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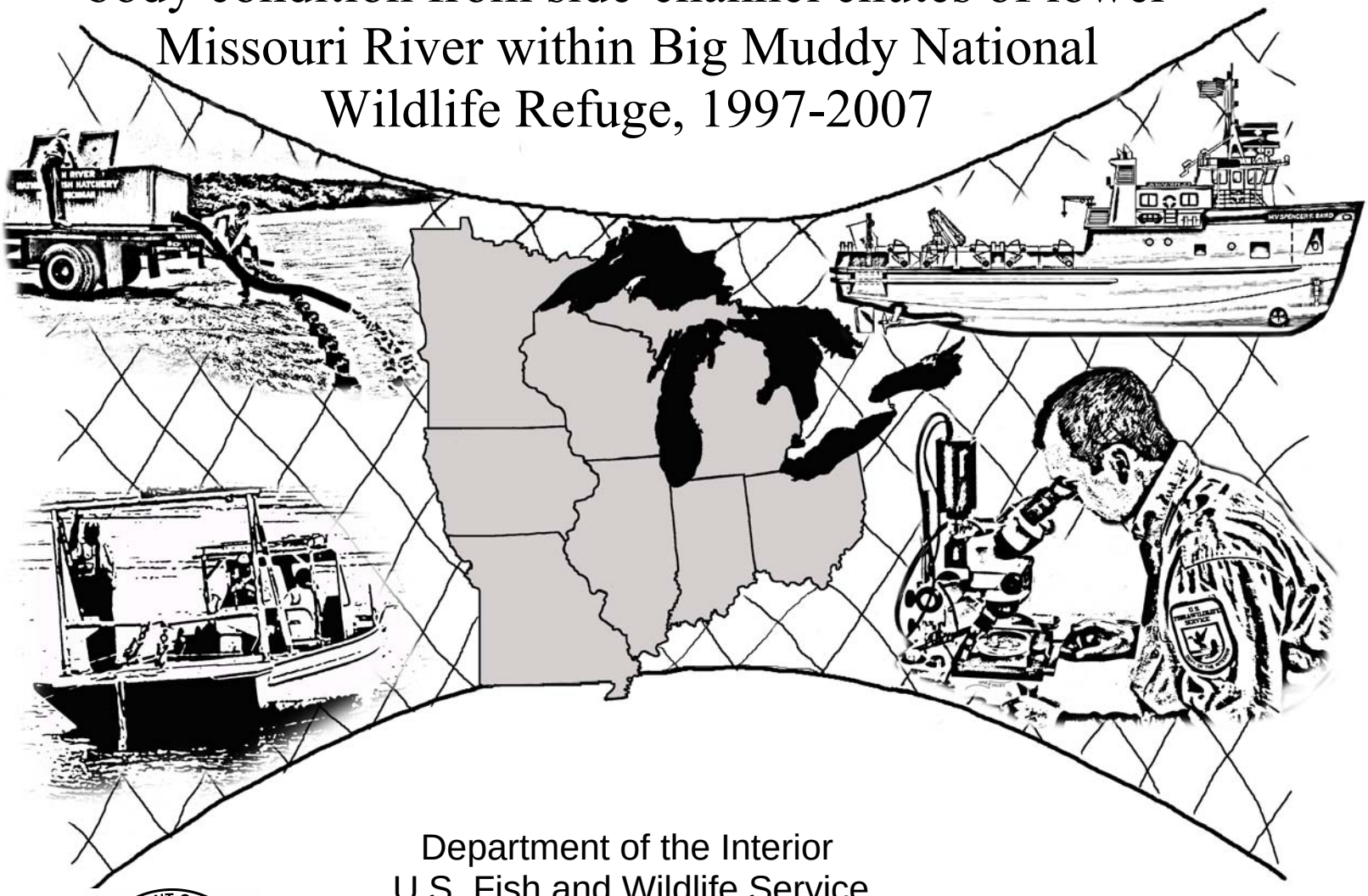
Trends in gizzard shad population abundance and body condition from side-channel chutes of lower Missouri River within Big Muddy National Wildlife Refuge, 1997-2007



Department of the Interior
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Great Lakes-Big Rivers Region

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Abstract

We evaluated gizzard shad (*Dorosomoa cepedianum*) population abundance (CPUE) and relative weight (W_r) to determine what trends existed from 1997 to 2007 in side-channel chutes of lower Missouri River. We collected gizzard shad with seven gears: seines, beam trawls, otter trawls, electrofishing, hoop nets, fyke nets and gill nets. Positive slope (m) from regression analysis across all gears indicated that gizzard shad population abundance was not decreasing during the study period ($m = 0.9$, $P_{m \neq 0} = 0.08$). However, results from electrofishing data indicate gizzard shad abundance (likely adults) was increasing from 1998 to 2007 ($m = 3.4$, $P_{m \neq 0} = 0.008$). Relative weights were decreasing during the study period ($m = -1.2$, $P_{m \neq 0} = 0.006$), and we detected a 5.4% decrease in W_r from 2000 (92.9) to 2006 (87.9) in gizzard shad ≥ 180-mm TL. Our W_r results support declining gizzard shad body condition reported in context of increasing Asian carps (*Hypophthalmichthys* spp.) abundance from Mississippi River. However, we can not determine whether this effect was due to a negative competition interaction with invasive Asian carps or increasing gizzard shad abundance and associated intra-species competition.

Introduction

During a public meeting conducted by Resource Scientists with the Missouri Department of Conservation (MDC) in 2007, polled anglers opposed (81%) any restrictive regulations on blue catfish (*Ictlaurus furcatus*) and flathead catfish (*Pylodictis olivaris*) harvest on the 82-mile reach of lower Missouri River from Glasgow to Jefferson City (per comm. K. Sullivan, MDC). Anglers suggested that over-harvest was not as critical a factor in declining catfish population or angler success rate as was catfish prey availability—that gizzard shad (*Dorosomoa cepedianum*) populations may have been declining for several years. Irons et al. (2007) discussed a 7% decrease in gizzard shad body condition in Illinois River from 2000 to 2006 in relation to increasing Asian carp (i.e., silver carp *Hypophthalmichthys molitrix*, bighead carp *H. nobilis*) abundance. Gizzard shad and Asian carps feed on similar items by filtering pelagic plankton and Asian carps have become increasingly more abundant in lower Missouri River since first sightings in 2001. Biologists from MDC considered the possibility of a negative competitive interaction between invasive Asian carps and native gizzard shad in lower Missouri River. The U.S. Fish and Wildlife Service - Columbia National Fish and Wildlife Conservation Office (CNFWCO) have a long-term fish monitoring dataset from side-channel chutes originating in 1997, and were asked by MDC to examine it to assess gizzard shad population abundance to address anglers' concerns.

Our objectives were to determine if annual gizzard shad abundance and relative weight had been decreasing, increasing, or unchanged, and determine percent change in relative weight between 2000 and 2006, in Missouri River chutes during the period 1997-2007.

Methods

Fish Sampling

Spatiotemporal description of study site and description of gears for the following fish sampling methods were largely from Mauldin et al. (2002). Fish monitoring began in 1997 and data were available through 2007. Sampling season ranged from April to October with 4-6 sample periods in each season and usually five to seven days in each

sample period. Eight chute sites were sampled and included in this study: Cranberry (river mile *RM* 281), Euphrase (RM 219), Lisbon (RM 214), Franklin (RM 194), Overton (RM 190), Portland (RM 112), Hermann (RM 77), and Johnson (RM 42) chutes (Figure 1). When sites could not be sampled due to environmental conditions (e.g., depth, low/high flows) the nearest accessible area was sampled. Columbia NFWCO staff used multiple gears to assess the fish community in various habitat types.

Figure 1. Map of study area showing eight chutes along lower Missouri River in Missouri, USA, included in study.

Since it was inappropriate to compare catch rates between active and passive sampling gears (Murphy and Willis 1996), catches were first pooled into active or passive gear-groups, then further seperated into groups of common unit-of-effort. This data

partitioning resulted in three gear-groups: (1) active gear where effort was measured in meters (hereafter called active-meter), (2) active gear where effort was measured in minutes (hereafter called active-hour) and (3) passive gear where effort was measured in minutes (hereafter called passive-hour).

Active-meter

Seining

Seine hauls were conducted in shallow sandy areas with low to moderate flows. The seine used was 7.6-m long, 2.4-m deep, and had a 6-mm bar mesh size; deminsions similar to those used by Grace and Pfleiger (1985) on Missouri River. Seine hauls were conducted by deploying one end of the seine at the edge of the bank, the other end perpendicular to the shoreline, and sweeping the fully extended seine downstream and then in towards the shoreline. Seining effort was measured in meters, and catch-per-unit-effort (CPUE) was expressed as number of fish per 10-m.

Beam trawling

Beam trawls effectively sample fishes in areas too deep to seine or set mini-fyke nets. The body of the beam trawl was 2-m wide, 0.5-m high, 5.5-m long, had an inner-mesh of 0.32 cm, an outer chafing mesh of 3.81 cm and contained a roller-rock lead-line. The trawl was attached to a metal frame and sled to ensure that the lead line stayed in contact with the river bottom. The trawl was attached to the bow of the boat by two nylon tow ropes that were 18.2 m in length. Trawl hauls were made in a downstream direction slightly faster than the current.

Otter trawling

Otter trawls effectively sample fishes in areas too deep to seine or set mini-fyke nets. The type of otter trawl used was a slingshot balloon trawl. Two methods of deployment and several mesh sizes were used on an experimental basis during this study. The first method of deployment was made off the bow of a 6.7-m river boat with two 30.5-m nylon tow ropes. The trawl was deployed and retrieved manually. The second method deployed and retrieved the trawl with a set of hydraulic winches (one for each nylon rope) off the stern of a 7.6-m jet powered v-hull boat as described by Doyle and Starostka

(2003). The body of the first of several mesh sizes of trawl was 4.88-m wide, 4.6-m long, 0.5-m high, had an inner mesh of 0.32 cm, an outer mesh of 3.81 cm and a roller-rock lead-line (Guterenrider et al.1995). The other two trawls were 6.7-m wide, 6.7-m long and either 1.6-cm (5/8 in) inner mesh with a 3.8-cm (1.5 in) outer mesh or 3.8-cm inner mesh with a 7.62-cm (3.0 in) outer mesh (Doyle and Starostka 2003). Trawl hauls were made in a downstream direction slightly faster than the current. Trawling efforts were measured in meters and CPUE was expressed as number of fish per 10-m.

Active-hour

Electrofishing

A boat with a boom-mounted electrofisher was used to collect fishes. Electrofishing runs were usually 15-30 minutes using pulsed DC current at 300-600 Volt, 6-10 amp, 40-millisecond pulse width with 60 pulses per second. CPUE was expressed as number of fish per hour. Electrofishing began in 1998.

Passive-hour

Hoop netting

Paired, unbaited, large and small hoop nets were used to collect fish. The large hoop net consisted of seven fiberglass hoops and was 4.8-m long with 3.7-cm bar nylon mesh. The largest hoop had a diameter of 1.2 m and the remaining hoops decreased incrementally by 2.5-cm. The small hoop net also consisted of seven fiberglass hoops. It was 3-m long with 1.8-cm bar nylon mesh. The first hoop had a diameter of 0.6 m and decreased incrementally by 2.5-cm. Large and small hoop net dimensions were similar to the standard gear used by the Long Term Resource Monitoring Program (LTRMP) on the Upper Mississippi River (Gutreuter et al. 1995). Hoop netting effort was measured in minutes and CPUE expressed as number of fish per hour.

Mini-fyke netting

Small Wisconsin-type fyke nets (hereafter mini-fyke nets) (0.6 m x 1.2 m frame) were used to sample small fishes, including young-of-the-year, in shallow depth and low velocities areas. Mini-fyke nets consisted of a 4.5-m long lead, two rectangular steel frames, and two circular hoops. Mini-fyke net dimensions were similar to standard gear

used by LTRMP (Gutreuter et al. 1995). Mini-fykes were set perpendicular to shore in areas with little current. Nets were often staked on-shore and set slightly downstream in areas with swift current. The cod end was either weighted or staked. Mini-fyke netting effort was measured in minutes, and CPUE was expressed as number of fish per hour.

Gill netting

Gill nets were comprised of 3.8, 5.1, 7.6, and 10.2-cm square mesh, each in 7.6-m long sections. Gill nets were either 30.5 or 61.0-m long and 2.4-m high. Nets were anchored upstream and set parallel to the current and left to soak for 12 to 24 hours. Gill netting effort was measured in minutes, and CPUE was expressed as number of fish per hour.

Data Management and Analysis

Abundance

Samples were included in analyses based on the following criteria:

- unit-of-effort measured and recorded
- number of samples collected with a particular gear used was reasonably comparable among years
- average number of samples collected per year within gear-group (i.e., one or more gears pooled) was greater than 20.

We calculated the mean and standard error of gizzard shad CPUE by year to compare among years. Regressions were run on mean CPUE for each gear-group to assess the inter-annual trend of gizzard shad abundance during the study period.

Relative weight

Comparison of average relative weight of gizzard shad among years was not subject to the same stringent inclusion criteria as CPUE. Therefore, relative weight was calculated for qualifying individuals (see below) where length (mm) and weight (g) were measured as:

$$W_r = (W/W_s)*100,$$

where W was the weight of an individual and W_s was a length-specific standard weight-length regression of gizzard shad (Anderson and Neumann 1996). We calculated W_s as:

$$\log_{10}(W_s) = a' + b^* \log_{10}(L),$$

where a' was the intercept, b the slope of the $\log_{10}$(weight)-$\log_{10}$(length) regression, and L the maximum total length of gizzard shad. We used published data for gizzard shad to partially parameterize W_s as $a' = -3.580$ and $b = 3.170$ (Anderson and Neumann 1996), and used our long-term dataset to parameterize L. We enforced the minimum size criteria 180-mm TL for gizzard shad used to calculate W_s suggested by Anderson and Neumann (1996). Fish used to determine W_s were grouped into size classes of 10-mm intervals because it provided the best balance in number of individuals per group (usually ≥ 5 individuals; Anderson and Neumann 1996) versus class breadth for W_s accuracy (i.e., relevancy of W_s to each sized individual within classes). Finally, we interpreted relative weights between 80 and 120 to indicate "good condition" (Anderson and Neumann 1996).

Results

Abundance

There were 6,831 samples and 34,572 gizzard shad collected during 1997-2007 (see Appendix-A Table A1). We identified 5,388 samples meeting our inclusion criteria and 24,704 gizzard shad were collected in those samples. Average number of samples collected per year was 91, 71, and 328 for gear-groups active-meter, active-hour, and passive-hour, respectively. Mean CPUE was highest during 2007 and lowest during 2001 for active-hour gear-group, but highest during 1999 for active-meter and passive-hour gear-groups (Table 1). Linear regression slope was positive for the active-hour gear ($P_{m\neq0} = 0.008$), but negative for active-meter and passive-hour gears ($P_{m\neq0} \geq 0.35$, overall slope $P_{m\neq0} = 0.08$; Figure 2A). The data were better fit to quadratic (mean $r^2 = 0.41$) than linear (mean $r^2 = 0.28$) curves (Figure 2B).

Relative weight

We found 4,025 gizzard shad with length and weight data available from the dataset; however, only 725 individuals were ≥180-mm TL. These 725 individuals were used to calculate W_s and parameterize W_r. Maximum TL (mm) of these 725 individuals was 451 ($n = 2$). Mean, median and mode TL (mm) of these 725 individuals was 263, 257, and 202 respectively, indicating the distribution of range 180-451-mm TL were skewed right

Table 1. Gizzard shad abundance as CPUE (# fish/10 meters, or # fish/hour), total number of fish, and total number of samples collected among years from 1997 to 2007 in chutes on lower Missouri River. Data are from samples where: 1) unit-of-effort was measured and recorded for gear used, 2) number of samples were reasonably comparable among years, and 3) average number of samples collected per year within gear-group (i.e., one or more gears pooled) was greater than 20. CPUE was expressed as mean ± standard error. Specific comparisons of CPUE should be made among years within gear-groups. Total number of fish and samples may be compared across gear-groups; however, total number of fish is a less accurate estimate of gizzard shad abundance than CPUE.

	[1]active gear (per 10 meters)			[2]active gear (per hour)			[3]passive gear (per hour)		
Year	CPUE	total # fish	# pulls	CPUE	total # fish	# runs	CPUE	total # fish	# sets
1997	0.046 ± 0.025	3	32			0	0.000	0	116
1998	0.060 ± 0.027	5	37	3.750 ± 1.436	3	4	0.154 ± 0.120	675	243
1999	9.079 ± 4.127	956	29			0	2.500 ± 1.147	14637	324
2000	0.060 ± 0.015	15	61	2.975 ± 0.380	11	13	0.012 ± 0.009	29	330
2001	6.856 ± 6.454	744	100	1.470 ± 0.301	16	33	0.066 ± 0.033	349	229
2002	3.968 ± 2.200	1263	130	9.271 ± 4.892	85	40	0.002 ± 0.001	21	373
2003	1.420 ± 0.991	387	103	11.694 ± 5.001	171	48	0.063 ± 0.037	547	380
2004	0.000	0	103	3.827 ± 0.319	30	81	0.000	0	386
2005	0.013 ± 0.007	25	64	13.390 ± 3.371	587	207	0.037 ± 0.018	121	150
2006	0.008 ± 0.004	4	168	26.254 ± 8.467	645	162	0.002 ± 0.0006	28	592
2007	0.003 ± 0.001	5	176	37.717 ± 16.05	1970	187	0.118 ± 0.076	1372	487

[1]seine, beam trawl, otter trawl

[2]electrofishing

[3]mini-fyke net, large hoop net, small hoop net, stationary gill net

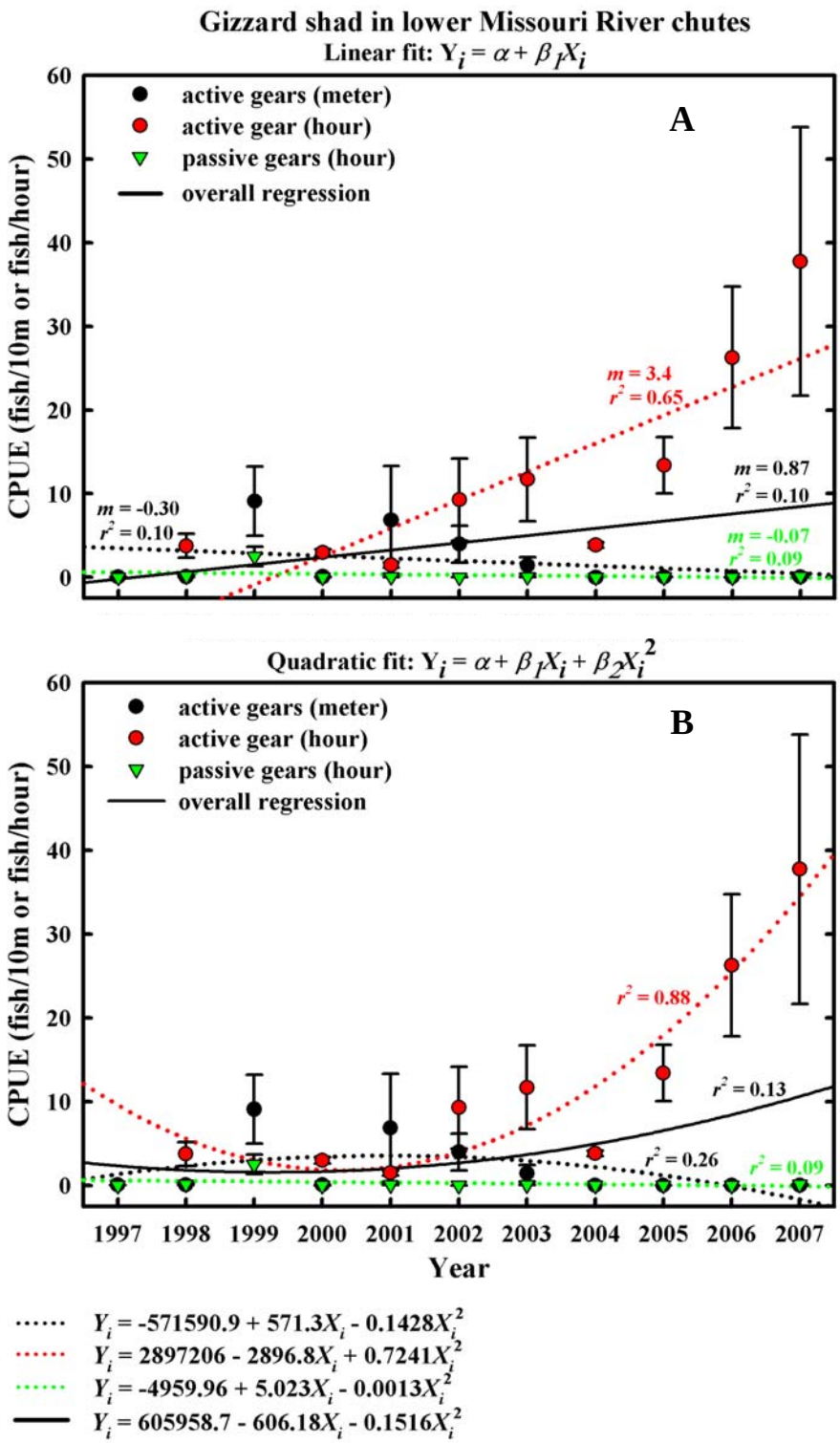

Figure 2. Gizzard shad CPUE (mean ± standard error) from Missouri River chutes 1997-2007, and (A) linear, and (B) quadratic regression through the means for active (circles) and passive (triangle) gear-groups. Regression statistics were added to plots where appropriate and parameterized equations for each quadratic curve were listed below plot-B.

and followed the distribution we expect for fisheries length data; right skewness provides support that we collected gizzard shad in a way that mimics their true population length distribution. However, Kolmogorov-Smirnov Goodness-of-Fit test (K-S) indicated W_r did not follow normal distribution (K-S = 0.41, $P < 0.01$) and did not satisfy this assumption for regression analysis. Two extreme W_r values, size classes 180-189 from 2003 (W_r = 309.1) and 230-239 from 2005 (W_r = 195.6), were removed from the dataset to achieve normal distribution (K-S = 0.31, $P = 0.84$). Slope of the regression on normalized W_r versus year was negative and significantly different than zero ($P = 0.006$; Figure 3). Relative weights displayed a wide range of variation, but most size-year combinations were between 50 and 150, and 52% were between 80 and 120.

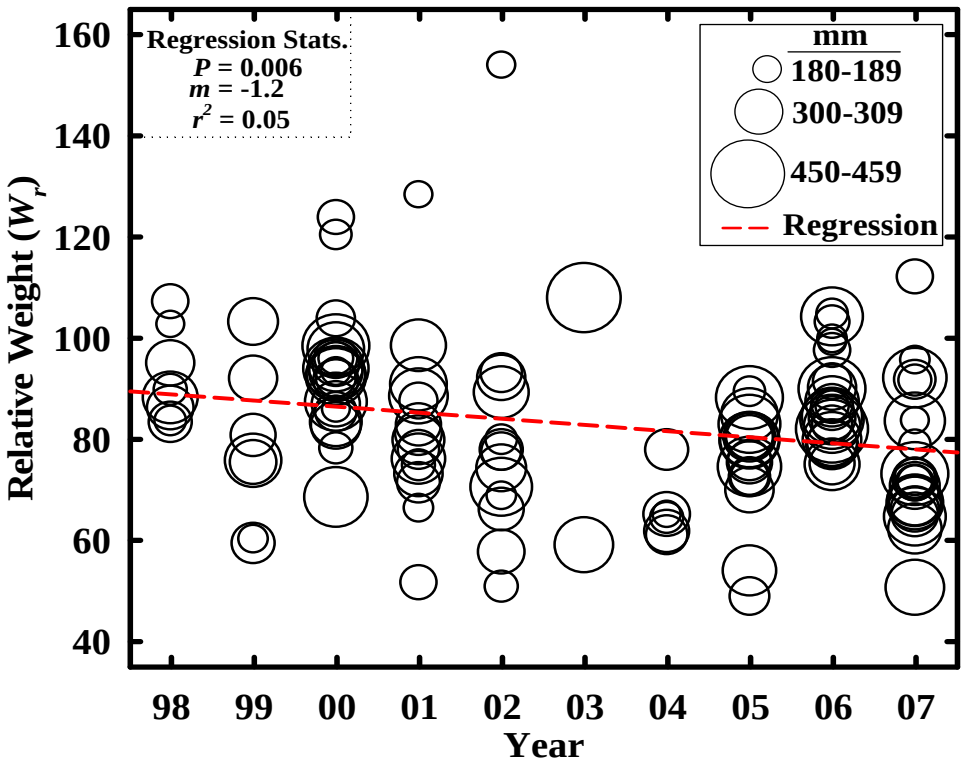

Figure 3. Distribution of relative weights (W_r) for gizzard shad by 10-mm (TL) size class collected in side-channel chutes on lower Missouri River from 1998 to 2007. Bubble size represents fish size-class. Twenty-five size-classes were created from the size range 180-451-mm TL. Dashed line is the regression through all bubbles irrespective of size; 'P' is the probability that the slope of regression is different from zero. The legend lists actual bubble size for the shortest, median, and largest length class for comparative reference.

Mean W_r pooled across all years was below 80 for 8 of 26 length classes, and above 100 for three length classes (see Appendix-A Table A2). Mean W_r pooled across size class was lowest in 2004 (66.5 ± 2.3 SE) and highest in 2003 (145.9 ± 56.0 SE; see Appendix-A Table A3). Average W_r in 2000 and 2006 was 92.9 and 87.9 respectively—therefore, percent change in W_r between these years was 5.4%.

Conclusion

Results of analyses on our eleven-year dataset indicate that gizzard shad abundance was neither significantly increasing nor decreasing during the study period. However, these data show signs to suggest gizzard shad abundance may have been increasing after 2002. These results of abundance are complex and confounded by gear biases. Electrofishing is likely the most effective of the suite of gears used to collect gizzard shad, but tends to bias against small sized fishes (Murphy and Willis 1996; Reynolds 2000). Benthic trawls and seines are common gears used on large rivers, but the pelagic behavior of gizzard shad schools are likely able to easily avoid the slow and noisy approaching net—our trawls fish only the near-bed zone, but gizzard shad are generally not known as benthic dwelling fishes. Hoop and mini-fyke nets generally bias towards small sized fishes because they sample the near-shore environment used by many young fishes as nursery. Therefore, we feel that electrofishing (i.e., active-hour) provides the best data to assess population change by adult gizzard shad during the study period. Our active-hour data does not support that gizzard shad abundance had decreased in Missouri River chutes from 1998 to 2007.

Interpretation of W_r is subjective. In absence of a widely accepted scale to describe gizzard shad condition from W_r we chose the range 80-120 to qualitatively imply "good condition". However, we stress application of this scale is not specific to gizzard shad, and is neither supported nor refuted in the scientific literature. Applying this qualitative scale to our results generally indicates that gizzard shad were not in poor condition during the study period. We interpreted the significant negative slope on the regression as a signal that over all size-classes and years, gizzard shad body condition was declining from 1998 to 2007. The 5.4% decrease we detected in gizzard shad body condition from

chutes in lower Missouri River between 2000 and 2006 supports the 7% decrease reported by Irons et al. (2007) between the same time periods in upper Mississippi River.

Conclusions from our results are limited to side-channel chutes and may not be representative of 1) gizzard shad abundance throughout their distribution in lower Missouri River or 2) the trophic interaction between Asian carps and gizzard shad. Some evidence exists in the literature indicating that gizzard shad switch feeding strategies from picking zooplankton (i.e., larger food items) early in life (*ca.* <30-mm TL) to filtering phytoplankton (i.e., smaller food items) later in life (Kutkuhn 1958; Cramer and Marzolf 1970). Silver carp may most directly threaten >30-mm TL gizzard shad because they both consume smaller sized plankton, whereas bighead carps may most directly threaten <30-mm TL gizzard shad because they both consume larger sized plankton; however, silver carp were not frequently seen in Missouri River until *ca*. 2001 and neither is known to frequently use side-channel chutes (per comm. D. Chapman, USGS-CERC). An ontogenetic diet switch by gizzard shad may further confound the difficult task of identifying competitive interactions and a lack of evidence that Asian carps frequently use side-channel chutes suggests such interactions may not be common within chutes. Therefore, we can not determine whether decreasing body condition in chutes was more related to 1) a negative competition interaction with Asian carps for food resources, or 2) increasing gizzard shad abundance and associated intra-species competition. However, it is entirely reasonable to hypothesize a stronger competitive interaction exists in areas where silver carp and >30-mm TL gizzard shad, and bighead carp and <30-mm TL gizzard shad, more frequently co-occur, such as in slow velocity areas (e.g., dike fields) of main-channel Missouri River.

We caution that our results be interpreted with the caveat that no active-hour gear-group samples were included in abundance analysis for 1997 and 1999. Furthermore, as with many long-term datasets, we assume that biologists modified gears, techniques, and sampling crews to more effectively collect fishes, and that collection efficiency was not constant, but likely increasing, during the study period. This assumption alone may

account for much of the weak positive slope detected in abundance of gizzard shad over the study period.

Acknowledgments

We thank Missouri River crews at Columbia NFWCO for collecting and storing data, and Wyatt Doyle for insightful reviews of earlier drafts of this report. Duane Chapman at USGS-Columbia Environmental Research Center provided important information about Asian carp feeding and movement habits.

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Appendix-A

Table A1. Number of samples collected by gear and year in chutes on lower Missouri River from 1997-2007. Asterisks denote gears used for analysis of gizzard shad abundance.

gear		year										
name	code	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
unknown	BP	0	0	0	1	0	0	0	0	0	0	0
beam trawl*	BT	17	23	16	31	10	6	0	17	0	0	0
otter trawl*	OT	0	0	0	0	44	46	36	23	66	327	183
unknown	OTL	0	0	0	0	0	26	0	0	0	0	0
unknown	OTM	0	0	0	0	0	56	0	0	0	0	0
push trawl	POT8W	0	0	0	0	0	0	0	0	0	24	0
push trawl	POT02W	0	0	0	0	0	0	0	0	0	52	0
push trawl	POT02S	0	0	0	0	0	0	0	0	0	0	134
unknown	PTW	0	0	0	0	0	0	0	0	9	0	0
seine*	SN	26	14	13	36	48	79	67	64	0	11	0
electrofishing*	EF	0	4	0	13	33	40	48	81	209	235	191
night electrofish.	NEFW	0	0	0	0	0	0	0	0	27	9	32
stationary gill net*	SGN	0	0	2	0	7	17	13	0	0	0	0
drifting gill net	DGN	6	0	0	7	0	0	0	0	0	0	0
unknown	DN	0	1	0	0	0	0	0	0	0	0	0
mini-fyke net*	FN	0	36	57	70	38	87	89	70	39	205	119
unknown	FYKE	0	0	0	0	3	0	5	0	0	0	0
large hoop net*	LHN	64	105	134	131	92	133	145	165	95	202	182
small hoop net*	SHN	63	104	133	130	95	136	136	151	18	185	186
unknown	XHN	0	0	0	0	0	0	0	0	277	0	0
set line	SL	0	11	6	0	0	0	0	0	0	0	0
trammel net	T	0	0	0	5	0	0	0	0	0	0	0
unknown	TN125	0	0	0	0	0	0	0	8	0	0	0
unknown	TN100	0	0	0	0	0	0	0	15	0	0	0
unknown	TN50S	0	0	0	0	0	0	0	0	19	128	86
unknown	STN50W	0	0	0	0	0	0	0	0	0	24	2
unknown	TN40	0	0	0	0	0	0	0	5	0	0	0
unknown	TN25S	0	0	0	0	0	0	0	0	0	9	0
unknown	TN12S	0	0	0	0	0	0	0	0	0	0	16
unknown	TN11S	0	0	0	0	0	0	0	0	0	38	79
unknown	TNS	0	0	0	0	0	0	0	0	0	2	0

Table A2. Descriptive statistics of mean length and weight (± standard error), mean relative weight (W_r; ± standard error), counts of 10-mm TL size-classes, and standard weights (W_s) of gizzard shad by 10-mm (TL) size-class collected from side-channel chutes in lower Missouri River pooled across years during the period 1998-2007. Blank standard error indicates it was not estimable.

length class	# gizzard shad	mean length	mean weight	W_s	mean W_r
180-189	44	183.6 ± 0.4	70.8 ± 4.9	69.2	102.2 ± 7.1
190-199	53	194.1 ± 0.4	76.8 ± 4.6	81.5	94.2 ± 5.6
200-209	47	204.0 ± 0.4	94.7 ± 5.8	95.2	99.4 ± 6.1
210-219	53	213.1 ± 0.3	94.0 ± 4.9	110.5	85.1 ± 4.4
220-229	29	223.8 ± 0.6	120.2 ± 9.4	127.3	94.5 ± 7.4
230-239	51	234.1 ± 0.4	157.7 ± 15.5	145.7	108.3 ± 10.7
240-249	44	243.2 ± 0.4	140.4 ± 4.9	165.9	84.6 ± 3.0
250-259	52	253.7 ± 0.4	149.6 ± 4.6	188.0	79.6 ± 2.4
260-269	46	263.8 ± 0.5	181.0 ± 8.6	212.0	85.4 ± 4.0
270-279	47	274.6 ± 0.4	195.7 ± 5.3	238.0	82.2 ± 2.2
280-289	35	283.3 ± 0.5	199.3 ± 5.6	266.1	74.9 ± 2.1
290-299	32	292.5 ± 0.5	232.8 ± 8.5	296.4	78.5 ± 2.9
300-309	37	303.8 ± 0.4	267.2 ± 9.4	329.0	81.2 ± 2.8
310-319	27	313.4 ± 0.5	282.0 ± 11.9	363.9	77.5 ± 3.3
320-329	24	324.6 ± 0.7	315.6 ± 14.5	401.3	78.6 ± 3.6
330-339	17	333.4 ± 0.5	335.1 ± 27.2	441.3	75.9 ± 6.2
340-349	20	343.5 ± 0.6	415.3 ± 18.0	483.9	85.8 ± 3.7
350-359	22	353.2 ± 0.6	445.5 ± 12.2	529.2	84.2 ± 2.3
360-369	13	364.1 ± 0.8	435.0 ± 34.1	577.4	75.3 ± 5.9
370-379	6	373.2 ± 0.8	540.3 ± 31.3	628.5	86.0 ± 5.0
380-389	8	381.8 ± 0.7	533.1 ± 41.0	682.6	78.1 ± 6.0
390-399	9	393.9 ± 1.0	593.0 ± 53.3	739.7	80.2 ± 7.2
400-409	1	400.0	750.0	800.1	93.7
410-419	5	415.8 ± 1.1	772.4 ± 41.2	863.8	89.4 ± 4.8
440-449	1	441.0	880.0	1075.5	81.8
450-459	2	451.0 ± 0.0	1242.5 ± 190.5	1153.3	107.7 ± 16.5

Table A3. Mean (± standard error) relative weight (W_r) of gizzard shad collected from side-channel chutes in lower Missouri River by year and 10-mm (TL) size-class during the period 1998-2007. Blank indicates no data, missing standard error indicates it was not estimable, and asterisk (*) indicates data was excluded from regression analysis.

length class	Year									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
180-189	102.5		85.8 ± 8.2	128.2 ± 34.4	153.8 ± 2.2	*309.1	65.0		99.0 ± 7.1	83.5 ± 5.4
190-199		60.1	93.2 ± 7.5	66.2 ± 14.7	68.7 ± 7.7				99.7 ± 5.6	95.5 ± 17.4
200-209	83.5 ± 20.5		120.2 ± 30.0		79.8 ± 34.6			89.2	104.6 ± 7.5	78.7 ± 3.9
210-219	89.6 ± 0.0		78.0 ± 7.3	74.7 ± 9.5	50.7		64.3		86.3 ± 4.3	91.4 ± 18.8
220-229			95.8 ± 6.7						103.0 ± 13.3	71.4 ± 3.4
230-239	107.1 ± 0.0		123.7 ± 37.9	51.5				*195.6 ± 109.8	97.4 ± 7.5	111.9 ± 35.4
240-249			103.7 ± 9.2	87.4				72.3 ± 2.8	91.2 ± 4.6	71.2 ± 1.8
250-259			91.8 ± 2.6		77.4 ± 13.0			48.8 ± 13.9	82.7 ± 3.5	72.4 ± 2.9
260-269			85.2 ± 1.8	77.7 ± 5.9	92.9		60.9	72.3 ± 2.1	86.8 ± 2.8	91.6 ± 14.9
270-279	83.2	59.2	95.9 ± 2.7	71.2 ± 1.9	77.7		77.7 ± 1.3	75.6 ± 2.7	85.6 ± 4.3	72.0 ± 1.7
280-289		80.6 ± 5.4	91.4 ± 4.3	82.7 ± 0.8	66.0 ± 8.1		61.6 ± 2.3	75.2 ± 1.9	75.0 ± 4.6	71.9 ± 2.9
290-299	86.0	75.2	94.6 ± 4.6	81.0	57.5 ± 3.9		64.9 ± 4.2	80.2 ± 11.1	83.9 ± 4.8	64.9 ± 3.5
300-309	94.8	91.8	86.8 ± 3.6	73.0	92.0 ± 0.8			69.7 ± 3.0	90.0 ± 5.8	66.0 ± 5.4
310-319		103.0	82.5 ± 4.3		74.1 ± 9.5			80.4 ± 13.1	79.1 ± 8.2	70.6 ± 2.4
320-329			83.2 ± 10.9	79.6 ± 10.1				80.1 ± 1.5	78.6 ± 5.5	67.5 ± 6.4
330-339			93.0 ± 0.3	75.9				53.8 ± 41.4	87.2 ± 7.6	62.1 ± 7.2
340-349	88.0		94.3 ± 3.1	98.3 ± 4.0	89.1				74.8 ± 8.9	67.7 ± 2.6
350-359		75.6	97.6 ± 8.4	90.7				84.6 ± 1.2	82.3 ± 1.2	67.2 ± 1.8
360-369			92.7 ± 2.9	88.3 ± 4.2		58.9		79.7 ± 0.0	79.7 ± 16.5	50.5 ± 15.6
370-379			92.1 ± 0.3					79.6	84.3 ± 17.5	83.4
380-389			87.2 ± 2.6		70.3			82.8	104.0	64.5 ± 9.4
390-399			68.3 ± 38.1					74.3	83.7 ± 4.0	91.9
400-409			93.7							
410-419			98.2 ± 3.6					88.0	89.7	72.9
440-449									81.8	
450-459						107.7 ± 16.5				