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Population Dynamics of a Reservoir Sport Fish Community in Response to Hydrology

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Abstract.—Sport fish from Normandy Reservoir, Tennessee, were sampled for more than 6 years with a variety of gears targeting different life stages. Normandy Reservoir experienced different hydrologic regimes over the sampling period that we roughly grouped into dry years (1992 and 1995), intermediate years (1993 and 1997), and wet years (1994 and 1996). Year-class strength of largemouth bass *Micropterus salmoides* was fixed each year by late summer or early fall. Catch of age-1 largemouth bass in spring electrofishing samples was directly related to the number of days the reservoir was at or over full pool when the fish were age 0. Largemouth bass produced in a wet year and intermediate year were more than twice as abundant at age 3 than fish produced in two dry years. Recruitment of spotted bass *M. punctulatus* could not be linked to reservoir hydrology. Crappies *Pomoxis* spp., white bass *Morone chrysops,* and saugeyes (walleye *Stizostedion vitreum* × sauger *S. canadense*) produced poor year-classes in dry years and strong year-classes in wet years. The responses of these latter three taxa in intermediate years were variable, although they were more characteristic of dry-year responses than wet-year responses. Recruitment of crappies, white bass, and saugeyes was positively related to mean daily discharge of the reservoir in the prespawn period (1 January to 31 March) each year. Recruitment of largemouth bass was dependent on high water during the spring and summer when fish were age 0. Water-level fluctuation in this Tennessee reservoir played a pivotal role in regulating year-class strength of most sport fish species. Attempts to enhance year-class strength of fishes in tributary storage impoundments should focus on altering the hydrology of systems.

Identifying mechanisms regulating recruitment and year-class strength is a prerequisite to successful fisheries management in any system, and these issues have come to the forefront of basic reservoir research in recent years. Methods of predicting effects of changes in reservoir operations on fish populations need to be addressed because modifying reservoir operations is one of the few options available to fishery managers trying to enhance a fishery. Water-level fluctuations, readily observed characteristics separating reservoirs from natural lakes, are the result of meeting the primary objectives of reservoir operation: hydropower generation, water supply, and flood control. High spring water levels in a variety of systems have effected strong year-classes in many fish species: walleye *Stizostedion vitreum* in Michigan (Jude 1992); walleye and yellow perch *Perca flavescens* in Minnesota (Kallemeyn 1987); and yellow perch, white bass *Morone chrysops,* and buffalo *Ictiobus* spp. in South Dakota (Martin et al. 1981). Spring flooding has been linked to enhanced year-class strength of largemouth bass *Micropterus salmoides* in other reservoirs (e.g., Aggus and Elliot 1975; Martin et al. 1981; Miranda et al. 1984; Noble 1986; Reinert et al. 1997). Some reservoirs are managed for spring flooding and above-average summer pools to provide more habitat for age-0 black bass *Micropterus* spp., based upon empirical evidence that the abundance of larger black bass usually increases in the following year (Ploskey et al. 1996). First-year growth and weekly survival of age-0 largemouth bass in Normandy Reservoir were related to reservoir hydrology (Sammons et al. 1999). Wet years produced large cohorts that hatched early, grew fast, and survived well; dry years produced small cohorts that hatched late, grew slower, and survived poorly. Management strategies usually assume that greater abundance of age-0 fish will increase recruitment into the fishery, but this view may be too simplistic. Empirical relations between year-class strength and hydrology are critical for proper management and can enhance the bargaining position of fish managers negotiating with water-resources managers. Effects of water-level manipulation are not documented sufficiently and still cannot be predicted with any degree of confidence (Miranda et al. 1984).

Our objectives were to (1) quantify relationships

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between water-level fluctuations and recruitment of sport fish populations in Normandy Reservoir, Tennessee, and (2) identify the critical period of recruitment to the fishery for black crappies *P. nigromaculatus* and white crappies *P. annularis* (hereafter ''crappies''), largemouth bass and spotted bass *M. punctulatus* (hereafter ''black bass''), white bass, and saugeyes (walleye × sauger *S. canadense).* Saugeyes were included in this study when they were found to be reproducing naturally in the reservoir (Fiss et al. 1997).

Methods

Each spring from 1992 to 1997, samples of larval crappies, white bass, and saugeyes in Normandy Reservoir (Sammons et al. 1999 describes this reservoir) were collected weekly to compare larval densities with measures of recruitment to the fishery (Sammons and Bettoli 1998a). We compared geometric mean density among years by using repeated measures analysis of variance (ANOVA) procedures (Maceina et al. 1994; SAS Institute 1995). Statistical significance for tests in the study was set at $\alpha = 0.05$, or at $\alpha = 0.10$ when $N \leq 5$.

Age-0 black bass were collected with a DC electrofishing unit and a hand-held anode (as described in Sammons et al. 1999); 24 stations (6 stations in each of 4 areas) were electrofished biweekly between July and September from 1992 to 1997. Black bass were also sampled in the spring (March–April) and fall (October–November) each year with a DC electrofishing boat equipped with boom-mounted electrodes. Each season we collected black bass at night from 40 randomly selected 100-m transects stratified by lake area and habitat (Sammons and Bettoli 1999). All black bass collected were sacrificed and their otoliths were removed. All electrofishing catch data (number of fish/100 m) were $\log_{10}(X + 1)$ transformed before analysis. Catch rates of different year-classes were calculated for each sample. We ranked the catch of each cohort over time in different gears to determine when year-class strength of black bass was fixed in Normandy Reservoir (Forney 1976). Comparisons of catch among years were made using ANOVA; differences in catch among years were tested using Tukey's Studentized range procedures.

Recruitment of crappies to the fishery was assessed in August cove samples at three sites, totaling 2.11 ha, where rotenone was applied following standard methods (Bettoli and Maceina 1996). Recruitment of white bass and saugeyes to the fishery was assessed using catch of age-1 fish in horizontal gill nets set lakewide in early October. Nets were deployed at 11 fixed stations each year. We used sinking experimental monofilament gill nets (46.9 m long × 1.8 m deep; six mesh sizes 19, 25, 38, 51, 64, and 76 mm). Catch data were $\log_{10}$ transformed and compared among years using ANOVA and Tukey's Studentized range procedure (SAS Institute 1995).

TABLE 1.—Hydraulic data for Normandy Reservoir over the course of the study. Data included first day of the year the reservoir achieved consistent (>10 d) full pool, number of days reservoir was at or over full pool during the spring and summer (Spring–summer DOFP), and mean daily discharge of Normandy Dam in the prespawn period (1 January to 31 March).

Year	First day of year at full pool	Spring–summer DOFP (d)	Prespawn mean discharge (m^3/s)
1991	120	78	27.6
1992	178	31	12.0
1993	116	68	11.7
1994	98	92	29.0
1995	129	40	10.0
1996	117	95	17.0
1997	124	80	24.0

All fish from boom-mounted electrofishing, cove samples, and gill-net samples were measured to the nearest millimeter total length (TL) and aged using right sagittal otoliths examined under a dissecting microscope in whole view. We verified ages of fish that appeared to be age 3 and older by cracking the left otolith in half through the focus, polishing the broken edge, mounting it under water, and using a fiber-optic strand (0.5-mm diameter) to illuminate annuli.

All water-level and discharge data were obtained from Tennessee Valley Authority. Water levels were recorded at the dam at midnight. Relations between the measures of recruitment for each species and hydraulic data were tested using simple linear regression (SAS Institute 1995).

Results

Hydrology

Water-level patterns in Normandy Reservoir were described by Sammons et al. (1999) and followed three distinct patterns during the study: dry, intermediate, and wet. Water levels in two dry years (1992 and 1995) were slow to reach full pool, and spring and summer reservoir water levels remained at or above full pool only briefly (≤40 d). In three intermediate years (1991, 1993, 1997), the reservoir reached full pool in late April (Table 1),

TABLE 2.—Geometric mean catch in electrofishing samples of six year-classes (1992–1997) of largemouth bass and spotted bass at intervals during their first year of life in Normandy Reservoir, Tennessee. Values in brackets are ranks; values in parentheses are upper and lower 95% confidence intervals.

Year-class	Geometric mean catch (fish/100 m)			
	Hand-held probe		Boom-mounted probes	
	Early Aug	Late Sep	Fall (age 0)	Spring (age 1)
Largemouth bass				
1992	1.70 [3]	0.70 [5]	0.15 [5]	0.19 [5]
	(0.97, 2.61)	(0.28, 1.24)	(0.02, 0.29)	(0.03, 0.37)
1993	4.81 [1]	0.95 [3]	0.43 [3]	0.60 [4]
	(3.44, 6.60)	(0.54, 1.46)	(0.23, 0.68)	(0.33, 0.91)
1994	2.50 [2]	1.54 [2]	1.20 [1]	1.74 [2]
	(1.62, 3.79)	(1.07, 2.14)	(0.71, 1.83)	(1.23, 2.38)
1995	1.62 [5]	0.42 [6]	0.09 [6]	0.16 [6]
	(0.84, 2.70)	(0.14, 0.73)	(0.00, 0.19)	(0.03, 0.32)
1996	1.69 [4]	0.79 [4]	0.35 [4]	1.83 [1]
	(0.97, 2.68)	(0.40, 1.23)	(0.17, 0.56)	(1.22, 2.60)
1997	1.29 [69]	1.93 [1]	0.67 [2]	0.71 [3]
	(0.69, 2.10)	(1.24, 2.83)	(0.42, 0.96)	(0.42, 1.07)
Spotted bass				
1992	0.52 [5]	0.58 [4.5]	0.57 [2]	0.85 [1]
	(0.26, 0.85)	(0.27, 0.98)	(0.32, 0.85)	(0.45, 1.37)
1993	0.11 [6]	0.06 [6]	0.56 [3]	0.71 [2]
	(0.00, 0.25)	(0.00, 0.19)	(0.33, 0.85)	(0.44, 1.02)
1994	1.20 [2]	1.44 [2]	1.45 [1]	0.53 [4]
	(0.64, 1.96)	(0.78, 2.34)	(0.97, 2.03)	(0.28, 0.83)
1995	0.64 [4]	2.52 [1]	0.43 [5]	0.33 [6]
	(0.26, 1.16)	(1.66, 3.66)	(0.25, 0.63)	(0.14, 0.54)
1996	1.44 [1]	1.11 [3]	0.44 [4]	0.65 [3]
	(0.75, 2.40)	(0.58, 1.83)	(0.22, 0.69)	(0.34, 1.03)
1997	0.88 [3]	0.58 [4.5]	0.35 [6]	0.51 [5]
	(0.52, 1.32)	(0.22, 1.05)	(0.18, 0.55)	(0.25, 0.82)

and spring and summer water levels remained at or above full pool for more than 60 d before falling below full pool in July. In two wet years (1994 and 1996), reservoir levels remained over full pool throughout much of the summer (>90 consecutive days; Table 1). In 1994, the reservoir exceeded full pool on March 25, and again on April 7; whereas, in 1996 the reservoir reached full pool on April 26. Mean daily discharge during the prespawn period (1 January–31 March) was highest in 1991, 1994, 1997, and 1996, indicating that these years were characterized by high precipitation.

Black Bass

Repeated measures ANOVA, which compared electrofishing catch rates throughout the summer each year, revealed annual differences in the density of age-0 largemouth bass (F = 9.42; df = 5, 710; P = 0.0001). Mean summer densities of age-0 largemouth bass were highest in 1993; slightly lower in 1994 and 1997; and similarly low in 1992, 1995, and 1996. Age-0 spotted bass summer densities also differed among years (F = 9.33; df = 5, 650; P = 0.0001); mean summer densities were highest in 1994 and 1996 and lowest in 1993.

There was often no relation between abundance of age-0 largemouth bass in midsummer (peak abundance) and abundance in late summer (Table 2); for instance, the most abundant year-class in early August samples (1993) was the third most abundant in late September samples. However, the abundance ranking of each largemouth bass cohort in late summer was similar to their rank in fall and spring electrofishing samples (Table 2), except for 1996, when abnormally high water levels in the fall decreased our sampling efficiency. Spotted bass showed no relationship among abundance ranks in any of the four time intervals examined for largemouth bass (Table 2).

Abundance of largemouth bass as age-1 fish in spring electrofishing samples was used as a measure of recruitment for each year-class; abundance varied almost an order of magnitude over 6 years (F = 17.69; df = 5, 234; P = 0.0001; Table 3). Spotted bass cohorts did not differ in abundance

TABLE 3.—Measures of recruitment for various fish species in Normandy Reservoir, Tennessee. Gear types are as follows: spring electrofishing (EF), mean density in cove samples (CR), and mean catch in horizontal gill nets (GN). Geometric means within species with a letter in common did not significantly differ (Tukey's test, $\alpha = 0.05$).

Species	Gear and unit	Year-classes						
		1991	1992	1993	1994	1995	1996	1997
Largemouth bass	EF (age-1 fish/100 m)		0.19 yz	0.58 yz	1.74 x	0.16 z	1.83 x	0.71 y
Spotted bass	EF (age-1 fish/100 m)		0.85 z	0.71 z	0.53 z	0.33 z	0.65 z	0.51 z
Crappies	CR (age-1 fish/ha)	97 y	0 z	1 z	1,358 x	0 z	35 y	
White bass	GN (age-1 fish/net night)	2.52 y	0.06 z	0.21 z	2.10 yz	0 z	0.81 yz	
Saugeye	GN (age-1 fish/net night)	0.57 z	0 z	0.06 z	2.84 y	0.06 z	0.21 z	

in any year ($F = 1.42$; df = 5, 234; $P = 0.2184$). Catch of age-1 largemouth bass was positively correlated with the number of days that Normandy Reservoir was over full pool when that cohort was age 0 (Figure 1). No such correlation existed for spotted bass.

Largemouth bass hatched in a high-water year (1994) and an intermediate year (1993) were more abundant as age-3 fish in spring electrofishing samples than cohorts produced in dry years (1992, 1995; Table 4). Sampling was terminated before the abundance of age-3 largemouth bass produced in 1996 and 1997 (wet and intermediate) was measured. Abundance of age-3 spotted bass was similar for all year-classes, regardless of reservoir hydrology when the cohort was age 0.

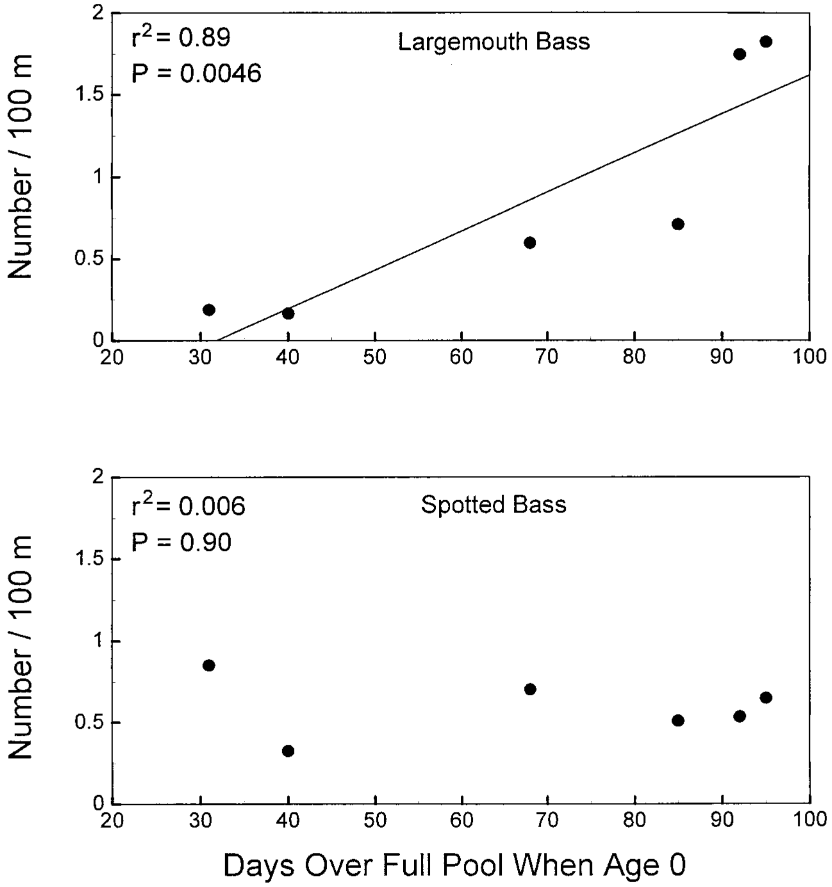

FIGURE 1.—Relations between catch of age-1 largemouth bass and spotted bass in spring electrofishing samples and number of spring and summer days, when the fish were age 0, that Normandy Reservoir was over full pool.

TABLE 4.—Geometric mean catch (95% confidence intervals) of age-3 largemouth bass ($F = 4.91$; df = 4, 156; $P = 0.0028$) and spotted bass ($F = 1.18$; df = 3, 156; $P = 0.3202$) produced in a wet year, an intermediate year, and two dry years in Normandy Reservoir, Tennessee. Means in columns with a letter in common did not significantly differ (Tukey's test, $\alpha = 0.05$).

Year-class	Hydrology	Geometric mean catch (fish/100 m)	
		Largemouth bass	Spotted bass
1992	Dry	0.169 z (0.052, 0.298)	0.509 z (0.314, 0.734)
1993	Intermediate	0.360 yz (0.163, 0.590)	0.244 z (0.097, 0.410)
1994	Wet	0.645 y (0.358, 0.994)	0.364 z (0.157, 0.607)
1995	Dry	0.189 z (0.080, 0.309)	0.406 z (0.198, 0.650)

Crappies, White Bass, and Saugeyes

Catch of age-1 crappies (mean 113 mm TL, range 70–256 mm) in cove samples differed among years ($F = 38.15$; df = 5, 12; $P = 0.0001$). Mean catch of age-1 crappies was highest for the 1994 year-class, intermediate for the 1991 and 1996 year-classes, and low for other year-classes (Table 3). Catch of age-1 crappies in cove samples was positively related to mean daily reservoir discharge from 1 January to 31 March in the year each year-class was produced (Figure 2).

Catch of age-1 white bass (mean 325 mm TL, range 254–394 mm) in gill nets differed among years ($F = 7.48$; df = 5, 60; $P = 0.0001$). Catch of the 1991 year-class was highest, followed by the 1994 and 1996 year-classes (Table 3). Catch in all other years was similar and low (Table 3). Peak larval catch of white bass was correlated with catch of age-1 fish in gill nets ($r^2 = 0.66$; $N = 5$; df = 1, 3; $P = 0.0953$). Catch of age-1 white bass in fall gill-net samples was positively related to mean daily reservoir discharge from 1 January to 31 March in the year each year-class was produced (Figure 2).

Catch of age-1 saugeyes (mean 419 mm TL, range 251–479 mm) in gill-net samples also differed among years ($F = 14.20$; df = 5, 60; $P = 0.0001$). Catch of the 1994 year-class was higher than any other year-class (Table 3). Catches of the 1991 and 1996 year-classes were 4–10 fold higher than the next highest year-class but were not significantly different (Table 3). Similar to white bass and crappies, catch of age-1 saugeyes in fall gill-net samples was positively related to mean daily reservoir discharge from 1 January to 31 March in the year each year-class was produced (Figure 2).

Discussion

Black Bass

In Normandy Reservoir, largemouth bass year-class strength was fixed late in the year and was dependent on the amount of water the system held throughout the summer. When water levels dropped in late summer, largemouth bass experienced reduced survival and abundance (Sammons et al. 1999). Reinert et al. (1997) also noted that a decrease in surface area of four southeastern reservoirs was linked to decreased abundance of age-0 black bass. Similar to our findings in Normandy Reservoir, Jackson et al. (1991) documented high mortality of age-0 largemouth bass in summers when water levels fell below the conservation pool in Lake Jordon, North Carolina. Decreasing water levels reduce shoreline cover available to age-0 black bass, exposing them to increased rates of predation and reducing their feeding efficiency (Aggus and Elliot 1975; Irwin et al. 1997).

High water levels in Normandy Reservoir increased the numbers of harvestable largemouth bass in the fishery. When fish were age 3, largemouth bass produced in a wet year were still more than twice as abundant as fish produced in either a dry or intermediate year. These increases fell within the range of those predicted or observed by other authors (Gutreuter and Anderson 1985; Novinger 1988). High-water years in Normandy Reservoir produced cohorts of largemouth bass characterized by bimodal length distributions and fast growth (Sammons et al. 1999), which allowed the fish to reach harvestable sizes (minimum length limit is 381 mm in Normandy Reservoir) faster than other cohorts. Largemouth bass in the upper length mode of both the 1994 and 1996 year-classes were 18–52% larger than fish in the 1992 or 1993 year-classes at similar life stages (Sammons and Bettoli 1998b).

Unlike largemouth bass, spotted bass recruitment was similar over all 6 years. Little work has been published on spotted bass ecology in reservoirs; however, either our gear did not sample them effectively or spotted bass recruitment was unaffected by reservoir water levels. Ploskey et al. (1996) found that biomass of small spotted bass in Bull Shoals Reservoir, Arkansas, was correlated with flooding during the spawning, postspawning, and summer periods. However, biomass of small spotted bass was not well correlated with abundance of the next-year's intermediate-sized spotted bass in that system ($r^2 = 0.30$; $P = 0.01$; Ploskey et al. 1996), making the effect of hydrology on

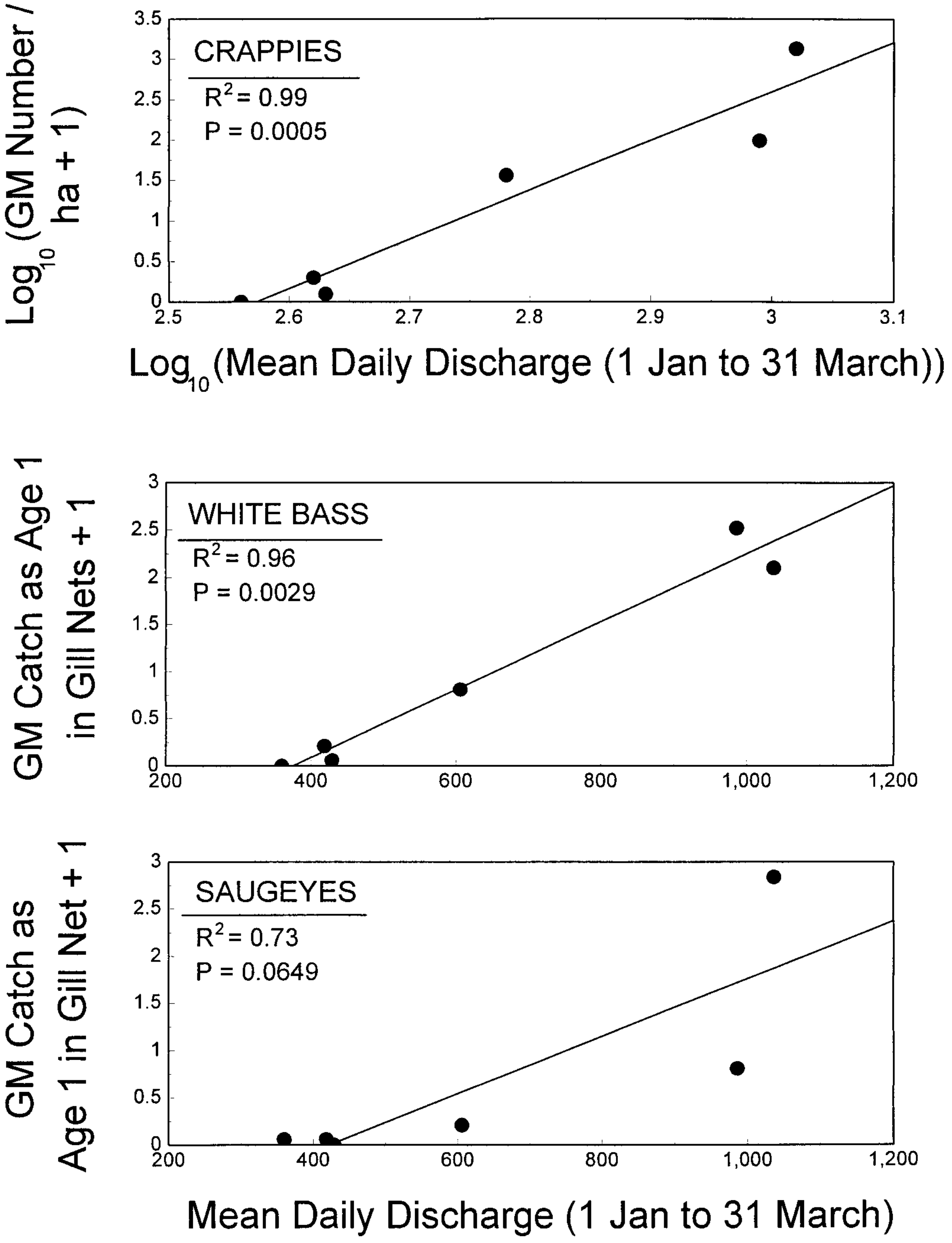

FIGURE 2.—Relations between geometric mean (GM) catches of crappies (top panel), white bass (middle), and saugeyes (bottom) to mean daily discharge from Normandy Reservoir, Tennessee, between 1 January to 31 March in the year each year-class was produced from 1992 to 1997.

recruitment to the fishery difficult to isolate. Abundance of age-0 spotted bass was greater with an increase in reservoir surface area during spring and summer in three of four southeastern reservoirs examined by Reinert et al. (1997).

Crappies

In Normandy Reservoir, the only strong year-classes of crappies produced during this study were in 1991, 1994, and 1996, which corresponded with high discharge levels early in the year. Catches of larval crappies were correlated with catch of the same year-class as age-1 fish in cove samples the following summer (Sammons and Bettoli 1998a), indicating that the critical period of these species was at or before the larval stage.

In reservoirs, water-level fluctuations are probably an important environmental variable determining crappie year-class strength (Willis 1986); however, the timing is different than that required for strong year-classes of largemouth bass. Groen and Schroeder (1978) and McDonough and Buchanan (1991) found that rising spring water levels increased relative abundance of white crappies. Similar to our data from Normandy Reservoir, Maceina and Stimpert (1998) noted that high water in late winter-early spring was required for crappies to reproduce successfully in Alabama tributary storage impoundments. They believed that high flows in these reservoir early in the year were a spawning cue for crappies, even in cases when the flow happened many weeks before the fish actually spawned. In Normandy Reservoir, strong year-classes of crappies were produced in years when mean daily discharge was more than 15 m^3/s in the prespawn period. In contrast, weak year-classes were produced when mean daily discharge in the prespawn period was under 15 m^3/s.

White Bass and Saugeyes

Effects of reservoir hydrology on fish species other than black bass and crappies are not well-known. In particular, little has been published in the primary literature about factors affecting white bass recruitment. As in Normandy Reservoir, white bass exhibit great variations in year-class strength in other systems (Yellayi and Kilambi 1976; Staggs and Otis 1996). In two South Dakota natural lakes, age-0 white bass abundance was correlated with spring precipitation and air temperature (Pope et al. 1997). Age-0 white bass were more abundant in Lake Francis Case, South Dakota, in a high-water year than a low-water year (Martin et al. 1981); however, precise measurements of year-class strength or hydrology were not given. In Normandy Reservoir, strong year-classes of white bass were produced in 1991, 1994, and 1996, and some reproduction occurred in 1993. Similar to crappies, high discharge levels in the prespawn period may have acted as a spawning cue for white bass; however, their reproduction may be less keyed to high discharge events than crappies because at least some fish spawned in 1993, when mean daily discharge was low (11.7 m^3/s). However, similar to crappies, discharge levels had to be more than 15 m^3/s if white bass were to produce a large year-class in Normandy Reservoir. Catch rates of larval white bass were correlated with gill-net catches of age-0 (Sammons and Bettoli 1998a) and subsequently age-1 fish. Therefore, it appears the critical period for this species is at or before spawning, similar to crappies.

Saugeyes, similarly, have not been extensively studied. Because natural recruitment of this stocked hybrid is usually an unwelcome surprise to fisheries managers, little research has been conducted to determine factors controlling such recruitment. However, high water has been linked to walleye spawning success in a number of systems (e.g., Kallemeyn 1987; Willis and Stephen 1987; Jude 1992). Walleye year-class strength in two Kansas reservoirs showed a domed response to spring storage ratios. Year-class strength was weak in years with high discharge, strongest at intermediate discharge, and virtually nonexistent in dry years (Willis and Stephen 1987). High water apparently decreased survival of juvenile fish to the point that recruitment was nil. However, similar to Normandy Reservoir, walleye recruitment was poor in dry years. Johnston et al. (1995) found that larval abundance of walleyes in a tributary of Dauphin Lake, Manitoba, was correlated to river discharge 35 d before median larval drift date. They speculated that adult walleyes coming upstream from the lake used high flows as a spawning cue. Although our larval sampling program began too late in the year to effectively sample saugeye larvae, large numbers of saugeye larvae were collected only in the year with the highest prespawn discharge levels (1994; Sammons and Bettoli 1998b) and the highest catch of age-1 fish in gill nets. It appeared that the critical period of saugeyes, similar to crappies and white bass, occurred at or before the larval stage.

Management Implications

Reservoir hydrology can play a pivotal role in fish recruitment. Not surprisingly, environmental requirements for successful spawning differ among species. Our results define the combination of hydraulic factors (reaching full pool early in spring; maintaining full pool for at least 90 d) that allow largemouth bass in Normandy Reservoir to produce strong year-classes. High water produced an expanded littoral habitat for age-0 largemouth bass, allowing them to experience rapid growth and survival (Sammons et al. 1999), which ultimately resulted in strong year-classes. Production of fast-growing largemouth bass ultimately resulted in more than twice as many adult bass recruiting to the fishery; many of those individuals reached harvestable size faster than cohorts spawned in other years. However, high water in the summer was of less benefit to other species, such as crappies, white bass, and saugeyes, all of which have limnetic larvae. The combination of hydraulic factors necessary for these species to produce strong year-classes was quite different from largemouth bass. Recruitment success for these species appeared to be linked to high discharge levels early in the year (mean of at least 15 $m^3 \cdot s^{-1} \cdot d^{-1}$ between 1 January and 31 March), before the spawning periods, and was probably a spawning cue for adults. Unlike largemouth bass, once the adults of these species spawned successfully, strong year-classes were assured. Management to improve crappie, white bass, and saugeye recruitment can be compatible with management for largemouth bass for two reasons. First, a strong serial correlation usually exists between hydrologic conditions in early spring, spring, and early summer. Conditions that produce high discharge in early spring usually produce above-average water levels in early summer. Second, high pool levels in summer, which are important to largemouth bass recruitment, can be provided without adversely affecting the recruitment of crappies, white bass, or saugeyes.

Novinger (1988) concluded that production of large year-classes of largemouth bass in Table Rock Reservoir was controlled by the timing, extent, and duration of flooding. Production of a strong year-class of largemouth bass could be achieved by manipulating water levels in the reservoir to flood no later than the middle of the largemouth bass spawning period and by maintaining high water levels through August. Biologists in other areas of the country have proposed similar plans to enhance year-class strength of fishes in reservoirs (Miranda et al. 1984; Ploskey 1986; Willis 1986).

Given the obvious benefits of high water to reservoir populations of largemouth bass, fisheries managers have attempted to artificially reproduce these effects. Most authors agree that the primary benefit of high water levels in reservoirs is increasing the amount of flooded vegetation available to age-0 black bass. Although some managers have attempted to change reservoir operations to artificially create floods (e.g., Ploskey 1986; Willis 1986), in most cases this is not possible because managing water levels for black bass would conflict with other water management plans. Therefore, reservoir managers have attempted to provide more cover for age-0 black bass and enhance their survival in years of low water by constructing shoreline habitat in areas with little natural cover.

Addition of spawning habitat may successfully increase year-class strength of black bass in systems where year-class strength is often fixed very early in life. Kramer and Smith (1962) found that year-class strength of largemouth bass in a natural lake was set by the time fish were 2 weeks old; in that system, increasing the number of fish that spawn may increase year-class strength. However, year-class strength of largemouth bass in Normandy Reservoir was set by late October. Novinger (1988) found a similar critical period in Table Rock Reservoir. In some reservoirs, enhancing spawning success would probably have little effect on year-class strength.

Novinger (1988) believed that any effect of habitat enhancement would be masked by systemwide effects of high water. We concur with this observation and believe that any increase in black bass year-class strength resulting from habitat enhancement in Tennessee tributary impoundments would be far outweighed by the typical increase gained in a high-water year. Trying to duplicate the effects of high water using artificial habitat enhancement would involve changing the habitat in virtually the entire reservoir, which would be prohibitively expensive. Maximizing the number of days at or over full pool in Normandy Reservoir will lead to more consistent recruitment, faster growth, and more individuals of virtually every sport fish species in the lake. Attempts to enhance year-class strength of largemouth bass in Tennessee impoundments should focus on the hydrology of systems and not on littoral habitat enhancement.

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