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Status, trends, and population demographics of selected sportfish species in the La Grange Reach of the Illinois River

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Research Article

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Abstract

Sportfish species, specifically, Yellow Bass *Morone mississippiensis*, White Bass *Morone chrysops*, Largemouth Bass *Micropterus salmoides*, Bluegill *Lepomis macrochirus*, Black Crappie *Pomoxis nigromaculatus*, and White Crappie *P. annularis*, often drive economically valuable fisheries in large river systems, including the Upper Mississippi River System (UMRS). Within the Illinois River, part of the UMRS, these species are routinely sampled by an ongoing, long-term fisheries monitoring program. Through this program, we investigated long-term trends, 1993 through 2017, in catch rates and relative weights and quantified demographic rates from 2012 through 2016. We found all six study species, with the exception of Yellow Bass, to have declining catch rates, with this decline being most stark in larger, older fishes. Population demographics for Yellow Bass, White Bass, Bluegill, and Black Crappie suggest populations are dominated by younger individuals, with only Black Crappie regularly living to age 3 and older, which may be driving population declines. Many environmental stressors are acting on the Illinois River that could be contributing to the lack of older and larger fishes, including but not limited to navigation efforts (impoundment by lock and dams, levee construction), altered hydrology, pollution, sedimentation, lack of overwintering habitat, and introduction of invasive species. Results of this study demonstrate that additional research to understand mechanisms driving reduced abundance and stunted age structure are needed to identify effective management actions that would benefit populations of recreationally valuable sportfish species.

Introduction

Recreational fishing has a large economic impact throughout the United States, with anglers spending $46.1 billion in fishing-related expenses in 2016 (US Department of the Interior [USDI] 2016). In the Upper Mississippi River System (UMRS) alone, outdoor recreation, including fishing, was estimated by the Upper Mississippi River Basin Association to produce annual revenue of $4 billion. The Illinois River system, part of the UMRS, also generates substantial revenue from fishing opportunities (Figure 1). According to the US Fish and Wildlife Service, Division of Economics, $411.3 million was generated by angling in the Illinois River corridor in 2011 (USDI 2016). The economic impact of recreational fishing is primarily driven by a short list of recreationally valuable species. In the lower Illinois River (Peoria, La Grange, and Alton Reaches), those include both traditionally sought-after species as well as nontraditional species (Table 1). Nontraditional fishes, usually harvested via bowfishing, are becoming more popular (J. Stein, Illinois Natural History Survey, personal communication), and when combined with more traditional fish species, they represent an important natural and economic resource that supports and diversifies both local and state economies and warrant study, conservation, and management.

The Illinois River fishery faces abundant challenges and environmental stressors, many brought on by human activity. These stressors include, among other factors, navigation efforts (impoundment by lock and dams, levee construction), altered hydrology, pollution, sedimentation, lack of overwintering habitat, and introduction of invasive species (Bellrose et al. 1983; Bhomik and Demissie 1989; Sparks et al. 1998; Chick and Pegg 2001; McClelland et al. 2012; Solomon et al. 2016; Fritts et al. 2017). Considering the popularity among anglers, the resulting economic impact, and these challenges and stressors, research and management regarding the health and status of fish communities of the Illinois River should be of vital importance.

There are several important aspects pertaining to the research and management of recreationally valuable species of any fishery, such as knowledge of long-term estimates of relative abundance and the size structure of fish populations (Zale et al. 2012; Ickes et al. 2014; Ratcliff et al. 2014) and dynamic rate functions (age structure, growth rates, and mortality), commonly referred to as population demographics (Quist and Isermann 2017). Knowledge of population demographics provides managers with information needed to assess recruitment variability and year class strength (Quist and Isermann 2017). Data on both relative abundance and population demographics is essential to understanding the overall health of a fishery. As such, the US Army Corps of Engineers' Upper Mississippi

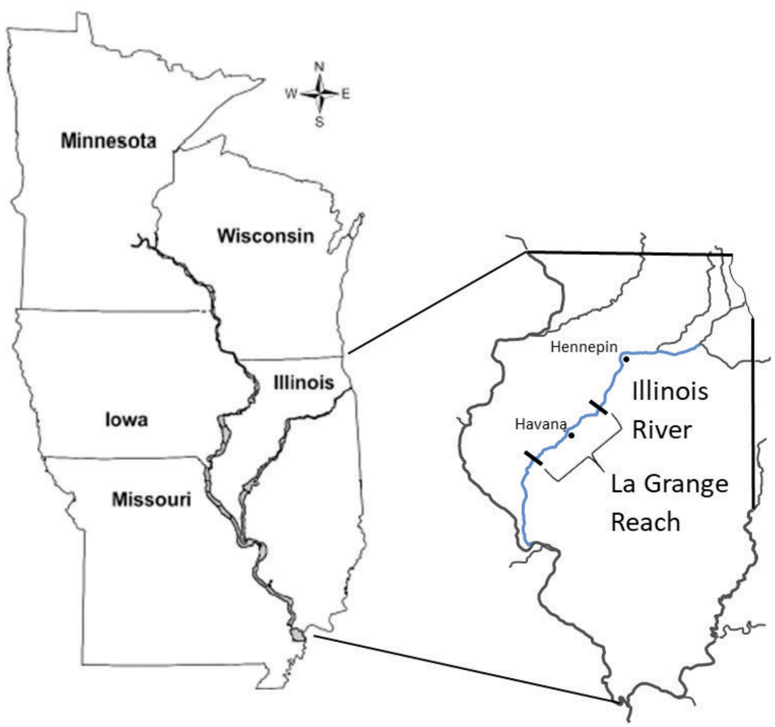

FIGURE 1 The Upper Mississippi River system, including the La Grange Reach of the Illinois River, delimited on the north end by the Peoria Lock and Dam (RM 158) and on the south end by the La Grange Lock and Dam (RM 80), each represented by a short black line.

TABLE 1 Traditional and non-traditional fish species commonly sought by anglers on the lower Illinois River

TRADITIONAL SPECIES	NON-TRADITIONAL SPECIES
Channel Catfish *Ictalurus punctatus*	Gar *Lepisosteus* spp.
Flathead Catfish *Pylodictis olivaris*	Buffalo *Ictiobus* spp.
White Bass *Morone chrysops*	Common Carp *Cyprinus carpio*
Largemouth Bass *Micropterus salmoides*	Grass Carp *Ctenopharyngodon idella*
Bluegill *Lepomis macrochirus*	Bighead Carp *Hypophthalmicthys nobilis*
Black Crappie *Pomoxis nigromaculatus*	Silver Carp *H. molitrix*
White Crappie *P. annularis*	
Sauger *Sander canadensis*	

River Restoration (UMRR) Program has identified sportfishery research as part of the framework for fisheries issues in the UMRS (Ickes 2018).

Accordingly, relative abundance and population demographics for recreationally viable species often receive substantial attention, including studies conducted on many large river systems, including the UMRS (Gutreuter et al. 1999; Pitlo and Rasmussen 2004 and references therein; Kirby and Ickes 2006; Smith et al. 2007; Bowler 2013; Bowler et al. 2013; Gibson-Reinemer et al. 2017a). However, the relative abundance and population demographics of fish species within dynamic and open river systems likely change over time in response to ongoing and emerging anthropogenic stressors acting on large rivers. Furthermore, many of the previously cited studies took place in areas of the UMRS vastly different from the current state of the lower Illinois River, leading to a lack of recent information on many recreationally valuable species on the lower Illinois River. For example, while much of the UMRS has been invaded by Bighead Carp *Hypophthalmicthys nobilis* and Silver Carp *H. molitrix*, the lower Illinois has the highest wild densities (Sass et al. 2010). For these reasons, we sought to evaluate long-term trends in relative abundance and population demographics of selected sportfishes in the lower Illinois River. The purpose of this article is to provide managers and policy makers with a current status of popular sportfishes in the La Grange Reach by documenting long-term trends of relative abundance and population dynamics.

Methods

Study site

The lower Illinois River is defined as extending south of the Great Bend near Hennepin, Illinois, river kilometer (RKM) 321.8, to the confluence of the Mississippi River at RKM 0, and encompassing the Peoria, La Grange, and Alton Reaches. The La Grange Reach of the Illinois River is a 125 km segment of the lower Illinois River between the La Grange Lock and Dam at RKM 129 and the Peoria Lock and Dam at RKM 254 (Figure 1). It is characterized by a wide floodplain surrounding the main channel and a mosaic of side channels, fully connected backwaters, and semi-connected backwaters (DeLong 2005; McClelland et al. 2012).

Data collection

The UMRR Program's Long-Term Resource Monitoring (LTRM) element has sampled the fish community of the La Grange Reach of the Illinois River annually since 1993 using stratified random sampling (SRS) and fixed-site sampling (two fixed sites; Bath Chute at RKM 181.8 and Peoria Lock and Dam tailwater zone (TWZ) at RKM 253.9). Stratified random sampling is performed during three distinct time periods: period 1, June 15 to July 31; period 2, August 1 to September 15; and period 3, September 16 to October 31, with fixed-site sampling occurring twice per period with selected gears. Sampling gears include pulsed direct-current (DC) daytime electrofishing, large and small hoop nets set in tandem, fyke netting, and mini fyke netting (Table 2). Additional details of LTRM sampling methodologies and rationale behind sampling can be found in Ratcliff et al. (2014) and Ickes et al. (2014), respectively.

In conjunction with annual LTRM sampling, subsamples of White Bass *Morone chrysops*, Bluegill *Lepomis machrochirus*, and Black Crappie *Pomoxis nigromaculatus* were collected annually during period 3 from 2012–2016 at both SRS and fixed sites for additional analyses of population demographics (age structure, growth rates, and mortality). The goal of subsampling was to collect a representative

TABLE 2 Fishing gears used in habitat strata on the La Grange Reach of the Illinois River

TYPE OF GEAR	MCB	SCB	BW	BATH CHUTE	TWZ
Day electrofishing	X	X	X	X	X
Fyke netting			X		X
Mini fyke netting	X	X	X	X	X
Hoop netting	X	X		X	X

Note: MCB main channel border, SCB side channel border, BW backwater, TWZ tailwater zone

sample of all sizes of fish present in the La Grange Reach with the exception of fishes < 60 mm, which were assumed to be young-of-year (YOY). Approximately 10 individuals of 10 mm length groups were collected per species; however, due to the scarcity of larger individuals, larger length groups often did not have 10 individuals. When the available size range was small (e.g., < 10 individuals per length groups), more than 10 individuals per length group were collected to achieve an adequate sample size for a given species within a given year. Subsampled fishes were systematically collected spatially and temporally throughout period 3 to reduce bias related to location and timing of capture. Fishes were collected primarily from fyke netting and day electrofishing, but specimens were also collected from mini fyke netting, large hoop netting, and small hoop netting (Appendix A, Table A.1). Additional fyke netting was also performed in selected backwaters (BW) on the La Grange Reach to supplement collections during 2014 (1 fyke net) and 2016 (5 fyke nets). Largemouth Bass *Micropterus salmoides* and White Crappie *P. annularis* were to be included in collection efforts, but insufficient numbers were collected in 2011 or in periods 1 and 2 of 2012 to justify inclusion in the population demographics study. Yellow Bass *Morone mississippiensis* were added to the study in 2014 following the same subsampling methods used for White Bass, Bluegill, and Black Crappie. Collections were further supplemented by ongoing collaborations with Western Illinois University in 2014 and 2015 (Anderson 2016; Lampo 2018).

Fishes collected for population demographics were identified, measured, and weighed in the field and then frozen for further processing in the lab following annual LTRM field sampling. Lab processing included assigning each individual fish a unique identification number and removing both sagittal otoliths. Otoliths were rinsed in tap water, dried on a paper towel, placed in coin envelopes, and archived at the Illinois River Biological Station in Havana, Illinois, USA. Archived otoliths were then digitally photographed so that the age of each fish could be estimated. Following aging techniques by Allen et al. (1998), Gutreuter et al. (1999), and Bowler et al. (2013), whole otoliths were placed in a shallow pool of tap water in an opaque black dish on a Leica S8 AP0 microscope and photographed with a Leica DMC2900 camera. All otoliths were photographed at 10x magnification. Two independent readers then estimated the age of each fish. If consensus could not be reached, a third reader was consulted. If readers could not agree on the age of a fish, that sample was discarded.

Data analysis

Catch per unit of effort (CPUE) was calculated as an indicator of relative abundance for each species from 1993 through 2017 for the LTRM gear that most effectively sampled each species specific for an individual strata. Fyke netting (# fish/net night) was used for Yellow Bass, White Bass, Black Crappie, and White Crappie; day electrofishing (# fish/15 minute electrofishing run) was used for Largemouth Bass and Bluegill. Fyke netting and day electrofishing were most effective in BW for all study species, so all CPUE analyses were restricted to BW SRS data. Additionally, Lubinski et al. (2001) identified fyke netting as the best gear to detect annual change in mean CPUE for Black and White Crappie in BW and day electrofishing as the best gear to detect annual change in mean CPUE of Largemouth Bass and Bluegill in BW. Lubinski et al. (2001) did not analyze Yellow Bass and only analyzed White Bass in main-channel border habitats, however, fyke nets have collected more Yellow and White Bass in BW than any other LTRM gear over the 25 years of sampling (LTRM Graphical Browser 2018).

Cumulative and size-specific CPUE were calculated annually for each species from 1993 through 2017, with size-specific CPUE based on proportional size distribution (PSD) classes: stock, quality, preferred, memorable, and trophy (Table 3) (Gabelhouse 1984; Neumann et al. 2012). CPUE was calculated for each individual PSD size class to investigate size-specific trends for each species. A cumulative CPUE was calculated if 50 or more (average of > two per year)

TABLE 3 Proportional size distribution (PSD) size classes for each study species

	STOCK	QUALITY	PREFERRED	MEMORABLE	TROPHY
Yellow Bass	100–179	180–229	230–279	280–329	> 330
White Bass	150–229	230–299	300–379	380–459	> 460
Largemouth Bass	200–299	300–379	380–509	510–629	> 630
Bluegill	80–149	150–199	200–249	250–299	> 300
Black Crappie	130–199	200–249	250–299	300–379	> 380
White Crappie	130–199	200–249	250–299	300–379	> 380

Note: All measurements are in millimeters.

Source: Based on Gabelhouse (1984)

individuals of a specific PSD size class had been sampled over the sampling time period (1993–2017).

Linear regression was used to determine trends in CPUE from 1994 through 2017 for all size classes of all study species. The year 1993 was omitted from linear regression analysis due to an extreme flood event that occurred throughout nearly all LTRM sampling. This is evident in CPUE trends as five of six study species' CPUE in 1993 are at or near zero (the only exception being White Bass). The La Grange Reach was in flood stage 287 days in 1993 and every day of the 139-day LTRM sampling window; the next closest year was 2015 with 55 of the 139 days during the LTRM sampling window in flood stage. Other significant floods have occurred during LTRM sampling since 1993, including the flooding in 2015 that was near record height; however, none of these flood events had nearly the duration of the 1993 flood (Table 4). Statistical significance for all size classes of all species is based on a $\alpha < .05$, and all statistical analysis was conducted in SigmaPlot 12.5 from Systat Software, San Jose, California, USA.

Relative weight (W_r) was calculated for each study species as an index of body condition (Neumann et al. 2012). Relative weights were calculated for all fishes from all strata that were weighed in period 3 by both SRS fyke netting and SRS day electrofishing from 1993 through 2017. All fishes at or above the species-specific minimum length for calculating W_r were included in analyses (minimum length: Yellow Bass, 70 mm; White Bass, 115 mm; Largemouth Bass, 150 mm; Bluegill, 80 mm; Black Crappie, 100 mm; and White Crappie, 100 mm). Modified z-scores were then calculated for W_r values, and all fish with a modified z-score of | > 3.5| were removed from the dataset, following methods outlined by Pendleton et al. (2017). Mean W_r and standard error (SE) were calculated for each year, and linear regression was used to determine trends in W_r over time for all fishes with statistical significance based on an $\alpha < .05$.

Population demographics analysis

After ages of all sacrificed fishes were estimated, age frequencies were calculated for all sacrificed fishes for all years. Ages were then assigned to all fishes 60 mm and larger collected by LTRM SRS monitoring from 2012 through 2016 for all study species by using known-age fish and the age-length key in Fisheries Analysis and Modeling Software (FAMS) (Slipke and Maceina 2010). All fishes under 60 mm collected during period 3 sampling were assumed to be YOY and were not sacrificed for age estimation and not included in any age-frequency analysis. All known-age fishes collected from both SRS and fixed-site sampling and using all gears for each individual year were used to assign ages to all unaged fishes collected from both SRS and fixed-site sampling that same year. Age assignments were not extrapolated across years: unaged fish from each year were assigned ages using that same year's estimated ages from sacrificed fishes (i.e., Black Crappie sacrificed and aged in 2016 were used to assign ages to other Black Crappie in 2016, not used to assign ages to Black Crappie in 2012).

Mean length at age was calculated for each species for each individual year. Von Bertalanffy growth models were developed for all years of data combined in FAMS, allowing the models to solve for theoretical maximum length ($L\infty$) and growth coefficient (*K*). Unweighted catch curves in FAMS were used to calculate total annual mortality, total annual survivorship, and theoretical maximum age. Unweighted catch curves were used as to not limit the influence of older and rarer year classes. Data from only sacrificed fishes collected via fyke netting were used in both von Bertalanffy growth models and catch-curves analysis.

TABLE 4 Total days above flood stage and total number of Long-Term Resource Monitoring (LTRM) sampling days above flood stage for the La Grange Reach of the Illinois River, 1993–2017

	DAYS ABOVE FLOOD STAGE	
YEAR	TOTAL DAYS	SAMPLING DAYS
1993	287	139
1994	62	0
1995	87	9
1996	75	40
1997	40	0
1998	151	34
1999	93	15
2000	24	24
2001	72	12
2002	92	13
2003	19	9
2004	55	16
2005	56	0
2006	23	0
2007	123	16
2008	176	49
2009	214	28
2010	144	38
2011	120	27
2012	7	0
2013	100	24
2014	90	34
2015	91	55
2016	64	22
2017	91	13

Note: 139 total sampling days within the LTRM sampling window

Results

LTRM SRS, CPUE, and Wr trends

Over the 25 years of data collection, 3,631 Yellow Bass, 54,062 White Bass, 8,284 Largemouth Bass, 81,739 Bluegill, 21,034 Black Crappie, and 9,079 White Crappie were collected from SRS sampling using all gears in all strata. For CPUE analysis, 1,445 Yellow Bass, 9,210 White Bass, 9,010 Black Crappie, and 2,336 White Crappie were collected by fyke nets, and 4,818 Largemouth Bass and 16,899 Bluegill were collected by day electrofishing from SRS sampling in BW. For W_r analysis, 631 Yellow Bass (mean 37.1 ± 38.9 [standard deviation (SD)/year]), 2,030 White Bass (88.3 ± 84.5 SD), 987 Largemouth Bass (39.5 ± 30.2 SD), 2,863 Bluegill (114.5 ± 86.9 SD), 2,203 Black Crappie (88.1 ± 64.9 SD), and 904 White Crappie (37.7 ± 42.0 SD) from 1993 through 2017 were used; however, several species have years (or multiple years) where data are lacking.

CPUE trends indicate declines in all study species over time with the exception of Yellow Bass, which have increased (Figure 2A). All PSD classes of Yellow Bass have increased over time, beginning in 2006, with statistically significant increases

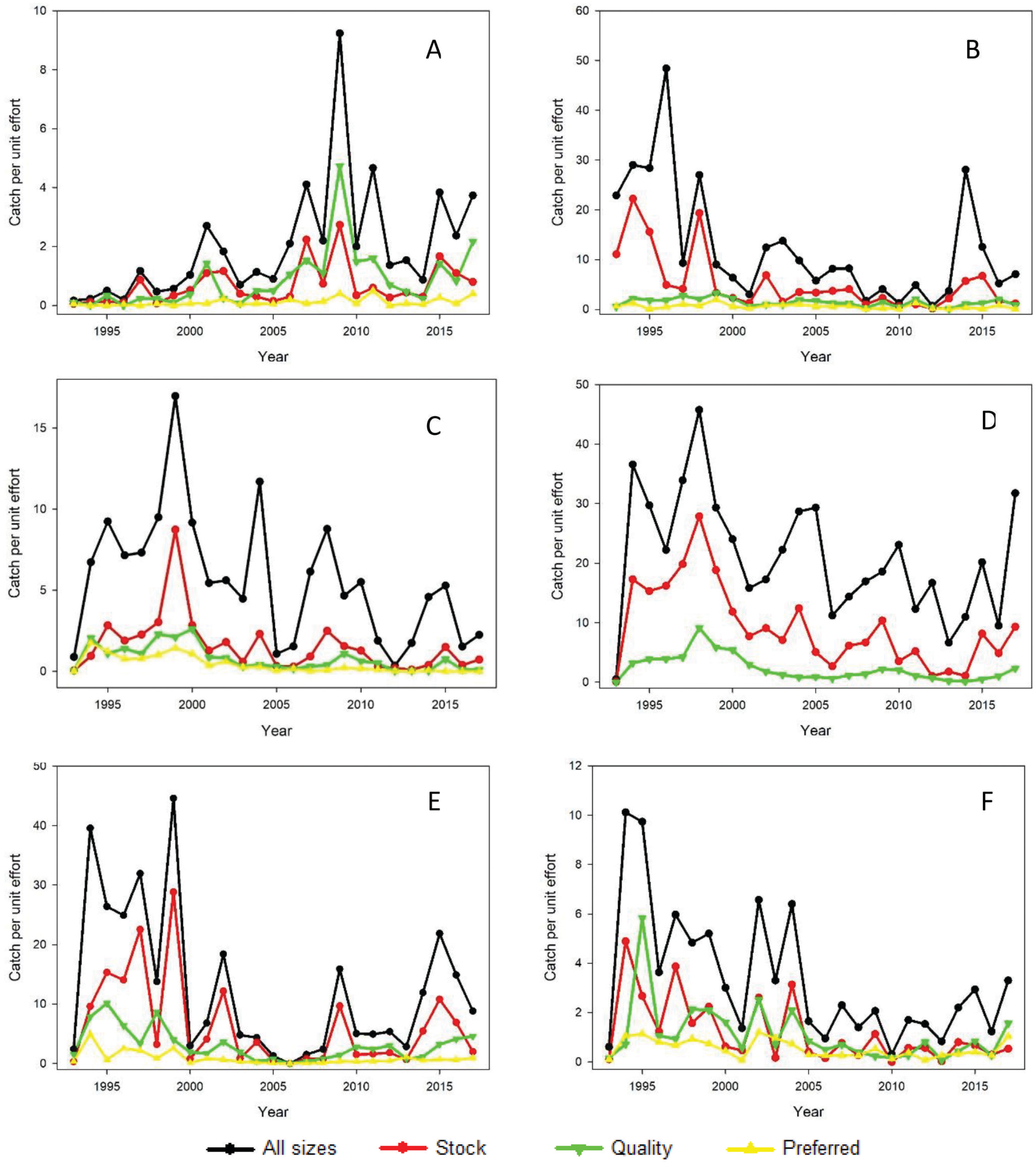

FIGURE 2 Catch per unit of effort (CPUE) from the La Grange Reach of the Illinois River, 1993–2017, of Yellow Bass (A), White Bass (B), Largemouth Bass (C), Bluegill (D), Black Crappie (E), and White Crappie (F), including all sizes of fishes and proportional size distribution (PSD) classes.

observed for all sizes, quality and preferred (Table 5). Only four trophy-size Yellow Bass were collected during this study, the only trophy-size individuals of any study species. White Bass, conversely, declined in the late 1990s with all sizes, stock, and quality being significant declines and preferred being nearly significant (p =.057) (Figure 2B; Table 5). Despite a six-year increase in White Bass CPUE from 2002 through 2007, White Bass have remained substantially lower than levels observed during the 1990s.

For Largemouth Bass, all sizes, stock, quality, and preferred declined significantly, most notably since the year 2000 (Figure 2C; Table 5). These declines were especially stark in quality and preferred size classes (the two highest r^2 of any CPUE trend among all species). Bluegill have exhibited a slow but steady significant decline in all sizes, stock, and quality size classes since the late 1990s (Figure 2D; Table 5). This decline included several short-term increases, but similar to Largemouth Bass, declines were most stark in the larger-sizes classes. Results indicate that smaller sizes of Bluegill and

TABLE 5 Linear regression of long-term trends in proportional size distribution size classes of each study species on the La Grange Reach of the Illinois River, 1994–2017

	ALL SIZES		STOCK		QUALITY		PREFERRED	
	p	r^2	*p*	r^2	*p*	r^2	*p*	r^2
Yellow Bass	.017*	.234	.116	.108	.024*	.212	.018*	.231
White Bass	.010*	.361	.004*	.316	.006*	.296	.057	.155
Bluegill	.002*	.350	< .001*	.540	< .001*	.442		
Largemouth Bass	.002*	.361	.019*	.225	< .001*	.515	< .001*	.713
Black Crappie	.043*	.166	.023*	.240	.015*	.240	.011*	.257
White Crappie	<.001*	.470	< .001*	.426	.013*	.250	.009*	.271

* Statistical significance

Largemouth Bass were still common in the system, albeit lower numbers than were observed in the 1990s; however, larger individuals were rare following declines observed in the early 2000s.

Black Crappie, similar to other species, declined sharply in the year 2000 with a significant decline for all sizes, stock, quality, and preferred Black Crappie (Figure 2E; Table 5). Despite noticeable short-term increase in all sizes, stock, and quality in certain years, Black Crappie remained depressed from levels seen in the 1990s. White Crappie, unlike other study species, drastically declined in 2005 and remained depressed from 2005 through 2017. Declines were significant for all sizes, stock, quality, and preferred White Crappie (Figure 2F; Table 5).

Not enough data were available to conduct CPUE-trend analyses of preferred Bluegill (n = 17) or memorable Yellow Bass (n = 27), White Bass (n = 6), Largemouth Bass (n = 2), Bluegill (n = 0), Black Crappie (n = 27), or White Crappie (n = 21). The only trophy-sized fishes collected of any species were Yellow Bass (n = 4).

Relative weight ranged from 85 to 120 for all study species nearly every year (Figure 3), and analyses showed no significant trends for any species from 1993 through 2017 (Table 6). Yellow Bass weights were not collected from 1993 through 1999, and other species have data missing in some years (Table 6). Sample sizes for all species are limited in certain years.

Population demographics

A total of 2,288 fishes were sacrificed for population demographic analyses: 327 Yellow Bass from 2014 through 2016 and 795 White Bass, 593 Bluegill, and 573 Black Crappie from 2012 through 2016 (Table 7).

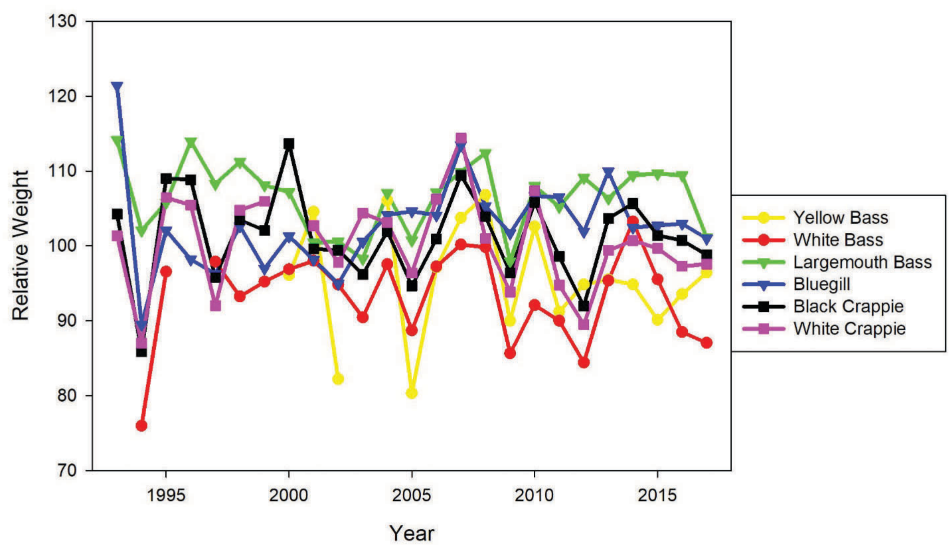

FIGURE 3 Relative weight (Wr) for Yellow Bass, White Bass, Largemouth Bass, Bluegill, Black Crappie, and White Crappie from the La Grange Reach of the Illinois River, 1993–2017. Note data are missing in some years for Yellow Bass, White Bass, and White Crappie.

TABLE 6 Mean annual relative weight (W_r), mean sample sizes, and results of linear regression analysis of trends of Yellow Bass, White Bass, Largemouth Bass, Bluegill, Black Crappie, and White Crappie collected from the La Grange Reach of the Illinois River, 1993–2017

	W_r (MEAN)	SAMPLE SIZE (*n*/YEAR)	*p*	r^2	YEARS OF MISSING DATA
Yellow Bass	94.0	37.1	.750	.0069	1993–99, 2003
White Bass	95.2	88.3	.963	.0001	1993, 1996
Largemouth Bass	106.9	39.5	.676	.0077	
Bluegill	102.1	114.5	.364	.0360	
Black Crappie	101.2	88.1	.796	.0029	
White Crappie	100.7	37.7	.586	.0137	2000

TABLE 7 Yellow Bass, White Bass, Bluegill, and Black Crappie sacrificed for population demographics in the La Grange Reach of the Illinois River, 2012–2016

YEAR	YELLOW BASS	WHITE BASS	BLUEGILL	BLACK CRAPPIE	TOTAL
2012	0	29	82	73	184
2013	0	176	102	54	332
2014	110	255	100	113	578
2015	108	167	175	129	579
2016	109	168	134	204	615
Total	327	795	593	573	2,288

Fishes were collected from day electrofishing, fyke netting, mini fyke netting, and small and large hoop netting in all strata; although the vast majority of fishes were collected via day electrofishing and fyke netting in backwaters (Appendix A, Tables A.1 through A.5). Strata information was not available on 9 Yellow Bass, 27 White Bass, and 19 Black Crappie in 2014 and 1 White Bass in 2015, hence the slight difference in numbers between Table 7 and Tables A.2 through A.5. Consensus age was reached for all sacrificed fishes, and no samples were discarded due to reader disagreement. Proportions of fish at age of sacrificed fishes of each species are in Figure 4.

Of sacrificed fishes, Yellow Bass and Bluegill age 3 and older were rare in the system, as were White Bass age 2 and older (Figure 4). Only Black Crappie regularly reached age 3 and were the only species represented by multiple age 5 individuals as well as individuals up to ages 6 and 7 years (Figure 4). The only exception to this was 2012: despite 2012 having far fewer collections of White Bass and Bluegill and the second fewest Black Crappie, 2012 had the most sacrificed age 2 White Bass, nearly the most age 3 Bluegill, nearly the most age 3 Black Crappie, and the most age 4 Black Crappie.

Ages were assigned to a total of 466 Yellow Bass from 2014 through 2016 and a total of 1,078 White Bass, 3,677 Bluegill, and 1,964 Black Crappie from 2012 through 2016 (Figure 5). Resulting age frequency graphs also indicate that individuals age 3 and older, with the possible exception of Black Crappie, were rare in the system for all species (Figure 5).

Mean length at age was determined for each species for each individual year (Figure 6). In most years, Yellow Bass, White Bass, and Bluegill reached stock size in their first year of growth (age 0), and Black Crappie reached stock size at age 1. In most years, Yellow Bass and White Bass reached preferred size in year 2, while Bluegill reached quality size in year 2 in all years except 2013 and only reached preferred size in 2012 and 2014 at age 4. Black Crappie usually reached preferred size in year 3 or older.

Growth rates of all fishes from von Bertalanffy growth models combined across all years are in Table 8. Mortality was estimated with all years combined together, with annual mortality of Yellow Bass 0.506, White Bass 0.770, Bluegill 0.601, and Black Crappie 0.344. Total annual survivorship for Yellow Bass was 0.494, White Bass 0.230, Bluegill 0.399, and Black Crappie 0.656, and theoretical maximum age for each species was 6.7 years for Yellow Bass, 4.0 years for White Bass, 5.6 years for Bluegill, and 11.3 years for Black Crappie.

Growth rates were pooled across all years due to the lack of older fishes in individual years, which led to unrealistic growth models in certain years. For example, estimated L∞ for Bluegill was 355.7 mm for 2014 data only (the Illinois state record Bluegill is 335.3 mm) and 191.0 mm for 2016 data only.

Mortality estimates were limited to fishes collected in fyke nets only, as fyke nets collected the majority of fishes for the majority of years. Mortality analyses were limited to data from all years combined because several species had insufficient sample sizes (n = 27 Black Crappie in 2012; only 2 year classes of White Bass in 2013 and 2015) or unbalanced age structure (n = 8 age 3 and n = 29 age 4 Black Crappie in 2012), making catch curves impossible.

TABLE 8 Theoretical maximum length (L∞), growth co-efficient (K), and r^2 for Yellow Bass, White Bass, Bluegill, and Black Crappie for all years combined from the La Grange Reach of the Illinois River, 2012–2016

	L∞ (MM)	K	r^2
Yellow Bass	307.9	.391	.996
White Bass	315.4	1.083	.868
Bluegill	224.3	.304	.992
Black Crappie	452.0	.154	.915

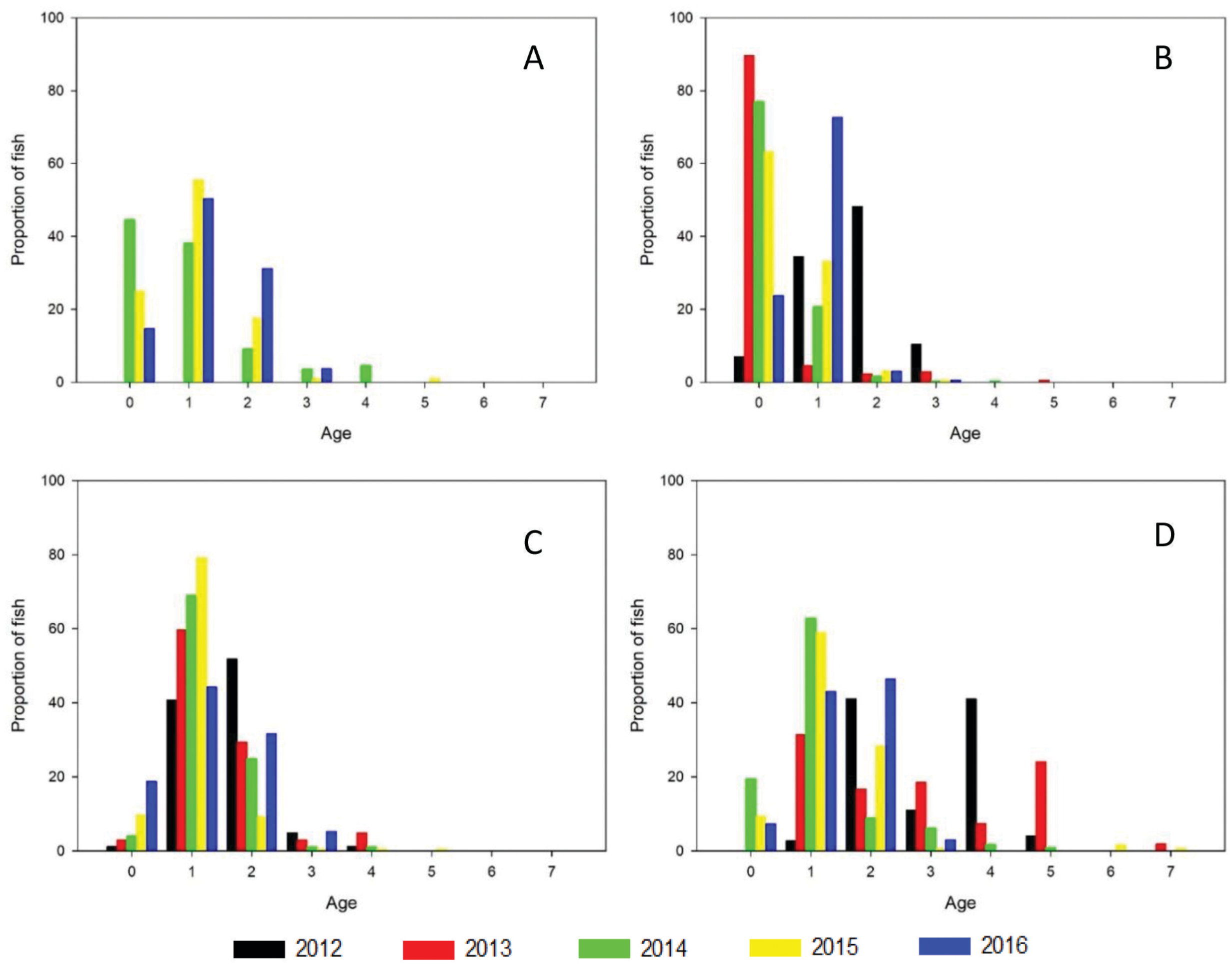

FIGURE 4 Proportion of fish at age of sacrificed Yellow Bass (A), White Bass (B), Bluegill (C), and Black Crappie (D) from the La Grange Reach of the Illinois River, 2012–2016. Note that there are no Yellow Bass in 2012 or 2013.

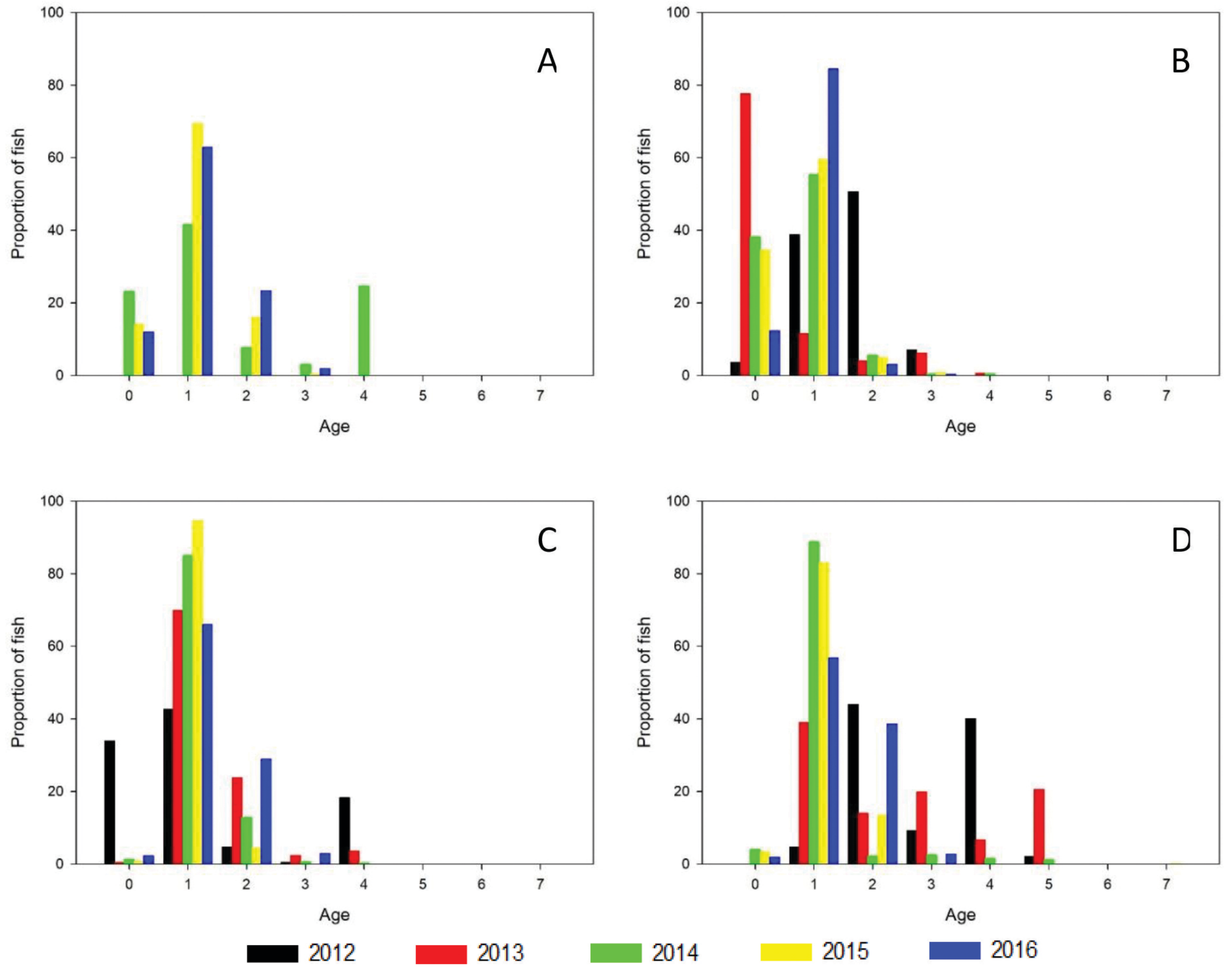

FIGURE 5 Proportion of fish at age of assigned age Yellow Bass (A), White Bass (B), Bluegill (C), and Black Crappie (D) from the La Grange Reach of the Illinois River, 2012–2016. Note that there are no Yellow Bass in 2012 or 2013.

Discussion

The relative abundance of all recreationally valuable sportfishes in the La Grange Reach of the Illinois River has declined over time in this study, with the exception of Yellow Bass, and many of the declines were statistically significant over the 25 years of standardized LTRM monitoring. Analysis of W_r values did not reveal any significant trends, and all fishes had healthy relative weights throughout the study. Age frequency of both sacrificed fishes and age-assigned fishes show populations dominated by younger year classes. White Bass seldom exceeded year 1, Yellow Bass and Bluegill seldom exceeded year 2, and only Black Crappie consistently grew into and past year 3. Growth rates were relatively fast, as most species reached stock size in their first year of growth (year 0) but rarely reached larger (such as memorable or trophy) sizes.

Results of this study suggest sportfishes were potentially being affected by a number of anthropogenic challenges and existing stressors, such as navigation efforts, altered hydrology, pollution, sedimentation, lack of overwintering habitat, and introduction of invasive species. Any or all of those stressors, as well as additional unknown stressors, could have resulted in the lack of larger, older individuals that would drive a recreational fishery and provide ample opportunities for anglers. Furthermore, results suggest that management action is likely needed in the La Grange Reach and the rest of the lower Illinois River to ameliorate effects of anthropogenic stressors and rehabilitate habitats occupied by sportfishes.

CPUE and relative weight trends: LTRM SRS data

Temporal context of the data collection is an important factor when considering trends in relative abundance. Standardized LTRM SRS sampling began in 1993, the same year as a historic flood event throughout the midwestern United States, including throughout the UMRS and lower Illinois River. Coinciding with this flood event were increased reproduction and recruitment of many sportfishes, including White Bass, Largemouth Bass, Bluegill,

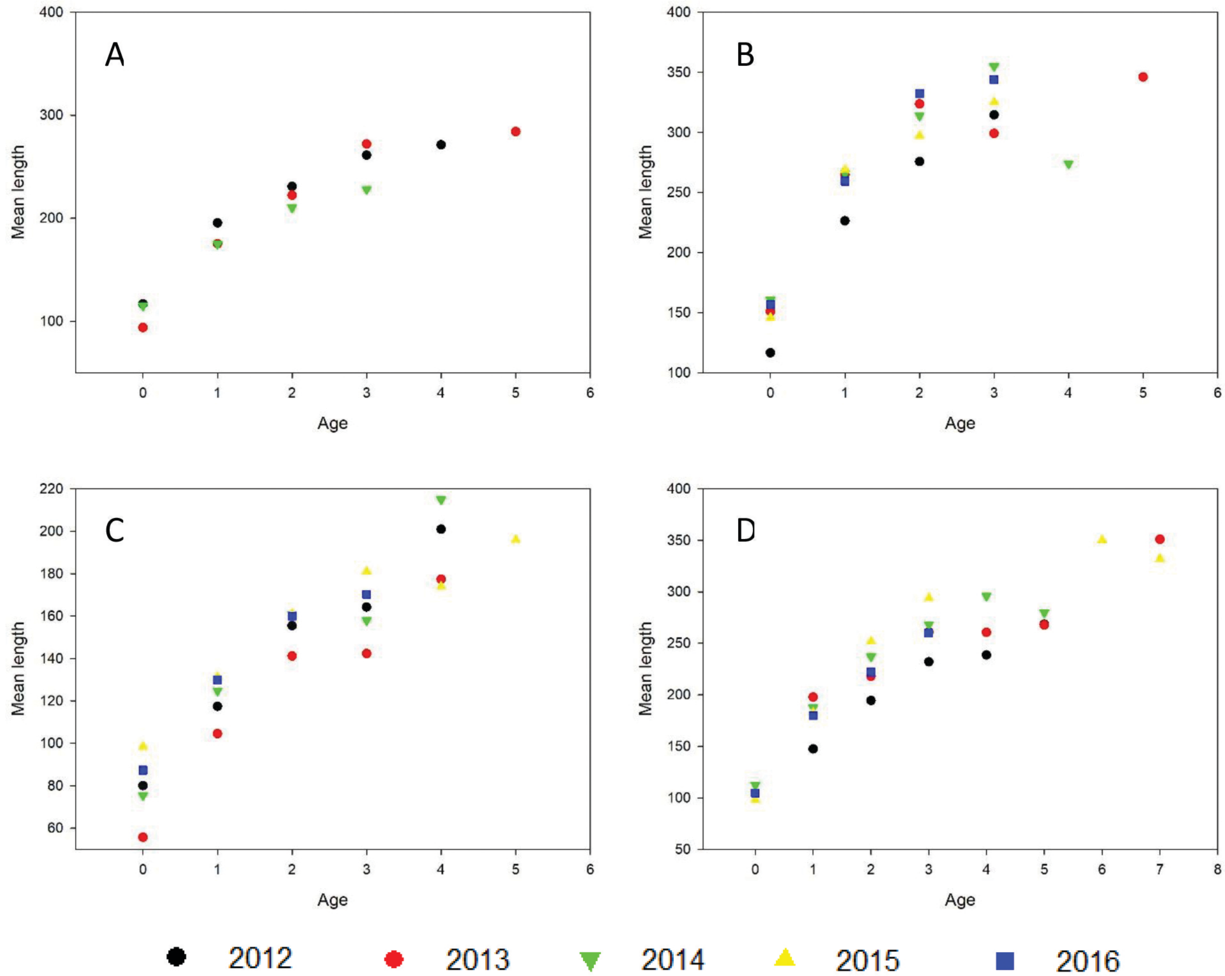

FIGURE 6 Mean length at age for Yellow Bass (A), White Bass (B), Bluegill (C), and Black Crappie (D) from the La Grange Reach of the Illinois River, 2012–2016. Note that Yellow Bass were only collected 2014–2016 and the differing scale of the y axis for Bluegill.

Black Crappie, and White Crappie (National Biological Service 1994; Koel and Sparks 2002; Barko et al. 2006). With these year classes growing through the 1990s and naturally reaching the end of their respective published life expectancies in the late 1990s and the very early 2000s, these populations could be returning to a more natural (normal) level following an inflation by the outlier 1993 flood event. This could give the illusion of declining trends observed in five of the six study species when it's possible the decline is not biologically significant and instead is a return to a more natural level for these species in this system.

To consider an even greater temporal context of sportfish CPUE throughout the lower Illinois River, the Long-Term Survey and Assessment of Large River Fishes in Illinois (LTEF) has conducted annual electrofishing relatively consistently since the 1950s, sampling 20 fixed sites throughout the lower Illinois River. Summary of LTEF data from 1959 through 2015 shows White Bass and Bluegill increasing with crappie spp. and Largemouth Bass in decline (LTEF program, unpublished data). In addition, Gibson-Reinemer et al. (2017b) show catch rate of sportfishes (13 species classified as sportfish for analysis) and overall species diversity and species richness all increasing in the lower Illinois River from the 1950s through the 2010s. These data conflict with results presented here, as all White Bass, Largemouth Bass, Bluegill, and both crappie species are all in decline from 1994 through 2017. However, when this greater temporal context is considered, it is important to consider that LTEF was started in a 1950s time period that Gibson-Reinemer et al. (2017b) refer to as "hopelessness of the 1950s," when common carp *Cyprinus carpio*, goldfish *Carassius auratus*, and their hybrids comprised 97% of catch on the uppermost portion of the Illinois River, and sportfishes were nearly absent from the upper Illinois River (0.8% of catch) and uncommon (8.8% of catch) on the lower river.

Another important factor is that the LTEF program sampled only side channel borders early within the program and shifted to main channels borders as more and more side channels were unnavigable due to sedimentation (Fritts et al. 2017), while LTRM samples multiple river strata. Although thorough analysis of the LTEF data has been published (McClelland et al. 2012 and references therein), more analysis of both LTRM and LTEF data is likely needed to provide further insight into long-term trends of sportfishes.

In addition, when considering the temporal context of flooding, extreme flood events have occurred with regularity since 2007. In 1993 the La Grange Reach experienced 287 days above flood stage, nearly every day from early March through early November, giving riverine species ample time to access inundated floodplain resources related to both reproduction and recruitment (National Oceanic and Atmospheric Administration). Recent extended high-water years of 2007 through 2011 all had > 120 days above flood stage (214 days in 2009), with each year having an extended spring flood from late February or early March through late May or early June, theoretically allowing adult and YOY fishes to access inundated floodplain resources. In addition, record (or near-record) flooding occurred in 2013 and 2015, although these flood events were of shorter duration (100 and 91 days, respectively). Based on duration of flood events, we may not expect populations to recover to post-1993 levels, but if sportfishes are indeed responding to prolonged flooding, it is realistic to expect a moderate, coinciding increase in relative abundance for all study species. For instance, during 2007 through 2017, increased catches should have been observed as a result of 2007–2011 flooding, yet there has only been a slight coinciding increase in relative abundance for the five sportfish species in decline. This lack of response to extended flooding indicates more factors could be drastically affecting populations of these study species.

Relative weight analyses demonstrated no statistically significant increase or decrease coinciding with changes in relative abundance of any study species. This is somewhat unexpected as a decline in numbers of study species should potentially lead to a decline in competition, subsequent increase in potential resources, and an increase in relative weight. Seeing no significant trends (either positive or negative) in body condition, combined with mean relative weights of study species between 94.0 and 106.9, show that fishes present in the system have had good body condition through the duration of this study.

Population demographics

Age frequency of both sacrificed fishes and age-assigned fishes shows populations dominated by younger fishes and generally lacking older individuals. This could also be driving the declines in CPUE over the study as populations' overall reproductive potential would be reduced by the lack of older, larger fishes. The use of both sacrificed fishes and age-assigned fishes is a powerful tool to document age structure of the La Grange Reach. Biases were minimized, as LTRM SRS data offer an unbiased assessment of the La Grange Reach using a multi-gear, multi-strata approach (Ickes et al. 2014; Ratcliff et al. 2014). This study also collected fishes over multiple years, giving a more complete picture of age structure rather than using one year of data. For example, should this study have only included 2012 fishes, conclusions would have been much different. In 2012 the number of sacrificed age 2 White Bass was nearly triple that of any other year and the second most sacrificed age 3 White Bass despite having the smallest sample size of any year by a huge margin (2012 n = 29, all other years n > 167). The year 2012 also had more sacrificed age 4 Black Crappie than all other years combined, again with mostly smaller sample sizes (only 2013 had fewer sacrificed Black Crappie). If the study had only included 2013 through 2016 and omitted 2012, results indicating the absence of older fishes would have been even more stark. Utilizing five years of data illustrates a more complete picture of the population demographics of selected species, and when taken with the standardized LTRM sampling, the data show a system dominated by smaller, younger individuals.

When considering results presented here, it is important to note the small, presumably YOY, fishes were not effectively sampled as we did not sacrifice fishes < 60 mm for age analysis. This could potentially lead to an overestimation of length at age for age 0 fishes as our study only subsampled the largest age 0 fishes present in a given year. Had those smaller fishes been collected for analysis, estimates of mean length at age of age 0 fishes for selected species would likely be smaller than those presented here.

Results of population dynamic studies from large rivers are often lacking in the literature, with most studies coming from ponds, lakes, and impoundments. This is especially true of Yellow Bass and White Bass, for which very few studies are published from any habitat, especially large rivers. When compared to results of the limited studies in the literature, sportfishes from the La Grange Reach are not reaching older-size classes as previously reported. In addition, sportfishes are growing to a longer length at age in their early growth years when compared to previous studies. Smith et al. (2011) reports Yellow Bass reaching ages 6 and 10, respectively, in two southern Illinois reservoirs and lengths of age 1 and age 2 Yellow Bass that are considerably smaller than results shown in this study. Similarly, the literature review by Carlander (1977) reports Yellow Bass reaching age 6 in two natural lakes in east central Wisconsin, age 7 in a southern Illinois impoundment, and age 8 in a natural lake in northern Iowa, similar to results of Smith et al. (2011), reporting lengths of age 1 and age 2 fish that are considerably smaller than results of this study. This study found only one age 5 Yellow Bass over the five years of collection. Also important to consider is that neither Smith et al. (2011) nor Carlander (1977) reports lengths of age 0, and many studies cited by Carlander (1977) were completed between 1952 and 1975.

White Bass numbers show a very similar pattern to those of Yellow Bass, when comparing the literature. A review of Carlander (1977) shows that White Bass are reaching age 4 in Pool 19 of the Mississippi River, 5 in a natural lake in north central Iowa, and 6 each in the Mississippi River in southeast Iowa and a natural lake in east central Wisconsin, and those fishes are considerably smaller at age 1 and age 2 than White Bass found in this study. Again, studies cited by Carlander (1977) did not report lengths of age 0 and were completed between 1946 and 1971. Results compiled from studies throughout the UMRS show White Bass reaching ages 11 and 8 in Pool 13 in 1993 and 1994, respectively, and ages 4 and 5 in pool 14 in 1993 and 1994, respectively (Pitlo and Rasmussen 2004) while only one age 4 and only one age 5 White Bass were collected during this five-year study. Pitlo and Rasmussen (2004) also state that mean lengths at age were well below the values from this study. A literature review by Jackson et al. (2008) reports the 95th percentile of age 1 White Bass is 227 mm in length, well below the > 250 mm length reported for age 1 in four of the five years of this study. Additionally, Jackson et al. (2008) also report the 75th percentile is 286 mm, again, well below the > 297 mm length for age 2 in four of the five years of this study.

Bluegill are reported by Pitlo and Rasmussen (2004) to grow to age 4 in Pools 3 and 9, age 5 in Pool 5a, age 6 in Pools 16 and 17, and age 7 in Pool 8: only one age 5 Bluegill was collected in five years of this study. Pitlo and Rasmussen (2004) also report mean length at age of Bluegill well below the values reported in this study through ages 1 and 2. Jackson et al. (2008) report the 95th percentile of age 1 Bluegill at 81 mm, age 2 at 136 mm, and age 3 at 179 mm; less than the 124.1 at age 1 and 155.3 at age 2 but very comparable to the 163.4 age 3 found in this study.

Black Crappie in Pool 13 grow to age 6 (Bowler et al. 2013), and Pitlo and Rasmussen (2004) list six years of age as "being about the maximum age . . . attained in the Mississippi River." Pool 13 Black Crappie had a mean length at age very comparable with those recorded here; however, age 0–2 Black Crappie in the La Grange Reach are reaching longer mean length at age than Pool 13, and age 3–6 from Pool 13 reach a longer mean length at age than in the La Grange Reach.

A study by Smith et al. (2007) from the La Grange Reach of the Illinois River focused on population demographics of White Bass, Bluegill, and Black Crappie (among others). These fish were collected in the fall from similar methods (LTRM) and also included fishes collected from local fishing tournaments. Mean lengths of age of ages 1, 2, and 3 White Bass collected from 1993 through 2001 by Smith et al. (2007) are substantially smaller than those collected here, but age 4 and 5 White Bass are very similar in size (although this study has a very small sample size of 4- and 5-year old individuals). Bluegill and Black Crappie follow a similar pattern: ages 1, 2, and 3 collected by Smith et al. (2007) are smaller than those collected in this study while ages 4 and 5 are similar in size. Smith et al. (2007) only reports the length of two age 6 Black Crappie, do not report lengths of any age 0 fish, and did not include Yellow Bass.

Potential impacts of environmental stressors on observed trends

The lack of older sportfishes could be due to the lack of quality overwintering habitat in the La Grange Reach. It has been shown that lack of overwintering habitat may limit fish production in the UMRS for a variety of reasons (Ickes 2018 and references therein), and multiple studies have shown the importance of backwater overwintering habitat to Centrarchid fishes on large rivers with connected floodplains (Gent et al. 1995; Knights et al. 1995; Raibley et al. 1997). As such, assessment of overwintering needs and habitat for fishes has been identified as a research issue for the UMRR Program (Ickes 2018). Specific to the La Grange Reach, Largemouth Bass were extensively studied in the 1990s and were shown to occupy off-channel areas with higher water temperatures and low (or absent) water velocities (Raibley et al. 1997). Raibley et al. (1997) also notes the degradation of Illinois River backwaters due to sedimentation, among other anthropogenic factors, and suggests that continued sedimentation will likely negatively affect Largemouth Bass and other fish populations, and restoration and/or rehabilitation of backwaters will likely ensure survival of fishes using these habitats.

It is reasonable to think that if this habitat degradation can affect Largemouth Bass, it will likely affect other Centrarchid species, such as Bluegill, Black Crappie, and White Crappie.

During an extensive study of overwintering requirements of selected riverine fishes, Sheehan et al. (1990) found that low temperatures (4°C and lower) can have negative effects on YOY Largemouth Bass and Bluegill, whereas Black Crappie are slightly more tolerant. Sheehan et al. (1990) also report that backwaters provide fishes with a low flow refuge that is warmer than the main channel but shallow, aggraded backwaters generally provide only marginal overwintering habitat and exhibit lower dissolved oxygen and temperatures. If many of the backwaters on the lower Illinois River are shallow and aggraded, they are likely a major limitation to Largemouth Bass and Bluegill. Older Black Crappie seen in this study support conclusions by Sheehan et al. (1990) that these fish may be better adapted to lower-quality overwintering habitat. On Pool 5 of the UMRS, Bluegill and Black Crappie have been shown to avoid areas where velocity is greater than 1 cm/second, temperature was < 1°C, and dissolved oxygen was generally < 5 mg/L (Knights et al. 1995). In Brown's Lake, located on Pool 13 of the UMRS, Largemouth Bass avoided areas of low oxygen (< 3 mg/L), which were located at depths of 1.8 m or greater (Gent et al. 1995). Studies similar to Knights et al. (1995) and Gent et al. (1995) are needed on the La Grange Reach or lower Illinois River to provide information about where fish are overwintering and to assess overwintering conditions present in the system.

Little is known of White Bass overwintering requirements but, in limited studies, White Bass and other Moronids tend to prefer deeper, warmer, off channel habitat (Garvey et al. 2003). Sheehan et al. (1990) state that White Bass occupy backwater habitats during winter. Despite the limited studies in the literature, we can surmise that White Bass, and very likely Yellow Bass, also use backwater habitats as overwintering areas. However, more research is likely needed, and, again, studies similar to Knights et al. (1995) and Gent et al. (1995) on the lower Illinois River could provide a better assessment of overwintering conditions required by these species. Additional study of all species is needed to identify causal mechanisms that could be driving results of this study, specifically, the lack of older and larger fishes.

Overwintering of fishes, along with other essential aspects of species' life histories, could also be affected by the altered hydrology of the Illinois River. The natural hydrology of the La Grange Reach (and much of the rest of the UMRS) is greatly altered from its historic state by a combination of levees, which cut rivers off of their floodplains, and dams facilitating navigation (Sparks et al. 1998; Schramm and Ickes 2016). This altered hydrology is characterized by an increase in flooding frequency and height in recent decades and changes in the timing of flooding (Sparks et al. 1998). In addition, Milly et al. (2002) suggest an increase in major (i.e., 100-year floods) flooding in large river basins in the future due to expected climate change and increase in greenhouse gases. More recently, Kelly et al. (2017) demonstrated increased stream flows in the Illinois River across daily, monthly, and annual scales. Kelly et al. (2017) also suggest that artificial agricultural drainage activities have led to an increase in flashiness (daily rate of change) and have amplified streamflow responses to small precipitation events. Other studies have also noted the role of agricultural drainage in runoff patterns and resulting stream flows, as well as the effect of a wetter climate on higher stream flows (Frans et al. 2013). Recent gage data from the La Grange Reach lends support to these studies, as six of the ten highest historical flood crests have occurred during the years of LTRM sampling (1993–2017) (National Oceanic and Atmospheric Administration). How much these changes in hydrology over the decades have affected the fish communities is an area in need of further study, and the role of these decades-long hydrologic changes in populations of sportfishes over the last 25 years is unknown. However, it is generally accepted that flooding allows fishes access to resources in the floodplain that are not available year-round (Junk et al. 1989; Gutreuter et al. 1999; Hogberg and Pegg 2015), and this increase in flooding should potentially lead to an increase in abundance of sportfish rather than the decreases seen in this study. This flooding benefit is also dependent on timing: the flood must occur when fish are ready to spawn and remain on the floodplain long enough for spawning individuals and YOY fishes to access inundated habitat and exploit prey resources. That the seemingly opposite effect is happening (increased flooding but fewer sportfishes) suggests that while an altered hydrology may be playing a role in the findings of this study, that role is likely complex and in need of further study.

Altered hydrology could also be exacerbating well-documented issues of the degraded quality of backwater lakes on the lower Illinois River and La Grange Reach (Bellrose et al. 1983; Bhomik and Adams 1989; Bhomik and Demissie 1989; Sparks et al. 1990; US Geological Survey [USGS] 1999). Many backwaters on the lower Illinois River suffer from excessive sedimentation and are losing their capacity to hold water (Bellrose et al. 1983; Bhomik and Demissie 1989). Bhomik and Demissie (1989) went on to state, "For all practical purposes, some of these lakes should no longer be called backwater lakes." Peoria Lake provides a prime example of sedimentation issues of the lower Illinois River: Upper Peoria Lake has lost 72% of its total volume due to sedimentation, and the lower Peoria Lake 51% (Bhomik and Adams 1989). In addition, high sedimentation rates have led to a loss in depth diversity in many backwater lakes and degradation of sediment quality, leading to platter-shaped backwater lake basins with loose flocculent substrates (USGS 1999 and references therein). Adequate depth and depth diversity in backwaters are important to support overwintering conditions (e.g., temperature, dissolved oxygen, and low velocity) to prevent overwintering mortality. When the vast amount of literature discussing the importance of backwater lakes and off-channel areas to sportfish life history is considered as part of the context of the results this study found, it creates a powerful narrative that lack of quality backwater habitat is very likely having a negative impact on native sportfish.

Fishes utilize several different life-history strategies in order to successfully maintain populations throughout many drastically different habitats. Winemiller (2005) discusses these at length, and sportfishes studied here exhibit several classic, *r*-selected life-history attributes: small size and short lifespan. Other *r*-selected traits not studied here are high reproductive effort, high fecundity, short generation time, and low or no parental care; however, the high abundance of age 1 and age 2 fish paired with low numbers of age 4 and 5 fishes suggests short generation times. Winemiller (2005) states that fishes with these life-history traits should be expected "in productive habitats subjected to frequent and intense disturbance, such as ephemeral pools, intermittent streams, and salt marshes." The La Grange Reach of the Illinois River is not nearly as hostile as habitats Winemiller (2005) describes, but it does suffer from a number of disturbances and stressors. Fox and Keast (1991) demonstrated that Pumpkinseed *Lepomis gibbosus* shows different life-history traits in lakes with the potential for winterkill versus lakes that don't experience winterkills, with fish in winterkill lakes maturing earlier and at a smaller size that those in nonwinterkill lakes. If lack of overwintering habitat and altered hydrology are indeed preventing these species from reaching older, larger sizes, it would suggest the species in this study, similar to results of Fox and Keast (1991), have adapted classic *r*-selected life-history traits to a dynamic and variable habitat.

Another potential explanation for declining abundance and lack of older, larger sportfishes is a potential limiting of food resources in backwaters of the La Grange Reach. It is well documented that the lower Illinois River does not contain aquatic vegetation (USGS 1999; Sparks et al. 1990; Gibson-Reinemer et al. 2017b), a well-known benefit to some Centrarchid species as it provides cover to invertebrates (a common prey of all species in this study) as well as protection of fishes from predation and promotion of growth to certain species (Bouska et al. 2018 and references therein). Additionally, lack of substrate quality could also limit the availability of food resources. As mentioned earlier, USGS (1999) and others state that sedimentation, along with permanent inundation, on the lower Illinois River have led to loose flocculent sediments and backwaters without depth diversity. It is possible this flocculent sediment is allowing macroinvertebrates to find refuge from predation. In Swan Lake, a backwater of the Alton Reach of the lower Illinois River, RMK 8.0–21.7, core sampling of the substrate showed macroinvertebrates were found up to 80 cm deep, and the majority of the biomass was in excess of 10 cm deep in the loose flocculent sediments (Timmerman 2007). This would potentially make these macroinvertebrates unavailable to most fish species and could lead to a potential loss of an important dietary component, as all species of this study are known to consume macroinvertebrates (Pflieger 1997; Wallus and Simon 2006; Driscoll and Miranda 1999; Wallus and Simon 2008). However, this potential explanation does not account for the stable and healthy W_r results observed throughout this study. All species of fish in this study had W_r means ranging from 94.0–106.9 throughout the study (an optimal W_r is 100), which does not indicate a lack of food resources. However, as the lack of aquatic vegetation in the lower Illinois River is well documented, and the positive impacts it can bring are presently absent in the system, this lack remains a potential stressor to fish populations.

In addition to macroinvertebrates, Moronids and Centrarchids all feed on zooplankton upon hatching and often through their first year of life before growing large enough to consume macroinvertebrates and other fishes (Pflieger 1997; Wallus and Simon 2006 and 2008). This puts Moronids and Centrarchids in potential competition, for a limited time, with Bighead Carp and Silver Carp, which are abundant throughout much of the lower UMRS and the lower Illinois River and with among the highest wild densities known in the La Grange Reach (Sass et al. 2010). Coinciding with this invasion by Bighead Carp and Silver Carp, DeBoer et al. (2018) documented a decline in both density and biomass of zooplankton that was negatively associated with biomass of Bighead Carp and Silver Carp. Irons et al. (2007) and Pendleton et al. (2017) show a decline in both body condition (W_r) and CPUE of native planktivores, and Solomon et al. (2016) documented a shift in the fish community in the La Grange Reach. All three studies identify changes that coincide with the establishment of Bighead Carp and Silver Carp in the La Grange Reach around the year 2000. Solomon et al. (2016) show that many sportfishes, including White Bass, Largemouth Bass, Bluegill, Black Crappie, and White Crappie, are all less abundant following the establishment of Bighead Carp and Silver Carp. Those results are supported by data presented here: CPUE trends of White Bass, Largemouth Bass, Bluegill, Black Crappie, and White Crappie all declined in the early 2000s and stay depressed through 2017, coinciding with the establishment and proliferation of Bighead and Silver Carps.

Bighead Carp and Silver Carp have been documented as having greatly affected both zooplankton and fish communities, but other potential effects on the ecosystem are also now being studied. Yallaly et al. (2015) speculate that undigested plankton found in Bighead Carp and Silver Carp feces provide possible nutrients for benthic organisms and, observed through mesocosm experiments in 37.1 L aquaria, YOY Channel Catfish *Ictalurus punctatus* and Blue Catfish *Ictalurus furcatus* can survive and grow on Bighead Carp and Silver Carp fecal pellets. A recent study by Collins and Wahl (2017) documents that Bighead Carp consumption of pelagic resources and subsequent egestion of material led to a trophic cascade in a mesocosm setting (.04 ha ponds of 1.5–1.75 m depths), leading to both an increase in phytoplankton and both larval and adult Chironomidae. This trophic cascade also led to a substantial decrease in Chaoboridae but with no observed changes in four other groups of macroinvertebrates (Collins and Wahl 2017). We are aware of no comparable studies conducted in a large river habitat, but these mesocosm studies demonstrate that increase of nutrients delivered to the benthos is an important potential effect of Bighead and Silver Carps on riverine ecosystems. However, the benefit to fishes in the lower Illinois River is potentially minimal if those benthic macroinvertebrates can find refuge in the substrate as described by Timmerman (2007). These and other similar studies underscore the fact that the Bighead Carp and Silver Carp invasions of the La Grange Reach and the lower Illinois River may have far-reaching, indirect effects on native biota that take time to unfold.

Management implications and future research needs

Implications of this study are potentially far reaching, as they demonstrate that populations of sportfishes in the La Grange Reach are in need of management and restoration. Do anglers still travel to the Illinois River to pursue Largemouth Bass? Are populations of other sportfish species still healthy enough to attract anglers and drive a robust fishery? Understanding the population demographics underlying the fishery can help define research and management needs. Additional research into the value of the fishery of the Illinois River would benefit greatly from updated information about fishing habits of anglers.

Future work is needed to better explain trends in relative abundance and lack of older, larger fishes in the La Grange Reach of the Illinois River. This could be accomplished through further analysis of data presented here. Future follow-up research could include a more in-depth analysis of what environmental drivers are causing results presented here. These analyses could include but are not limited to altered hydrograph, direct effects of recent flooding on sportfishes using existing LTRM data, potential food limitations, fishing pressure, effects of invasive species, availability of overwintering conditions, fecundity and reproduction, and updated studies on the loss of backwater habitats due to sedimentation. The LTRM element is in a unique position to investigate or facilitate investigation of the effects of many of these knowledge gaps and environmental drivers on the Illinois River system. In addition, the use of LTRM data in studies such as this highlights the utility and power of long-term data, without which this study would not be possible.

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Appendix: Catches of Selected Sportfish by Gear Type and Strata

TABLE A.1 Total number of Yellow Bass, White Bass, Bluegill, and Black Crappie collected by year and gear type for population demographics in the La Grange Reach of the Illinois River, 2012–2016

	2012				2013				2014				2015				2016				
	D	F	HN	M	D	F	HN	M	D	F	HN	M	D	F	HN	M	D	F	HN	M	TOTAL
Yellow Bass									16	93		1	26	57	3	22	19	70		20	327
White Bass	5	23	1		53	84	22	17	71	183	1		91	49	9	18	69	84	1	14	795
Bluegill	20	59	1	2	54	35	5	8	6	94			83	80	4	8	18	106		10	593
Black Crappie	4	68		1	22	27	2	3	31	79		3	43	72	4	10	10	190		4	573
Total	29	150	2	3	129	146	29	28	124	449	1	4	243	258	20	58	116	450	1	48	2288

Note: D day electrofishing, F fyke, HN large and small hoops combined, M mini fyke

TABLE A.2 Number of Yellow Bass collected by year, gear type, and strata for population demographics in the La Grange Reach of the Illinois River, 2012–2016

	DAY ELECTROFISHING				LARGE HOOP			SMALL HOOP			FYKE		MINI FYKE				
	MCB	SCB	BW	TWZ	MCB	SCB	TWZ	MCB	SCB	TWZ	BW	TWZ	MCB	SCB	BW	TWZ	TOTAL
2012																	
2013																	
2014	2	4		1							93		1				101
2015	7	2	14	3			2	1			57		16	5	1		108
2016	5		14								69	1			20		109
Total	14	6	28	4			2	1			219	1	17	5	21		318

Note: MCB main channel border, SCB side channel border, BW backwater, TWZ tailwater zone

TABLE A.3 Number of White Bass collected by year, gear type, and strata for population demographics in the La Grange Reach of the Illinois River, 2012–2016

	DAY ELECTROFISHING				LARGE HOOP			SMALL HOOP			FYKE		MINI FYKE				
	MCB	SCB	BW	TWZ	MCB	SCB	TWZ	MCB	SCB	TWZ	BW	TWZ	MCB	SCB	BW	TWZ	TOTAL
2012	1	1	1	2		1					18	5					29
2013	6	13	21	13	1	3	2	12	4		44	40	3	3		11	176
2014	10	25	7	2			1				175	8					228
2015	16	24	32	18		2	5	2			48	1	7	10	1		166
2016	19	13	34	3	1						65	19	3		11		168
Total	52	76	95	38	2	6	8	14	4		350	73	13	13	12	11	767

Note: MCB main channel border, SCB side channel border, BW backwater, TWZ tailwater zone

TABLE A.4 Number of Bluegill collected by year, gear type, and strata for population demographics in the La Grange Reach of the Illinois River, 2012–2016

	DAY ELECTROFISHING				LARGE HOOP			SMALL HOOP			FYKE		MINI FYKE				
	MCB	SCB	BW	TWZ	MCB	SCB	TWZ	MCB	SCB	TWZ	BW	TWZ	MCB	SCB	BW	TWZ	TOTAL
2012		2	12	6		1					56	3			2		82
2013	1	3	27	23				5			10	25	1	1		6	102
2014		3	3								94						100
2015	3	5	38	37				4			80		3		5		175
2016	2	1	11	4							86	20	5		4	1	134
Total	6	14	91	70		1		9			326	48	9	1	11	7	593

Note: MCB main channel border, SCB side channel border, BW backwater, TWZ tailwater zone

TABLE A.5 Number of Black Crappie collected by year, gear type, and strata for population demographics in the La Grange Reach of the Illinois River, 2012–2016

	DAY ELECTROFISHING				LARGE HOOP			SMALL HOOP			FYKE		MINI FYKE				
	MCB	SCB	BW	TWZ	MCB	SCB	TWZ	MCB	SCB	TWZ	BW	TWZ	MCB	SCB	BW	TWZ	TOTAL
2012		2	1	1							67	1			1		73
2013	1	2	19			2					24	3		1	2		54
2014		1	6	3							74	5	1		2		92
2015	2	6	22	13				4			72		6	4			129
2016	3	2	5								158	32	1	1	2		204
Total	6	13	53	17		2		4			395	41	8	6	7		553

Note: MCB main channel border, SCB side channel border, BW backwater, TWZ tailwater zone