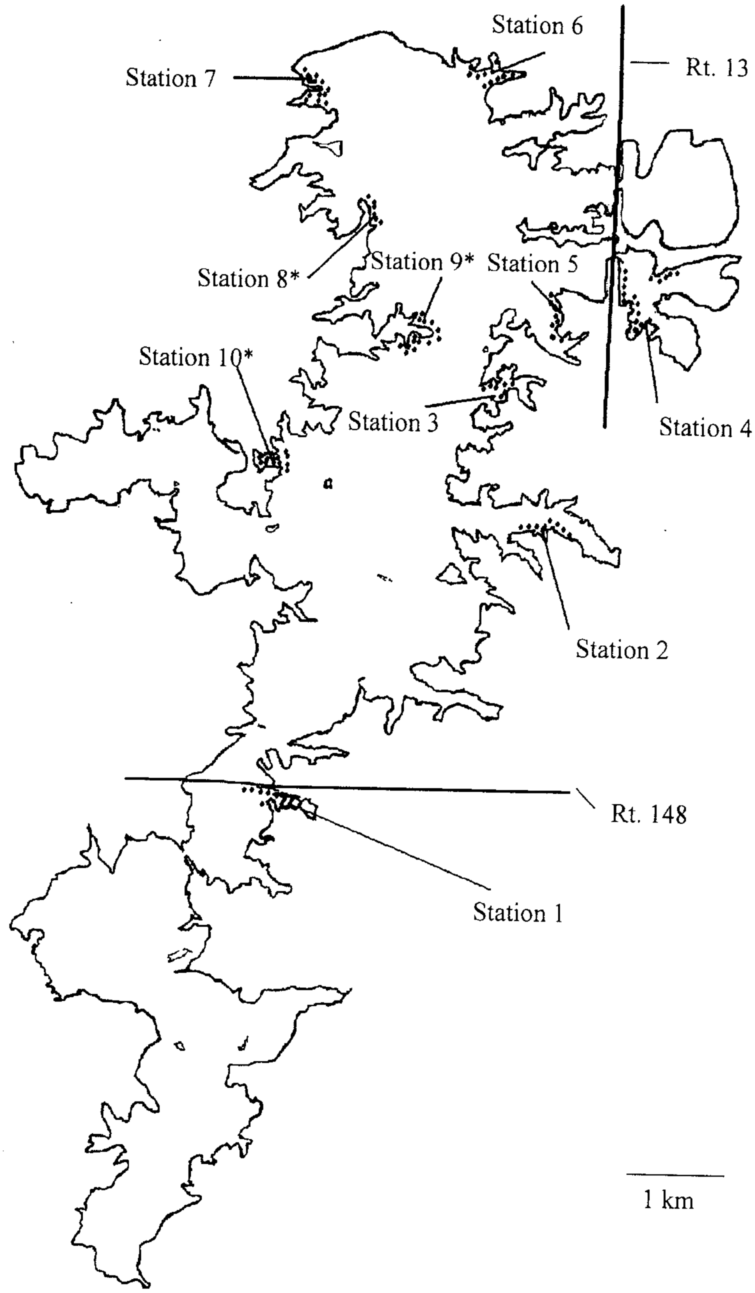

Figure 1. Stocked and unstocked (*) stations sampled in Crab Orchard Lake, Illinois for age-0 and age-1 largemouth bass.

of age-0 bass into and out of the stations should have been limited (Copeland and Noble 1994).

Statistical significance of contribution among stations and CPUE was tested using multivariate analysis with repeated measures (Maceina et al. 1994). The distribution of percent contribution was normalized using arcsine transformation and catch data were log10 transformed to normalize the distribution for statistical analyses. Comparison of total lengths among wild and the various groups of stocked bass were made by analysis of variance (ANOVA). Tukeys posthoc test was used to determine statistical significance among each group (a = 0.05).

Relative survival (RS) of the stocked bass reared with the different diets was determined by comparing ratios of the number of bass stocked in each diet treatment group to that of those recaptured (Heidinger et al. 1985; Heidinger and Brooks 1998) as follows:

$$RS = (n_f/N_f)/(n_e/N_e);$$

n_f = number of bass stocked at size f and later recaptured; N_f = number of bass stocked at size f; n_e = number of bass stocked at size e and later recaptured; N_e = number of bass stocked at size e. Confidence limits (95%) for RS estimates were calculated assuming binomial distributions. Statistical significance was determined at $p = 0.05$.

Results

Catch Rates

From fall 1993 through 1998, 1,623 age-0 marked and unmarked largemouth bass were collected from all 10 stations by electrofishing in Crab Orchard Lake. Annual fall electrofishing catch per hour (CPUE) values averaged 39.2 and ranged from 18.2 to 73.9 (Table 2). The mean CPUE's were statistically different among stations ($p = 0.0024$; $F = 3.67$) and among years ($p = 0.0001$; $F = 15.86$). When the stations were grouped into stocked (7) versus unstocked (3), CPUE's for age-0 bass from the stocked stations averaged 42.7 which was significantly higher ($p = 0.0069$; $F = 26.08$) than the CPUE of 30.9 at the unstocked stations. When only wild bass CPUE's were considered, however, there were no significant differences ($p = 0.1650$) between stocked (CPUE = 33.5) and unstocked stations (CPUE = 29.9).

From spring 1994 through spring 1999, 843 age-1 bass (marked and unmarked) were collected. Spring CPUE's for age-1 bass averaged 16.6 and ranged from 7.3 to 33.7 (Table 2). The mean CPUE's were not statistically different among stations ($p = 0.2782$), but they were different among years ($p = 0.0001$; $F = 8.76$). The CPUE's were not significantly different between stocked (CPUE = 18.3) and

Table 2. Mean electrofishing catch per hour of age-0 and age-1 largemouth bass in Crab Orchard Lake, Illinois, in seven stocked and three unstocked stations. Age-0 bass were collected in October, and age-1 bass were collected in March or April. Standard deviations are in parentheses. Stocked bass were fed one of three diet types: minnows, pellets, or pellets followed by minnows.

	Stocked stations (n = 7)			Unstocked stations (n = 3)			All stations
Year-class	Wild bass	Stocked bass	Total bass	Wild bass	Stocked bass	Total bass	Total bass
				Age-0			
1993	41.8	8.8	50.6	29.0	1.7	30.7	44.6
	(21.7)	(5.8)	(22.3)	(11.4)	(1.5)	(12.4)	(21.4)
1994	14.8	4.0	18.8	15.0	1.7	16.7	18.2
	(5.9)	(2.6)	(6.8)	(10.1)	(2.1)	(10.2)	(7.4)
1995	53.8	22.6	76.3	67.3	1.0	68.3	73.9
	(17.3)	(15.0)	(27.2)	(47.4)	(1.7)	(46.5)	(31.5)
1996	27.6	4.1	31.7	20.0	0.0	20.0	28.2
	(19.9)	(3.4)	(20.4)	(3.6)	(0.0)	(3.6)	(17.6)
1998	29.6	6.6	36.2	18.3	0.3	18.7	30.9
	(18.6)	(3.7)	(19.9)	(8.1)	(0.6)	(8.0)	(18.7)
Mean	33.5	9.2	42.7	29.9	0.9	30.9	39.2
	(21.3)	(10.0)	(27.7)	(27.6)	(1.4)	(27.5)	(27.9)
				Age-1			
1993	34.1	3.0	37.1	25.0	0.7	25.7	33.7
	(22.2)	(2.0)	(21.2)	(15.9)	(0.6)	(16.3)	(19.7)
1994	5.8	0.3	6.1	9.6	0.7	10.3	7.3
	(5.8)	(0.5)	(5.6)	(4.0)	(0.6)	(4.5)	(5.4)
1995	16.0	7.0	23.0	7.3	1.3	8.6	18.7
	(5.7)	(5.6)	(4.9)	(6.9)	(1.5)	(8.4)	(8.9)
1996	12.6	2.2	14.7	10.1	0.0	10.1	13.3
	(5.4)	(2.0)	(4.0)	(10.0)	0.0	(10.0)	(6.1)
1998	8.4	2.0	10.4	9.0	0.7	9.7	10.2
	(6.4)	(1.3)	(7.0)	(2.6)	(0.6)	(3.1)	(5.9)
Mean	15.4	2.9	18.3	12.2	0.7	12.9	16.6
	(14.6)	(3.5)	(15.0)	(10.3)	(0.8)	(10.5)	(13.9)

unstocked (CPUE = 12.9) stations when all bass were combined ($p = 0.3860$) or when only wild bass CPUE's of stocked (CPUE = 15.4) and unstocked (CPUE = 12.2) stations (0.7259) were tested.

Contribution to Year-Class

The percent contribution of stocked bass to total collected at age-0 from all 10 sampling stations (stocked and unstocked) ranged from 14.6 percent (1993) to 21.2 percent (1995) and averaged 16.0 percent (Table 3). Over the five-year period, minnow-reared bass averaged 9.3 percent of the total age-0 bass collected, and bass raised on either pellets or the pellet/minnow combined diet averaged 6.6 percent of the total year-class. Examination of 1,214 age-0 bass collected only from stocked stations increased the mean contribution of stocked bass to 19.8 percent. Percent contribution averaged higher for minnow-reared (12.0%) than pellet-reared bass (7.8%).

The percent contribution of stocked bass to total bass collected at age-1 when all 10 sampling stations were sampled ranged from 6.0 percent (1995) to 27.8 percent (1996) and averaged 13.8 percent (Table 3). Minnow-reared bass averaged 9.7 percent and pellet-reared bass averaged 4.1 percent of all the age-1 bass sampled. The spring samples of age-1 stocked bass collected from only stocked stations averaged 15.9 percent of the total collected. Minnow-reared bass averaged 11.0 percent of the total sampled, and pellet-reared bass averaged 5.0 percent. In 1996, USFWS and IDNR biologists collected 60 age-2 bass and 13.8 percent were stocked.

At age-0 there was no significant statistical relationship between percent contribution of stocked bass and year-class strength determined by

Table 3. Percent contribution to year-class of wild and stocked largemouth bass in Crab Orchard Lake, IllinoisThe stocked bass were reared on diets of minnows, pellets, or a combination of pellets followed by 14 days of minnows prior to stocking in 1994 and 1995. Total number of bass collected is in parentheses. Relative survivals (RS) represent comparison of survival as number of minnow-reared to pellet-reared bass collected.

Year-class	All ten stations (%)				Seven stocked stations (%)			Three unstocked stations (%)		
	Wild	Minnow	Pellet	RS	Wild	Minnow	Pellet	Wild	Minnow	Pellet
					Age-0 (fall)					
1993	85.4	8.1	6.4	1.3	83.2	9.3	7.5	94.6	4.3	1.1
	(399)	(38)	(30)	(68)	(312)	(35)	(28)	(87)	(4)	(1)
1994	81.1	5.6	13.3*	0.4[a]	79	7.6	13.3*	86.8		13.2*
	(116)	(8)	(19)	(27)	(83)	(8)	(14)	(33)		(5)
1995	78.8	9.7	11.5*	0.8	71.4	13	15.7*	97.9	1.4	0.7*
	(405)	(50)	(59)	(109)	(264)	(48)	(58)	(141)	(2)	(1)
1996	90.2	8.7	1.1	7.6[a]	87	11.5	1.5	100		
	(238)	(23)	(3)	(26)	(174)	(23)	(3)	(64)		
1998	84.7	14.5	0.9	16.2[a]	80.4	18.4	1.1	98.2	1.8	
	(199)	(34)	(2)	(36)	(144)	(33)	(2)	(55)	(1)	
Mean	84.0	9.3	6.6	5.3	80.2	12.0	7.8	95.5	1.5	3.0
Total	(1,357)	(153)	(113)	(268)	(977)	(147)	(105)	(380)	(7)	(7)
					Age-1 (spring)					
1993	92.9	5	2.1	2.4[a]	91.6	6.1	2.7	97.4	2.6	
	(316)	(17)	(7)	(24)	(241)	(16)	(7)	(75)	(2)	
1994	94.0	6.0	0.0*	μ	95.0	5.0	0*	92.9	7.1	*
	(63)	(4)		(4)	(37)	(2)		(26)	(2)	
1995	72.2	16.7	11.1*	1.5[a]	70.3	18.0	11.6*	84.6	7.7	7.7*
	(143)	(33)	(22)	(55)	(121)	(31)	(20)	(22)	(2)	(2)
1996	89.1	8	2.9	3.2[a]	85.3	10.8	3.9	100		
	(122)	(11)	(4)	(15)	(87)	(11)	(4)	(35)		
1998	84.2	12.9	3	4.1[a]	80.6	15.3	4.2	93.1	6.9	
	(85)	(13)	(3)	(16)	(58)	(11)	(3)	(27)	(2)	
Mean	86.2	9.7	4.1	2.8	84.1	11.0	5.0	93.6	4.9	1.5
Total	(729)	(78)	(37)	(114)	(544)	(71)	(35)	(185)	(8)	(2)

*Fingerling largemouth bass were reared in ponds on a prepared diet until 10–14 days prior to stocking when they were offered live minnows as forage.

[a]Relative survivals with a superscript are significant at $p = 0.05$.

electrofishing CPUE if all stations (stocked and unstocked) were used in the model (p = 0.5195) or when only stocked stations were used in the analysis (p = 0.5946). There was also no significant statistical relationship between percent contribution and year-class strength at age-1 for all stations (p = 0.9852) and only stocked stations (p = 0.4330).

Relative Survival

Relative survival (RS) of age-0 stocked bass collected during the three years when pellet-reared bass were fed only pellets, favored minnow-reared bass by a margin ranging from 1.3:1–16.2:1 over the pellet-reared bass (Table 3). The RS's were statistically significant (p = 0.05) in each year except 1993. Relative survival from two years of the study, when bass were fed the combined diet, favored bass fed the combined diet over minnow-reared bass by 2.4:1 (1994) and 1.2:1 (1995). Only the 1994 RS was statistically significant.

In all five years, relative survival of bass collected in the spring at age-1 favored minnow-reared bass (Table 3). In spring 1995, four minnow-reared bass were the only stocked fish collected; otherwise, all RS's for age-1 bass were statistically significant.

Nine age-2 stocked bass were collected by FWS in fall 1996. Five were minnow-reared and four were fed the combined diet. The RS of 1.23:1 favored survival of minnow-reared bass, but was not statistically significant.

Movement

Areas where stocked bass were collected indicated limited movement of age-0 bass from the seven stocked stations to the three unstocked stations. The stocked bass were collected in numbers relative to the distance of the unstocked stations to stocked stations. If the bass were to move pelagically, Station 9 (Figure 1) was located closest to any stocked station (0.9 km) and 11 of the 14 age-0 stocked bass were collected there during the five-year study. Station 10 was furthest (2.0 km) from any stocked station. No age-0 stocked bass were collected from Station 10 during the study, and six age-1 stocked bass were collected. Station 8 was 1.5 km from any stocked stations. Only three age-0, two age-1, and two age-2 stocked bass were collected at this site.

Discussion

Electrofishing samples from the seven stocked and three nonstocked stations indicate that bass stocked at densities of 3.5–4.9 per ha (1.4–2.0/a) averaged 16.0 percent of the age-0, 13.8 percent of age-1 and 13.8 percent of age-2 year-classes. Stocked bass contributed a higher percentage to the year-classes when electrofishing samples only from the stocked stations were analyzed. On average, 19.8 percent of the age-0 and 15.9 percent of the age-1 bass were stocked. The difference is especially evident when the contribution of stocked fish to the year-class at the three nonstocked stations was considered. Only 4.5 percent of the age-0 and 6.4 percent of the age-1 bass collected at these stations were stocked fish.

We compared CPUE of age-1 wild bass to percent contribution of stocked bass to determine the effect of natural recruitment on stocked bass contribution (Figure 2). Stocked bass percent contributions tended to increase when wild bass CPUE ranged from a very low CPUE (six per hour) through a CPUE of about 29 per hour; however, percent contribution was again low (8%) when recruitment of wild bass was highest during this study (38 per hour). Thus, our limited data indicated that stocking at 3.5–4.9 bass per ha contributed the least to year-class strength in years when natural recruitment was low (less than 10 bass per hour) or high (greater than 37 bass per hour). But, stocking contributed from 14 percent to 29 percent when age-1 wild bass CPUE was from 7 to 17 per hour.

At age-1, there were no significant differences in CPUE between the stocked and unstocked stations for wild bass—possibly because of the combination of movement over time of stocked bass into unstocked stations and wild bass into stocked stations. Contribution of stocked bass dropped from 16.0 percent to 13.8 percent at all stations from age-0 to age-1, but did not drop at all from age-1 to age-2 (13.8%). Increasing percent contributions from age-0 to age-1 in the unstocked stations provide additional evidence that movement was at least partly responsible for the decrease in stocked bass contribution to year-class strength in the stocked stations.

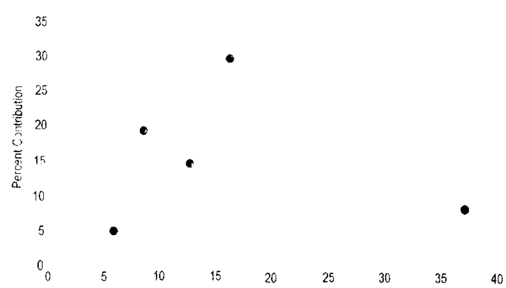

Figure 2. Percent contribution of age-1 stocked bass to catch per hour of age-1 wild bass in Crab Orchard Lake, Illinois.

Distances that age-0 stocked bass were recovered from stocked stations in our study depended on the probable routes—pelagic versus shoreline (Figure 1). No age-0 stocked bass were collected from Station 10—the station located furthest from any stocked stations (2.0 km pelagically; 4.0 km by shoreline). Because no markers were used to distinguish among stations stocked, all we can report is that some age-0 bass moved at least 0.9–1.5 km to reach the nearest unstocked station (Station 8). Age-0 stocked bass would have moved at least 0.9–2.5 km to reach Station 9. This result agrees with the findings Copeland and Noble (1994) that there is limited movement of age-0 bass in a lake.

Krieger (1981) postulated that failure of stocked bass to increase catch rates in Chatfield Reservoir, Colorado was caused by displacement of wild bass. In our study there was a significantly higher mean CPUE of all age-0 bass from the seven stocked stations (42.7) than the three unstocked stations (30.9). There was no significant difference in mean CPUE of wild bass between the stocked (33.5) and unstocked stations (29.9). Thus, at the stocking densities used during this study, based on these CPUE differences, stocked bass contributed to age-0 bass numbers over and above the wild production and were probably not displacing the wild bass in a completely compensatory manner. Buynak and Mitchell (1999) also postulated that stocking 10.7–11.4 cm long sub-adult largemouth bass into Taylorville Lake, Kentucky, at densities from 4.0 to 11.2 fish per ha for five years did not have a detectable negative impact on year-class strength or abundance of wild largemouth bass.

Results of comparisons of survival to age-0 between the minnow-reared and pellet-reared bass were mixed. Minnow-reared bass had higher relative survival rates to age-0 than pellet-reared bass in all three years that they were stocked, and the difference in RS were statistically significant in two of the three years. Although bass reared on pellets and fed minnows for 14 days prior to stocking had higher relative survival rates to age-0 than minnow-reared bass in both years they were stocked, the differences were only statistically significant in 1994.

Except for 1998, the pellet-reared bass were smaller (7–19 mm in four years; 42 mm in 1996) at stocking than the minnow-reared bass. This could have increased their vulnerability to predation (Boxrucker 1982; Fullerton et al. 2000). Alternatively, in all cases the pellet-reared bass were stocked later (5–34 days) than the minnow-reared fish. This should have favored their relative survival to age-0 (fall), because they would have been vulnerable to predation for a shorter period of time than the minnow-reared bass.

It may be that higher mortality of the age-0 pellet-reared bass was due to behavioral anomalies, including water column positioning, prey selection, and predator pressure. Predation due to the first two of these anomalies might be reduced for bass offered minnows prior to stocking. Initially after stocking, pellet-reared bass may instinctively search the water surface for food and be more vulnerable to predators. Older largemouth bass are numerous in Crab Orchard Lake, and larger bass prefer prey located higher in the water column (Savino and Stein 1982; Wahl 1995). Stocked bass foraging away from their refuges would be more susceptible to predation. This is especially true since larger bass also prefer to ambush prey at the edge of weed beds and structure (Wanjala et al. 1986; Annett et al. 1996). Werner et al. (1983) reported small bluegill reduced their foraging behavior and stayed in cover to prevent predation from largemouth bass. Similar behavior of age-0 largemouth bass has been shown to reduce growth and energy density (Garvey et al. 1998) and possibly result in increased overwinter mortality (Fullerton et al. 2000).

In this study, it appeared that overwinter mortality was higher for pellet-reared bass and those fed the combined diet than minnow-reared bass. Relative survival to age-1 significantly favored minnow-reared bass over those fed a prepared diet exclusively or subsequently with minnows in all years. It is, however, unclear if the mortality was size-related. Wild age-0 bass at the time of the fall samples were smaller than the pellet-reared or minnow-fed bass (Table 4). For the minnow-reared bass and those sequentially fed pellets and minnows, this size difference was extenuated by the time the age-1 bass were sampled in the spring. Wild and pellet-reared bass were not significantly longer in the spring versus the fall samples ($p > 0.5840$). Minnow-reared and bass sequentially fed pellets and minnows were significantly longer in the spring samples than the fall samples ($p = 0.0001$). Although the increase in length could be size-related mortality, it is likely that there would be mortality associated with size of pellet-reared bass at the same time that there was with minnow-reared bass if there was overwinter mortality. This is especially true since minnow-reared bass in our study were significantly larger than all other groups of bass in the fall samples. Thus, it is possible that more forage was available to the larger bass and growth, not mortality, occurred between the two sample

Table 4. Mean total lengths of stocked and wild largemouth bass collected from Crab Orchard Lake, Illinois at age 0 (fall samples) and age 1 (spring samples). Asterisks in years column indicate pellet-reared bass that were also fed minnows for a 14-day period prior to stocking. Total length differences represent length at age 1 minus age 0.

	Age 0			Age 1				
Year	*N*	Total length (mm)	Standard deviation	Year	*N*	Total length (mm)	Standard deviation	Total length differences (mm)
Wild bass								
1993	399	112	21	1994	314	113	23	1
1994	116	121	12	1995	63	127	15	6
1995	399	121	18	1996	165	130	26	9
1996	238	125	20	1997	122	125	16	0
1998	199	146	15	1999	85	154	16	8
Mean		123	21	Mean		124	25	1
Minnow-fed bass								
1993	46	193	25	1994	19	201	31	8
1994	8	170	21	1995	4	173	37	3
1995	50	170	24	1996	33	195	24	25
1996	19	137	40	1997	8	157	29	20
1998	34	160	13	1999	13	174	19	13
Mean		171	30	Mean		188	29	17
Pellet-fed bass								
1993	22	170	32	1994	5	184	27	14
1994*	19	123	16	1995*	0			
1995*	58	135	26	1996*	22	157	26	21
1996	7	123	37	1997	7	128	28	6
1998	2	171	14	1999	3	167	24	–4
Mean		160	38	Mean	155	36		–5
Mean*		132	24	Mean*	157	26		25

periods. Diet deficiencies have been implicated for higher overwinter mortality of bass fed prepared diets, but we did not investigate the condition of bass collected in this study.

Reduced contribution of all stocked bass over time was, at least in part, due to movement. Some stocked bass moved into areas not sampled, and wild bass were likely moving into and away from stocked stations as the bass aged. Increased movement of both stocked and wild bass would cause a continual decrease in the contribution of stocked bass until stocked and natural bass would be totally desegregated when considering specific stations. Copeland and Noble (1994) reported that 83–90 percent of tagged age-0 bass and 56–67 percent of tagged age-1 bass in B. Everett Jordan Lake, North Carolina, were recaptured within 58 m of their release. They also reported that a small proportion of bass from both age classes had moved well over 2,000 m. Noble et al. (1994; citing Jackson et al. 1993) reported that a similar study in the same lake that compared movement of stocked and wild bass tagged as fingerlings revealed that stocked bass movement was slightly more extensive than wild bass. In this study, it appeared that desegregation among our stations may have occurred by age-2, since percent contribution of stocked bass was the same at age-1 and age-2.

In conclusion, stocked bass contributed to the population in Crab Orchard Lake, and the contribution was dependent upon age at sampling and diets that stocked bass were fed prior to stocking. In large reservoirs such as Crab Orchard Lake, contribution of age-0 stocked bass to natural recruitment in the entire lake will not be fully realized at specific sites for at least one year to allow for movement and desegregation of stocked and natural bass. Stocked bass fed minnows survived at a higher rate through age-1 than bass fed a sequential diet of pellets followed by minnows or fed only pellets. Stocked largemouth bass fed the combined diet survived better than stocked bass fed pellets. Relative survival calculations for age-0 through age-2 stocked bass indicated that, unless the cost to raise advanced largemouth bass on a minnow diet is approximately three times the cost of using pellets, bass stocked as advanced fingerlings should be raised on a minnow (natural) diet prior to stocking. Further studies are needed to examine the behavior of stocked bass and to determine the most appropriate methods of identifying optimal stocking areas and stocking densities.

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