Effects of Post-stocking Flows on Striped and Hybrid Striped Bass Recruitment in the Ohio River

Douglas T. Henley, *Kentucky Department of Fish and Wildlife, #1 Sportsman Lane, Frankfort, KY 40601*

Abstract: The Kentucky Department of Fish and Wildlife Resources and bordering states stock striped bass (*Morone saxatilis*) and hybrid striped bass (*Morone saxatilis* x *Morone chrysops*) into the Ohio River. These stockings resulted in the development of *Morone* spp. sport fisheries in several pools of the Ohio River along Kentucky's border. Recruitment of striped and hybrid striped bass into these fisheries has been highly variable. Fall recruitment patterns of striped and hybrid striped bass were evaluated. It was determined that river flow during or just after stocking had a major influence on the contribution of the stocked striped and hybrid striped bass fingerlings to fall year-class strength estimates. Fall striped bass electrofishing catch rates ranged from 22.1 (SE = 6.2) to 41.4 (SE = 12.8) fish/h when river flows were below the 24-year average for July. Hybrid striped bass electrofishing catch rates during the same flow periods ranged from 7.8 (SE = 2.9) to 18.9 (SE = 7.0) fish/h. However, fall electrofishing catch rates for both species declined during years when the July mean flow exceeded the 24-year average. Hybrid striped bass fall catch rates [3.5 (SE = 0.8) – 5.4 (SE = 1.5) fish/h] during these years, however, consistently exceeded those observed for striped bass [0.1 (SE = 0.1) – 1.4 (SE = 0.7) fish/h]. Stocking of hybrid striped bass at 12 fish/ha is recommended with the continued stocking of striped bass at 12 fish/ha to provide a trophy component to the *Morone* spp. fishery in the Ohio River.

Key Words: striped bass, hybrid striped bass, stocking, river flow, Ohio River

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 60:118–124

Canalization of the Ohio River began in 1885 by the U. S. Army Corps of Engineers and ended with the present day 18 high-lift locks and dam system. Dams, commercial navigation, flood plain modifications, and water quality degradation have influenced fish distribution and abundance (Trautman 1981, Pearson and Krumholz 1984, Van Hassel et al. 1988). Ohio River lock chamber studies conducted by the Kentucky Department of Fish and Wildlife Resources (KDFWR) and the Ohio River Sanitation Commission (ORSANCO) have documented improved fisheries and indicated that an abundant forage base is present in the river with gizzard shad (Dorosoma cepedianum) comprising 22% to 74% of the total fish biomass (Henley 1995).

The Kentucky Department of Fish and Wildlife Resources began stocking striped bass (*Morone saxatilis*) in the Ohio River in 1976 to establish an additional sport fishery, provide for a trophy fishery and to better utilize the abundant forage base present in the Ohio River (Jackson 1986). Since stocking began, the KDFWR has stocked over 22 million striped bass in the Ohio River. These stockings have resulted in the development of striped bass fisheries in several pools of the Ohio River. In addition to the striped bass stocking by Kentucky, Ohio and West Virginia have stocked an estimated 12.6 million hybrid striped bass, (*Morone saxatilis* x *Morone chrysops*), in the pools adjacent to (Markland, Meldahl, and Greenup pools) and upriver of Kentucky (R. C. Byrd to New Cumberland pool) since 1983.

Recent creel surveys have shown the importance of both species to angler's creel in the Ohio River. Angler catch in 2002 creel surveys in J. T. Myers, McAlpine, and Markland tailwaters indicated that hybrids accounted for 71% of the total catch of the two species while striped bass made up 21% of the catch (O'Bara 2004). Striped bass, however, accounted for about 68% of the total harvest and about 76% of the total weight harvested.

Striped and hybrid striped bass fisheries in the Ohio River have been highly variable. Creel surveys on the Ohio River have consistently shown variable catch rates of *Morone* spp. between years (Schell et al. 1996, O'Bara 2004). Henley (1991) provided circumstantial evidence that several sources of mortality could be factors limiting this fishery. These sources included angler harvest, delayed mortality following release by sport or commercial anglers (commercial entanglement gear), and excessive summer water temperatures. Although these factors may contribute to mortality, they did not completely explain the periodic poor year-classes observed.

Striped bass characteristically exhibit variable year-class strength as populations along the east coast of the United States typically produce strong year-classes every 6–8 years (Koo 1970, Van Winkle et al. 1979, Kernehan et al. 1981). Year-class production of striped bass can be influenced by both density-independent and dependent variables. Density-independent variables such as environmental conditions during and around the spawn can influence survival of early larval striped bass and directly influence subsequent year-class strength (Goodyear et al. 1985, Uphoff 1989). Thus by the time striped bass reach the juvenile stage, year-class strength has been established (Ulanowicz and Polgar 1980, Cooper and Polgar 1981). Although some density dependent factors (predation, food resources, disease, cannibalism) can influence striped bass reproductive success, density-independent factors appear to play a greater role (Boynton et al. 1981, Dey 1981, Robichaud-LeBlanc et al. 1998). Environmental factors such as water temperature (Dey 1981, Kernehan et al. 1981, Uphoff 1989), flow (Turner and Chadwich 1972, Rulifson and Manooch 1990, McKown and Young 1992), and turbidity (Muncy et al. 1979, Morgan et al. 1983, Breitburg 1988) can have extreme influences on year-class development. The formation of a dominant year-class is most likely related to a number of interacting factors; however, an extreme in any one variable can diminish year-class viability (Kernehan et al. 1981).

The Kentucky Department of Fish and Wildlife Resources initiated this study to evaluate and compare recruitment patterns of striped and hybrid striped bass in the Ohio River. Results will be used to make recommendations for future *Morone* spp. stockings in the Ohio River.

Study Area

The Ohio River forms approximately 1,068 km of the northern border of Kentucky. The river begins at the confluence of the Allegheny and Monongahela rivers at Pittsburgh, Pennsylvania, and flows 1,578 km southwest to its confluence with the Mississippi River at Cairo, Illinois. The channel width of the Ohio River ranges from 1,219 m at Louisville to nearly 2,591 m near Lock and Dam 53 in the lower river. The Ohio River has 18 high-lift and 2 wicket style lock and dam facilities that provide a 3-m navigation channel along the entire length of the river. The present evaluation was conducted in Markland and Cannelton pools of the Ohio River (Fig. 1). Markland Dam located at river kilometer 855 impounds about 11,281 ha of water stretching 153 km upstream to the Meldahl Dam just above Cincinnati, Ohio. Of the total area in Markland Pool, just over 1,214 ha are considered backwater areas. Cannelton Lock and Dam lies 304 km downstream of Markland Pool at river kilometer 1,160. Cannelton Pool is 183 km in length

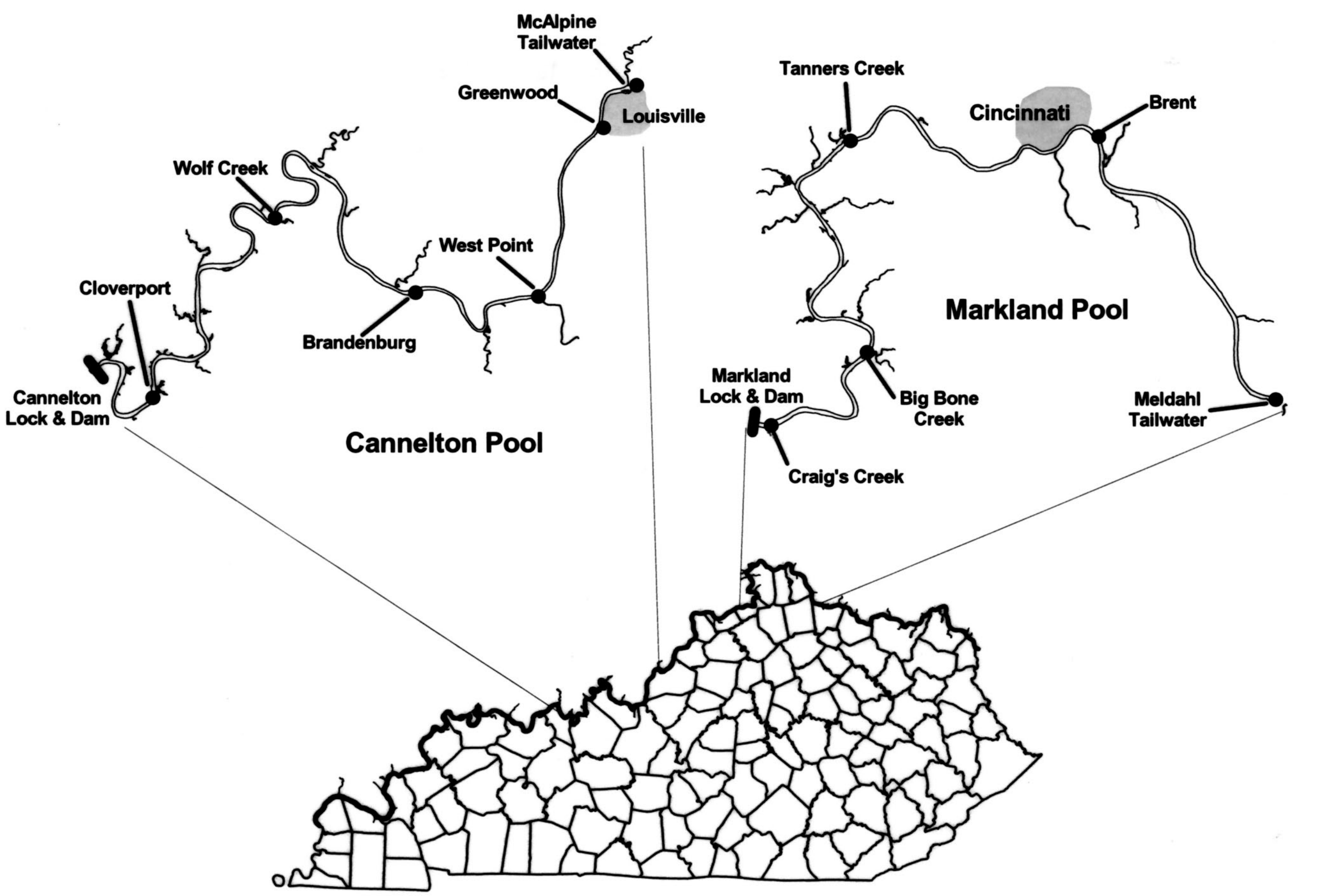

Figure 1. Map of Ohio River and Survey Sites.

and impounds 10,113 ha of water. Nearly 890 ha of this pool are considered backwater areas.

Methods

Stocking

Striped bass and hybrid striped bass were reared to about 43 mm at the Minor Clark Fish Hatchery in Morehead, Kentucky. Striped bass were stocked in Markland Pool during the study period at a rate of approximately 25 fish/ha. Cannelton Pool was stocked with hybrid striped bass at a rate of approximately 24 fish/ha. These stocking rates continued in each pool for the remainder of the study. Stocking sites in each pool varied from main stem to embayment sites depending on river conditions. Fish were stocked in June (hybrid striped bass) or July (striped bass). Ohio River gage and flow data were obtained from the Corps of Engineers web site http://www.lrl.usace.army.mil/wc/.

Sampling

Young-of-the-year (YOY) striped and hybrid striped bass were collected nocturnally from the littoral areas of the Markland and Cannelton pools of the Ohio River in water <2 m in depth and over a variety of substrates (silt, sand, gravel, and bedrock) using Smith-Root Model GPP 5.0 pulsed DC electrofishing gear. Normal electrical settings ranged between 4 and 6 amps during each 15-minute run conducted at each of 5 survey sites located along the length Markland Pool. Transects were located at Meldahl Tailwater; Brent/Cincinnati, Tanners Creek, Big Bone Creek, and Craigs Creek (Fig. 1). Sampling was conducted at 6 sites in the Cannelton Pool. These sites were located at McAlpine Tailwater, Louisville, West Point, Brandenburg, Wolf Creek, and Cloverport (Fig. 1). Sampling was conducted at each transect each year in October.

All *Morone* spp. collected were measured to the nearest mm and weighed to nearest gram. Otoliths from a subset of *Morone* spp. <305 mm were used to differentiate YOY from age-1 fish collected in October.

Young-of-the-year white bass, (*Morone chrysops*), striped bass, and hybrid striped bass are difficult to distinguish visually. As a result, starch gel electrophoresis was used to differentiate proteins and identify these fish. Southern Illinois University (SIU) at Carbondale, Illinois, was contracted to identify samples collected from 1996 through 1998. Horizontal starch gel electrophoresis was conducted using 2 gel-buffer systems: Tris-borate-EDTA I (EBT), and Tris-citrate III (TCIII).

Beginning in 1999, the Kentucky Department of Fish and Wildlife began the use of electrophoresis similar to the methods employed by SIU (Avise and Van Den Avyle 1984, Habicht 1993) to identify YOY *Morone* spp. Only one loci was used to differentiate the three species, although other loci were tried. Glucose-6-Phosphate Isomerase (GPI; EC# 5.3.1.9) successfully identified striped bass, hybrid striped bass, and white bass.

Data Analysis

Differences in catch-per-unit-effort (CPUE) among species, pools, and years, as well as, length differences between YOY *Morone* spp. were analyzed using Analysis of Variance (ANOVA; SAS 1988). CPUE in each pool was regressed separately against Ohio River flow during the months of June, July, and August.

Results

Electrofishing Surveys

A total of 495 YOY striped bass were collected in October electrofishing surveys in Markland Pool (Table 1). Effort consisted of 153 runs totaling 39.1 hours of electrofishing. From 1998 to 2002, striped bass YOY catch rates ranged from 0.1 (SE = 0.1) to 41.4 (SE = 12.8) fish/h.

A total of 346 hybrid striped bass YOY were collected in electrofishing surveys conducted during October surveys from 1998–2002 in Cannelton Pool (Table 1). Effort consisted of 181 transects that totaled 45.9 hours of electrofishing. Hybrids catch rates ranged from 3.5 (SE = 0.8) to 18.9 (SE = 7.0) fish/h during the study.

Effects of Post-stocking Flow

The amount of flow during or just following stocking influenced survival of YOY striped bass in Markland Pool. River flows

Table 1. Electrofishing effort and catch-per-unit effort (fish/h) of all *Morone* species collected from Markland and Cannelton pools of the Ohio River in October from 1998 to 2002.

		Number and species composition CPE (f/h)				
Pool	Year	Total runs	Total effort (h)	Striped bass	CPE	SE
Markland	1998	34	8.9	5	0.6	0.2
	1999	32	8.1	330	41.4	12.8
	2000	31	8.0	1	0.1	0.1
	2001	29	7.3	10	1.4	0.7
	2002	27	6.8	149	22.1	6.2
		153	39.1	495		
	Year	Total runs	Total effort (h)	Hybrid striped bass	CPE	SE
Cannelton	1998	39	10.1	35	3.5	0.8
	1999	36	9.3	72	7.8	2.9
	2000	34	8.4	44	5.4	1.5
	2001	36	9.1	34	3.8	1.5
	2002	36	9.0	161	18.9	7.0
		181	45.9	346		

during July (Table 2) ranged from unusually low in 1999 (32% of the 24-year mean) to above average in 1998 (161% of the 24-year mean). Catch rates of YOY striped bass stocked in Markland Pool during low flow periods in July 1999 and 2002 (63% of the 24-year mean) were 41.4 (SE = 12.8) and 22.1 (SE = 6.2) fish/h (Table 1). However, during the high flow years of 1998 (161% of the 24-year mean) and 2001 (110% of the 24-year mean), catch rates in the fall for YOY striped bass were extremely low (0.6 (SE = 0.2) and 1.4 (SE = 0.7) fish/h). Years with moderate flows during July (2000–91%) resulted in YOY catch rates of 0.1 (SE = 0.1) (fish/h).

The influence of July river flow on fall catch rates of Cannelton Pool YOY hybrid striped bass was not as pronounced and provided a more consistent return compared to YOY striped bass. During 1998 (172% of the mean) and 2001 (116% of the mean) when river flows exceeded the 24-year mean (Table 2), catch rates of YOY hybrid striped bass ranged between 3.5 (SE = 0.8) and 3.8 (SE = 1.5) fish/h (Table 1). Flow rates during 2000 (105% of the mean) slightly exceeded the 24-year mean resulting in 5.4 (SE = 1.5) YOY hybrid striped bass per hour being sampled. Catch rates of YOY hybrid striped bass during low flow years of 1999 (29% of the mean; 7.8 (SE = 2.9) fish/h) and 2002 [55% of the mean; 18.9 (SE = 7.0) fish/h] exceeded the other years, although catch rates of YOY hybrid striped bass were lower than those observed for YOY striped bass.

Catches of stocked YOY striped (Markland Pool) and hybrid striped bass (Cannelton Pool) followed similar trends. However, catch rates of YOY striped bass and hybrid striped bass were significantly different from each other in 4 of 5 years (Fig. 2). Only in 2002 were catch rates of both species statistically similar ($F = 0.10$, $P \leq 0.75$). YOY striped bass catch rates [41.4 (SE = 12.8) fish/h] significantly exceeded that of hybrid striped bass [7.8 (SE = 2.9) fish/h] in 1999 ($F = 5.46$, $P \leq 0.02$). Catch rates of hybrid striped bass [3.5 (SE = 0.8) fish/h] were significantly higher than those of striped bass [0.6 (SE = 0.2) fish/h] in October 1998 ($F = 5.04$, $P \leq 0.05$). Similar conditions occurred in 2000 and 2001, when hybrid striped bass catch rates [5.4 (SE = 1.5) and 3.8 (SE = 1.5) fish/h] were significantly greater than striped bass [0.1 (SE = 0.1) and 1.4 (SE = 0.7) fish/h] (2000, $F = 7.35$, $P \leq 0.02$; 2001, $F = 3.10$, $P \leq 0.08$).

In an effort to describe annual catch differences, fall YOY *Morone* catch rates were regressed against June, July, and August monthly mean river flows observed during each year of stocking. An inverse relationship was observed between mean July flows and the subsequent fall catches of stocked YOY striped bass from Markland Pool ($R^2 = 0.71$; $P \leq 0.07$; Fig. 3). The mean monthly June and August flow was also compared to fall YOY striped bass catch rates and were correlated ($R^2 = 0.61$; $P \leq 0.12$ and $R^2 = 0.63$;

Table 2. Mean monthly flow for Markland and Cannelton pools of the Ohio River for June, July, and August from 1998 to 2002 as percent of the mean monthly value for the same months from 1978 to 2002.

Pool	Month	24-year mean flow (m^3/s)	Year 1998	1999	2000	2001	2002
Markland	June	2,559	145	25	88	88	94
	July	1,666	161	32	91	110	63
	August	1,304	62	36	116	95	45
Cannelton	June	3,035	156	20	89	85	97
	July	1,888	172	29	105	116	55
	August	1,540	64	32	118	106	33

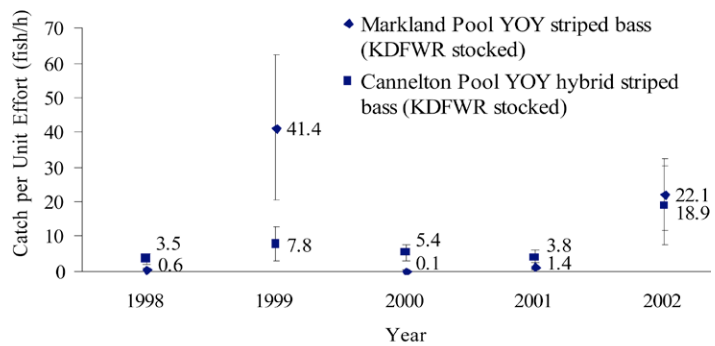

Figure 2. October catch-per-unit-effort of KDFWR stocked YOY striped and hybrid striped bass from Markland and Cannelton pools of the Ohio River from 1998 to 2002. Error bars represent 90% confidence intervals.

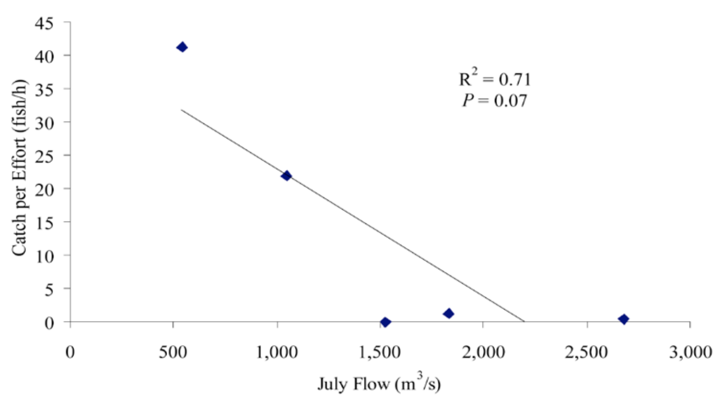

Figure 3. Relationship between October catch-per-unit-effort of YOY striped bass and mean July flow (m^3/s) from Markland Pool of the Ohio River from 1998 to 2002.

$P \leq 0.11$, respectively), but not as strongly as July. No significant relationships were found between hybrid striped bass catch rates in the fall and flows in July ($R^2 = 0.39$; $P \leq 0.25$) (Fig. 4); however, relationships appeared to be similar to those seen with striped bass.

The highest catch rates of YOY striped bass [22.1 (SE = 6.2) and 41.4 (SE = 12.8) fish/h] in Markland Pool were observed following mean July flows ranging between 538 and 1,316 m^3/s (1999 and 2002). Mean July flows greater than 1,416 m^3/s resulted in low fall catch rates [0.1 (SE = 0.1) -1.4 (SE = 0.7) fish/h]. The mean July flow in 2000 was 1,521 m^3/s resulting in a fall catch rate of 0.1 (SE = 0.1) fish/h. Markland mean flows in 1998 and 2001 ranged between 1,829 and 2,675 m^3/s, with fall YOY catch rates of 0.6 (SE = 0.2) and 1.4 (SE = 0.7) fish/h, respectively. Below average flows in July 1999 and 2002 (555 and 1,035 m^3/s) in Cannelton Pool resulted in catch rates of 7.8 (SE = 2.9) and 18.9 (SE = 7.0) hybrid striped bass/h, respectively. Hybrid striped bass in Cannelton Pool seemed to be able to survive slightly higher July flows than striped bass. Elevated July river flows in 2000 and 2001 (1,990 and 2,193 m^3/s , respectively) resulted in hybrid striped bass catch rates of 5.4 (SE = 1.5) and 3.8 (SE = 1.5) fish/h, respectively. Hybrid striped bass catch rates of 3.5 (SE = 0.8) fish/h were observed when the mean July flow exceeded 3,229 m^3/s in 1998.

Discussion

River conditions, during or just after stocking, may have negatively impacted survival of striped and hybrid striped bass fingerlings that were stocked into Markland and Cannelton pools of the Ohio River. Fall year-class strength estimates of both species stocked from 1998 through 2002 were inversely related to July flows. The exact variables responsible for reducing survival of both species are not fully known, but may be related to increased velocities, turbulence, turbidity, and changes in water temperature that can occur during periods of high rates of flow (Ulanowicz and Polgar 1980, Cooper and Polgar 1981, Uphoff 1989).

Increased flows and turbidity can directly impact survival of stocked fingerlings by negatively affecting their feeding abilities (Cleary 1956, Muncy et al. 1979) or by loss of orientation and displacement of some YOY fish (Turner and Chadwick 1972). High flows and increased turbidity can also indirectly impact survival of the stocked fingerlings by negatively impacting their food resources by reducing reproductive potential of prey species, scouring the bottom and either displacing invertebrate food items or smothering them with silt (Cleary 1956, Muncy et al. 1979). Reduced food availability has been shown to limit predator fish survival in reservoirs (Ploskey and Jenkins 1982). Since growth, mortality, and abundance are related in many fish species, the conditions that negatively influence survival of *Morone* spp. will also influence prey species (Dey 1981). All of these variables either independently or together can negatively impact year-class strength of the two species and eventually result in fluctuations or declines in their sport fisheries in the Ohio River.

McKown and Young (1992) suggested that annual variability in year-class strength from natural reproduction of striped bass in the Hudson River was influenced by hydrographic events that occurred during or shortly after spawning. Results of our study indicate that the striped and hybrid striped bass fingerlings that were stocked into the Ohio River were similarly impacted by early summer hydrographic events that occurred during or shortly after stocking. Study results indicate that there may be critical flow rates during or shortly after stocking for both species in the Ohio River that result in both decreased survival and variable year-class production. For example, fall age-0 year-class estimates were higher for the stocked striped bass when the average July flow was below 1,473 m^3/s [range 22.1 (SE = 6.2) – 41.4 (SE = 12.8) fish/h] as compared to 0.1 (SE = 0.1) – 1.4 (SE = 0.7) fish/h when July flows exceeded this flow. Critical July flows for hybrid striped bass appeared to be slightly higher (1,586 m^3/s) with year-class estimates ranging from 7.8 (SE = 2.9) to18.9 (SE = 7.0) fish/h compared to 3.5 (SE = 0.8) – 5.4 (SE = 1.5) fish/h when July flows exceeded this flow. Year-class production for striped bass was greater than that seen for hybrid striped bass during years when flow was below the critical levels; however, when flows exceeded critical levels not only was year-class production greater for hybrid striped bass but it was also less variable than that observed for striped bass.

Other variables can impact survival and subsequent year-class strength of the stocked striped and hybrid striped bass. Michaelson et al. (2001) found first year survival in Smith Mountain Lake to be poor in some years due to unknown reasons, presumably not predation. Van Den Avyle and Higginbotham (1979) rec-

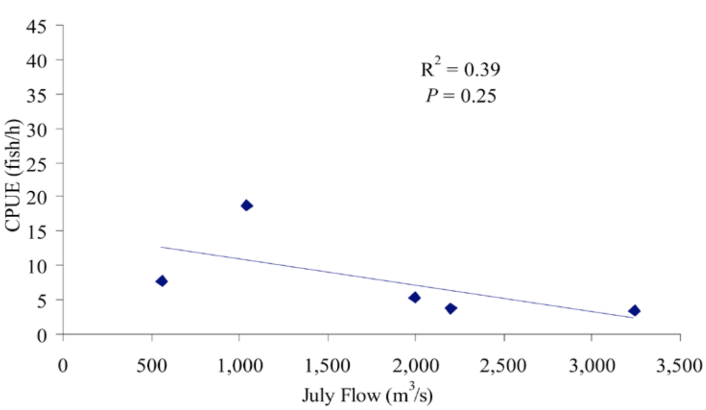

Figure 4. Relationship between October catch-per-unit-effort of YOY hybrid striped bass and mean flow (m^3/s) from the Cannelton Pool of the Ohio River from 1998 to 2002.

ommended stocking large fingerling striped bass (51–102 mm), which was similar, but slightly larger than the fish stocked in this study. As a result, size of the fingerlings stocked was likely not an important variable impacting survival of fingerling *Morone* spp. in the Ohio River.

Even though hybrid striped bass appear to out perform striped bass that are stocked into the Ohio River, striped bass do provide anglers with benefits. Population sampling indicates that striped bass account for 89% of the >610 mm *Morone* spp. sampled over the course of this study. Recent creel surveys showed that although hybrid striped bass comprised 72% of the total number of *Morone* spp. caught and released by anglers, striped bass made up 68% of all *Morone* spp. harvested and 76% of the total weight harvested (O'Bara 2004). As a result, stocking of striped bass in the Ohio River provides anglers with a trophy component and is valuable to the overall fishery in the river.

Management Implications

This study indicates that striped bass year-class strength was more variable than that observed for hybrid striped bass. High river flows during or after stocking negatively impacted year-class strength of both species with impacts believed to be greater on striped bass. During low flow years, striped bass year-class strength did exceed that of hybrid striped bass. However, during those years when river flows were moderate to excessive, hybrid striped bass fall year-class strength estimates exceeded that of striped bass.

Both species contribute positively to the overall *Morone* fishery in the Ohio River and as a result, future plans for the fishery in the Ohio River should include the stocking of both species. Hybrid striped bass should be stocked to attempt to reduce the fluctuations in the *Morone* fishery in the river while striped bass should be stocked because of their potential to provide larger or trophy specimens to this fishery. Therefore it is recommended to continue stocking the Ohio River with *Morone* spp. with the stocking rates split equally between striped bass (up to 12 fish/ha) and hybrid striped bass (up to 12 fish/ha). Stocking sites should be along the channel border at access sites in the middle to upper portion of the receiving pool. Stocking fish during a high water event resulted in low returns of YOY fish in the fall. When possible, YOY *Morone* spp. stockings should be postponed until suitable water conditions are available to afford maximum survival of the stocked fish.

Acknowledgments

The author wishes to thank the many people who have helped to bring this project to completion. I wish to thank the following technicians who have helped over the years: J. McDowell, R. Mehlbauer, T. McCoy, A. Mullins, and E. Janney. Thanks also goes to N. Thompson and H. Layson for help during their summers off from school. Don Bunnell was very helpful with statistical analysis of this data. And finally I would like to thank B. Kinman, G. Buynak, J. Ross, and J. Axon for laboring through the many drafts of this document and providing necessary guidance.

Literature Cited

Avise, J. C. and M. J. Van Den Avyle. 1984. Genetic analysis of reproduction of hybrid white bass X striped bass in the Savannah River. Transactions of the American Fisheries Society 113: 563–570.

Boynton, W. R., T. T. Polgar, and H. H. Zion. 1981. Importance of juvenile striped bass food habits in the Potomac Estuary. Transactions of the American Fisheries Society 110:56–63.

Breitburg, D. L. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117:72–77.

Cleary, R. E. 1956. Observations of factors affecting smallmouth bass production in Iowa. Journal of Wildlife Management 20:353–359.

Cooper, J. C. and T. T. Polgar. 1981. Recognition of year-class dominance in striped bass management. Transactions of the American Fisheries Society 110:180–187.

Dey, W. P. 1981. Mortality and growth of young-of-the-year striped bass in the Hudson River Estuary. Transactions of the American Fisheries Society 110: 151–157.

Goodyear, C. P., J. E. Cohen, and S. W. Christensen. 1985. Maryland striped bass: recruitment declining below replacement. Transactions of the American Fisheries Society 114:146–151.

Habicht, C. 1993. Electrophoresis identification of *Morone* species, and in vivo ova storage, induced gynogenesis and induced triploidy in white bass. M.S. Thesis, Department of Zoology, Southern Illinois University, Carbondale.

Henley, D. T. 1991. Seasonal movement and distribution of striped bass in the Ohio River. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 45:370–384 .

———. 1995. Ohio River sport fishery investigations. Completion Report, Bulletin 95, Kentucky Department of Fish and Wildlife Resources. Frankfort.

Jackson, R. V. 1986. Assessment of the sport fishery at Meldahl Pool and Tailwater of the Ohio River. Completion Report, Bulletin 80, Kentucky Department of Fish and Wildlife Resources. Frankfort.

Kernehan, R. J., M. R. Headrick, and R. E. Smith. 1981. Early life history of striped bass in the Chesapeake and Delaware Canal and vicinity. Transactions of the American Fisheries Society 110:137–150.

Koo, T. S. Y. 1970. The striped bass fishery in the Atlantic states. Chesapeake Science 11:73–93.

Michaelson, D. P., J. J. Ney, and T. M. Sutton. 2001. Largemouth bass predation on stocked striped bass in Smith Mountain, Virginia. North American Journal of Fisheries Management 21:326–332.

McKown, K. A. and B. H. Young. 1992. Effects of year class strength on size of young-of-the-year striped bass. Pages 265–275 *in* C. L. Smith, editor. Estuarine Research in the 1980's. Hudson River Environmental Society, Seventh Symposium on Hudson River Ecology. State University of New York Press, Albany.

Morgan, R. P. II, V. J. Rasin Jr., and L. A. Noe. 1983. Sediment effects on eggs and larvae of striped bass and white perch. Transactions of the American Fisheries Society 112:220–224.

Muncy, R. J., G. J. Atchison, R. V. Bulkley, B. W. Menzel, L. G. Perry, and R. C. Summerfelt. 1979. Effects of suspended solids and sediment on reproduction and early life of warmwater fishes. Iowa State University of Science and Technology. Ames. EPA Contract CC80741-J. U. S. Environmental Protection Agency. Corvallis.

O'Bara, C. J. 2004. Ohio River Recreational Angling Survey 2001–2003. West Virginia Division of Natural Resources, Parkersburg, West Virginia.

Pearson, W. D. and L. A. Krumholz. 1984. Distribution and status of Ohio River fishes. ORNL/SUB/79–7831/1. Oak Ridge National Laboratory, Oak Ridge.

Ploskey, G. R. and R. M. Jenkins. 1982. Biomass model of reservoir fish and fish-food interactions, with implications for management. North American Journal of Fisheries Management 2:105–121.

Robichaud-LeBlanc, K. A., S. C. Courtenay, and T. J. Benfey. 1998. Distribution and growth of young-of-the-year striped bass in the Miramichi River Estuary, Gulf of St. Lawrence. Transactions of the American Fisheries Society 127:56–69.

Rulifson, R. A. and C. S. Manooch III. 1990. Recruitment of juvenile striped bass in the Roanoke River, North Carolina, as related to reservoir discharge. North American Journal of Fisheries Management 10:397–407.

SAS. 1988. SAS/STAT user's guide, release 6.03 edition. SAS Institute, Cary, North Carolina.

Schell, S. A., D. J. Bright, J. A. Marshall, and M. A. Greenlee. 1996. Ohio River recreational use survey 1992–1993. Ohio Department of Natural Resources, Division of Wildlife. Athens.

Trautman, M. B. 1981. The fishes of Ohio. Ohio State University Press, Columbus.

Turner, J. L. and H. K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 101:442–452.

Ulanowicz, R. E. and T. T. Polgar. 1980. Influence of anadromous spawning behavior and optimal environmental conditions upon striped bass (*Morone saxatilis*) year-class success. Canadian Journal of Fisheries and Aquatic Sciences 37:143–154.

Uphoff, J. H. Jr. 1989. Environmental effects on survival of eggs, larvae, and juveniles of striped bass in the Choptank River, Maryland. Transactions of the American Fisheries Society 118:251–263.

Van Den Avyle, M. J. and B. J. Higginbotham. 1979. Growth, survival and distribution of striped bass stocked in Watts Bar Reservoir, Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33:361–370.

Van Hassel, J. H., R. J. Reash, H. W. Brown, J. L. Thomas, and R. C. Matthews Jr. 1988. Distribution of upper and middle Ohio River fishes, 1973–85: I. Associations with water quality and ecological variables. Journal of Freshwater Ecology 4:441–458.

Van Winkle, W., B. L. Kirk, and B. W. Rust. 1979. Periodicities in Atlantic Coast striped bass (*Morone saxatilis*) commercial fisheries data. Journal of the Fisheries Research Board of Canada 36:54–62.