8-2002

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Published in *North American Journal of Fisheries Management*, Vol. 22, Issue 3 (August 2002) at doi: 10.1577/1548-8675(2002)022<0995:RSOTSO>2.0.CO;2

North American Journal of Fisheries Management 22:995–1006, 2002

Relative Survival of Three Sizes of Walleyes Stocked into Illinois Lakes

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Abstract.—The ability to differentially batch-mark several size-groups of fish stocked concurrently in lakes or rivers makes it possible to compare survival within a single year. We evaluated stocking of walleyes *Stizostedion vitreum* in Illinois during 1991–1996. Ten lakes were stocked with combinations of two or three sizes of walleyes, including fry and small (50-mm) and large (100-mm) fingerlings. This permitted a total of 73 lake-year comparisons: fry versus large fingerlings (23 lake-years), fry versus small fingerlings (29 lake-years), and small versus large fingerlings (21 lake-years). Stocked fish were differentially marked with oxytetracycline or fin clips. Electrofishing catch per effort, relative survival, and population estimates were used in conjunction with production costs to compare size-based contributions and survival. Survival generally favored fingerlings over fry (70% of lake-years for small fingerlings, 67% for large fingerlings) and small fingerlings over large fingerlings (72% of lake-years). In some lake-years, fry and large fingerlings had the highest survival. Fish stocked as fry and small fingerlings were larger than large fingerlings beginning their third year of growth. Based on our results, stocking small fingerlings will generally be more cost-effective than stocking fry or large fingerlings. However, if fry or large fingerlings are available, stocking assessment on specific lakes may allow biologists to determine particular lakes where alternative sizes could be economically feasible.

More than 1.17 billion walleyes *Stizostedion vitreum* are stocked into North American waters each year because of their popularity as a sport fish and the ease by which they are propagated (Heidinger 1999). Many stockings are conducted annually despite very limited or no contribution to the fisheries. Stocking multiple sizes of walleyes in a single lake or river is one method used to optimize stocking success. During recent decades, numerous studies have attempted to compare survival of stocked fry and different sizes of fingerlings (Ellison and Franzin 1992). Until recently, the results of most studies were confounded by the inability to positively identify individuals from the stocked size-groups. Thus, stock assessments have been made from inferences based on total lengths in the first fall after stocking, by counting daily rings to affirm known-aged hatchery fish (Fielder 1992), by assuming limited natural reproduction following stocking (McWilliams and Larscheid 1992; Mitzner 1992), and by stocking fry and fingerlings in alternate years (Carlander et al. 1960; Forney 1975).

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Received October 2, 2000; accepted September 8, 2001

Genetic and chemical marking techniques have greatly improved stocking assessments during recent years (Murphy et al. 1983; Jennings and Philipp 1992; Koppelman et al. 1992; Brooks et al. 1994; Heidinger and Brooks 1998). Although previous studies indicated that stocking larger walleyes may be preferable to smaller fish (Heidinger et al. 1987; Santucci and Wahl 1993), other results have not always favored stocking advanced-sized walleyes (Kraai et al. 1985; Jennings and Philipp 1992; Koppelman et al. 1992).

Given the many factors that could affect stocked walleye survival, without many years of assessments, it is nearly impossible to predict the stocking success of multiple sizes of walleyes when single sizes of walleyes are stocked each year. Differences such as water temperatures, dissolved oxygen, forage abundance, predatory pressure, and water levels are just a few variables that fluctuate among years and lakes. Fluctuating annual conditions may profoundly affect survival of stocked walleyes and thereby confound comparisons of walleyes stocked at various sizes each year. Stocking multiple sizes of walleyes within the same year eliminates effects of environmental and biological

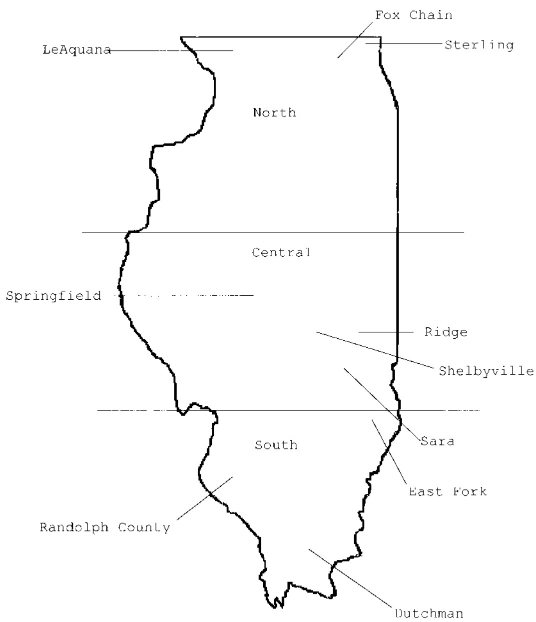

FIGURE 1.—Locations of the 10 Illinois study lakes used to compare relative survival among walleyes stocked as fry, small fingerlings, and large fingerlings during 1991–1996. The three geographic regions (south, central, and north) were used to determine the significance of latitude on size-specific survival.

differences that occur from year to year. Evaluation of stocking multiple sizes of marked walleyes in a number of lakes for several years will lead to better generalizations and more appropriate management recommendations.

Our objective was to quantify survival when three sizes of walleyes were stocked concurrently into 10 Illinois lakes during 1991–1996. We compared survival and contribution of sizes after adjusting for initial poststocking mortality (Clapp et al. 1997). We also assessed the effects of growth and latitude of the lakes on size-specific survival. Stocking multiple sizes within a year and lake could increase competition among size-groups for forage and habitat and thereby increase cannibalism. However, in our study lakes, walleyes had essentially no natural recruitment, and standing stocks were relatively low. Therefore, effects of competition on size-specific survival were considered negligible; yearly fluctuations of biotic and abiotic factors within and among the study lakes were of greater importance for survival.

Study Areas

The 10 lakes used for walleye stocking were located throughout Illinois (Figure 1). Natural recruitment was nonexistent in all lakes except Lake Shelbyville, where limited natural recruitment occurred during 2 years of the study. Recruitment was not considered a significant influence on stocking success. Because the characteristics of Lake Shelbyville appeared to be optimal for walleye survival, it was included in the study despite limited walleye reproduction. Surface areas of the lakes ranged from 6 to 4,455 ha, average depths were 4–8 m, and maximum depths were 8–24 m (Table 1).

Methods

Walleye fry were produced primarily from fertilized eggs procured from states other than Illinois and stocked at 3–5 d posthatch. Fingerlings were reared on invertebrates in Illinois hatchery ponds until they were either stocked at approximately 50 mm (total length) or moved to indoor raceways and reared to approximately 100 mm. Intensively reared walleyes were fed sequential sizes of BioDry (BIO-OREGON, Inc., Warrenton, Oregon) feed until 1 week before stocking; minnows were provided the final week (Wahl et al. 1995). Walleye fingerlings were stocked from shore, and fry were stocked away from the shore. Stocking dates and densities were dependent on availability of fish of desired size, zooplankton abundance in the rearing ponds, and growth rates. In some cases, timing of stocking fry or small fingerlings was adjusted to coincide with forage abundance, but forage abundance was not significantly correlated with the number of stocked walleyes collected during this study (Hoxmeier et al. 1999). Ranges of stocking dates were 4 April to 1 June for fry, 18 May to 11 July for small fingerlings, and 14 July to 31 August for large fingerlings.

All walleye fry and small fingerlings (34–69 mm) were marked by immersion in 500 mg/L oxytetracycline (OTC) for 6 h before stocking (Brooks et al. 1994). Walleyes marked as fry had fluorescent marks located around the otolith core (nucleus) and were distinguishable from walleyes marked as fingerlings, which had marks located at approximately 30–60 daily rings beyond the nucleus. Large fingerlings (95–110 mm) were marked with paired fin clips. Walleyes were stocked in lakes at latitudes ranging from 37°30′00″N to 42°28′26″N but, for statistical comparisons, were divided into southern, central, and northern areas (range, approximately 300 mi; Figure 1). Not all sizes of walleyes were always stocked in the same year in each lake (Table 1). Stocking densities varied according to availability,

TABLE 1.—Walleye stocking and relative survival for 10 Illinois lakes and reservoirs during 1991–1996. Walleyes were stocked as fry, at approximately 50 mm total length (small) or 100 mm total length (large). Numbers stocked were adjusted for initial stocking mortality.

Lake (ha)	Size stocked	Number stocked/ha	Number of lake-years: Stocked	Number of lake-years: With recoveries	Number recovered	Relative survival[a]: *N*	Relative survival[a]: Mean	Relative survival[a]: Range	Number lake-years relative survival favors[b]
				Large fingerlings versus fry					
Sterling (53)	Fry	1,396–2,471	4	4	1–53				2
	Large	35–68	4	4	21–107	4	728:1	43–2,390:1	2
LeAquana (16)	Fry	2,471–2,713	5	3	0–7				0
	Large	62–91	5	4	0–145	3	410:1	239–739:1	4
Springfield (1,715)	Fry	2,595	1	1	1				0
	Large	4	1	1	18	1	5,722:1		1
Ridge (6)	Fry	3,333–7,156	5	2	0–30				2
	Large	67–120	5	2	0–10	2	21:1	2–39:1	0
Shelbyville (4,455)	Fry	1,162–2,733	3	3	2–10				0
	Large	2–6	3	3	6–60	3	2,441:1	1,730–3,102:1	3
Randolph (26)	Fry	2,500–5,000	5	4	0–6				2
	Large	62–127	5	1	0–4	1	60:1		0
Total	Fry		23	17		14			6
	Large		23	15					10
				Small fingerlings versus fry					
Sterling (53)	Fry	1,396–2,471	4	4	1–53				1
	Small	51–90	4	4	12–70	4	186:1	14–389:1	3
LeAquana (16)	Fry	2,471–2,713	5	3	0–7				2
	Small	39–109	5	5	3–43	3	50:1	26–97:1	2
Fox Chain (2,663)	Fry	2,328–2,471	2	1	0–23				1
	Small	15–98	2	1	0–2	1	13:1		0
Ridge (6)	Fry	3,333–7,156	4	2	0–30				2
	Small	89–143	4	2	0–8	2	6:1	4–9:1	0
Shelbyville (4,455)	Fry	941–2,733	6	6	2–110				0
	Small	2–29	6	6	2–122	5	1,045:1	133–1,846:1	5
Sara (237)	Fry	2,198	1	1	15				0
	Small	86	1	1	31	1	45:1		1
East Fork (379)	Fry	2,546	1	1	4				0
	Small	99	1	1	115	1	706:1		1
Randolph (26)	Fry	2,500	5	4	0–6				1
	Small	100	5	5	5–33	4	172:1	21–274:1	4
Dutchman's (53)	Fry	2,226	1	0	0				0
	Small	111	1	1	2				0
Total	Fry		29	25		21			7
	Small		29	26					16
				Large fingerlings versus small fingerlings					
Sterling (53)	Small	35–68	4	4	12–70	0			3
	Large	51–90	4	4	21–107	2	6:1	3–9:1	1
LeAquana (16)	Small	62–91	5	5	3–43	1	15:1		2
	Large	39–109	5	4	0–145	3	14:1	2–29:1	2
Ridge (6)	Small	67–81	4	2	0–8	0			1
	Large	89–143	4	2	0–10	1	11:1		1
Shelbyville (4,455)	Small	2–6	3	3	2–110	0			2
	Large	4–13	3	3	6–60	1	6:1		1
Randolph (26)	Small	62–127	5	5	5–33	1	3:1		5
	Large	100	5	1	0–4	0			0
Total	Small		21	19		2			13
	Large		21	14		7			5

[a] Relative survival was calculated only when at least five walleyes and both sizes were recovered.

[b] Relative survival greater than 117:1 (large fingerlings:fry), 42:1 (small fingerlings:fry), or 3:1 (large:small fingerlings) favored the larger walleyes stocked when at least five total fish were recovered. If five or more of only one size was recovered, then relative survival favored the size recovered.

lake size, and stocking mortality. Numbers stocked were adjusted for stocking mortality estimates (0–100% for all sizes stocked; Clapp et al. 1997; Hoxmeier et al. 1999). Subsamples (≥100) of stocked walleye fry were placed in three plastic tubs (133 L) for 24 h. Subsamples of fingerlings (≥25) were placed in floating cages (3.2-mm mesh) for 48 h after stocking. Two types of cages were used throughout the study. The first was 1.5 m deep × 0.75 m in diameter, and the second was 4 m deep × 1 m diameter. Mortality estimates did not differ significantly between cage types (Clapp et al. 1997). Walleye subsamples of at least 25 fish were measured to the nearest 1.0 mm at the time of stocking and during fall collections. After adjustments for mortality estimates, average density estimates were 2,448 fry per hectare (range, 671–7,143), 79 small fingerlings per hectare (2–125), and 51 large fingerlings per hectare (1–118). The affects of stocking densities on numbers collected was assessed with three-way analysis of variance (ANOVA; $\alpha = 0.05$). The model included number collected as the dependent variable. The independent variables included number stocked per hectare, lake, and year.

We collected walleyes twice monthly in each lake during fall (September–December) and from that data computed catch per unit effort (CPUE) and population estimates. Walleyes were collected by AC 3-phase electrofishing at night and with trap nets (4 × 5 ft) and gill nets (100 m long, 1.27-cm-bar mesh). At the end of each year, we analyzed a subsample of unclipped fish for OTC marks. The proportion of fry and small fingerlings was then compared with catch rates of previously captured, unclipped fish. The adjusted numbers were used for computing CPUE, population estimates, and relative survival. For relative survival, we did not consider the effects of water temperature on susceptibility of walleyes to methods of collection. To increase numbers of walleyes used for relative survival estimates, age-0 through age-3 walleyes were collected during the final year of the study. Contributions were determined by combining fish from respective age and size cohorts.

Ages of all walleyes were estimated from otoliths (Heidinger and Clodfelter 1987) or by distinctive paired fin clips (large fingerlings). Relative survival (RS) between walleyes stocked at different sizes was determined by comparing ratios of the number of walleyes stocked to those recaptured by year-class (Heidinger et al. 1987; Heidinger and Brooks 1998), as follows:

$$\mathrm{RS} = (n_f/N_f)/(n_e/N_e),$$

where n_f = number of walleyes stocked at size f and later recaptured, N_f = number of walleyes stocked at size f, n_e = number of walleyes stocked at size e and later recaptured, and N_e = number of walleyes stocked at size e. Relative survival was calculated when at least five walleyes were recovered from the stocking and at least one walleye was collected from each size-class. The statistical significance of each relative survival estimate was based on the probability that the stocking percentage of a size-group ($P_o = N_f$/total stocked) was equal to the percent returned ($\hat{P} = n_f$/total returned) of the same size-group (Zar 1984:384–385). The binomial nature of the survival comparisons allowed us to determine 95% confidence limits ($\alpha = 0.05$). Statistical significance was confirmed if P was outside the 95% confidence limit for P_o. Each single year of stocking one lake is referred to as one lake-year.

Relative survival was used as the index of survival because population estimates could not always be determined. In addition, fall sample sizes of age-0 walleyes could be augmented by including walleyes older than age 0 collected in subsequent samples. Pairwise comparisons of RS included (1) large fingerlings versus fry, (2) small fingerlings versus fry, and (3) large versus small fingerlings. The RS index was also used in conjunction with production costs to determine a cost–benefit for each of the paired stocking comparisons.

Production costs increase as the size at stocking increases because of extended periods of feeding, maintenance, and handling (Heidinger 1999). Additionally, because of limited pond space and increased mortality, fewer walleyes can be reared to successively larger sizes. Thus, more fry than fingerlings can be produced and stocked, as can more small fingerlings than advanced fingerlings. To adjust for the costs associated with producing each of the three sizes stocked, significance of stocking one size over the other was determined by adjusting relative survival to reflect differences in production costs. We used an average cost of US$8.00 to produce 1,000 fry or $0.008 per fry (Gunterson et al. 1996) and $0.34 per 50-mm fingerling (American Fisheries Society 1992). At these prices, it costs 42 times more to produce a small fingerling than to produce fry. For fingerling stocking to be more successful than fry, RS must favor the fingerlings by a ratio at least 42:1 over fry. If small fingerlings survived at a lower ratio, then stocking would favor fry over the small fingerlings. Similarly, it costs $0.94 to produce a single large fingerling. Thus, large fingerling survival must be 117 times that of fry, and three times that of small fingerlings. Stocking larger, more expensive fingerlings over smaller fingerlings was considered successful only when RS was sufficient to negate differences in production costs.

To determine whether latitude affected relative survival, the lakes were categorized into three general locations: southern, central, or northern Illinois. A two by three contingency table was used in to determine whether survival favored one size over another among the three areas. The contingency table divided larger sizes versus smaller and the three geographic areas previously described. Survival was considered to favor the larger size stocked when relative survivals were significant or when only one size was collected survival favored that size. We hypothesized that size-specific survival was not due to location. Statistical significance for chi-square analysis was set at $\alpha = 0.05$.

We also assessed fall electrofishing CPUE of age-0 walleyes and made population estimates in lake-years when all three sizes were stocked concurrently. We used ANOVA to compare CPUE across all three size-classes of stocked walleyes. We used Tukey post hoc analyses to determine significance among the three size-groups, when appropriate. To account for stocking rate variability, we adjusted CPUE by dividing by the number of fish stocked and used ANOVA to compare CPUEs across all sizes of walleyes stocked. The adjusted CPUE was rescaled by multiplying by 1,000 (CPUE/1,000 fish stocked). Log-transformation was used to normalize the data before analysis. Statistical significance was determined at $\alpha = 0.05$. Data for CPUE was not always collected; thus, relative survival was also used. In addition, population estimates for each size-group were determined by using the Schnabel mark–recapture procedure. For walleyes not stocked as large fingerlings, stocking size was determined by multiplying the percentage of walleyes collected as fry or small fingerlings (during night electrofishing in a given lake and year) and the number of fish collected during the previous sampling dates.

Results

The number of walleyes collected from each size-group was not affected by stocking densities for fry ($F = 1.58$; df = 20, 11; $P = 0.2206$), small fingerlings ($F = 4.14$; df = 18, 11; $P = 0.0666$), or large fingerlings ($F = 1.59$; df = 15, 8; $P = 0.2587$). Fry, small fingerlings, and large fingerlings were stocked in the same lake in 21 lake-years. Since no walleyes were collected in 3 lake-years, data were available for analysis from 18 lake-years. The CPUE data were not collected in 1 lake-year; thus, data were available for analysis from 17 lake-years. Across all lakes and years, CPUE of age-0 walleyes was not significantly related to size ($F = 2.69$; df = 2, 51; $P = 0.0800$). Catch rates of age-0 walleyes ranged from 0.85 fish/h for fry to 3.09 fish/h for large fingerlings (Figure 2). When CPUE was adjusted for stocking density, CPUE differed significantly among size-groups ($F = 5.11$; df = 2, 51; $P = 0.0090$), large fingerlings contributing more than fry (Figure 2; Tukey test, $P < 0.05$). The CPUE of small fingerlings was not significantly different from the CPUE of fry or large fingerlings.

Fall population estimates of age-0 walleyes were obtained for 24 stockings in 11 lake-years (Table 2). On average, 9.2% of large fingerlings, 2.9% of small fingerlings, and 0.07% of fry survived through their first fall.

Relative survival analyses for each pairwise size comparison allowed us to include lakes where two size-groups were stocked and to include samples collected beyond age 0; this resulted in an additional 10 lake-years of stocking. Fry were stocked in 32 lake-years and none were collected in 7 (22%); large fingerlings were stocked in 24 lake-years and none were collected in 9 (38%); and small fingerlings were stocked in 30 lake-years and none were collected in 4 (13%).

Large Fingerlings versus Fry

Six lakes were stocked, which provided a total of 23 lake-years for comparing relative survival of large fingerlings versus fry (Table 1). Fewer than five walleyes were recovered in 7 lake-years. Thus, 16 of 23 lake-years had sufficient walleye survival to warrant further analysis. Relative survival favored large fingerlings in 15 of 16 lake-years. Only one of the two sizes of stocked walleyes was collected in 2 of the 16 lake-years: (1) 1992 large fingerlings stocked in LeAquana (29 walleyes) and (2) 1993 fry stocked in Randolph County Lake (6 walleyes). In those cases, relative survival was believed to favor the size collected. Relative survival determined for the remaining 13 of 14 lake-years ranged from 39:1 to 5,722:1 (large fingerlings:fry), and large fingerlings always demonstrated significantly higher survival than fry when both sizes were recovered in those years (Table 3). Relative survival

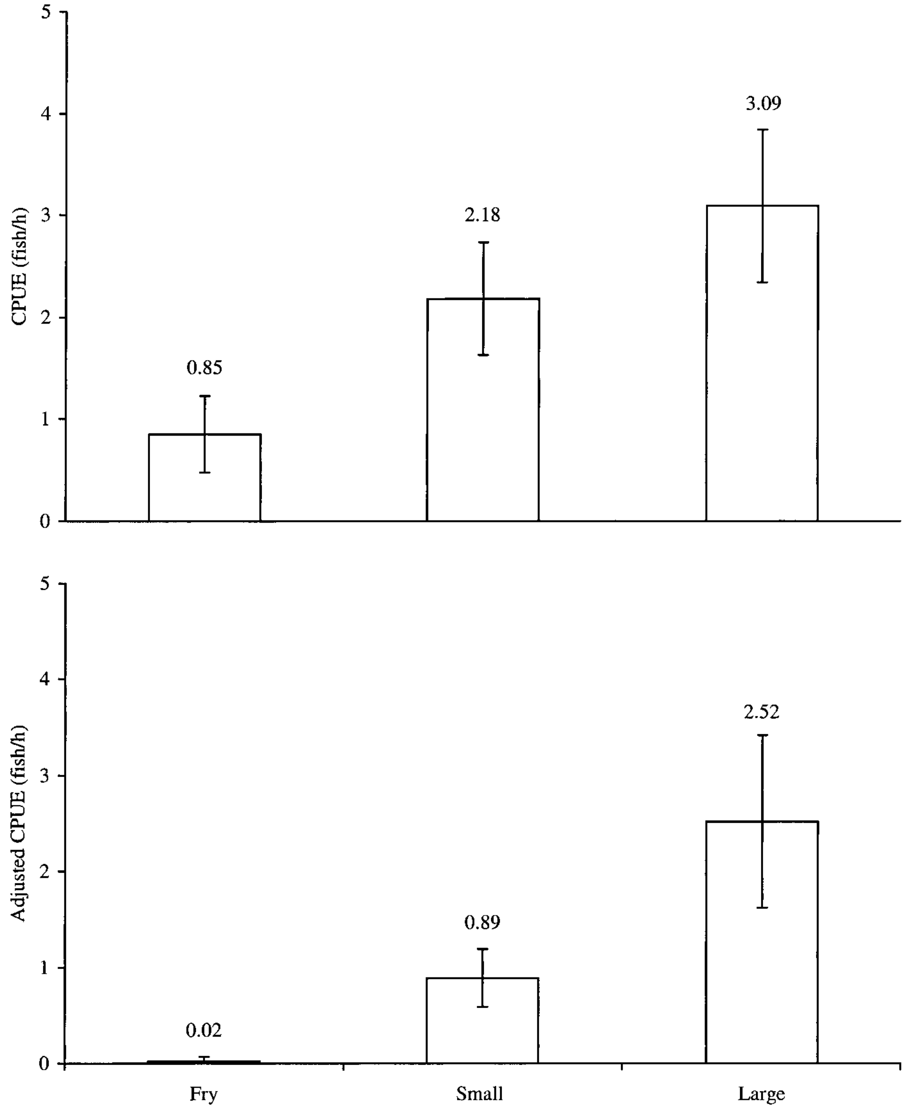

FIGURE 2.—Catch per unit effort (CPUE) and adjusted CPUE of walleyes stocked into Illinois reservoirs as fry (stocked within 5 d posthatch), small fingerlings (50 mm total length), or large fingerlings (100 mm) during 1991–1996. Estimates of CPUE are based on night electrofishing during the first fall after stocking. Adjusted CPUE is calculated by dividing CPUE by the number of fish stocked and multiplying by 1,000. Vertical lines represent standard errors. Data are from lakes where all three size-classes were stocked.

was insignificant between large fingerlings and fry in 1 lake-year.

When production costs were considered, results favored stocking large fingerlings (relative survival > 117:1) in 10 of 16 (63%) lake-years (Table 1). Relative survival was variable among lakes and years but was fairly consistent within lakes among years. Survival favored large fingerlings for all 8 lake-years in three lakes: Shelbyville, LeAquana, and Springfield. Conversely, relative survival favored fry stocking in Ridge Lake and Randolph County Lake in all 4 lake-years. In Sterling Lake, survival varied with size at stocking because it favored fry in 2 lake-years and fingerlings in 2 lake-years.

Small Fingerlings versus Fry

Walleyes were stocked to compare survival of fry and small fingerlings among 29 lake-years in nine lakes. Fewer than five walleyes were collected

TABLE 2.—Population estimates, 95% confidence intervals (CIs), and percent survival of three size-classes of walleyes stocked in Illinois reservoirs during 1992–1996. Population estimates were conducted in the fall using Schnabel mark–recapture methods. Ridge Lake estimates are based on numbers collected after the lake was drained.

Lake	Year	Population estimate (95% CI)			Survival (%)		
		Fry	Small	Large	Fry	Small	Large
LeAquana	1992		102 (60–256)	79 (39–394)		6.4	7.8
	1993			245 (172–398)			22.5
	1994			249 (122–1,245)			25.1
	1996	3 (1–87)	48 (26–132)	56 (28–281)	0.01	2.7	4.9
Ridge			0				
	1994	3	22	8	0.01	0	1.9
Shelbyville	1995	85	503 (346–806)		0.2	2.9	
Sterling	1996	516 (396–923)	193 (79–1,110)		0.01	0.4	
	1993	170 (56–1,087)	84 (1–4,779)	159 (102–302)	0.1	6.5	4.4
	1994	251 (56–5,946)		88 (52–221)	0.2	1.8	2.7
	1995			289 (154–920)			15.6
	1996	5 (1–113)	76 (43–184)	31 (15–156)	0.01	2.8	1.7
Combined					0.08	2.9	9.6

in 6 lake-years, and stockings in those years were excluded from further analysis. Small fingerlings were collected exclusively for 2 lake-years of stocking in Lake LeAquana in 1992 (43 walleyes) and Randolph County Lake in 1995 (33 walleyes). When both sizes were collected, relative survival ranged from 4:1 to 1,846:1 (fingerlings:fry) over 21 lake-years (Table 1). Relative survivals significantly favored small fingerlings in 19 of 23 lake-years (Table 3).

When production costs were considered, results favored stocking small fingerlings (relative survival > 42:1) in 16 of 23 (70%) lake-years (Table 1). Survival results within lakes favored fry exclusively in two lakes (Ridge Lake and Fox Chain of Lakes) for 3 lake-years, and fingerlings exclusively in three lakes (Lake Shelbyville, East Fork Lake, and Lake Sara) for 7 lake-years.

Large Fingerlings versus Small Fingerlings

Five lakes were stocked in 21 lake-years to compare survival between small and large fingerlings (Table 1). Less than five walleyes were collected following three stockings. Survival of the two sizes of stocked fingerlings was variable among years and lakes and within lakes among years. Only small fingerlings were collected in 4 lake-years in Randolph County Lake (22%). Both size-groups were collected in 14 lake-years. When both size-groups were collected, large fingerlings survived significantly better than small fingerlings from 7 of 18 (38%) stockings and small fingerlings survived significantly better than large fingerlings in 2 lake-years (11%). In 5 lake-years (28%), survival of small and large fingerlings was not significantly different (Table 3).

When production costs were considered, results favored stocking small fingerlings (relative survival > 3:1) in 13 of the 18 lake-years (72%). With the exception of Randolph County Lake, where survival favored small fingerlings in all 5 lake-years, mixed results occurred among years within lakes (Table 2).

Latitude

Latitude and the areas where lakes were located did not significantly affect the survival of walleyes stocked as fry versus large fingerlings (χ^2 = 3.8095 [df = 2 for all χ^2 tests], N = 16, P = 0.1489) or small fingerlings (χ^2 = 0.7834, N = 23, P = 0.6759). Relative survival of large versus small fingerlings was also not dependent upon latitude (χ^2 = 5.0610, N = 18, P = 0.0796). However, the small number of lake-years associated with several of the three areas may have biased the results (Table 4). In 5 lake-years, survival never favored large fingerlings over small fingerlings stocked in the southern area (Randolph County Lake). In the central Illinois lakes, survival favored large fingerlings over small fingerlings in 2 of 5 lake-years. In the northern Illinois lakes (Sterling and LeAquana), large fingerlings survived better than small fingerlings in 5 of 8 lake-years.

Production cost comparisons indicated that location (by latitude) was not a factor influencing size-related survival for fry versus large fingerlings (χ^2 = 3.9111, N = 16, P = 0.1415) or small fingerlings (χ^2 = 1.4831, N = 23, P = 0.4764) or for large fingerlings versus small fingerlings (χ^2 = 2.6723, N = 18, P = 0.2629). Small sample sizes may have biased the results (Table 5). However, as with the previous analysis, bias from the small sam-

TABLE 3.—Relative survival and 95% confidence intervals (CIs) of walleyes stocked in Illinois reservoirs from 1991 to 1996. Relative survival favored the larger of the two size-groups being compared unless the value is enclosed in parentheses, which indicates that survival favored the smaller fish. The infinity symbol (∞) indicates that only one stocked size-group was represented. Relative survival was determined after adjusting numbers stocked by stocking mortality. P_o is the percentage of a size-group among all fish captured in subsequent samples. Statistical significance, determined using a two-tailed binomial test (Zar 1984:385), is indicated with an asterisk.

Lake	Year stocked	Relative survival	Confidence interval (95%)	Number collected	P	95% CI for P_o
			Large fingerlings:fry			
LeAquana	1992	∞		29	*	
	1993	739	348–1,883	152	0.9540*	0.0075–0.0678
	1994	253	82–1,260	60	0.9500*	0.0194–0.1687
	1995	0		0		
	1996	239	74–1,230	31	0.9032*	0.0010–0.1793
Randolph County	1992	0		1		
	1993	(∞)		6	*	
	1994	0		1		
	1995	0		0		
	1996	60	11–321	8	0.5000*	0.0000–0.4029
Ridge	1992	0		0		
	1993	0		0		
	1994	0		3		
	1995	2	0–12	31	0.0323	0.0000–0.1421
	1996	39	16–93	25	0.4000*	0.0000–0.1639
Shelbyville	1992	3,102	554–31,416	8	0.7500*	0.0000–0.3716
	1993	2,492	532–15,407	9	0.6667*	0.0000–0.3381
	1995	1,730	879–3,799	70	0.8571*	0.0000–0.0632
Springfield	1995	5,722	903–23,857	19	0.9474*	0.0000–0.1858
Sterling	1993	75	53–107	158	0.6772*	0.0082–0.0659
	1994	43	28–64	110	0.5182*	0.0041–0.0748
	1995	2,390	415–95,752	71	0.9859*	0.0035–0.0987
	1996	404	99–3,557	23	0.9130*	0.0000–0.1945
			Small fingerlings:fry			
Dutchman's	1995	0		2		
East Fork	1996	706	268–2,637	119	0.9664*	0.0118–0.0924
Fox Chain	1992	0		0		
	1994	13	1–52	25	0.0800	0.0000–0.1572
LeAquana	1992	∞		43	*	
	1993	26	8–86	14	0.5000*	0.0000–0.2923
	1994	27	7–148	41	0.7857*	0.0090–0.4071
	1995	0		3		
	1996	97	28–4,050	20	0.8500*	0.0014–0.2617
Randolph County	1992	192	26–8,510	9	0.8889*	0.0000–0.3870
	1993	21	5–82	11	0.4546*	0.0000–0.3395
	1994	274	40–11,814	12	0.9167*	0.0000–0.3223
	1995	∞		33	*	
	1996	203	67–819	23	0.8261*	0.0000–0.1885
Ridge	1992	0		0		
	1993	0		0		
	1995	9	3–20	38	0.2105*	0.0007–0.1455
	1996	4	(1)–15	17	0.1177	0.0000–0.2595
Sara	1996	45	23–90	46	0.6739*	0.0053–0.1497
Shelbyville	1991	882	454–1,769	45	0.6667*	0.0000–0.0861
	1992	0		4		
	1993	1,846	613–9,089	113	0.9735*	0.0024–0.0666
	1994	1,434	476–7,062	111	0.9730*	0.0041–0.0747
	1995	1,498	770–3,276	81	0.8765*	0.0000–0.0520
	1996	133	100–177	232	0.5259*	0.0010–0.0302
Sterling	1993	59	41–87	121	0.5785*	0.0038–0.0690
	1994	14	8–23	80	0.3375*	0.0071–0.0997
	1995	281	42–12,032	13	0.9231*	0.0000–0.3120
	1996	389	98–3,371	30	0.9333*	0.0009–0.1771

TABLE 3.—Continued.

Lake	Year stocked	Relative survival	Confidence interval (95%)	Number collected	P	95% CI for P_o
			Large fingerlings:small fingerlings			
LeAquana	1992	(15)	(9)–(26)	72	0.5972*	0.0345–0.1778
	1993	29	14–73	152	0.9540*	0.3337–0.5020
	1994	10	5–20	68	0.8382*	0.2353–0.4803
	1995	0		3		
	1996	2	1–5	45	0.6222*	0.2550–0.5591
Randolph County	1992	∞		8	*	
	1993	∞		5	*	
	1994	∞		11	*	
	1995	∞		33	*	
	1996	(3)	(1)–(14)	23	0.8261*	0.3601–0.7821
Ridge	1992	0		0		
	1993	0		0		
	1995	(4)	(1)–(197)	9	0.8889	0.2810–0.9179
	1996	11	2–103	12	0.8333*	0.0919–0.6337
Shelbyville	1992	6	1–66	8	0.7500*	0.0383–0.7082
	1993	1	0–3	116	0.0517	0.0117–0.0923
	1995	1	1–2	131	0.4580	0.3341–0.5106
Sterling	1993	1	1–2	177	0.6045	0.4493–0.6235
	1994	3	2–5	84	0.6786*	0.3054–0.5258
	1995	9	5–17	82	0.8537*	0.2985–0.5228
	1996	1	1–2	49	0.4286	0.2794–0.5769

ple sizes would tend to lead to the conclusion that there were differences among the areas.

Discussion

Relative survival, CPUE, and population estimates all indicated that fingerlings (large and small) generally survived at higher rates than fry, but trends in survival between the two sizes of fingerlings were similar. However, when production costs were included in the stocking assessments, stocking of small fingerlings was advantageous over large fingerlings in 72% of the 21 lake-years. Koppelman et al. (1992) stocked three size-groups of walleyes (equivalent to those in this study) in two Missouri impoundments, and small fingerlings also generally survived at higher rates than the other two sizes.

When stocking assessments were analyzed by lake and production costs were considered, sur-

TABLE 4.—Contingency tables used to determine whether the location of Illinois reservoirs affected size-specific survival of walleyes stocked concurrently during 1991–1996. Relative survival comparisons included large fingerlings versus fry, small fingerlings versus fry, and large versus small fingerlings. Numbers represent the number of lake-years in which survival favored one size over the other. Survival favored the larger-sized walleyes only if the relative survivals were statistically significant (α = 0.05) or, if only one size was recovered, when at least five walleyes were collected.

Size stocked	Location of reservoir: South	Central	North	All reservoirs	Test results
Large	1	5	8	14	$\chi^2{}_2 = 3.8095$
Fry	1	1	0	2	$P = 0.1489$
Total	2	6	8	16	
Small	6	7	8	21	$\chi^2{}_2 = 0.7834$
Fry	0	1	1	2	$P = 0.6759$
Total	6	8	9	23	
Large	0	2	5	7	$\chi^2{}_2 = 5.0610$
Small	5	3	3	11	$P = 0.0796$
Total	5	5	8	18	

TABLE 5.—Contingency tables used to determine whether the location of Illinois reservoirs affected size-specific survival of walleyes stocked concurrently during 1991–1996. Survival favored the larger-sized walleyes only if the relative survivals were at least 117:1 favoring large fingerlings over fry, 42:1 favoring small fingerlings over fry, or 3:1 favoring large fingerlings over small fingerlings or, if only one size was recovered, when at least five walleyes were collected. See the caption to Table 4 for additional details.

Size stocked	Location of reservoir: South	Central	North	All reservoirs	Test results
Large	0	4	6	10	$\chi^2{}_2 = 3.9111$
Fry	2	2	2	6	$P = 0.1415$
Total	2	6	8	16	
Small	5	6	5	16	$\chi^2{}_2 = 1.4831$
Fry	1	2	4	7	$P = 0.4764$
Total	6	8	9	23	
Large	0	2	3	5	$\chi^2{}_2 = 2.6723$
Small	5	3	5	13	$P = 0.2629$
Total	5	5	8	18	

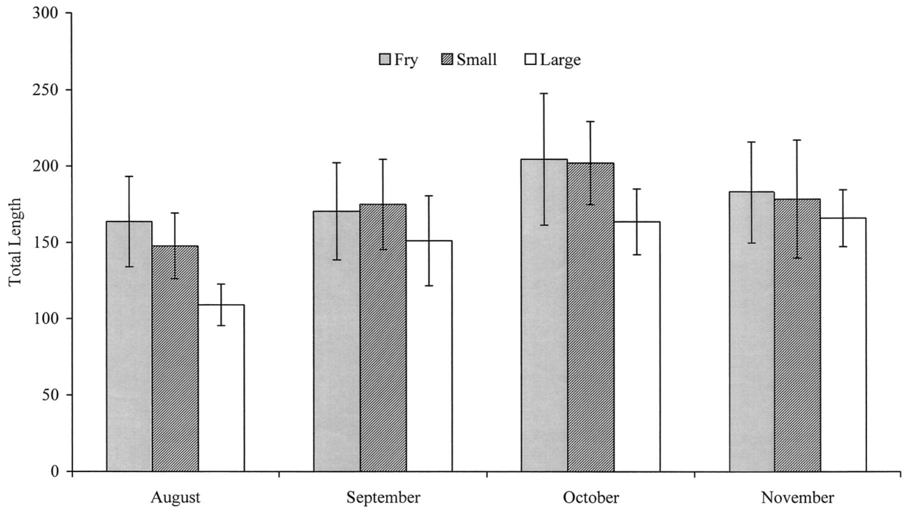

FIGURE 3.—Total lengths (mm) of walleyes collected at age 0 that were stocked in 10 Illinois lakes as fry, small fingerlings, or large fingerlings during 1991–1996. Vertical lines represent standard errors.

vival favored fry over fingerlings more often than not in some lakes, and survival also favored large fingerlings over small fingerlings in some lakes. To optimize hatchery resources, the variable results of this study emphasize the need for size-related stocking assessments on a lake-specific basis. Large variability of relative survival occurred among lakes and, to a lesser degree, within lakes among years for all size comparisons. Jennings and Philipp (1992) found that walleye fry survival was higher than small or large fingerling survival in two of three northern Illinois lakes in 1987. In 1992, however, survival was greater for large fingerlings than for other sizes. In our study, relative survival favoring large versus small fingerlings was much more variable than for fry and either of the fingerling sizes. Except for Randolph County Lake, where survival always favored small fingerlings over large fingerlings, there was no consistency of size-dependent survival within any given lake. Only when production costs were considered, did stocking smaller, less expensive fingerlings demonstrate an advantage over larger fingerlings.

Because larger sizes of fish are less susceptible to predators, larger fingerlings would probably show a higher survival rate than the smaller sizes. Such was the case in an earlier study with walleyes stocked in Ridge Lake (Santucci and Wahl 1993). Other studies have found size at stocking is a major factor influencing survival of muskellunge *Esox masquinongy* and channel catfish *Ictalurus punctatus* and have shown that increased survival is positively correlated with size (Santucci et al. 1994; Dudash and Heidinger 1996; Szendrey and Wahl 1996; McKeown et al. 1999). Predation was largely responsible for discrepancies in the survival of stocked fish. Other studies have indicated that under some circumstances, larger sizes at stocking were not advantageous (Kraai et al. 1985; Jennings and Philipp 1992; Koppelman et al. 1992; Margenau 1999). The advantage of stocking 100-mm over 50-mm walleyes would partially be dependent upon predator abundance and size. In our study, largemouth bass *Micropterus salmoides* were moderately abundant in all the reservoirs. A 250-mm (total length) largemouth bass could readily consume both 100-mm and 50-mm walleyes. Thus, the only advantage of stocking 100-mm walleyes would be a shortened period of susceptibility (due to growth) to predators. In our study, slower growth rates may have negatively affected survival of large fingerlings because they were smaller from the time of stocking and throughout their first fall than either fry or small fingerlings (Figure 3). In fact, we found the large fingerling growth disparity continued at least through age-2. Limited growth in the first fall after stocking may have contributed to predation and resulted in lower numbers within a few weeks following stocking. Similar growth patterns for intensively reared walleyes were reported by Larscheid (1995) and Olson et al. (2000), who postulated that predation on advanced walleye fingerlings was due to their limited ability to forage and attendant slow growth. In our study, large fingerlings were smaller at stocking than fry or small fingerlings that were already in the reservoirs, and larger fingerlings remained smaller throughout the study.

The advantage of stocking a 100-mm walleye over smaller fish is also diminished if behavior causes greater susceptibility to predators for longer periods. Behavior in this case relates not only to the ability of the walleyes to forage, but also to avoid predation. Intensively reared walleyes may not inhabit essential refuges that would hide them from predators (Wahl 1995), especially if they are searching for surface- rather than benthic-dwelling prey. Additional direct assessments of the importance of predation in determining size-specific survival of stocked walleyes under a range of environmental conditions are needed.

Another possible detriment to survival of large fingerlings was stocking late in the summer when water surface temperatures were at their maximum (Clapp et al. 1997). Stress of handling coupled with high water temperatures may have reduced survival rates because of adverse physiological and behavioral effects. Availability of large quantities of vulnerable forage in the lakes at the time of stocking is also questionable. The large fingerlings grew slower in the rearing facilities than did those stocked as fry or small fingerlings. Smaller sizes at stocking may have limited their ability to find optimal prey sizes in adequate numbers and ultimately affected growth just after stocking and into the third growing season. The growth patterns of advanced fingerlings in our study were similar to those observed in New York lakes (Olson et al. 2000). Olson et al. (2000) and Wahl et al. (1995) questioned the ability of intensively reared walleyes to switch from prepared diets to piscivory and suggested that introducing minnows to advanced fingerlings may increase their ability to recognize and capture small fish in the wild. In our study, minnows were offered to the large fingerlings 1 week before stocking, and survival of the large fingerlings was similar to that observed by Olson et al. (2000) for large fingerlings fed only commercial food pellets.

Culture of advanced-sized walleye fingerlings has increased, but additional information on survival of intensively reared walleyes is needed. The minnows offered before stocking in our study did not increase the walleye size and apparently did not increase their ability to switch to piscivory in the wild. Successful stocking of advanced walleye fingerlings must include optimizing growth rates before stocking and timing of stocking to reduce losses due to handling and heat-related stressors.

Our results indicate that stocking small fingerlings would generally be most productive, given current stocking rates and costs to produce the various fish sizes. However, the variability of survival in this and other studies underscore the importance of stocking assessments for individual lakes (Margenau 1999; Olson et al. 2000). When costs associated with production are considered, stocking of fry and large fingerlings had limited success in our study, but continued stocking may be cost-effective for some lakes. For example, because fry stocking is the most easily accomplished stocking strategy, identification of lakes effectively managed with fry stockings should be a high priority for the fishery manager. If rearing techniques continue to improve, stocking advanced walleye fingerlings may become more effective than small fingerlings and fry.

Acknowledgments

This cooperative project was funded by Southern Illinois University at Carbondale, the Illinois Natural History Survey, and the Illinois Department of Natural Resources (Federal Aid in Sportfish Restoration Act, F-118-R). We express our appreciation to the following colleagues: S. Krueger, A. Brandenburg, E. Hansen, D. Clapp, J. Waddell, J. Ross, D. Harrison, B. Sims, L. Pitcher, M. Garthaus, R. Anderson, J. Boase, M. Desjardins, L. Einfalt, K. Eisenbarth, T. Galarowicz, K. Goodwin, M. Herbert, J. Jonas, R. Mauk, B. Nerbonne, D. Pavlik, D. Partridge, K. Schnake, and E. Stark.

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