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Relative Survival and Contribution of Saugers Stocked in the Peoria Pool of the Illinois River, 1990–1995

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Abstract.—Numbers of sauger *Stizostedion canadense* declined in the Peoria Pool of the Illinois River from the 1970s to the 1990s. Stocking was evaluated as a means of supplementing natural reproduction in the pool. Marked fry were stocked in 1991–1994 (20–176/ha), and marked fingerlings were stocked in 1990–1995 (<1–20/ha). In 1990, fingerlings with a mean total length of 44 mm were stocked in June, and 92-mm fingerlings were stocked in September and October. Relative survival was 4.9:1 in favor of the 44-mm fingerlings. During 1991–1994, relative survival averaged 440:1 for stocked fingerlings (39–61 mm) versus fry. From 1990 to 1995, contribution of stocked saugers to the year-classes averaged 33.9% at age 0. Because of the immigration of wild saugers into Peoria Pool and emigration of stocked and wild fish to other pools, contributions of stocked saugers to individual year-classes decreased each year subsequent to stocking. Mean contribution of stocked saugers at harvestable ages (age 2 and older) was 9.1%. Total contribution of all stocked saugers after 6 years to all year-classes was 22.8%.

Saugers *Stizostedion canadense* are important sport fish in Peoria Pool of the Illinois River, as they are in many areas where they are the predominant percid (Carlander 1950; Vanicek 1964; Schoumacher 1965; Priegel 1969; Scott and Crossman 1973; Davidoff 1978; Hackney and Holbrook 1978; Rawson and Scholl 1978). Although native to the Illinois River, in recent times, saugers have inhabited the 117.9-km Peoria Pool only since the 1970s. For many years before 1970, pollution from municipal waste and nutrients in runoff from farmland caused frequent periods of low oxygen or anoxic conditions that prevented sport fish from surviving in the pool (Mills et al. 1966; Starrett 1972). Water quality gradually improved following implementation of wastewater treatment, soil conservation programs, and a municipal refuse disposal project. By the mid-1970s, fish species diversity had increased, and species that are tolerant of turbid water had become established in the nutrient-rich river. Because saugers tolerate turbid water (Scott and Crossman 1973; Pflieger 1975; Nelson and Walburg 1977; Schupp and Macins 1977; Rawson and Scholl 1978; Crance 1988), and there was an abundance of prey, they were among the first sport fish to proliferate and produce a fishery.

Initially, exploitation of sauger was perceived to be excessive. Thus, a regulation was implemented during the 1980s that limited anglers to six saugers per day. Despite the regulation, in spring (March and April) when angler catch and harvest rates of saugers are usually at peak, harvest rates were only 0.03 fish/h in 1989 and 0.05 fish/h in 1990 (Heidinger et al. 1996). Annual harvest rates of saugers in the Peoria Pool were only 0.006 and 0.02 fish/h in 1989 and 1990, respectively. In comparison, Thorn (1984) reported annual harvest rates of 0.07–0.27 fish/h in Pool 4 of the Mississippi River during 1977–1981. Harvest rates were 0.14–0.29 fish/h in the Lake Francis Case tailwater during 1954–1959 and 0.21–0.24 fish/h in the Lake Oahe tailwater during 1960–1963 (Nelson and Walburg 1977).

Because sauger harvest in the Peoria Pool appeared to be declining severely, a project was initiated in 1987 to develop management options that would enhance the sauger population in Peoria Pool. Stocking was considered a possible method to supplement natural recruitment, especially during years of weak natural year-classes. While some literature concerning stocking saugers into lakes exists (McCarraher et al. 1971; Rawson and Scholl 1978), we found only personal communication references to river stockings in peer-reviewed literature (Carlander et al. 1978; Hackney and Holbrook 1978; Conover 1986; Hesse 1994). Most river stockings were perceived to have failed or were ultimately of little consequence to sauger fisheries. Only an introductory sauger stocking in the Appalachicola River, Florida, was considered successful (personal communication in Hackney and Holbrook 1978).

The objectives of this study were to determine (1) if stocking could contribute to year-class

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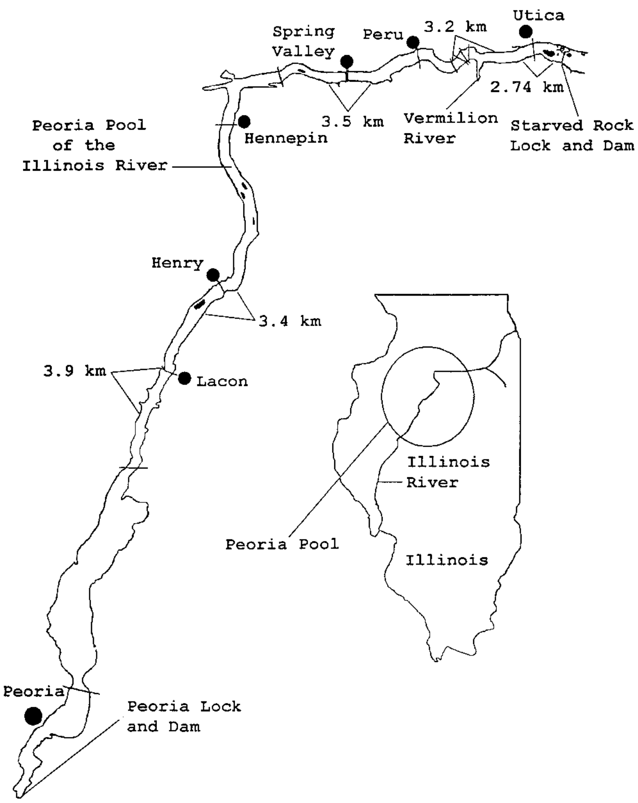

FIGURE 1.—The Peoria Pool of the Illinois River. The pool extends 117 km from Starved Rock Lock and Dam to Peoria Lock and Dam. Numbers represent distances electrofished at specific sites that were routinely sampled.

strength at age 0, (2) the relative survival of stocked fry versus stocked fingerlings, and (3) the contribution of stocked sauger to the fishery in the Peoria Pool of the Illinois River.

Study Area

The Illinois River is formed at the confluence of the Kankakee and Des Plaines rivers in northeastern Illinois. It flows 390.1 km to the Mississippi River at Grafton, Illinois (Mills et al. 1966). The Chicago Sanitary and Ship Canal adds additional flow (91.7 m/s) indirectly from Lake Michigan through the Des Plaines River at Lockport, Illinois (Starrett 1972).

Peoria Pool is the fourth of six pools formed by navigation dams and extends 117.9 km from Starved Rock Lock and Dam (river kilometer, RK, 371.7 from the confluence with the Mississippi River) to Peoria Dam (RK 253.6). Water flow is regulated by 10 tainter gates that are 5.8 m high and 18.3 m wide. Discharge through Starved Rock Lock and Dam ranges from 176.2 to 747.7 m^3/s (Mades 1981). Average velocity is 0.27 m/s at normal river stages. Pool levels are set at 134.6 m above sea level. The drainage area of Peoria Pool is approximately 28,674 km^2.

Water flows primarily from east to west in the upper portion of the pool above the bend near Hennepin (Figure 1). The bend is an apparent line of demarcation of preglacial drainages, and the river bed is primarily rock and hard clay (Starrett 1972). Most of the pool's lower half has been filled by a silt deposit that has created deep, soft mud over rocky substrate. Because of bottomland drainage and siltation, there are also intermittent reaches of soft mud substrate above Hennepin. Peoria Pool's turbidity ranges from 15 to 140 Jackson turbidity units (JTU) at pool level and may reach over 1,000 JTU at flood levels (Mills et al. 1966). Turbidity at pool level is largely due to sediment inputs from extensive farmland along the river and resuspension of sediments by frequent barge activity (Nielsen et al. 1986).

Methods

Saugers stocked in Peoria Pool were produced from broodfish collected at the Masters' Walleye

TABLE 1.—Saugers marked with oxytetracycline hydrochloride and stocked in the Peoria Pool of the Illinois River from 1990 through 1995.

Month and year stocked	Total length of fingerlings (mm)		Number stocked	Number stocked/ha	Stocking location
	Mean	SD			
Jun 1990	44	5	125,000	8.5	Spring Valley
Sep–Oct 1990	92	7	53,823	3.7	Spring Valley
Apr 1991	[a]		1,000,000	67.7	Spring Valley
Jun–Jul 1991	61	7	84,411	5.7	Spring Valley
Apr 1992	[a]		2,600,000	176.1	Spring Valley
Jun–Jul 1992	52	6	34,107	2.3	Spring Valley
Apr 1993	[a]		1,800,000	121.9	Spring Valley
Jun–Jul 1993	55	6	169,344	11.5	Spring Valley
Jun–Jul 1993	55	6	122,114	8.3	Peru
Jun–Jul 1993	55	6	72,675	4.9	Lacon
Apr 1994	[a]		300,000	20.3	Spring Valley
Jun 1994	58	6	23,124	1.6	Spring Valley
Jun 1994	58	6	10,951	0.7	Lacon
Jun 1995	39	3	121,037	8.2	Spring Valley
Jun 1995	39	3	31,097	2.1	Lacon

[a] Fry were stocked.

Circuit Tournament at Spring Valley, Illinois (Figure 1) during March and April 1990–1995. The broodfish were transported to LaSalle Fish Hatchery near Marseilles, Illinois. Broodfish with ovulated eggs were immediately stripped, and the eggs were fertilized by means of the dry method described by Moore (1987). Broodfish with eggs that had not ovulated were injected with human chorionic gonadotropin (HCG) at 500 IU HCG/454 g sauger and stripped after ovulation. Fertilized eggs were incubated at the hatchery in McDonald-type jars.

Fry produced at the hatchery were either stocked in the Peoria Pool or into rearing ponds at LaSalle Hatchery. Before they were stocked into the river, all saugers were marked by immersion in a solution of oxytetracycline hydrochloride (OTC; 500 mg/L) and sodium phosphate dibasic anhydrous buffer (300 mg/L) for 6 h (Brooks et al. 1994). This method allowed saugers stocked as fry to be distinguished from saugers stocked as fingerlings because the fluorescent marks were located at different positions on the otoliths. Fry were marked in plastic bags at 3–5 d posthatch as they were transported in hauling boxes at densities of 100,000 fry/16 L water. All fry were stocked at Spring Valley immediately after immersion in OTC. Sauger fingerlings were held in 437-L raceways for marking. Sodium phosphate dibasic anhydrous was added to OTC and 19 L water to adjust the pH to 6.8–7.0, and then the slurry was slowly poured into each raceway. Pure oxygen was diffused into the water via air stones during immersion, and a water flush was started immediately after the 6-h marking period. All fingerlings were transported in hauling tanks to the stocking sites subsequent to marking.

Subsamples of sauger fry and fingerlings immersed in OTC were placed in experimental rearing ponds at Southern Illinois University at Carbondale and used as controls to verify that stocked saugers had identifiable fluorescent marks on their otoliths.

Sauger fry were stocked at Spring Valley in 1991–1994. Fingerlings that were 39–58 mm mean total length (TL) were stocked at Spring Valley in 1990–1992; at Lacon, Spring Valley, and Peru in 1993; and at Lacon and Spring Valley in 1994–1995 (Table 1). In 1990, 92-mm fingerlings were also stocked at Spring Valley. Stocking densities in the Peoria Pool ranged from 20.3–176.1 fish/ha for fry and 2.3–20.4 fish/ha for fingerlings (Table 1).

Saugers were collected from several sites in Peoria Pool by electrofishing at night during August–December 1990–1994 and October 1995 (Figure 1). Electrofishing was conducted with a boat-operated three-phase generator (240 V AC; 5,000 W) connected to a balanced six-electrode array (Novotny and Priegel 1974). Fall electrofishing effort and catch per hour are given in Table 2.

Contributions to year-class strengths were determined by collecting saugers during spring and summer 1991 (age 1), 1992 (age 1–2), 1993 (age 1–3), 1994 (age 1–4) and 1995 (age 1–5). Saugers collected by electrofishing were usually younger than age 2. Otoliths of older fish were collected primarily from carcasses donated by anglers and

TABLE 2.—Electrofishing effort (hours) and catch per hour of wild age-0 saugers in the Peoria Pool of the Illinois River during August–December 1990–1995.

Year	Hours of effort	Number of fish collected	Catch per hour
1990	74.0	437	5.9
1991	61.0	63	1.0
1992	65.0	267	4.1
1993	52.0	2,465	47.4
1994	40.0	24	0.6
1995	8.2	27	3.3

from broodfish that died at LaSalle Hatchery. Pools located below (LaGrange Pool) and above (Starved Rock Pool) Peoria Pool were sampled by electrofishing in an attempt to document emigration of stocked sauger from Peoria Pool. Personnel from the Illinois Natural History Survey at Havana, Illinois, provided a portion of the saugers examined from LaGrange Pool.

Returns of stocked saugers collected from the Illinois River were enumerated by examining sagittal otoliths for fluorescent OTC marks (Brooks et al. 1994). Relative survival (RS) between groups of saugers stocked at different ages and sizes was determined by comparing ratios of the number of saugers stocked to the number recaptured (Heidinger et al. 1987) as follows:

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

n_f = number of sauger from group f that were later recaptured; N_f = number of sauger stocked from group f; n_e = number of sauger from group e that were later recaptured; and N_e = number of sauger stocked from group e. Confidence limits (95%) for RS estimates were calculated with the assumption of binomial distributions. Statistical significance between RS values was determined at $P = 0.05$ by using Z-scores where $-1.96 \geq Z \geq 1.96$.

Total lengths of saugers collected each month were recorded, and growth differences between stocked and unstocked saugers were analyzed by an analysis of variance (ANOVA; $P = 0.05$) with the SAS general linear model procedure (Cody and Smith 1991).

Results and Discussion

During fall 1990, 488 age-0 saugers were collected from the Peoria Pool, and otoliths from 100 (20%) of the saugers had fluorescent marks, which indicated that they had been stocked. Survival of the 44-mm fingerlings was 4.9 times higher ($P <$ 0.05) than for the 92-mm fish (Table 3).

Saugers stocked in late September 1990 at 92 mm TL were, on average, 71 mm shorter than all other age-0 saugers collected in Peoria Pool at that time (Table 4). Based on stocked saugers collected from the Peoria Pool, growth of saugers stocked in September continued to be slow through November. The saugers stocked at 92 mm would have been more susceptible to predators because they were smaller than all other age-0 saugers. Throughout the 6-year study, total lengths of fingerling saugers stocked in June were similar (P = 0.0677–0.1598) to those of wild saugers.

Mean RS for 52–61-mm fingerling : fry was 440:1 during 1991–1994, and RS ranged from 73:1 to 770:1 in favor of fingerlings over fry during those years (Table 3). Each year the differences were statistically significant (Z = 21.66–84.35; P

TABLE 3.—Relative survival of saugers stocked as fry and fingerlings in the Peoria Pool of the Illinois River from 1990 through 1993.

Year and age of stocked saugers	Mean total length	Percent of total stocked	Number of fish returned	Percent of total returned	Relative survival	95% confidence interval	Z-score[a]
1990							
Fingerlings	44	70.0	92	92.0	4.9	2.8–15.6	4.9268
Fingerlings	92	30.0	8	8.0	1.0		
1991							
Fry		92.2	5	2.4	1.0		
Fingerlings	61	7.8	202	97.6	478.6	251.0–3,645.2	84.3532
1992							
Fry		98.7	10	9.0	1.0		
Fingerlings	52	1.3	101	91.0	769.9	455.5–1,993.8	84.0110
1993							
Fry		83.2	7	6.4	1.0		
Fingerlings	55	16.8	103	93.6	72.7	40.3–269.4	21.6619

[a] Significant at $-1.96 \geq Z \geq 1.96$; $P = 0.05$.

TABLE 4.—Mean (SD) total lengths (TL) of age-0 saugers collected and measured from Peoria Pool by electrofishing during fall 1990–1995. Saugers collected were wild, stocked as fry (SFR), or stocked as fingerlings (SFI).

Year and age or origin	Mean TL at stocking (mm)	Age-0 saugers collected in: Aug TL (mm)	Aug N	Sep TL (mm)	Sep N	Oct TL (mm)	Oct N	Nov TL (mm)	Nov N
1990									
Wild		143 (15)	27	180 (18)	15	197 (19)	87	204 (19)	49
SFI	44	137 (14)	23	163 (16)	2	185 (26)	10	185 (16)	57
SFI	92					100 (23)	5	100 (1)	3
1991									
Wild		136 (16)	7	168 (11)	9	187 (25)	29	189 (27)	19
SFR		154 (12)	4			159	1		
SFI	61	138 (17)	78	158 (13)	20	170 (18)	79	185 (22)	19
1992									
Wild		131 (22)	20	181 (9)	36	195 (12)	53	213 (20)	6
SFR		133	1	177 (21)	7	190 (11)	2		
SFI	52	133 (24)	11	176 (18)	46	197 (12)	37	214 (37)	6
1993									
Wild		145 (16)	342	151 (20)	107	170 (22)	171	159 (21)	232
SFR		148 (11)	5	169 (16)	2	173	1		
SFI	55	143 (19)	57	164 (19)	20	182 (18)	30	162 (25)	15
1994									
Wild		162 (11)	2	146	1	170 (16)	4	193 (19)	6
SFI	58	150	1	184	1	184 (1)	2		
1995									
Wild						185 (15)	28		
SFI	39					192 (16)	8		

< 0.05). In 1994, no saugers that were stocked as fry were collected; therefore, it was not possible to estimate RS.

Growth rates among wild, fry-stocked, and the smaller fingerling-stocked saugers were similar from August through October of each year (Table 4). No fry-stocked saugers were collected in November of any year during this study, and too few age-1 saugers were collected in spring to allow an estimate of overwinter mortality.

We used the 1991–1993 mean RS for stocked fingerlings versus fry to calculate the number of fry it would have been necessary to stock in order to achieve the same survival obtained from the fingerling stockings. An average of 140,772 fingerlings were produced and stocked each year in the Peoria Pool during 1990–1995; therefore, 440 times that number (or 62 million fry) would have been required annually to equal the contribution of stocked fingerling saugers.

In 1990, fecundity of Peoria Pool saugers was determined to be 40,726–46,830 eggs per 454 g of age-2 and age-3 females (Brooks 1993). Hatch rates of sauger eggs incubated in McDonald-type jars at LaSalle Hatchery averaged approximately 40% (E. Hansen, Illinois Department of Natural Resources, personal communication). Thus, more than 3,000 females would have been required to produce 62 million fry. Whereas, based on 25% survival from fry to 50-mm fingerlings typical in the LaSalle Fish Hatchery ponds, approximately 14 females would be required to produce 140,772 50-mm fingerlings.

Relative survival estimates were used to evaluate the performance of different size-groups stocked in the river. We also examined contributions of all stocked saugers to year-class strengths and, ultimately, to the fishery. During the 6-year study, contributions of stocked saugers were dependent on the amount of natural reproduction and ages of the year-classes examined.

Contributions at age 0 to the year-classes averaged 33.9% and ranged from 15.4% to 75.8% (Table 5). Contributions at age 0 were lowest for the 1990 (21.8%) and 1993 (15.4%) year-classes when, based on electrofishing catch-per-hour data, natural reproduction was highest (Table 2). This occurred despite stocking higher densities of fingerlings (12 and 25 fish/ha) than in all other years (2–10 fish/ha; Table 1). In 1991 and 1992, natural reproduction was low, and contributions of age-0 stocked saugers were higher at 75.8% and 44.9%. Although contributions of age-0 stocked saugers were low in 1994 (23.5%) and 1995 (22.2%), the total number of age-0 saugers collected from Peoria Pool was only 17 and 36, respectively. La-

TABLE 5.—Percentages of stocked saugers collected in the Peoria Pool of the Illinois River. Stocked saugers were marked by immersion in oxytetracycline hydrochloride. The total numbers of saugers collected and examined for marks are given in parentheses.

Year captured	Age						Total contribution[a]
	0	1	2	3	4	5	
1990	21.8 (501)						21.8 (501)
1991	75.8 (265)	6.8 (307)					38.8 (572)
1992	44.9 (225)	35.0 (641)	12.5 (8)				37.3 (874)
1993	15.4 (952)	64.4 (59)	26.0 (41)	14.8 (71)			18.4 (1,106)
1994	23.5 (17)	9.8 (845)	18.2 (11)	2.5 (80)	1.4 (71)		9.0 (1,024)
1995	22.2 (36)		5.1 (78)		11.1 (9)	6.0 (50)	9.2 (173)
Average	33.9	29.0	15.5	8.7	6.3	6.0	22.8

[a] Represents the contribution of stocked fish to all saugers collected in corresponding year. Otoliths from most age-2 and older saugers were taken from carcasses donated by anglers.

Jeone et al. (1992) reported similar results stocking fingerling walleyes *Stizostedion vitreum* (11 fish/ha) into a strong 1987 year-class in the Mississippi River. The initial stocking had a negligible contribution to the year-class. In contrast, walleyes stocked (27–30 fish/ha) into relatively weak year-classes in 1988 and 1989 contributed 46% and 39% to the respective year-classes.

The effects that a large natural year-class has on the contribution of stocked saugers became apparent following a very strong 1993 year-class. After 6 years, total contributions of stocked saugers (all age-classes marked and collected) averaged 22.8% and ranged from 9.0% to 38.8% (Table 5). Total contributions were lower (9.0–18.4%) in 1993–1995 than in the previous years (21.8–38.8%). Decreases in total contribution during the latter 3 years were due, at least in part, to the abundant 1993 year-class.

In general, contributions of stocked saugers declined within a year-class as the cohorts aged (Table 5). A number of factors, loss of marks, differential mortality, and movement of saugers to and from the pool, were examined to determine their possible contributions to the declines.

Loss of marks was not expected to have affected contribution of stocked saugers. Otoliths from pond-held groups of saugers marked by immersion in OTC ($N = 47$) had 100% marks when examined at age 1. Otoliths from age-4 and age-5 saugers collected in the Illinois River ($N = 5$) have also shown mark intensities comparable with those in otoliths of age-0 saugers. Based on these observations, we do not suspect loss of marks to be a contributing factor.

Differential mortality (i.e., overwinter mortality; susceptibility to harvest) is also not suspected to have affected the contribution of stocked saugers to the population. Because growth of stocked age-0 saugers was approximately that of wild age-0 saugers in fall of each year, size-dependent differential mortality for stocked and wild sauger did not explain the decline (Toneys and Coble 1979). Decreases in contributions continued through all age classes and were, in fact, less from age 0 to age 1 than in most other age spans. Age-2 and older saugers were collected primarily by anglers with hook and line, and stocked sauger should have mixed with wild saugers in the river to the extent that they were neither more nor less susceptible to anglers than unstocked fish.

Movement of saugers into and out of Peoria Pool is the most reasonable explanation for the apparently diminishing contribution that stocked saugers made to year-classes over time. Sauger emigration from the pool would consist of wild as well as stocked saugers; whereas, sauger immigration from other pools would consist only of wild saugers. Thus, the combined effects of sauger emigration and immigration resulted in an increase in the number of unmarked fish in the population, thereby decreasing the contribution of stocked saugers within the Peoria Pool.

To verify that emigration was occurring, saugers were collected downstream of the Peoria Pool in LaGrange Pool (1991–1993) and upstream of the Peoria Pool in Starved Rock Pool (1993–1994). Of the 378 saugers that were collected from LaGrange Pool during 1991–1993, 7 (1.9%) had been stocked in Peoria Pool. Two had been stocked as fry, two as 50-mm fingerlings, and three as 92-mm fingerlings. In Starved Rock Pool, 1 of 44 (2.3%) saugers collected in 1993 and 1994 had navigated upriver through Starved Rock Lock and Dam following stocking. Therefore, emigration of stocked saugers had occurred.

Movement of sauger between pools is not surprising because they are wide ranging and are known to migrate over 60 km in the Mississippi River (Scott and Crossman 1973). Saugers in the Peoria Pool move in annual patterns from Starved Rock Lock and Dam at least 30 km downriver to Peoria Lake (Heidinger et al. 1996). The movement is seasonal and similar in pattern to that of saugers in the Missouri River above Lewis and Clark Lake (Nelson 1968). The Peoria Lock and Dam is a low-head dam. In high-water periods from late spring throughout summer when the saugers are most likely to be inhabiting the lower portion of the pool, it would be conceivable for saugers to move unobstructed between the LaGrange and Peoria pools. Upriver movement through the lock at Starved Rock Lock and Dam during fall, winter, and early spring would be more restricted, but not impossible. Stocked walleyes exhibited extensive movement between Pools 14 and 15 in the Mississippi River (LaJeone et al. 1992). Walleye fingerlings stocked in Pool 14 contributed 69% to the 1989 year-class in Pool 15. Paragamian and Kingrey (1992) reported that walleye fingerlings stocked in Cedar River, Iowa, were collected in two additional connecting rivers. Because the two percids often exhibit similar movement patterns in lotic systems, some movement of saugers through locks and dams is likely.

If movement of stocked and wild saugers was similar and emigration equal, emigration alone would not have influenced contribution percentages within a year-class. Thus, the combination of emigration and immigration resulted in decreasing contributions of stocked saugers within the pool as each year-class aged.

The results of this study indicated that stocking 50-mm saugers was preferable to stocking sauger fry in the Peoria Pool of the Illinois River. The lack of success for fry stocking and successful fingerling stockings have also been reported for walleyes in rivers (Cleary and Mayhew 1961; Paragamian 1988; Paragamian and Kingery 1992; Li et al. 1996b). Stocking sauger fingerlings in the Peoria Pool contributed substantially to year-classes when natural reproduction was low and stocking did not follow a strong natural year-class. Stocked saugers also contributed to the Peoria Pool fishery. Sauger are initially harvested by most anglers in the Peoria Pool at age 2 (Heidinger et al. 1996). Based on otolith examinations of all age-2 and older saugers collected almost exclusively by anglers and in fishing tournaments, 9.0% of saugers harvested were stocked fish.

The effects of stocking saugers may go beyond benefitting the creel. This is especially true in years when saugers are stocked into very large year-classes (Li et al. 1996a). Growth rates during this study were sufficient to conclude that stocking saugers probably did not increase numbers beyond the capacity of the river system. However, the effects that a recent strong 1996 year-class will have on a sauger population already considered to be quite large remains to be seen (Li et al. 1996b). Identification of biotic and abiotic factors associated with sauger year-class strength may aid biologists trying to determine in which years stocking will contribute most to a given cohort and when it may be prudent not to stock at all.

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