POPULATION DYNAMICS OF FLATHEAD, CHANNEL, AND BLUE CATFISH IN THE WABASH RIVER

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Final Report

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EXECUTIVE SUMMARY

- This report provides information on abundance, age-structure, growth, mortality, and movement of flathead (FHC, *Pylodictis olivaris*), channel (CCF, *Ictalurus punctatus*), and blue (BCF, *Ictalurus furcatus*) catfish in the Wabash River.

- The Wabash River was divided into three treatments based on different catfishing regulations throughout the river (see methods): The non-commercial treatment (NON; above river-mile (RM) 311); The Indiana-only commercial treatment (IN; RM 200 to 311); and the Indiana-Illinois treatment (IN-IL; RM 0 to 200).

- Catfish were collected in 2005 (62%), 2006 (20%), and 2007 (18%) with a combination of GPP electrofishing (42%), magneto electrofishing (32%), and hoop net gear (26%). Most of the catfish (N = 2,132) were collected in the IN-IL treatment (65%), followed by the IN (27%) and the NON (8%) treatments. Flathead catfish, CCF, and BCF comprised 63%, 29%, and 8% of the sample.

- Mean catch-per-unit-effort was 1.1 catfish/net-night for hoop nets, and 51 catfish/hour for GPP electrofishing.

- Pectoral spines were removed from 62% (N = 1,321) of the catfish collected and two independent analysts agreed on 98% of the annular formations.

- Age-5 CCF grew slower (13.1 to 14.3 in; mean range among treatments) than either similar aged FHC (16.8 to 18.3 in) or BCF (17.2 to 19.6 in).

- Annual survival (S) for FHC was highest (81%) in the NON treatment, and similar between the IN (66%) and IN-IL (62%) treatments; alternatively, S was highest (69%) for CCF in the IN treatment, followed by the IN-IL (63%) and NON (58%) treatments; S of BCF among all treatments was 81%.

- Anglers returned 5% of the catfish tagged (61 of 1,120), which resulted in annual exploitation estimates between 0 and 4% among species, treatments, and years.

- There was no relationship between the distance post-released catfish moved (maximum r^2 = 0.30) and the time fish were *at-large* (maximum = 785 days).

- Policy makers are encouraged to implement: (1) a 15 in minimum size limit for catfish along the IN-IL treatment, and (2) a daily creel of one catfish ≥ 33 in to increase recruitment and ensure continued trophy angling opportunities.

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INTRODUCTION

Catfish are among the most pursued group of sport fish in Indiana. Angler preference surveys reveal that catfish consistently rank only behind panfish and black bass in Indiana (Broussard and Haley 2005; Shipman 1995, 1987; IDNR 1978). Channel catfish (CCF) have a statewide distribution, are relatively easy to catch, and are favored table fare, which contributes to their popularity. Flathead (FHC) and blue catfish (BCF) are often sought after by Hoosiers for their trophy-size potential (Aterburn et al. 2007), where current state records stand at 79.5 and 104.0 lbs, respectively (IDNR, 2008). Several reviews cover the biology and management of CCF (Hubert 1999), FHC (Jackson 1999), and BCF (Graham 1999) in *Catfish 2000* (Irwin et al. 1999).

The commercial and sport catfish fisheries in the Wabash River have been of recent concern among biologists as evidenced by the attention these fisheries have received over the last decade. Lauer (2000) described the age and growth of catfish in the Wabash River and reported mean lengths-at-age-5 for CCF (14.8 in), FHC (18.4 in), and BCF (19.6 in). Willenberg (2000) described population characteristics for CCF and FHC from the lower Wabash River (river-mile (RM) 0 to 200). He reported that catfish were generally less than 20 in and 7 years of age and suggested the lack of larger and older catfish in his sample indicated high levels of exploitation. Colombo et al. (2005) concentrated on the population dynamics of CCF and expanded the study to include the commercially and non-commercially fished reaches of the Wabash River to Logansport, Indiana (RM 343). These authors reported higher proportions of large CCF in the non-commercially fished reaches and concluded that a 15 in minimum size limit would effectively alleviate any threat of recruitment over-fishing.

Inadequate datasets for FHC and BCF for much of the Wabash River provided the impetus for this research. The purpose of this paper was to determine if current harvest and length limit regulations are serving to: (1) recruit catfish to reproductive size classes, and (2) protect old (10 + years), trophy (≥ 33 in) catfish. The primary objectives of this study were to determine catfish: (1) relative abundance; (2) age, growth, and size structure; (3) survival and exploitation; and (4) movement among two commercially and one non-commercially fished treatments. This information can be used to justify recommendations intended to sustain catfish fisheries in the Wabash River and provide the catalyst needed to initiate a work-group to review statewide catfish length and creel limits.

METHODS

Study Area

The Wabash River was the area of investigation for this study. From its origin near the town of St. Henry, Ohio, the Wabash River meanders 276 mi across northern and western Indiana before it forms the 200 mi border between Indiana and Illinois prior to its confluence with the Ohio River near Uniontown, Kentucky. The Wabash River drains 73 counties in Indiana and a total land area of 32,821 mi^2, ranking as the second largest sub-basin of the Ohio River valley (Tennessee River valley, 40,893 mi^2). The headwater elevation of the Wabash River is 876 ft from which the river descends 2.3 ft/mi to Logansport, Indiana and 0.6 ft/mi thereafter to its mouth (Gammon 1998). J. Edward Rousch Lake (formerly Huntington Reservoir) is the only impoundment along the entire stretch of the Wabash River near Huntington, Indiana.

Regulations pertaining to catfish in the Wabash River differ among three reaches, which served as treatments for this study (Figure 1). The uppermost treatment was defined as the non-commercial (NON) treatment above river-mile (RM) 311 near Lafayette, Indiana, where only sport anglers are allowed to harvest catfish ≥ 10 in. Sport and commercial anglers are allowed to harvest catfish in the Indiana-only (IN) reach from RM 200 to 311 where there is a 10 in minimum length limit. The lower 200 mi of the Wabash River forms the state boundary between Indiana and Illinois where catfish are harvested by sport and commercial anglers with different regulations between the states. Illinois has a 15 in minimum length limit that applies only to commercial anglers, whereas Indiana has a 10 in minimum length limit that applies to both commercial and recreational anglers.

Sample gear

Catfish were sampled from the Wabash River with hoop nets from April to July in 2005 and 2007. One pound of cheese trimmings was placed in a bait bag (12 in *x* 12 in *x* 1/4 in square mesh; Miller Net Company, Inc., Memphis, Tennessee) and tied to the cod end of each hoop net. Five 1.0 inch bar-mesh double-throated hoop nets and five 1.25 inch bar-mesh double throated hoop nets (both 7 hoop; 3 ft diameter; 12 ft long) were alternately deployed overnight in six, four, and nine, one-mile reaches within the NON, IN, and IN-IL treatments, respectively (Table

1). This sampling protocol was repeated so that each reach was sampled in the spring (i.e., April to May) and again in the early summer (i.e., June to July).

During mid-summer (i.e., June to August) from 2005 to 2007, catfish were sampled with a 3-bar magnetic motor (Morris and Novak 1968) and a gas-powered-pulsator (GPP; Smith-Root, Inc., Seattle, Washington), which produced an alternating-electric current (AC) and a low pulse (15 pulse/s) direct-electric current (DC), respectively. Fifteen minute transects were devised for GPP sampling in proximity to natural (i.e., woody debris, log-jams, etc.) or anthropogenic (i.e., rip-rap, bridge pilings, etc.) structures in each treatment. Electrofishing transects were generally in different locations than hoop net reaches.

Field data

All FHC, CCF, and BCF were assigned a serial number and measured for total length (± 0.1 in). Wet weight was measured with a toploading mechanical dial scale (Douglas Homs Corporation, Belmont, California) for fish up to 2.2 lbs (± 0.1 oz). Linear spring scales (Pesola ©, Barr, Switzerland) were used to measure the wet weight of fish up to 11 lbs (± 2 oz), 22 lbs (± 4 oz) and 110 lbs (± 18 oz). Catfish greater than 10 in TL were fitted with a T-bar anchor tag (Floy Tag Inc., Seattle, Washington) in the musculature at the base of the dorsal spine. Among species, treatments, and years, a pectoral spine was disarticulated (Mayhew 1969) for five fish in each 0.4 in (10 mm) length group above 4 in (100 mm) TL and stored in scale envelopes until processed in the laboratory. After the adipose fin was clipped as a secondary mark, fish were released near the site of capture.

Laboratory process

Pectoral spines were left to air dry for a minimum of 14 d before they were sectioned in the laboratory. An Isomet™ low speed saw (Buehler, Ltd., Lake Bluff, Illinois) was used to make multiple 0.03 in (75 µm) cross sections of the articulating process to capture the origin between the ventral process and basal recess. If the origin of a cross section had not been eroded by the central lumen, it was placed under transmitted light against a black background, submerged in glycerin (Humco, Texarkana, Texas), and viewed under a dissecting scope and photographed with a Paxcam™ digital camera (MIS, Inc., Franklin Park, Illinois). Images of all cross sections were uploaded into PowerPoint® (Microsoft Corporation, Redmond, Washington),

which provided analysts the ability to adjust image quality (i.e., frame size, brightness, contrast, etc.) and independently mark annuli (i.e., drawing tools) without knowledge of fish length or age. A concert read was conducted to resolve discrepancies between analysts. Ages that could not be agreed upon were excluded from further analysis.

Statistics

Relative abundance was measured by catch-per-unit-effort (CPUE) and relative stock density (RSD) indices were calculated among species, treatments, and years. Hoop net CPUE was defined as the number of catfish collected per net-night. Electrofishing CPUE was defined as the number of catfish collected per hour of GPP sampling. Relative stock density indices were calculated using suggested lengths for FHC from Daugherty and Sutton (2005a) and similarly for CCF and BCF from Anderson and Neumann (1996).

Length-frequency distributions for each species were tested for differences among treatments with Kolmogorov-Smirnov tests. Catfish condition was estimated with relative weight (W_r) where:

$$W_r = W_i/W_s \bullet 100$$

Individual weights (W_i) were divided by standard weight (W_s) equations derived for FHC (Bister et al. 2000), CCF (Brown et al. 1995), and BCF (Muoneke and Pope 1999).

Age bias plots were used to assess the ability of two independent analysts to accurately and precisely mark annular formations. After a concert read was conducted among age analysts, age-length keys were used to expand the age data to fit the length frequency distribution of the sample. Age-frequency distributions for each species were then compared among treatments with Kolmogorov-Smirnov tests (Statistix 9.0, Tallahassee, Florida).

The anterior lobe from the basal recess was used as the axis to measure the radial distances of spine cross sections with SigmaScan 5.0 (SPSS Inc., Chicago, Illinois). Annular measurments were transposed into FishBC 2.0 (Doll and Lauer, Ball State University, Indiana) to estimate mean back-calculated lengths among species, treatments, and years. Ninety-five percent confidence intervals were generated by:

$$95\% \text{ CI} = \text{SE} \bullet t_{(\alpha = 0.05)}$$

to determine if mean back-calculated lengths differed among treatments. Growth among species and treatments was modeled with Fisheries Analysis and Simulation Tools (FAST © 2.0) using the von Bertalanffy equation:

$$l_t = L_\infty[1\text{-}e^{-K(t-t_o)}]$$

where l_t is the fish length at time t, L_∞ is the theoretical maximum length for an average individual in the population, K is a growth coefficient, and t_o is a correction factor to adjust for time when length is theoretically zero (Ricker 1975).

To assess the annual survival rate of catfish among species, treatments, and years, the natural and fishing mortality rates were estimated. Three methods were used to estimate annual survival S (Miranda and Bettoli 2007) of catfish, which was pooled by years and gear type: (1) Heincke's method; (2) Robson-Chapman's method; and (3) catch-curve regression.

The annual rate of exploitation for each species of catfish was estimated with the Ricker (1975) method for multi-year mark-recapture data:

$$u_i = (f_{i\cdot} \bullet f_{\cdot i}) / (m_i \bullet k_i).$$

where u_i is the annual exploitation estimate, $f_{i\cdot}$ is the number of tagged fish in year i harvested by anglers over all years, $f_{\cdot i}$ is the number of marked fish harvested each year i despite the year in which they were marked, m_i symbolizes the number of catfish marked in year i, and k_i is the total number of marked catfish harvested after year i of catfish marked before year i. Commercial and sport anglers were provided an incentive (REWARD, mail to INDNR) to voluntarily return tags from marked catfish. Upon receiving a tag, the INDNR mailed a baseball cap and follow-up letter to the angler that asked them when, where, and how the catfish was caught.

Tag returns from commercial and recreational anglers in addition to recaptures from field staff provided data to assess catfish movement. Catfish were considered *at-large* from the day of release to the day of recapture. To test the null hypothesis that sample treatments were independent, the linear distance from the center of the main-channel between the release and recapture locations was estimated in river-miles and regressed against the number of days tagged fish were *at-large*.

RESULTS

Abundance

Over the three-year study, catfish (N = 2,132) were collected in 2005 (62%), 2006 (20%) and 2007 (18%; Table 2). Catfish were collected with a combination of GPP-electrofishing, magneto-electrofishing, and hoop net gear (42%, 32%, and 26%, respectively). Hoop nets were not set in 2006 due to transition of personnel, while samples collected in 2007 lacked ~50% of hoop net sets and GPP electrofishing effort due to drought. The majority of catfish were collected in the IN-IL treatment (65%), followed by the IN (27%) and NON (8%) treatments. Species composition was 63%, 29%, and 8% for FHC, CCF, and BCF, respectfully.

Channel catfish captured in 1.0 in hoop nets were significantly (t = 12.2; df = 436; P < 0.001) smaller (12.0 ± 3.7 in; mean ± SD) than fish captured in 1.25 in mesh hoop nets (16.3 ± 3.4 in). Flathead catfish mean (± SD) length was similar (t = 1.31; df = 96; P = 0.194) between fish collected in 1.0 and 1.25 in mesh hoop nets (19.1 ± 4.6 and 20.3 ± 4.1 in, respectively). The grand mean CPUE for catfish (N = 546) collected with hoop nets was 1.1 catfish/net-night (Table 3). These data indicate that CPUE was close (± 0.3) to 1.0 catfish/net-night among hoop net type (i.e., 1.0 and 1.25 in bar mesh), year (i.e, 2005 and 2007), and treatment (i.e., NON, IN, and IN-IL). The only exception was catfish collected in the IN treatment of 2005 where mean CPUE nearly doubled (1.8 catfish/net-night) other estimates. Although CCF were more frequently collected (80%) with hoop nets than either FHC (18%) or BCF (2%), the CPUE (mean, range) within species was generally similar among treatments and years for FHC (0.2, 0 to 0.6), CCF (0.9, 0.4 to 1.8), and BCF (0.01, 0 to 0.2).

The grand mean CPUE for catfish (N = 866) collected with GPP-electrofishing was 51 catfish/hour (Table 4). These data indicate CPUE was similar among years (range: 45 to 57) but differed among treatments. Catch rates were highest in the IN-IL treatment (65 fish/hour), and decreased in the upstream direction (IN: 39 fish/hour; NON: 13 fish/hour). Although FHC were more frequently collected (84%) with GPP-electrofishing than either BCF (10%) or CCF (6%), the CPUE (mean, range) within species was generally similar among years for FHC (44, 40 to 50), BCF (7, 5 to 14), and CCF (2, 1 to 5).

Trophy (≥ 40 in) FHC were collected in all three treatments, yet RSD values indicated they were more abundant in the NON treatment (2%), than in the IN or IN-IL treatments (<

0.01%). Further, the percentage of quality, preferred, and memorable (≥ 20 in) FHC were greater in the NON treatment (41%) than either the IN (4%) or IN-IL (7%) treatments (Table 5). Memorable and trophy CCF (≥ 28 in) were not observed in any treatment during the study. Quality and preferred CCF (≥ 16 in) decreased in the downstream direction (36, 32, and 24% in the NON, IN, and IN-IL treatments, respectively). Blue catfish were not collected in the NON treatment and few were collected in the IN treatment. Within the IN-IL treatment, memorable and trophy BCF were scarce but present (< 1%), while numbers of quality and preferred BCF were relatively high (57%).

Age and growth

Length-frequency distributions for FHC (Figure 2) indicated that smaller fish represent a significantly larger portion of the sample with respect to each treatment in the downstream direction (all $D \geq 0.10$; all $P \leq 0.02$). Conversely, CCF length-frequency distributions (Figure 3) among treatments were similar (all $D \leq 0.13$; all $P \geq 0.19$). Blue catfish length frequencies (Figure 4) among treatments were not compared because either no BCF were collected (NON), or so few were collected (IN) that comparisons would have yielded erroneous interpretation.

Relative weights for FHC were inversely proportional to length among all treatments (Figure 5). Moreover, relative weights among all length bins of FHC were generally higher in the downstream direction. Likewise, CCF had higher relative weights among smaller length bins in the downstream direction. Blue catfish in the IN-IL treatment had high (mean = 97.0) relative weights among all length bins.

Pectoral spines were removed from 62% (N = 1,321) of the catfish collected. Age-bias plots (Figure 6) indicate that Analyst I generally marked more annuli per spine section (among all species of catfish) than Analyst II. Thus, either Analyst I over-aged catfish, or Analyst II under-aged catfish. Initially, agreement (± 0 years) between analysts was identical for FHC and CFF (38%) and only slightly lower for BCF (35%; Table 6). Less than one third of the ages derived by independent analysts deviated more than ± 1 year for FHC (19%), CCF (24%) and BCF (32%). After the concert read, analysts agreed on 98% of spine annuli. The remaining 2% (N = 31) of the spine sections not agreed upon were excluded from further analysis.

The proportion of older-aged FHC (Figure 7) and CCF (Figure 8) was significantly higher in the NON treatment than observed in the IN treatment (all $D \geq 0.25$; all $P \leq 0.02$).

Similarly, older-aged FHC and CCF represented a significantly higher proportion of the sample in the IN treatment than in the IN-IL treatment (all $D \geq 0.10$; all $P \leq 0.02$). Blue catfish age frequencies (Figure 9) were not compared among treatments because either no BCF were collected (NON), or too few were collected (IN) to make meaningful comparisons.

Flathead catfish grew slower ($K = 0.101$) but had the potential to reach a larger size (L_∞= 47.0 in; Figure 10) in the NON treatment than in either the IN ($K = 0.248$, L_∞= 29.4 in) or IN-IL treatments ($K = 0.150$, L_∞= 43.0 in). Channel catfish had higher predicted maximum lengths in the NON (30.5 in) and IN (28.2 in) treatments compared to the IN-IL treatment (23.8 in; Figure 11). Growth coefficients for CCF increased in the downstream direction (0.104, 0.117, and 0.185 in the NON, IN, and IN-IL treatments, respectively). Because either no or few BCF were collected in the NON and IN treatments, data were insufficient to compare growth rates among treatments for this species (Figure 12).

Back-calculated mean (± SE) length-at-age-10 FHC compared among all treatments was greater (34.3 ± 2.3; Table 7) than either CCF (20.6 ± 0.9 in; Table 8) or BCF (26.7 ± 0.7; Table 9). Flathead catfish mean (± 95% CI) length-at-age-5 increased in the upstream direction and was highest in the NON treatment (18.3 ± 2.2 in), followed by the IN (17.3 ± 0.7 in), and IN-IL (16.8 ± 0.7 in) treatments (Table 10). Channel catfish mean (± 95% CI) length-at-age-5 increased in the downstream direction and was highest in the IN-IL treatment (14.3 ± 0.5 in), followed by the IN (14.0 ± 0.4 in) and NON (13.1 ± 0.5 in) treatments. Blue catfish mean (± 95% CI) length-at-age-5 in the IN-IL treatment was 17.2 ± 0.6 in.

Survival and exploitation

Of the three methods used to estimate total annual survival, the Robson-Chapman method produced tighter confidence intervals among all species and treatments than either Heincke's method or catch-curves (Table 11). Yet, regardless of which method was used to estimate annual survival, the models generally produced trends that remained consistent within species and among treatments. For example, annual survival (± 95% CI) estimated with the Robson-Chapman method was highest for FHC in the NON treatment (81 ± 6%) and decreased in the IN (66 ± 3%) and IN-IL (62 ± 3%) treatments and this trend was similar using both Heincke's method and catch-curves. Channel catfish annual survival (± 95% CI) estimated with the Robson-Chapman method was lowest in the NON treatment (58 ± 8%), increased in the IN

treatment (69 ± 5%), and decreased again in the IN-IL treatment (63 ± 5%) and this trend was also observed using Heincke's method. Total annual survival (± 95% CI) of BCF in the IN-IL treatment was 81 ± 3% using the Robson-Chapman method. Analysis of the linear regression slopes (Z) produced by catch-curves (Figure 13) indicated that the instantaneous rate of natural mortality of FHC was significantly different among all treatments (all $F \geq 11.1$; all $df \geq 8$; all $P \leq 0.01$). Alternatively, catch-curves indicated that the instantaneous rate of natural mortality of CCF was similar among all treatments (all $F \leq 1.7$; all $df \geq 6$; all $P \geq 0.22$). Because either no or few BCF were collected in the NON and IN treatments, data to compare Z values for this species were insufficient.

Ninety-four percent ($N = 1120$) of the catfish greater than 10 in were marked with a T-bar anchor tag and 61 were eventually returned by anglers. Annual exploitation rates of all species combined ranged from 0.4 to 2.2% and when separated by species and treatment was always equal to or less than 4.3% (Table 12). Slightly more tags were returned by recreational anglers ($N = 32$) than commercial anglers ($N = 27$). Although the range of the length distribution of catfish harvested by commercial anglers was higher (13.0 to 41.9 in) than fish harvested by recreational anglers (11.9 to 30.4 in), the difference was not statistically significant ($D = 0.32$; $df = 16$, $P = 0.23$). Mean (± SE) length of catfish harvested by commercial anglers (20.2 ± 1.1 in) was similar ($t = 0.76$; $df = 57$; $P = 0.45$) to fish harvested by recreational anglers (19.1 ± 1.0 in). Furthermore, the number of tags returned by Indiana anglers ($N = 32$) paralleled those returned by Illinois anglers ($N = 27$). The relative percentage of catfish harvested by species was highest for FHC (7%), followed by BCF (6%) and CCF (3%; Table 13). The relative percentage of catfish harvested by treatment was highest in the IN-IL (6%) treatment, followed by the IN (4%) and the NON (1%) treatments (Table 14). Commercial anglers were more likely to return tags from FHC (4%) than either CCF (1%) or BCF (0%), whereas recreational anglers returned more tags from BCF (6%) than either FHC (3%) or CCF (2%). Most (79%) of the commercial and recreational anglers used either hoop nets ($N = 24$) or rod and reel ($N = 24$) to harvest catfish (Table 15).

Movement

Sixty-five catfish either harvested by anglers ($N = 57$) or recaptured by IDNR personnel ($N = 8$) during the study provide information to assess catfish movement. Overall, catfish

remained near the area they were tagged and released. The maximum upstream and downstream movement of FHC was 21 and 22 mi, respectively. Most (50%) FHC remained within ± 2 mi of where they were released regardless of how many days they were *at-large* (Figure 14). Similarly, CCF remained near the site they were released (± 5 mi) regardless of how many days they were *at-large*. Most BCF also remained close to the site released (± 11 mi), however one fish was observed 27 mi downstream from the initial site of capture.

DISCUSSION

The purpose of this study was to examine whether present regulations are serving to ensure the sustainability (i.e., high abundance, broad age-class distribution, low annual mortality) of catfish populations in the Wabash River. Catfish are currently managed with different regulations in the Wabash River with respect to previously described treatments (NON, IN, IN-IL). The major findings of this research support a growing body of evidence (Colombo et al. 2005; Willenberg 2000) that catfish in the non-commercially fished reach of the Wabash River exhibited: (1) higher proportions of larger (and older-aged) fish; and (2) lower annual mortality (and exploitation) rates.

Estimates of CPUE for catfish collected with hoop nets provided evidence that proportionally larger fish resided in the upstream direction of the Wabash River. Overall mean CPUE estimates for catfish collected with 1.0 in mesh hoop nets (1.3 fish/net night) were similar to those reported by Willenberg (2000; 1.0 fish/net night) and Colombo et al. (2005; 1.6 fish/net night). The overall mean CPUE estimate with 1.25 in mesh nets (0.9 fish/net night) was higher than the estimate reported by Colombo et al. (2005; 0.4 fish/net night). An important dimension of the catch data revealed that smaller CCF (mean = 12.2 in) were collected in 1.0 in mesh hoop nets than collected in 1.25 in mesh nets (mean = 16.3 in). When mean CPUE data between mesh sizes were combined with the dataset reported by Colombo et al. (2005), there was an interaction between the catch rates and treatments. For example, mean CPUE of CCF collected with 1.0 in mesh nets (i.e., smaller CCF) decreased (1.6, 1.3, 1.2 fish/net night) in the upstream (IN-IL, IN, NON, respectively) direction, whereas the mean CPUE of CCF collected with 1.25 in mesh nets (i.e., larger CCF) increased (0.3, 0.5, 0.6 fish/net night, respectively) in the upstream direction. In either case, the differences in catch rates (and correlated length distributions) were more distinct between the IN-IL and IN treatments than between the IN and NON treatments. This

information indicates that larger CCF were proportionally less abundant in the interjurisdiction waters that border Illinois than in the upstream reaches.

Relative stock density indices corroborated CPUE data. Channel catfish of quality size increased in the upstream direction. Similarly, RSD values for larger FHC were proportionally higher in the NON treatment. Memorable and trophy RSD indices for FHC in the NON treatment (6%) were comparable to other studies. Ten percent of the FHC in the Cape Fear River, North Carolina were between memorable and trophy sizes (Ashley and Buff 1986). Daugherty and Sutton (2005a) suggested that FHC in the St. Joseph River, Michigan experienced minimal exploitation and reported 8% were either memorable or trophy status. The substantial decline (36 to 39%) in FHC of quality size or greater in the commercially fished treatments of the Wabash River suggests high levels of harvests. Reduced catfish densities would also explain the increase in relative weights among FHC in the commercially fished reaches. Intra- and inter-specific competition has probably been reduced in the commercially fished treatments and increased food availability has resulted in higher relative weights among FHC.

Analysis of age-frequency data indicated that there were proportionally older-aged catfish in the upstream direction of the Wabash River. Seventeen percent of all CCF collected in the NON treatment were equal to or greater than 10-years of age, compared to just 4% and 1% in the IN and IN-IL treatments, respectively. Colombo et al. (2005) reported similar findings of 8%, 3%, and 1% for CCF greater than or equal to 10-years of age in the NON, IN, and IN-IL treatments, respectively. Willenberg (2000) did not report any CCF 10-years of age or older in the IN-IL treatment. Flathead catfish greater than or equal to 10-years of age represented 20%, 4%, and 1% of the sample from the NON, IN, and IN-IL treatments, respectively. Just 1% of the FHC sample collected by Colombo et al. (2005) was greater than or equal to 10-years of age. Willenberg (2000) did not report any FHC greater than or equal to 10-years of age in the IN-IL treatment. Harvest of FHC from the St. Joseph River, MI, was reportedly low where 11% of the sample was 10-years of age or older (Daugherty and Sutton 2005a), which supports findings from the non-commercially fished reach of the Wabash River.

Flathead catfish and CCF exhibited opposite trends with regard to annual growth among treatments. Without exception, flathead catfish in the NON treatment grew faster every year to age-5 than in the IN and IN-IL treatments. Conversely, CCF grew faster every year to age-5 (except age-1) in the IN-IL treatment than in the IN, and NON treatments. In some respects,

growth estimates were comparable to other studies but differed among others. Willenberg (2000) and Hoffman (2006) reported mean lengths of 16.9 and 16.4 in for age-5 FHC in the IN-IL treatment and East Fork White River, respectively, which parallels the mean estimate of 16.8 in for the Wabash River. The mean estimate of 14.3 in for age-5 CCF in the IN-IL treatment was well under the 16.6 in mean estimate reported by Willenberg (2000) and the 16.8 in estimate reported by Hoffman (2006). In fact, the age-5 mean length estimate from the Wabash River was also under the age-4 mean length estimate reported by Willenberg (2000; 15.0 in) and Hoffman (2006; 15.5 in).

Jackson (1999) contended FHC are sexually mature at 3 to 5 years. Thus, the current 10 in minimum length limit offers little protection for first-year spawning recruits because age-3 FHC in the Wabash River are already averaging 11.1 to 11.8 in. Hubert (1999) suggested CCF are sexually mature at 4 to 5 years. Again, the current 10 in minimum length limit offers little protection for first-year spawning recruits because age-4 CCF in the Wabash River are already 11.4 to 12.3 in. Blue catfish also mature in 4 to 5 years (Graham 1999), yet age-4 BCF in the Wabash River also average above (14.7 to 15.9 in) the 10 in minimum length limit.

The annual survival and exploitation estimates were perhaps the most definitive evidence that there was higher angling pressure in the downstream direction of the Wabash River. Annual survival of CCF was estimate to be 82, 76, and 65% among the NON, IN, and IN-IL treatments, which were similar to the trends (71, 65, and 46%) reported by Colombo (2005). Gerhardt and Hubert (1991) stated exploitation was low for CCF in the Powder River, Wyoming and reported the annual survival rate was 77%. The annual survival rate estimates for FHC in the commercially fished treatments (55 to 69%) of the Wabash River where also similar to previous studies. Willenberg (2000) stated that annual survival of FHC in the IN-IL treatment was 59% and Daugherty (2005a) reported a 67% annual survival rate for FHC in the St. Joseph River, Michigan. The overall exploitation estimate in the NON treatment was much lower (0.1%) than recorded in the IN (1%) and IN-IL (4%) treatments. Green et al. (1983) reported just 29% of the tags known to be recovered by anglers were returned. Similarly, Zale and Bain (1994) reported that anglers returned fewer tags (33 to 37%) than they did when a reward was offered (64 to 67%). Thus, if the assumption is made that just two-thirds (i.e., because reward tags were used) of the tags recovered by anglers were actually returned in this study, exploitation would have increased to 11, 5, and 9% for FHC, CCF, and BCF as well as increased to 0.2, 2, and 7% among

the NON, IN, and IN-IL treatments. This information indicates that FHC are harvested at a higher rate than either CCF or BCF and overall, the IN-IL treatment receives the greatest angler pressure among treatments.

All aspects investigated governing the population dynamics of catfish in this study indicated that desirable qualities of the fishery decrease in the downstream direction of the Wabash River but to a greater degree for FHC. Because large FHC have small home ranges (Daugherty and Sutton 2005b), they are perhaps more vulnerable to angling pressure than CCF or BCF because they inhabit structures (i.e., woody debris) visually obvious to seasoned anglers. Flathead catfish in the non-commercial treatment (NON) exhibited: (1) higher proportions of larger and older fish; (2) faster annual growth; (3) a lower rate of exploitation; and (4) a lower rate of total annual mortality than fish in the downstream treatments (IN and IN-IL).

Channel catfish exhibited similar (but to a lesser degree) population trends with the exception that annular growth was faster in the downstream direction. Blue catfish were not sampled as effectively as the other catfish species, and future efforts should address this issue. Although most (75 to 81%) respondents of past angler surveys agreed that harvest and size-limits are useful management tools, they were indecisive (35 to 38% favored; 40 to 42% opposed) as to whether such regulations should be implemented for catfish (Shipman 1996). However, the data presented in this paper indicates that the current 10 in minimum size limit is not protecting first-year spawning recruits among any species of catfish. In addition, the lack of a creel limit on trophy catfish may have decreased the proportion of large catfish in the commercially fished reaches of the Wabash River. If the minimum length limit is increased to 15 in and a one-fish over 33 in daily creel limit is implemented, the quality of the catfish fishery in the Wabash River will likely be enhanced to the contentment of anglers unsatisfied (28%; Shipman 1996) with the catfish resources in Indiana's rivers.

RECOMMENDATIONS

- Implement a 15-in minimum size limit for catfish along the lower 200-mile interjurisdictional border (IN-IL).

- Implement a daily creel of one catfish greater than or equal to 33 in for the Wabash River.

- Form a work-group, as originally proposed by Hoffman (2006), to facilitate review of state-wide catfish creel and length-limit regulations.

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Table 1. Sample locations for catfish in the Wabash River from 2005 to 2007.

Treatment	Reach	Site	River-miles	Boat Launch
IN-IL	1	1	11.9-12.9	New Haven, IL
IN-IL	1	2	26.3-27.3	Dogtown, IN
IN-IL	1	3	50.3-51.3	New Harmony, IN
IN-IL	2	1	72.0-73.0	Grayville, IL
IN-IL	2	2	95.9-96.9	Mt. Carmel, IL
IN-IL	2	3	118.2-119.2	St. Francisville, IL
IN-IL	3	1	143.0-144.0	Russellville, IL
IN-IL	3	2	167.0-168.0	Hutsonville, IL
IN-IL	3	3	191.2-192.2	Darwin, IL
IN	4	1	244.0-245.0	Montezuma, IN
IN	4	2	264.3-265.3	Perrysville, IN
IN	4	3	281.2-282.2	Attica, IN
IN	4	4	295.0-296.0	*Private*[a], IN
NON	5	1	312.4-313.4	Mascouten Park, IN
NON	5	2	318.4-319.4	Mascouten Park, IN
NON	5	3	324.0-325.0	*Private*[b], IN
NON	5	4	330.0-331.0	*Private*[c], IN
NON	5	5	335.5-336.5	French Post Park, IN
NON	5	6	341.5-342.5	French Post Park, IN

[a] Ramp near river-mile 298.2 across from Collier's Island.
[b] Ramp just upstream from the confluence of the Tippecanoe River on the south shore.
[c] Ramp near Pittsburg, IN near river-mile 330.6.

Table 2. The number of catfish collected and marked (parenthesis) in the NON, IN, and IN-IL treatments of the Wabash River in 2005 (’05), 2006 (’06), and 2007 (’07).

Species	$NON_{'05}$	$NON_{'06}$	$NON_{'07}$	$IN_{'05}$	$IN_{'06}$	$IN_{'07}$	$IN\text{-}IL_{'05}$	$IN\text{-}IL_{'06}$	$IN\text{-}IL_{'07}$	$Total_{ALL}$
Flathead	31 (7)[a]	13 (9)	8 (8)	193 (94)	158 (70)	11 (10)	562 (312)	195 (70)	180 (82)	1351 (662)
Channel	73 (36)	13 (2)	26 (26)	161 (88)	22 (1)	17 (12)	223 (123)	4 (1)	79 (42)	618 (331)
Blue	0 (0)	0 (0)	0 (0)	11 (6)	4 (0)	0 (0)	75 (65)	8 (2)	65 (54)	163 (127)
Total	104 (43)	26 (11)	34 (34)	365 (188)	184 (71)	28 (22)	860 (500)	207 (73)	324 (178)	2132 (1120)

[a] Marked with a Floy ® tag.

Table 3. Comparative hoop net (1.0 and 1.25 inch bar mesh) catch-per-unit-effort (fish/net night) estimates for flathead (FHC), channel (CCF), and blue (BCF) catfish in the non-commercial (NON), Indiana-only commercial (IN) and Indiana-Illinois (IN-IL) treatments of the Wabash River in 2005 and 2007.

2005									
Treatment	$FHC_{1.0}$	$FHC_{1.25}$	$CCF_{1.0}$	$CCF_{1.25}$	$BCF_{1.0}$	$BCF_{1.25}$	$Total_{1.0}$	$Total_{1.25}$	$Total_{All}$
NON (25, 25)[a]	0.1 (2)[b]	0.0 (1)	1.0 (24)	0.8 (19)	0.0 (0)	0.0 (0)	1.0 (26)	0.8 (20)	0.9 (46)
IN (45, 45)	0.1 (4)	0.2 (8)	1.6 (74)	1.6 (73)	0.0 (0)	0.0 (0)	1.7 (78)	1.8 (81)	1.8 (159)
IN-IL (88, 90)	0.3 (26)	0.3 (26)	0.9 (79)	0.6 (51)	0.0 (1)	0.0 (0)	1.2 (106)	0.9 (77)	1.0 (183)
Total (158, 160)	0.2 (32)	0.2 (35)	1.1 (177)	0.9 (143)	0.0 (1)	0.0 (0)	1.3 (210)	1.1 (178)	1.2 (388)

2007									
Treatment	$FHC_{1.0}$	$FHC_{1.25}$	$CCF_{1.0}$	$CCF_{1.25}$	$BCF_{1.0}$	$BCF_{1.25}$	$Total_{1.0}$	$Total_{1.25}$	$Total_{All}$
NON (15, 15)	0.3 (5)	0.2 (3)	0.5 (8)	1.2 (18)	0.0 (0)	0.0 (0)	0.9 (13)	1.4 (21)	1.1 (34)
IN (14, 14)	0.6 (8)	0.2 (3)	0.7 (10)	0.5 (7)	0.0 (0)	0.0 (0)	1.3 (18)	0.7 (10)	1.0 (28)
IN-IL (50, 50)	0.2 (10)	0.0 (2)	1.1 (57)	0.4 (18)	0.2 (8)	0.0 (1)	1.5 (75)	0.4 (21)	0.9 (96)
Total (79, 79)	0.3 (23)	0.1 (8)	1.0 (75)	0.5 (43)	0.1 (8)	0.0 (1)	1.3 (106)	0.7 (52)	1.0 (158)

[a] Number in parenthesis refers to the total number of net nights per 1.0 and 1.25 in bar mesh nets, respectively.
[b] Number in parenthesis refers to the total number of fish captured.

Table 4. Comparative catch-per-unit-effort (fish/hour) estimates using a gas-powered-pulsating (GPP) electrofisher for flathead (FHC), channel (CCF), and blue (BCF) catfish in the non-commercial (NON), Indiana-only commercial (IN) and Indiana-Illinois (IN-IL) treatments of the Wabash River in 2005 (’05), 2006 (’06), and 2007 (’07).

Treatment	$FHC_{'05}$	$FHC_{'06}$	$FHC_{'07}$	$CCF_{'05}$	$CCF_{'06}$	$CCF_{'07}$	$BCF_{'05}$	$BCF_{'06}$	$BCF_{'07}$	$Total_{'05}$	$Total_{'06}$	$Total_{'07}$	$Total_{All}$
NON (0, 2, 0)[a]	NS [b]	7 (13) [c]	NS	NS	7 (13)	NS	NS	0 (0)	NS	NS	13 (26)	NS	13 (26)
IN (0.5, 4.5, 0)	16 (8)	35 (158)	NS	6 (3)	5 (22)	NS	0 (0)	1 (4)	NS	22 (11)	41 (184)	NS	39 (195)
IN-IL (4, 2, 4)	55 (218)	84 (167)	42 (167)	1 (3)	2 (4)	1 (4)	5 (23)	2 (3)	14 (56)	61 (244)	87 (174)	57 (227)	65 (645)
Total (4.5, 8.5, 4)	50 (226)	40 (338)	42 (167)	1 (6)	5 (39)	1 (4)	5 (23)	1 (7)	14 (56)	57 (255)	45 (384)	57 (227)	51 (866)

[a] Number in parenthesis refers to the total effort in hours per sample year (’05, ‘06, and ’07, respectively).
[b] Not sampled
[c] Number in parenthesis refers to the total number of fish captured.

Table 5. Relative stock density (RSD) indices for flathead (FHC), channel (CCF), and blue (BCF) catfish collected in the non-commercial (NON), Indiana-only commercial (IN), and Indiana-Illinois (IN-IL) commercial fishing treatments of the Wabash River from 2005 to 2007.

	RSD[a] (%)			
	Quality	Preferred	Memorable	Trophy
FHC[b]				
NON	33	4	4	2
IN	2	1	<1	<1
IN-IL	5	<1	<1	<1
CCF[c]				
NON	33	3	0	0
IN	30	1	0	0
IN-IL	24	0	0	0
BCF[d]				
NON	NS[e]	NS	NS	NS
IN	20	13	7	0
IN-IL	49	8	<1	<1

[a] RSD subscripts below correspond to minimum length (in) values per category.

[b] Q_{20}, P_{28}, M_{34}, and T_{40} (Daugherty and Sutton 2005a).

[c] Q_{16}, P_{24}, M_{28}, and T_{36} (Anderson and Neumann 1996).

[d] Q_{20}, P_{30}, M_{35}, and T_{45} (Anderson and Neumann 1996).

[e] Not sampled.

Table 6. Percent frequencies of agreement and disagreement for catfish ages determined by two independent analysts using pectoral spine cross-sections.

Species	N	Agreement (%)	Disagreement (%)			
			± 1 yr	± 2 yrs	± 3 yrs	± > 4 yrs
Flathead	763	38 (289)[a]	43 (325)	12 (92)	3 (27)	4 (30)
Channel	444	38 (169)	38 (167)	13 (58)	5 (21)	6 (29)
Blue	143	35 (50)	31 (45)	18 (26)	8 (11)	8 (11)

[a] Number in parenthesis refers the actual number of catfish in the sample.

Table 7. Back-calculated mean (± SE) length-at-age data for flathead catfish collected in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

		Mean total length-at-age (in)									
Year	Treatment	1	2	3	4	5	6	7	8	9	10
2005	NON	5.2 (0.2)[a]	9.8 (0.4)	13.9 (0.5)	17.4 (0.7)	21.2 (0.8)	22.8 (0.9)	24.3 (1.0)			
2005	IN	4.3 (0.1)	7.9 (0.2)	10.9 (0.2)	14.5 (0.3)	18.3 (0.4)	21.9 (0.4)	24.0 (0.5)	26.7 (0.8)	28.0 (1.0)	
2005	IN-IL	4.6 (0.1)	9.1 (0.2)	12.8 (0.3)	15.6 (0.3)	18.5 (0.7)	22.4 (1.1)	24.1 (1.5)	28.9 (1.4)	32.0 (1.9)	34.3 (2.3)
2006	NON	5.2 (0.6)	8.8 (0.7)	12.0 (0.8)	15.4 (0.8)	19.8 (0.8)	22.3 (0.7)	24.1 (0.8)	25.6 (1.1)		
2006	IN	5.4 (0.2)	9.2 (0.2)	12.9 (0.5)	15.9 (0.7)	19.1 (0.8)	22.5 (1.1)	26.5 (1.9)	28.3 (2.2)	28.7 (2.9)	
2006	IN-IL	4.6 (0.1)	8.3 (0.2)	10.6 (0.4)	13.2 (0.6)	15.4 (1.2)					
2007	NON	5.0 (0.9)	7.9 (1.3)	10.6 (1.7)	13.4 (2.1)	15.8 (2.5)	16.9 (3.1)	18.6 (4.2)			
2007	IN	5.2 (0.4)	9.6 (0.6)	13.0 (0.6)	16.7 (0.6)	19.6 (0.7)	21.7 (0.8)				
2007	IN-IL	5.0 (0.2)	9.2 (0.3)	12.2 (0.5)	15.2 (0.8)	18.4 (1.1)	19.9 (1.6)	24.0 (4.3)			

[a] Standard errors were estimated with a minimum of five data points.

Table 8. Back-calculated mean (± SE) length-at-age data for channel catfish collected in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

		Mean total length-at-age (in)									
Year	Treatment	1	2	3	4	5	6	7	8	9	10
2005	NON	4.4 (0.2) [a]	7.2 (0.2)	9.4 (0.2)	11.7 (0.2)	13.6 (0.3)	15.1 (0.3)	16.3 (0.3)	17.8 (0.4)	19.2 (0.7)	20.6 (0.9)
2005	IN	4.0 (0.1)	7.3 (0.1)	10.0 (0.1)	12.4 (0.2)	14.0 (0.3)	15.7 (0.3)	16.9 (0.4)	18.0 (0.5)	18.1 (0.5)	18.8 (0.8)
2005	IN-IL	4.1 (0.1)	8.0 (0.1)	10.7 (0.2)	13.2 (0.3)	15.0 (0.4)	16.5 (0.4)	17.8 (0.5)	19.1 (0.6)	18.5 (0.8)	
2006	NON	N/A									
2006	IN	4.4 (0.3)									
2006	IN-IL	4.4 (0.3)									
2007	NON	4.4 (0.2)	7.2 (0.3)	9.4 (0.3)	11.3 (0.3)	13.0 (0.4)	14.5 (0.5)	16.0 (0.7)	17.8 (0.8)		
2007	IN	5.0 (0.3)	8.4 (0.4)	11.1 (0.7)	13.0 (0.8)	14.6 (1.5)					
2007	IN-IL	4.5 (0.1)	8.3 (0.2)	10.2 (0.3)	12.6 (0.4)	14.3 (0.5)	16.1 (0.6)				

[a] Standard errors were estimated with a minimum of five data points.

Table 9. Back-calculated mean (± SE) length-at-age data for blue catfish collected in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

		Mean total length-at-age (in)									
Year	Treatment	1	2	3	4	5	6	7	8	9	10
2005	NON	N/A									
2005	IN	6.0 (0.6)	9.3 (0.7)	12.8 (1.1)	15.9 (1.3)	19.6 (1.5)	22.9 (1.6)	25.3 (1.8)	27.5 (2.0)	29.9 (2.6)	
2005	IN-IL	4.5 (0.1)	8.3 (0.3)	11.6 (0.3)	14.4 (0.3)	17.2 (0.3)	19.6 (0.3)	21.3 (0.3)	22.9 (0.4)	24.5 (0.5)	26.7 (0.7)
2006	NON	N/A									
2006	IN	N/A									
2006	IN-IL	N/A									
2007	NON	N/A									
2007	IN	N/A									
2007	IN-IL	5.4 (0.2)	9.2 (0.3)	11.9 (0.4)	14.9 (0.5)	17.7 (0.5)	19.9 (0.5)	21.9 (0.4)	23.1 (0.5)	24.3 (0.6)	25.8(1.0)

[a] Standard errors were estimated with a minimum of five data points.

Table 10. Mean length (in)-at-age (± 95% CI) for flathead (FHC), channel (CCF), and blue (BCF) catfish among the NON, IN, and IN-IL treatments of the Wabash River, all years combined.

Species	Age	NON	IN	IN-IL
FHC	1	5.2 (4.4-5.9)	4.8 (4.6-5.0)	4.7 (4.6-4.9)
	2	8.6 (7.6-9.7)	8.3 (8.1-8.5)	8.5 (8.3-8.7)
	3	11.8 (10.3-13.2)	11.1 (10.8-11.5)	11.7 (11.4-12.1)
	4	15.4 (13.7-17.2)	14.4 (13.8-14.9)	14.5 (14.0-15.1)
	5	18.3 (16.2-20.5)	17.3 (16.7-18.0)	16.8 (16.2-17.5)
CCF	1	4.4 (4.1-4.6)	4.1 (3.9-4.3)	4.2 (4.1-4.4)
	2	7.2 (6.8-7.6)	7.5 (7.3-7.8)	8.0 (7.8-8.2)
	3	9.4 (9.1-9.8)	10.0 (9.7-10.3)	10.4 (10.1-10.7)
	4	11.4 (11.0-11.7)	11.9 (11.5-12.3)	12.3 (11.9-12.7)
	5	13.1 (12.7-13.6)	14.0 (13.6-14.4)	14.3 (13.8-14.7)
BCF	1	N/A	6.0 (4.5-7.4)	4.9 (4.7-5.2)
	2	N/A	9.2 (7.3-11.2)	8.6 (8.3-9.0)
	3	N/A	12.8 (9.9-15.7)	11.7 (11.3-12.1)
	4	N/A	15.9 (12.6-19.2)	14.7 (14.1-15.2)
	5	N/A	19.6 (15.8-23.3)	17.2 (16.6-17.7)

Table 11. Percent total annual survival (± 95% CI) estimates for flathead, channel, and blue catfish collected in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

Species & Estimator	NON	IN	IN-IL
Flathead			
Heincke's	86 (57-115)	67 (58-76)	69 (64-74)
Robson-Chapman	81 (75-87)	66 (63-69)	62 (60-66)
Catch-curve	91 (13-170)	69 (63-76)	55 (42-67)
Channel			
Heincke's	53 (34-72)	74 (60-88)	60 (48-72)
Robson-Chapman	58 (50-66)	69 (64-74)	63 (58-68)
Catch-curve	82 (66-97)	76 (62-90)	65 (39-90)
Blue			
Heincke's	NS[a]	NS	78 (63-93)
Robson-Chapman	NS	NS	81 (78-84)
Catch-curve	NS	NS	94 (82-107)

[a] Not sampled.

Table 12. Annual exploitation estimates for catfish (all species combined; above) and annual exploitation by species and treatment (below) from tag returns of marked flathead (FHC), channel (CCF), and blue (BCF) catfish in the Wabash River from 2005 to 2007. The character m_i symbolizes the number of catfish marked in year i; $f_i\cdot$ is the number of tagged fish in year i harvested by anglers over all years; $f\cdot_i$ is the number of marked fish harvested each year i despite the year in which they were marked; k_i is the total number of marked catfish harvested after year i of catfish marked before year i; u_i is the annual exploitation estimate that results from the Ricker (1975) equation: $u_i = (f_i\cdot \bullet f\cdot_i) / (m_i \bullet k_i)$.

		Angler recaptures			Statistics		
Year	m_i	2005	2006	2007	$f\cdot_i$	k_i	u_i (%)
2005	731	16			16	55	2.2
2006	155	25	0		25	44	1.8
2007	234	14	5	1	20	20	0.4
$f_i\cdot$		55	5	1			

		u_i (%)			
Species	Treatment	2005	2006	2007	Mean
FHC	NON	0.0	0.0	0.0	0.0
FHC	IN	4.3	1.4	0.0	1.9
FHC	INIL	2.2	0.8	0.0	1.0
CCF	NON	0.0	0.0	0.0	0.0
CCF	IN	1.1	0.0	0.0	0.4
CCF	INIL	2.4	0.0	0.0	0.8
BCF	NON	NS[a]	NS	NS	NS
BCF	IN	0.0	0.0	0.0	0.0
BCF	INIL	1.5	0.0	1.9	1.1

[a] Not sampled.

Table 13. The number of flathead, channel, and blue catfish tag returns from the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007. Values in parenthesis reflect relative percentages based on the number of catfish available for harvest (i.e., the number of catfish tagged).

	Treatment				
Species	Unknown[a]	NON	IN	IN-IL	Total
Flathead	1 (0.2)	1 (4.2)	11 (6.3)	31 (6.7)	44 (6.6)
Channel	2 (0.6)	0 (0.0)	1 (1.0)	7 (4.2)	10 (3.0)
Blue	0 (0.0)	NS[b]	0 (0.0)	7 (5.8)	7 (5.5)
Total	3 (0.3)	1 (0.1)	12 (1.1)	45 (4.0)	61 (5.4)

[a] The treatment (i.e, NON, IN, IN-IL) where a fish was recaptured is unknown.
[b] Not sampled

Table 14. Angler type and state of residence for anglers that returned catfish tags in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007. Values in parenthesis reflect relative percentages based on the number of catfish available for harvest (i.e., the number of catfish tagged in each treatment).

	Treatment				
Angler Type/Residence	Unknown[a]	NON	IN	IN-IL	Total
Commercial	0 (0.0)	0 (0.0)	5 (1.8)	22 (2.9)	27 (2.4)
Recreational	3 (0.3)	0 (0.0)	6 (2.1)	23 (3.1)	32 (2.9)
Unknown[b]	0 (0.0)	1 (1.1)	1 (0.4)	0 (0.0)	2 (0.2)
Total	3 (0.3)	1 (1.1)	12 (4.3)	45 (6.0)	61 (5.4)
IL Angler	1 (0.1)	0 (0.0)	0 (0.0)	26 (3.5)	27 (2.4)
IN Angler	2 (0.2)	1 (1.1)	11 (3.9)	18 (2.4)	32 (2.9)
Unknown[c]	0 (0.0)	0 (0.0)	1 (0.4)	1 (0.1)	2 (0.2)
Total	3 (0.3)	1 (1.1)	12 (4.3)	45 (6.0)	61 (5.4)

[a] The treatment (i.e, NON, IN, IN-IL) where a fish was recaptured is unknown.
[b] The angler type (i.e, commercial or recreational) is unknown.
[c] The angler's state of residence (i.e, IL or IN) is unknown.

Table 15. Angler type and recapture method of tag returns for flathead (FHC), channel (CCF), and blue (BCF) catfish in the Wabash River from 2005 to 2007. Values in parenthesis reflect relative percentages based on the number of catfish available for harvest (i.e., the number of catfish tagged in each treatment).

	Species				
Angler Type/Method	Unknown[a]	FHC	CCF	BCF	Total
Commercial	0 (0.0)	24 (3.6)	3 (0.9)	0 (0.0)	27 (2.4)
Recreational	0 (0.0)	18 (2.7)	7 (2.1)	7 (5.5)	32 (2.9)
Unknown[b]	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	2 (0.2)
Total	0 (0.0)	44 (6.6)	10 (3.0)	7 (5.5)	61 (5.4)
Hoop Net	0 (0.0)	21 (3.2)	3 (0.9)	0 (0.0)	24 (2.1)
Jug-Line	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.8)
Rod-Reel	0 (0.0)	14 (2.1)	6 (1.8)	4 (3.1)	24 (2.1)
Trot-Line	0 (0.0)	6 (0.9)	1 (0.3)	2 (1.6)	9 (0.8)
Unknown[c]	0 (0.0)	3 (0.5)	0 (0.0)	0 (0.0)	3 (0.3)
Total	0 (0.0)	44 (6.6)	10 (3.0)	7 (5.5)	61 (5.4)

[a] The species (i.e, BCF, CCF, FHC) recaptured is unknown.
[b] The angler type (i.e, commercial or recreational) is unknown.
[c] The angler's method of recapture (i.e, bank-pole, hoop net, jug-line, etc.) is unknown.

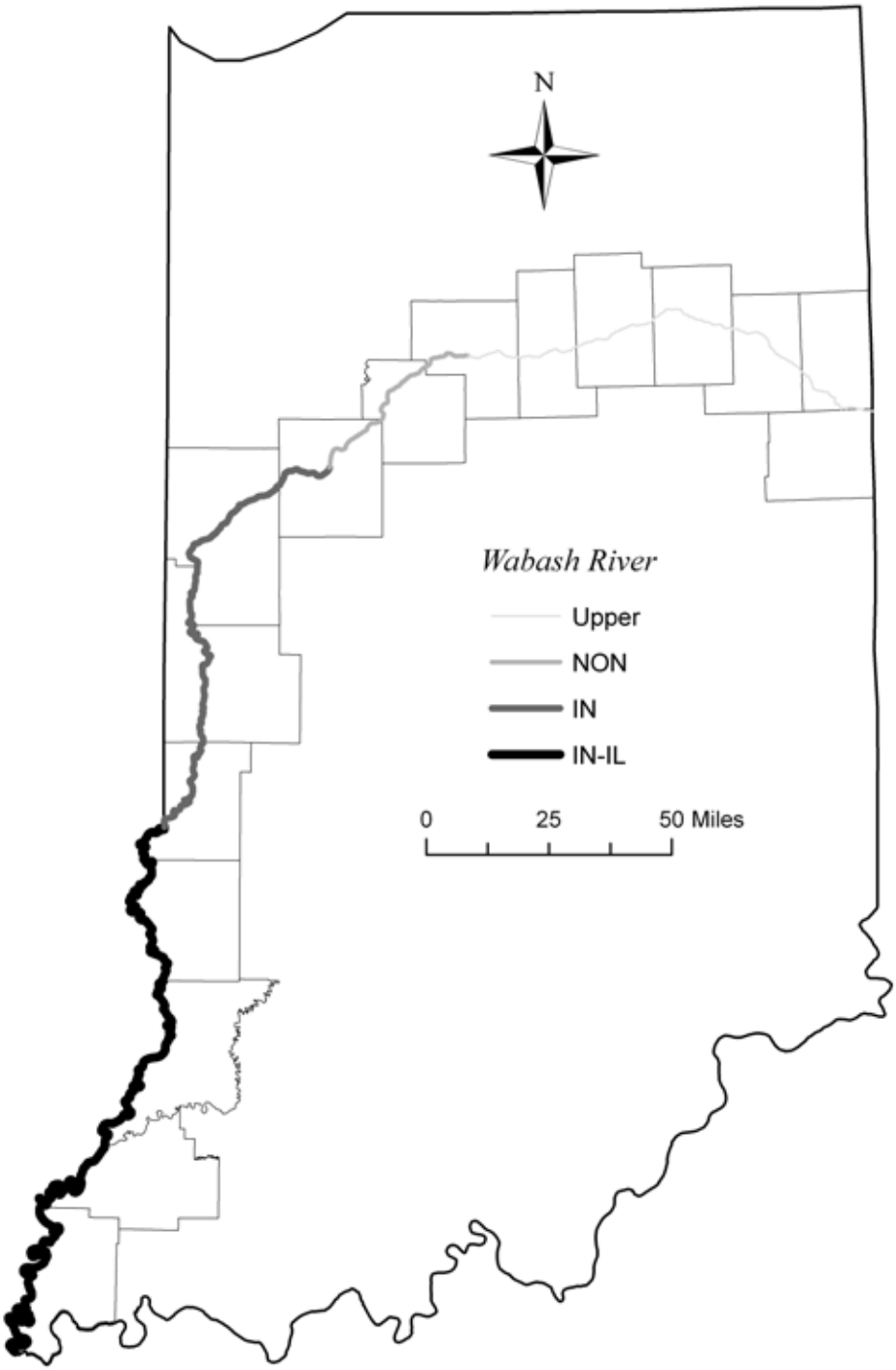

Figure 1. The non-commercial (NON), Indiana-only commercial (IN), and Indiana-Illinois (IN-IL) treatments of the Wabash River.

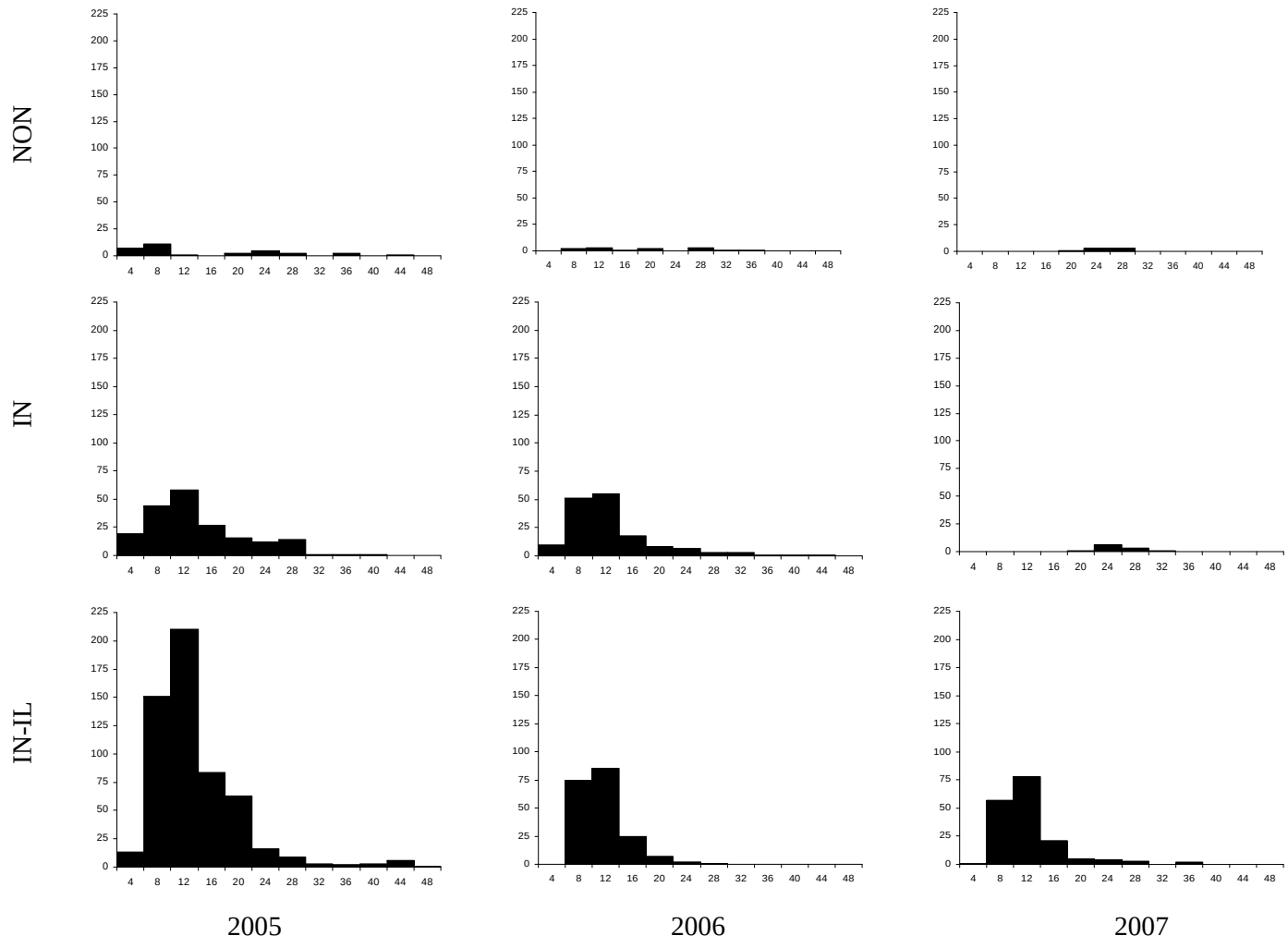

Figure 2. Flathead catfish length-frequency (inches, *x*-axis; N, *y*-axis) distributions by year and treatment, Wabash River.

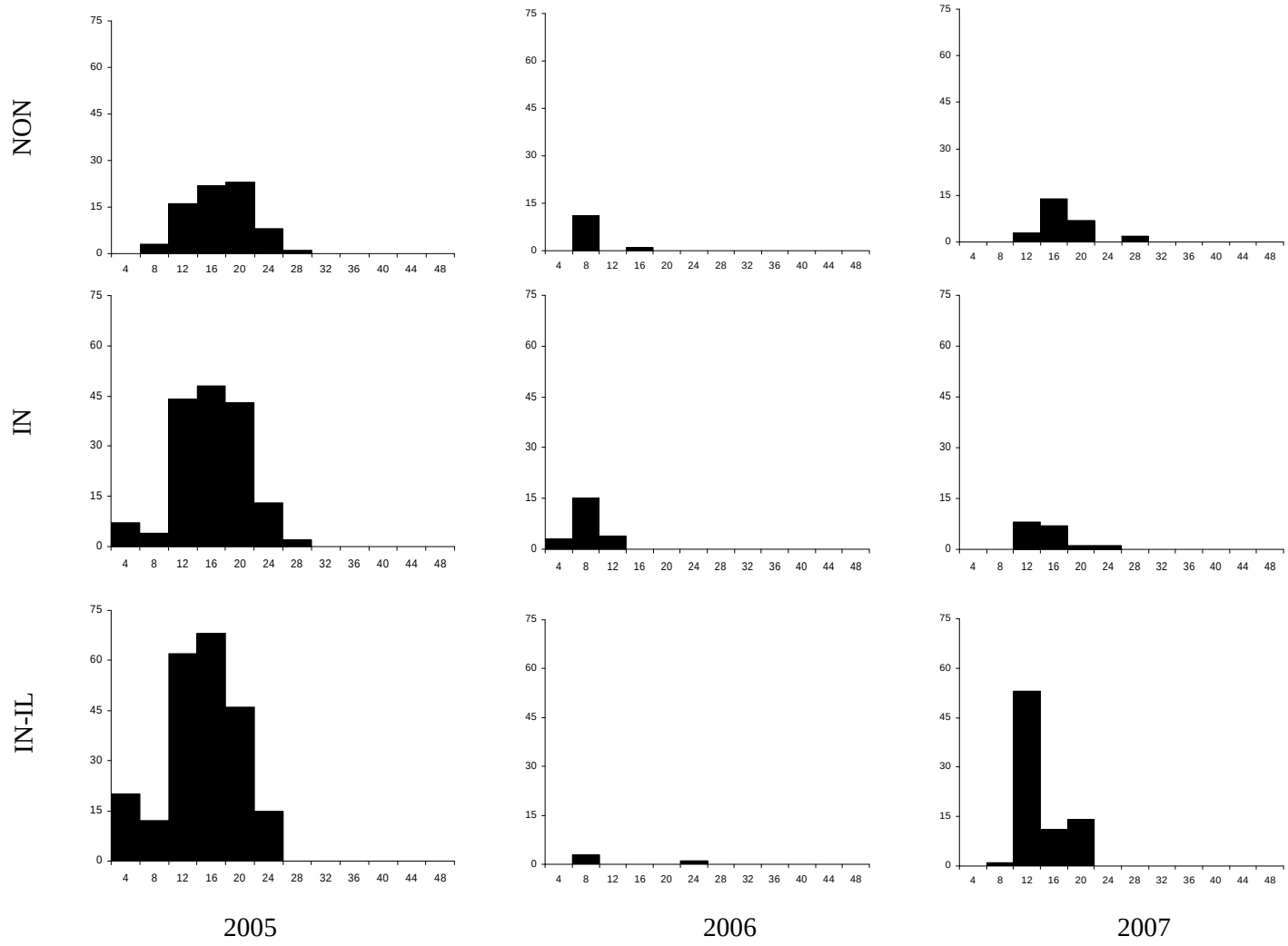

Figure 3. Channel catfish length-frequency (inches, *x*-axis; N, *y*-axis) distributions by year and treatment, Wabash River.

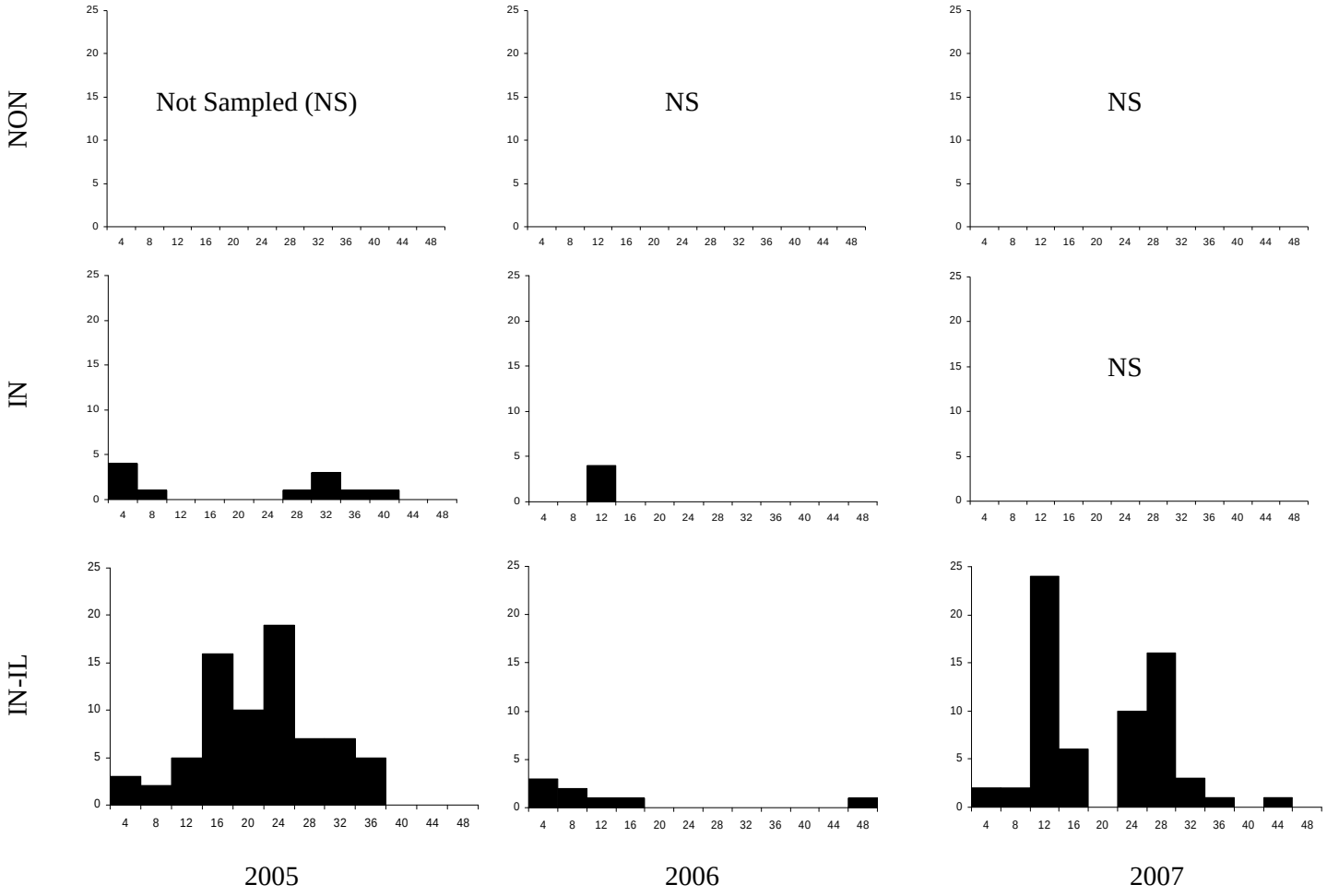

Figure 4. Blue catfish length-frequency (inches, *x*-axis; N, *y*-axis) distributions by year and treatment, Wabash River.

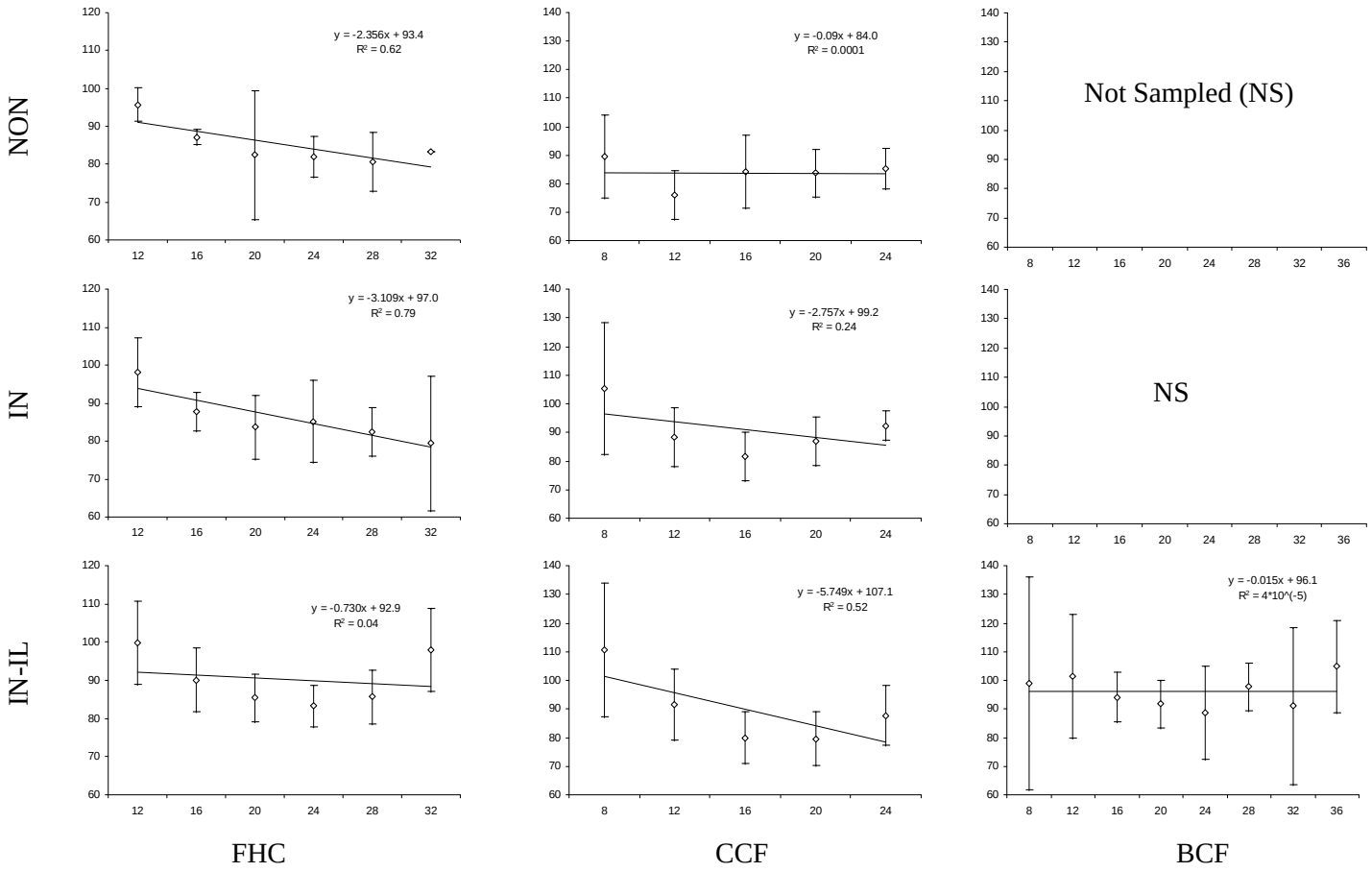

Figure 5. Mean (± SD) relative weights (*y*-axis) per four-inch length bin (*x*-axis) for flathead (FHC), channel (CCF) and blue (BCF) catfish collected in the non-commercial (NON), Indiana-only commercial (IN), and Indiana-Illinois commercial (IN-IL) fishing treatments.

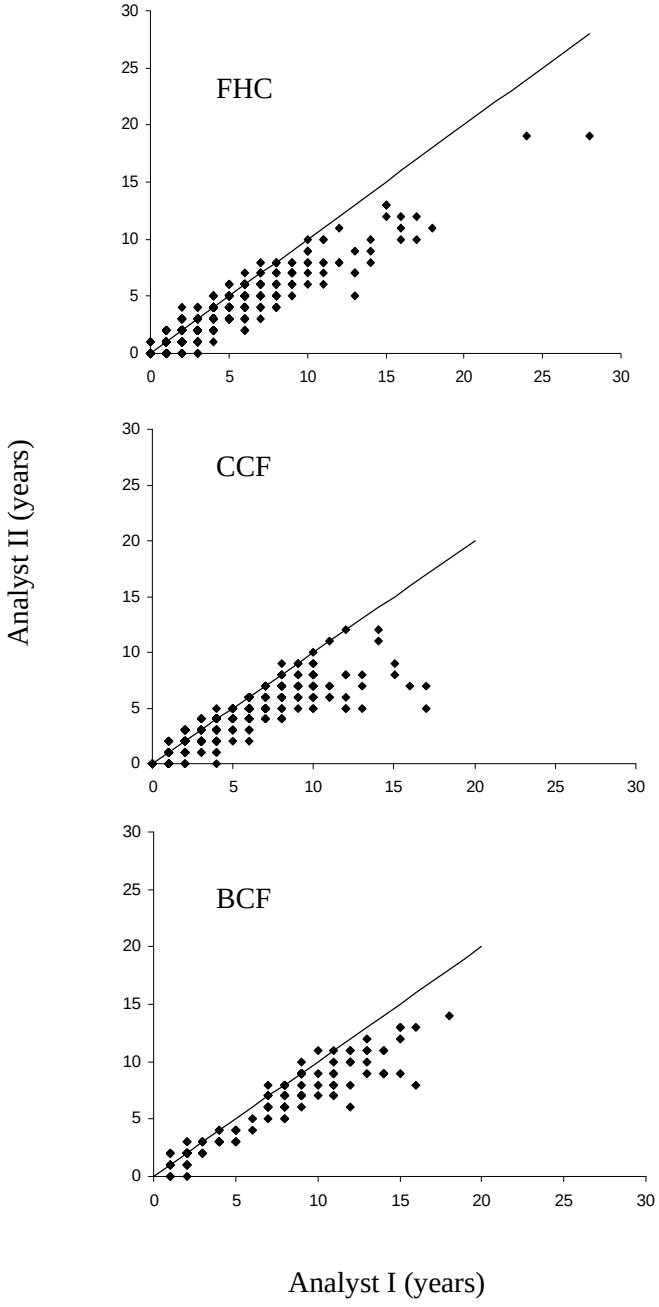

Figure 6. Comparative age (years) agreements between Analyst I (*x*-axis) and Analyst II (*y*-axis) using pectoral spines among flathead (FHC), channel (CCF), and blue (BCF) catfish collected in the Wabash River, 2005 to 2007.

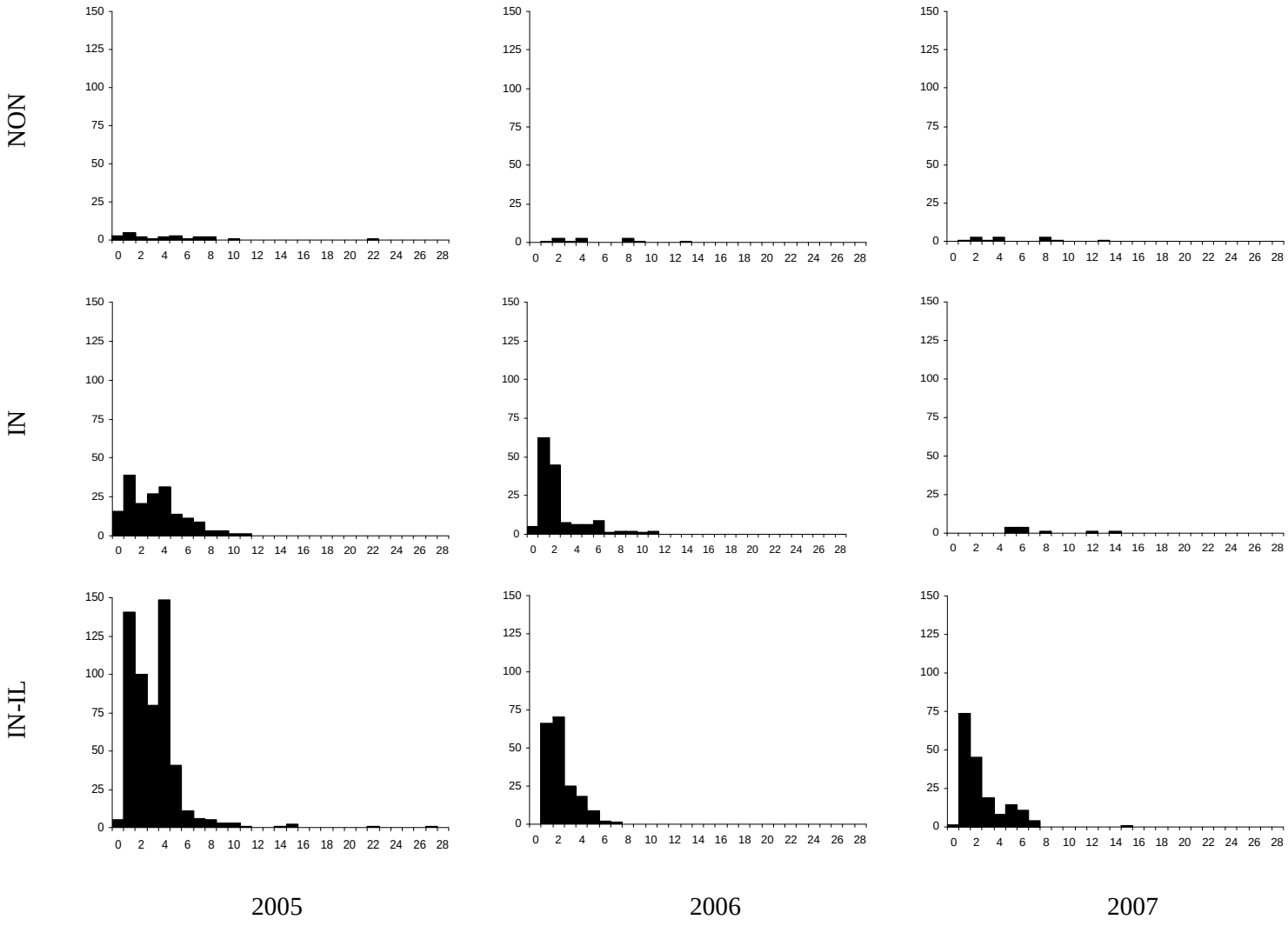

Figure 7. Flathead catfish age-frequency (years, *x*-axis; N, *y*-axis) distributions by year and treatment, Wabash River.

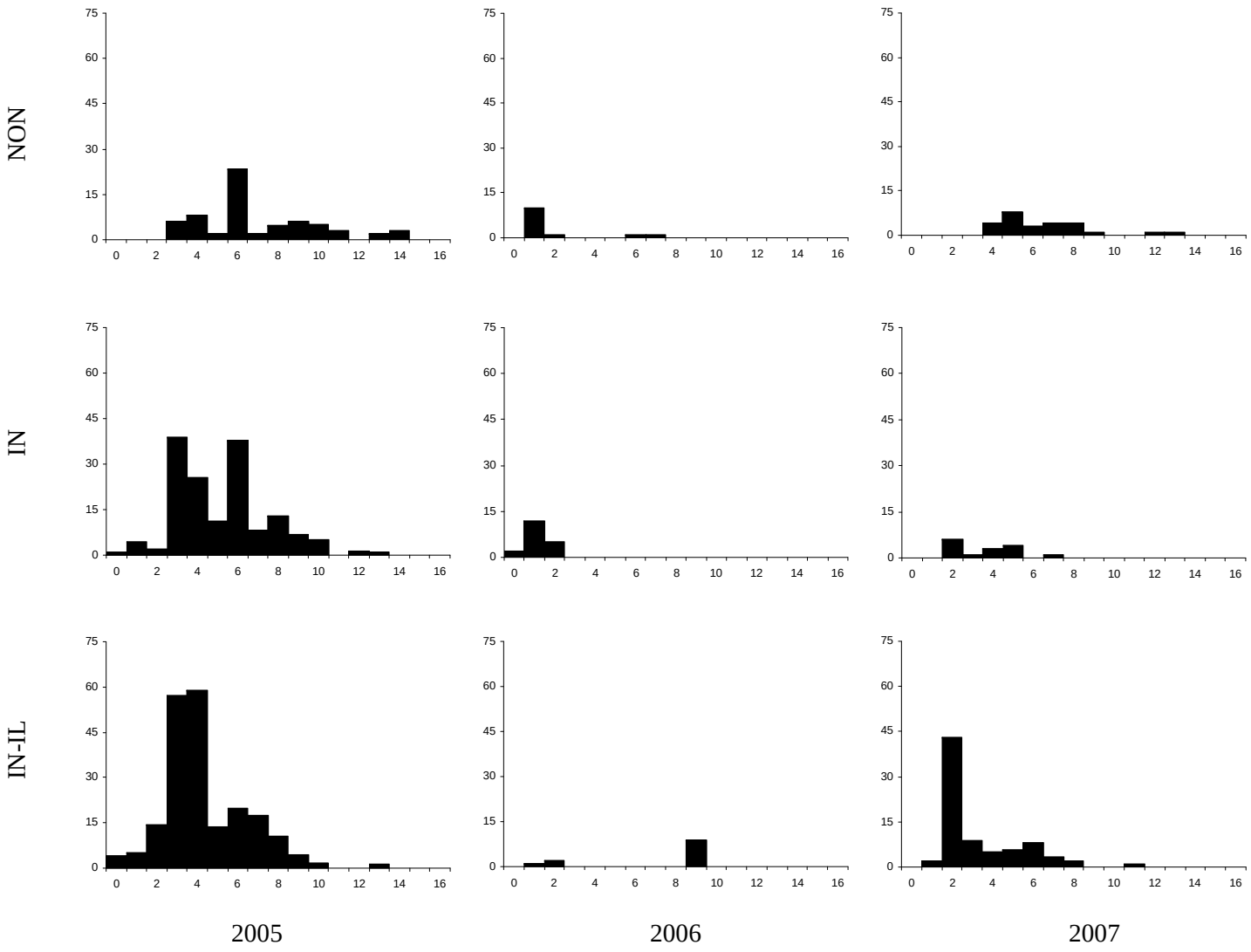

Figure 8. Channel catfish age-frequency (years, *x*-axis; N, *y*-axis) distributions by year and treatment, Wabash River.

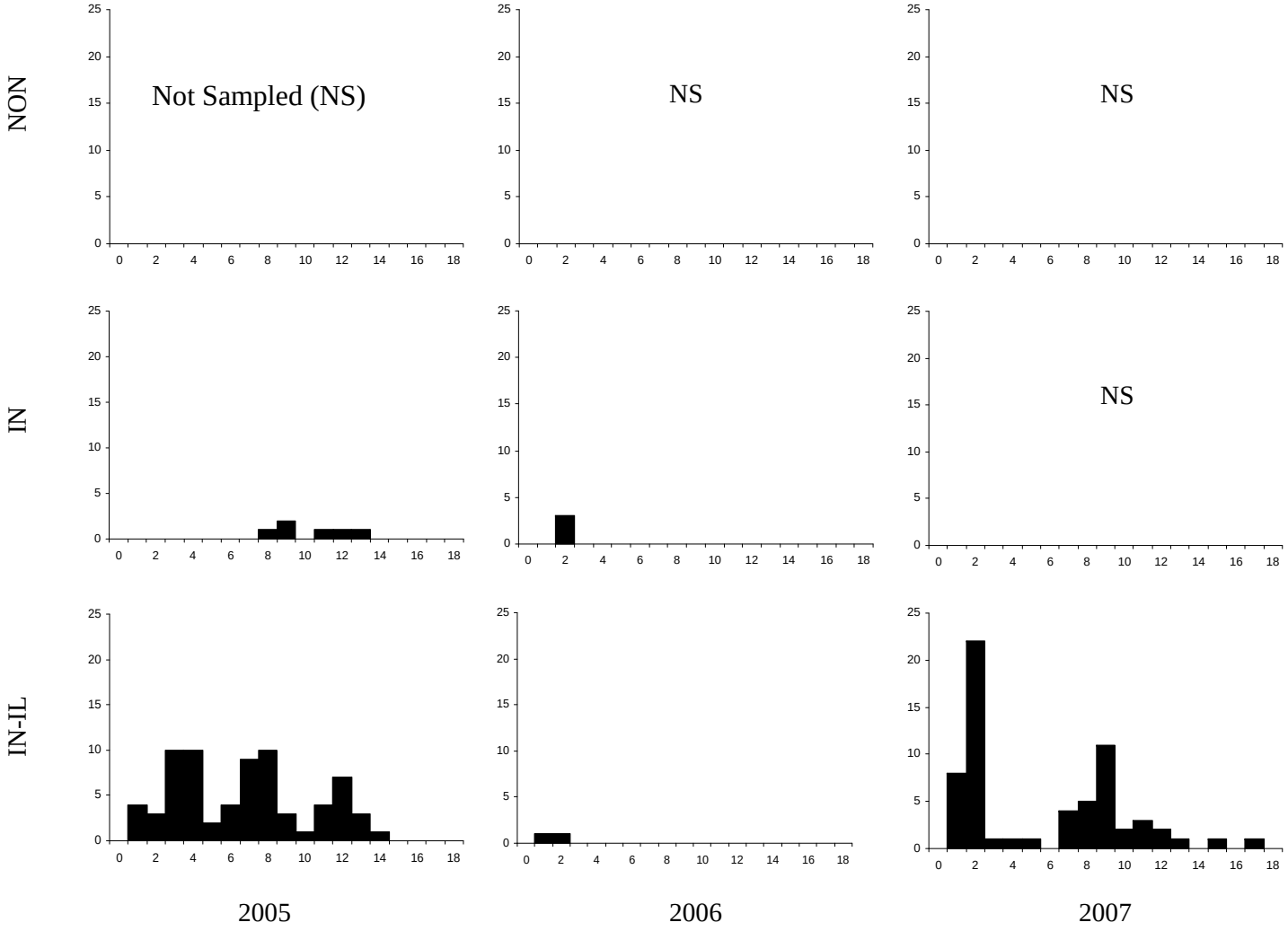

Figure 9. Blue catfish age-frequency (years, *x*-axis; N, *y*-axis) distributions by year and treatment, Wabash River.

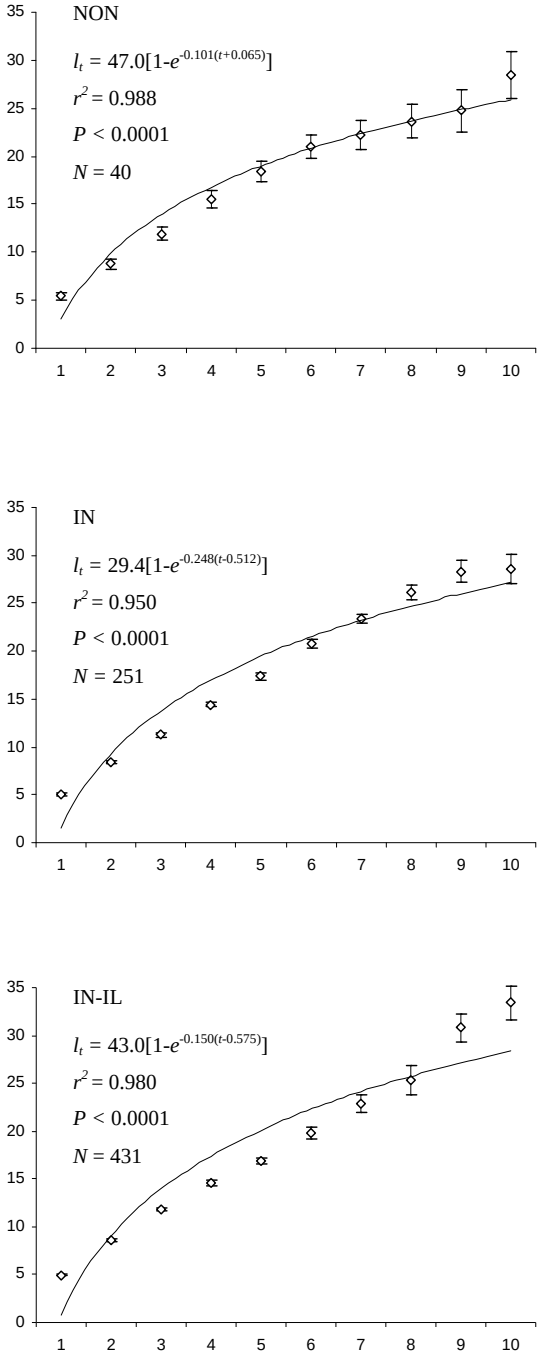

Figure 10. Predicted von Bertalanffy growth equation for mean (± SE) length-at-age data (years, *x*-axis; inches, *y*-axis) of flathead catfish in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

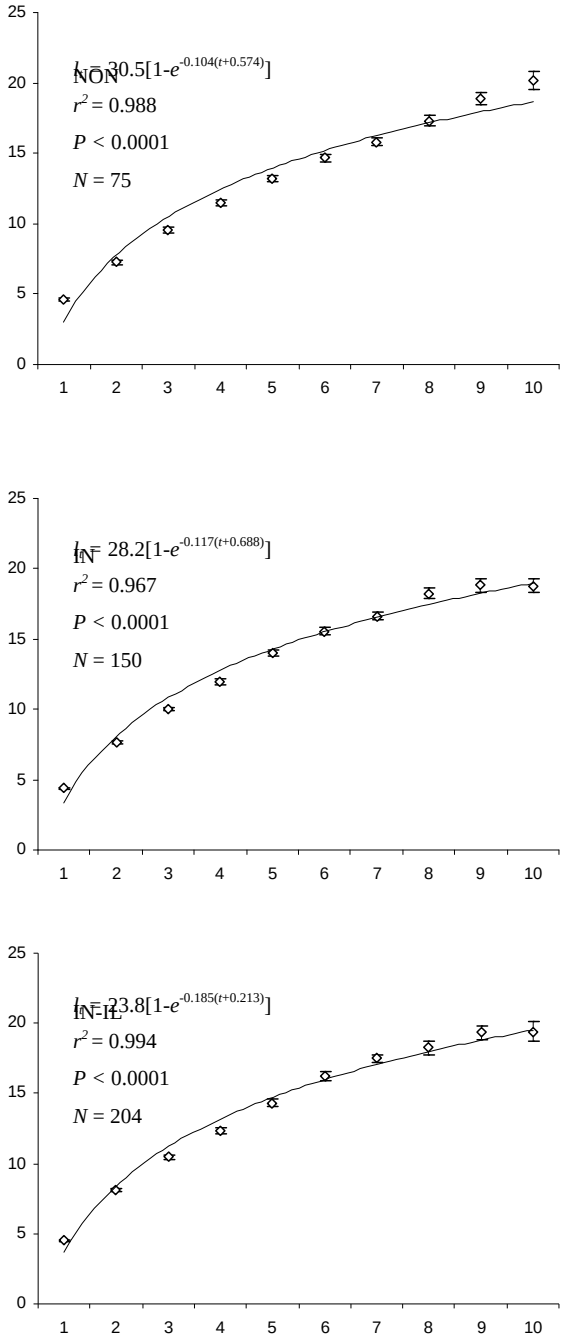

Figure 11. Predicted von Bertalanffy growth equation for mean (± SE) length-at-age data (years, *x*-axis; inches, *y*-axis) of channel catfish in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

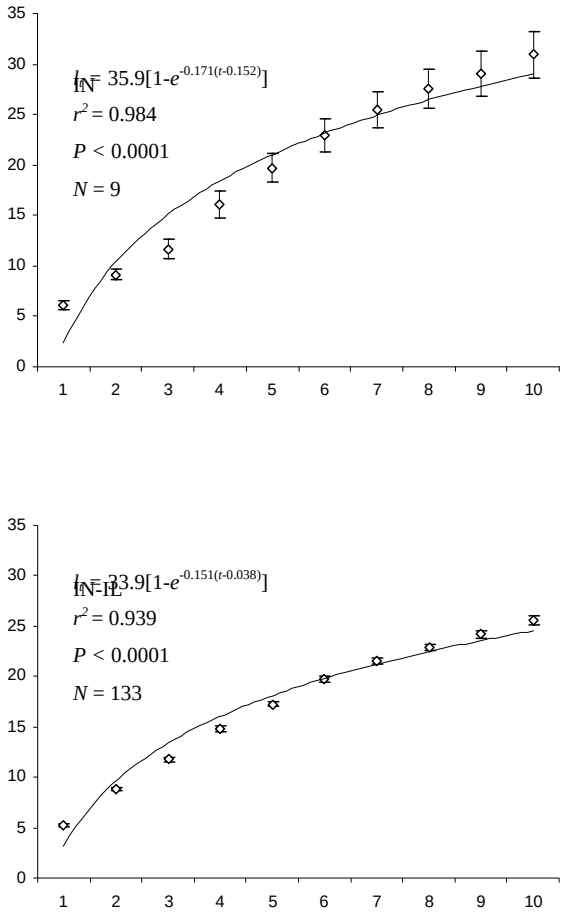

Figure 12. Predicted von Bertalanffy growth equation for mean (± SE) length-at-age data (years, *x*-axis; inches, *y*-axis) of blue catfish in the NON, IN, and IN-IL treatments of the Wabash River from 2005 to 2007.

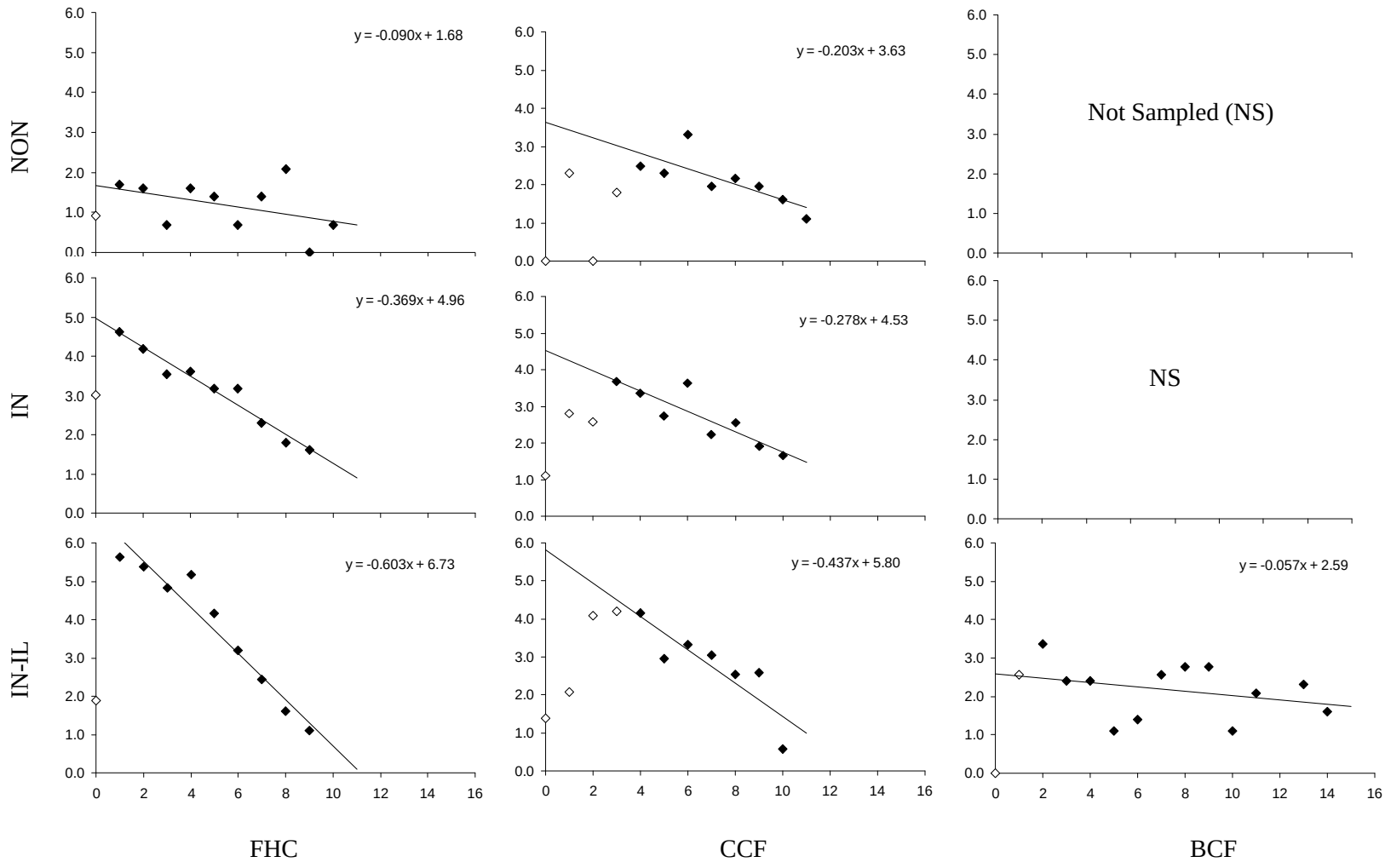

Figure 13. Catch-curve regressions (years, *x*-axis; Log_e frequency N, *y*-axis) for flathead (FHC), channel (CCF), and blue (BCF) catfish collected in the NON, IN, and IN-IL treatments of the Wabash River. The slope of the line is the instantaneous total mortality rate, *Z*. The line-of-best-fit was estimated using the age groups considered fully recruited to the sampling gear (i.e., black data points).

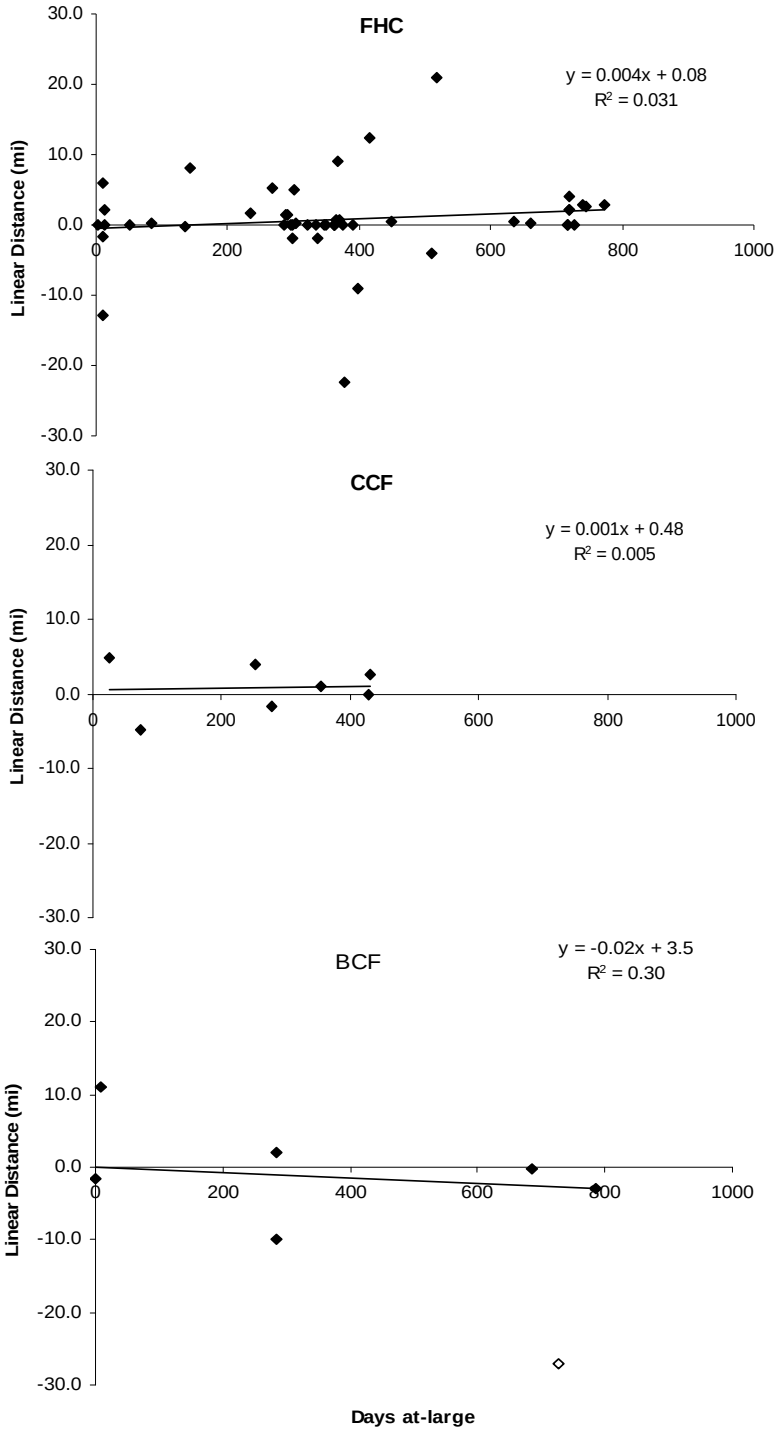

Figure 14. The linear distribution (mi) of post-release flathead (FHC), channel (CCF), and blue (BCF) catfish regressed against the number of day's fish were at-large.