Use of Drift Nets for Assessing Reproductive Output and Suggestions for Stocking Needs of Channel Catfish in Streams

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Abstract: We used larval drift nets to assess reproductive output of channel catfish (*Ictalurus punctatus*) in order to determine stocking needs in the Kings, Mulberry, Illinois, and Buffalo rivers in Arkansas. In each river, drift nets were deployed at the head of riffles and fished on random dates from 15 June to 22 July 1991 to determine relative abundance of young-of-year (YOY) catfish. Abundance of YOY catfish, an index of reproductive output, varied significantly among rivers, although all rivers are similar in geomorphology and located in the same physiographic region of the state. The Illinois River had the highest average catch (56.7 YOY channel catfish/net) and the Buffalo River had the lowest (1.0 YOY channel catfish/net). Age structure of adult channel catfish in the Buffalo River verified low reproductive output documented from drift net samples, as no Age 1 catfish were collected in 1991 or 1992 and 93% of the existing population consisted of previously stocked fish. Drift nets proved useful as a simple technique to assess reproductive output of channel catfish in moderate-size rivers. Subsequently, this information was useful in determining stocking needs for these rivers.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:520–530

Stocking to enhance cool-water and warm-water fisheries remains a well established and popular management tool (Noble 1986). Although basic pre-stocking criteria such as potential impacts to resident biota, suitability of stocking habitat, and social and economic considerations have been outlined (Murphy and Kelso

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1986) and subsequently investigated for many salmonid species, only recent refinements in stocking practices have included criteria for determining stocking needs (Potter and Barton 1986). It may be necessary to supplementally stock some waters that support existing wild populations to compensate for poor recruitment, overharvest, or loss of habitat, but stocking criteria for such waters must still be established (Wydoski 1986). For most game fishes, especially warm-water game species, techniques for assessment of stocking needs in response to inadequate reproduction or recruitment have not been adequately developed. Recent refinement of sampling techniques for larval and early-juvenile fishes may allow early detection of weak year-classes (Noble 1986). Thus, for some species it may have become possible to predict or detect the need for supplemental stocking early enough for management practices to be implemented, if such needs can be related to production.

In the United States, channel catfish (*Ictalurus punctatus*) culture and management for game fish purposes is second in importance only to that of largemouth bass (*Micropterus salmoides*), and catfish stocking programs currently exist in 35 states (Smith and Reeves 1986). In Arkansas, more than 1 million channel catfish, mostly of catchable size, are stocked annually in public and private waters (Ark. Game and Fish Comm. stocking records). In spite of these management schemes, relatively little information exists on pre-stocking guidelines or techniques to determine stocking needs for channel catfish within a particular body of water or in response to yearly variation in abundance through natural reproduction and recruitment. Such information is important because criteria for implementation of any management program, such as supplemental stocking, must be that there is some benefit (Noble 1986).

The objective of this study was to develop pre-stocking criteria for supplemental channel catfish stocking in the Buffalo River and other warm-water streams in Arkansas by assessing reproductive output and recruitment of existing populations.

Funding for this project was provided by the National Park Service (NPS), U.S. Department of the Interior. We thank J. Pitlo, Iowa Department of Natural Resources, for critical review of this manuscript. Special thanks to J. Walters, D. Bowman, and A. Thompson for assistance with data collection. Arkansas Game and Fish Commission and NPS provided permits for this study.

Methods

Study Areas

Reproductive output of channel catfish was assessed in the Illinois, Mulberry, Kings, and Buffalo rivers of northwestern Arkansas (Fig. 1). Age class structure sampling was restricted to the Buffalo River. All 4 rivers originate in the Boston Mountains and are typical clear-water Ozark streams characterized by long pools separated by short riffles. Land use in the watersheds of the Kings, Mulberry, and Illinois rivers consists of agriculture and forestry. The Buffalo River flows through National Park Service (NPS) land and has been managed by NPS since 1972.

Discharge of the 4 rivers varies seasonally, with a general pattern of high flow

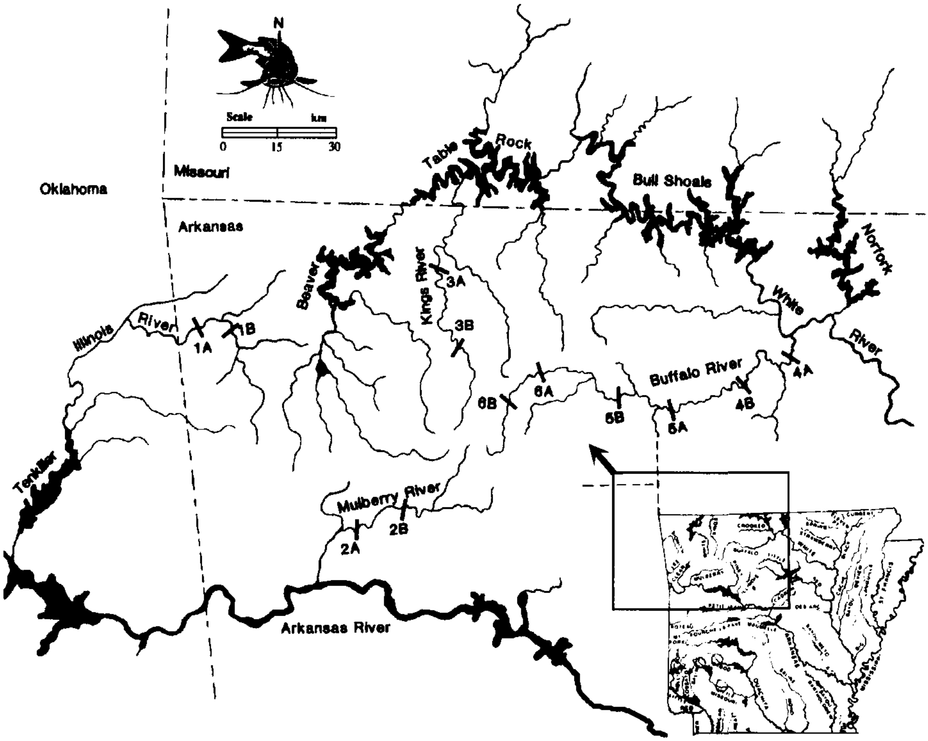

Figure 1. Study sites on the Illinois, Mulberry, Kings, and Buffalo rivers of northwestern Arkansas.

during spring and early summer and low flow in late summer and autumn, but local storms can produce high water in any season. Low discharge during late summer and autumn results in intermittent flows and isolated pools in headwater reaches. Average annual discharge for Kings River is 12 m^3/sec and ranges from 0.01 to 35.3 m^3/sec (U.S. Geol. Surv. 1988). The Mulberry River has slightly higher gradient (4.3 m/km) than the other 3 rivers; average annual discharge is 15.3 m^3/sec (U.S. Geol. Surv. 1988). Average annual discharge for the Illinois River is 22.2 m^3/sec (U.S. Geol. Surv. 1988). Average annual discharge reported for the middle reach of the Buffalo River (the only data available) is 25.8m^3/sec and ranges from 0.04 to 555.0 m^3/sec (U.S. Geol. Surv. 1988).

Because of heavy angler pressure and low productivity typical of clear-water Ozark streams (Allen Carter, Ark. Game and Fish Comm., pers. commun.), each of the 4 rivers is stocked annually with 500 to 4,000 catchable-size (>280 mm) channel catfish (Broach 1967). These rivers have been supplementally stocked with various fish species since the mid-1940s, but stockings during the past 10 to 15 years have consisted exclusively of catchable-size channel catfish (Ark. Game and Fish Comm. records).

Assessment of Populations

To determine stocking needs for channel catfish, reproductive output and recruitment into the existing catchable population were assessed. Since it has been shown that larval channel catfish occur in the nocturnal drift of streams (Armstrong 1984, Floyd et al. 1984, Muth and Schmulbach 1984), larval drift nets were used to assess the abundance of Age-0 channel catfish, which represented an index for reproductive output. Successful reproduction and recruitment from previous years were determined from relative age class abundance of the existing channel catfish population in the Buffalo River.

Larval Drift.—Sampling sites were selected from 3 reaches of the Buffalo River (upper, middle, lower) and from middle reaches of the Kings, Mulberry, and Illinois rivers, for a total of 6 sites. Sampling sites in each river consisted of 2 sampling stations, a lower site (A) and an upper site (B) about 15 km apart (Fig. 1). Sampling stations were located at the heads of riffles just downstream from large pools. Young-of-year (YOY) channel catfish were collected with rectangular drift nets (net opening 20 × 30 cm, total net length = 1.2 m, nylon mesh size = 0.5 mm) positioned across a transect at the head of a riffle. Nets were anchored in the riffle, with the 20-cm side resting on the substrate, by driving 2 steel rods through brackets on each side of the net into the substrate. Four nets were fished at each sampling station, and both localities (A and B) were fished simultaneously on each sampling date. Sampling was initiated 15 June 1991 and continued until each station had been sampled 4 times (4 nets × 2 stations × 4 sampling dates = 32 net samples/river or reach). The sampling schedule for the 6 sites was divided into 4 6-day intervals, with each site being randomly assigned to a sampling day within each of the 4 intervals (nested block design).

Sampling was initiated at sunset and continued until sunrise, with a total sampling time of about 8 hours. This nocturnal sampling regime was chosen because Armstrong (1984) reported channel catfish drift occurs only at night, with a bimodal peak 3 hours after sunset and 3 hours before sunrise. Nets were emptied at midnight and sunrise unless extensive drifting debris reduced net efficiency, in which case nets were emptied hourly. Large plant materials (e.g., leaves and branches) were rinsed and discarded, and all remaining net contents were preserved in 5% formalin solution buffered with borax (Taylor 1977) for later separation and identification in the laboratory. All YOY channel catfish caught in the drift nets were identified, enumerated, and a subsample of 10 fish per net was measured for total length [TL] to the nearest 0.5 mm.

Water velocity (measured with a torpedo-type flowmeter) and depth were measured at each net to allow standardization of water volume sampled by individual nets. Based on volume of water sampled, the number of YOY channel catfish collected from each net (catch) was adjusted to represent an equal sampling effort, using the following equation: catch × mean depth of all nets (23.0 cm)/depth net was fished × mean water velocity through all nets (25.0 cm/s)/water velocity passing through net. Total catch per individual net thus represented the approximate number of YOY channel catfish collected per 330.0 m^3 of water sampled. Additional variables measured at the beginning and end of each sampling interval included water temperature, turbidity, and discharge. The lowest site (Site 4; Fig. 1) of the Buffalo River was used for comparisons of Age-0 catfish abundance among rivers.

Differences in the abundance of YOY channel catfish and physical variables measured among and within river sites were compared by analysis of variance (ANOVA) using the Statistical Analysis System (SAS Inst. 1988). The ANOVA model was a randomized block design, with each river sampled within each of 4 time blocks and sampling stations were nested within each river site. To satisfy assumptions of the statistical analysis (i.e., constant variance of catches among rivers and normal distribution of residuals), total catch/individual drift net was adequately transformed using a standard ln(x + 1) transformation (Box and Cox 1964). A significant difference was found ($P < 0.01$), and the ANOVA was followed by Bonferroni's Multiple Range Test to identify river sites that differed from one another. Regression analysis was used to identify any potential relationships between water depth or velocity and catch rates of YOY channel catfish from individual rivers ($N = 32$ drift net samples for each river).

Age Structure Assessment.—Abundance and age structure of the adult channel catfish population in the Buffalo River was evaluated to determine the level of natural reproduction and recruitment from previous years. Adult channel catfish were collected at sites throughout the river during July through September in 1991 and 1992 with baited (pressed soybean cake) hoop nets, trotlines, and electrofishing. All channel catfish captured were weighed (mm), measured (TL), and a pectoral spine was removed for age determination before being returned alive to the river. In the laboratory, spines were cut into thin cross-sections with a Dremel® moto tool and aged under a dissecting microscope as described by Sneed (1951) and Marzolf (1955). In addition, pectoral spine cross-sections of all catfish were examined to identify any hatchery-reared fish stocked in previous years by the presence of extremely wide spacing between the first and second annulus followed by narrow spacing between each subsequent annulus (Siegwarth 1994).

Results

Larval Drift

A total of 3,300 YOY channel catfish was collected from 192 drift net samples in the 4 rivers. Mean (±SD) total length of a subsample of 640 YOY channel catfish was 16.8 ±1.0 mm. The length of these fish was remarkably consistent over the 8-week sampling period (15 June to 20 July) and among the 4 rivers sampled. Because of this consistent small size, all YOY channel catfish collected were believed to be between 5 and 10 days old, and to have recently dispersed from nesting areas (Saksena 1961). The highest number of YOY channel catfish was collected from the Illinois river ($N = 2,007$), and the lowest number ($N = 0$) was collected from the uppermost Buffalo River site. Adjusted mean number of YOY channel catfish caught/drift net varied among rivers, ranging from 56.7 fish for the

Table 1. Comparison of mean (± SE) number of Age-0 channel catfish/drift net, total discharge, water temperature, and turbidity among study sites on the Kings, Mulberry, Illinois, and Buffalo rivers, Arkansas. Values in each row without a letter in common are significantly different ($P < 0.01$).[a]

Variable	River				Total d.f.	F-value
	Buffalo	Kings	Mulberry	Illinois		
Adjusted average catch/net	1.0 (±0.4)	26.1 (±9.0)	25.9 (±9.9)	56.7 (±13.0)	—	—
Transformed ln(x+1) average catch/net	0.4^x (±0.1)	1.9^y (±0.3)	2.3^y (±0.3)	3.4^z (±0.2)	127	15.3
Total discharge (m^3/s)	2.5^y (±0.4)	0.2^z (±0.1)	0.4^z (±0.1)	1.9^y (±0.2)	15	22.1
Water temperature (° C)	29.2 (±0.3)	25.7 (±0.4)	27.1 (±0.03)	25.3 (±0.02)	15	4.8[b]
Turbidity (ppm)	0.8 (±0.2)	2.6 (±1.3)	4.8 (±3.1)	3.9 (±0.4)	15	2.1

[a] Comparisons were not made beween adjusted average catch/net due to violations of statistical assumptions (unequal variance between sites).

[b] General model significant, but no differences existed among individual treatments ($P > 0.05$).

Illinois River to 1.0 fish for the lower site of Buffalo River (Table 1). Analysis of catches among the 4 rivers showed significantly ($P < 0.01$) lower mean catches from the Buffalo River when compared with the Kings, Mulberry, and Illinois rivers (Table 1). The Illinois River also had significantly ($P < 0.01$) higher catch rates than did the Kings and Mulberry rivers.

The presence of YOY channel catfish from 15 June through 22 July in all 4 rivers indicated a protracted spawning period, with generally lower catches later in the season, except for the Illinois River which had a bimodal peak of YOY catch rates. Catches of YOY channel catfish in the Illinois, Mulberry, and Kings rivers were consistently higher than in the Buffalo River; however, catches from all rivers varied spatially and temporally (Fig. 2). The Kings River had the highest variation among sampling stations because no YOY channel catfish were caught at the upper station (3B), while >800 YOY catfish were collected at the lower station (3A). The riffle of the upper Kings River sampling station became intermittent during the final sampling period and was assumed to have no larval catfish present.

Although catches of YOY channel catfish within the Buffalo River were sparse, spatial patterns of catches in the 3 reaches indicated a longitudinal increase in abundance from upper to lower river sites. Average catch from the lowest site on the Buffalo River was significantly ($P < 0.01$) higher than catches from sites on the upper or middle reaches of the river. No YOY channel catfish were caught from the uppermost three sampling stations (5B, 6A, 6B; Fig. 1) of the Buffalo River.

Differences in abundance of YOY channel catfish among the 4 rivers appeared to be related to differences in total discharge (river size), with the exception

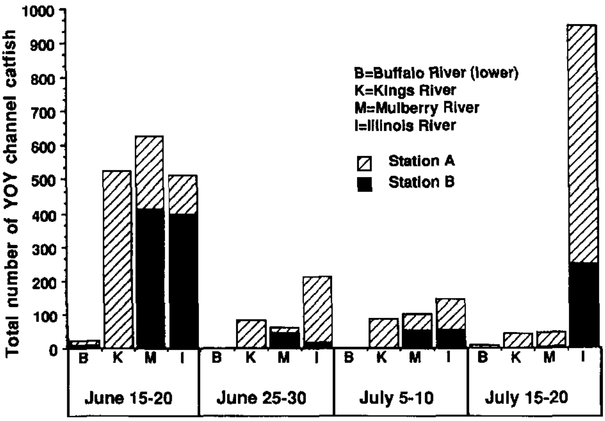

Figure 2. Total adjusted number of young-of-year channel catfish collected in drift nets on the Buffalo, Kings, Mulberry, and Illinois rivers during 4 time intervals.

of the Buffalo River which had the highest discharge and lowest abundance of YOY channel catfish (Table 1). This relation did exist, however, among the 3 reaches of Buffalo River, where YOY channel catfish were increasingly more abundant in lower, higher-discharge sites. Differences in YOY channel catfish abundance among rivers did not appear to be related to water temperature or turbidity. Water temperatures among the 4 rivers did not differ significantly, as all had mean temperatures between 25° and 29° C (Table 1). Turbidity also did not differ significantly, although turbidity levels for the Buffalo River were consistently lower than the other 3 rivers (Table 1).

Variation in catch rates of YOY channel catfish for individual drift nets was not significantly related to water depth or velocity for any of the 4 rivers (least squares regression analysis, $r^2 < 0.20$ for all but 1 river), and there was no relation between catch rates and lateral position of drift nets set across the riffle. This showed there was no apparent preferences for current, depth, or lateral habitat in the river channel, and YOY channel catfish in the size range collected (14–19 mm) did not avoid drift nets placed in areas of the riffle with lower velocity.

Age Structure Assessment

In 1991, 44 adult channel catfish were collected from >40 hoop net-days and 10 trotline nights of effort in the Buffalo River. In 1992, 235 catfish were collected from about 80 hoop net-days of effort. More than 86% of adult channel catfish were collected from the lower river, near stations 4A and 4B, despite lower sampling effort in this reach. Overall hoop net catch-per-unit-effort (CPUE) for all reaches of the Buffalo River was 0.48 channel catfish/net-day in 1991 and 2.25/net-day in 1992. Overall CPUE for trotlines in 1991 was 0.70 channel catfish/trotline-night. No adult channel catfish were collected from reaches above Station 6A (Fig. 1).

Channel catfish age distribution ranged from age 2 through 12, however, more than 51% and 74% of the channel catfish collected in 1991 and 1992, respectively, were Age 2 or 3. In a typical population structure, the age distribution of channel catfish observed in the Buffalo River would represent successful reproduction and recruitment from previous years; however, no Age-1 catfish were collected, and evidence from pectoral spine cross-sections and size at age (Siegwarth 1992) indicated that about 93% of all channel catfish collected from the river during both years had a hatchery origin.

Discussion

Drift net sampling measured the relative abundance of YOY channel catfish and provided an index of spawning success and/or reproductive output of adult channel catfish for each river. Downstream drift of YOY channel catfish in response to actual adult reproductive activity was demonstrated by Gerhardt and Hubert (1990). Thus, the appearance of YOY channel catfish in drift nets represented downstream dispersal from spawning areas, with higher catches representing increased reproductive success.

Location of drift nets within a riffle did not significantly affect catch efficiency; however, nets were not placed in extremely deep or low-velocity areas. Depths of 20 to 55 cm and velocities >20 cm/sec seemed to provide the highest overall catches, but no significant relations existed within rivers. In contrast, Armstrong (1984) reported that horizontal (across the channel) drift density of YOY channel catfish appeared to be affected by river discharge levels, and that more YOY catfish drifted near the surface than near the bottom.

The small consistent size of YOY channel catfish collected in drift nets over the 36-day sampling period indicates that catfish >19 mm TL either avoid the nets or are not present in the drift beyond this size. Consistent catches of larger fishes of other species (percids, cyprinids, centrarchids) suggest that larger YOY channel catfish were not present in the drift. Catches of small YOY channel catfish throughout the summer also indicates a protracted spawning period for catfish during June and July in each river. Armstrong (1984) also reported all YOY channel catfish collected in drift nets from the Illinois River were within the size range of 14.0 to 16.0 mm standard length, suggesting that fish size and gear efficiency were consistent between years. Other investigators have collected larval channel catfish beyond this size range using other gear types. For example, in the lower White River, Indiana, Schlueter (1971) collected YOY channel catfish from 25 to 50 mm SL during August and September by seining shallow water sandbars. Holland-Bartels and Duval (1988) and Pitlo (1991) sampled YOY channel catfish ranging from 15 to 75 mm SL using larval otter trawls in navigation pools of the upper Mississippi River. Absence of YOY channel catfish >19 mm from drift nets may indicate that riffles are not utilized by juvenile catfish larger than this size.

Drift samples indicate that YOY channel catfish abundance varies among rivers and among different reaches of the Buffalo River. The Illinois River had the highest abundance of YOY channel catfish; however, differences in river size may explain lower abundances from the Kings and Mulberry rivers. Extrapolation of catch data to total discharge in the Illinois River indicated >22,000 YOY channel catfish drifted past a given point in a single night during peak drift periods. Armstrong and Brown (1983) reported on larval drift for the same sampling site on the Illinois River as Station 1A in the present study. They found similar abundances of YOY channel catfish in drift net samples, with a peak drift occurring on 23 June and 22 July. Their findings and the results of this study indicate that channel catfish reproduction in the Illinois River is probably consistently high during most years. Channel catfish have been historically abundant in the Illinois River and are frequently caught by anglers (Moore and Paden 1950, Geihsler et al. 1975).

The Buffalo River had the lowest abundance of YOY channel catfish of the 4 rivers sampled. In addition, assessment of the adult population demonstrated an almost complete lack of natural reproduction and recruitment from previous years. It is unclear why YOY channel catfish are less abundant in the Buffalo River because measured physical characteristics do not significantly vary from the other 3 rivers. The low abundance of YOY channel catfish collected in drift net samples appeared to be a direct consequence of the sparse adult catfish population. Cashner and Brown (1977) conducted a longitudinal survey of fishes in the Buffalo River and collected channel catfish only in the lower 8.8 km of the river. The Buffalo River may naturally support only low densities of adult channel catfish, or their numbers are limited by factors other than those we measured.

Abundance of YOY channel catfish within the Buffalo River was highest in the lowest reach. The upper reach of the Buffalo River does not appear suitable for channel catfish reproduction, as no YOY catfish were collected above Station 5A (Fig. 1). Absence of YOY channel catfish was also observed in the upper Kings River station (3B). The absence of YOY channel catfish in the upper stations of both the Kings and Buffalo rivers may be due to a lack of suitable habitat for adult fish during spawning or lack of suitable spawning conditions in these reaches; both reaches become intermittent during late summer. Adult channel catfish may avoid first and second order streams because of intermittent discharge patterns typical of headwater reaches in Ozark streams.

Longitudinal differences in YOY channel catfish abundance in the Buffalo River coincided with relative abundance of adult channel catfish. Eighty-four percent of YOY channel catfish collected from the Buffalo River were taken at the lowest station (4A), while >86% of adult channel catfish were collected in proximity to the lower river site despite lower sampling effort for adults in this reach. In addition, 75% of marked channel catfish stocked in 1991 were recaptured downstream of their original release locations, with most of these fish recaptured in the lower third of the Buffalo River. This extensive downstream movement, higher density of adult fish, and higher abundance of YOY catfish illustrate the preference and substantially greater abundance of channel catfish in the lowest reaches of the Buffalo River.

Natural resource agencies charged with maintaining catchable populations of channel catfish in streams may be able to use information on abundance of YOY channel catfish drift to assess supplemental stocking needs. As Helms (1975) suggested for trawling in large rivers, larval drift nets may be a useful technique for predicting future year-class strength of channel catfish for smaller river systems if relationships are confirmed between YOY abundance and Age-1 abundance the following year. In navigation pools of the upper Mississippi River, Pitlo (1991) noted high trawl catches of YOY channel catfish appear as strong Age-1 year-classes the following year, and years of low trawl catches resulted in weaker Age-1 year-classes the following year. This type of information is important for evaluating recruitment fluctuations, future population abundance, and early detection of supplemental stocking needs.

Based on results of this study, drift nets were useful for detecting differences in reproductive output of channel catfish among individual rivers, and for identifying the need for supplemental stocking in the Buffalo River. Drift net results indicate that the Kings, Mulberry, and Illinois rivers have adequate channel catfish reproduction to sustain abundant populations. Annual fall stocking of additional channel catfish in these rivers probably contributes little to the existing populations. In contrast, the Buffalo River does not support a self-sustaining channel catfish population, as few YOY catfish were found in drift net samples, and age structure assessment indicated only a fraction of naturally spawned catfish from previous years have been recruited into the adult population.

To adequately evaluate the use of drift nets for early detection of supplemental stocking needs, further investigation is needed to provide a longer-term data base on trends of YOY channel catfish abundance in small riverine systems. Additional information is also needed to confirm relations between abundance of YOY channel catfish and abundance of Age-1 fish the following year.

Literature Cited

Armstrong, M. L. 1984. Drift of fish larvae in the Illinois River, Arkansas. M.S. Thesis, Univ. Ark., Fayetteville. 47pp.

Armstrong, M. L. and A. V. Brown. 1983. Diel drift and feeding of channel catfish alevins in the Illinois River, Arkansas. Trans. Am. Fish. Soc. 112:302–307.

Box, G. E. P. and D. R. Cox. 1964. An analysis of transformations. J. Royal Stat. Soc. B 26:211–243.

Broach, R. W. 1967. Arkansas catchable channel catfish program. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 21:445–452.

Cashner, R. C. and J. D. Brown. 1977. Longitudinal distribution of the fishes of the Buffalo River in northwestern Arkansas. Tulane Studies in Zool. and Bot. 19:37–46.

Floyd, K. B., R. D. Hoyt, and S. Timbrook. 1984. Chronology of appearance and habitat partitioning by stream larval fishes. Trans. Am. Fish. Soc. 113:217–223.

Geihsler, M. R., E. D. Short, and P. D. Kittle. 1975. A preliminary checklist of the fishes of the Illinois River, Arkansas. Ark. Acad. Sci. Proc. 29:37–39.

Gerhardt, D. R. and W. A. Hubert. 1990. Spawning habitat of channel catfish in the Powder River system, Wyoming-Montana. Prairie Nat. 22:155–164.

Helms, D. R. 1975. Variations in the abundance of channel catfish year classes in the upper Mississippi River and causative factors. Iowa State Conserv. Comm. Tech. Ser. 75-1, Des Moines. 49pp.

Holland-Bartels, L. E. and M. C. Duval. 1988. Variations in abundance of young-of-the-year channel catfish in a navigation pool of the upper Mississippi River. Trans. Am. Fish. Soc. 117:202–208.

Marzolf, R. C. 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of channel catfish. J. Wildl. Manage. 19:243–249.

Moore, G. A. and J. M. Paden. 1950. The fishes of the Illinois River in Oklahoma and Arkansas. Am. Mid. Nat. 44:76–95.

Murphy, B. R. and W. E. Kelso. 1986. Strategies for evaluating fresh-water stocking programs: past practices and future needs. Pages 303–313 *in* R. H. Stroud, ed. Fish culture in fisheries management. Am. Fish. Soc., Bethesda, Md.

Muth, R. T. and J. C. Schmulbach. 1984. Downstream transport of fish larvae in a shallow prairie river. Trans. Am. Fish. Soc. 113:224–230.

Noble, R. L. 1986. Stocking criteria and goals for restoration and enhancement of warm-water and cool-water fisheries. Pages 139–146 *in* R. H. Stroud, ed. Fish culture in fisheries management. Am. Fish. Soc., Bethesda, Md.

Pitlo, J. M., Jr. 1991. Mississippi River investigations. Fed. Aid to Fish Res. Proj. No. F-109-R-6, Iowa Dep. Nat. Resour., Des Moines. 76pp.

Potter, B. A. and B. A. Barton. 1986. Stocking goals and criteria for restoration and enhancement of cold-water fisheries. Pages 146–159 *in* R. H. Stroud, ed. Fish culture in fisheries management. Am. Fish. Soc., Bethesda, Md.

Saksena, V. P., K. Yamamoto, and C. D. Riggs. 1961. Early development of channel catfish. Prog. Fish-Cult. 23:156–161.

SAS Institute. 1988. SAS/STAT user's guide, release 6.03 edition. SAS Institute, Cary, N.C. 588pp.

Schlueter, R. A. 1971. Appearance and summer growth of young-of-the-year *Morone chrysops* and *Ictalurus punctatus* in the lower White River, Pike County, Indiana. Proc. Ind. Acad. Sci. 80:467–468.

Siegwarth, G. L. 1992. Channel catfish of the Buffalo National River, Arkansas: population abundance, reproductive output, and assessment of stocking catchable size fish. M.S. Thesis, Univ. Ark., Fayetteville. 107pp.

———. 1994. Identification of hatchery-reared channel catfish by means of pectoral spine cross sections, Trans. Am. Fish. Soc. 128:830–834.

Smith, B. W. and W. C. Reeves. 1986. Stocking warm-water species to restore or enhance fisheries. *In* R. H. Stroud, ed. Fish culture in fisheries management. Am. Fish. Soc., Bethesda, Md. 481pp.

Sneed, K. E. 1951. A method for calculating the growth of channel catfish (*Ictalurus lacustris punctatus*). Trans. Am. Fish. Soc. 80:174–183.

Taylor, W. R. 1977. Observations on specimen fixation. Proc. Biol. Soc. Washington. 90:753–763.

U.S. Geological Survey. 1988. Statistical summary of selected water-quality data (water years 1975 through 1985) for Arkansas rivers and streams. U.S. Geol. Surv. Water-Resour. Invest. Rep. 88-4112, Washington, D.C. 247pp.

Wydoski, R. S. 1986. Informational needs to improve stocking as a cold-water fisheries management tool. Pages 41–57 *in* R. H. Stroud, ed. Fish culture in fisheries management. Am. Fish. Soc., Bethesda, Md.