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Recruitment Variation of Crappies in Response to Hydrology of Tennessee Reservoirs

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Abstract.—Black crappies *Pomoxis nigromaculatus* and white crappies *P. annularis* were sampled to index recruitment in seven Tennessee reservoirs (four main-stem and three tributary storage impoundments). Crappie recruitment in tributary storage impoundments appeared to be consistently higher in years of high discharge during the prespawn period (1 January–31 March). A similar relation was found in one main-stem impoundment; however, crappie recruitment in two main-stem impoundments was inversely related to discharge during the spawning period (1 April–30 May), and little recruitment variation was found in the fourth main-stem impoundment. In general, reservoir hydrology appeared to have a stronger effect on crappie recruitment in tributary storage impoundments than in main-stem impoundments, possibly because recruitment was more variable in tributary systems. Thus, it is likely that crappie populations will rarely have strong year-classes simultaneously over a wide geographic area or even within a single watershed.

Recruitment of fishes is a keystone topic of interest to fisheries managers. Ability to predict year-class strength of fishes in advance is a powerful tool assisting biologists to forecast future harvests and angler satisfaction with fisheries resources (Colvin 1991). Fish recruitment is often driven by external abiotic forces such as rainfall (Pope et al. 1997), wind (Guy and Willis 1995), and air temperature (Nelson 1978). In reservoirs, hydrology can play a major role in fish recruitment (Ploskey 1986). Although recruitment of largemouth bass *Micropterus salmoides* in reservoirs has been frequently evaluated (e.g., Miranda et al. 1984; Ploskey et al. 1996; Maceina and Bettoli 1998), other sport fishes have been less frequently studied.

Black crappie *Pomoxis nigromaculatus* and white crappie *P. annularis* (hereafter crappies) are important sport fish in most reservoirs, often ranking first or second in angler preference (Colvin 1991; McDonough and Buchanan 1991; Mitzner 1991). Crappie recruitment is variable; a strong year-class often forms only once every 3–5 years in many large systems (Swingle and Swingle 1967; Guy and Willis 1995). Widely fluctuating year-class strength can cause problems for fisheries managers because harvest is often supported by one or two year-classes (Colvin 1991), and several years of poor recruitment can significantly reduce

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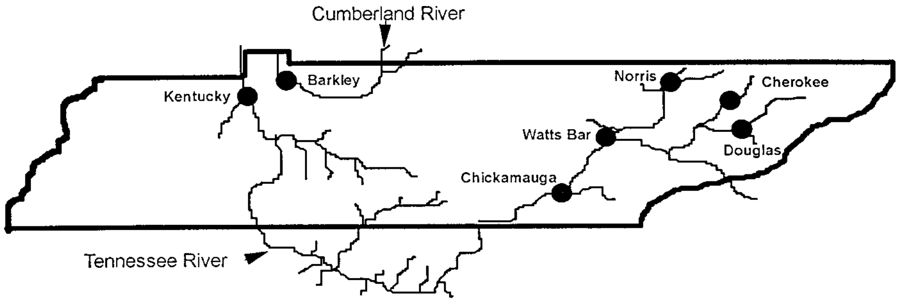

FIGURE 1.—Location of seven Tennessee reservoirs sampled for black and white crappies with trap nets and electrofishing from 1992 to 1999.

harvest rates. Some research has indicated that crappie recruitment in reservoirs may be affected by water levels (Mitzner 1991) or flushing rates (Beam 1983). Strong year-classes of crappies in tributary storage impoundments in Alabama were associated with high winter water levels (Maceina and Stimpert 1998). However, crappie recruitment is often not synchronous even within a small geographic area (Colvin 1991), and more work is needed to more fully define variations in crappie recruitment in reservoirs. The objective of this study was to identify relations between reservoir hydrology and year-class strength of crappies in Tennessee reservoirs.

Methods

Fish were collected from seven reservoirs in two watersheds throughout Tennessee (Figure 1). Reservoirs were of two types: (1) main-stem impoundments that typically had low retention times (<30 d) and minimal water-level fluctuations (<3 m), and (2) tributary storage impoundments that typically had high retention times and large water-level fluctuations (Table 1).

TABLE 1.—Reservoir type (M = main stem, T = tributary), size at full pool, mean depth, mean annual water-level fluctuation, and mean annual hydraulic retention time for the seven Tennessee reservoirs sampled for black and white crappies.

Reservoir	Type	Size (ha)	Mean depth (m)	Water fluctuation (m)	Retention time (d)
Barkley	M	23,458	4.6	1.6	6
Cherokee	T	12,272	12.3	16.6	168
Chickamauga	M	14,337	5.0	2.3	10
Douglas	T	12,393	10.1	18.8	105
Kentucky	M	64,922	5.2	1.6	23
Norris	T	13,851	15.7	18.0	250
Watts Bar	M	16,038	7.9	1.9	19

Crappie recruitment was assessed by one of two methods. Whenever possible, recruitment was estimated using historical catch databases of age-0 crappies in fall trap-net samples (fish/net-night) obtained by the Tennessee Wildlife Resources Agency (TWRA). Catches of age-0 crappies were analyzed because previous data has indicated that year-class strength of crappies is set at the larval stage in Tennessee reservoirs (Sammons and Bettoli 1998a; Sammons et al. 2000). This method allowed us to test the longest possible period in each reservoir, thus increasing power of the tests. However, due to nonstandardization of sampling sites and low catches, this was only possible in Barkley Reservoir (N = 34 net-nights annually) and Cherokee Reservoir (N = 106 net-nights annually). Barkley Reservoir was sampled from 1991 to 1998; Cherokee was sampled from 1992 to 1999, except 1994. In the remaining six lakes, recruitment variation was assessed using residuals derived from catch curves (Maceina 1997).

Crappies were collected for catch-curve analyses using trap nets or DC electrofishing in the fall. Trap nets were standard Indiana style with 13-mm mesh. Nets were set in fixed locations within each reservoir; fish were removed from the nets after 24 and 48 h. Electrofishing was conducted during the day at a maximum of 10 sites selected from the length of the reservoir (upper, middle, and lower sections; Maceina and Stimpert 1998). Sampling was designed specifically to obtain large numbers of fish (>200); therefore, samples were not standardized by transect length or time. Species were pooled for analysis if samples were composed of roughly equal numbers of each species. Otherwise, analysis was performed using the more abundant species within the reservoir (Table 2). We assumed that species-specific differences in recruitment did not occur (Maceina and Stimpert 1998); data from Normandy Reservoir, Tennessee, supported this

TABLE 2.—Tennessee reservoirs sampled for crappie catch-curve analyses, along with the capture gear, ages, and total number of fish (*N*) used in the analyses.

Reservoir	Species	Gear	Ages	*N*
Barkley	Both crappies	Trap net	0–5	685
Cherokee	Black crappie	Trap net	0–5	381
Chickamauga	Black crappie	Electrofishing	2–7	256
Douglas	Both crappies	Trap net	0–7	664
Kentucky	White crappie	Trap net	0–6	1,319
Norris	Black crappie	Trap net	0–7	1,467
Watts Bar	White crappie	Electrofishing	2–9	178

assumption (Sammons and Bettoli 1998b). All crappies collected were measured for total length (mm) and weight (g). A subsample (10 fish per 2.54-cm length-group of each species) was taken to the laboratory, where otoliths were removed for aging. Ages were then assigned to the rest of the sample using an age–length key. Catch-curve analyses (Ricker 1975) were performed on age structure by regressing the natural logarithm of the number of crappies caught in each year-class with age. Catch-curves were created using weighted regression to decrease the influence of rare, older fish (Steel and Torrie 1980; Slipke and Maceina 2000). Crappies were assumed to have recruited to trap nets by age 0 (mean TL = 80 mm, range = 47–157 mm) and to electrofishing by age 2 (mean TL = 186 mm, range = 120–296 mm; Table 2).

Hydrologic data for each reservoir were obtained from the Tennessee Valley Authority. Mean daily discharge and reservoir storage volumes were calculated for three periods each year: prespawn (1 January to 31 March), spawning (1 April to 30 May) and summer (1 June to 30 September). Crappie recruitment was related to these hydrologic variables using simple linear or nonlinear regression (SAS Institute 1996). Each reservoir was examined individually, except for Watts Bar and Chickamauga reservoirs, which were combined to increase power. This was reasonable because Watts Bar Reservoir is immediately above Chickamauga Reservoir on the upper Tennessee River and both function similarly. In that case, each residual and discharge combination for both reservoirs were pooled to create the regression model. Crappie recruitment was assessed using both residuals from catch curves and catch of age-0 crappies in Barkley and Cherokee reservoirs to compare the two methods. Significance for all statistical tests was set at $\alpha = 0.10$.

Results

Crappie recruitment in Cherokee and Douglas reservoirs was significantly and positively related to mean daily discharge in the prespawn period (Table 3). A similar relation, but only marginally significant, was observed in Norris Reservoir. Models derived from catch-curve residuals and catch of age-0 fish in Cherokee Reservoir performed similarly (Table 3). No other relations were detected between recruitment and discharge in any other period, and no relations between recruitment and storage volume were detected in any period.

Similar to the tributary storage impoundments, crappie recruitment in Barkley Reservoir was positively related to prespawn discharge using either the residual or catch of age-0 models (Table 3). Crappie recruitment in Chickamauga and Watts Bar reservoirs was negatively correlated to discharge during the spawning period. A similar relation was found in Kentucky Reservoir; however, it only explained 3% of the variation in crappie recruitment (Table 3). No other significant relations were found between crappie recruitment and any other hydrologic variable in any period in any reservoir.

Discussion

Models derived from catch-curve residuals and catch of age-0 crappies in trap nets provided similar results for Cherokee and Barkley reservoirs; however, in each case the catch-curve model was weaker. This is probably due to the fact that catch-curve models had slightly less power because of a smaller sample size. However, it appears that both methods provided similar estimates of recruitment in those two systems.

Crappie recruitment in tributary storage impoundments appeared to be influenced by high discharge events early in the year, before crappie spawning. This is similar to the relation found for crappies in Normandy Reservoir, Tennessee, also a tributary storage impoundment (Sammons and Bettoli 2000). Similar relations have been observed in other systems. Years of above average precipitation usually resulted in higher than normal discharge and water levels in Tennessee res-

TABLE 3.—Individual relationships between measures of crappie recruitment and reservoir discharge for the seven Tennessee reservoirs. Measures of recruitment were either the catch of age-0 fish in fall trap-net samples or residuals generated from catch curves. Mean daily discharge was measured during either the prespawning or spawning period. The sign in parentheses next to the r^2 value indicates whether the relationship was positive or negative.

Reservoir by type	Measure of recruitment	Discharge period	df	P	r^2
Tributary					
Cherokee	Age 0 catch	Prespawning disch	1, 5	0.0769	(+) 0.75
	Residuals	Prespawning disch	1, 4	0.0961	(+) 0.56
Douglas	Residuals	Prespawning disch	1, 6	0.0093	(+) 0.70
Norris	Residuals	Prespawning disch	1, 5	0.1104	(+) 0.43
Main stem					
Barkley	Age-0 catch	Prespawning disch	1, 6	0.0246	(+) 0.60
	Residuals	Prespawning disch	1, 4	0.0715	(+) 0.45
Chickamauga and Watts Bar	Residuals	Spawning disch	1, 12	0.0730	(−) 0.24
Kentucky	Residuals	Spawning disch	1, 4	0.0804	(+) 0.03

ervoirs (Sammons and Bettoli 1998b, 2000). Miller et al. (1990) noted that abundance of age-0 black crappies in Lake Okeechobee, Florida, was correlated with high lake levels from December through April. Similar to our results, strong year-classes of crappies in tributary storage impoundments in Alabama were related to high winter water levels but not to reservoir hydrology during and after the spawn (Maceina and Stimpert 1998).

High water levels and flows before the spawning period may act as a spawning cue for adults (Maceina and Stimpert 1998), although the exact mechanism is not known. High water could allow greater feeding opportunities that could increase crappie condition and fecundity, leading to higher reproductive capability (Tyler and Dunn 1976). However, Mathur et al. (1979) found that fecundity of crappies in a Pennsylvania reservoir was not related to crappie recruitment. Maceina and Stimpert (1998) speculated that reproductive hormones in crappie populations of main-stem reservoirs may be influenced by hydrology, ultimately regulating recruitment success. However, further research in two Alabama reservoirs revealed that erratic crappie recruitment was not related to plasma hormonal concentrations or fecundity of female black and white crappies (Abernethy 2000). Furthermore, annual larval production of crappies in Normandy Reservoir, a tributary storage impoundment, was often zero in dry years, which suggested that crappies may not have spawned at all in those years (Sammons and Bettoli 1998a). Thus, the mechanism that drives the relation between high winter flows and successful crappie recruitment remains unclear.

Unlike tributary storage impoundments, high discharge during the spawning period appeared to be detrimental to crappie recruitment in Chickamauga and Watts Bar reservoirs. Others working on systems with low retention times have reported poor crappie recruitment in years with high discharge; however, the seasonal timing was often different than those found in our study. Crappie recruitment in Kansas reservoirs was enhanced after implementation of a water management plan that called for high water levels and low discharge during and after the spawning period (Groen and Schroeder 1978; Beam 1983). Densities of larval crappie were positively correlated to the amount of floodwater stored from April to August in Lake Rathbun, Iowa (Mitzner 1991). McDonough and Buchanan (1991) found that larval crappie densities in Chickamauga Reservoir, Tennessee, were higher when water levels were high 1 week before the spawning period and discharge was low during the larval stage. Unlike Chickamauga and Watts Bar reservoirs, crappie recruitment in Barkley Reservoir was not influenced by discharge during the spawning period. Instead, high discharge events in the prespawn period were linked to strong crappie year-classes. Maceina and Stimpert (1998) noted that high discharge levels in the winter had to be followed by low discharge levels during the spawn and postspawning periods to ensure strong year-classes of crappies in Alabama reservoirs with low retention times. However, the two relations we found between crappie recruitment and discharge during the spawning period in Tennessee reservoirs were noticeably weaker than for those between recruitment and prespawn discharge. Thus, it appears that prespawning period discharge may be more critical for crappie recruitment in Tennessee reservoirs than discharge at other times.

In general, reservoir hydrology appeared to affect crappie recruitment more in tributary storage impoundments than in main-stem reservoirs. The relations for individual reservoirs were usually stronger and explained more variation in crappie recruitment in the tributary storage impoundments than in the main-stem impoundments. A probable reason for this is that crappie recruitment in main-stem impoundments was more consistent than in tributary storage impoundments. Although poor or nonexistent year-classes were common in tributary storage impoundments, this was less frequently observed in any of the four main-stem impoundments we examined. Barkley Reservoir had three poor and five strong year-classes from 1992 to 1999 (T. D. Broadbent, personal communication). Over the same time period, Cherokee Reservoir had six poor and two strong year-classes (J. A. Negus, personal communication). The coefficient of determination (r^2) from a catch curve can be used as a rough measure of recruitment consistency. Consistent recruitment produces small differences between observed catch at age and values predicted from catch-curve analysis, hence a relatively high r^2. The mean r^2 of catch curves for the tributary storage impoundments was 0.76, while that of the mainstems was 0.88. The r^2 from the Kentucky Reservoir catch curve was 0.96, which indicated that there was essentially no variation in recruitment in that reservoir for the last 6 years, a potential reason why hydrology explained little variation in recruitment in that reservoir.

Management Implications

Understanding recruitment of crappies is crucial to successful management of these fishes. Given their well-known propensity to have boom-or-bust recruitment cycles (Colvin and Vasey 1986; Guy and Willis 1995) and the fact that crappie fisheries are often supported by one or two large year-classes (Colvin 1991; Sammons and Bettoli 1998b), the ability to predict the occurrence of poor year-classes becomes essential to maintain angler satisfaction. Our results have indicated that crappie recruitment is not only variable within a reservoir but that it also varies among reservoirs. Thus, it is unlikely that reservoir crappie populations will have strong year-classes simultaneously over a wide geographic area, or even within a single watershed.

Colvin (1991) observed that year-class strength of crappies in four Missouri reservoirs was not synchronous; that is, although each reservoir had strong and weak year-classes, the years in which each occurred did not coincide among lakes. This observation concurs with results from our study and emphasizes the need for system-specific management. In Tennessee, crappie recruitment was linked to reservoir hydrology; however, the critical time and nature of the relation (positive or negative) differed between tributary storage and main-stem impoundments. Although high precipitation events may benefit crappie recruitment in a tributary storage impoundment, these same events may prove to be detrimental to crappie reproduction in a nearby main-stem impoundment. Thus, managers must take steps to define the relations of crappie recruitment to hydrology in their systems.

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