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Smallmouth Bass Movement and Habitat Use In the Upper Mississippi River, St. Cloud to Coon Rapids

By

Eric R. Altena
Minnesota Department of Natural Resources
Montrose

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Abstract

Radio transmitters were surgically implanted in 30 smallmouth bass captured in six locations, on a 96 km reach of the Mississippi River between the St. Cloud and Coon Rapids Dams. Movements were documented over a 12-month period, and habitat use associated with each fish location was characterized. Over 2000 individual fish locations were recorded during the 12-month period.

Smallmouth bass made distinct fall migrations of up to 27 km to wintering areas, and spring migrations of up to 29 km to spawning areas. Stream depth used by smallmouth bass during summer ranged from 0.1 to 4.6 m. Smallmouth used deeper water during cold-water periods. Smallmouth bass commonly used eddy habitats throughout the majority of the year, and moderately used pools and runs. Riffles, center channel run/eddies, backwaters and tributaries were not used as often.

Smallmouth bass in this stretch of the Mississippi River had relatively small home ranges during summer and winter. Home range size during summer varied between 0.4 and 19.0 ha, while winter home ranges were between 0.2 and 20.2 ha. Smallmouth bass traveled distances which ranged from 1.7 and 54.6 km, which could have a significant impact on angling regulations.

Radio telemetry was a valuable tool in determining behavior and movement patterns of larger smallmouth bass for this area of the Mississippi River. We observed several smallmouth bass that crossed the regulation boundary in Dayton. A better understanding was gained of the influence of artificially increased temperatures due to a nuclear power generation and manually adjusted flows from hydroelectric operation.

Introduction

Specific information is needed about smallmouth bass (*Micropterus dolomieui*) movement and habitat use, in the portion of the Mississippi River from Coon Rapids Dam to St. Cloud Dam, to properly evaluate the effects of potential development and the existing experimental regulations. This portion of the river is 96 km long, and an experimental angling regulation for smallmouth bass has been in place on the river since 1990. The regulation consists of a 305 mm to 508 mm protected slot limit and a three fish daily bag limit, with only one fish larger than 508 mm. This regulation was in effect from the Highway 101 Bridge at Elk River upstream to Highway 24 at Clearwater until 1999, a distance of 50 km. In 2000, the regulation area was extended upstream to the St. Cloud Dam and downstream to the confluence of the Crow River at Dayton, a distance of 75 km (Figure 1).

Fisheries population data collected by Xcel Energy, which operates a nuclear power generation facility in Monticello, suggests that the smallmouth bass population size structure has improved and abundance has increased within the past 15 years (Hiebert 1999, Altena 2001). Although this improvement appears to coincide with the regulation of the past 10 years, the improvement may be due in part to increased release ethics among anglers, declaration of fish consumption advisories, and favorable environmental conditions. Smallmouth bass year class production within this area of the Mississippi River has been favorable, with fish less than 178 mm captured at high rates by electrofishing during 1988, 1992, 1995, 1998, 2000 and 2002 (Figure 2).

Evaluation of the experimental regulation has been confounded by the possibility that smallmouth bass move into and out of the current regulation zone. Examples of smallmouth bass movement within this stretch have been documented. One smallmouth tagged by the DNR at Elk River in 1992 was recovered 14 days later downstream at the mouth of Minnehaha Creek in Minneapolis, a distance of 40 km. Previous research on the Mississippi River suggests that smallmouth bass make seasonal migrations. Marod (1994) found that smallmouth bass moved into deep pool areas of the Mississippi above the Little Falls Dam during the fall. However, low tag retention limited the effectiveness of that study. Similar fall migrations of smallmouth bass to wintering areas have been documented in the Snake River, Idaho (Munther 1970) as well as the Embarrass and Wolf Rivers in Wisconsin (Langhurst and Schoenike 1990). Todd and Raebeni (1989) found that smallmouth bass in the Jacks Fork River, Missouri, moved upstream as much as 7.5 km and downstream as much as 5.7 km during peak movement periods. Similarly, Lyons and Kanehl (2000) concluded that smallmouth bass in the Pecatonica River system in Wisconsin moved as much as 20.8 km, with a mean range of 6.5 km annually. However, Beam (1990) found that smallmouth bass in the Huron River (Michigan) had small annual ranges; some fish moved 20 m while larger fish moved as much as 370 m. The author suggested that habitat features might have restricted movement within that system.

The goals of this study were (1) to record the movements of smallmouth bass across regulated boundaries; (2) characterize movement and habitat use on a seasonal, daily, and hourly basis; and (3) to determine if the movement of smallmouth bass could have an effect on population size structure.

Study Area

The Mississippi River between St. Cloud and Coon Rapids dams is characterized by moderate bluff lands and areas of flood plain forest. Land uses within a 1000 m-wide corridor in the area from St. Cloud to Dayton consist primarily of agricultural (26%), forested (24%) and residential/commercial development (22%). The area from Dayton to Coon Rapids is largely residential/commercial development. The portion of the river between St. Cloud and Clearwater is designated as a state Scenic River, while the portion from Clearwater to Anoka is designated as recreational. These designations were put in place to protect the unique nature of these areas. The combined designated areas represent 8,160 ha. These designations may allow more native habitat to remain in place and provide a buffer from encroaching development (Figure 3). The area from Anoka to Coon Rapids has no designated status.

The Mississippi River within this 96 km reach has a gradient of 0.48 m/km, a sinuosity of 1.2, a mean width of 264 m, and a mean depth of 1.5 m. The drainage area at St. Cloud Dam is 21,435 km^2, whereas the drainage area at Coon Rapids Dam is 30,737 km^2. Typical substrates range from boulder and cobble to areas of gravel and sand. This portion of river has 13 boat accesses, yet angling pressure is light. Fishing pressure ranged from 715.3 to 1,101 hr/km (Sledge 1998, Wang and Diedrich 1992) compared to a similarly regulated area of the Upper James River in Virginia (Smith 2000, Personal comm.). Creel surveys in 1992 and 1997 between St. Cloud and Dayton also found annual catch rates were average to above average for anglers targeting smallmouth bass (0.84/hr and 0.49/hr, respectively)(Wang and Diedrich 1992, Sledge 1998) compared to other lakes and rivers with smallmouth bass.

Electrofishing data collected by Xcel Energy and the Minnesota DNR indicates an increase in abundance and improvement in size structure of smallmouth bass since implementation of the regulation in 1990 (Figure 2). In addition to the experimental regulation, Minnesota observes statewide fishing seasons and additional harvest restrictions for smallmouth bass. The smallmouth bass season opens in late May and is closed to harvest from mid-September to mid-February. These restrictions are intended to protect the concentration of smallmouth bass during spawning and wintering. During 2001, the bass season opened 25 May, while harvest of all smallmouth bass was prohibited after 17 September 2001.

Methods

Thirty smallmouth bass were captured at six sites by electrofishing and angling during August 2001 (Figure 4). A Smith Root 5.0 gpp electrofishing boat was used. Fish were between 319-493 mm in total length and weighed 470–1700 g. Smallmouth bass were implanted with radio transmitters following the methods of Winter (1983) and Hart and Summerfelt (1975). Following surgery the fish were held in an on-board circulating live well until they were able to maintain an upright body position (5-10 min), then released within 1.0 km of the capture site. Five fish were implanted at each of the six sites. Tags were either 7.5 grams or 15 grams (in air). Tag weights were well below suggested maximum 2% of body weight for all fish implanted (Winter 1983). Information on individual fish is presented in Table 1. Frequencies ranged between 49.025 mhz and 49.691 mhz, and were separated by a minimum of 30 mhz.

Tags were programmed with an alternating on-off schedule. During periods of anticipated high activity (April through October), tags were switched on for Monday, Wednesday, and Friday. Otherwise tag were switched on for Tuesday and Thursday. The programmed schedule allowed tags to have a minimum life expectancy of 18 months for 15 g tags; and 14 months for 7.5 g tags (Advanced Telemetry Systems, Isanti, Minnesota).

Starting in September of 2001, locations were determined by boat, traveling the entire reach in an alternating up or downstream direction. The boat was equipped with a four m, four element, yagi antenna and scanning receiver. Increased location accuracy (to 3 m) was achieved using a signal attenuator, hand-held loop antenna and a whip antenna with 0.5 cm of center core exposed, held under the water surface (Advanced Telemetry Systems, Isanti, Minnesota). Test runs with telemetry equipment allowed navigators to arrive within 3 m and recover dropped tags. Individual fish locations were recorded with a global positioning system (Trimble Navigation Limited) and were differentially corrected by post processing. Post-processed data was accurate to within 3 m, if a minimum of 20 points were recorded. Aerial locations were collected during winter from a fixed wing aircraft equipped with a Garmin® GPS receiver to give an expected accuracy within 100 m. Triangulated locations were collected from shore with a hand-held loop antenna to achieve an expected accuracy of 10 m. Habitat use recorded at each location collected by boat included: dominant substrate (by visual observation or by probing with a long section of PVC pipe), habitat category and overhead cover type within 1 m of each location. Habitat types were defined as follows: run - high velocity area with no noticeable wave action; riffle - high velocity area with noticeable wave action; run/eddy - center channel current break with high velocity areas on either side; eddy - low velocity area along shore with reverse direction of flow; pool - area of no visible water velocity; backwater - area outside of normal pool elevation; and tributary - attached stream or river. Overhead cover components were defined as: not noticeable - no visible cover component; depth - areas where no other overhead cover was observed and water depth was greater than 1.2 m; woody debris - wood in or within close proximity to water surface; rock - boulder or cobble combination allowing overhead protection; AM/PM/shade - shade in the fish location due to overhanging objects during periods of lower sun elevation. Additional attributes included water temperature, time, and depth (recorded to nearest 0.1 m with LCD depth sounder). Climatology information for the study area was obtained through the Minnesota State Climatology Office (http://climate.umn.edu/hidradius/radius.ASP) for Becker, MN (Site 210570), a site close to the river. Hourly discharge from St. Cloud dam was available through the United States Geological Services (http://water.usgs.gov/mn/nwis/current/?type=flow).

Smallmouth bass were located three times per week from September through October 2001 and April through August 2002. From November through March, fish were located by boat, air or triangulated from shore once per week. The period from 17 June through 8 August 2002 included eight days of monitoring proximate groups of fish, every two hours during daylight. Two separate all-day sampling periods were performed on all fish. Due to hazardous navigation, night locations were not attempted.

Analysis of home range and relative movement was performed using Arcview® 3.3 with Animal Movement Analysis (Hooge 1995) and spatial analyst extensions. Minimum convex polygon (MCP) home ranges are defined as the total area an animal uses. Adaptive Kernel at the 50% and 95% contours (Kernel 50 and Kernel 95, respectively) are defined as home range areas with an associated probability the animal will be in this location. Home range estimates were clipped within the river shape file boundary that was adjusted and digitized from recent aerial photographs. Home ranges were defined for winter (November 2001-March 2002), summer (July through August 2002) and summer-all-day (17 June-8 August 2002). Comparisons of home range between seasons were only made using MCP due to smaller sample sizes in winter. Travel distances were calculated by converting sequential points to poly-lines. These lines were drawn to give the shortest possible path of travel from point to point, while remaining within the river channel. Movements of less than three meters were considered non-significant due to location variability and error in GPS data. Amount of time in or out of regulated area was calculated as a percentage of locations out of the regulated area relative to season. Additional analysis was performed using Microsoft Excel 2000 Analysis Tool Pack®. Due to mortality of five fish during the course of the study, and one fish with a tag transmitting on an inconsistent schedule, only 24 fish were used for seasonal and all-day analysis of movement, home range, and habitat use.

Results

Individual smallmouth bass locations were recorded by boat (1844 locations), triangulation from shore (78), and from the air (132). Overall, water depth used by smallmouth bass was between 0.15 m and 7.38 m, with a mean depth of 1.54 m. Smallmouth bass use of depth varied by month with maximum depth used during April and minimum depth used in June and July (7.38 m and 0.15 m, respectively) (Table 2). Winter (November-March) depths ranged from 0.30 to 6.46 m with a mean depth of 1.88 m, whereas summer depths ranged between 0.15 and 5.43 m with a mean depth of 1.27 m (Table 2). Predominant habitat types used by smallmouth bass included eddies, pools, and runs, 32.7%, 27.1% and 25.4%, respectively(Table 3). However, habitat type varied throughout the year. The use of runs was highest during August and September, (57.1% and 51.6% respectively), whereas the use of pools was highest during January through March, and November (66.7% and 61.5%, respectively).

Discharge at St. Cloud Dam ranged between 74 and 598 m^3/s during the study, with a daily mean of 181 m^3/s. Discharge was higher than the 10 yr mean for most of the period sampled, with peaks occurring in April (382.51 m^3/s), May (364.84 m^3/s) and July (598.76 m^3/s) (Figure 5). An increase of backwater habitat use was also observed during periods of higher discharge during May and July. Conversely, an increase in use of riffles and center channel run/eddy areas was observed during June when discharge was lower (Table 3).

Predominant substrates observed at smallmouth bass locations included cobble, sand, gravel, silt and boulder (Table 4). This substrate composition is similar to what was generally observed in this portion of the Mississippi River, although habitat transects were not performed to verify this quantitatively. A correlation between habitat type, substrate and depth was found in two instances. A highly positive correlation was found between pools with silt that were between 3 m and 5 m. Additionally, runs with cobble and gravel that were less than 1 m deep also had a positive correlation.

Overhead cover used by smallmouth bass was difficult to quantify, because limited visibility in water made many observations of cover difficult to pinpoint. However, the majority of noticeable overhead cover components were: depth greater than 1.2 m, woody debris, rock, and AM/PM/shade (Table 5). Use of woody debris and flotsam corresponded with periods of higher flow, while use of AM/PM/shade corresponded with periods of lower flow.

Crossing the regulation boundary

During the course of the study, five smallmouth bass crossed the regulation boundary at Dayton. They traveled to wintering areas or spring spawning areas. All of the five smallmouth bass in the Dayton area were originally captured and tagged outside of the regulation boundary. Four of these smallmouth bass (49.551, 49.691, 49.551 and 49.532) were observed outside of the regulated area (61%, 71%, 76%, and 92% of observations, respectively). However, two fish (49.691 and 49.532) made long migrations to spawning areas (16.2 and 16.6 km, respectively), and one moved into the regulated area during the summer peak flow event in July. One fish from the Elk River area migrated to the Champlin/Coon Rapids area for winter (25 km), and returned to a spawning area at Elk River by late April, prior to the fishing opener.

Smallmouth bass movement and the influence of warm water

Smallmouth bass annual ranges (farthest extent upstream to farthest extent downstream) were between 1.7 and 54.6 km, with a mean of 13.5 km. Smallmouth bass made distinct fall migrations of up to 27 km to wintering areas, and spring migrations of up to 29 km to spawning areas. Smallmouth bass migration during fall started as early as 28 September and the latest migration towards a wintering area was 29 November. Spring migrations to spawning areas occurred as early as 28 March and extended through 24

May (Table 6). Distance between sequential locations ranged between 3 m and 29,441 m with a median of 80.5 m overall (Table 7). Peak movement rates were observed during May (342.8 m/d) and October (247.2 m/d), and were least noticeable during winter when movement declined to less than 41.9 m/d during December (Figure 6). However, distance measurements during winter may have been biased due to lower sample size and technique (air or triangulation).

There were differences in dates and duration of movement between two groups of smallmouth bass (N= 14, seven upstream and seven downstream of discharge) in the Mississippi River near Monticello. Smallmouth bass migration to wintering areas for fish above the influence of the warm-water discharge at Monticello occurred between 12 September and 24 October. Smallmouth bass within the influence of the warm-water discharge moved to wintering locations between 1 October and 29 November. The migration to wintering areas was significantly earlier for smallmouth bass upstream of the discharge based on the results of a paired T – test α =0.05, than those within the discharge (P=0.018). Alternatively, smallmouth bass downstream of the warm-water discharge began spawning activity earlier than smallmouth bass above the discharge, although not significantly (P= 0.10). The date of movement to spawning areas for smallmouth bass below the discharge was between 28 March and 15 May, while fish upstream of the discharge began movement to spawning areas between 4 April and 22 May. Spawning activity was longer for fish upstream of the influence of the warm water discharge (4 April – 14 June, Mean = 50 d), while the observed spawning activity was shorter for fish below the discharge (28 March –10 June, Mean 43 d). The difference was not significant (P = 0.08).

Several smallmouth bass were observed in potential nesting areas for longer periods; these individuals were presumed to be male. Low water clarity limited our view of spawning activity; however, three male radio-tagged smallmouth bass were observed guarding nests containing smallmouth bass fry as late as 14 June. Other potential spawning locations were verified by observing signs of nest building.

Home range characteristics

Smallmouth bass had net annual distances as far as 54.6 river km; however, distinct areas were occupied by smallmouth bass during summer and winter. Kernel home ranges at the 50% contour (core area of activity) during summer were between 0.08 and 8.07 ha, with a mean home range size of 1.81 ha. Kernel home ranges at the 95% contour were between 0.60 and 24.98 ha with a mean size of 6.49 ha (Table 8). Minimum Convex Polygon (MCP) home ranges during summer were between 0.42 ha and 19.17 ha, with a mean MCP home range size of 4.41 ha. Winter home range calculations were limited to MCP due to smaller sample sizes and varied between 0.22 and 20.18 ha, with a mean of 3.46 ha (Table 8). A non-significant positive relationship ($P = 0.363$, $R^2 = 0.037$) between smallmouth bass length and summer MCP home range size was observed; whereas a non-significant negative relationship ($P = 0.216$, $R^2 = 0.068$) was observed between winter MCP home range size and smallmouth bass length.

A tendency of homing was observed by all but one smallmouth bass in our study. Nearly all smallmouth bass returned to their original sites of capture following the spring spawning migrations in 2002. One fish that was originally captured near Clearwater migrated downstream and established a summer home range near Dayton. However, 23 fish returned to their original 2001 capture site (mean 146 m, range 8 – 700 m).

Patterns in home range size were observed by groups of fish in both summer and winter. St. Cloud and Becker area smallmouth bass had small mean MCP home range sizes in winter (0.4 and 1.4 ha, respectively). However, Elk River and Monticello area smallmouth bass had larger mean MCP home range sizes (6.4 and 6.0 ha, respectively) during winter and were located within 5 km downstream of warm water discharge at Monticello. St. Cloud and Dayton area smallmouth bass had small mean MCP home range sizes in summer (1.9 and 2.0 ha, respectively), whereas, Becker, Elk River and Clearwater smallmouth bass had mean MCP home range sizes between 4.7 ha and 8.5 ha (Table 8).

All-day monitoring

All-day monitoring included locations recorded between 0500 and 2200 hours (N= 382 individual locations) and revealed trends in home range and movement that were slightly different than seasonal analysis. All-day habitat use and depth were similar to summer location data from seasonal analysis. Depths were between 0.15 m and 3.64 m with a mean depth of 1.20 m. Depths throughout the day were shallowest during morning (0500-0900) and evening (1900-2200). Mean depth of locations was 1.13 and 1.06 m, respectively. Mean depths recorded during mid-day (1000-1500) and afternoon (1600-1800) were only slightly greater, 1.3 and 1.27 m respectively (Table 9). During summer all-day monitoring, smallmouth bass used run habitat the majority of the day (45% of all locations), along with eddy (33.8%) and center channel run/eddy (13.9%) habitats (Table 10). Summer all-day monitoring locations indicated that the general habitat type used throughout the day varied somewhat with runs used more during morning and evening, while pool use increased during mid-day and afternoon.

Substrate types used by tagged smallmouth bass during all-day monitoring were predominantly cobble and gravel, 38.2% and 29.8 %, respectively. Least used substrates were boulder and silt, 12.3% and 3.4 %, respectively (Table 11). Substrate use did vary somewhat; and was related to depth and habitat type. An increase in the use of cobble was observed during morning and evening, 43.1% and 45.3%, respectively. An increase in the use of boulder and silt was observed during the afternoon,16.9% and 6.2%, respectively. Overhead cover during all-day monitoring was not discernable for 39.8% of locations. In areas where overhead cover was determined, use of AM/PM/Shade, depth greater than 1.2 m and woody debris were observed at higher frequencies than remaining overhead cover types (Table 12). Use of overhead cover types appeared to change somewhat during the day; bass sought rock during afternoon hours and used woody debris in the evening.

All-day monitoring of smallmouth bass revealed summer home ranges between 0.09 and 34 ha (MCP and Kernel 50). The estimates for Kernel 50 home range from all-day monitoring were significantly larger than summer home range estimates from seasonal analysis (Paired T-test, α =0.05, P = .010). Factors that may have contributed to estimate variability include sample size (all-day, 8 - 20 locations; seasonal, 22 - 31 locations for summer period) and location accuracy. However, there was not a highly significant difference between MCP home range sizes from all-day monitoring and seasonal estimates (P = 0.33). Smallmouth bass traveled less between locations during all-day monitoring (0.9 – 1470.2 m, mean 124.7 m)(Table 13) than distances calculated in seasonal values for each group of fish (0.0 – 2604.6 m, mean 157.7 m). The difference was not highly significant (P = 0.10).

At the end of our study, we attempted to recover radio-tagged smallmouth bass by electrofishing and angling. Our efforts were hampered by above average discharge during August 2002, and below average water clarity. We recaptured seven radio-tagged smallmouth bass in an effort to document effects of transmitter surgery and healing, verify sex, and estimate age and growth. We found that smallmouth bass were incorrectly sexed at the time of surgery, 30 – 40% of the time, and the impact of transmitter surgery appeared minimal. Growth over the period varied between 5 and 28 mm for the seven fish recaptured. However, there may have been some bias that could be attributed to the transmitter's effect on individual fish growth. Internal body condition of all recaptured fish indicated that the growth of implanted smallmouth bass was likely not affected by tag implant surgery. Generous amounts of fat was observed in the peritoneal cavity of all smallmouth bass recaptured. This fat build up was also observed in smallmouth bass without radio transmitters during DNR electrofishing on the Mississippi River in 2002.

Discussion

Seasonal movements and habitat use

During fall, smallmouth bass were apparently active up to the period they entered wintering areas. The dates of migration appeared to coincide with an abrupt increase and subsequent decrease in water temperature during October 2001. At their wintering sites, bass were much less active and used areas of slack current that were shallower than suggested by previous studies (Langhurst and Schoenike 1990, Lyons and Kanehl 2000, Marod 1994, Munther 1970). The use of pools or large eddy areas relatively devoid of current was noticeable during the coldest months of the study whereas run habitat was used more often in summer. Wintering locations were maintained through April 2002 for the majority of the smallmouth bass tracked. Most movement during spring occurred following an abrupt rise in water temperature, and smallmouth bass appeared to migrate to areas conducive to spawning (Figure 7). These areas were typified by slower current with gravel and sand as the dominant substrate types. Most bedding activity occurred in eddy, backwater, or in the lee of islands. Only one of the smallmouth bass appeared to use a tributary for spawning. The migration of several fish from the Monticello and Clearwater areas to spawn just downstream of the St. Cloud dam was unexpected. The area just downstream of St. Cloud has many islands and provides the most diverse habitat in this portion of the Mississippi River. The use of this area by other fish species during spring has been documented through angler accounts; however, electrofishing surveys to document the congregation of fish in the area have not been performed. This area is within the limits of St. Cloud and the Minnesota Scenic River designation. The potential for development is high. Population growth is predicted to significantly increase by 2020, and there is undeveloped land immediately downstream. While the scenic designation offers some level of protection, the ultimate decision about development within city limits is up to local government units. During 2003, the DNR will attempt to document spawning congregations of smallmouth bass and other species by electrofishing. Outreach efforts will be made to communicate to local government officials the importance of preserving riparian habitat and undisturbed shoreline in the St. Cloud area.

Habitat types used by smallmouth bass in our study were predominantly eddies. These areas where rock or woody debris have diverted current from the bank create a velocity void. These eddies generally have a deeper portion where the current has scoured the substrate. Substrate composition in most eddies used by smallmouth bass in our study was sand in deeper portions (> 1.2 m), and sand/gravel in portions that were shallower. Our study suggested that these habitat types are important during all parts of the year for some smallmouth bass. Pressure from encroaching development and increases in impervious surfaces may result in an increase in silt deposition in these critical areas. Consideration should be given to increasing the use of buffer strips as a tool to reduce the impacts of runoff into the Mississippi River and its tributaries.

Crossing the regulation boundary and potential effect on population structure

The tendency for smallmouth bass to move great distances in our study may have affected population size structure in the past. In the history of the bass regulation on the Mississippi River, there have been two sets of boundaries; Clearwater to Elk River (1990-1999) and St. Cloud to Dayton (1999-current)(Figure 1). Our telemetry data showed that smallmouth bass residing from 9.1 km upstream to 3.2 km downstream crossed the current regulation boundary in Dayton during the spring, fall and periods of higher than average discharge. Some fish from the Dayton area moved as far as 15 km upstream during spring to spawn, whereas one fish from upstream of the boundary moved 17 km downstream to a wintering area. The early regulation boundary may have allowed fish to be more vulnerable to harvest because several wintering and spawning areas were outside of the protected regulation area. Prior to the statewide closure to harvest, there may have been increased opportunities to harvest smallmouth bass in fall and winter hibernacula.

It appears that since the placement of the original experimental regulation boundaries, the population has experienced favorable changes. Electrofishing catch rates have significantly increased (Paired T-test α = 0.05, P = 0.004) for the target size range (305 - 508 mm) from the 11-year period prior to the initial regulation in1990 to the 11- year period after 1990. There has been less variation in year class production since 1992 (Figure 2). In addition, the implementation of the statewide fall no-harvest rule for smallmouth bass may have kept spawning stock in the population for longer periods. The increased abundance of brood stock smallmouth bass and more stable discharge profiles during spring may have decreased variability in year class production since 1992.

The increase in the regulation boundary to include the area from St. Cloud to Dayton, has likely offered further protection to a portion of the population. During annual electrofishing since 1999, catch rates seemed to improve in the St. Cloud and Clearwater stations (previously located above the regulated boundary); however, more data will need to be collected to determine if the improvement is significant. It seems likely that if the regulation has been offering more protection from harvest there may be future increases in catch rates of target size smallmouth bass in both of the previously unregulated areas of the Mississippi River from St. Cloud to Clearwater and Elk River to Dayton. Future electrofishing efforts in these areas may indicate whether a change in the smallmouth bass population has occurred due to the increased regulation area.

Effects of channel size and morphology

Smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids exhibited large annual movements (mean 13.6 km). This has distinct implications for management of smallmouth bass in the Mississippi River. Todd and Rabeni (1989) found that smallmouth bass occupy summer home ranges (0.05 - 0.5 ha) in the Jacks Fork River in Missouri that were smaller than what was observed on the Mississippi River. The sections studied in the Jacks Fork River were narrower (29.5 and 44.5 m) than the section used in this study (264 m). Similarly, smallmouth bass in the Huron River in Michigan had smaller ranges of movement (20 - 370 m) than the Mississippi River, but again, the channel width was smaller (28 - 45 m)(Beam 1990). Lyons and Kanehl (2000) also found a limited range (6.5 km mean) for smallmouth bass in the Pecatonica River of Wisconsin. This system was also morphologically smaller than the Mississippi River.

Populations of smallmouth bass appear to have varying movement patterns and home range size based on local river morphology. The Mississippi River in the study area had a mean width of 264 m, which suggests that smallmouth bass populations in larger river systems may occupy larger home ranges and migrate longer distances. The period when most movement occurred in our study was during spring, to and from spawning areas. Perhaps in smaller systems, all of the required habitat components exist within a shorter distance of a typical home range. Conversely, in a larger river system such as the Mississippi, the preferred habitat may only be available in certain areas. Although habitat measurements were not performed, the Mississippi River has relatively low diversity of habitat types throughout much of the study area. Several of our smallmouth bass traveled long distances during spring to areas that had a higher concentration of islands. It is likely that these areas with islands offer diverse habitat that has suitable substrate and velocity refuges for nesting.

Several other species of fish in large river systems appear to have large seasonal migrations from their normal home ranges (Pitlo 1985, Pegg et.al. 1997, Snedden et. al. 1999, Ickes et.al. 2000). Ickes et al (2000) found that a population of walleye and sauger in pool 4 of the Mississippi River occupied an annual range between 37 and 61 km, and that thermally treated water had no apparent effect on distribution of these two species. Similarly, spotted gar in the Atchafalaya River basin in Louisiana were found to have home range areas between 1.0 and 1627.3 ha with a median home range size of 265 ha (Snedden et.al. 1999). The authors suggested habitat variability and flood pulse as factors that led to larger distributions.

The influence of warm water and catch & release angling

A portion of the regulated area is influenced by warm-water discharge from the nuclear power generation facility at Monticello. The influence of warm-water discharge on fish behavior has been researched (Ickes et al 1999, Cooke and Bunt 2000); but the influence of warm water discharge on smallmouth bass in this portion of the Mississippi River has not been evaluated. In our study, groups of smallmouth bass that wintered above and below the discharge plume moved at different times to wintering areas and to spawning areas. This warm-water discharge elevated temperatures on the west side of the river channel in a band 20-100 m wide, and up to 10 km downstream of the plant. While these differences may influence a portion of the population, the telemetry data suggest that the warm-water discharge does not draw fish from more than a few kilometers either upstream or downstream of the nuclear plant. This is contrary to angler reports of many smallmouth bass caught in the warm-water discharge during winter. Increased activity of smallmouth bass caused by the influence of the warm-water discharge may lead us to believe there are more fish in the area.

Several of the radio-tagged smallmouth bass were caught and released by anglers. Three radio-tagged fish were caught multiple times. In all, we had 15 reports of radio tagged smallmouth bass caught and released by anglers. The survival of angler caught smallmouth bass has been perceived by some of the angling public as an issue of concern. The limited information from our radio-telemetry fish may suggest that survival could be high even with the potential impact of angling and transmitter surgery.

Effects of hydropower discharge

The relationship between discharge and smallmouth bass nesting success has been previously evaluated in this stretch of the Mississippi River (Swenson et al. 1989, Simonson and Swenson 1990, Hiebert 1999) and in other systems (Paragamian and Wiley 1987, Lukas and Orth 1995). Operations of the hydroelectric dam in St. Cloud may alter natural discharge profiles during daily operation. During typical operations of the facility, weekly cleaning and subsequent closure and reopening of gates at the outlet structure cause changes in stage and discharge (up to 0.3 m and 84 m^3/s, respectively) over a three to four hour period. These abrupt changes have the potential to cause water in nesting areas to become too shallow for smallmouth bass to use.

Our telemetry data suggest that smallmouth bass spawn timing (28 March - 14 June) may be vulnerable to hydroelectric dam operations if screen cleaning (reducing discharge) or high electrical demand events (increasing discharge) occur during this time period. Four smallmouth bass migrated during spring (up to 26 km) to build nests and spawn in the Beaver Islands area, less than one kilometer downstream of the St. Cloud Dam. The presence of quality spawning habitat (eddies and side channels behind islands) found in the St. Cloud area may put a significant spawning population of smallmouth bass at risk of nest abandonment, and subsequent year class failure, if flows are altered at this sensitive time. This influence may be exaggerated if sudden drops in discharge occur at flows below 200 m^3/s during peak nest guarding in June (Swenson et. al. 1989, Simonson and Swenson 1990). Our observations from spring 2002 indicated that two radio-tagged smallmouth bass may have abandoned nests in backwater areas during this time, when discharges dropped below 150 m^3/s. Smallmouth bass year class strength can be positively influenced by lower discharge between April and June when nesting occurs; however, abrupt changes in stage during this time may cause potential failure. Hiebert (1999) documented that mean flows below 170 m^3/s during May and June resulted in subsequent good year class production for smallmouth bass in the Mississippi River.

Flows between 150 and 200 m^3/s may offer smallmouth bass a best-case scenario for spawning. However, this level of flow may be difficult to control given typical environmental conditions during spring. If natural flows are allowed to persist, this should allow for smallmouth bass to nest and guard successfully. Agreements have been made with controlling authorities at the St. Cloud dam to minimize adjustments to flow; however, efforts need to be made to avoid major fluctuations during typical spawning seasons.

Sampling concerns

The size of the study area and environmental conditions during the study period may have affected our interpretation of overall distribution of smallmouth bass. However, time, technological and budget constraints limited study duration. An ideal study period would have included two full years of telemetry to document nesting site fidelity, wintering site fidelity, and repetitive migration patterns.

Discharge was abnormally low during June and abnormally high during July and August of 2002; mean flows for July and August 2002 were 35% greater than the 14 year mean (Figure 5). These abnormally high flows may have affected smallmouth bass behavior by allowing flooded terrestrial habitat to be available during high flow periods. In contrast, the observation of nest abandonment (2 fish) due to dropping water levels during our study, may not have been as prevalent during a year with a more normal discharge curve.

The value of the information gained from telemetry is high, however, insight into the movement, migration, age and growth and distribution of smaller smallmouth bass is still lacking. The information gained from the seven radio-tagged fish we recaptured has led to increased scrutiny of age and growth of smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids dams. The use of external tags that remain in place for several years would allow for better estimates of age and growth and distribution. Widespread external tagging of smallmouth bass may shed light on the movement, distribution, age and growth of smaller fish and corroborate the information collected from telemetry. By tagging all smallmouth bass captured during annual electrofishing (range = 200-700) and documenting recaptures by electrofishing and angler returns, a better understanding of age, growth, distribution, and movement the greater portion of the population may be gained.

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Table 1. Summary of tagging and tracking history of radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Transmitter frequency (MHZ)	Total length (mm)	Weight (g)	Tag size (g)	Sex	Date implanted	Date last located	Number of times located	Number of days at large
49.025	475	1700	14.2	F	15-Aug-2001	19-Mar-2002	36	216
49.045	446	1275	14.2	M	15-Aug-2001	19-Aug-2002	96	369
49.065	467	1625	14.2	F	16-Aug-2001	19-Mar-2002	39	215
49.095	449	1350	14.2	F	15-Aug-2001	19-Aug-2002	98	369
49.115	412	900	14.2	F	7-Sep-2001	19-Aug-2002	92	346
49.134	418	1100	14.2	F	16-Aug-2001	23-Aug-2001	2	7
49.154	461	1575	14.2	M	16-Aug-2001	19-Aug-2002	102	368
49.174	425	1150	14.2	F	17-Aug-2001	19-Aug-2002	89	367
49.191	428	1160	14.2	M	15-Aug-2001	19-Aug-2002	98	369
49.211	378	830	14.2	F	17-Aug-2001	19-Aug-2002	84	367
49.231	415	1000	14.2	F	17-Aug-2001	19-Aug-2002	91	367
49.271	407	1050	14.2	M	17-Aug-2001	19-Aug-2002	52	367
49.291	373	816	14.2	M	17-Aug-2001	19-Aug-2002	105	367
49.311	355	750	14.2	M	17-Aug-2001	19-Aug-2002	94	367
49.351	434	1050	14.2	F	7-Sep-2001	19-Aug-2002	100	346
49.371	429	1100	14.2	M	20-Aug-2001	19-Aug-2002	97	364
49.391	461	1460	14.2	F	20-Aug-2001	19-Aug-2002	96	364
49.411	398	1040	14.2	F	20-Aug-2001	19-Aug-2002	93	364
49.431	386	820	14.2	F	20-Aug-2001	19-Aug-2002	98	364
49.451	405	910	14.2	F	20-Aug-2001	19-Aug-2002	26	364
49.471	363	680	14.2	M	7-Sep-2001	19-Mar-2002	35	193
49.491	453	1450	14.2	F	20-Aug-2001	19-Aug-2002	97	364
49.511	493	1500	14.2	F	21-Aug-2001	19-Aug-2002	31	363
49.532	411	1080	14.2	F	21-Aug-2001	19-Aug-2002	97	363
49.551	375	865	14.2	M	21-Aug-2001	15-Jul-2002	77	328
49.591	376	715	14.2	M	21-Aug-2001	19-Aug-2002	95	363
49.611	335	520	7.8	M	15-Aug-2001	19-Aug-2002	101	369
49.631	339	570	7.8	F	16-Aug-2001	19-Aug-2002	101	368
49.651	319	470	7.8	F	17-Aug-2001	24-Jul-2002	74	341
49.671	454	1280	7.8	F	7-Sep-2001	19-Aug-2002	94	346
49.691	349	620	7.8	M	21-Aug-2001	19-Aug-2002	88	363

Table 2. Depth (m) used by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Depth (m)	Sept	Oct	Nov	Dec	Jan-Mar	Apr	May	Jun	Jul	Aug	Overall
Min	0.31	0.31	0.31	0.62	0.31	0.22	0.31	0.15	0.15	0.31	0.15
Mean	1.52	1.84	1.96	1.95	1.66	1.97	1.23	1.07	1.33	1.28	1.55
Max	5.23	5.85	6.46	6.46	4.62	7.38	4.62	3.08	4.31	4.62	7.38

Table 3. Habitat type used (percent) by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Type	Sept	Oct	Nov	Dec	Jan-Mar	Apr	May	Jun	Jul	Aug	Overall
Eddy	6.5	23.4	14.9	28.1	20.5	53.2	51.4	28.5	45.7	31.2	32.7
Pool	20.4	56.0	61.5	39.3	66.7	29.5	12.1	6.3	5.0	4.5	27.1
Run	51.6	16.1	12.8	15.7	12.8	6.4	13.1	40.1	31.2	57.1	25.4
Center channel run/eddy	18.8	3.7	5.4	14.6	0.0	2.3	14.5	19.3	9.0	4.5	9.7
Backwater	0.0	0.7	4.7	2.2	0.0	6.8	9.0	1.0	7.0	0.0	3.7
Riffle	2.7	0.0	0.0	0.0	0.0	0.0	0.0	4.8	1.5	2.6	1.2

Table 4. Substrates used (percent) by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Substrate	Sept	Oct	Nov	Dec	Jan-mar	Apr	May	Jun	Jul	Aug	Overall
Cobble	44.1	31.1	18.9	9.0	7.7	17.7	21.4	37.7	36.7	48.7	29.1
Sand	18.8	27.8	29.1	40.4	42.3	36.8	47.6	15.0	14.1	13.6	28.3
Gravel	33.3	23.4	12.2	19.1	17.9	20.0	21.7	31.4	30.2	26.6	24.3
Silt	0.5	10.6	33.8	27.0	28.2	24.1	3.8	1.4	11.1	3.2	11.9
Boulder	3.2	7.0	6.1	4.5	3.8	1.4	5.5	14.5	8.0	7.8	6.4

Table 5. Overhead cover type used (percent) by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Overhead cover	Sept.	Oct.	Nov.	Dec.	Jan.-Mar.	Apr.	May	Jun.	Jul.	Aug.	Overall
Not noticeable	26.3	32.2	39.9	55.1	47.4	31.4	39.0	57.5	37.2	50.0	39.8
Depth	45.7	48.7	38.5	38.2	28.2	30.5	17.6	15.9	18.6	18.8	29.7
Woody debris	5.9	5.1	6.1	2.2	1.3	21.8	19.0	3.4	23.1	7.1	11.1
Rock	8.6	8.4	12.2	2.2	1.3	6.4	12.8	13.0	4.5	11.0	8.9
AM/PM/shade	12.9	0.7	0.7	0.0	0.0	2.7	9.7	7.2	6.5	12.3	5.9
Vegetation	0.0	1.1	2.7	1.1	0.0	0.0	0.0	2.4	8.5	0.0	1.6
Ice	0.0	0.0	0.0	1.1	21.8	4.5	0.0	0.0	0.0	0.0	1.5
Root wad	0.0	1.1	0.0	0.0	0.0	0.5	1.7	0.5	1.0	0.0	0.7
Bridge piling	0.5	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Flotsam	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.5	0.0	0.3
Undercut	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.6	0.1

Table 6. Dates of movement and temperatures for radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Date of fall movement	Temperature (°C)	Date of spring movement	Temperature (°C)
9/12/2001	20.0	3/28/2002	6.7
10/18/2001	12.2	4/30/2002	12.6
10/17/2001	12.2	5/4/2002	12.8
11/29/2001	1.1	5/24/2002	16.7

Table 7. Summary of distances traveled (m) between locations of radio-tagged smallmouth bass (boat locations) in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

Transmitter frequency (MHZ)	Minimum	Mean	Maximum	Sum
49.045	4.1	924.5	29441.7	90602.2
49.095	1.5	508.3	16567.3	50832.4
49.115	0.0	652.0	16645.7	54767.3
49.154	1.8	348.8	6930.5	35928.3
49.174	4.0	219.1	1620.2	17529.5
49.191	1.1	882.6	24190.8	86491.8
49.211	3.6	217.0	3286.1	16274.9
49.231	2.4	198.8	3054.9	16104.7
49.291	3.0	709.6	28910.6	68826.5
49.311	0.0	526.7	12575.7	46347.8
49.351	0.5	274.2	3545.2	27692.2
49.371	2.0	189.6	2211.1	17444.0
49.391	0.7	194.1	1732.1	17466.1
49.411	1.9	804.6	25233.6	70001.2
49.431	2.3	383.4	12229.3	35268.8
49.491	1.6	460.1	11960.2	41870.0
49.532	0.8	621.6	16777.8	55946.3
49.551	2.8	376.3	6290.2	23705.6
49.591	1.3	153.0	2586.6	13463.5
49.611	2.0	100.2	1391.8	10119.9
49.631	3.0	267.1	3379.3	26980.7
49.651	3.0	146.3	2074.7	9656.1
49.671	0.0	263.1	2286.4	23418.1
49.691	1.4	807.5	16231.2	69442.3

Table 8. Summary of home range areas (ha) of radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, September 2001 through August 2002.

		MCP (ha)		Kernel Summer (ha)	
Area	**Frequency**	**Summer**	**Winter**	**Kernel 50**	**Kernel 95**
	49.174	2.22	0.27	0.28	5.21
	49.211	1.00	0.22	8.07	1.48
	49.231	1.04	0.57	0.52	1.72
St. Cloud	49.651	0.51	0.54	0.21	4.63
	49.115	5.07	0.64	3.11	8.60
	49.311	4.71	2.27	1.44	5.82
Clearwater	49.671	4.34	3.45	3.31	8.23
	49.045	7.85	3.76	5.49	1.95
	49.095	9.95	0.26	0.56	12.18
	49.191	15.37	0.85	0.97	24.98
Becker	49.611	0.94	3.33	0.46	1.23
	49.154	0.49	2.97	4.35	1.27
	49.351	2.35	1.03	1.42	3.34
Monticello	49.631	7.12	8.47	0.08	14.25
	49.371	2.58	6.15	0.44	5.23
	49.391	4.31	7.05	1.51	5.44
	49.411	19.17	3.05	1.23	23.46
	49.431	2.11	0.33	4.46	4.93
Elk River	49.491	4.38	1.56	1.93	5.92
	49.291	6.70	6.66	0.27	7.21
	49.532	0.63	3.06	0.43	1.89
	49.551	0.42	3.13	1.47	2.77
	49.591	0.86	3.28	0.41	0.60
Dayton	49.691	1.70	20.18	1.02	3.47
	Min	0.42	0.22	0.08	0.60
	Mean	4.41	3.46	1.81	6.49
	Max	19.17	20.18	8.07	24.98

Table 9. Depth (m) used by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, during all-day monitoring, 17 June through 8 August 2002.

Depth	Morning	Mid-day	Afternoon	Evening	Overall
Minimum	0.15	0.30	0.30	0.30	0.15
Mean	1.13	1.30	1.27	1.06	1.20
Maximum	3.34	3.65	3.04	3.04	3.65

Table 10. Habitat type used (percent) by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, during all-day monitoring, 17 June through 8 August 2002.

Type	Morning	Mid-day	Afternoon	Evening	Overall
Run	49.0	40.0	46.2	48.0	45.0
Eddy	25.5	38.6	32.3	37.3	33.8
Center channel Run/eddy	19.6	12.9	15.4	6.7	13.9
Pool	2.0	6.4	4.6	4.0	4.5
Riffle	2.9	2.1	0.0	0.0	1.6
Backwater	1.0	0.0	1.5	4.0	1.3

Table 11. Substrate type used (percent) by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, during all-day monitoring, 17 June through 8 August 2002.

Substrate type	Morning	Mid-day	Afternoon	Evening	Overall
Cobble	43.1	31.4	36.9	45.3	38.2
Gravel	26.5	32.9	26.2	32.0	29.8
Sand	15.7	19.3	13.8	13.3	16.2
Boulder	12.7	12.9	16.9	6.7	12.3
Silt	2.0	3.6	6.2	2.7	3.4

Table 12. Overhead cover type used (percent) by radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, during all-day monitoring, 17 June through 8 August 2002.

Overhead cover	Morning	Mid-day	Afternoon	Evening	Overall
Not noticeable	46.1	48.6	32.3	21.3	39.8
AM/PM/shade	25.5	12.9	32.3	44.0	25.7
Depth	11.8	17.1	12.3	8.0	13.1
Woody debris	7.8	11.4	12.3	18.7	12.0
Vegetation	3.9	2.9	4.6	4.0	3.7
Rock	3.9	2.9	4.6	2.7	3.4
Root wad	1.0	2.1	0.0	1.3	1.3
Flotsam	0.0	0.7	1.5	0.0	0.5
Undercut	0.0	1.4	0.0	0.0	0.5

Table 13. Summary of distances traveled (m) between locations of groups of radio-tagged smallmouth bass in the Mississippi River between St. Cloud and Coon Rapids, MN, during all-day monitoring, 17 June through 8 August 2002.

Distance (m)	St. Cloud	Clearwater	Becker	Monticello	Elk River	Dayton	Overall
Sum	9937.5	3717.2	5781.7	8981.8	7245.5	7618.3	43282.0
Minimum	1.1	6.2	2.0	3.2	0.9	1.6	0.9
Mean	152.9	82.6	123.0	204.1	106.6	97.7	124.7
Maximum	833.7	313.5	336.8	1470.2	1059.0	581.0	1470.2

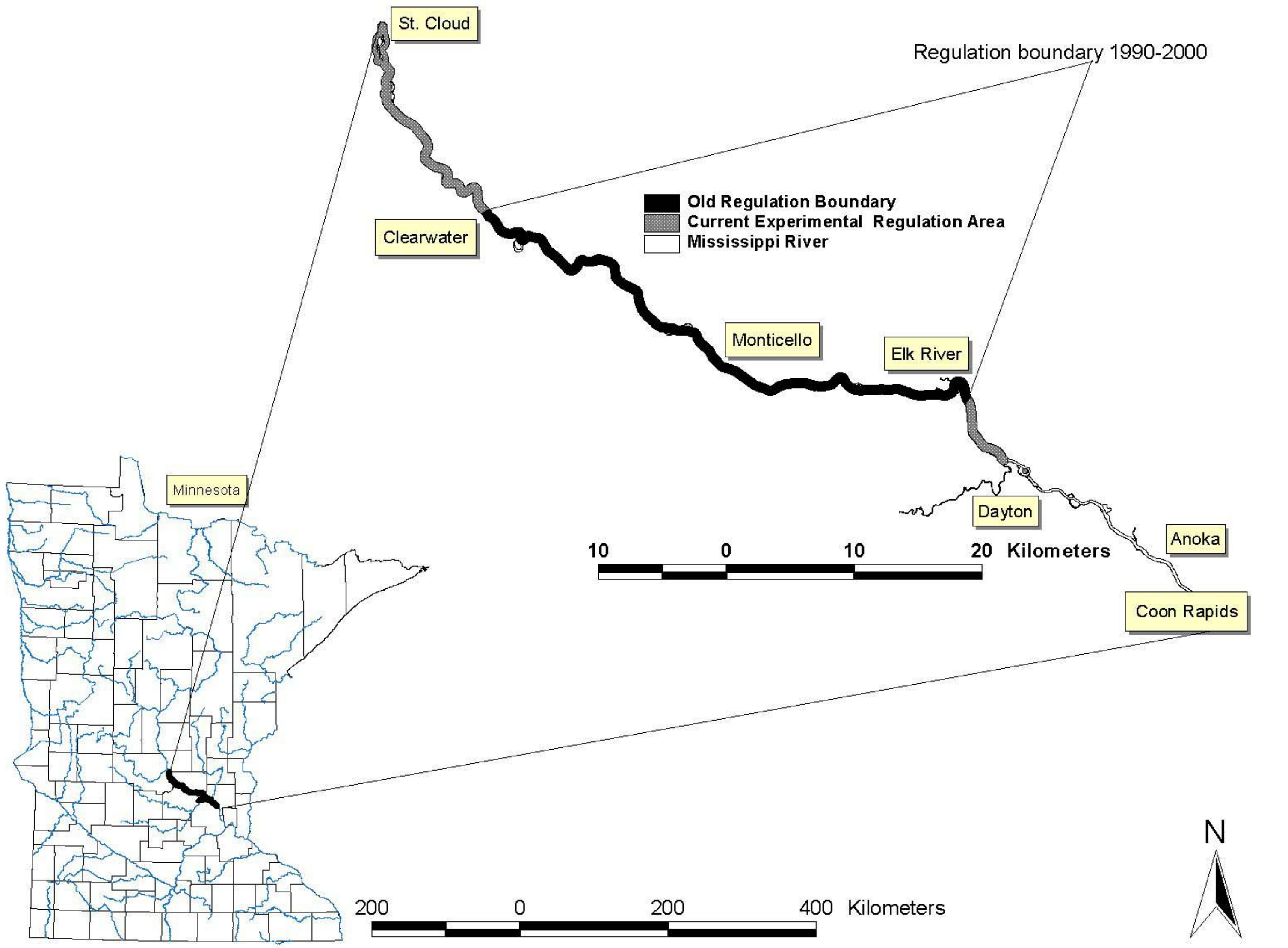


Figure 1. Study area with in the Mississippi River between St. Cloud dam and Coon Rapids Dam, Minnesota, 2001-2002.

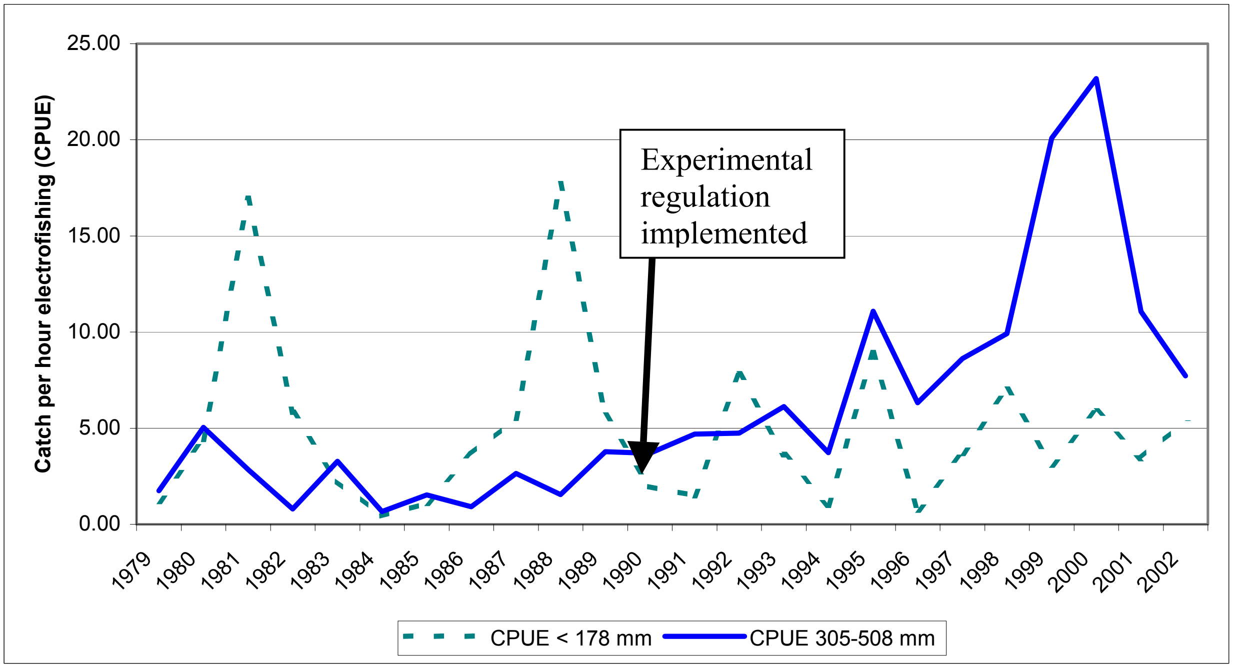


Figure 2. Catch per hour of smallmouth bass, < 178 mm and 305-508 mm collected by electrofishing on the Mississippi River near Monticello, Minnesota by Xcel energy 1979-2002.

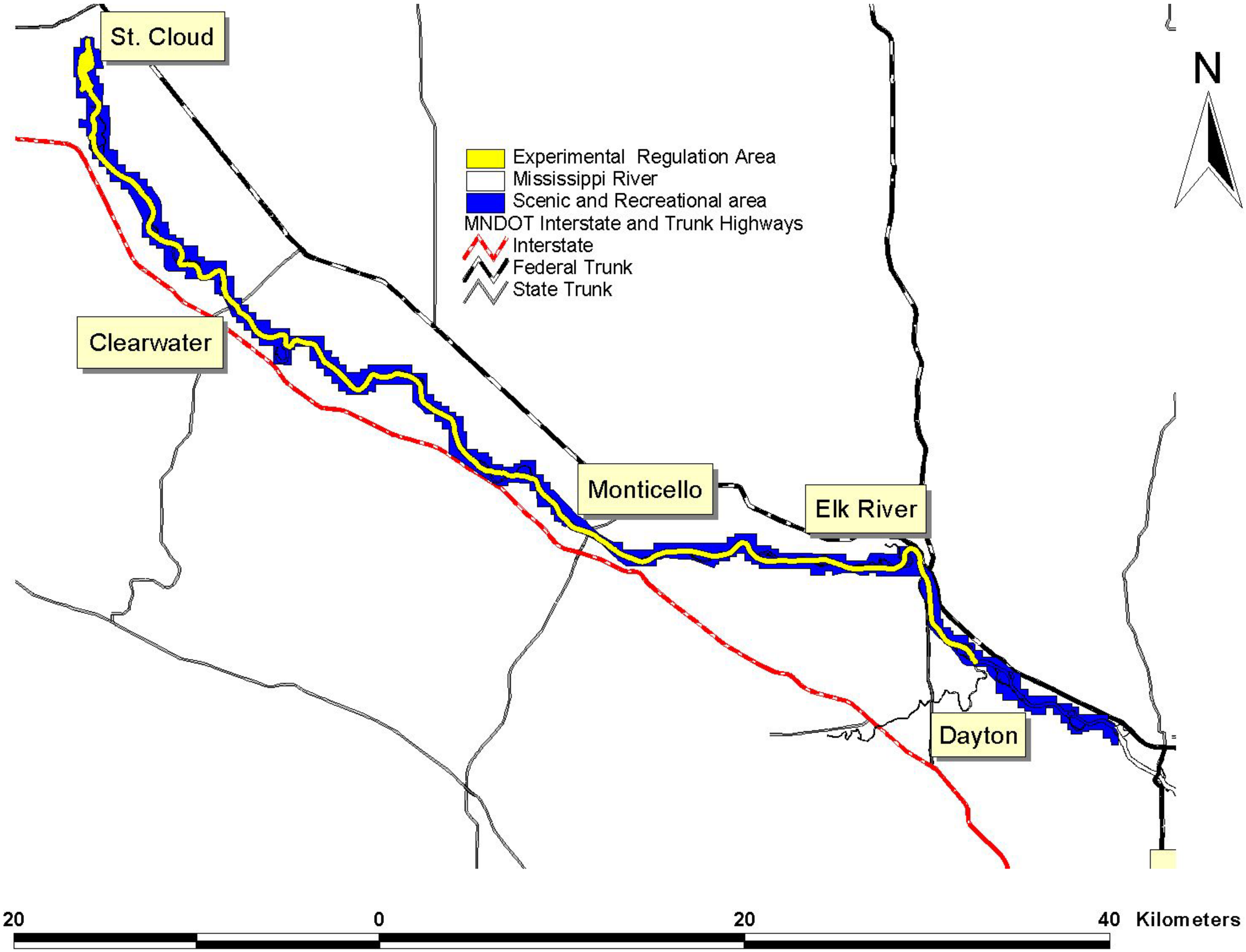


Figure 3. Scenic and recreational boundary of the Mississippi River between St. Cloud Dam and Coon Rapids Dam.

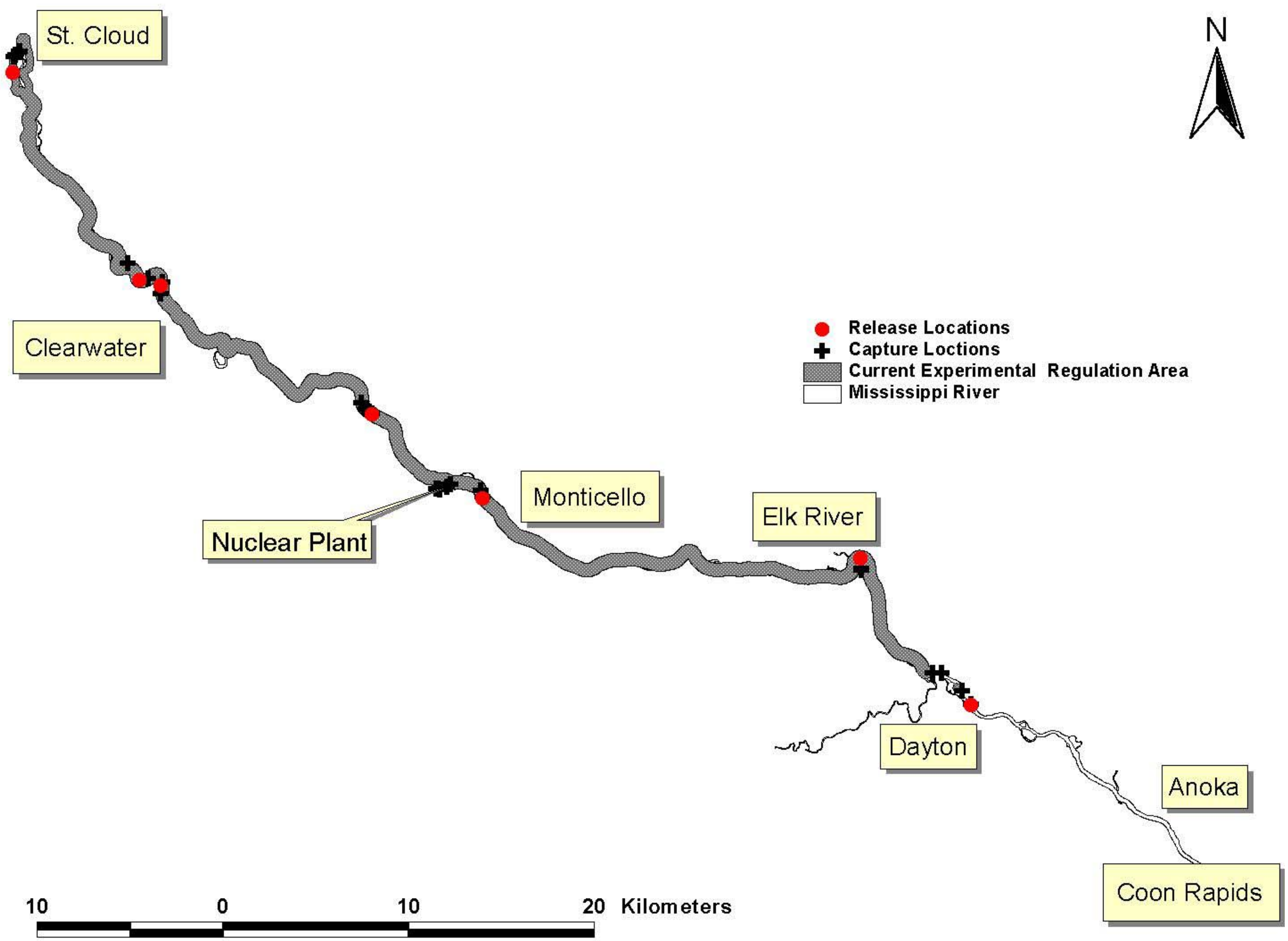


Figure 4. Capture and release sites of radio tagged smallmouth bass on the Mississippi River between St. Cloud dam and Coon Rapids Dam, Minnesota, 2001-2002.

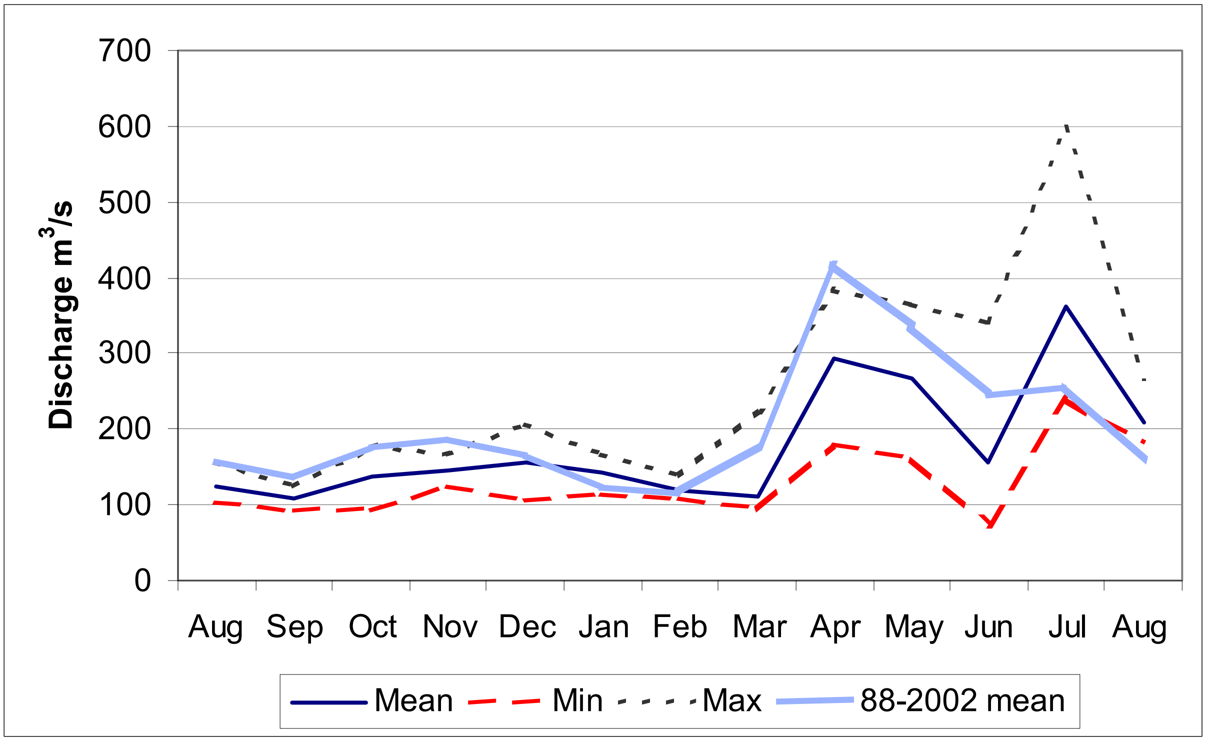
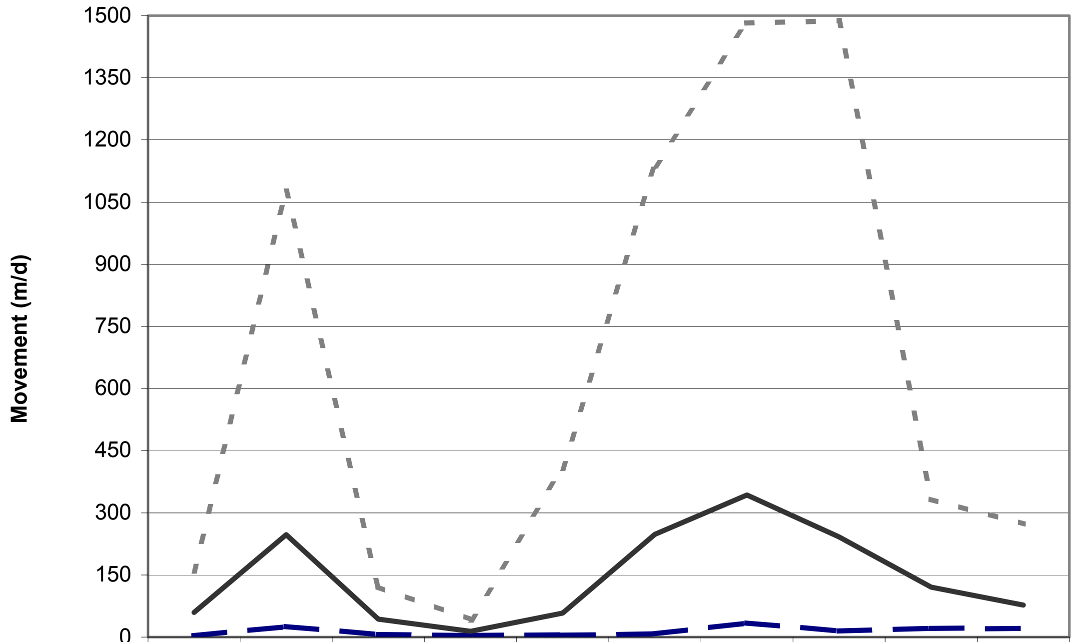


Figure 5. Minimum, mean, and maximum monthly discharge, and 1988-2002 mean discharge (m^3/s) from St. Cloud Dam, Mississippi River, Minnesota, from 1 August 2001 to 31 August 2002.



	Sept	Oct	Nov	Dec	Mar	Apr	May	Jun	Jul	Aug
Min Daily	3.1	25.7	6.3	3.6	4.5	7.9	34.3	14.6	21.0	20.3
Mean Daily	59.8	247.2	43.1	13.6	57.6	248.1	342.8	242.1	120.5	77.5
Max Daily	159.0	1076.5	121.4	41.9	407.3	1138.0	1482.0	1487.4	333.0	272.4

Figure 6. Smallmouth bass minimum, maximum and mean movement between positions (m/d) on the Mississippi River between St. Cloud dam and Coon Rapids Dam, Minnesota 2001-2002.

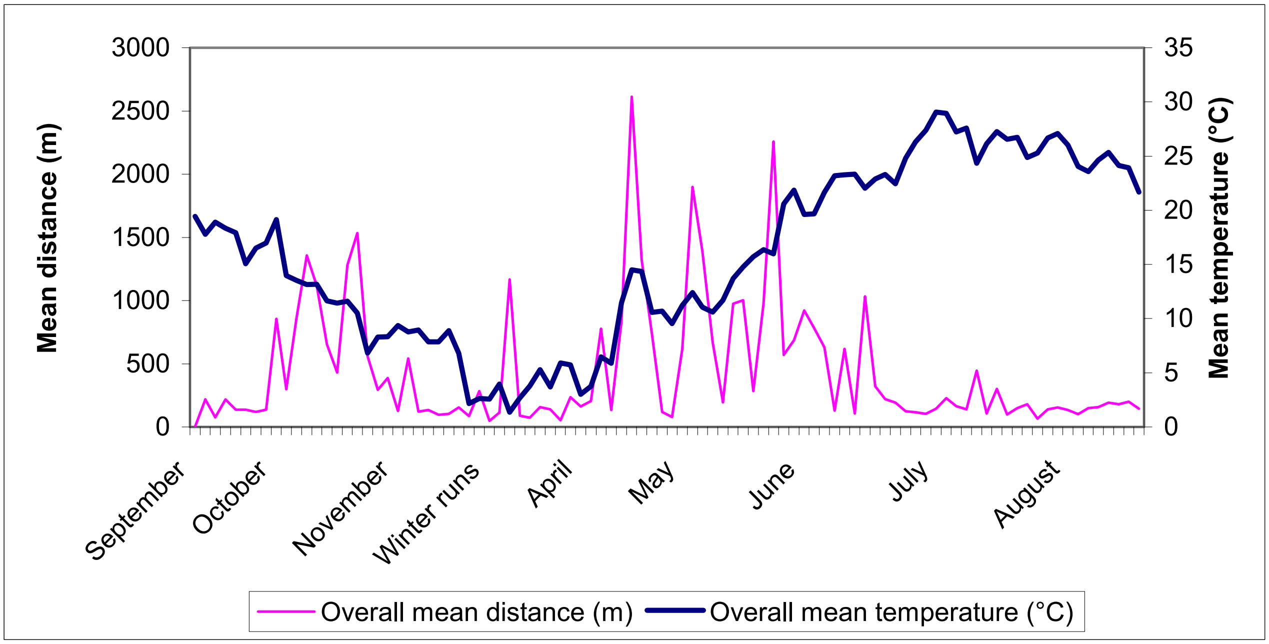
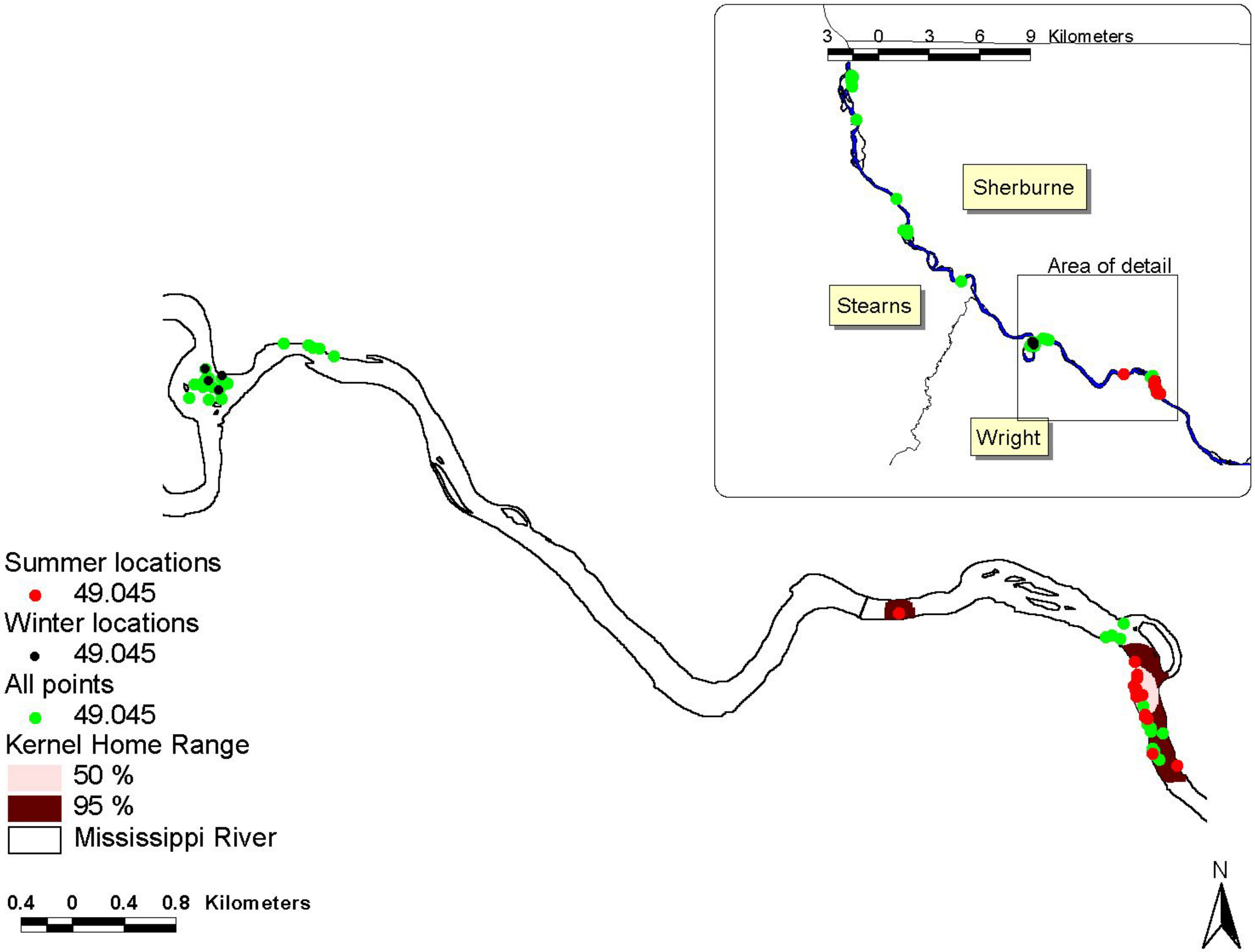
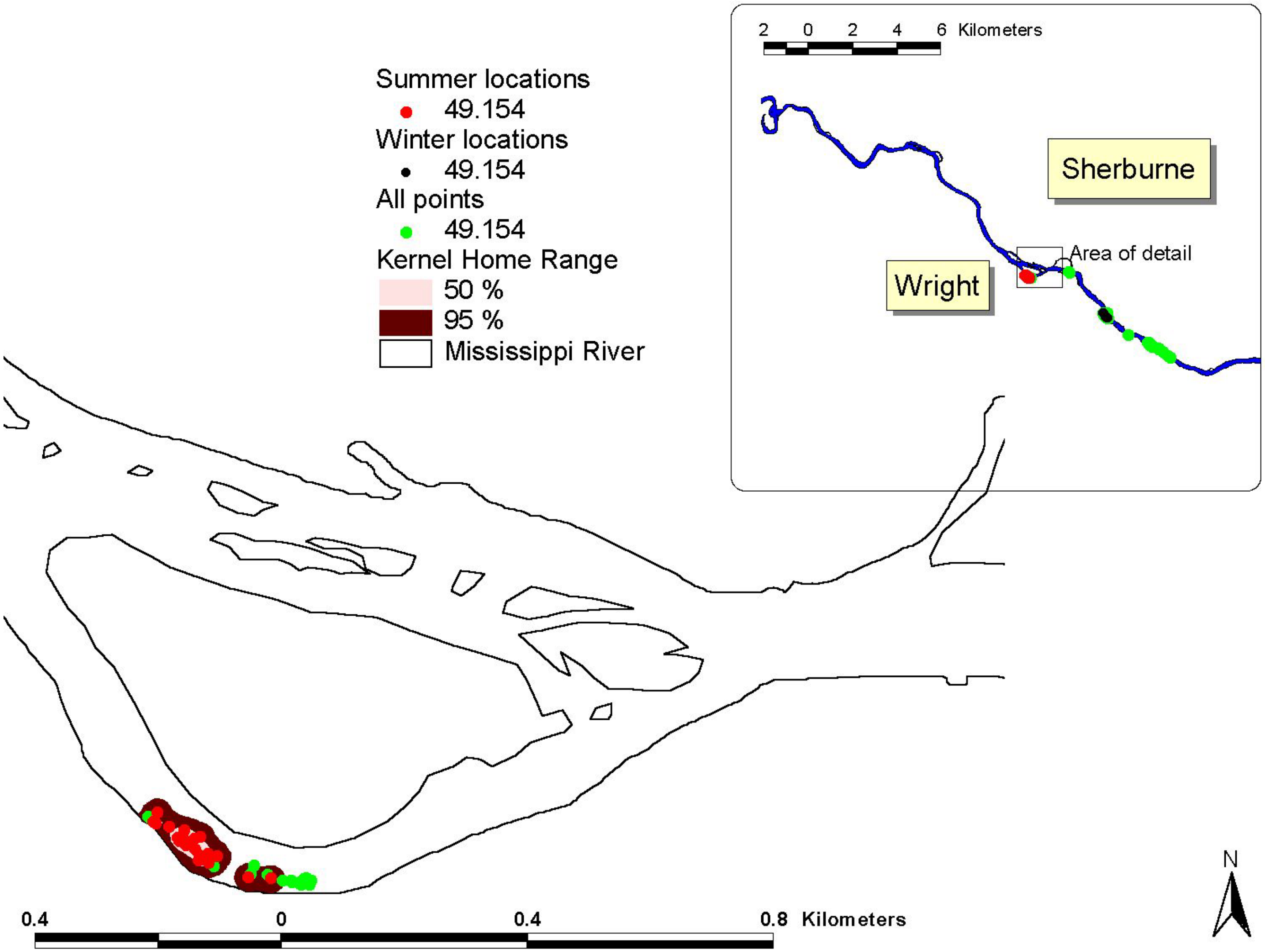
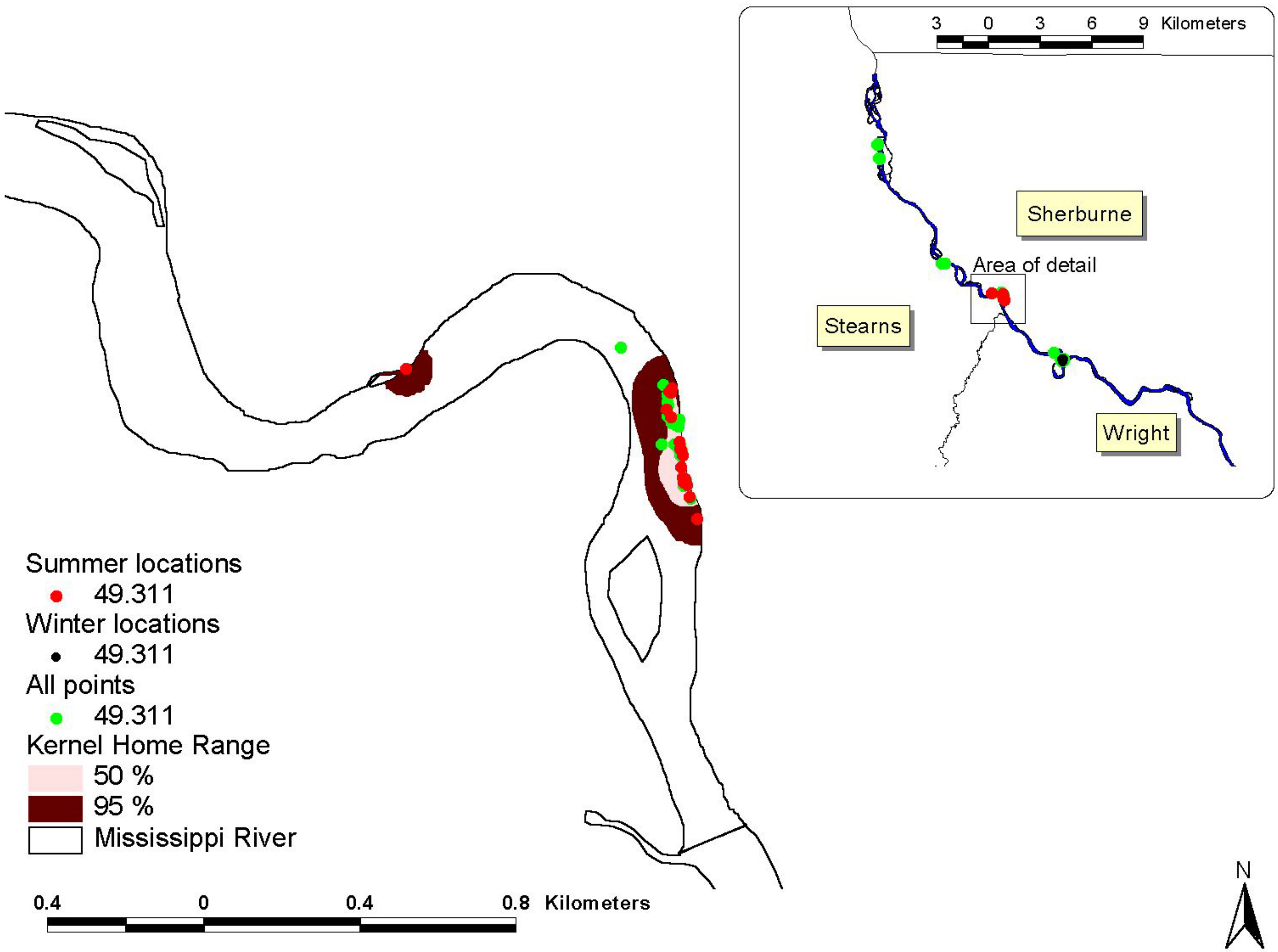


Figure 7. A comparison of smallmouth bass mean distance (m) and mean water temperature (°C) on the Mississippi River between St. Cloud dam and Coon Rapids Dam, Minnesota, 2001-2002.

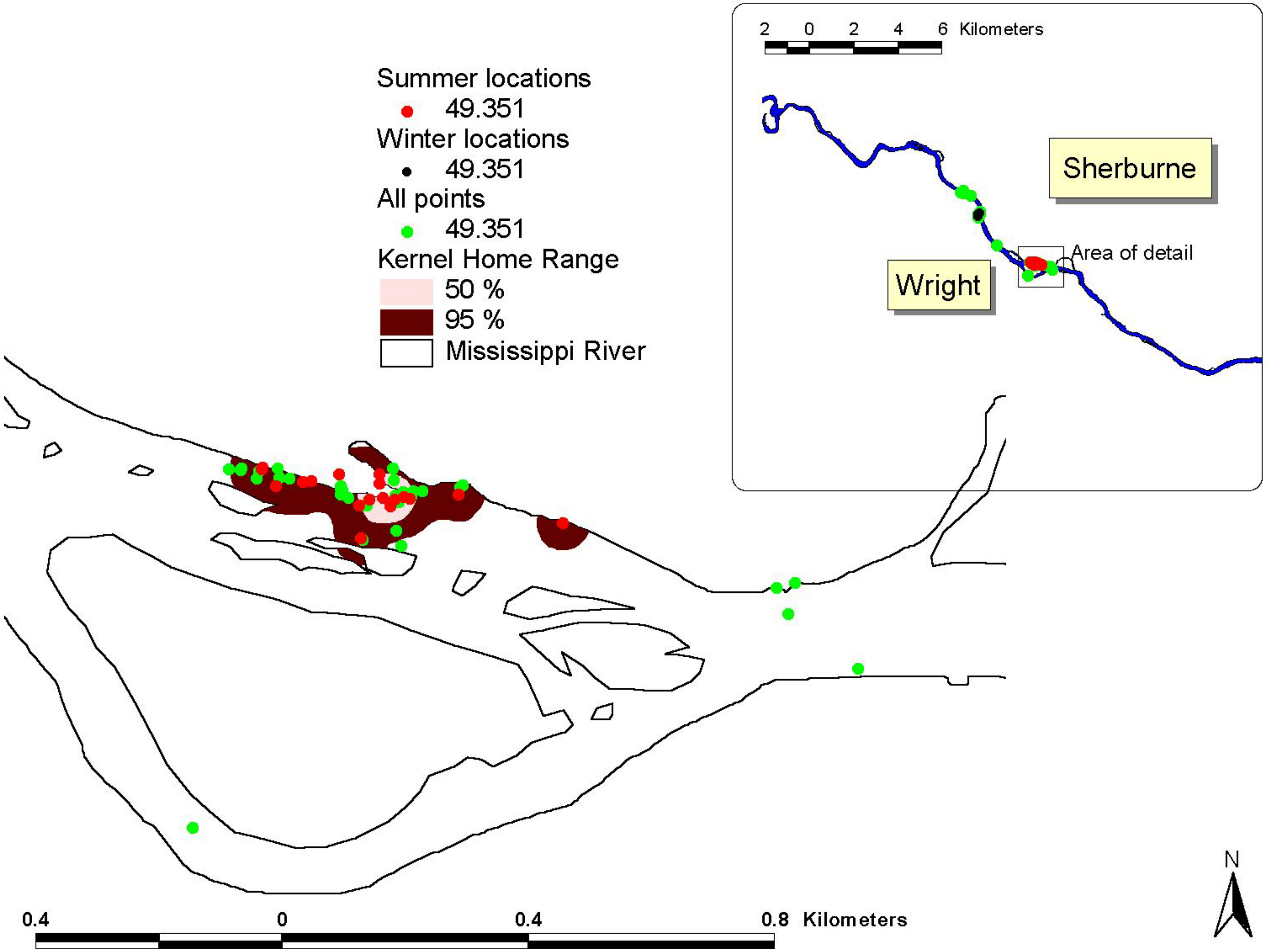
Appendix: Individual locations of recaptured smallmouth bass, summer Kernel home range, summer, winter and transitional points, Mississippi River between St. Cloud and Coon Rapids dams, Minnesota 2001-2002.

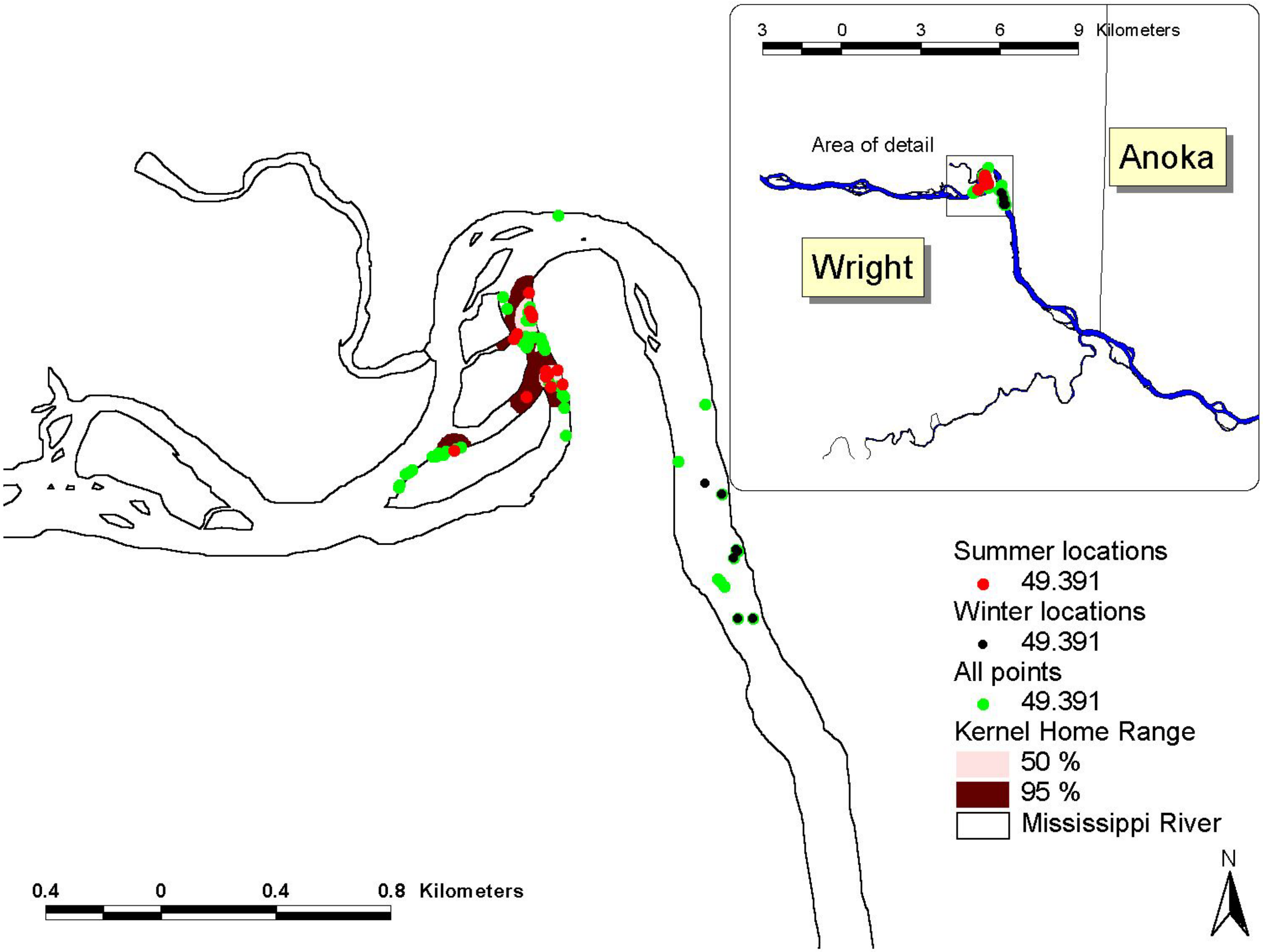

3 0 3 6 9 Kilometers
Sherburne
Area of detail
Stearns
Wright
Summer locations
49.045
Winter locations
49.045
All points
49.045
Kernel Home Range
50 %
95 %
Mississippi River
0.4 0 0.4 0.8 Kilometers
N


Summer locations
49.154
Winter locations
49.154
All points
49.154
Kernel Home Range
50 %
95 %
Mississippi River
2 0 2 4 6 Kilometers
Sherburne
Wright
Area of detail
0.4 0 0.4 0.8 Kilometers
N

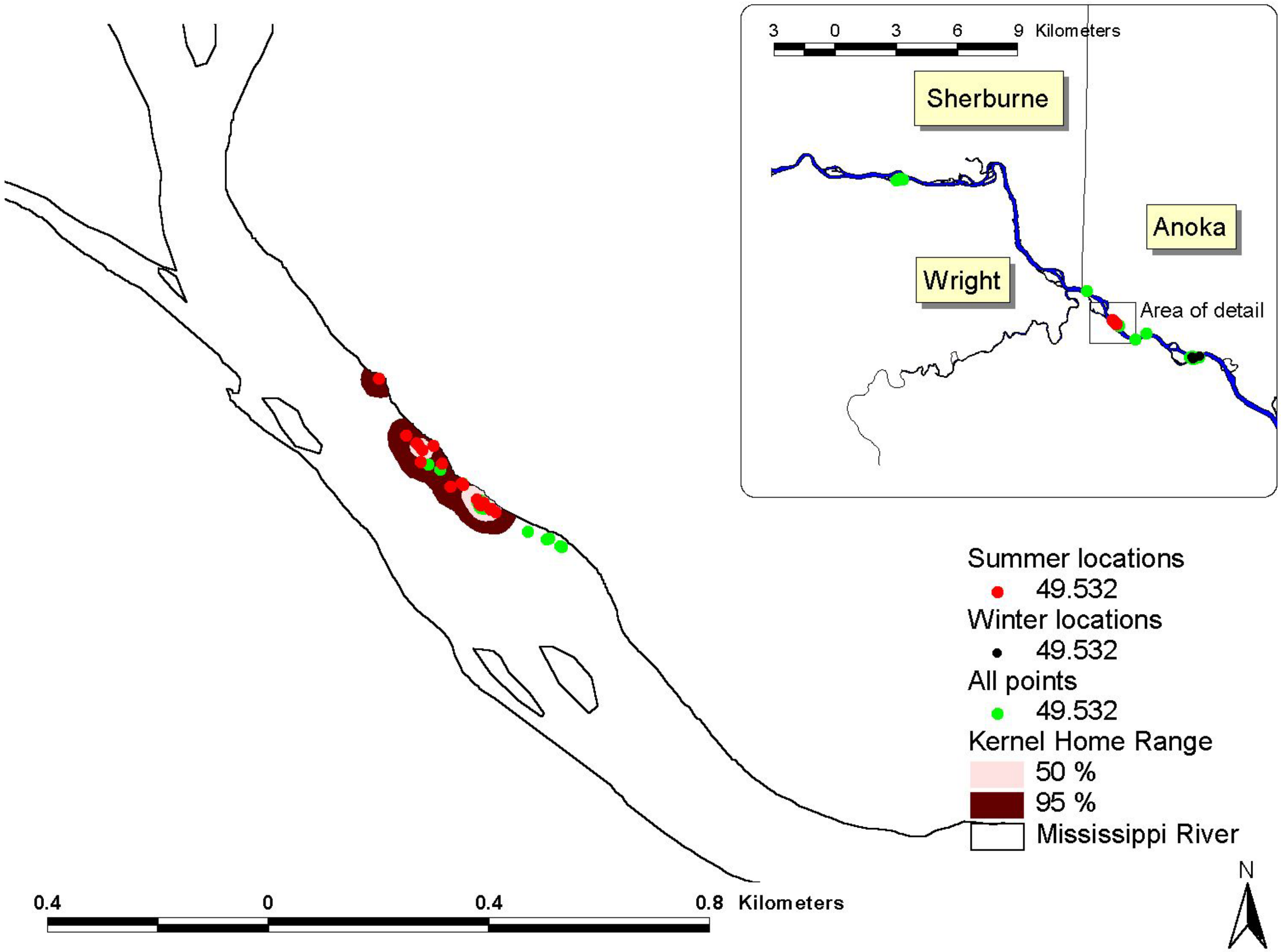


3
0
3
6
9
Kilometers
Sherburne
Area of detail
Stearns
Wright
Summer locations
49.311
Winter locations
49.311
All points
49.311
Kernel Home Range
50 %
95 %
Mississippi River
0.4
0
0.4
0.8
Kilometers
N


Summer locations
49.351
Winter locations
49.351
All points
49.351
Kernel Home Range
50 %
95 %
Mississippi River
2 0 2 4 6 Kilometers
Sherburne
Wright
Area of detail
0.4 0 0.4 0.8 Kilometers
N



3
0
3
6
9
Kilometers
Area of detail
Anoka
Wright
Summer locations
49.391
Winter locations
49.391
All points
49.391
Kernel Home Range
50 %
95 %
Mississippi River
N
0.4
0
0.4
0.8
Kilometers


3 0 3 6 9 Kilometers
Sherburne
Anoka
Wright
Area of detail
Summer locations
49.532
Winter locations
49.532
All points
49.532
Kernel Home Range
50 %
95 %
Mississippi River
0.4 0 0.4 0.8 Kilometers
N