

Evaluation of the status, distribution and habitats of Northern Pike in the Upper Mississippi River

Study 7038 Completion Report
Federal Aid to Fish Restoration

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Period Covered: 1 July 2010 – 30 June 2017
Iowa Department of Natural Resources
Chuck Gipp, Director

SPORT FISH RESTORATION

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MISSISSIPPI RIVER FISHERIES RESEARCH
COMPLETION REPORT

Study 7038:
Evaluation of the status, distribution and habitats of Northern Pike in the Upper Mississippi River

Approach 1: Literature search and review of previous northern pike papers
Approach 2: Evaluations of methods used to sample Northern Pike
Approach 3: Assess Upper Mississippi River Northern Pike populations
Approach 4: Evaluate seasonal movements and habitat selection of Northern Pike
Approach 5: Evaluation of the Northern Pike fishery in the Upper Mississippi River
Approach 6: Completion Report

Period Covered: July 1, 2010 - June 30, 2017

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CONSERVATION & RECREATION DIVISION
Iowa Department of Natural Resources
Chuck Gipp, Director

STUDY 7038

Evaluation of the status, distribution and habitats of Northern Pike in the Upper Mississippi River

OBJECTIVE

To develop, by 2017, recommendations for management of Northern Pike in the Upper Mississippi River.

Approach 1

Literature search and review of previous northern pike papers.

OBJECTIVE

Perform literature search and review on sampling techniques, age and growth methods and other pertinent information for Northern Pike populations in the Upper Mississippi River.

Approach 2

Evaluations of methods used to sample Northern Pike.

OBJECTIVE

Determine sampling methods that efficiently collect Northern Pike and provide an unbiased estimate of relative abundance and size- and age structure for Northern Pike populations in the Upper Mississippi River.

Approach 3

Assess Upper Mississippi River Northern Pike populations.

OBJECTIVE

Determine growth, mortality, size- and age-structure, fecundity, recruitment, relative weight, and relative abundance of Northern Pike in Pool 10 and 13 of the Upper Mississippi River.

Approach 4

Evaluate seasonal movements and habitat selection of Northern Pike.

OBJECTIVE

Identify seasonal patterns of movement and habitat use by Northern Pike in Pool 10 and 13 of the Upper Mississippi River.

Approach 5

Evaluation of the Northern Pike fishery in the Upper Mississippi River.

OBJECTIVE

Describe the Northern Pike fishery in Pool 11 and 13 of the Upper Mississippi River, and assess anglers' opinion about the northern pike populations.

Approach 6

Completion Report.

OBJECTIVE

To compile, analyze, and publish findings of this investigation.

Table of Contents

Executive Summary

Northern Pike provide an important recreational fishery for Upper Mississippi River (UMR) anglers. Despite their popularity with anglers, little recent (<30 years) information existed on Northern Pike populations in the UMR prior to this study. This study was initiated in 2010 to provide information needed to inform Northern Pike management on the UMR in Iowa by: 1) evaluating methods used to sample Northern Pike, 2) assess Northern Pike populations across several UMR pools, 3) evaluate seasonal movements and habitat selection of Northern Pike on the UMR, and 4) evaluate the UMR Northern Pike fishery and angler opinions. Major findings from this research were as follows:

- Spring standard fyke netting yielded the highest catch rates of gears evaluated and was the most efficient method for sampling northern pike populations in this study but undersampled Northern Pike < 400 mm. Electrofishing yielded the least size biased samples but sampling efficiency and catches were too low to allow population demographic assessments.

- Mean catch rates were much lower in the lower impounded navigation pools compared to upper impounded navigation pools sampled during this study. Mean catch rates of Northern Pike in fyke nets were significantly correlated to total acres of backwater habitat within the pool sampled. The Upper Mississippi River Restoration Program's Long Term Resource Monitoring element Northern Pike day EF CPUE and percent frequency of submersed aquatic vegetation showed significant parallel increasing trends over time in Pool 13.

- Maximum observed age for female Northern Pike was 10 years compared to 8 years for males. Female Northern Pike grew faster and achieved a greater size than males. Males constituted 77% of fish captured from 325-575 mm TL, while females comprised 97% of fish captured >700 mm TL. UMR Northern Pike were robust with mean female Wr in Pools 10, 11, and 13 of 112, 116, and 122 and male Wr of 104, 108, and 105, respectively. Annual mortality estimates ranged from 47-59%.

- Transmittered Northern Pike occupied backwater habitat extensively throughout the year and utilized overwintering backwater habitat in the same manner as Centrarchids (water temperature 2-5°F greater than main channel, little or no water velocity [≤0.03 ft/sec] with adequate dissolved oxygen). However, unlike Centrarchids, Northern Pike appeared to be much more tolerant of flow and could utilize side channels or other areas of flow where backwaters are degraded.

- Cold water inputs (e.g., springs, cold water tributary mouths) did not appear to be vital to Northern Pike survival during periods of warm water. Results from this study indicate these areas are most likely sinks due to high observed harvest rate (67%) of transmittered Northern Pike that moved to cold water areas in summer.

- A total of 523 angler interviews were conducted across three fisheries management districts along the UMR. Anglers reported catching Northern Pike from every UMR pool in Iowa. Proportion of anglers that catch Northern Pike by district decreased moving downstream with 77.4%, 75.9%, and 15.3% of anglers reporting having caught Northern Pike in the Guttenberg, Bellevue and Fairport districts, respectively. Proportions of anglers that harvest pike (42.3%, 25.5%, and 2.5%) and specifically targeted pike (27.4%, 17.9%, and 2.5%) followed a similar downstream decrease (Table 9). This mirrors changes in river habitat and decrease in Northern Pike populations that are observed along the Mississippi River in Iowa. Of anglers that reported specifically targeting Northern Pike, 27% stated they don't harvest them, indicating presence of a catch-and-release fishery.

Introduction

Northern Pike provide an important recreational fishery for Upper Mississippi River (UMR) anglers. Northern Pike consistently ranked 8th to 10th in harvest by anglers on Pools 11 and 13 of the UMR (Steuck et al. 2009). Angler expectations from the UMR fishery vary greatly because anglers target this species for a variety of reasons. Some anglers target Northern Pike due to their trophy potential, while others are more consumption orientated and target this species for their mild tasting flesh. For many anglers, Northern Pike are a non-target species that they appreciate for the uniqueness that they offer to their angling experience. In order to effectively manage this fishery for this diverse angling group, biologists need information on Northern Pike population dynamics, angler opinions, and habitat availability in the UMR.

Despite their popularity with anglers, little information existed on Northern Pike populations in the UMR prior to this study. Previous investigations of Northern Pike in the UMR (Gengerke 1977; Holland and Huston 1984) were over 30 years old and more recent information was needed. Hatchery operations provided some of these data (Gritters 2007); however these methods were known to have some biases (Pierce and Tomcko 2003). The Upper Mississippi River Restoration (UMRR) Program's Long Term Resource Monitoring (LTRM) element conducted extensive fisheries monitoring using multiple gears across habitat strata (i.e., main channel border, side channel, backwaters, etc.) in Pool 13 annual since 1993; however LTRM did not have an age and growth component and was focused on a single pool. New and updated information was needed on growth, mortality, size- and age-structure, fecundity, recruitment, relative weight, and relative abundance for UMR populations. Additionally, periodic assessments of the UMR Northern Pike populations were necessary to develop adequate management strategies and to provide baseline information to assess future changes in this fishery (e.g., habitat and water quality changes, increases in fishing pressure, fishing regulation changes).

Sampling methods for Northern Pike had not been evaluated in Iowa prior to this study and this information was needed for routine monitoring and periodic population assessments. Northern Pike are not efficiently collected by gear routinely used to sample UMR fisheries. Spring fyke netting is often an efficient method for collecting Northern Pike from other populations (Snow and Beard 1972; Priegel and Krohn 1975; Kempinger and Carline 1978; Mosindy et al. 1987: Laine 1989; Pierce and Tomcko 2003; Pierce 1997); however, this method can misrepresent size- and age-structure and be biased towards large, sexually mature fish (Pierce and Tomcko 2003). Many authors report lower population estimates for age 2 fish than age 3 fish, indicating that they were underestimating the number age 2 fish in the population. Multi-mesh experimental gill nets (Pierce and Tomcko 2003; Wolfert and Miller 1978; Pierce 1997), bottom trawls (Wolfert and Miller 1978), angling (Margenau 1987) and eletrofishing (Schoenebeck and Hansen 2005) have also been used to sample Northern Pike populations. While there have been several evaluations of sampling methods in lakes, effectiveness of these methods had not been evaluated on large river systems, such as the UMR, prior to this study.

Alterations to the landscape of the Midwest have forever changed habitat availability for Northern Pike populations in the UMR. Serious habitat degradation has occurred since the late 1800's due to changes in Iowa's landscape (Menzel 1981) and facilitation of commercial navigation and flood protection (Tweet 1975). Resource managers in Iowa are concerned about continued loss and degradation of riverine habitats. The UMR continues to realize sedimentation of the backwater habitats, loss of side channels, high nutrient loads, poor water quality and changes in flow and thermal inputs. The effects that these habitat changes have had on Northern Pike are relatively unknown. Hassler (1970) found that silt deposition of one mm per day substantially increased mortality of larval Northern Pike and erratic water temperature fluctuations after the spawn had the same effect. Additionally, Northern Pike cannot sustain extended periods with water temperatures above 25°C (Casselman 1978; Bevelhimer et al. 1985) but these conditions occur frequently during summers in the UMR. Prior to this study, biologists suspected that UMR Northern Pike sought out cool water inflows during these periods. Headrick and Carline (1993) found that Northern Pike in two southern

Ohio reservoirs moved to small, cool water areas where they could maintain their body temperature near 25°C. Headrick and Carline (1993) hypothesized that high water temperatures and low DO in the summer affected larvae viability, similar to Striped Bass in southern impoundments (Coutant 1987). By incorporating telemetry this study sought to quantify habitat and water quality factors that are needed to maintain healthy populations in the UMR.

Little data existed on home ranges or seasonal movements of Northern Pike in the UMR. Gelwicks (2000) documented long distance seasonal movements of Northern Pike, Walleye, Channel Catfish, and Smallmouth Bass on the Wapsipinicon River in Iowa. Gelwicks (2004) also documented long-distance, seasonal movements of Walleye, Channel Catfish and Smallmouth Bass in the Turkey River. Some of these fish moved between the Turkey River and Pool 11, Mississippi River to take advantage of overwintering habitat in the Mississippi River. Several radio-telemetry studies on Northern Pike in lacustrine environments have documented limited movement parallel to shore (Daina et al. 1977; Cook and Bergersen 1988; Margenau 1986). Home ranges were poorly defined and fish seemed to occupy one area for a period of time but they frequently moved to new areas. Most studies have documented Northern Pike using areas with abundant macrophytes and water depths ranging between 3-12 feet. Headrick and Carline (1993) looked at movements related to water temp and DO levels in two Ohio reservoirs. They found that Northern Pike were seeking out cooler water near drop offs and submerged stream beds in the summer as opposed to northern lakes where the fish stayed in near-shore vegetation year round. These studies also found that as the water temperatures approached 26° C the habitable zone for Northern Pike shrank. Very few studies have assessed movement in large rivers. Information on seasonal movement patterns of Northern Pike in the UMR was needed to identify home range, and identify seasonally important habitats that should be protected or enhanced. Additionally, the role that tributary streams played in the overall health of Northern Pike populations in the UMR was unknown and warranted further investigation. Iowa is near the southern edge of the range for this species (Pflieger 1997) where summer water temperatures may reach near lethal levels; consequently, cool and coldwater tributaries may provide critical summer habitat (Daina 1987).

Therefore, the objective of this study was to develop, by 2017, recommendations for management of Northern Pike in the Upper Mississippi River. To accomplish that, this study was conducted via five main approaches. The objectives of those approaches were to: 1) perform a literature search and review of sampling techniques, age and growth methods and other pertinent information for Northern Pike populations in the Upper Mississippi River; 2) determine sampling methods that efficiently collect Northern Pike and provide an unbiased estimate of relative abundance and size- and age structure for Northern Pike populations in the Upper Mississippi River; 3) determine growth, mortality, size- and age-structure, fecundity, recruitment, relative weight, and relative abundance of Northern Pike in Pool 10 and 13 of the Upper Mississippi River; 4) identify seasonal patterns of movement and habitat use by Northern Pike in Pool 10 and 13 of the Upper Mississippi River; and 5) describe the Northern Pike fishery in Pool 11 and 13 of the Upper Mississippi River, and assess anglers' opinion about Northern Pike populations.

Methods

Study Area: Northern Pike populations in Iowa's section of the Upper Mississppi River (UMR) were assessed for this study (Figure 1). The UMR is defined as the 854 river miles between St. Anthony Falls, MN and the mouth of the Ohio River. The northern portion, from St. Anthony Falls to Alton, IL, has been impounded by a series of 26 locks and dams and channelized with training structures to improve navigation. Northern Pike were sampled from Pools 10, 11, 13, 16, and 17, UMR for this study. Radio telemetry was conducted in Pools 10 and 13 and angler opinion surveys were conducted in Pools 9-19. Information from the US Army Corps of Engineers' Upper Mississippi River Restoration Program's Long Term Resource Monitoring Element collected from Pools 8 and 13 was also utilized.

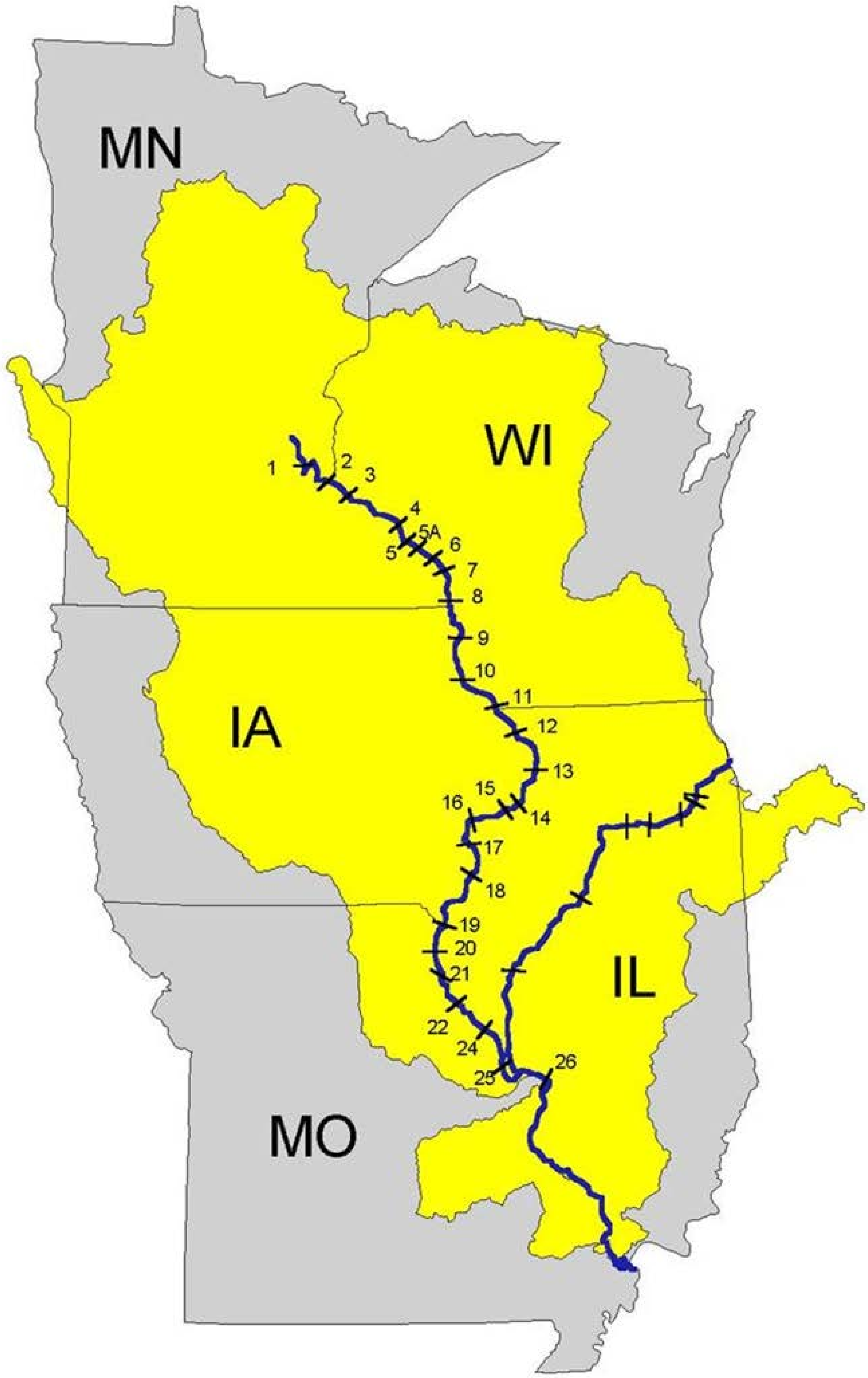

Figure 1. Map of the Upper Mississippi River basin. Numbers correspond to Lock and Dams enumerated by the U.S. Army Corps of Engineers. Pools are numbered by the dam forming the pool.

Approach 1: A thorough literature search and review of sampling techniques, age and growth methods and other pertinent information for Northern Pike populations in the Upper Mississippi River was performed during the first year of this study (FY2011). The information compiled from that process is included and cited throughout this report.

Approach 2: We evaluated efficacy, efficiency, and sampling bias among several sampling methods for Northern Pike on the UMR: spring and fall standard framed fyke netting; fall backwater shoreline day electrofishing; and summer electrofishing near the mouth of cool and coldwater streams and springs. Boat mounted pulsed-DC electrofishing was conducted along shorelines and vegetation beds in backwaters of Pool 10 in fall 2011. Time (seconds) was recorded for each run and catch per unit effort (CPUE) was reported in fish/hr. Electrofishing was also conducted at the mouths of cool and coldwater streams and in the vicinity of springs in Pools 9, 10, and 13. Sampling began immediately above the cold water input and continued downstream until water temperatures returned to ambient conditions, typically less than 100 yards. If tributaries were navigable, their lower reaches were also sampled.

Standard frame fyke nets (0.9 m by 1.8 m with 15 m long and 1.3 m high leads consisting of 19 mm mesh with two throats) were deployed in spring (March – early April) and fall (Sept. – early November) in backwaters of Pool 10 (2011 and 2012) and Pool 13 (2012). Nets were set in morning and fished approximately 24 hrs with CPUE reported as fish per 24-hr set. Net sites were not randomly selected and nets were set to maximize number of fish captured. When nets were lifted the following morning, Northern Pike were enumerated, sexed (spring only; male or female based on presence of gametes when pressure was applied near the vent or unknown if no gametes were visible), measured (total length [TL]; nearest mm) and weighed (nearest g). Nets that received wildlife damage (i.e., muskrats chew large holes in net) or were disturbed post-deployment were censored.

One-way analysis of variance (ANOVA) was used to determine differences in catch rates between spring and fall standard framed fyke netting and between fall backwater and summer coolwater electrofishing, as well as differences in mean capture length and efficiency among all gears ($\alpha = 0.05$). Efficiency was compared among gears by calculating mean number of fish captured per crew day for each gear. Overnight sets for standard fyke nets were considered one day as deploying and retrieving this gear typically only took half of two days.

Additionally, pool-wide electrofishing and standard framed fyke netting data from the Upper Mississippi River Restorations (UMRR) Program's Long Term Resources Monitoring (LTRM) element from 1993-2016 in Pool 13 was evaluated to assess population trends and size bias between standard fyke nets and electrofishing. The LTRM conducts stratified random sampling in three six-week periods from 15 June – 31 October. Standard framed fyke nets used by LTRM are identical to those used in this study and CPUE is reported as fish per 24-hr set. Standard LTRM electrofishing samples are 15-min pulsed DC shoreline runs.

Approach 3: Northern Pike abundance was assessed in the UMR by sampling Pools 10, 11, 13, 16, and 17 each spring during 2011-2015 with standard framed fyke nets (0.9 m by 1.8 m with 15 m long and 1.3 m high leads consisting of 19 mm mesh). Nets were set in morning and fished approximately 24 hours. When nets were lifted the following morning, Northern Pike were enumerated, sexed (male or female based on presence of gametes when pressure was applied near the vent or unknown if no gametes were visible), measured (total length [TL]; nearest mm) and weighed (nearest g). Relative Weight (Wr) was computed as described by Wege and Anderson (1978) using standard weight (Ws) values reported by Murphy et al. (1991; a = -3.727 and b = 3.059). Northern Pike greater than or equal to 254 mm were tagged with an individually numbered Floy tag (FD-94) inserted below the dorsal fin through the proximal pterygiophores. The anterior portion of the anal fin was cut as a secondary mark to measure tag loss. Recapture information was to be used to determine movements and growth rates. However, insufficient recaptures were collected to conduct planned population estimates. Additionally, most recaptures were from the same gear used to mark fish (spring standard fyke) which has been shown to severely underestimate population size (Pierce 1997).

Anal fin rays were removed from 10 fish per 25-mm length group from Pools 10 and 13 in 2012-2013 and read for age estimation. When possible, age structures were collected equally from both sexes. Anal fin rays were used for age estimation due to concerns about sacrificing large numbers of fish and they have been found to provide as reliable and precise age estimates as otoliths or cleithra (Babaluk and Craig 1990; Oele et al. 2015). Scales were not collected as they have been found to have low precision and high reader bias (Oele et al. 2015; Blackwell et al. 2016). Ages were assigned to unaged fish using age-length keys constructed using methods detailed by Isermann and Knight (2005). Weighted catch-curves were used to estimate annual mortality for both sexes in each pool. Pooled mean lengths at age (both pools, both years) were used to calculate a Von Bertalanfy growth function.

Fecundity was estimated from 56 gravid female Northern Pike collected from Pool 13 in April 2013, immediately prior to the spawn. Any females captured that extruded eggs when pressure was applied to the abdomen were released. All female Northern Pike retained were euthanized and transported to the laboratory where their whole ovaries were removed and individually weighed (nearest 0.01 gram) before being preserved in 70% ethanol. Egg counts from three subsamples (front, middle, and back) of preserved ovaries were weighed and enumerated. Total number of eggs per ovary was calculated by multiplying total preserved ovary weight by the average number of eggs per subsample (# egg/g) with total fecundity being the sum of both ovaries. Scales, anal fin rays, otoliths and cleithras were collected from fish that were sacrificed for fecundity data to evaluate the precision of each aging structure. However, because our sample size (N = 56) was small relative to other comprehensive assessments that were published during this study (Faust et al. 2013; Oele et al. 2015; Blackwell et al. 2016), this portion of the study was no longer necessary and therefore discontinued.

Approach 4: From September 2011 through January 2015, seasonal movements and habitat use of adult Northern Pike were monitored with radio telemetry in Pools 10 and 13 of the UMR. Northern Pike for radio tag implantation were collected with a combination of standard fyke nets and boat mounted pulsed-DC electrofishing. In October 2011, twenty Northern Pike (Table 1) were collected from Norwegian and Methodist lakes of the Sny Magill Bottoms complex in Pool 10 (Figure 2). One of these fish died shortly after release so an additional Northern Pike was collected from the same area in November 2011 for tag re-implantation. After the first year of telemetry, 8 recovered radio transmitters were re-implanted in Northern Pike in the Sny Magill complex in October 2012. In September and October 2012, an additional forty Northern Pike were surgically implanted with radio transmitters into an alternate site in Pool 10 and two new sites in Pool 13. In Pool 10, ten fish were implanted in Bussey Lake north of Guttenberg, Iowa. In Pool 13, twenty Northern Pike were radio transmittered in Crooked Slough near Bellevue, Iowa and ten in lower Pool 13 in the Sabula Lake/Hubbell Slough complex near Sabula, Iowa (Figure 3).

Table 1. Date, location, number, mean and range TL and weight of Northern Pike radio transmittered at various locations in Pools 10 and 13, Upper Mississippi River 2011-2012.

Implantation	Location	Number	Mean TL (mm)	TL Range (mm)	Mean Weight (g)	Weight Range (g)
October 2011	Sny Magill Bottoms, Pool 10	20	716	630-923	2,351	1,520-5,067
November 2011	Sny Magill Bottoms, Pool 10	1	662	-	1,792	-
October 2012	Sny Magill Bottoms, Pool 10	8	673	573-773	2,116	1,646-2,832
Sept/Oct 2012	Bussey Lake, Pool 10	10	628	593-890	2,168	1,242-5,992
Sept/Oct 2012	Crooked Slough, Pool 13	20	703	612-873	2,240	1,506-4,448
Sept/Oct 2012	Sabula Lake/Hubbell Slough Pool 13	10	653	586-700	1,754	1,276-2,188

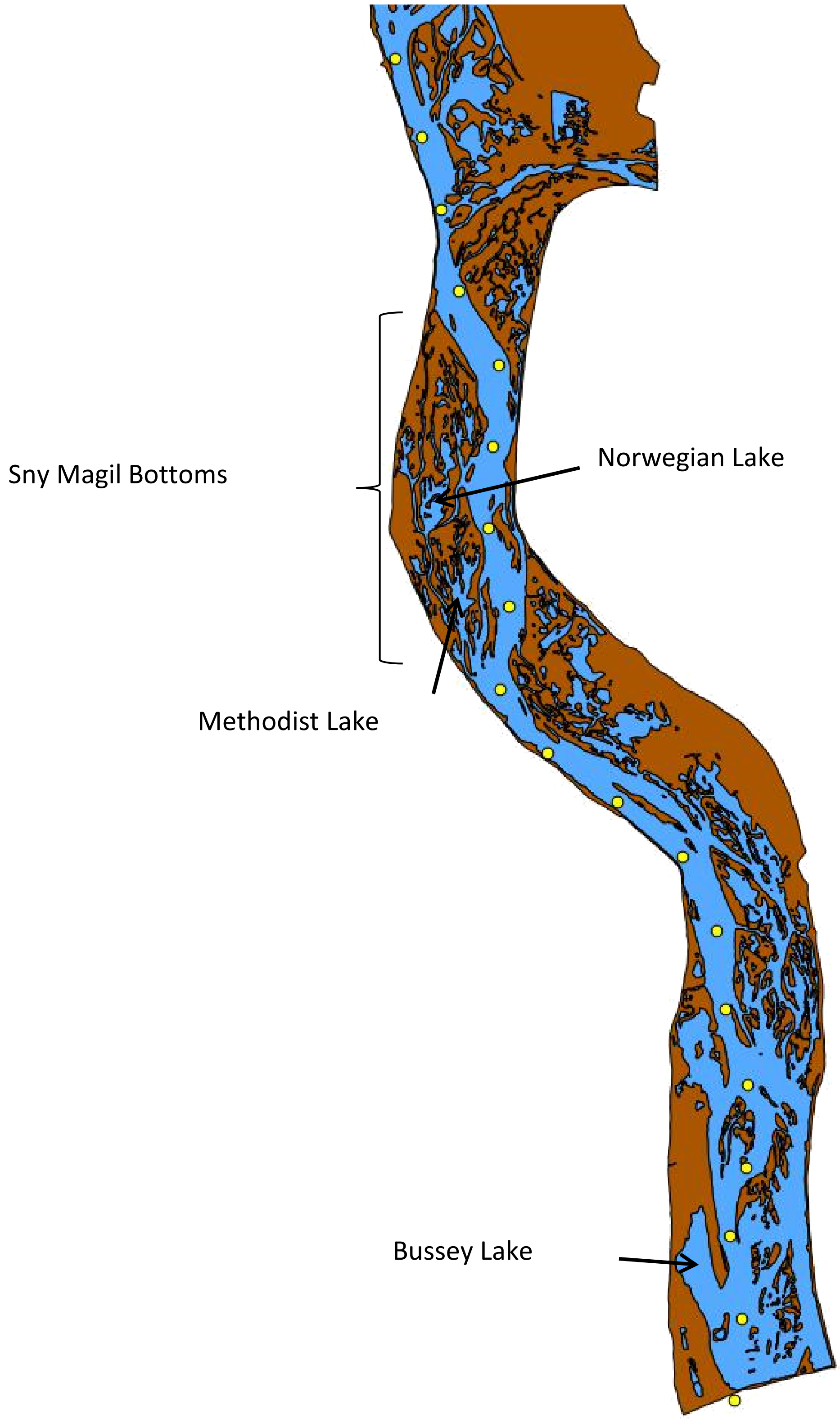

Figure 2. Norwegian and Methodist Lakes within the Sny Magil Bottoms complex and Bussey Lake in Lower Pool 10, Upper Mississippi River. Yellow dots denote main channel river miles.

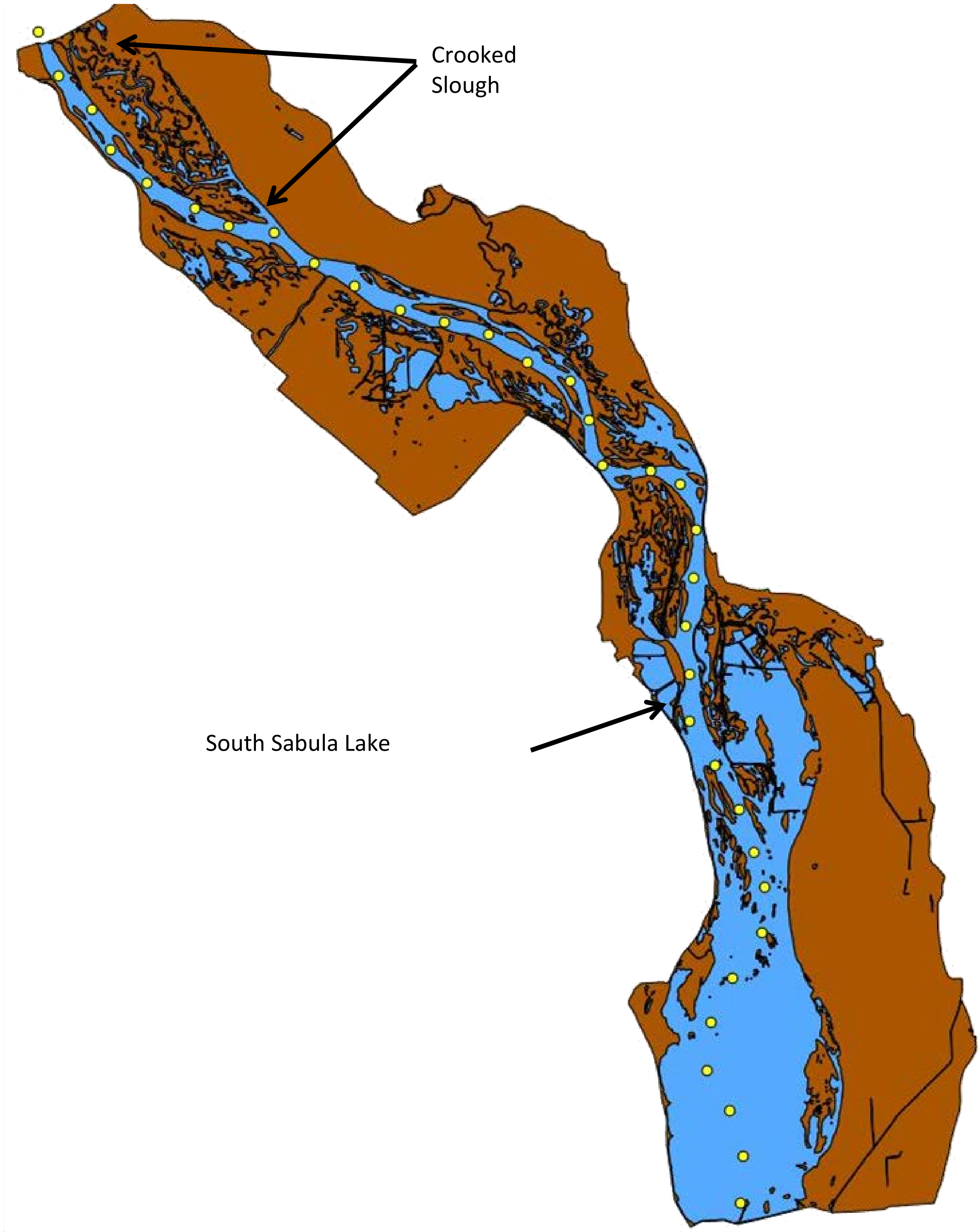

Figure 3. Crooked Slough and South Sabula Lake in Pool 13, Upper Mississippi River. Yellow dots denote main channel river miles.

Prior to surgery, fish were immobilized with pulsed direct current (PDC) electroanethesia because mandated post-treatment holding times for food fishes precluded the use of chemical anesthetics (Vandergoot et al. 2011). Radio transmitters (Model # F1850 Advanced Telemetry Systems, Isanti, MN) were surgically implanted into the body cavity similar to methods described for Walleye, Sauger, and Largemouth Bass by Pitlo (1984, 1989 and 1992). Fish were placed head-first into a capped 102 mm PVC pipe. The capped end of the pipe had holes drilled to allow water movement and was placed into a tub of water. With the exception of the last 203 mm of the capped end, one third of the pipe was cut away to allow surgical access. A mid-ventral incision was made anterior to the pelvic girdle and tags were inserted into the body cavity. The transmitter antenna was guided through the side of the body cavity wall with a needle. The incision was closed with three stiches using sterile vicryl. Radio transmitters were 70 mm in length, 17 mm in diameter, 25 grams in weight, and manufactured with a 12-hr duty cycle (i.e., active 8 am to 8 pm, inactive 8 pm to 8 am) with an expected battery life to 730 days. Transmitter weight was maintained at ≤2% of fish body weight (Ross and McCormich 1981). Transmitters had unique frequencies that allowed identification of individual fish. All radio tagged fish were also tagged with an individually numbered Floy tag (FD-94) inserted below the dorsal fin through the proximal pterygiophores for external identification. After surgery and tagging, fish were placed in a recovery tank and released near the point of capture once equilibrium and normal swimming activity returned (normally within 10 minutes) to minimize bias associated with holding fish long term post-surgery (Ovidio and Philippart 2003).

Radio tagged fish were relocated using an ATS Model R4000 receiver with a handheld or boat/hovercraft mounted yagi antenna. Searches began at the lake of tagging and expanded outward until all fish were located. If fish were missing, the search was expanded to the navigation pool. Two aerial searches with a plane were also conducted to attempt to locate missing fish; however none were located with this method. Handheld global positioning system units were used to record fish locations. Depth, water temperature, dissolved oxygen, current velocity, and habitat type (i.e., backwater lake, side channel, main channel border) were recorded at each fish location. Mean depth, water temperature, and current velocity were calculated within each habitat type in the open water and ice seasons. The ice season was defined as the time that backwater lakes were ice covered and varied annually based on river and weather conditions.

Approach 5: Creel surveys were conducted in Pools 11 and 13 as part of Study 7017, Approach 4 (Steuck 2008) from 1993 - 2010. Northern Pike ranked 10th in harvest during summers 2003-2010 in Pool 13 (Table 2). Mean annual summer harvest of Northern Pike in Pool 13 was 122 fish with a harvest rate of 0.005 f/hr (Table 3). The creel survey conducted in pools 10 and 13 from 1993 through 2010 did not effectively creel sufficient numbers of Northern Pike anglers to describe this fishery. We also suspect that Northern Pike anglers were not encountered in proportion to their use of these resources. Northern Pike anglers often fish in backwater lake complexes, mouths of coldwater streams, and through the ice during winter. These areas were not targeted during the Walleye creel as part of Study 7017, Approach 4. After reviewing these data, we determine that it would be cost prohibitive to conduct a targeted creel survey for Northern Pike. Instead we opted to focus Study 7038, Approach 5 on an angler opinion survey conducted at multiple access areas along the UMR.

Table 2. Composition and number of sport fish harvested from Pool 13, May-October (Summer), Upper Mississippi River. Mean does not include October 2004 data.

Species	Year								Mean
	2003	Oct-04	2005	2006	2007	2008	2009	2010	
Freshwater drum	9,474	57	4,725	3,706	3.055	5,207	7,720	3,131	4,852
Bluegill	1,467	218	2,541	4,044	2,112	979	613	501	1,751
Channel catfish	4,643	172	2,158	2,962	1,661	2,801	4,727	1,325	2,897
Sauger	3,187	2,219	1,080	3,025	711	1,305	1,510	703	1,646
Crappie sp.	4,507	391	704	909	495	552	668	82	1,131
Walleye	1,559	194	426	1,160	499	835	1,244	590	902
White bass	647	829	3,068	1,319	1,740	743	992	261	1,253
Bullhead sp.	347	0	0	0	2	0	0	0	50
Largemouth bass	145	0	68	252	102	277	304	92	177
Yellow perch	7	13	22	26	18	10	21	9	16
Northern pike	72	4	69	43	71	110	365	122	122
Carp	0	0	117	4	21	62	104	27	48
Flathead catfish	411	26	210	114	155	147	290	171	214
Smallmouth bass	20	2	0	4	20	55	51	18	24
Total	26,486	4,138	15,188	17,568	10,662	13,083	18,609	7,032	15,518

Table 3. Summary of angler catches and harvest of northern pike Pool 13, May-October (Summer), Upper Mississippi River. Mean does not include October 2004 data.

	Year								Mean
	2003	Oct-04	2005	2006	2007	2008	2009	2010	
No. caught	283	5	198	127	301	385	727	251	325
No. harvested	72	4	69	43	71	110	365	122	122
No. released	211	2	129	81	232	275	365	128	203
Catch rate (f/hr)	0.007	0.001	0.009	0.005	0.020	0.017	0.022	0.014	0.014
Harvest rate (f/hr)	0.002	0.001	0.003	0.002	0.005	0.005	0.011	0.007	0.005
Release rate (f/hr)	0.005	0.000	0.006	0.003	0.015	0.012	0.011	0.007	0.009

Angler opinion surveys were conducted from May-August 2012 and 2013 by Iowa DNR Aquatic Invasive Species Program watercraft inspectors (inspectors were paid using state funds and their time was not coded to the Fisheries Research grant). One watercraft inspector was stationed in each of three fisheries management districts along the UMR: Guttenberg (Pools 9-11), Bellevue (Pools 12-15), and Fairport (Pools 16-19). Watercraft inspectors roved throughout the district across multiple pools and access areas inspecting watercraft and educating the public on aquatic invasive species, law, and prevention techniques. Anglers encountered during these inspections were interviewed on-site for a Northern Pike angler opinion survey.

The angler opinion survey consisted of five questions. The first question was, “Do you catch Northern Pike while fishing the Mississippi?” If anglers responded “no” to this question the survey ended. If they responded “yes,” they were asked three additional questions: 1) From which Mississippi River pools do you catch Northern Pike; 2) Do you normally harvest Northern Pike; 3) Do you ever specifically target Northern Pike while fishing the Mississippi River? Anglers were also asked to rate their overall satisfaction with Northern Pike fishing on the Mississippi River on a scale of 1-5 with 1 = very dissatisfied, 2 = somewhat satisfied, 3 = neutral, 4 = somewhat satisfied, and 5 = very satisfied. Results were pooled by management district for analysis.

Results

Approach 2: Twenty-eight Northern Pike (Mean TL = 579 mm; Figure 4) were sampled during nineteen electrofishing runs conducted at ten sites near the mouths of cool or coldwater streams and springs in Pools 9, 10, and 13 during 2010 and 2012. CPUEs (11.7 fish/hr, SE = 6.4) were highly variable (range 0 – 100 fish/hr) and dominated by zero catches (N=14). Twenty Northern Pike were collected during nine fall backwater shoreline electrofishing surveys in Pool 10 during 2011. Mean CPUE (6.7 fish/hr; SE = 1.7) and TL (Mean = 535 mm; Figure 4) did not differ from summer electrofishing (ANOVA; df = 1; P ≥ 0.25) therefor fish from both seasons were pooled for gear selectivity comparisons. Northern Pike were commonly observed actively avoiding the electrical field and evading capture during both seasons.

One hundred seventy-three spring and 196 fall standard fyke net sets were deployed in Pools 10 and 13 in 2011 and 2012. Spring standard fyke net CPUE was significantly higher than fall standard fyke netting CPUE in each Pool and year (ANOVA; df = 1; p ≤ 0.0075; Table 4). Mean TL of Northern Pike captured in fall standard fyke nets (624 mm, SE = 7.5) was significantly larger than Mean TL from spring standard fyke netting (565 mm, SE = 4.0) and electrofishing (560 mm, SE = 18.9), which did not differ (ANOVA, df = 2, P ≤ 0.0001; Figure 5). Spring standard fyke netting (58 fish/crew day) was significantly more efficient than fall standard fyke netting, fall electrofishing, or summer electrofishing (8, 4, and 10 fish/crew day; Table 5), which did not differ (ANOVA; df = 3; P < 0.0001). Examination of the 23 year LTRM standard fyke net and electrofishing length frequencies indicates that fyke netting undersamples Northern Pike <400 mm (Figure 6).

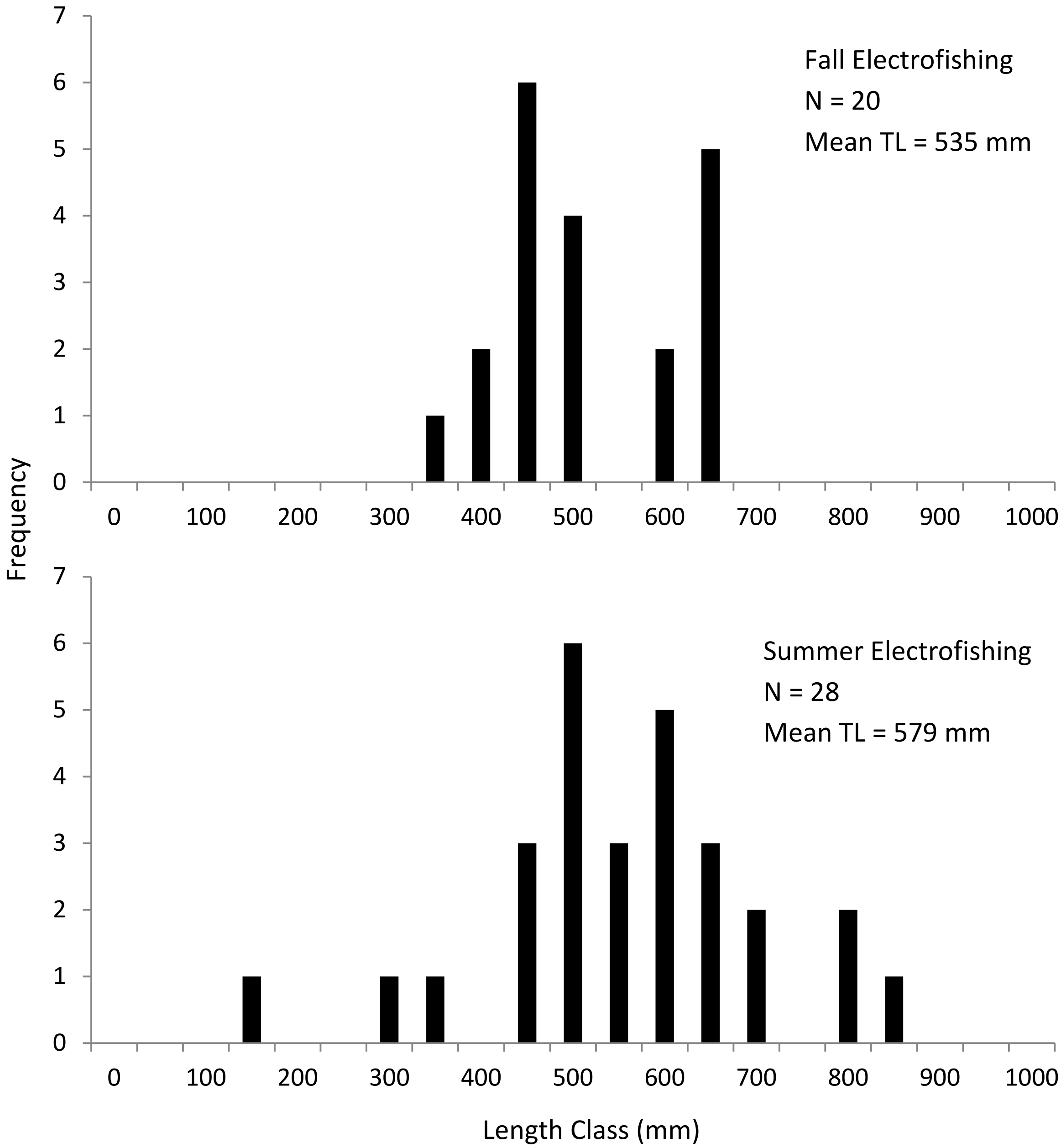

Figure 4. Northern Pike length frequency from summer and fall electrofishing in Pools 9, 10, and 13 UMR.

Table 4. Catch per unit effort of spring and fall standard fyke nets (24 hr set) of Northern Pike from Pools 10 and 13, Upper Mississippi River 2011-2012.

Pool	Year	Spring		Fall		P-value
		N	CPUE	N	CPUE	
10	2011	70	3.2	43	0.95	0.0075
10	2012	37	7.7	62	0.56	< 0.0001
13	2012	66	5.8	91	0.91	< 0.0001

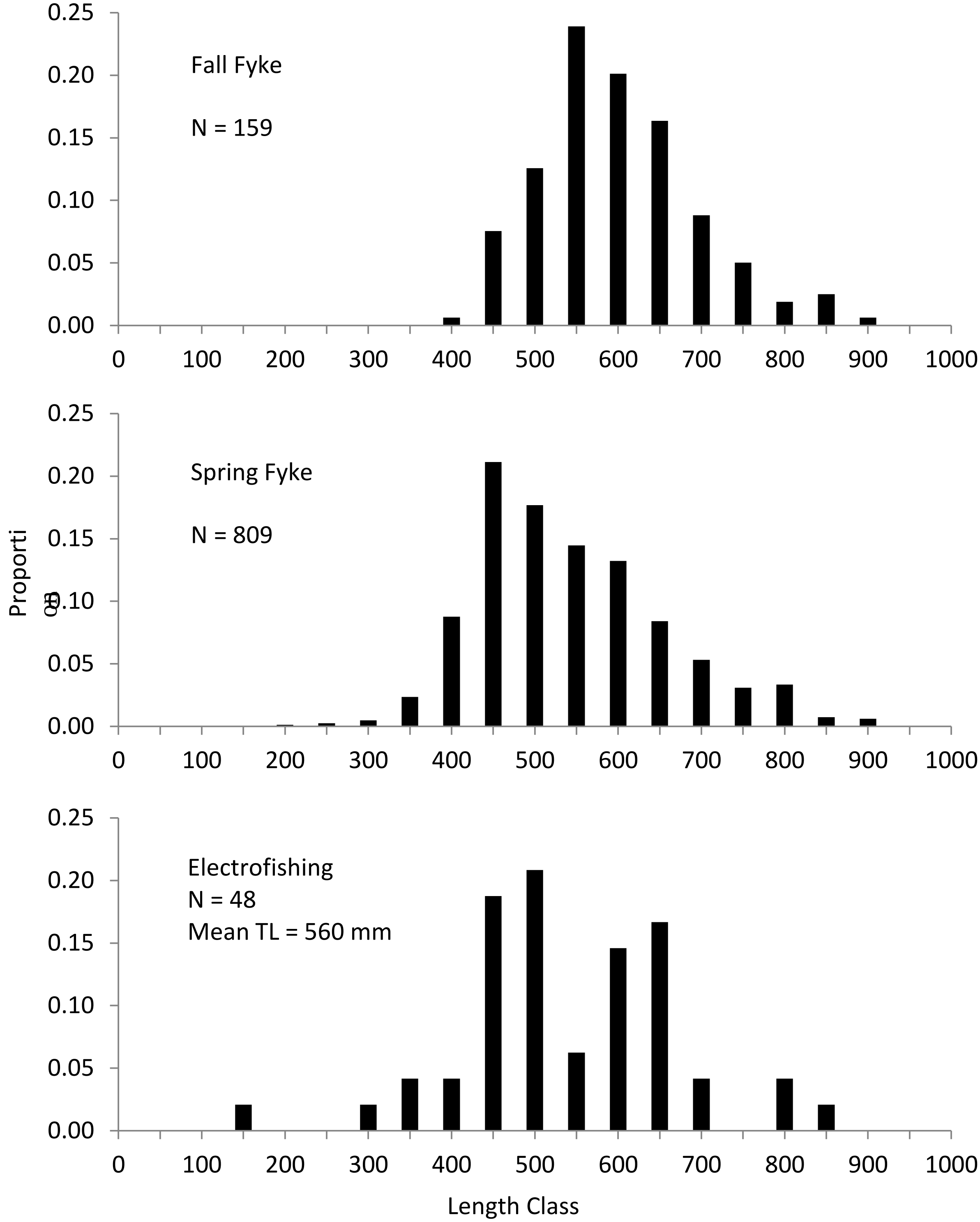

Figure 5. Northern Pike length frequency from spring fyke, fall fyke, and electrofishing in Pools 9, 10, and 13, UMR.

Table 5. Mean Northern Pike capture efficiency (fish/crew day) of spring standard fyke netting, fall standard fyke netting, summer electrofishing, and fall electofishing evaluated in Pools 9, 10, and 13, Upper Mississippi River 2010-2012.

Gear	Crew Days	# Fish	Mean (SE)	Min	Max
Spring Fyke	20	1167	58.4 (4.9)	13	98
Fall Fyke	21	159	7.6 (1.1)	1	17
Summer EF	8	28	3.5 (2.1)	0	17
Fall EF	2	20	10.0 (5)	5	15

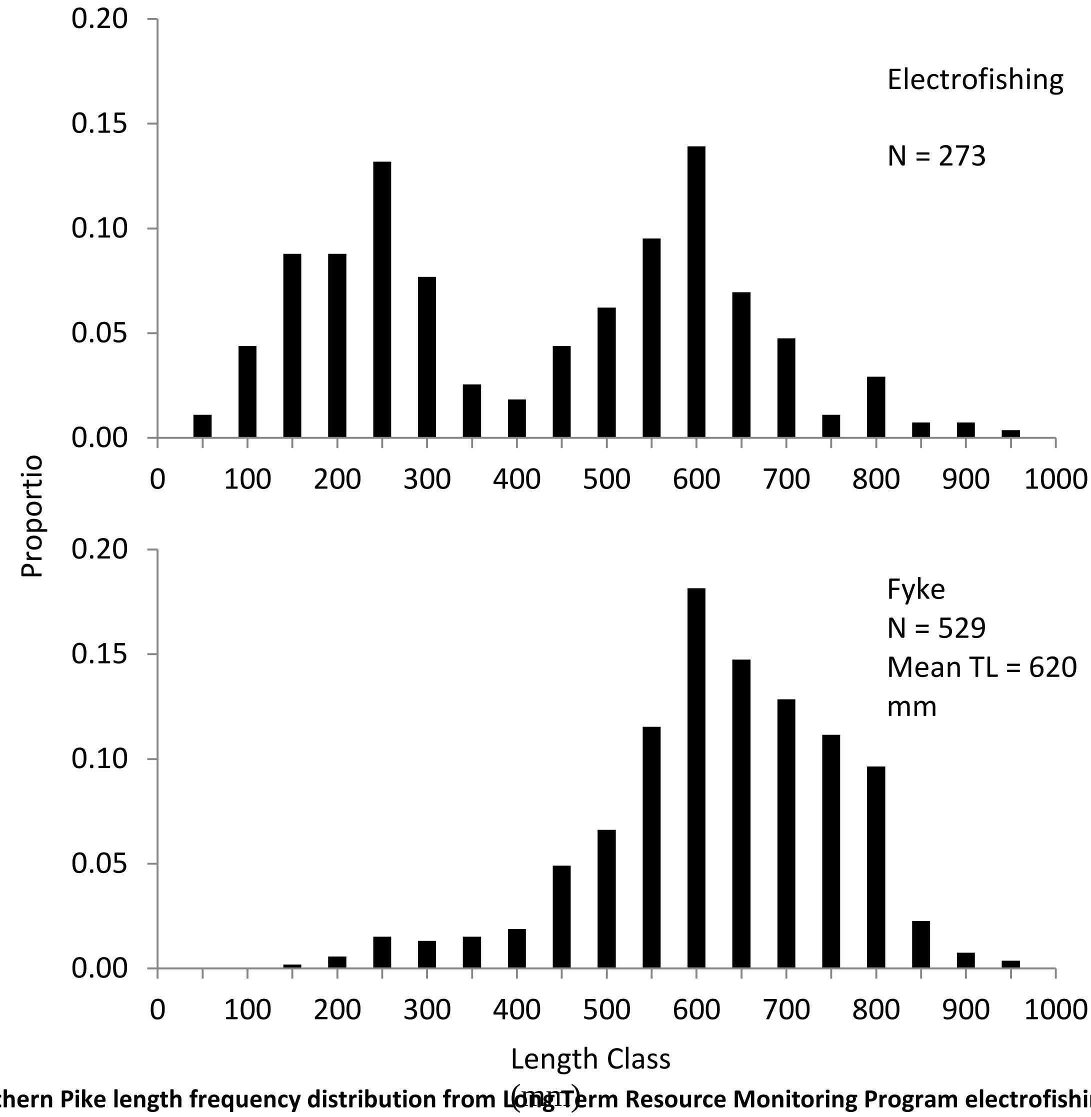

Figure 6. Northern Pike length frequency distribution from Long Term Resource Monitoring Program electrofishing and standard fyke net samples in Pool 13, Upper Mississippi River 1993-2016.

Approach 3: Northern Pike catch rates were higher in the three northern pools (Pools 10, 11, and 13) than in the two southern pools (Pool 16 and 17; Table 6). Northern Pike abundance was very low below Pool 13. Only eight Northern Pike were captured in Pool 16 while two were captured in Pool 17. Aquatic area classified as backwater habitat is much lower in Pools 16 and 17 (Figure 7; Theiling et al. 2000). Mean catch rate of Northern Pike in fyke nets was significantly related to total acres of backwater habitat within the pool sampled (r^2 = 0.92, p = 0.012; Figure 8. Total acres of aquatic vegetation (submersed, floating leaf, and emergent combined) was significantly correlated to total backwater acres (r^2 = 0.96, p < 0.001; Theiling et al. 2000). LTRM Northern Pike day EF CPUE and percent frequency of submersed aquatic vegetation showed significant increasing trends over time in Pool 13 (R^2 > 0.24; P < 0.015; Figure 9).

Table 6. Catch per unit effort of spring standard fyke nets (24 hr set) of Northern Pike from Pools 10, 11, 13, 16 and 17, Upper Mississippi River in years 2011-2015.

Pool	2011	2012	2013	2014	2015	MEAN
10	3.2	7.7	7.4	12.3		7.7
11	5.0					5.0
13		5.8	16.2			11.0
16					0.5	0.5
17				0.1		0.1

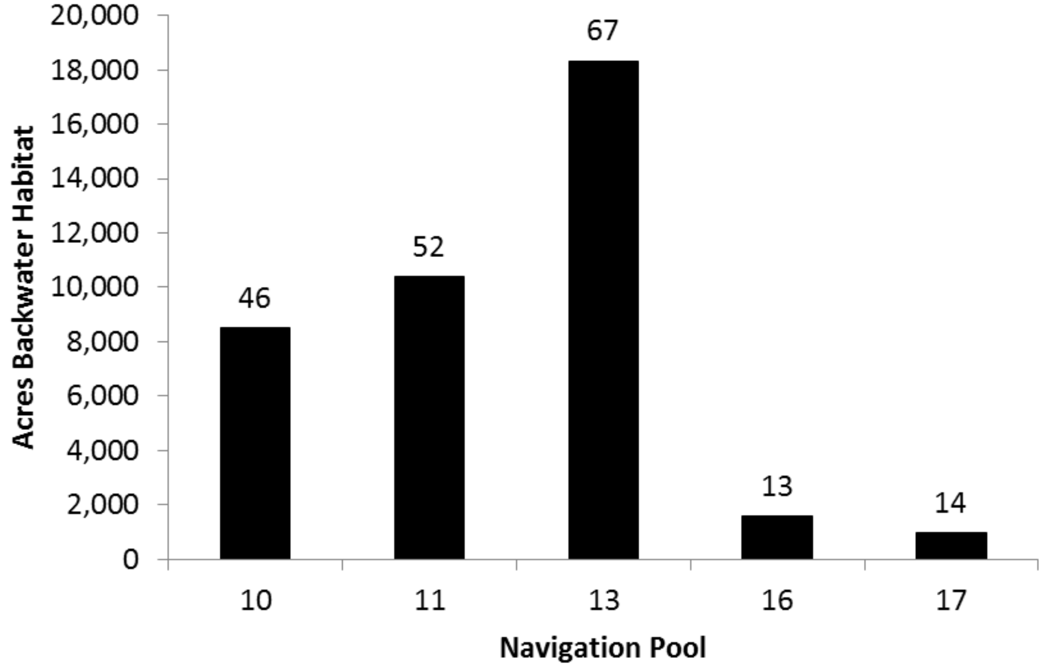

Figure 7. Acres of backwater habitat in Navigation Pools 10, 11, 13, 16, and 17 of the upper Mississippi River. Number above bars is percentage of total aquatic area within a pool classifies as backwater.

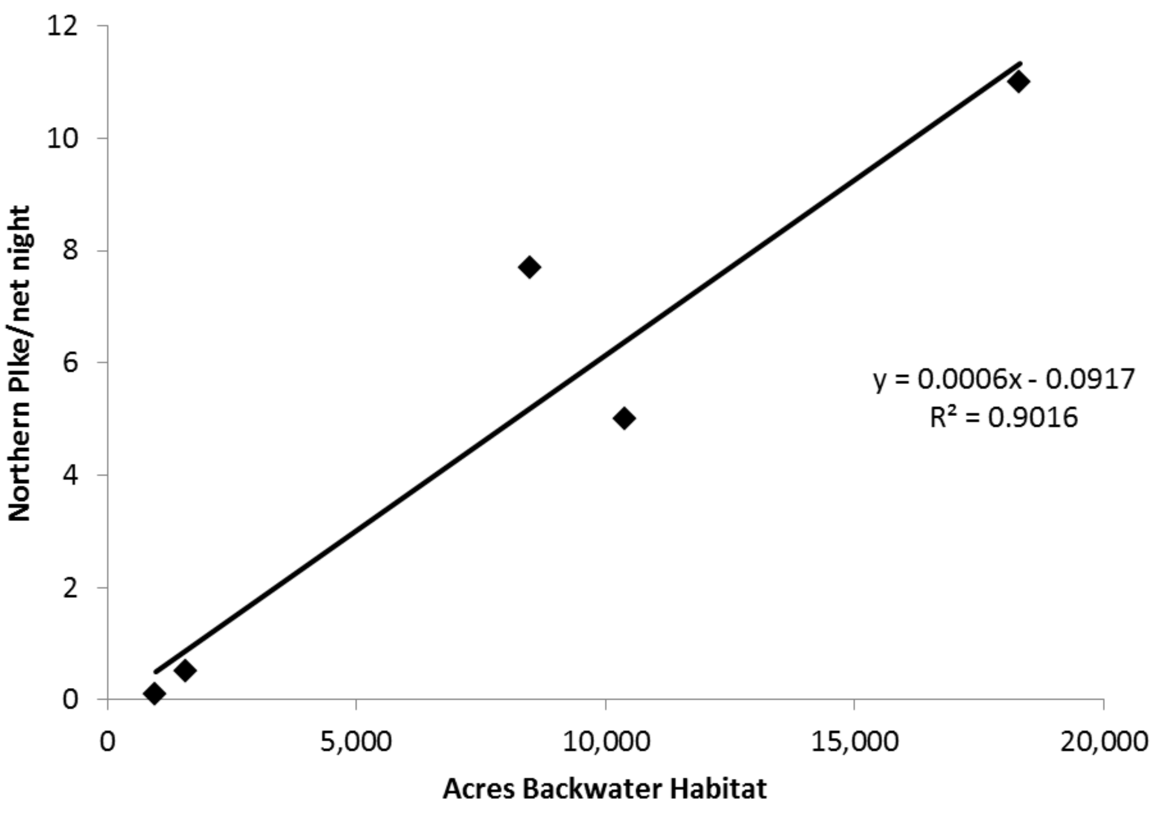

Figure 8. Relationship of mean spring Northern Pike fyke net catch rate to acres of backwater habitat in navigation pools 10, 11, 13, 16, and 17 of the upper Mississippi River (r2 = 0.90, p = 0.0135).

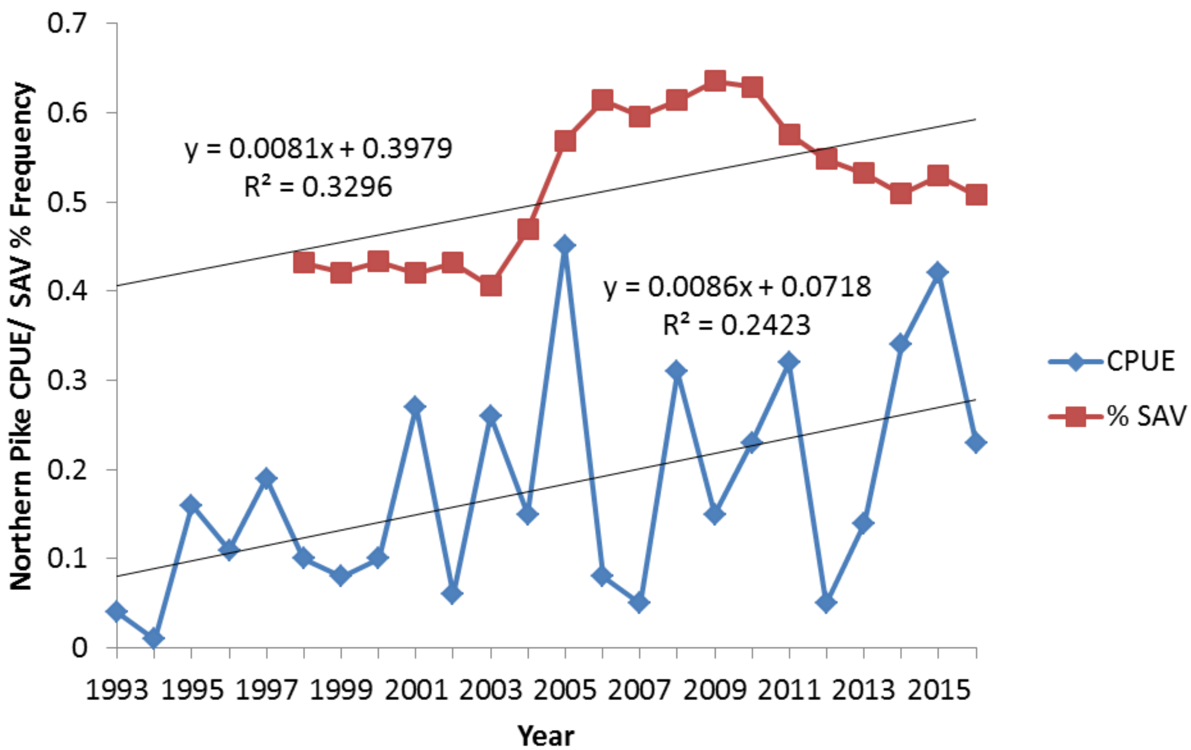

Figure 9. Pool wide trends in LTRM Northern Pike day electrofishing CPUE and submersed aquatic vegetation (SAV) % frequency in Pool 13, UMR 1993-2016 (P< 0.015). Stratified random vegetation sampling did not begin until 1998.

Females fully recruited to spring standard fyke netting at Age-4, a year later than males (Figure 10). Female annual mortality in Pool 13 (A= 0.47) was lower than females in Pool 10 (A = 0.56), which was nearly identical to males in both pools (A = 0.59). Age-1 Northern Pike were absent from our sample, therefore, mean length at Age-1 derived by Gengerke (1977) was included in the von Bertalanffy growth model (Age-1 mean TL; Male = 352 mm, Female = 397 mm). Growth curves estimated using this approach fit our data on observed lengths at age reasonably well (Figure 11). Female Northern Pike grew faster and achieved a greater size and age than males (Figure 12). Males constituted 77% of fish captured from 325-575 mm TL, while females comprised 97% of fish captured >700 mm TL (Figure 13). UMR Northern Pike were robust with mean female Wr in Pools 10, 11, and 13 of 112, 116, and 122 and male Wr of 104, 108, and 105, respectively.

In total, 1,828 Northern Pike were floy tagged in Pools 10, 11, and 13 from 2011-2013 (Table 7). One hundred and seventy-seven fish were recaptured by Iowa DNR crews during this study and during sampling for other projects and management activities. Tag retention rate was high (4 lost tags, 97.7%). Anglers reported harvesting 36 and releasing nine Northern Pike from 2011-2015. Estimated harvest rate, corrected for tag loss, was 2%. Two Northern pike originally tagged in Pool 13 and recaptured in Pool 12 (1 by Iowa DNR, 1 angler harvest) were the only example of inter-pool movement recorded during this study.

Gravid female Northern Pike ranged in size from 512-927 mm and 913-7,976 g and fecundity ranged from 21,829-182,062 eggs/fish (Mean = 63,402). The length-fecundity relationship was best described by (Figure 14):

Fecundity = 277.78(TL) - 120,437

Gonadosomatic index (mean = 0.18) and eggs per kg of body weight (mean = 26,792 egg/kg) were unrelated to total length. On average the left ovary in most (i.e., 53 of 56) fish was 15% larger than the right.

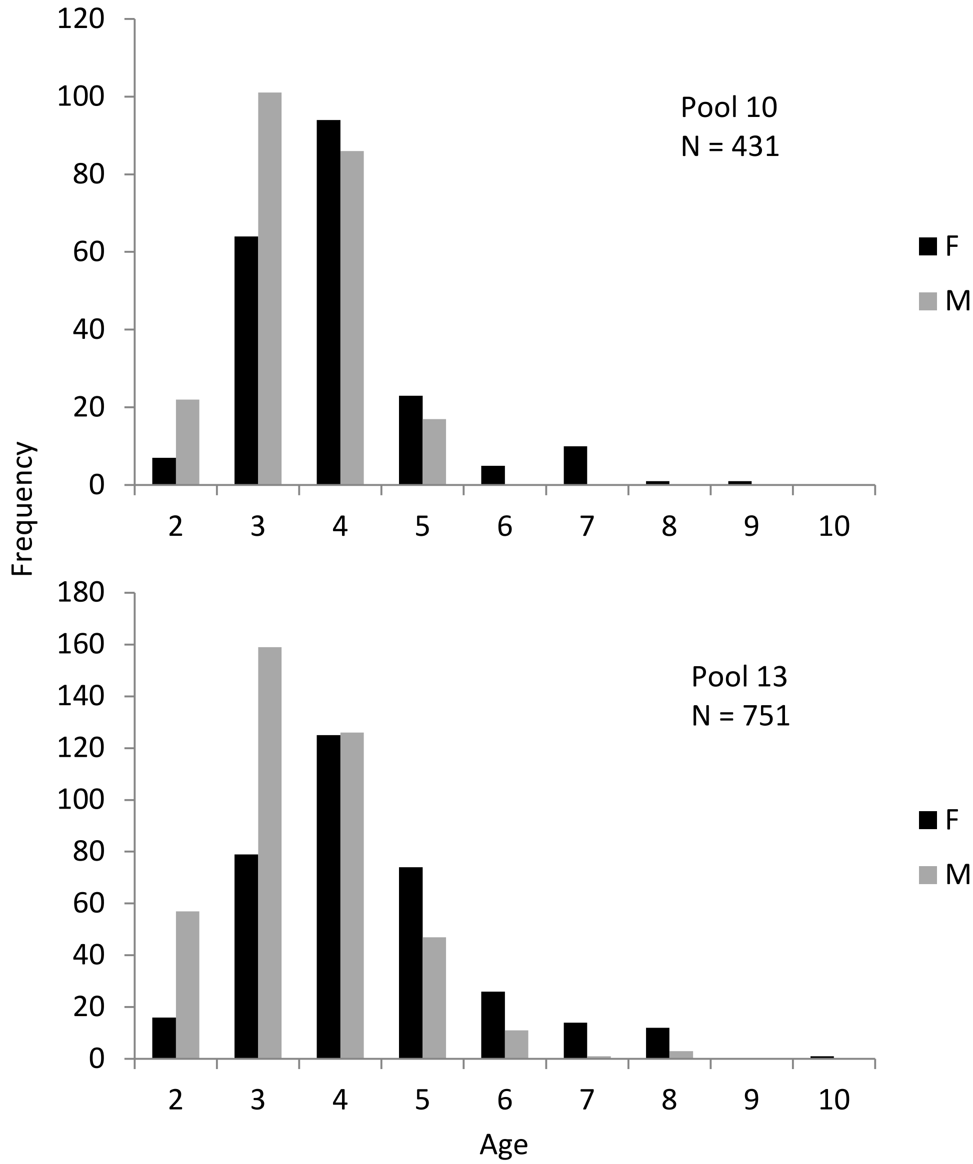

Figure 10. Male and female Northern Pike age distribution from spring standard fyke netting in Pools 10 and 13, Upper Mississippi River 2012-2013.

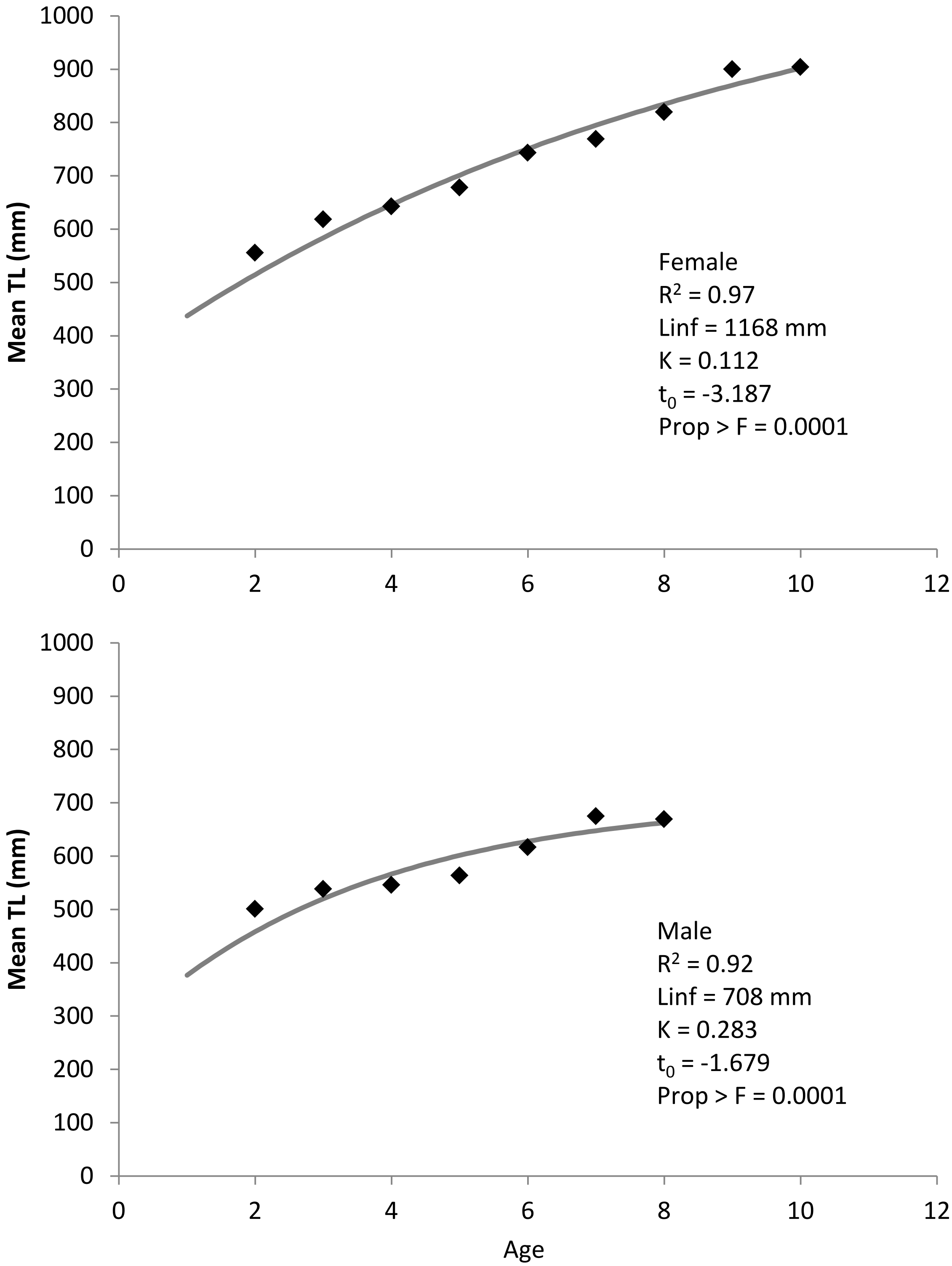

Figure 11. Male and female mean length at age (black diamonds) and Von Bertallanfy growth model (grey line) from Pools 10 and 13, Upper Mississippi River 2012-2013.

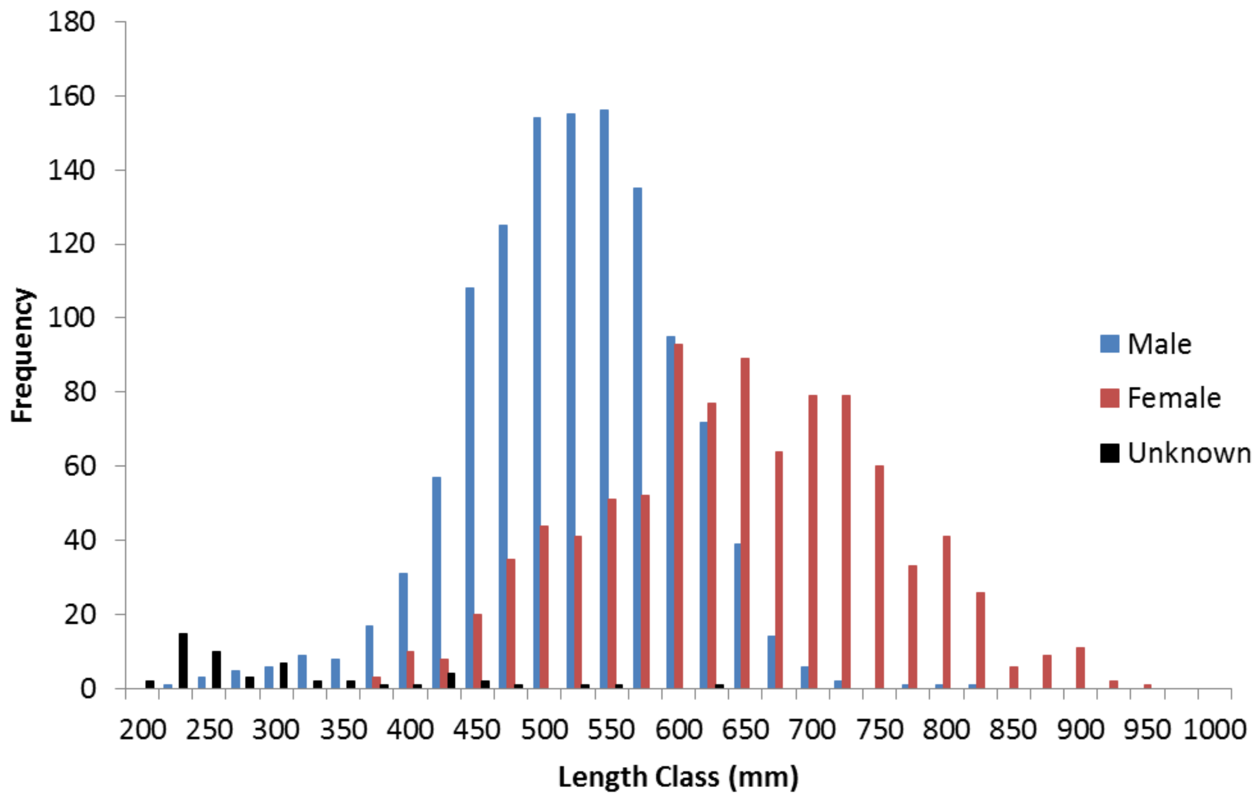

Figure 12. Length frequency of male, female, and unknown sex Northern Pike captured in spring standard fyke nets in Pools 10, 11, and 13, Upper Mississippi River 2011-2014.

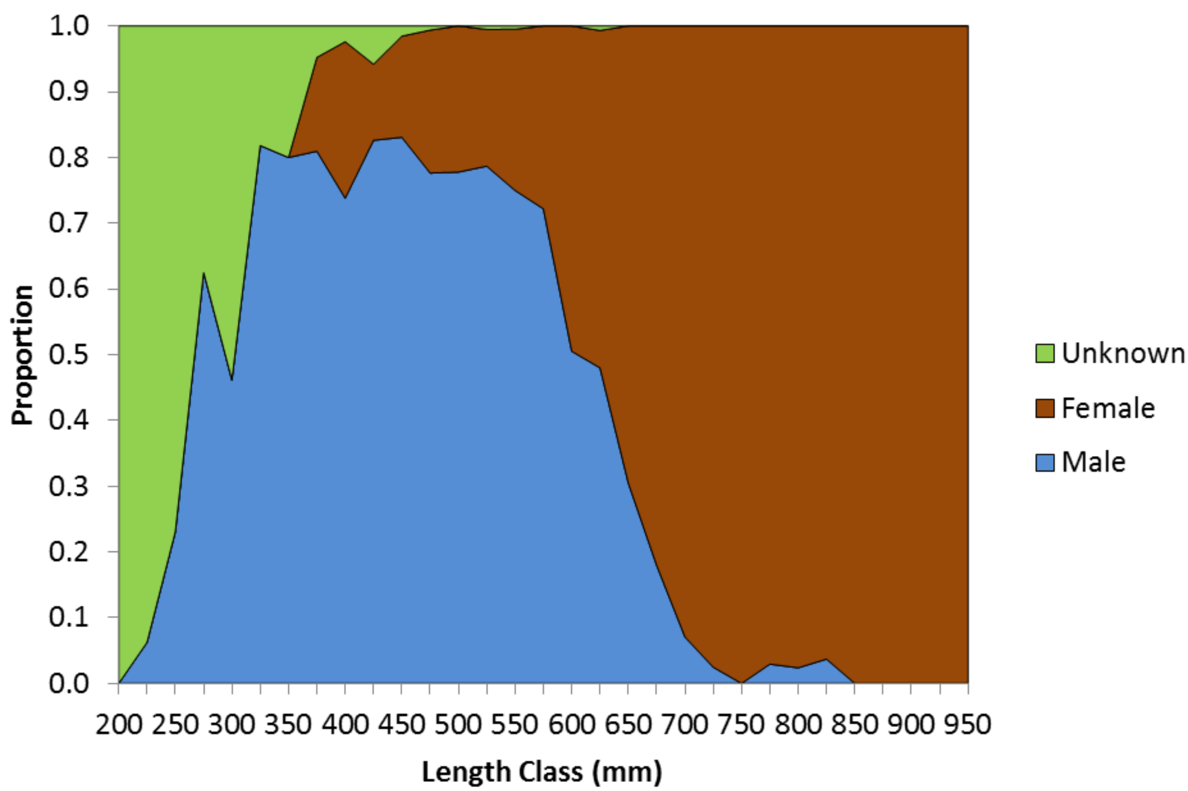

Figure 13. Proportion of male, female, and unknown sex Northern Pike per 25-mm length class captured in spring standard fyke nets in Pools 10, 11, and 13, Upper Mississippi River 2011-2014.

Table 7. Number of Northern Pike tagged, recaptured, lost tags, and reported harvested or released by anglers in Pools 10, 11, and 13, Upper Mississippi River 2011-2015.

Year	Pool	Tagged	Recapture	Lost Tag	Angler Harvest	Angler Release
	10	251	13	0	2	0
2011	11	424	32	1	6	0
	13	0	0	0	0	0
	10	242	16	0	2	1
2012	11	0	0	0	1	0
	13	405	29	0	1	0
	10	175	19	2	8	0
2013	11	0	0	0	2	0
	13	331	60	1	5	1
	10	0	0	0	2	0
2014	11	0	0	0	0	0
	13	0	3	0	2	3
	10	0	0	0	5	0
2015	11	0	0	0	0	0
	13	0	1	0	0	1
	10	668	48	2	19	1
Total	11	424	32	1	9	0
	13	736	93	1	8	8
	Total	1828	173	4	36	9

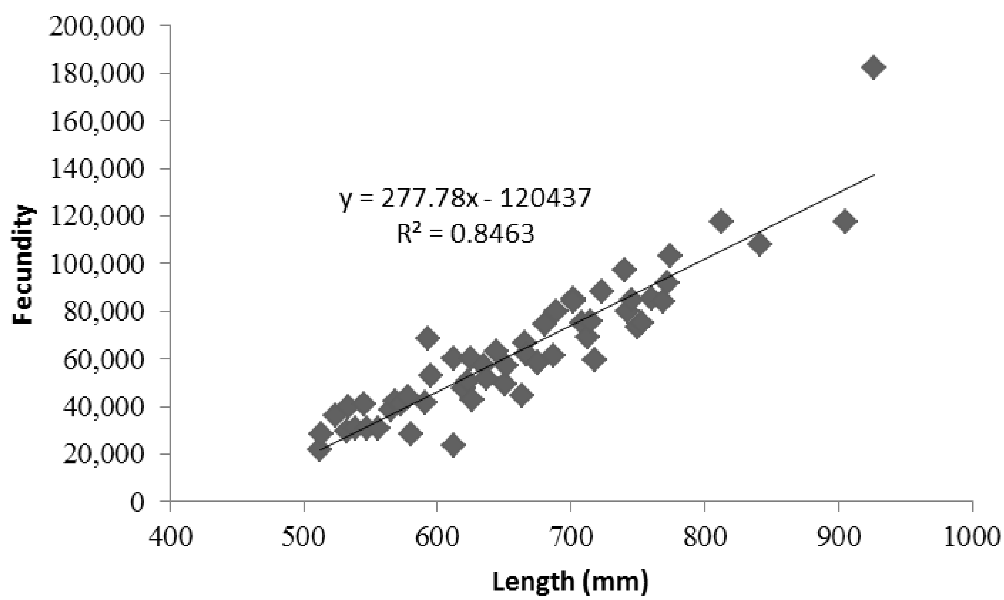

Figure 14. Length fecundity relationship for Northern Pike collected in Pool 13, UMR, April 2013 (n = 55, p < 0.001).

Approach 4: Of the 21 Northern Pike that were radio tagged in 2011 (20 initially tagged in October, and one in November), one died before the first tracking event (6 days post tagging) for an observed short term tagging mortality rate of 5%. Exploitation of this group was 25% in the first year: two fish were harvested by ice anglers and three were harvested during open water. In 2012, no short term tagging mortality was observed in the Northern Pike in Pool 10; however, three fish in Pool 13 died within 12 days post-surgery. Overall short term tagging mortality was 8% in 2012 which is similar to the 5% observed in 2011 (X^2 = 0.1685, P =0.68). Exploitation was 30% for the first year for fish tagged at Bussey Lake in Pool 10: three fish were harvested by ice anglers. No Northern Pike were reported harvested in Pool 13.

In Pool 10, crews logged 82 tracking events resulting in 572 individual locations from October 2011 through July 2014. Each fish was located an average of 15 times (range: 0 to 40; Appendix A). In Pool 13, crews logged 50 tracking events resulting in 255 individual locations from October 2012 through January 2015. Each fish was located an average of 9 times (range: 0 to 16; Appendix B). We were unable to collect water quality and UTM data for 46 locations (18%) in Pool 13 because fish were located in the Crooked Slough closed area. The closed area was formerly part of the Savannah Army Depot and is an inviolate refuge due to the presence of unexploded ordinances. Only 6 radio transmitted Northern Pike were contacted during the final tracking period in January 2015.

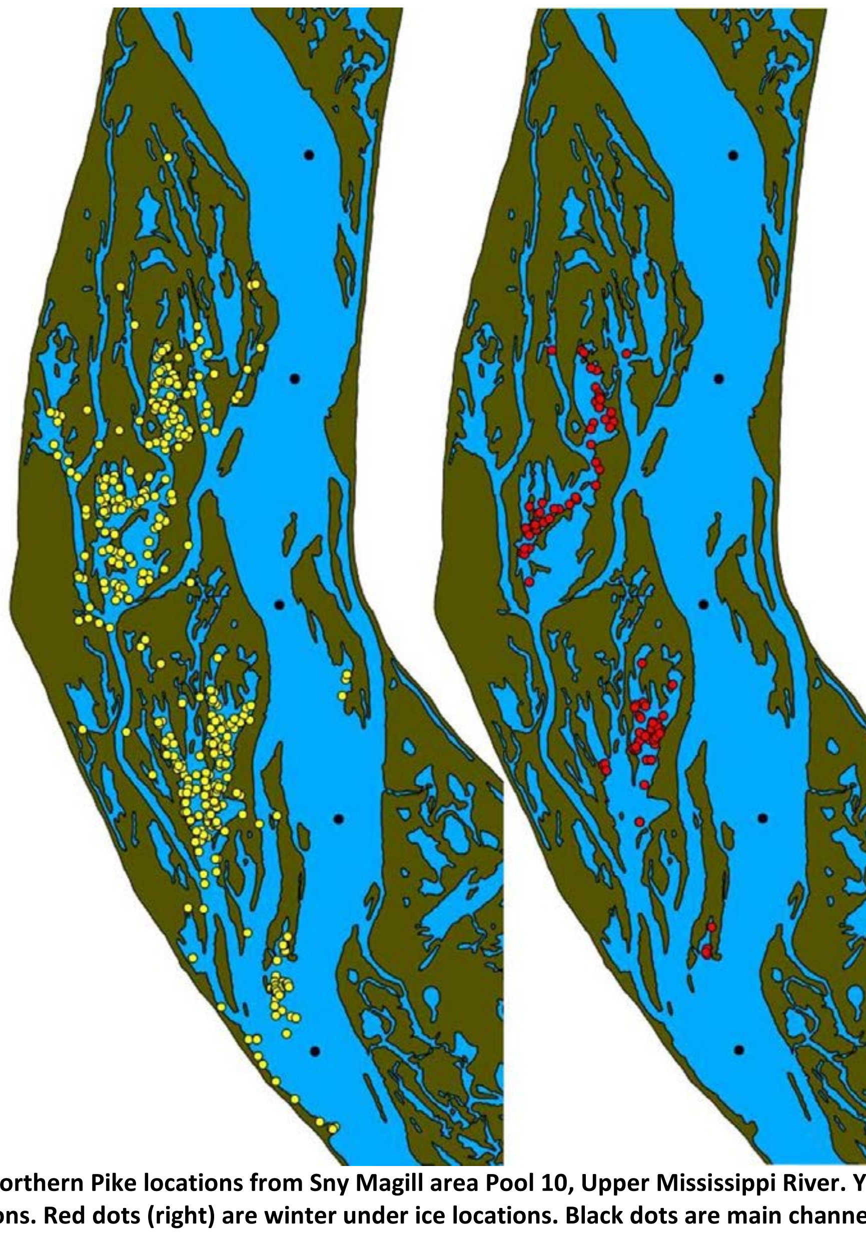

Figure 15. Radio tagged Northern Pike locations from Sny Magill area Pool 10, Upper Mississippi River. Yellow dots (left) are open water locations. Red dots (right) are winter under ice locations. Black dots are main channel river miles.

Northern Pike occupied 3 habitat strata: backwater lakes, side channels and the main channel border of the UMR. Backwater habitat was utilized extensively in both open water (90% fish locations) and under ice (100%) seasons in Pool 10 (Table 8). Northern Pike in Pool 10 exhibited a much reduced winter range compared to the open water season (Figure 15). Backwater habitat was occupied most commonly in open water (55%) and under ice (58%) seasons in Pool 13, however side channel habitat was also heavily utilized in both seasons (Open water = 40%, Ice = 42%). Mean water velocity at side channels site occupied by Northern Pike in the winter (0.11 ft/sec, SE = 0.03) was less than half that of sites occupied during the open water season (0.23 ft/sec, SE = 0.04; Table 6). Flows were not detected at any backwater sites during the winter in either pool. However, lower mean water temperatures in Pool 13 (1.1 °C, SE = 0.16) compared to Pool 10 (2.2°C, SE = 0.10; Table 8) indicate greater connectivity or water exchange in Pool 13 backwaters.

Table 8. Percent of total contacts and mean (SE) depth, current velocity, and water temperature measured at Northern Pike locations in backwater lake (BL), side channel (SC), and Main Channel Border (MB) habitat strata during open water and under ice conditions in Pools 10 and 13, Mississippi River, 2011-2015.

		Pool 10				Pool 13			
		% Locations	Depth (m)	Velocity (ft/sec)	Temp (°C)	% Locations	Depth (m)	Velocity (ft/sec)	Temp (°C)
Open	BL	90	1.1 (0.03)	0.02 (0.004)	18.5 (0.43)	55	1.5 (0.12)	0.02 (0.01)	18.5 (0.97)
	SC	3	1.5 (0.24)	0.34 (0.14)	21.7 (2.12)	40	1.8 (0.14)	0.23 (0.04)	13.8 (1.09)
	MB	7	1.6 (0.03)	0.12 (0.06)	20.8 (1.44)	5	2.6 (0.68)	0.30 (0.09)	7.2 (1.34)
Ice	BL	100	1.0 (0.03)	0*	2.2 (0.10)	58	1.1 (0.09)	0*	1.1 (0.16)
	SC	-	-	-	-	42	1.9 (0.33)	0.11 (0.03)	0.6 (0.12)
	MB	-	-	-	-	-	-	-	-

*All values zero, no standard error.

In July 2012, 90% of recorded daily high temperatures in eastern Iowa were higher than historical averages (National Weather Service, unpublished data). Surface water temperatures in backwater lakes of Pool 13 exceeded 32.2˚C. More than 100 dead Northern Pike were observed in a Pool 13 backwater lake (Darren Witt, USFWS, personal communications). Widespread reports of Northern Pike mortality occurred throughout the UMR, including Pools 10 and 13, through July and August. During this period, three of 16 (19%) active radio tagged Northern Pike moved to cool water inputs: two sought thermal refuge in Sny Magill Creek, a cold water stream that enters the Mississippi River in the Sny Magill backwater complex, and one moved to a cold water seep near Prairie du Chien, Wisconsin. Two of the three fish were subsequently harvested during this period. Northern Pike anglers in the UMR are known to concentrate their efforts on cold water inputs in the summer for high catch rates. Of the remaining thirteen radio tagged Northern Pike, four suspected heat related mortalities occurred. The proportion of Northern Pike that moved to cold water inputs during this time of thermal stress was much lower than expected. However, fish that did not seek out thermal refuges had a higher survival rate (69% vs. 33%) due to high angler harvest in cold water areas.

Approach 5: A total of 523 interviews were conducted across the three management districts (Table 9). The percentage of anglers that catch Northern Pike by district decreased moving downstream with 77.4%, 75.9%, and 15.3% of anglers reporting having caught Northern Pike in the Guttenberg, Bellevue and Fairport districts, respectively. Proportions of anglers that harvest pike (42.3%, 25.5%, and 2.5%) and specifically targeted pike (27.4%, 17.9%, and 2.5%) followed a similar downstream decrease (Table 9). Likewise, mean angler satisfaction ratings decreased in a downstream direction (3.3, 3.0, and 2.7; Figure 16). This follows changes in river habitat and decrease in Northern Pike populations that are observed along the Mississippi River in Iowa. Of anglers that reported specifically targeting Northern Pike, 27% stated they don't harvest them, indicating presence of a catch-and-release fishery.

Table 9. Number of interviews and proportion of anglers that reported catching, harvesting, and targeting Northern Pike (NP) on the Mississippi River within the Iowa Department of Natural Resources Guttenberg, Bellevue, and Fairport Management districts during an angler use survey 2012 and 2013.

	Guttenberg	Bellevue	Fairport
Interviews	84	125	314
Percent Catch NP	77.4	75.9	15.3
Percent Harvest NP	42.3	25.5	2.7
Percent Target NP	27.4	17.9	2.5

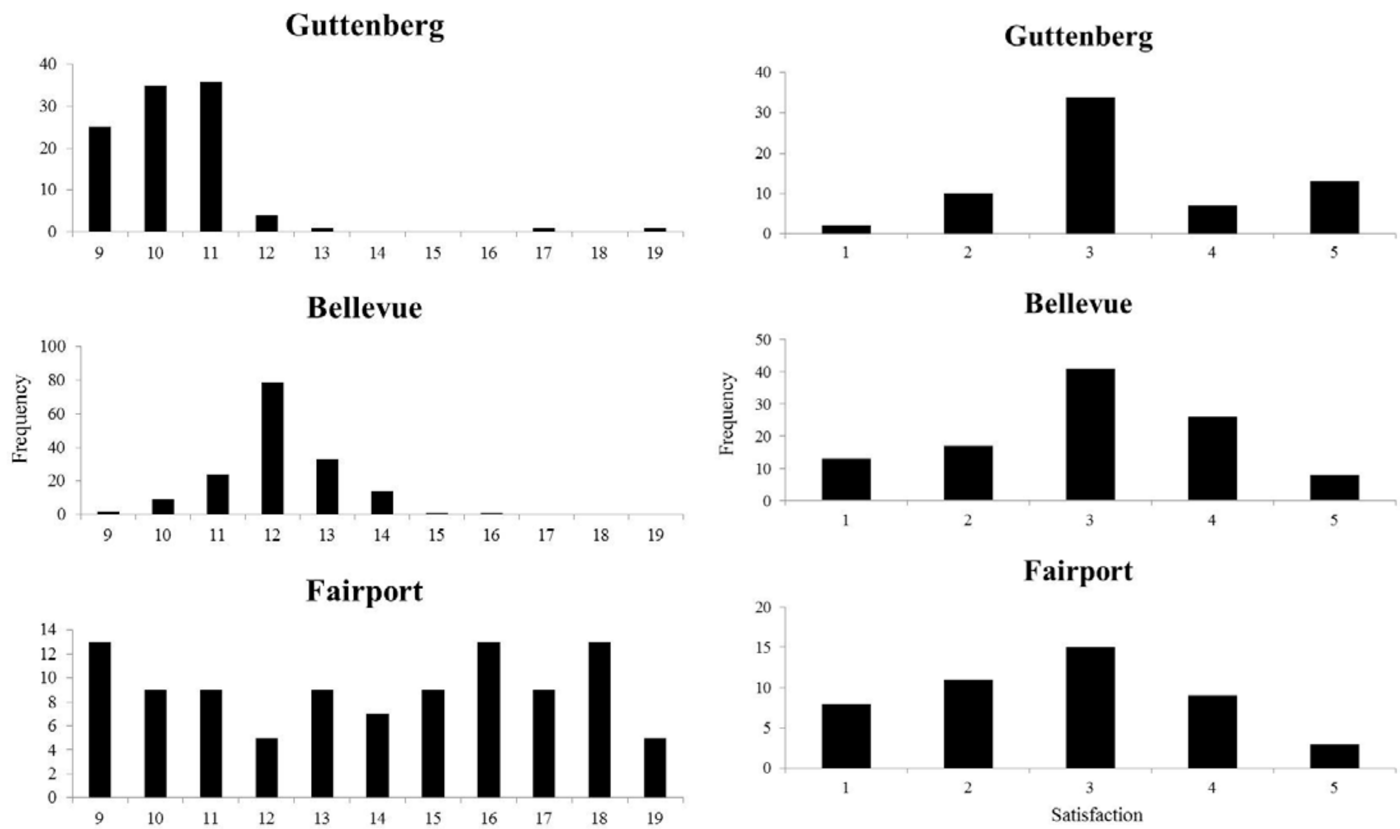

Figure 16. Pools that anglers reported catching Northern Pike (left) and angler satisfaction with Mississippi River Northern Pike fisheries (right; 1 = Very dissatisfied, 2 = somewhat dissatisfied, 3 = neutral, 4 = somewhat satisfied, and 5 = very satisfied). Data from an angler opinion survey conducted within the Iowa DNR Guttenberg, Bellevue, and Fairport fish management districts in 2012 and 2013.

Anglers reported catching Northern Pike from every pool of the Mississippi River. Anglers interviewed in the Guttenberg and Bellevue Management districts tended to fish close to home with 93% and 78% reporting catching Northern Pike within their district. Two anglers interviewed in Guttenberg district that reported catching Northern Pike in Pools 17 and 19 were from the Fairport District. Anglers interviewed in the Fairport district (Pools 16-19) reported catching Northern Pike from every pool in Iowa with over 60% of reported pools being in another management district and Pool 9, the farthest away, was the most commonly reported pool.

Discussion

Spring fyke netting was the most efficient method for sampling northern pike populations in this study. Catch rates from fall standard fyke netting and electrofishing were very low. Northern Pike were commonly observed actively avoiding the boat and electrical field while electrofishing. Schoenbeck and Hansen (2005) found that catchability of Northern Pike was negatively related to specific conductance. LTRM pool wide median specific conductance in Pool 13 during summer and fall commonly exceed maximums observed in their study. Variations in species-specific conductivity can lead to variable catchability among species when standard sampling settings are used (Miranda and Dolan 2003). While not tested during this study, future work to identify standard electrofishing settings optimized for Northern Pike may be warranted.

Electrofishing provided a less biased size distribution than standard fyke netting as fyke nets undersampled Northern Pike <400 mm. Pierce and Tomcko (2003) found that fyke nets undersampled Age-0 and Age-1 Northern Pike; however, this gear effectively sampled mature fish and did not confound populations analyses for mature fish. Spring standard fyke netting had the additional advantage of allowing external sex determination that was not possible with other gears.

While electrofishing is less size selective than netting, time necessary to capture a large enough sample for population dynamics assessments makes this gear unfeasible. Miranda (2007) determined that sample sizes required for estimating length frequency distributions and mean length increased with species-specific maximum size among Bluegill, White Crappie, and Largemouth Bass. Sample sizes of 225-425 and 130-160 Largemouth Bass were required to estimate a 2.5-cm histogram within 10% with 80% confidence and mean length, respectively. Based on these sample size requirements and observed gear efficiencies (# fish/crew day) from this study, 4-8 spring standard fyke net crew days would be required to estimate a 2.5-cm histogram within 10% with 80% confidence. Sampling effort requirements for estimating 2.5-cm length frequencies from fall standard fyke nettings (30-56 days), summer coldwater electrofishing (65-122 days), and fall electrofishing (23-43 days) are too great to make them viable options for fish management teams. Likewise, spring standard fyke netting was more efficient than other gears at estimating mean length (3 days vs. 13-46 days).

Northern Pike growth and mean length at age were similar to reported values for Pool 10, 1990-1991 (Pitlo and Rasmussen 2004), other regional studies (Neumann et al. 1994; Rydell et al. 2008), and within the range of observations for lotic systems in North American (Rypel 2012). Growth, mean length at age, and annual mortality were all less than observed by Gengerke (1977). However, these rates are not directly comparable as Gengerke (1977) utilized scales for age and growth which has been shown to underestimate the age of Northern Pike which would positively bias growth and mortality estimates (Oale et al. 2015).

Northern Pike fecundity as a function of length was similar to previous studies on the UMR in Iowa (Gengerke 1977). Our observation that the left ovary outweighed the right ovary in 94% of females by an average of 15% was unexpected. While typically symmetrical, asymmetry in testes and ovaries has been observed in some fish around breeding season but the reason is unknown (Turner 1919, Robertson 1957, Sanwal and Khana 1972, Dalela et al. 1977; Ratty et al. 1990). Ratty et al. (1990) speculated that asymmetry observed in Albacore *Thunnus alalunga* would allow for prolonged spawning by staggering the development of gonads. This did not appear to be the case in Northern Pike in this study as the mean number of eggs per gram was identical between the right and left ovaries. Although untested, we postulate that the position of unpaired internal organs may restrict the size of one ovary.

Iowa fisheries managers have long observed that Northern Pike abundance generally decreases as you move from northern to southern Iowa pools. Sampling for this study supports that assumption. Pike populations are robust and healthy within the upper pooled portion of the river (Pool 13 and upstream). The amount of backwater habitat within a pool appears to drive Northern Pike abundance within the study area. Backwaters are important year round habitat for Northern Pike and were the most commonly occupied habitat type by radio tagged fish in Pools 10 and 13 during both open water and ice seasons. Undegraded backwaters support diverse aquatic vegetation (Moore et al. 2000). Submerged aquatic vegetation is vital Northern Pike spawning (McCarraher and Thomas 1972), rearing (Holland and Huston 1984), and foraging (Webb and Skadsen 1980) habitat. LTRM data shows an increasing trend in Northern Pike day electrofishing catch rates in Pool 13 from 1993-2016, which mirrors an observed increasing trend in the percent frequency of submersed aquatic vegetation in Pool 13 since 1998.

While long term monitoring data are unavailable for the lower pooled portion (Pool 16-20), sampling from this study indicate populations in this stretch are much less robust. This matches manager's observations and is likely due to differences in geomorphology and habitat quality in this river stretch. Much of the floodplain in the lower pooled portion is levied, limiting areas of off-channel habitat. Additionally, turbidity in this stretch is often too high to support consistent growth of aquatic vegetation (Theiling et al. 2000; Moore et al. 2010).

Northern Pike occupy backwater habitat extensively throughout the year and utilize overwintering backwater habitat in the same manner as Centrarchids as defined by Steuck (2010; water temperature 2-5°F greater than main channel, little or no water velocity [≤0.03 ft/sec] with adequate dissolved oxygen). However, unlike Centrarchids, Northern Pike appear much more tolerate flow and can utilize side channels or other areas of flow where backwaters are degraded. Cold water inputs do not appear to be vital to Northern Pike survival during periods of warm water. Results from this study indicate these areas are most likely sinks due to high observed harvest rate (67%) of transmittered northern pike that moved to cold water areas in summer.

Anglers utilization of Northern Pike varies from incidental catch to a targeted trophy catch-and-release fishery. Anglers are mostly satisfied with the Northern Pike fishery in the northern pools (Pools 9-14) and unsatisfied in southern pools. This mirrors changes in habitat (decrease in overall acres of backwater habitat) and catch rates observed in this study. Restoration of backwater habitat may help populations in southern pools, but other drivers (e.g., levied floodplain, higher turbidity) limit the amount of backwater habitat and aquatic vegetation that can be created in lower pools and likely limits Northern Pike population potential.

Backwater habitat is vital for Northern Pike populations as demonstrated by the positive relationship between backwater area in a pool and spring standard fyke net catch rates. In Iowa, UMR Northern Pike populations are robust where adequate habitat (backwaters and aquatic vegetation) is present and limited where it is absent or highly degraded. Restoration and protection of backwater habitat and aquatic vegetation on the Mississippi River benefits Northern Pike populations and will be necessary to maintain and enhance populations in the future as off channel areas continue to degrade.

Recommendations

1. Managers should utilize spring fyke netting for Northern Pike population assessments on the Upper Mississippi River. However, this gear undersamples < Age-2 Northern Pike. Electrofishing most effectively samples juveniles and should be used if these ages need to be targeted.
2. Continue with current management strategies in Pools 9-13 as Northern Pike populations have increased over the past 24 years as indicated by Long Term Resource Monitoring data. If Northern Pike are a management priority in more southern pools efforts should be focused on restoring backwater habitat and aquatic vegetation abundance.
3. Continue to support habitat restoration of backwaters and techniques such as island construction and drawdowns that promote aquatic vegetation to enhance or maintain healthy Northern Pike populations on the UMR.

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Appendix A. Tag ID, length, weight, tag date, date of last location, tracking duration, number of locations and fate of Northern Pike radio tagged in Pool 10, UMR 2011-2012.

Tag ID	Length (mm)	Weight (g)	Tag Date	Last Located	Tracking Duration	No. Locations	Fate
148.014	655	1796	10/6/2011	11/8/2012	399	26	Harvested
148.023	712	1973	10/4/2011	11/23/2011	50	4	Harvested
148.023(B)	647	1646	10/29/2012	3/15/2013	137	3	unknown
148.034	865	3688	10/4/2011	7/24/2012	294	13	Dead
148.034 (B)	638	1612	10/29/2012	7/23/2013	267	7	Dead
148.046	705	2037	10/3/2011	8/14/2012	316	24	Dead
148.046 (B)	573	1228	10/29/2012	7/15/2014	624	9	Alive
148.054	700	2957	10/4/2011	8/17/2012	318	25	Harvested
148.054 (B)	771	3002	10/29/2012	10/29/2012	0	0	unknown
148.065	742	2504	10/4/2011	10/14/2013	741	38	Dead
148.102	630	1520	10/5/2011	7/17/2012	286	20	unknown
148.123	738	2413	10/3/2011	7/15/2014	1016	40	Alive
148.135	665	1978	10/5/2011	8/20/2012	320	21	Dead
148.135 (B)	678	2282	10/29/2012	10/29/2012	0	0	Harvested
148.143	787	3093	10/5/2011	7/9/2012	278	16	unknown
148.152	655	1665	10/3/2011	12/13/2012	437	28	unknown
148.164	692	1864	10/6/2011	9/6/2012	336	23	Harvested
148.164 (B)	628	2186	10/29/2012	10/14/2013	350	4	Dead
148.183	738	2431	10/3/2011	7/3/2012	274	19	Harvested
148.183 (B)	683	2138	10/29/2012	10/16/2013	352	10	Dead
148.195	752	2631	10/5/2011	10/31/2011	26	3	Dead
148.195 (B)	662	1792	11/21/2011	11/8/2012	353	25	Dead
148.203	640	1687	10/5/2011	12/13/2012	435	30	unknown
148.212	683	1919	10/6/2011	3/10/2014	886	35	Dead
148.223	923	5067	10/6/2011	3/14/2012	160	9	Harvested
148.235	653	1896	10/5/2011	7/23/2012	292	22	Dead
148.235 (B)	698	2458	10/29/2012	1/4/2013	67	3	Harvested
148.244	733	2454	10/3/2011	7/23/2013	659	34	unknown
148.255	697	2016	10/25/2011	7/23/2013	637	31	Dead
148.574	725	2426	10/17/12	7/15/2014	636	12	Alive
148.523	890	5592	10/31/12	8/30/2013	303	4	Dead
148.554	603	1390	10/16/12	12/13/2012	58	1	Harvested
148.564	734	2238	11/6/12	12/13/2012	37	1	Harvested
148.584	665	2068	10/18/12	6/11/2013	236	3	unknown
148.594	627	1358	11/5/12	1/3/2013	59	2	Harvested
148.624	593	1242	10/31/12	7/15/2014	622	6	Alive
148.772	698	2206	10/31/12	12/13/2012	43	1	unknown
148.923	605	1325	11/5/12	7/15/2014	617	8	Alive
148.954	692	1838	10/31/12	7/15/2014	622	12	Alive

Appendix B. Tag ID, length, weight, tag date, date of last location, tracking duration, number of locations and fate of Northern Pike radio tagged in Pool 13, UMR 2012.

Tag ID	Length (mm)	Weight (g)	Tag Date	Last Located	Tracking Duration	No. Locations	Fate
148.304	612	1506	9/26/2012	3/12/2014	532	12	Dead
148.313	643	1830	9/25/2012	11/14/2014	780	14	Alive
148.323	646	1548	9/25/2012	11/14/2014	780	14	Alive
148.333	873	4448	9/26/2012	NA	0	0	unknown
148.344	771	2394	9/24/2012	2/19/2014	513	9	Dead
148.352	650	1714	9/26/2012	11/26/2012	61	3	Dead
148.362	805	3498	9/25/2012	11/27/2012	63	2	unknown
148.372	647	1944	9/25/2012	8/12/2014	686	13	Alive
148.384	649	1784	9/25/2012	1/12/2015	839	14	Alive
148.394	684	1916	9/26/2012	2/19/2014	511	10	Dead
148.403	708	2152	9/25/2012	8/13/2014	687	7	unknown
148.414	805	3020	9/26/2012	1/12/2015	838	15	Alive
148.423	656	1880	9/25/2012	8/26/2013	335	9	Dead
148.433	665	1990	9/25/2012	10/17/2013	387	5	Dead
148.444	728	2162	9/26/2012	8/13/2014	686	13	Dead
148.454	678	1904	9/26/2012	10/17/2013	386	9	unknown
148.465	629	1622	9/25/2012	11/14/2014	780	14	Alive
148.475	856	3614	9/26/2012	10/29/2013	398	7	Dead
148.483	638	1622	9/26/2012	10/1/2012	5	1	unknown
148.493	721	2252	9/25/2012	1/12/2015	839	16	Dead
148.512	700	2156	10/3/2012	9/17/2014	714	12	Alive
148.533	672	1722	10/3/2012	10/15/2012	12	1	Dead
148.545	672	1860	10/1/2012	7/14/2014	651	4	unknown
148.605	671	2188	10/2/2012	1/12/2015	832	14	Alive
148.651	686	2048	10/1/2012	7/14/2014	651	6	unknown
148.683	642	1684	10/1/2012	7/14/2014	651	13	unknown
148.745	659	1740	10/3/2012	8/13/2014	679	11	Alive
148.835	609	1388	10/1/2012	NA	0	0	Dead
148.864	631	1478	10/4/2012	10/15/2012	11	1	Dead
148.894	586	1276	10/2/2012	3/29/2013	178	6	unknown