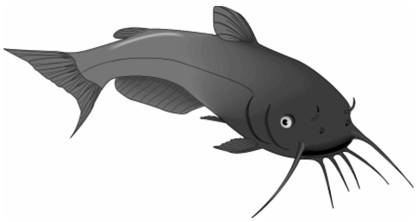
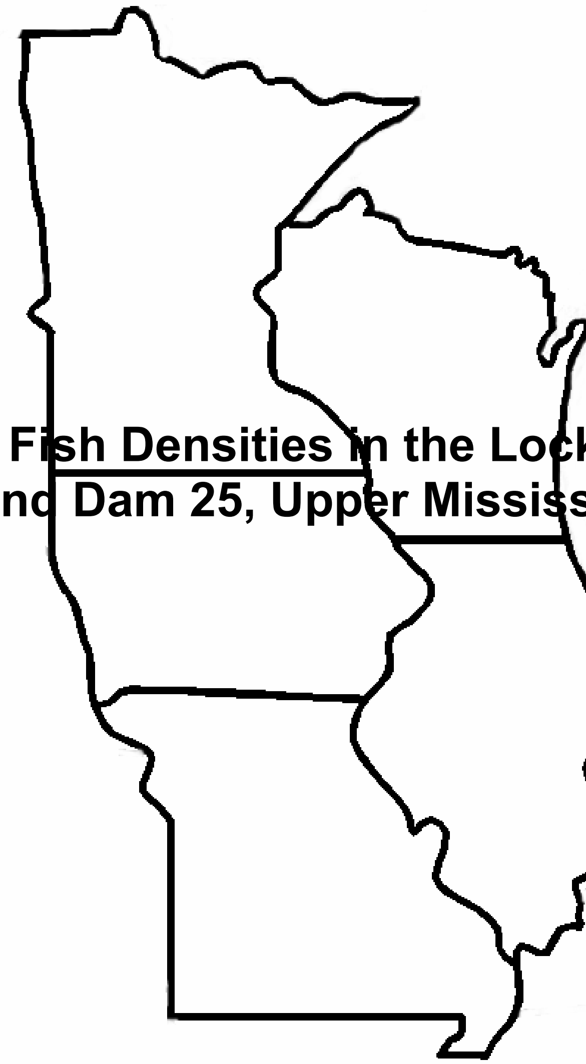
ENV Report 57

Interim Report For The Upper Mississippi River – Illinois Waterway System Navigation Study





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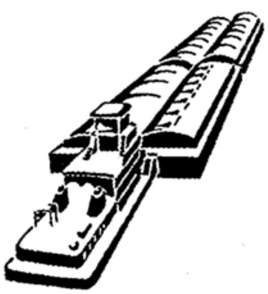

March 2005

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Upper Mississippi River - Illinois Waterway System Navigation Study

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Seasonal Fish Densities in the Lock Chamber at Lock and Dam 25, Upper Mississippi River

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Interim report

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ABSTRACT: Due to fluctuating water levels, high jet velocities, and turbulence resulting from towboat propellers, lock chambers do not provide suitable aquatic habitat and should be unattractive to fish. However, because there is the possibility that fish that use lock chambers can be entrained by towboat propellers, a hydroacoustic study was conducted from June 2002 through May 2003 to characterize the seasonal density of fish in Lock and Dam 25. High fish densities in the lock during the spring, summer, and fall (mid-April through November) and low densities during the winter reflect the abundance of fish in the main channel during these periods.

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Preface

The work reported herein was conducted as part of the Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study. The information generated for this interim report will be considered as part of the plan formulation process for the System Navigation Study.

The UMR-IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts, Rock Island, St. Louis, and St. Paul, under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing and, in consideration of existing system lock constraints, will result in traffic delays that will continue to grow in the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements in the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report that is the decision document for processing to Congress.

This study was conducted by the U.S. Army Engineer District, St. Louis. This report was written by Mr. Brian L. Johnson, Dr. Thomas M. Keevin, Mr. Eric A. Laux, and Mr. Thixton B. Miller of the Environmental Analysis Branch, U.S. Army Engineer District, St. Louis; Mr. Donald J. Degan of Aquacoustics, Inc.; and Dr. David J. Schaeffer of the Department of Veterinary Biosciences, University of Illinois.

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1 Introduction

On the Upper Mississippi River System (UMRS), there are a total of 37 locks and dams (29 on the Mississippi River and eight on the Illinois River) that maintain commercial navigation on the system. Aside from Lock 27, Melvin Price Lock, and Lock 19, both of which have usable lengths of 366 m (1,200 ft), locks on the UMRS have a usable length of about 183 m (600 ft).

It would appear that lock chambers would not provide suitable aquatic habitat and would be unattractive to fish. Water levels are constantly raised and lowered with the lockage of commercial navigation traffic. Towboats, within the confined area of a lock, continually recirculate the lock's water volume, potentially exposing the fish to multiple propeller entrainment events that can cause fish mortality (Gutreuter et al. 2003). Towboat propellers can produce jet velocities that exceed 6 m/sec, entrain high volumes of water and create major turbulent hydraulic forces (Maynord 1999). The confined flow fields within a lock also create high shear stress and pressure changes that are detrimental to fish. However, a survey of five 366 m locks on the Ohio River produced fish abundance estimates ranging from 10,340-17,887 fish in a rotenone survey and from 11,543-14,962 fish in hydroacoustic surveys (Hartman et al. 2000). The objective of this study was to determine seasonal fish densities and species composition at Lock and Dam 25, a representative 183 m lock on the UMRS.

2 Materials and Methods

The study was conducted at Lock and Dam 25, located at River Mile 241.4 on the Upper Mississippi River near Winfield, Missouri. The lock first opened on May 18, 1939, and had approximately 6,000 lockages of both commercial and recreational craft in 2001 (U.S. Army Corps of Engineers 2003).

Continuous records that are kept for temperature at Lock and Dam 25 - as well as water elevations immediately upstream (Pool 25) and downstream (tail-water) of the dam - were used for this study. Water elevations were used to calculate water depth and water volume in the lock. Hydroacoustic fish surveys were conducted to provide seasonal fish abundance estimates for Lock 25 using a BioSonics model DT 6000 with a 200-kHz split beam transducer. The hydro-acoustic system was calibrated to U.S. Navy standards at the BioSonics, Inc. laboratory in Seattle, Washington. An in situ calibration was performed before any data were collected and again at the conclusion of the study. Data collection parameters for the DT 6000 system were set to sample to -60 db from 1.0 m below the transducer to within 15 cm of the lock bottom. Depth of the transducer during sampling was 0.5 m below the surface. Data were collected at a pulse length of 0.2 m/sec at 15 pings per second. The speed of sound calculation was generated from the surface water temperature collected during each survey. Tracked fish counts were generated with EchoView® 2.25 software using an alpha-beta track-detection algorithm (see Table 1 for tracking parameters). Tracked targets were reviewed and edited manually by removing obvious non-fish targets, merging split tracks, and splitting merged tracks. These tracks were further filtered to remove tracks with a mean TS of less than 7.6 cm total length (-51.7dB converted using Love (1977)). Fish density was calculated as the number of fish in a transect divided by the sample volume of that transect. Sample volume was calculated from the transducer nominal beam width, 6.5 deg for our system. The sample volume was calculated as follows:

- Sample width (at bottom) = 2*depth*Tan (beam width/2)
- Sample volume = (width*depth*transect length)/2.

Hydroacoustic surveys were conducted on a monthly basis. The survey was conducted on four equally spaced transects along the length of the lock and was repeated twice during each sampling period. No survey was conducted during January because of low water and ice conditions.

Table 1. Single Target Detection Criteria and Fish Tracking Parameters for Fish Tracks

Algorithm	4D (range, angles and time)		
Alpha	0.40	0.40	0.40
Beta	0.2	0.2	0.20
Target Gates			
Exclusion distance	4.0	4.0	0.1
Missed ping expansion	0	0	0
Weights			
Major axis	0		
Minor axis	0		
Range	1		
TS	0		
Ping gap	0		
Minimum number of targets in a track	3		
Minimum number of pings in a track	1		
Maximum gap between single targets	2		

Total counts on each sampling day were calculated using the data from the eight hydroacoustic transects. Some lower-bounded 95 percent confidence intervals calculated using arithmetic values were <0; therefore, the data were treated as coming from a lognormal distribution, and geometric average counts and their asymmetric confidence intervals were used. In computing these values, transects with 0 fish were replaced by 0.001 fish.

Fish species composition in Lock 25 was determined using ancillary data collected during a concurrent study of fish mortality resulting from locking towboats. Two sampling methods were employed to determine species composition. Immediately after a towboat passed through the lock, dead or injured fish were dip netted from the surface. In addition, the lock bottom was sampled with a 4.9 m (16 foot) long, 3.8 cm (1.5 inch) mesh, otter trawl deployed along four equally spaced transects, each approximately 168 m (550 feet) long. Sampling was conducted during June 17-20, 2002; August 26-29, 2002; October 21-25, 2002; December 2-6, 2002; and April 14-16, 21-22 and 24, 2003.

3 Results

There was considerable seasonal and daily variability in the number of fish estimated to be in the lock chamber at Lock and Dam 25 (Figure 1 and Table 2). In general terms, the highest fish densities were observed during the summer and fall (August through November) and again during the spring (mid-April through May). The highest density occurred on August 29 when 14,356 (10,177-20,251) fish were estimated to be in the lock. The high August densities reflect schools of gizzard shad (*Dorosoma cepedianum*) in the lock. For example, on August 26 we visually observed at least four large distinct schools of gizzard shad that blackened the water column.

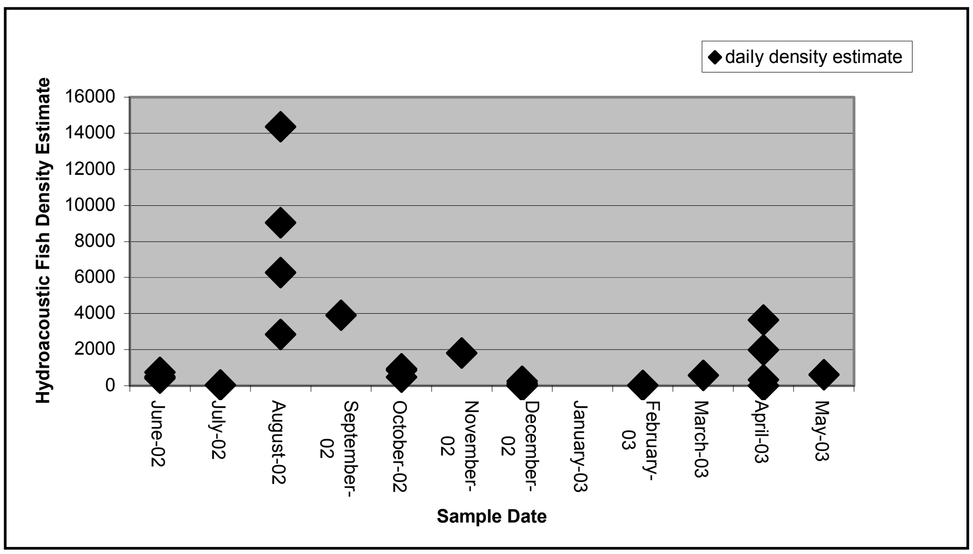

Figure 1. Seasonal abundance of fish in Lock 25, Upper Mississippi River, obtained by a BioSonics Model DT 6000 with a 200-kHz split beam transducer

The lowest densities occurred during the winter months, when there were very few fish observed in the lock, and extended through mid-April. The lowest observed density was on December 6th when only one (0-8) fish was estimated to be in the lock.

Lock species diversity was extremely low (Tables 3 and 4). Four species (gizzard shad, channel catfish (*Ictalurus punctatus*), blue catfish (*Ictalurus furcatus*), and freshwater drum (*Aplodinotus grunniens*)) comprised 96 percent

Table 2. Seasonal Abundance of Fish in Lock 25, Upper Mississippi River, Obtained by a Biosonics Model DT 6000 with a 200-kHz Split Beam Transducer

Sampling Date	Water Temp °C	Geometric Mean	Lower 95 Percent Limit	Upper 95 Percent Limit
06/18/02	23.8	414	324	530
06/19/02	23.8	500	414	603
06/20/02	23.8	746	558	999
07/22/02	30.0	38	3	519
08/26/02	27.2	2837	2059	3910
08/27/02	27.2	9045	5302	15431
08/28/02	27.2	6281	2963	13314
08/29/02	27.2	14356	10177	20251
09/26/02	22.2	3915	3110	4927
10/21/02	12.2	856	405	1809
10/22/02	12.2	938	868	1012
10/24/02	11.1	470	275	805
11/21/02	7.2	1812	1287	2550
12/02/02	3.3	14	1	230
12/03/02	3.3	249	141	440
12/04/02	3.3	116	16	835
12/05/02	2.2	4	0	59
12/06/02	2.2	1	0	8
01/00/03	River Frozen - No Access			
02/20/03	0.6	13	1	202
03/24/03	8.8	575	301	1099
04/14/03	12.2	5	0	96
04/15/03	12.2			
04/16/03	12.7	316	192	519
04/21/03	14.4	1985	731	5394
04/22/03	13.8	3633	1568	8418
05/28/03	20.0	613	267	1406

Table 3. Number of Fish Captured by Month Segregated by Capture Technique (Trawling or Dipnet) and Condition of the Fish (Live or Recently Dead)

Month	Gizzard Shad	Freshwater Drum	Blue Catfish	Channel Catfish	Other
Live Fish Captured by Trawling					
June	0	28	17	3	0
August	5	29	19	17	0
October	6	47	34	71	4
December	16	0	0	1	0
April	1	11	0	112	8
Sub-total	**28**	**115**	**70**	**204**	**12**
Recently Dead Fish Captured by Trawling					
June	0	0	0	0	0
August	4	0	1	0	0
October	6	6	0	0	1
December	46	1	0	0	0
April	7	6	0	0	10
Sub-total	**63**	**13**	**1**	**0**	**11**
Recently Dead Fish Collected from the Surface					
June	1	0	0	0	0
August	65	9	3	2	1
October	5	1	0	0	0
December	56	0	0	0	0
April	6	11	0	1	2
Sub-total	**133**	**21**	**3**	**3**	**3**
TOTAL	**224**	**149**	**74**	**207**	**26**

Table 4. Total Number of Fish Captured per Month and Catch per Unit Effort

A unit of effort is defined as one set of four trawls and fish collected from the surface just prior to trawling after a towboat lockage.

Month	# of Samples	Gizzard Shad	Freshwater Drum	Blue Catfish	Channel Catfish	Other
June	11	1 (0.09)	28 (2.55)	17 (1.55)	3 (0.27)	0 (0.00)
August	10	74 (7.40)	38 (3.80)	23 (2.30)	19 (1.90)	1 (0.10)
October	21	17 (0.81)	54 (2.57)	34 (1.62)	71 (3.38)	6 (0.29)
December	18	118 (6.56	1 (0.06)	0 (0.00)	1 (0.06)	0 (0.00)
April	20	14 (0.70)	28 (1.40)	0 (0.00)	113 (5.65)	20 (1.00)
TOTAL	**80**	**224 (2.80)**	**149 (1.86)**	**74 (0.93)**	**207 (2.59)**	**26 (0.33)**

of the total catch. Summer (June and August) sampling resulted in the capture of five species (gizzard shad, bigmouth buffalo (*Ictiobus cyprinellus*), channel catfish, blue catfish, and freshwater drum).

During the fall (October) sampling period, eight species were collected (gizzard shad, emerald shiner (*Notropis atherinoides*), bigmouth buffalo, channel catfish, blue catfish, white bass (*Morone chrysops*), sauger (*Stizostedion canadense*) and freshwater drum). Only three species (gizzard shad, channel catfish, and freshwater drum) were captured during the winter (December). Fourteen species were captured during spring (April): paddlefish (*Polyodon spathula*), shortnose gar (*Lepisosteus platostomus*), gizzard shad, common carp (*Cyprinus carpio*), river carpsucker (*Carpiodes carpio*), smallmouth buffalo (*Ictiobus bubalus*), bigmouth buffalo, river redhorse (*Moxostoma carinatum*), golden redhorse (*Moxostoma erythurum*), channel catfish, white bass, sauger, walleye (*Stizostedion vitreum*), and freshwater drum.

4 Discussion

Hartman et al.'s (2000) September hydroacoustic abundance estimates of 11,543 - 14,962 fish in a 366 m lock chamber are similar to our September estimates of 3,110 - 4,927 fish in a 183 m lock. Although there may be large numbers of fish in locks during certain seasons, the populations are undoubtedly transient as evidenced by the high daily and seasonal variability in observed densities in the lock chamber. The high variability in densities of gizzard shad, a common inhabitant of locks (Hartman et al. 2000, this study), reflects the schooling nature of gizzard shad (Pflieger 1997).

Because of the extreme hydraulic conditions within locks and lack of diverse aquatic habitats, locks undoubtedly support transient fish populations rather than a resident population. Locks are situated adjacent to dams and their tailwaters. Bodensteiner and Lewis (1992) suggested that tailwaters produce harsh environmental conditions, including high velocity, high turbulence, and scoured bottoms, which support few species, especially small size classes. Locks may be attractive to fish because they provide a slackwater refuge from the harsh conditions of the adjacent tailwaters. It is common practice for lock masters to leave the downstream lock gates open while waiting for up-bound tows to arrive at the lock, thus facilitating fish access to the lock chamber. Another factor restricting the development of a resident fish population within locks is the passage of towboats. Locking tows create harsh hydraulic conditions, including high propeller jet velocities, pressure changes, and shear forces, as they recycle the confined water in the lock through their propellers (Maynord 1999). In addition, passage of fish through towboat propellers results in fish mortality (Gutreuter et al. 2003; Killgore et al., in preparation, Keevin et al., in preparation); therefore, fish populations in the lock are continuously depleted by lockage of the towboats.

In the five locks sampled by Hartman et al. (2000), the most abundant fishes were minnows and shiners (20-42 percent), gizzard shad (20-38 percent), freshwater drum (16-30 percent), and skipjack herring *Alosa chrysochloris* (up to 15 percent at Racine). Although rotenone sampling was employed on the Ohio River, while netting of dead and alive fish was used in this study, there were some similarities in the species collected and their abundances. Gizzard shad (33 percent of total catch) and freshwater drum (22 percent) abundances were similar to the Ohio River study. The trawl net size that was used in our study precluded capture of minnows, and only one emerald shiner was incidentally caught by trawling. Channel catfish (30 percent of total catch) and blue catfish (11 percent) were abundant in Lock 25 but not mentioned in the Ohio River study. This may be a reflection of differences in the effectiveness of the sampling techniques. Catfish species are highly susceptible to capture by bottom trawling while rotenone sampling may be less effective at capturing benthic fish species. The common species in the Lock 25 (gizzard shad, freshwater drum, channel catfish and blue catfish) reflect the relative numeric density of fish species in the main channel of the Mississippi River. Dettmers et al. (2001) found freshwater drum and gizzard shad to be the two most abundant fish species in the main channel of Pool 26, the pool immediately downstream of Lock and Dam 25, and channel catfish and blue catfish to be common.

High fish densities in the lock during the spring, summer and fall (mid-April through November) and low densities during the winter reflect the abundance of fish in the main channel during these periods. For example, we captured live freshwater drum during both the summer and fall and again in the following spring. Only one recently dead freshwater drum was captured during December trawling. Dettmers et al. (2001) considered the freshwater drum a "multiple-season user" of the main channel, meaning that they use the main channel for multiple, but not all seasons during the year. Freshwater drum use the main channel during the summer and autumn because of favorable food resources (Wahl et al. 1988) and utilize backwaters as temperature refugia during winter to avoid prolonged exposure to near-freezing water temperatures (Bodensteiner and Lewis 1992). Channel catfish produced similar results with live trawl captures during the summer, fall, and spring and only one specimen captured during the winter. Blue catfish were present in the lock during the summer and fall but absent during the winter and spring.

Hydroacoustic sampling during December and February demonstrated that there were very few fish in the lock chamber during the winter months. A drop in fish density began in December as water temperatures dropped, and on December 4th only 4 (0-59) fish were in the lock when water temperatures reached 2.2 °C. On February 20th the water temperature was 0.6 °C and only 13 (1-202) fish were in the lock. As temperatures approach 0 °C, many riverine species actively seek areas of warmer water and low current velocity (Sheehan et al. 1990; Bodenstiner and Lewis 1992; Knights et al. 1995). Thus, many species would have moved out of the tailwaters area, adjacent to the lock, to seek improved habitat conditions as water temperatures dropped during the winter. Gizzard shad, with the exception of one specimen each of freshwater drum and channel catfish, was the only species captured in the lock during the winter. The increase in fish diversity during the spring sampling period reflects their presence in the main channel, possibly making spawning movements or moving from over-wintering sites.

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14. ABSTRACT
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15. SUBJECT TERMS

Fish	Hydroacoustics	Lock and Dam 25
Fish density	Lock chamber	Mississippi River

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