Stocking Size and Population Dynamics of Channel Catfish in Virginia Impoundments

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Abstract: Sub-adult channel catfish *(Ictalurus punctatus)* were marked with fin clips and stocked into 5 Virginia small (13- to 65-ha) impoundments from 1993–1996 to determine optimum stocking size and population dynamics. Four years of treatment stockings were compared to 4 years of standard (fingerling) stockings using gill net and creel surveys. Gill net catch per unit effort (CPUE) was higher ($P = 0.04$) during the treatment phase, and percentage of marked fish within populations steadily increased and reached a high of 91% in 1997. No evidence of natural reproduction was observed. Overall, abundance and stocking size were directly related ($r^2 = 0.57$, $P = 0.01$), but there was no significant difference among the 4 treatment cohorts, suggesting that catfish 254–315 mm total length were equally abundant the year following stocking. Harvest was higher ($P = 0.05$) during and immediately following treatment stockings. Total annual mortality *(A)* based on cohort analysis ranged from 34%–51%. A catch curve for treatment fish throughout the study yielded an *A* of 37% (age 2–6). Growth was moderate, as quality size (410 mm) was attained after 2 growing seasons.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 56:65–74

Channel catfish are an important sport and food fish, and put-grow-take fisheries for this species are popular in small impoundments (Michaletz and Dillard 1999). Virginia anglers spent an estimated 1.9 million days fishing for catfish in 1996, and catfish ranked fourth in angler preference behind black bass, trout and panfish (U.S. Fish and Wildl. Serv. 1996). Channel catfish natural reproduction and recruitment may be reduced or even nonexistent in small impoundments, and populations are frequently maintained by stocking (Krummrich and Heidinger 1973, Eder and McDannold 1987). The Virginia Department of Game and Inland Fisheries (VDGIF) stocks about 274,000 channel catfish fingerlings annually. Historically, these fingerlings averaged <130 mm total length, and high mortality due to predation likely occurred in the centrarchid-based small impoundments where they were predominately stocked (Storck and Newman 1988, Santucci et al. 1994). Recent investigations focused on the benefits of stocking larger catfish, but recommendations have been variable. For example, Spinelli et al. (1985) concluded that 150-mm catfish were most cost-efficient based on tank trials, but Illinois recommendations were for catfish <200 mm in 1 study (Santucci et al. 1994) and >200 mm in another (Storck and Newman 1988). Jackson and Francis (1999) recommended 230-mm catfish in Nebraska, while Howell and Betsill (1999) suggested that catfish >238 mm were most appropriate in Texas. Shaner et al. (1996) reported optimum size >254 mm in Alabama.

The primary objective of this study was to determine if increasing stocking size resulted in larger channel catfish populations (and subsequently, increased harvest) in Virginia small impoundments. Secondary objectives were to determine optimum stocking size and describe population characteristics of channel catfish in Virginia small impoundments.

Field collections would not have been possible without the assistance of D. Bowman, P. Bugas, J. Kauffman, L. Martin, S. Reeser, F. Spuchesi, and E. Steinkoenig. This manuscript was enhanced by reviews and comments from D. Bowman, V. DiCenzo, J. Kauffman, D. Michaelson, and G. Palmer. This project was partially funded through Federal Aid in Sportfish Restoration DJ Project F-111-R.

Methods

This study was conducted in 5 small impoundments in northern and western Virginia. Lakes were included in the study based on availability of historical creel data and ability to integrate proposed sampling into district workloads. Impoundments varied from 13 to 65 ha and contained warmwater fish communities in which the dominant predator was largemouth bass *(Micropterus salmoides).* Study lakes had established channel catfish populations prior to the initiation of the study, were eutrophic (except Motts Reservoir was mesotrophic), and were owned or managed by VDGIF as public fishing lakes. Channel catfish harvest at all study lakes was governed by a statewide 20 fish per day creel limit and no size limit during all phases of the study.

From 1993–1996, treatment stockings of larger channel catfish (total length range 254–284 mm) were made at the 5 study lakes. These 4 years of treatment stockings were preceded and followed by standard fingerling stockings of VDGIF-reared channel catfish that typically averaged about 130-mm total length except at Lake Robertson where the stocking of larger fish continued. Generally, pre treatment stockings were conducted annually at average rates of 114/ha, while treatment and post treatment stockings were at the same rate. Treatment stocking rates were based on rates reported for similar size catfish in other waters (e.g., Eder and McDannold 1987, Santucci et al. 1994) and historical precedent whereby VDGIF-owned lakes received fish at higher rates than municipal lakes. Thus, treatment stockings of channel catfish fingerlings were 62/ha in all lakes except Motts (a municipal lake), and 25/ha in Motts. Treatment fish were procured from the private sector—bids were specified "channel catfish average size of 254 mm with minimal variation." Catfish were marked with fin clips (Santucci et al. 1994, Parrett et al. 1999) at Front Royal Fish Cultural Station. Typically, about 9,000 16-month-old catfish were received in November and marked with an adipose, right pelvic, left pelvic, or multiple (combo) fin clip. Catfish were subsampled for total length (mm) and weight (g) and stocked within 48 hours. The first 2 years of the study, 100 marked catfish were held in hatchery raceways for 1 week to evaluate delayed mortality associated with handling and fin clipping. This practice was discontinued because no fish showed signs of stress.

Lakes were sampled in fall—usually October—from 1993 to 2000 with monofilament gill nets 30.5-m long and 2.4-m deep. Gill nets generally provide the least biased estimates of channel catfish abundance and length distributions (Robinson 1999, Santucci et al. 1999). Nets were single panel and had bar mesh sizes of 19, 32, and 51 mm. Effort was 12 net nights (4 nets per mesh) annually per lake. Horizontal gill nets were randomly set on lake bottoms off points perpendicular to shorelines. Six nets (2 per mesh) were fished on 2 consecutive nights at each study lake. Channel catfish were removed from nets, inspected for fin clips, measured for total length (mm) and weight (g), and released. Pectoral spines were removed from catfish without fin clips, and transverse sections were then used to determine age (Devries and Frie 1996). Catch per unit effort (CUPE)—the number of channel catfish caught per net night—was used as a measure of relative abundance (Mitzner 1999), and first year index (FYI) was used as an indicator of year class strength. FYI was computed as the CPUE of a given cohort, 1 year post stocking.

Access point daytime creel surveys were scheduled annually for study lakes, but budgetary and personnel constraints resulted in a patchwork of completed surveys. Only 2 lakes (Brittle and Orange) had adequate creel survey data sets that allowed meaningful comparisons of treatment stockings. At these lakes, 4 years of treatment data (1994–1997) were compared to 4 years of fingerling data.

Data were analyzed using SYSTAT (Wilkinson 1997). *T*-tests, analysis of variance (with Tukey's post hoc test for multiple comparisons), and linear regression were used to discern trends and treatment effects. Catch data were natural log transformed when needed to normalize distributions, and cohort catch curves were used to calculate mortality estimates of the 4 marked year classes (Van Den Avyle 1993). Cohorts from all lakes were combined to increase sample size. For tests comparing catch rates, 1994–1997 were used as treatment years since cohorts were not vulnerable to the gear until the year following stocking. Thus, there were 4 treatment and 4 control years, the latter of which included 1993 and 1998–2000.

Results

Channel catfish procured from the private sector met, and frequently exceeded, bid criteria, and total length variability within years was relatively low (CV = 8%–15%). However, variability among years was high, as treatment fish had significantly different total lengths most years (Table 1). Furthermore, at Lake Robertson, where treatment stocking continued after being curtailed at other study lakes, total length of purchased catfish was significantly different on several occasions. This annual variability in catfish size was beneficial because it enhanced comparisons between stocking size (mean total length) and FYI. Fingerlings from the VDGIF hatchery system were less variable in size but were much smaller (Table 2).

A total of 699 channel catfish were sampled from 1993–2000, of which 489 were marked. The combined CPUE increased during the 4-year treatment phase reaching a peak in 1997 before declining in 1998 (Table 3). Overall, CPUE was high-

Table 1. Descriptive statistics for subsampled treatment channel catfish stocked into 5 Virginia impoundments with associated first year index (FYI = cohort CPUE 1-year post stocking). Treatment stockings in 1997–2000 were into Lake Robertson only. Column means with the same letter were not significantly different ($P < 0.05$).

Year	Clip	*N*	Length (mm)	CV	Weight (g)	CV	FYI
1993	Adipose	100	284[a]	0.14	204	0.51	0.9
1994	Right pelvic	100	284[a]	0.12	168[c]	0.42	0.3
1995	Left pelvic	161	254	0.08	130[d]	0.28	0.5
1996	Combo	147	264	0.10	147[cd]	0.40	1.1
1997	Combo	44	315[bc]	0.15	306	0.44	1.2
1998	Adipose	50	289[b]	0.12	240	0.40	0.5
1999	Right pelvic	100	315[c]	0.13	275	0.43	0.3
2000	Left pelvic	50	305	0.13	257	0.41	n/a

Table 2. Descriptive statistics for subsampled post treatment channel catfish stocked into Lakes Brittle, Motts, Orange, and Shenandoah with associated first year index (FYI = cohort CPUE 1-year post stocking). Column means with the same letter were not significantly different ($P < 0.05$).

Year	Clip	*N*	Length (mm)	CV	Weight (g)	CV	FYI
1997	none	160	139[a]	0.12	24[b]	0.38	0.1
1998	none	104	135[a]	0.20	23[b]	0.61	0.2
1999	none	130	148	0.10	26[b]	0.35	0.2
2000	none	117	136[a]	0.14	20	0.42	n/a

Table 3. Combined channel catfish gill net catch, catch per effort (CPUE = number per net night of all lakes/nets combined) with number and percent marked within samples at 5 Virginia study lakes. Treatment stocking years were 1994–1997.

Year	Catch (*N*)	CPUE	*N* marked	Percent marked
1993	76	1.3	0	0
1994	89	1.5	63	71
1995	75	1.3	53	71
1996	98	1.6	85	87
1997	174	2.9	158	91
1998	58	1.0	46	79
1999	66	1.1	44	67
2000	63	1.1	40	63
Total	699		489	70

Table 4. Creel statistics from Lakes Orange and Brittle showing channel catfish harvest. S = standard and T = treatment stockings.

Year	Phase	Hours/ha	Kg harvest	Kg/effort	Mean wt (g)
		Lake Brittle			
1989	S	1297	182	0.14	590
1990	S	1502	129	0.09	531
1991	S	1606	46	0.03	822
1992	S	1603	111	0.07	404
1994	T	1578	475	0.30	431
1995	T	1331	267	0.20	522
1996	T	1151	252	0.22	704
1997	T	1139	206	0.18	581
		Lake Orange			
1988	S	694	450	0.65	840
1994	T	1497	1260	0.84	572
1995	T	824	1174	1.42	731
1996	T	750	1898	2.53	785
1997	T	652	1806	2.77	686
1998	S	330	168	0.51	894
1999	S	414	522	1.26	931
2000	S	250	258	1.03	481

er during the treatment phase (mean = 1.8, $N = 23$) than during other years (mean = 1.0, $N = 17$; $P = 0.04$). Additionally, CPUE at Lake Robertson (mean = 1.9, $N = 3$) was higher than at other lakes (mean = 0.9; $N = 3$; $P = 0.06$) after treatment stockings were discontinued everywhere except Lake Robertson. The CPUE varied among lakes but was usually highest at Motts Reservoir and lowest at Lake Shenandoah.

The percentage of marked fish within surveyed populations increased each year during the treatment phase and peaked in 1997 at 91%. The only unmarked catfish sampled during the study belonged to cohorts proceeding or following treatment stockings. Thus, no natural reproduction was documented at any of the study lakes during 8 years, and the lack of unmarked fish belonging to the 1993–1996 cohorts strongly suggested that no natural reproduction and/or recruitment occurred. Marked fish composed 100% of the catch in 1996–2000 at Lake Robertson.

Catfish abundance, based on FYI, was related to mean total length of fish stocked ($r^2 = 0.57$, $P = 0.01$). However, when post treatment cohorts were omitted, there was no relationship between catfish size and FYI suggesting that all treatment-size catfish (254–315 mm total length) were equally abundant the year following stocking. The FYI was greater for treatment (0.69) than for standard-size (0.17) catfish ($P < 0.01$).

Harvest was higher at Lake Brittle (mean annual harvest = 117 vs. 300 kg, $P = 0.05$) and Lake Orange (349 vs. 1534, $P < 0.01$) during the treatment phase (Table 4). However, fishing pressure was not constant during the study (at Lake Orange, pressure during the treatment phase more than doubled). Nonetheless, catch per ef-

Table 5. Cohort mortality rates (A) with related statistics for treatment catfish based on catch curves. Data pooled across all study lakes. *N* = number of years cohort sampled.

Mark (clip)/year	*N*	*A*	r^2	*P*
Adipose/1993	6	51%	0.96	0.001
R. pelvic/1994	6	35%	0.77	0.021
L. pelvic/1995	5	34%	0.78	0.048
Combo/1996	4	37%	0.50	0.297
Mean		39%		

Table 6. Mean total length at capture (mm) of treatment channel catfish based on fall gill net samples (with sample sizes). Age 1 fish subsampled prior to stocking.

		Age							
Year	Fin clip	1	2	3	4	5	6	7	8
1993	Adipose	284 (100)	373 (63)	460 (29)	486 (23)	500 (11)	515 (2)	522 (1)	605 (1)
1994	R. pelvic	284 (100)	365 (24)	437 (24)	491 (23)	545 (2)	584 (3)	495 (1)	
1995	L. pelvic	254 (161)	349 (38)	419 (50)	462 (12)	522 (14)	509 (8)		
1996	Combo	264 (147)	336 (74)	388 (14)	486 (12)	461 (17)			
	Mean	269 (508)	354 (199)	429 (117)	484 (70)	494 (44)	527 (13)		

fort (kg harvested per hour per ha) was higher at both sites during the treatment phase (0.08 vs. 0.23 at Lake Brittle, $P < 0.01$; 0.86 vs. 1.89 at Lake Orange, $P = 0.08$) supporting CPUE trends in gill net data. There was no difference in mean size harvested between treatment and standard phases at either Lake Brittle (558 g vs. 586 g; $P = 0.80$) or Lake Orange (695 vs. 785; $P = 0.44$).

Total annual mortality based on cohort analysis ranged from 34%–51% (Table 5). However, when a catch curve was calculated for the entire study period (all treatment cohorts over all years and lakes), total annual mortality was 37% for fish aged 2–6 ($r^2 = 0.94$, $P < 0.01$). Survival was fairly consistent for the first 3 years (mean $S = 0.65$, SD = 0.05), but declined to 0.37 between age 5 and 6.

Channel catfish reached quality size (410 mm) 2 growing seasons post stocking at age 3 (Table 6). The annual growth increment declined from 55 to 10 mm after age 4, and the von Bertalanffy growth parameter (*K*) was 0.28. Fish from the initial treatment cohort were sampled each year, but no preferred size (>610 mm) catfish were observed. The 2 cohorts with longer hatchery mean lengths retained their size advantage throughout the study. Growth of most marked cohorts was usually significantly faster at Lakes Orange and Robertson than at other lakes. Population size structures appeared unaffected by treatment stockings, as proportional stock density (Anderson and Neumann 1996) varied from 31 to 76 during the study, but no trend was apparent.

Discussion

The increase and subsequent decline in CPUE during and following treatment stockings strongly suggests that stocking larger fish (254–315 mm) enhanced catfish populations. This is consistent with other studies (Storck and Newman 1988, Howell and Betsill 1999) that demonstrated stocking larger fish resulted in better survival and, consequently, enhanced populations. The significant increase in FYI of treatment cohorts over fingerling supported these findings, as treatment cohorts survived better than 135–148 mm fingerlings. In fact, the overall relationship between mean stocking length and FYI in the present study ($r^2 = 0.57$, $N = 10$, $P = 0.01$) was nearly identical to that of a Texas study ($r^2 = 0.56$, $N = 19$, $P < 0.01$; Howell and Betsill 1999). However, the lack of a similar relationship among only treatment cohorts suggested that catfish > 254 mm survived at a commensurate rate and no additional benefit was gained by stocking fish up to 315 mm. This was similar to a study by Jackson and Francis (1999) who found that survival was likely higher for 230 mm and 280 mm channel catfish than for 180 mm fish. Shaner et al. (1996) determined that a maximum cost-benefit ratio was achieved by stocking 305 mm catfish, but the greatest increase in cost-benefit ratio occurred when stocking length was increased from 203 mm to 254 mm.

Alternatively, it is possible that stocking catfish longer than the maximum fingerling size of 148 mm but shorter than the minimum treatment size of 254 mm may have enhanced populations as well. Santucci et al. (1994) found no differences in mortality and harvest of 200 mm and 250 mm catfish in an Illinois impoundment. Storck and Newman (1988) and Bonar et al. (1997) found that stocking 150 mm to 200 mm catfish resulted in increased survival over fingerlings, but Storck and Newman (1988) cautioned that even their largest size group (185–220 mm) suffered high natural mortality and suggested that further economy could be achieved by stocking larger fish. Although additional study with catfish between 200 mm and 250 mm would likely help elucidate the issue in Virginia waters, it seems prudent to recommend stocking channel catfish up to 254 mm when possible.

Stocking rate, while not a focus of the study, was variable due to historical precedent. Statistical comparisons were not possible due to the lack of replication, but it was noteworthy that the 1 impoundment (Motts) stocked at 25/ha usually produced higher CPUE values than those stocked at 62/ha. The higher rate was similar to that used by investigators in related studies (Howell and Betsill 1999, Mitzner 1999). Higher survival realized by stocking larger catfish in the present study may have allowed an adequate population to persist despite a low annual stocking rate at Motts Reservoir. Fishing pressure at this reservoir (mean = 178 hours/ha, $N = 4$, SD = 18) was lower than most in the study. Thus, an annual stocking rate of 25/ha is likely adequate to sustain a channel catfish population in Virginia small impoundments if fishing pressure is relatively low (e.g., below 200 hours/ha).

Creel survey data supported gill net trends, as mean weight harvested was significantly higher during and immediately following the treatment phase at the 2 lakes examined. At Lake Orange, harvest increased 340%. All surveys were conducted during daytime, so bias associated with unsampled night angling should have been equal. Harvest was likely much higher throughout the study, as most study lakes were open to fishing 24 hours per day and nighttime catches of channel catfish can exceeded daytime catches (Parrett et al. 1999). It was unlikely that the stocking of larger catfish encouraged "early" harvest (e.g., provided a put-and-take fishery), because the mean weight of harvested fish did not change.

The 2 best estimates of total annual mortality were calculated by different methods: 51% (cohort-based for adipose-clipped cohort) and 37% (catch curve for all treatment cohorts over all years). However, other cohort curves were similar to the overall catch curve suggesting that a good mortality estimate of channel catfish in Virginia small impoundments is around 40%. Much of the total mortality was likely fishing mortality, as predation on treatment cohorts and natural mortality were likely low (Santucci et al. 1994, Howell and Betsill 1999). In a summary of channel catfish mortality rates, Hubert (1999) reported total mortality estimates between 13% and 88% but cautioned that assumptions of accurate aging, constant recruitment and representative sampling were often violated. Estimates in the present study were likely fairly accurate because they were derived from known age fish stocked at constant annual rates and were sampled by multiple-size gill nets.

Channel catfish growth was rapid and exceeded many published accounts. Fall-collected fish averaged 429 mm at age 3, while those sampled in 6 other southeastern reservoirs averaged only 302 mm (Hubert 1999). Growth in the present study was also faster than that reported for catfish in Florida (Crumpton 1999). However, large size "at age" was likely due to a growth advantage realized throughout the culture process (during the 16 months) that persisted after stocking.

These findings have implications for catfish stocking in Virginia small impoundments. Efforts should be made to stock 254 mm total length channel catfish. It is possible that smaller fish (as short as 200 mm) may experience commensurate survival, but fish < 200 mm should be avoided. Additionally, no gain was readily apparent by stocking larger catfish (up to 315 mm). Annual stockings of 62/ha appear adequate for maintaining channel catfish populations in small impoundments with high fishing pressure (e.g., 1500 hours/ha), but a stocking rate of 25/ha is likely suitable on waters with less pressure.

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