

An evaluation of winter habitats used by bluegill, black crappie, and white crappie in Pools 11-14 of the Upper Mississippi River

Study 7021 Completion Report
Federal Aid to Fish Restoration
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Michael J. Steuck

Period Covered: 1 July 1998 – 30 June 2010

Iowa Department of Natural Resources

Patricia L. Boddy, Interim Director

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COMPLETION REPORT

MISSISSIPPI RIVER INVESTIGATIONS

PROJECT F-160-R

Study 7021. An evaluation of winter habitats used by bluegill, black crappie and white crappie in Pools 11-14 of the Upper Mississippi River

Job 1. Winter habitat preferences of adult bluegill, black crappie and white crappie

Job 2. Description of Upper Mississippi River habitats occupied by adult bluegill, black crappie and white crappie

Job 3. Completion Report

Period Covered: 1 July 1998 - 30 June 2010

Prepared By: Michael J. Steuck — Fisheries Research Biologist — 12/22/2010 Date

Approved By: George Scholten — Fisheries Research Supervisor — 12/22/2010 Date

CONSERVATION & RECREATION DIVISION

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TABLE OF CONTENTS

Study 7021. An evaluation of winter habitats used by bluegill, black crappie and white crappie in Pools 11-14 of the Upper Mississippi River

Job 1: Winter habitat preferences of adult bluegill, black crappie and white crappie.

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STUDY 7021

An evaluation of winter habitats used by bluegill, black crappie and white crappie in pools 11-14 of the Upper Mississippi River

OBJECTIVE

To describe, by 2010, the characteristics of overwinter habitat utilized by bluegill, black crappie and white crappie populations in the Upper Mississippi River, locate these habitats and develop recommendations designed to maintain and improve these habitats.

JOB 1

Winter habitat preferences of adult bluegill, black crappie and white crappie

OBJECTIVE

To determine the winter habitat preferences of adult bluegill, black crappie and white crappie in several pools of the Upper Mississippi River.

JOB 2

Description of Upper Mississippi River habitats occupied by adult bluegill, black crappie and white crappie

OBJECTIVE

To describe the physical and chemical nature of winter habitat selected by adult bluegill, black crappie and white crappie.

JOB 3

Completion report

OBJECTIVE

To compile, analyze, and publish findings of the investigation

COMPLETION REPORT
RESEARCH PROJECT SEGMENT

STATE: IOWA **TITLE:** An evaluation of winter habitats used by bluegill, black crappie and white crappie in the Upper Mississippi River

JOB NO.: 1 - 3

Abstract – The objectives were to determine the winter habitat preferences of adult bluegill (*Lepomis macrochirus*), white crappie (*Pomoxis anularis*) and black crappie (*Pomoxis nigromaculatus*) in various pools of the Upper Mississippi River and to describe the physical and chemical nature of winter habitat selected by these fish. Three hundred sixty-eight bluegill, white crappie, black crappie and largemouth bass (*Micropterus salmoides*) were radio tagged during the winters from 1998-1999 to 2008-2009. Fish were collected from main channel border and backwater lake habitat with electrofishing gear. All fish from 2001-2002 through 2008-2009 were radio tagged externally by tying the transmitter to several dorsal spines. Short term fish mortality was reduced to 0% by changing attachment techniques from internal attachment to external dorsal spine attachment. Fish were tracked for an average of 94 days for bluegill, 129 days for white crappie, 125 days for black crappie and 119 days for largemouth bass. The majority (91.7%) of the movement of radio tagged fish was <3.5 river miles and 50% of the fish moved ≤ 0.80 miles between summer and winter habitat. Bluegill, black crappie, and white crappie moved an average of 1.23, 1.50, and 0.90 miles between summer and winter habitats. Fish selected backwater habitat 87.1 percent of the time when ice cover existed. Physical and chemical measurements of habitats occupied by radio-tagged bluegill, white crappie, black crappie and largemouth bass were collected when fish were located. Radio-tagged fish (98%) moved from main channel border or side channels to backwater lakes as fall progressed into winter and water temperatures declined below 50°F. Backwater lake habitat exhibited shallower water, higher water temperatures and little current compared to main channel, main channel border or side channel habitats. Winter habitat can be defined as backwater areas as small as ½ acre in size, water temperatures 2-5 °F (mean = 35.1 °F) greater than main channel or side channel habitat and little or no water velocity (mean <= .03 feet/sec). The only time fish were found in areas with lower water temperatures (32°F) and higher flows (0.10 ft/sec) was when backwater area oxygen levels declined to critical levels(<4 mg/L) and the fish moved out of the backwaters to less suitable habitat in the side channels. Backwater habitat can be constructed or modified to create areas with suitable temperatures and flows (temperatures 3-5 °F greater than main channel or side channel habitat and flows <= 0.04 ft/sec). Fish use of such areas has been documented by radio telemetry to increase as these conditions are met.

Introduction

The Upper Mississippi River (UMR) is one of Iowa's most significant fishery resources and provides over 1.9 million days of fishing annually to Iowa anglers (IMR Systems, LTD 1986). Bluegill (*Lepomis macrochirus*) and crappie (i.e., white crappie *Pomoxis anularis* and black crappie *Pomoxis nigromaculatus*) have historically been the most frequently caught fish on the UMR (Rock 1963; Lopinot 1968; Fleener 1975; Gent 1991). In the early 1990s, that ranking declined to 3rd for crappies and 4th for bluegill (Pitlo 1995) and in 1994, all state members of the Upper Mississippi River Conservation Committee (UMRCC) Fisheries Technical Section voiced concern about the decline in bluegill numbers (UMRCC 1995). Many suspected these declines were the result of continued habitat loss and degradation.

Habitat loss, degradation and changes in water quality due to sedimentation have continued at an alarming rate on the UMR (Breitenbach and Peterson 1980; LePage 1980). Historic and recent river modifications and construction to facilitate commercial navigation, flood control, commercial development, and hydropower development have altered riverine habitats and biota on the UMR (Rasmussen 1979). The loss and change in physical habitats and change in water quality have caused concern relative to the status of bluegill and crappie.

Resource managers have long recognized the importance of overwintering habitat and water quality to freshwater fish in riverine systems. As early as the mid-1940's, members of the UMRCC conducted investigations on the effects of winter drawdowns on fish populations in the UMR (UMRCC 1945-1948). As river levels declined due to winter drawdowns, water flowed out of backwater lakes into the main channel and common carp *(Cyprinus carpio)*, northern pike *(Essox lucius)*, crappie spp., and bowfin *(Amia calva)* moved out of backwater lakes, while bluegill and largemouth bass *(Micropterus salmoides)* tended to remain and became trapped. These results prompted the U.S. Army Corps of Engineers (COE) to discontinue the practice of winter drawdowns in UMR navigation pools.

Sheehan et al. (1990) studied the winter habitat requirements of young-of-the-year (YOY) freshwater drum *(Aplidinotus grunniens)* and bluegill and found backwater lakes acted as thermal refuges for these species. They noted an absence of information in the literature regarding winter habitat requirements of fishes and questioned the assumption that winter is a period of inactivity for fish and, therefore, a period of stability for fish populations.

Knights et al. (1995) reported that bluegill and black crappie in Pool 5 of the UMR avoided habitats with low water temperatures (≤1°C) and current velocities that exceeded 0.03 ft/s. However, mortality of radio tagged fish was high (77% and 63% of the radio-tagged bluegill and crappie, respectively) during this study and bluegill and crappie lived an average of only 49 and 61 days, respectively. Recovery of radio-tagged fish showed little or no healing of the incision and most fish had a fungal infection covering the incision.

Pitlo (1992) radio tagged largemouth bass and noted the long distances these fish moved between summer and winter habitat. Largemouth bass wintered in backwater lakes, away from river currents, and where water temperatures were 2-5°F warmer than main channel temperatures. Similarly, Raibley et al. (1997) found that radio tagged largemouth bass wintered in backwaters, off-channel coves, ditches, and marinas where water temperatures were warmer and current velocity were reduced (i.e., 0.07 ft/s compared to 0.62 ft/s in the main channel). Since only three overwintering areas were located in a 13-mile river segment, Pitlo (1992) noted winter habitat might be the limiting habitat for largemouth bass on the UMR.

Backwater areas on the UMR have received significant amounts of sediments since impoundment (Brietenbach and Peterson 1980; LePage 1980) and this sedimentation reduced the amount and quality of backwater areas that serve as overwintering sites. Due to these high sedimentation rates, the estimated life expectancy of some UMR backwaters may be limited to 50 years (McHenry et al. 1976). In the Illinois River, declines in populations of yellow perch (*Perca flavescens)* and largemouth bass in a backwater lake were linked to sedimentation (Jackson and Starret 1959). Raibley et al. (1997) also noted as sedimentation filled backwaters along the Illinois River, river levels became ever more critical to maintain adequate water depths and stable water quality for wintering largemouth bass.

Resource managers have recognized the need to restore backwater areas but generally relied on observational information and physical/chemical data measured at existing quality backwaters to guide restoration efforts. Gent et al. (1995) reported on rehabilitation of a UMR backwater lake. This was accomplished by increasing water depth through dredging and the installation of a water control structure designed to connect the backwater to the main channel which allowed oxygenation of the backwater during periods of hypoxia. Prior to rehabilitation, radio-tagged largemouth bass moved out of the backwater complex during winter hypoxia periods; however, after rehabilitation, radio-tagged largemouth bass remained in the backwater complex during both winter and summer periods.

Recent habitat restoration projects in the Habitat Rehabilitation and Enhancement Program (HREP) have focused on restoring backwaters along the Mississippi and Illinois rivers. This program is administered by the U.S. Army Corps of Engineers in partnership with the Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Illinois Department of Natural Resources, Missouri Department of Conservation, U.S. Fish and Wildlife Service, and the Iowa Department of Natural Resources. Through post-restoration monitoring and adaptive management, HREP projects continue to evolve and improve, and many innovative techniques for restoring habitat on large rivers have been developed.

The loss and change in aquatic habitat, including change in water quality and siltation of backwater areas, have resulted in a need to better understand habitats critical to the well-being of crappie and bluegill. A better understanding of the physical and chemical nature of winter habitat is necessary to refine design guidance for future habitat restoration projects to benefit these and other important species.

Methods

Data for this project were collected during 11 study segments from July 1, 1998 through June 30, 2009. Throughout this report, each study segment is referenced based on the year it began (e.g., 1998 refers to the July 1, 1998 through June 30, 1999 study segment).

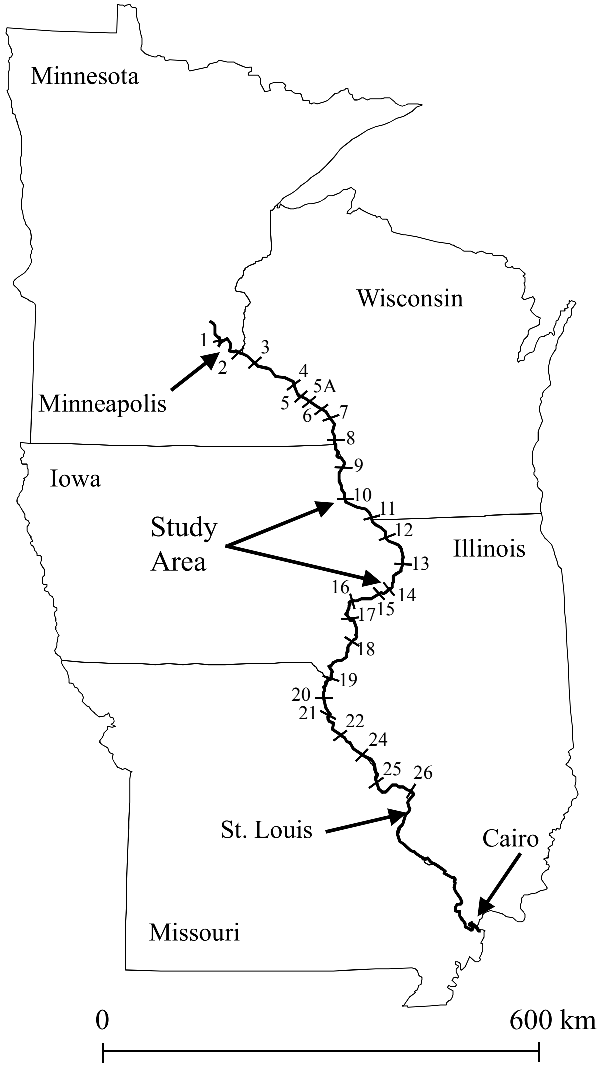

Figure 1. Map of the Upper Mississippi River basin. Numbers correspond with Lock and Dam enumeration by the U.S. Army Corps of Engineers. Pools are numbered by the dam forming the pool. Study area encompassed Pools11, 12, 13 and 14.

Bluegills, black crappie, white crappie and largemouth bass were captured with a boat mounted Smith Root Type VI-A electrofishing unit in Pools 11, 12, 13 and 14 of the UMR (Figure 1) during September-October 1998-2008. Fish deemed large enough were equipped with a radio transmitter (Advanced Telemetry Systems ATS], Isanti, MN) in the 48-49.999 MHz range. Model 357 radio transmitters weighed 3.52 g, had a life expectancy of 150 days and were used to radio-tag black and white crappie and largemouth bass. Model F1540 radio transmitters, weighing 2.0 g, had a 78-day life expectancy and were used to radio-tag bluegill. Several experimental Model 357 radio transmitters were used successfully during 2002 and 2003. These transmitters had the radio and battery components of the transmitters separate and connected with flexible wire so they could be placed on each side of the dorsal spine for even distribution of weight. This experimental transmitter was used for all black crappie, white crappie and largemouth bass during 2004-2008.

Transmitter weight in water was <2% of fish weight as recommended by Winter (1996) and Ross and McCormick (1981), thus, fish as small as 7 oz were tagged. If a transmitter was recovered due to fish capture or death, effort was made to re-use the transmitter. As a result, some fish were tagged late October to early December.

Radio attachment was by surgical internal implant or by external attachment. Surgical implant procedures were similar to those described by Pitlo (1986 and 1989). Three methods of external attachment were evaluated: Method 1 was attachment through the dorsal muscle; Method 2 involved tying the transmitter to the dorsal spines; and Method 3 involved pinching the dorsal spines between the radio and battery component of the transmitter using stainless steel suture or braided fishing line. Preparation of the radio transmitters was similar for methods 1 and 2 of external attachment. Method 1 utilized a 16-inch length of braided fishing line attached by a square knot to the middle of the transmitter. One of the tag ends was then half-hitched in a series toward one end of the transmitter, allowing 6 inches of free line at the end of the transmitter. The remaining free tag end was half-hitched toward the other end of the transmitter. All half-hitches were pulled tight so that the knots were in a straight line, along the center, and on the same side of the transmitter (Figure 2). Method 2 utilized two 16-inch pieces of fishing line tied to opposite ends of the transmitter with a square knot. A half-hitch was then placed on each side of the square knot to keep it in place. This allowed two, 6-inch tag ends of fishing line on each end of the transmitter. Knots in the fishing line were secured to the transmitter by drops of fast setting adhesive and allowed to dry and set before tying the next series of knots (Figure 2). When the adhesive had dried, the entire transmitter was coated with a sealant to prevent the fishing line from unraveling. During the initial project segment, the sealant used was

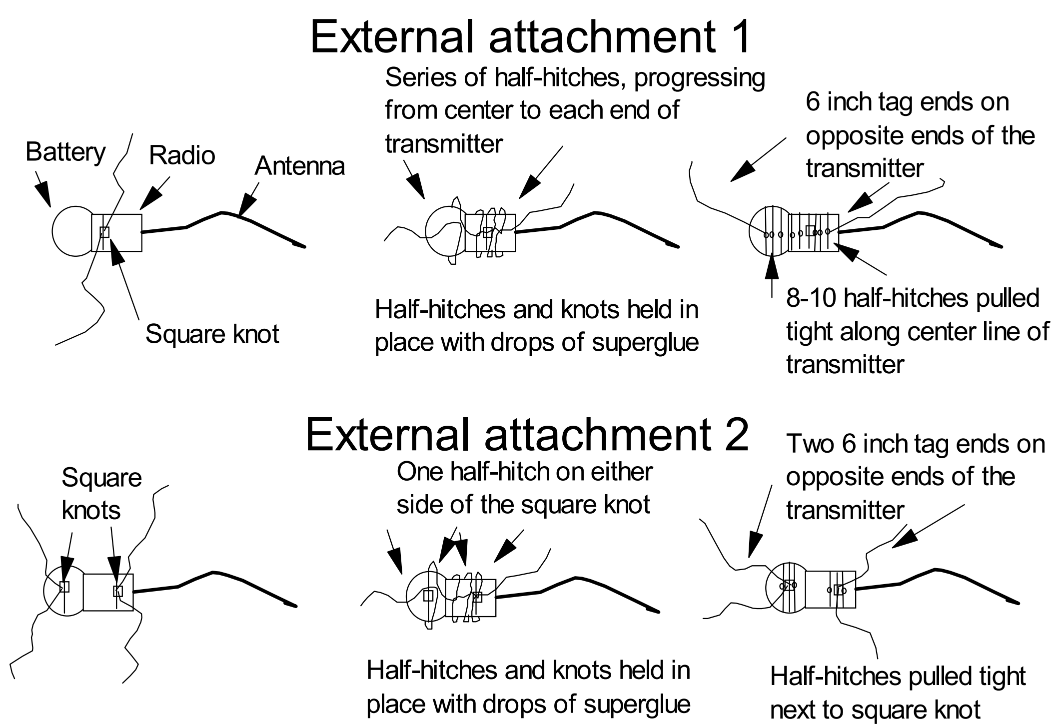

Figure 2. Schematic of transmitter preparation for the two methods of external transmitter attachment to bluegill, black crappie, and white crappie in Pool 13, Upper Mississippi River.

"Plastidip", a commercially available heavy-duty, flexible, rubber coating used to insulate tool handles. During subsequent project segments, a special sealant was used that was supplied by the radio transmitter manufacturer (i.e., ATS).

Method 1 required the radio transmitters be attached to the dorsal muscle. Using this method, the 6-inch tag end of line attached to the front of the transmitter (the end opposite the antenna) was inserted through the eye of a 3-inch round darning needle. The needle was then pushed through the dorsal muscle about 0.5-0.7 inch below the base of the 3rd dorsal spine and exited on the opposite side of the fish. The other 6-inch tag end of fishing line was threaded and pushed through the dorsal musculature in the same manner, about 0.5 inch posterior the first one. The two ends of fishing line were then inserted through holes in opposite ends of a short (0.75 inch long by 0.25 inch wide) piece of hard plastic. The line was snugged and knotted by bringing the two lines together and tying several overhand knots to secure the transmitter. The short piece of hard plastic was used to keep the fishing line separated to prevent muscle damage during the knotting process.

Attachment for Method 2 required threading a 3-inch darning needle with the anterior tag ends of the fishing line. The needle was then pushed through the dorsal fin as close as possible on either side of the base of the 3rd dorsal spine. The same method was used to secure the posterior tag ends of the fishing line to the 5th dorsal spine. The transmitter was then secured to the dorsal spines by 3-4 overhand knots. External attachment by Method 2 was used for all bluegill from 2000-2008.

Attachment Method 3 using experimental Model 357 radio transmitters required placing the radio component on one side of the dorsal spines and the battery component on the other side of the dorsal spines. Stainless steel suture material shaped into a long "horseshoe" or braided fishing line using a 3-inch round darning needle was inserted through holes drilled into the battery side and around the third dorsal spine then through the holes drilled on the transmitter side. The stainless suture material was then twisted with a clamping forceps or the braided fishing line was tied. This pinched the dorsal spine between the two sides of the transmitter fixing it in place. The process was then repeated around the fifth or sixth dorsal spine that matched up with the remaining holes in the transmitter (Figure 3). External attachment by Method 3 was used for all black crappie, white crappie and largemouth bass from 2004-2008.

Figure 3. Photo showing attachment of experimental transmitter to the dorsal spines of a black crappie in Pool 11, Upper Mississippi River.

Bluegill, black crappie, white crappie and largemouth bass were collected from habitats that were classified as main channel borders, side channels and backwater sloughs, lakes and ponds of Pools 11-14 of the UMR (Figure 1). These habitats were described by Pitlo and Rasmussen (2004) and included:

1. Main channel – The portion of the river through which large commercial craft operate. It has a minimum depth of 9 ft and width of 400 ft.
2. Main channel border – The area between the navigation channel (main channel) and the main riverbank, island or submerged definition of the old main river channel. It includes all areas in which wing dams occur and buoys often mark the outer edge of this habitat.
3. Side channel – All departures from the main channel or main channel border in which there is current during normal river stages.
4. Backwater lakes and ponds – These are generally floodplain depressions, oxbows or cutoff meanders and are connected to the river during normal river stages. There is little to no current, substrate is silt and there is generally substantial vegetation.

Most fish were released at the point of capture; however, several fish (N = 29) were moved into a new section of a habitat restoration project in Pool 11 during 2006, 2007 and 2008 to see if they returned to the original capture site or remained where released. The location and movement of radio-tagged bluegill and crappie were monitored using an ATS Model R2000 receiver with either a boat/hovercraft mounted yagi or handheld loop antenna throughout the fall and winter, and ceased after ice breakup in the spring. The following criteria were used to determine the fate (alive or dead) of the fish and the use of corresponding data collected when a fish was located:

1. Survived – fish moved at least 0.1 mile from capture/previous location to a different location in a direction not consistent with the current velocity. Radio-tagged fish were considered to have "survived" if they were harvested by an angler after tagging.
2. Died – fish location was static or moved short (i.e., < 0.1 mi) distances from capture/previous location to a different location consistent with the current velocity. Fish exhibiting this behavior were double checked by disturbing the location with a depth pole (95.5% of all fish locations were in < 10 ft of water) to see if the fish would move.
3. Censored – the fish was never located following tagging. (i.e., a missing fish) or the fish survived tagging and was located only once or twice within two weeks post tagging and then was never located again.

Fish locations were recorded using a handheld global positioning system unit or on a detailed map of the pool. Fish determined to have "survived" were used to compute longevity and movement. Longevity is the total number of days between the tagging date and the last known position before it was determined "dead" or angler harvested. Movement was computed as the distance (straight line river miles [RM]) between the release location and the last known position.

Each time a radio-tagged fish was located, habitat type (i.e. side channel, backwater lake, main channel border, etc), water depth [from the surface of the water (without ice cover) or the bottom of the ice (during ice cover) to the substrate], current velocity, dissolved oxygen, and water temperature were recorded. Current velocity, water temperature and dissolved oxygen were recorded at 8 in below the surface of the water without ice cover or the bottom of the ice when ice was present. Water depth was collected using a 10 ft sounding pole, a sounding line marked at 1 ft intervals, or a Lowrance Eagle electronic depth finder. Current velocity was measured using a Marsh McBirney Model 201 Current Meter. Dissolved oxygen and water temperature and were recorded using a Yellow Springs Instruments Model 55 temperature/oxygen meter.

During 2004-2008, all bluegill and crappie were radio tagged in the lower reaches of Pool 11 (RM 583-589.4) to evaluate the Pool 11 Islands HREP projects that were completed in this area. This is a large open water area with very few backwaters and side channels. Winter habitat in two sites of the Pool 11 Islands area, Mud Lake and Upper Sunfish Lake, were restored by: 1) dredging backwater areas to increase depth; 2) restoration of islands to reduce current velocities, re-suspension of sediment, wind fetch and wave action; and 3) creating upstream openings to introduce oxygenated water into these backwater complexes during winter periods. Construction was completed in two phases; the Sunfish Lake portion began fall 2002 and was completed fall 2004 and the Mud Lake portion began fall 2004 and was completed in summer 2005 and then modified in summer 2006.

Results

A total of 368 fish, comprising 105 bluegill, 103 black crappie, 125 white crappie and 35 largemouth bass were captured and implanted or fitted with radio transmitters during September-October 1998-2008 (Table 1).

In 1998 and 1999, surgical implant of radio tags at 75-78°F water temperature (N = 11) resulted in 100% mortality of the three species tested (Table 2). Survival of white crappie (1 of 2 fish) increased and all three black crappie survived when fish were internally tagged at 63-69°F water temperature; however, the one bluegill internally tagged at that temperature did not survive. At 41-52°F water temperature, crappie mortality due to surgical implantation was eliminated (N = 5) and survival of bluegill with tags surgically implanted (N = 3) improved to 67% (Table 2).

The two external methods of radio attachment evaluated in 1999 improved survival for all three species. During this evaluation, only one bluegill died of the 8 fish that were tagged externally through the

Table 1. Year (winter), location (pool) and number of Upper Mississippi River fish radio-tagged each winter.

Winter	Pool	Bluegill	Black Crappie	White Crappie	Largemouth Bass	Total
1998-1999	13	6	7	7		20
1999-2000	13	12	13	13		38
2000-2001	13	10	9	11		30
2001-2002	12	12	6	13		31
2002-2003	12	10	12	8		30
2003-2004	14	10	4	18		32
2004-2005	11	9	3	15		27
2005-2006	11	10	10	10	10	40
2006-2007	11	9	13	7	11	40
2007-2008	11	10	17	3	10	40
2008-2009	11	7	9	20	4	40
Total		105	103	125	35	368

Table 2. Mortality rates associated with fish internally tagged with radio transmitters, Pool 13, Upper Mississippi River, 1998 and 1999. Numbers in parenthesis are number of fish in each treatment.

	Temperature (°F)		
Fish Species	75-78	63-69	41-52
Bluegill	100% (4)	100% (1)	33% (3) [b]
Black Crappie	100% (4)	0% (3) [a]	0% (2) [c]
White Crappie	100% (3)	50% (2)	0% (3)

[a] Angler harvest after 28 d
[b] Angler harvest after 21 d
[c] Angler harvest after 18 d

dorsal muscle (i.e., Method 1; Table 3). All four fish (1 bluegill; 1 black crappie; 2 white crappie) tagged by tying the transmitter to the dorsal spine (i.e., Method 2) survived the tagging process. All external attachments were accomplished at water temperatures <63°F. Subsequently, from 2000 through 2008 all fish (N = 310) were tagged using the dorsal spine attachment method at water temperatures that ranged from 44° to 77°F and survival was 100%.

Table 3. Mortality comparisons of fish marked with externally attached radio transmitters, Pool 13, Upper Mississippi River, 1999. Numbers in parenthesis indicate the number of fish in each treatment.

	Attachment Type	
Fish Species	Dorsal Muscle	Dorsal Spine
Bluegill	33% (3)[a,b]	0% (1)
Black Crappie	0% (2)	0% (2)[c]
White Crappie	0% (3)	0% (2)

[a] Angler harvest after 45 d
[b] Disappeared after 15 d, harness of transmitter cut, assumed to be angler harvest
[c] Anal fin spine experiment, tag lost

In total, 95 bluegill, 88 black crappie, 117 white crappie and 24 largemouth bass survived tagging process and were monitored long enough to identify critical habitats. Fish determined to be "dead" (N = 34) or "censored" (N = 44) were excluded from analysis. Typically, we found transmitter life was nearly twice expected, warranty life. Transmitter life of radio-tagged bluegill averaged 94 days, black crappie 125 days, white crappie 129 days and largemouth bass 119 days. The mean number of locations per fish used to identify critical habitat and distance moved was 5.1 for bluegill, 8.0 for black crappie, 8.3 for white crappie, and 4.9 for largemouth bass (Table 4).

Movements and habitats frequented by several bluegill, black crappie, white crappie and largemouth bass monitored are shown in Figures 4-7. These movement patterns are representative of 98% of the movement observed by fish designated "survived" during this study (N = 324). Fish tagged in main channel border or side channel habitat moved into backwater habitat to over winter, those that were tagged in the backwater habitat tended to stay there through the winter. Fish moved from main channel border to backwater lakes as water temperatures declined into the 50-55°F range (e.g., Figure 8). Winter habitat was provided by backwater lakes in 87.1% of under ice fish observations whereas 12.3% occurred in side channel habitat and 0.6% occurred in main channel border habitat (Table 5). In open water (ice free), largemouth bass had the highest percentage of locations in main channel border (30.9%).

Table 4. Study segment (July 1-June 30) and mean number of days fish were tracked in Pools 11-14, Upper Mississippi River. Includes fish that disappeared or were harvested by anglers midway through the winter.

Study Segment	Bluegill	Black Crappie	White Crappie	Large mouth Bass
1998	poor survival	poor survival	poor survival	-
1999	87	122	166	-
2000	83	97	131	-
2001	105	120	112	-
2002	120	142	125	-
2003	83	139	128	-
2004	64	101	129	-
2005	74	133	111	113
2006	123	166	179	141
2007	100	109	97	93
2008	105	123	115	128
Mean	94	125	129	119

Table 5. Number and percent of fish locations by species, habitat type, under ice and open water from Pools 11-14, Upper Mississippi River.

	Under ice		Open water	
Habitat	Number	Percent	Number	Percent
Bluegill				
Backwater	184	82.9	225	66.6
Side Channel	35	15.8	92	27.2
Main channel border	3	1.4	21	6.2
Black crappie				
Backwater	313	88.7	228	60.5
Side Channel	36	10.2	138	36.6
Main channel border	4	1.1	11	2.9
White crappie				
Backwater	476	87.0	307	65.9
Side Channel	71	13.0	157	33.7
Main channel border	0	0.0	2	0.4
Largemouth bass				
Backwater	51	96.2	53	65.4
Side Channel	2	3.8	3	3.7
Main channel border	0	0.0	25	30.9
All species combined				
Backwater	1,024	87.1	813	64.4
Side channel	144	12.3	390	30.9
Main channel border	7	0.6	59	4.7

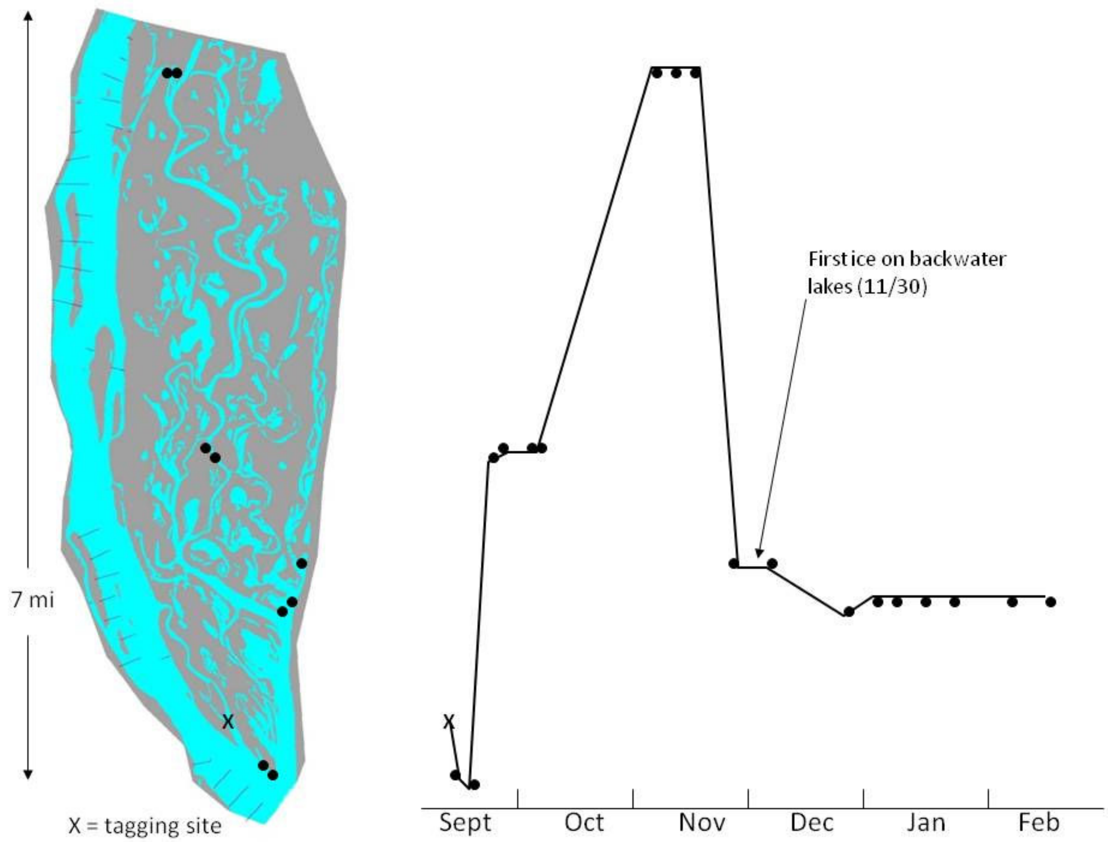

Figure 4. Locations for radio tagged black crappie 49.661 in Crooked Slough, upper Pool 13, Upper Mississippi River, 1999-2000. X denotes capture, tagging and release site.

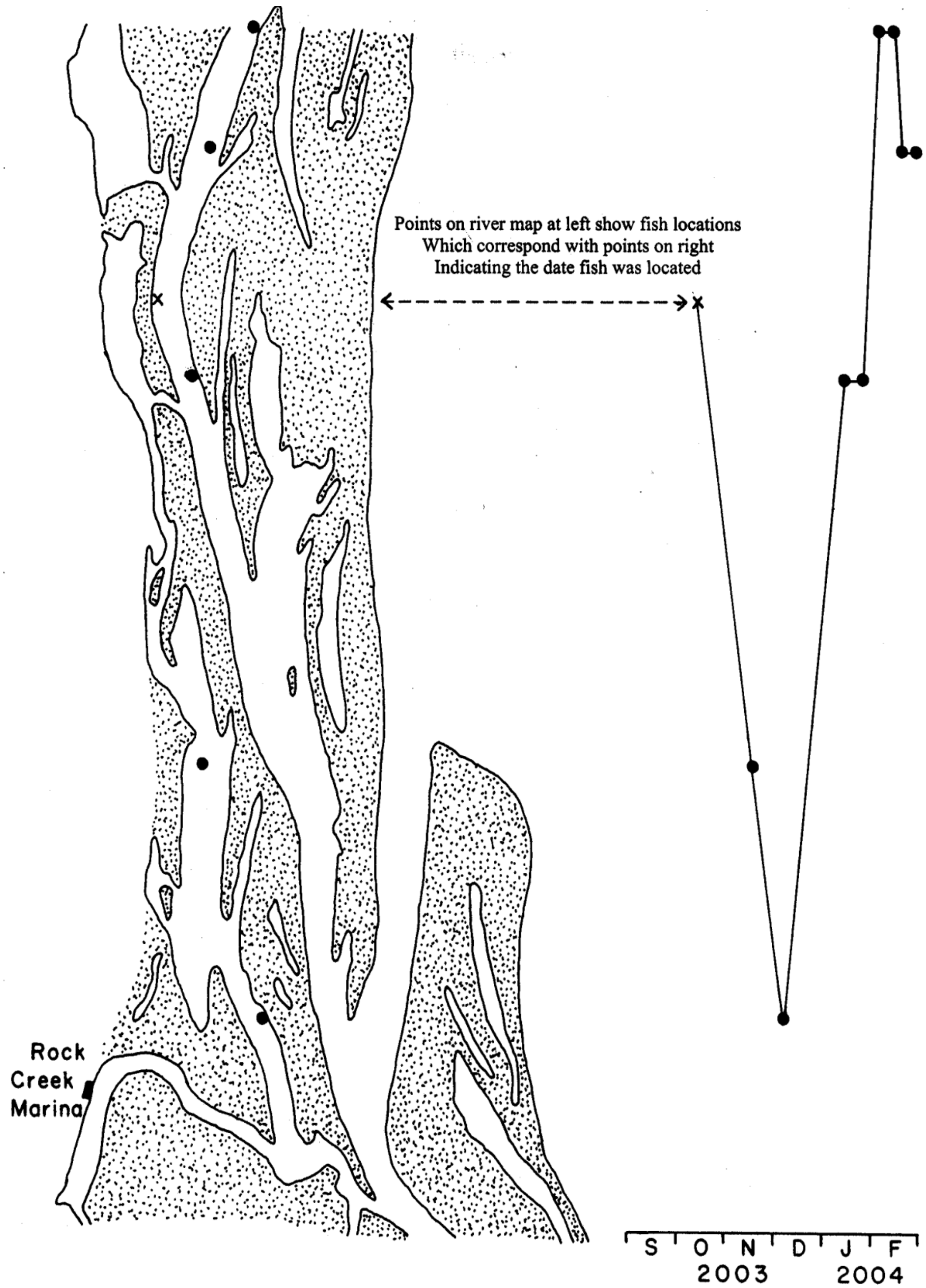

Figure 5. Locations for radio tagged black crappie 49.095 in Schrickers Slough, Pool 14, Upper Mississippi River, 2003-2004. X denotes capture, tagging and release site.

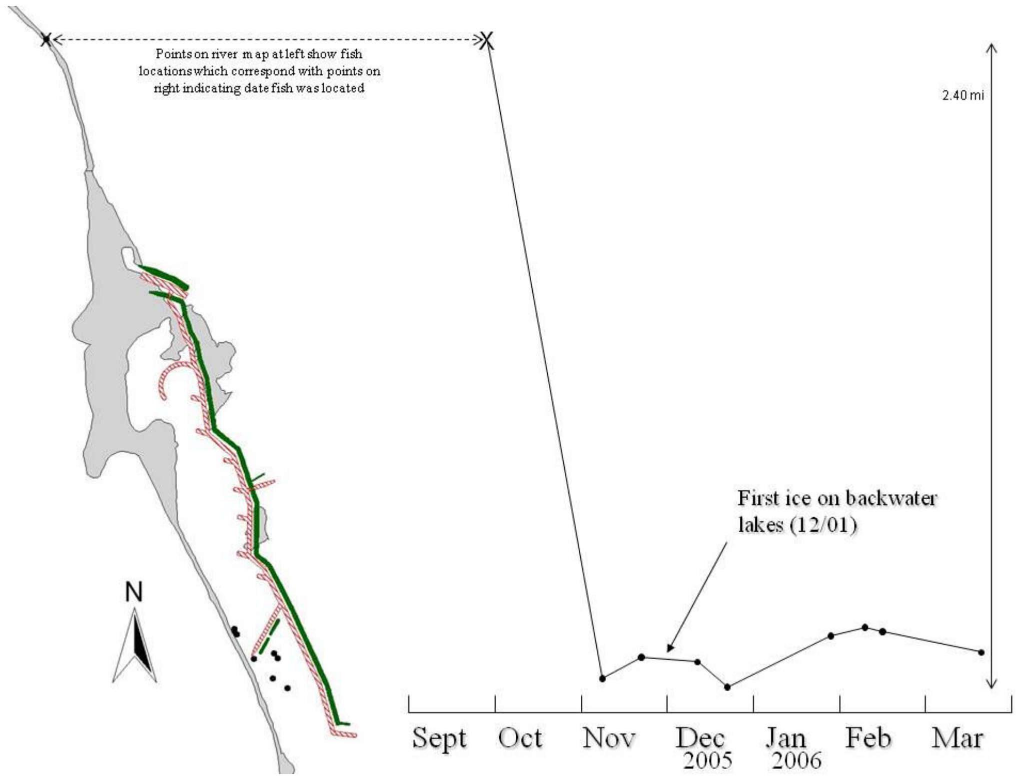

Figure 6. Locations for radio tagged black crappie 49.154 in Mud Lake, lower Pool 11, Upper Mississippi River, 2005-2006. X denotes capture, tagging and release site.

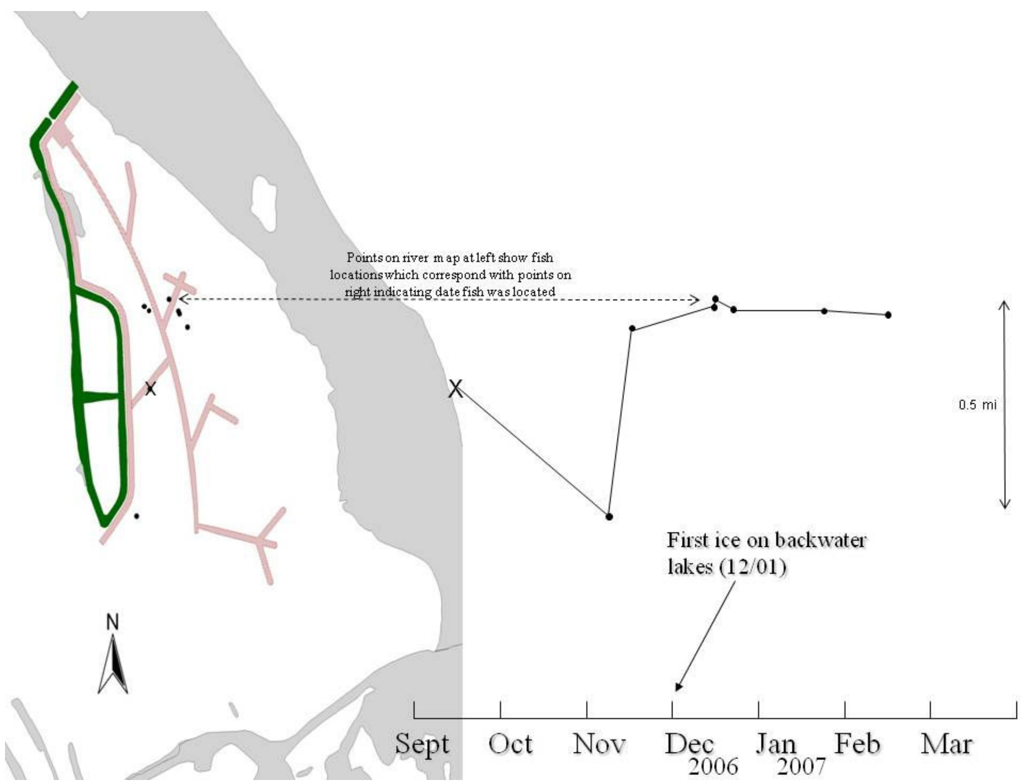

Figure 7. Locations for radio tagged white crappie 49.621 in Sunfish Lake, lower Pool 11, Upper Mississippi River, 2006-2007. X denotes capture, tagging and release site.

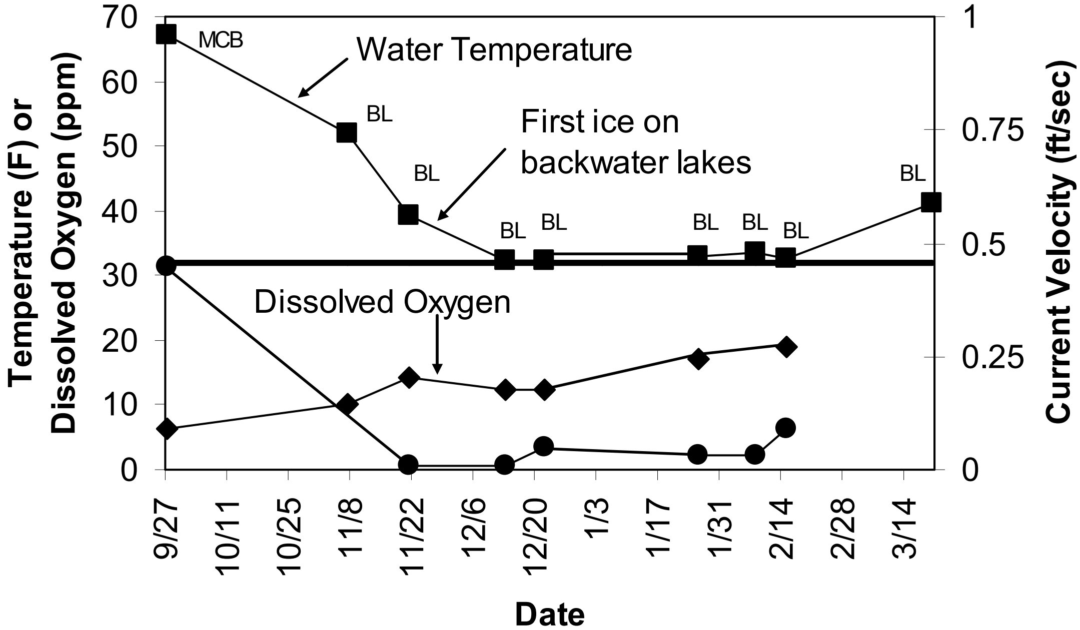

Figure 8. Water temperature (square points), dissolved oxygen (diamond points), and current velocity (circle points) measured at each location for radio tagged black crappie 49.154 in Pool 11, Upper Mississippi River, 2005. MCB = main channel border, BL = backwater lake.

Table 6. Number (N), mean, standard deviation (SD) and range of distance traveled in miles to wintering areas by fish as determined by radio telemetry from Pools 11-14, Upper Mississippi River. Does not include relocated fish.

Pool	Species	N	Mean (SD)	Range
11	Bluegill	38	0.81 (1.00)	0.01 - 5.10
	Black crappie	38	0.83 (0.58)	0.02 - 2.45
	White Crappie	43	0.43 (0.74)	0.02 - 4.54
	Largemouth bass	22	0.93 (0.96)	0.00 - 3.76
12	Bluegill	5	1.86 (1.47)	0.50 - 3.90
	Black crappie	6	3.57 (2.58)	1.40 - 7.80
	White Crappie	5	2.68 (3.67)	0.50 - 9.20
13	Bluegill	12	2.44 (1.55)	0.00 - 5.25
	Black crappie	10	2.90 (1.87)	0.75 - 5.75
	White Crappie	14	1.71 (1.23)	0.00 - 5.00
14	Bluegill	3	0.62 (0.28)	0.30 - 0.85
	Black crappie	2	0.98 (0.32)	0.75 - 1.20
	White Crappie	4	0.84 (0.34)	0.55 - 1.30
Combined	Bluegill	58	1.23 (1.32)	0.00 - 5.25
	Black crappie	56	1.50 (1.60)	0.02 - 7.80
	White Crappie	66	0.90 (1.42)	0.00 - 9.20
	Largemouth bass	22	0.93 (0.96)	0.00 - 3.76

On average, bluegill, black crappie, and white crappie moved 1.23, 1.50, and 0.90 river miles (RM) between summer and winter habitats (not including fish that were relocated by the investigator; Table 6). Several long distance movements (up to 9.2 miles) were observed for each species during this study. In 2002, one radio-tagged black crappie moved 5.5 RM and a white crappie moved 9.4 RM. During 2004, one bluegill moved 5.3 RM and another bluegill moved 3.0 RM. In 2006 a white crappie moved 3.4 RM. These distances were measured on a linear line and swimming distance would be greater due to sinuosity of river channels. Although some individual fish moved greater distances, most panfish (91.7%) moved less than 3.5 RM (mean = 1.16 RM) and 85% moved 2 RM or less between summer and winter habitat (Figure 9).

Mean dissolved oxygen and water temperature at fish locations were 12.1 mg/L (mode = 20.0) and 35.1°F (mode = 34.0°F), respectively (Table 7). Mean current velocity was 0.01 ft/sec (mode = 0.00 ft/sec) and mean depth was 4.30 ft (mode = 3.00 ft). Nearly 98% of all under ice current

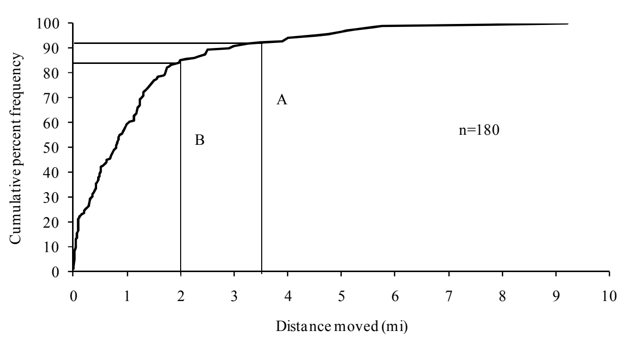

Figure 9. Cumulative percent frequency of the distance (river miles) fish moved to winter locations determined by radio telemetry from Pools 11-14, Upper Mississippi River. Line A depicts where 91.7% of the fish moved less than 3.5 mi and line B depicts where 85.0% moved 2 mi or less.

Table 7. Mean, standard deviation (SD), range and mode of water quality parameters and depth measured at each fish location from Pools 11-14, Upper Mississippi River under ice and open water during the winter from 1998-1999 through 2008-2009.

	Dissolved Oxygen (mg/L)	Temperature (°F)	Current Velocity (ft/sec)	Water Depth (ft)
Under ice (N = 1195)				
Mean (SD)	12.1 (5.0)	35.1 (2.6)	0.01 (0.04)	4.30 (2.46)
Range	0.9-32.0	32.0-48.0	0.00-0.33	0.00-23.0
Mode	20.0	34.0	0.00	3.00
Open water (N = 1302)				
Mean (SD)	12.6 (3.81)	50.1 (9.20)	0.11 (0.24)	4.35 (2.61)
Range	4.0-30.6	33.4-77.0	0.00-1.50	1.00-24.00
Mode	11.6	47.0	0.00	3.00

velocity readings were ≤0.10 ft/s where as only 81% of open water velocity readings were ≤0.10 ft/s (Figure 10). Water quality parameters varied little between species (Table 8).

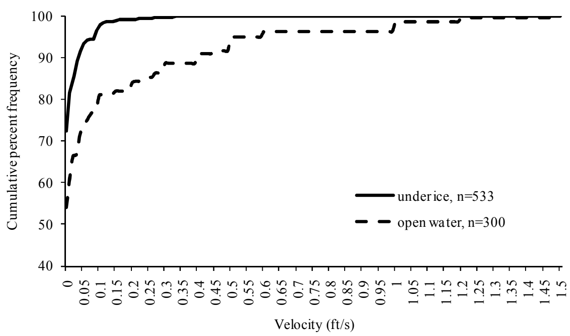

Figure 10. Cumulative percent frequency of water velocity readings (ft/s) at under ice and open water fish locations determined by radio telemetry from Pools 11-14, Upper Mississippi River.

Backwater habitat where fish overwintered lacked water currents found in sloughs and main channel border areas (Table 7) and also contained water 2-5°F warmer than main channel or side channel habitats (i.e., backwater water temperatures averaged 35.1°F compared to main channel or side channel habitat which averaged 32.9°F; Tables 7-8). Comparison of water quality parameters by species revealed little differences. Most notably, largemouth bass tolerated lower mean water temperatures (33.3°F versus 35.4, 35.1 and 35.1°F for bluegill, black crappie and white crappie, respectively) and were located in areas with deeper mean depths (6.8 ft versus 3.7, 4.4 and 4.2 ft for bluegill, black crappie and white crappie, respectively; Table 8).

Periods of hypoxia where fish were located were noted in several backwater areas. Fish in these areas moved out of backwater habitat into side channel habitat and then back again as dissolved oxygen levels returned to acceptable levels. For example, dissolved oxygen concentrations declined to 4.1 mg/l in lower Mud Lake on September 12, 2006. Bluegill and crappie moved to the southern end of Mud Lake where oxygen levels were above 5 mg/l. Within two days the dissolved oxygen levels in Mud Lake steadily increased to 10-15 mg/l and the fish responded by returning to Mud Lake.

In 2004 when sampling fish outside the Mud Lake was difficult, one bluegill and two black crappie captured in the Mud Lake marina or inside the Mud Lake project area were released up to one mile outside of Mud Lake (Figure 11). These fish returned to the marina or to Mud Lake and remained there until ice out (Table 9). Fish use in the upper portion of Mud Lake in Pool 11 was low during the winters of 2004 and 2005. The width and depth of the upstream opening to Mud Lake was reduced with rock in summer 2006 in an effort to reduce flows through this area. After this modification, fish use in Mud Lake increased during the winter in 2006, 2007, and 2008.

Table 8. Mean, standard deviation (SD), range and mode of water quality parameters and depth measured at each fish location by species from Pools 11-14, Upper Mississippi River under ice during the winter from 1998-1999 through 2008-2009.

	Dissolved Oxygen (mg/L)	Temperature (°F)	Current Velocity (ft/sec)	Water Depth (ft)
	Bluegill (N = 227)			
Mean (SD)	12.3 (4.57)	35.4 (2.64)	0.01 (0.03)	3.7 (2.03)
Range	3.3-32.0	32.0-41.4	0.00-0.15	0.0-18.0
Mode	9.5	36.5	0.00	3.0
	Black crappie (N = 357)			
Mean (SD)	12.5 (4.69)	35.1 (2.91)	0.02 (0.04)	4.4 (2.75)
Range	2.2-25.5	32.0-48.0	0.00-0.27	1.0-23.0
Mode	20.0	32.5	0.00	3
	White crappie (N = 555)			
Mean (SD)	11.6 (5.42)	35.1 (2.43)	0.01 (0.03)	4.2 (2.25)
Range	0.9-32.0	32.0-48.0	0.00-0.33	0.5-20.0
Mode	11.3	34.0	0.00	2
	Largemouth bass (N = 56)			
Mean (SD)	14.1 (2.97)	33.3 (1.63)	0.02 (0.02)	6.8 (2.81)
Range	8.8-20.0	32.0-48.0	0.00-0.10	2.8-12.1
Mode	12.9	32.5	0.00	10

Table 9. Original capture site and overwintering areas for bluegill, black crappie, and white crappie that were released at a site different than the original capture site in lower Pool 11, Upper Mississippi River after tagging during winters 2004-2008. Censored fish are those fish not found after release.

	Original			Overwintering Site		
Year	Capture Site	Release Site	N	Mud Lake	Sunfish Lake	Censored
2004-2005	Mud Lake	Outside Mud Lake	3	3	0	0
2006-2007	Flatrock Lake	Sunfish Lake	4	0	3	1
2006-2007	Mud Lake	Sunfish Lake	2	0	1	1
2007-2008	Flatrock Lake	Sunfish Lake	3	0	2	1
2007-2008	Mud Lake	Sunfish Lake	6	2	1	3
2008-2009	Mud Lake	Sunfish Lake	7	1	2	4
2008-2009	Flatrock Lake	Sunfish Lake	2	0	1	1
2008-2009	Sunfish Lake	Mud Lake	2	1	0	1
		Total	**29**	**7**	**10**	**12**

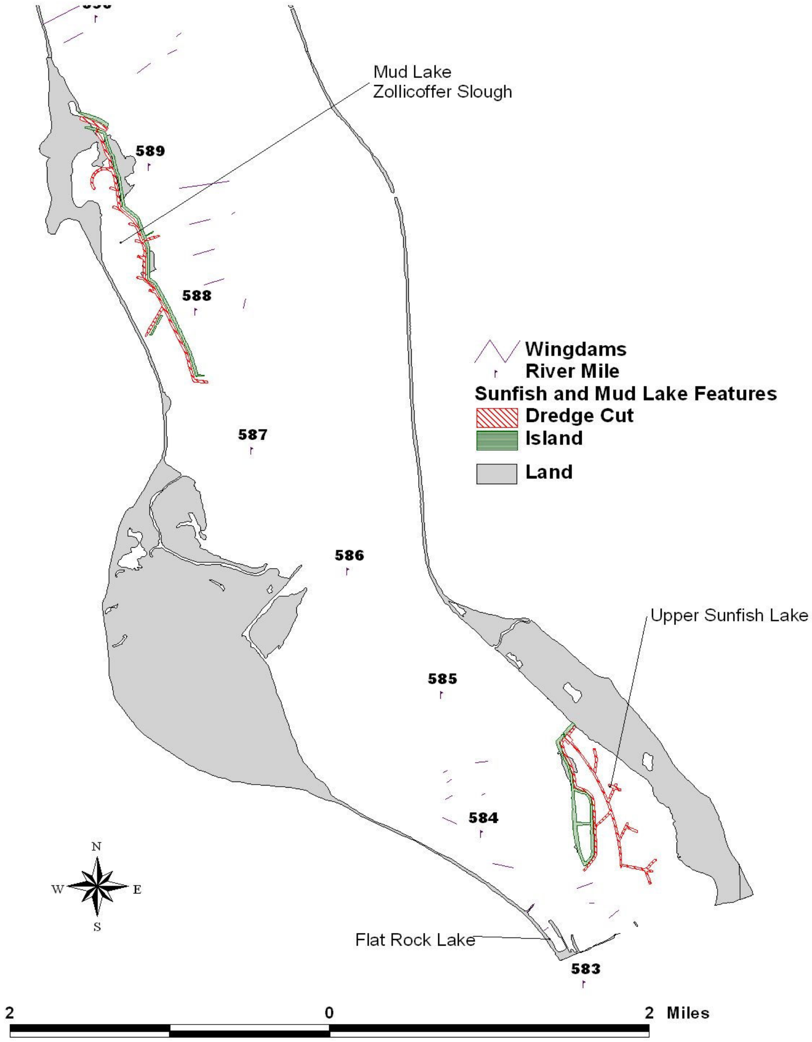

Figure 11. Map of lower Pool 9, Mississippi River.

The Sunfish Lake HREP project (Figure 11) was completed in November 2004. No adult bluegill and crappie large enough to radio tag were collected from 2004-2007. During 2008, three bluegill, one black crappie and seven white crappie large enough to radio tag were captured in Sunfish Lake. In an attempt to determine if habitat in Sunfish Lake was suitable for bluegill and crappie in 2006-2008, several fish were captured from the Flat Rock and Mud Lake areas, radio-tagged and released in Sunfish Lake. In 2006, one of two white crappie released into Sunfish Lake remained there throughout the winter until ice out. In 2007, two bluegill captured in Flat Rock Lake and released in Sunfish Lake wintered in Sunfish Lake, one black crappie captured in Mud Lake and released in Sunfish Lake, wintered in Sunfish Lake and two black crappie captured in Mud Lake and released in Sunfish Lake moved back to Mud Lake. In 2008, one bluegill captured in Mud Lake and released in Sunfish Lake moved back to Mud Lak e, two white crappie captured in Mud Lake and released in Sunfish Lake wintered in Sunfish Lake and one white crappie captured in Flat Rock Lake and released in Sunfish Lake wintered in Sunfish Lake. One white crappie captured in Sunfish Lake and released in Mud Lake wintered in Mud Lake (Table 9).

Discussion

In first year of the study, considerable time was spent trying to capture bluegill large enough to carry the Model 357 transmitters. As a result, several radio-tagged fish were marginal in size and this small size may have contributed to the higher than anticipated mortality. During all subsequent years, bluegills were tagged with smaller transmitters (Model F1540) and, as a result, survival improved. The transmitters harnessed to bluegill averaged 94 days of operation. This period was sufficient to identify critical habitats and met the 78-day guaranteed life of the transmitter.

In 1998 and 1999, high mortality was observed for all species tagged internally when water temperatures were in the mid-70°F. High infection rates were likely the cause of high mortality. Use of surgical staples, as recommended by Swanberg et al. (1999), did not improve survival. Fish were radio tagged in early fall at higher water temperatures (≥ 60°F) because Pitlo (1992) reported largemouth bass radio tagged in October at temperatures ≤ 60°F experienced high mortality. Pitlo (1992) suggested that water temperatures were too cold to promote adequate healing of incisions and that this may have led to high mortality from infection.

High mortality of radio tagged panfish species may not be unusual. Petering and Johnson (1991) reported losing half of their radio-tagged white crappie to postoperative mortality. Knights et al. (1995) reported mortality of 63% for internally radio-tagged black crappie and these fish lived an average of 61 days after surgery. In contrast, Guy et al. (1994) successfully tracked 34 out of 37 white crappie using ultrasonic transmitters. However, the short battery life of their transmitters (40 and 47 days) could have resulted in an underestimate of true postoperative mortality.

During 1999, two black crappie and 5 white crappie that were implanted internally at colder water temperatures were successfully tracked during a 4-5 month period. This tracking period was considerably longer than many of the previously cited studies.

Survival rates were greater for bluegill and crappie that received internally implanted transmitters at low water temperatures than those at high water temperatures (Table 2). This agrees with Knights and Lasee (1996) who held bluegill with surgically implanted transmitters at two water temperatures, 42.8 and 68°F. They found little healing of incisions in fish held at lower temperatures; however, survival was higher due to lower rates of infections. They suggested that radio-telemetry with internal transmitters might provide a more accurate assessment of habitat use during cold water periods than warm water periods because fish held at lower temperatures had lower mortality, lower tag loss and less severe tissue response that might influence behavior. This also suggests that as water temperatures increase in spring, infections and mortality of radio tagged fish may increase because of infections.

External radio transmitter attachment was successful during the latter years of this study. These attachment methods were less invasive and fish survival with externally attached transmitters was high (100% after 1 week, 85% after four months). During early project segments, external tagging was completed in water temperatures of 50-62°F and fish survival was excellent (Pitlo 2002; 2003). During latter project segments, fish were externally tagged at water temperatures that ranged from 60-74°F. Nearly 85% of the fish survived four months following this surgery, while less than 50% of the tagged fish survived similar trauma during the two previous study segments. The decrease in fish survival to 50% during those two project segments may have been due to increased angler harvest as indicated by angler auger holes and missing fish or predation by otters as indicated by recovery of the transmitter with chewed up antennas.

Fish with internal implants had minimal healing and most fish had fungal infections covering the incision. Lack of healing was probably due to radio tagging during periods of cold water (Oct. 30, 1991 through Feb. 12, 1992). Pitlo (1986) reported poor healing of incisions in largemouth bass that were implanted with transmitters during late fall. In contrast, he reported much better results for fish handled and tagged prior to October.

Successful internal tagging can be accomplished at low (<55°F) water temperatures. However, by the time the water temperature declines to this range, many fish have moved into or close to winter habitat. To completely document movement to winter habitat, fish must be tagged at higher water temperatures, in a variety of summer habitats.

Anglers returned several transmitters and several were found on land or at the edge of the water during the various study segments. During some winters several fish tagged in September were tracked into December and January, and then fish simply disappeared. These fish may have been harvested by anglers and radio transmitters were not returned to us. On several occasions, anglers had radio-tagged fish in live wells or fish baskets and were not aware that the fish was radio-tagged. These anglers readily released their fish when informed of the study. Also, anglers that were aware of the study reported catching and releasing at least 3 of the radio tagged fish. Fish were radio tagged and released in Flat Rock Lake and Mud Lake in September 2004. As of mid February 2005, all radio tagged fish were still at Flat Rock Lake (where there was little ice fishing) and no tagged fish remained in Mud Lake (a heavily used ice fishing location). These observations suggest that anglers may have harvested radio tagged fish that disappeared from Mud Lake. Prior to tagging in September 2005 signs were placed at all access points and bait shops in the project area to reduce loss of fish due to angler harvest. Signs anglers about the tagging project and requested that they release radio tagged fish so researchers could continue collecting location and habitat information. Signs have increased angler awareness of the project and have increased number of days that radio-tagged fish were tracked.

We are unaware of any studies that address wintertime predation of sunfish by muskrat, mink or otter. During 2005, 5 radio transmitters were found on land or at the edge of the water with chew marks on the transmitters and antennas, and fresh otter tracks and slides in the vicinity. Radio transmitters were also recovered from muskrat houses. Tracks in the snow around muskrat houses containing radio transmitters indicated both mink and otter activity in the immediate area. It is unknown if radio-tagged fish were alive or dead when carried into the muskrat house.

Largemouth bass were added to the project to provide more comprehensive information concerning location and characteristics of winter habitat for Centrarchid species. Telemetry and water quality information suggested that largemouth bass behave similar to white and black crappie and bluegill in this study area with two exceptions. Largemouth bass tolerated lower mean water temperatures and were located in deeper mean depths than the other species (Table 8).

Radio-tagged fish did not use the upper portion of the Mud Lake area during 2005. Lack of use of this area by tagged fish was likely attributable to higher flows (mean = 0.08 ft/sec) found in this area during 2004 and 2005 (other years mean = 0.01 ft/sec). Water velocities collected suggested velocities were not ideal in this area so Iowa DNR and the Rock Island District COE cooperated to decrease flows into and through the area by partially filling the two openings into the Mud Lake project area with rock. Monitoring of fish movements and locations during 2006, 2007, and 2008 indicated that flows were sufficiently reduced during those years to improve fish use in the upper portion of Mud Lake including dredged canals (Figure 12).

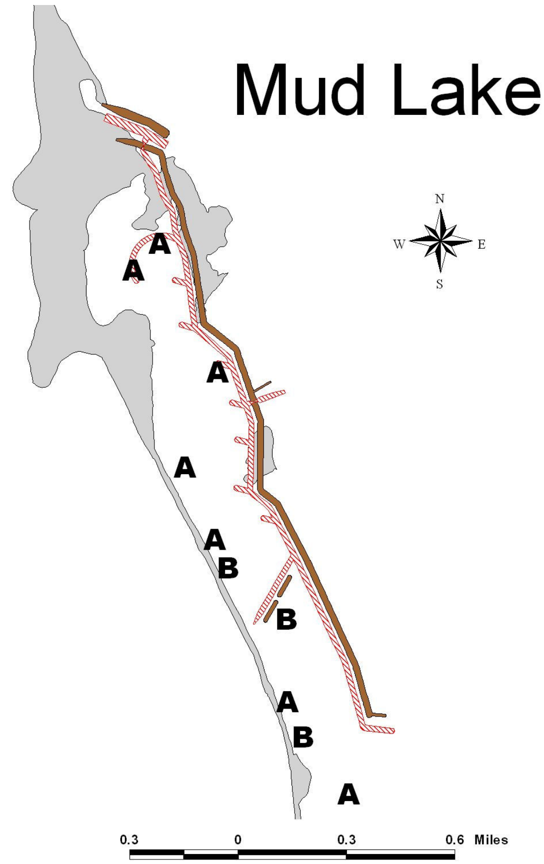

Figure 12. General locations of bluegill, black crappie and white crappie before (B) and after (A) reducing flows through Mud Lake, lower Pool 11, Upper Mississippi River.

Adult bluegill and crappie were uncommon in Sunfish Lake prior to completion of the habitat restoration project (Iowa DNR unpublished data). The area was devoid of suitable habitat prior to this project. After completion of the barrier islands, wind fetch and water velocity were reduced and vegetation growth filled in most areas except dredge cuts. Many small bluegill and crappie were captured but very few adults could be found as opposed to the Mud Lake area which had an existing adult population of bluegill and crappie prior to project construction. Lack of adult fish for several years after project completion in Sunfish Lake has been seen in other habitat projects. Bertom/McCartney Lakes and Pool 8 Islands Phase 2 took four to eight years before small bluegill and crappie grew to adult size and established a population in these project areas (Jeff Janvrin, WI DNR personal communication). Electrofishing in Sunfish Lake portion of the project area yielded no adult bluegill or crappie large enough to attach radio-transmitters until 2008 (4 years post construction) when 11 adult fish (3 bluegill, 1 black crappie and 7 white crappie) were captured and radio tagged, indicating that an adult population was developing. Monitoring Sunfish Lake will determine if fish colonization in this area is similar to other habitat projects.

Movement of 98% of the fish (not already in backwater lake habitat) in early fall was from main channel border, side channel and backwater lake habitat to winter habitat provided by specific areas of backwater lakes. Habitat in these backwater lakes over wintering areas lacked water currents and also contained warmer water. Radio-tagged fish moved from main channel border tagging sites to backwater lakes as winter progressed and were almost always located in backwater lakes after ice over. Centrarchid backwater winter habitat was characterized as having higher water temperatures of 2-5°F warmer and little to no current when compared to main channel border, side channel habitats or open water locations. Knights et al. (1995) reported bluegill and black crappie avoided habitats where temperatures were low (≤33.8°F) and current velocity exceeded 0.03 ft/s. Largemouth bass from our study were located in areas with lower mean water temperatures (33.3°F versus 35.4, 35.1 and 35.1°F for bluegill, black crappie and white crappie) and located in deeper mean depths (6.8 ft versus 3.7, 4.4 and 4.2 ft for bluegill, black crappie and white crappie). Fish wintered in areas that ranged from 0.5 to 453 acres suggesting that wintering areas do not need to be large in extent. On average, bluegill, black crappie, and white crappie moved 1.23, 1.50, and 0.90 miles between summer and winter habitats. These distances were measured on a straight line; however, swimming distance would be greater due to sinuosity of river channels. Although some individual fish moved greater distances, most panfish (91.7%) moved less than 3.5 miles (mean = 1.16 mi), 85% moved 2 miles or less and 50% moved ≤ 0.80 miles between summer and winter habitat suggesting that habitat restoration projects be spaced less than 3 miles apart because most fish move less than 1.5 miles in one direction to reach winter habitat.

Aerial photographs of lower Pool 11 (RM 583-589.4) show few backwater lakes, cutoff side channels and sloughs that would offer winter habitat (warmer water, suitable dissolved oxygen levels and no current) for fish to survive the winter. Carlson (1992) reported that nearly 60% of largemouth bass in the Hudson River Estuary used five known winter refugia. These refugia offered shelter from tidal currents a time when metabolic rates were slowed.

Habitat in lower Pool 11 changed during June 2005 when the first segment of the HREP project was completed (Upper Sunfish Lake). The second segment (Mud Lake) was completed in fall 2006. This new habitat is expected to help restore some critical backwater lake habitat that filled in with sediment and lost protection from current. Aerial photographs that show many backwaters, cutoff side channels or sloughs have given the false impression of adequate winter habitat for bluegill, white and black crappie. It is important for managers to use extreme caution when interpreting GIS aquatic habitat overlays and other aerial habitat maps without the important supportive bathymetry, water quality data and validation through late fall sampling of fish communities when water temperatures are < 50°F.

Loss and change in aquatic habitat, including change in water quality and siltation of backwater areas will continue to occur through time on the UMR due to constraints that facilitate navigation and agriculture in this system. Habitat construction and restoration is costly and time consuming, yet is needed to maintain and improve backwater habitat on large rivers. Results of this study provide resource managers with information needed to efficiently and effectively construct backwater habitat suitable for bluegill, black crappie and white crappie.

Recommendations

1. Radio tagging should begin in mid-late August, but transmitters should be restricted in warm water temperatures to external attachment. Some investigators recommend internal tags be used at water temperatures less than 55°F but, because of good survival, the ability to tag fish at any water temperature and the ease of attachment, we recommend transmitters be attached externally. Mortality of fish due to transmitter attachment was reduced to zero by changing attachment techniques from internal surgical implants to external attachment on dorsal spines.

2. Bluegill, black crappie and white crappie as large as possible should be tagged to accommodate transmitters with sufficient battery life.

3. Signs should be posted informing anglers that radio-tagged fish are in the area and request release of these fish. This will help increase the amount of time fish can be tracked.

4. Radio tagged bluegill, black crappie, white crappie and largemouth bass (98%) move from main channel and side channel habitat to backwater habitat as ice cover increased and water temps declined below 50°F. Studies aimed at evaluating winter habitat of Centrarchids should occur at temperatures ≤50°F.

5. Winter habitat can be defined as backwater areas as small as ½ acre in size, water temperatures 2-5°F (mean = 35.1°F) greater than main channel or side channel habitat (mean = 32.9°F) and little or no water velocity (mean ≤0.03 feet/sec). The only time fish were found in areas with lower temperatures and higher flows was during periods of hypoxia in backwaters when fish moved in to less suitable habitat. When constructing panfish habitat, these conditions should be provided to ensure winter use by bluegill, black crappie and white crappie.

6. Habitat restoration projects should be spaced no more than 3 miles apart since on average, bluegill, black crappie, and white crappie moved 1.23, 1.50, and 0.90 river miles between summer and winter habitats and most panfish (91.7%) moved less than 3.5 river miles, 85% moved 2 river miles or less, 75% moved 1.4 river miles or less and 50% moved 0.80 river miles or less between summer and winter habitats.

7. Continue to evaluate flows in Mud and Sunfish Lakes and manage for flows suitable for bluegill and crappie to use all portions of these areas.

Acknowledgements

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