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Migratory Behavior and Angling of Steelhead in the
Pere Marquette River, Michigan

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MIGRATORY BEHAVIOR AND ANGLING OF STEELHEAD IN THE PERE MARQUETTE RIVER, MICHIGAN.

By

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ABSTRACT

MIGRATORY BEHAVIOR AND ANGLING OF STEELHEAD IN THE PERE MARQUETTE RIVER, MICHIGAN.

By

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Radio-telemetry studies indicate that the pumped-source fish passage built around a pulsed-DC electrical sea lamprey barrier on the Pere Marquette River, MI was effective at passing at least 67% of tagged adult steelhead. Steelhead were captured using trap nets and hook-and-line fishing in 2000 and 2001, and their movements were monitored as they approached and ascended the fish ladder. Of the fish tagged at the mouth of the river, 68% were successful at traveling upstream to the barrier. These fish moved upstream faster in 2001 than in 2000, taking a mean time of 76.8 hours to reach the barrier. Once arriving at the barrier, fish were present for a mean time of 184.4 hours before ascending the ladder.

An angler survey was conducted on the Pere Marquette River, MI in order to characterize the spring recreational fishery. The study area consisted of 17 sampling sites located from Baldwin downstream to Ludington on the mainstem of the river. Anglers fishing the Pere Marquette from public access sites during the spring months of 2000 and 2001 most often targeted steelhead, and effort totaled an average of 110,000 hours per year. This is a dramatic increase in effort since the time of the last angler survey, nearly twenty years ago. Anglers caught an average of 19,000 steelhead and 24,000 suckers per spring. Most anglers fishing for suckers were from local counties, while those pursuing steelhead typically traveled greater distances.

"We must be the change we wish to see in the world"

-Mahatma Gandhi

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Last and most importantly, to my wife Karen, whose patience and understanding allowed me to earn this degree. "I love you with all that I am…"

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INTRODUCTION

The Pere Marquette River is one of the last remaining free-flowing coastal streams in Michigan. It has been designated a Michigan "Natural River" and a National "Wild and Scenic River", and is highly regarded by anglers for its resident and anadromous fish populations. Much of the angling pressure occurs in the spring when many native and introduced species from the Great Lakes move into the river for spawning (Kruger 1985). The most sought after species in the spring fishery is the steelhead (*Oncorhynchus mykiss*), while the longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), and several species of redhorse (*Moxostoma spp.*) also support important fisheries. The sea lamprey (*Petromyzon marinus*) also enters the river to spawn in the spring.

The invasion of the sea lamprey into the Great Lakes has resulted in one of the largest and most intensive efforts to control a vertebrate predator ever attempted (Smith and Tibbles 1980). For the past 50 years, a number of different methods have been used in an attempt to control sea lamprey. One such method, a migration barrier, is intended to prevent passage of adult sea lamprey to upstream spawning habitat. However, migration barriers may limit reproduction by other potamodromous fish species, harming fisheries dependent on spawning migrations.

Sea lamprey were first discovered in the Great Lakes in the late 1930's, and by the mid-1940's they had contributed to a significant decrease in lake trout (*Salvelinus namaycush*) populations (Smith and Tibbles 1980). The decimated fishery prompted the development of a sea lamprey control program, and in 1950, mechanical weirs and traps were installed in tributaries to prevent sea lamprey from spawning. Electrical barriers soon followed; however, control measures did not become effective until the development of the chemical TFM (3-trifluoromethyl-4nitrophenol). This toxicant is applied to streams to destroy ammocetes (larval lampreys). In 1959, TFM was endorsed by the Great Lakes Fishery Commission as the accepted method of control (Dahl and McDonald 1980). Presently, the sea lamprey control program depends largely on TFM as a control measure. However, the high cost of TFM treatment and public sentiment against the use of a chemical control measure has prompted a shift toward alternative control methods.

Electric field barriers were first used in 1952. They could be built and operated at less cost and with greater efficiency than mechanical traps, and by 1960, 132 electric barriers had been installed on Great Lakes tributaries (Smith and Tibbles 1980). The barriers used 110-volt, 60 cycle alternating current (AC) to energize an electrode array fixed in the stream. No provisions were made in the barrier to allow other fish species to pass, so traps were installed at the downstream end of the electric field to capture migrating fish, which could then be transported upstream. The traps, however, caused interruptions in the electric field, allowing sea lamprey to pass through. There was also excessive mortality by electrocution of desirable species migrating upstream. Modifications to the barriers included the addition of pulsated direct current (DC) leads to divert fish into traps. This change greatly reduced, but did not eliminate, mortality of the desirable fish (Hunn and Youngs 1980).

A truly complete and efficient electrical barrier was not realized during this period of sea lamprey control. It is believed that under ideal circumstances the electrical barrier could stop the migration of sea lamprey; however, most barriers were not operated long enough to be accurately evaluated (McLain et al. 1965). With the adoption of TFM as a control measure, the barriers were only used as a means of assessing the number of spawning lamprey, and by 1966, they were removed from all Lake Michigan tributaries (Smith and Tibbles 1980). Although TFM has been used successfully since it was developed, the rising cost of the chemical has led to a renewed interest in the use of electric barriers. Rivers such as the Pere Marquette, which have large amounts of habitat that must be treated with TFM, are at the top of the list for alternative control methods.

In October 1999, an electric lamprey barrier with a fish passage structure was completed on the Pere Marquette River at Custer, MI. Previous attempts at operating an electric weir at this site were unsuccessful. The first weir was operated in 1964 and 1965 and was effective at blocking the lamprey migration, but was harmful to other fish. A new weir was installed and operated in the spring of 1989. Again, the weir was effective at blocking sea lamprey, no mortality of steelhead adults or smolts was observed, and northern pike and suckers were able to pass downstream through the barrier. However, the barrier did not allow any species of fish to pass upstream (Rozich 1989, unpublished).

The current barrier began operation on March 21, 2000. Several modifications were made in order to allow upstream passage of steelhead. The fish passage consists of a channel with a series of jumps navigable to steelhead but impassable to non-jumping fish, including sea lamprey. River water is pumped through the channel at a velocity high enough to create an attraction flow, allowing steelhead to swim through the passage and around the electric grid. In addition to the passage, the barrier has also been changed from AC to a pulsed DC gradient electric grid, which is generally accepted to be much less damaging to fish (Reynolds 1996). The new system uses controllable electronics and updated software to provide a consistent and uniform electrical field oriented such that a fish moving parallel to the stream flow will always encounter the maximum voltage gradient.

Management considerations

Steelhead were first introduced to the Pere Marquette River in 1885, and were naturalized shortly thereafter. Steelhead in Lake Michigan tributaries typically spend two years in the river after hatching, and then migrate to the lake in early spring, where they spend another 1 to 3 years before returning to the river to spawn. The spawning period normally lasts from 4 to 7.5 weeks and spawning takes place in areas dominated by large gravel and cobble substrate (Biette et al. 1981). Steelhead have been most successful in rivers that provide unobstructed passage from the lake to spawning habitat, and that have water temperatures that are conducive to juvenile survival (e.g., <20°C). The operation of the electric barrier to the Pere Marquette could obstruct passage, thereby limiting the reproductive capabilities of adult steelhead.

Little is known about the behavioral response of adult steelhead to a migration barrier, or the energetic costs associated with the delay that may occur while searching for a passage. Palmisano and Burger (1988) used an electric barrier to guide chinook salmon (*O. tshawytscha*) adults into a side channel where a weir and trap were installed to capture the fish. The salmon were able to locate the alternate channel but the time that they spent searching for the passage was not recorded. Bjornn et al. (1998) used radio telemetry to study the migration of chinook salmon past dams and through reservoirs in the Lower Columbia and Snake River system. They found that 90-94% of the salmon were able to pass over the dams. The median times for salmon to pass the dams ranged from 0.25-0.86 days for the dams without fish traps, and up to 5.4 days for dams that operated fish traps. With an increase in the time it took for a salmon to pass through the lower Snake River, came a subsequent decrease in the likelihood of the salmon completing its spawning migration. Andrew and Geen (1960) discussed how delays below fish passages could adversely affect, or even totally prevent spawning success of sockeye salmon (*O. nerka*) in the Fraser River.

Many of the habitat characteristics of the Pere Marquette River that allow for successful reproduction of steelhead are also favorable to the sea lamprey. Ironically, habitat enhancement programs such as streambank stabilization and sand removal, which have been intended to increase salmonid production, also benefit the sea lamprey (Smith and Tibbles 1980). While sea lamprey begin their upstream migration as early as April, they do not begin nest construction until the water warms to about 15° C (Manion and Hanson 1980). For successful spawning, sea lamprey require a steady unidirectional flow of water, sand and gravel substrates, and suitable water temperatures (e.g. 10°C to 26.1°C) (Applegate 1950). Blocking sea lamprey from this spawning habitat can effectively control their population (McLain et al. 1965).

In addition to any biological concerns attributed to the barrier, it is also important to realize that the operation of the barrier could have an effect on the upstream fishery. The history of trout and salmon in the Pere Marquette has been well documented (Kruger 1985), but no recent work has been done to quantify the fishery. Species other than steelhead are also important. Suckers, for example, are exploited as they make their spring spawning migration, and although little is known about their importance in the recreational fishery, provisions for their passage were not incorporated in the initial design of the barrier and fishway. During the months of March and April, anglers can be found along the banks of the Pere Marquette attempting to catch the migrating suckers. Upstream of the barrier, in Walhalla, MI, the annual sucker festival attracts large crowds to celebrate the sucker fishery. A better understanding of the spring fishery on the Pere Marquette is critical to the operation of the barrier, because to the anglers, the success of the barrier will most likely be measured in how it affects their angling experience.

This two-year study was designed to determine the effects of an electrical sea lamprey barrier on the migratory behavior of adult steelhead into the Pere Marquette River, and to characterize the spring recreational fishery. The objectives were to: 1) describe the timing of migration initiation by adult steelhead and the distribution of dates of arrival of radio-tagged fish at the Custer weir site, 2) determine the speed of upstream movement by adult steelhead from the old US 31 bridge at Ludington to Custer, through the weir, and from Custer to Bowman Bridge, 3) to determine the percent of steelhead passing the electrical barrier at Custer, and 4) to characterize the spring fishery in terms of total effort, targeted effort, and catch per effort.

CHAPTER 1: A DESCRIPTION OF THE MIGRATORY BEHAVIOR OF STEELHEAD (*Oncorhynchus mykiss*) IN THE PERE MARQUETTE RIVER, MICHIGAN.

ABSTRACT

Radio-telemetry studies indicate that the pumped-source fish passage built around a pulsed-DC electrical sea lamprey barrier on the Pere Marquette River, MI was effective at passing at least 67% of tagged adult steelhead. I captured steelhead using trap nets and hook-and-line fishing in 2000 and 2001. I tagged a total of 113 fish by either surgical or gastric implantation, and monitored their movements as they approached and ascended the fish ladder. I captured most (87) at the mouth of the river, approximately 20 km downstream of the barrier, and captured additional fish (26) directly below the barrier. Of the fish tagged at the mouth of the river, 68% were successful at traveling upstream to the barrier. These fish moved upstream faster in 2001 than in 2000, taking a mean time of 76.8 hours to reach the barrier. Once arriving at the barrier, fish were present for a mean time of 184.4 hours before ascending the ladder.

Fish that ascended the ladder were twice as active in seeking passage as those that did not ascend the ladder. Successful fish moved from one antenna to another a mean of 7.1 times per hour. All fish that entered the ladder eventually ascended, and navigated the channel quickly (mean 0.58 hours). Most passage through the ladder was during daylight hours for tagged and untagged fish.

INTRODUCTION

The Pere Marquette River is one of the last free flowing coastal streams in Michigan. It is a state "Natural River" and a national "Wild and Scenic River", and is highly regarded by anglers for its resident and anadromous fish populations. The river supports a naturally-reproducing run of steelhead (*Oncorhynchus mykiss*), and like many Great Lakes tributaries, has been colonized by sea lamprey (*Petromyzon marinus*). As part of the effort to control sea lamprey, an electrical barrier was installed on the Pere Marquette in 1999 to prevent their passage to upstream spawning habitat. A pumped-source fish passage built around the barrier is designed to facilitate the upstream migration of steelhead.

Electrical barriers have been used successfully for completely blocking spawning migrations of sea lamprey (Swink 1999), as well as guiding adult chinook salmon (*O. tshawytscha*) into a channel where they could be trapped (Palmisano and Burger 1988). However, little is known about the behavior of steelhead as they encounter an electrical barrier, or the efficiency of this unique design of fish passage. More common fish passage scenarios, such as hydroelectric dams with pool and fall fish ladders, have been studied extensively in recent years, and passage rates in excess of 90% are common (Bjorn et al. 2000, Gowans et al. 1999).

This two-year study was designed to determine the effects of an electrical sea lamprey barrier on the migratory behavior of steelhead in the Pere Marquette River, MI. In order to achieve this, I met the following objectives: 1) describe the timing of migration, 2) determine the proportion of fish that succeed in bypassing the weir, 3) measure the rate of ascent from the mouth of the Pere Marquette River to the electrical sea lamprey barrier, 4) measure the amount of time required by fish to bypass the electrical barrier, and 5) to measure the time required by fish to reach spawning habitat after passing the barrier.

STUDY SITE

The Pere Marquette River is located along the eastern shoreline of Lake Michigan in west central Michigan (Figure 1). The watershed encompasses an area of 1956 km^2 and contains 612 lineal kilometers of streams. From the headwaters near Chase to Pere Marquette Lake in Ludington, the Pere Marquette River courses a distance of about 154 km (MDNR/IFR 1998). The historic mean discharge in the spring (February - April) is 914 cfs (USGS 2001). In 2000, the mean discharge in spring was 671 cfs, and in 2001 it was 1040 cfs.

The electrical sea lamprey barrier is located at the Custer Road Bridge, about 2 km south of Custer, MI, and approximately 20 km upstream of the river mouth. There is no documented spawning habitat available to sea lamprey downstream of the barrier (Ellie Koon, USFWS, personal communication). A pulsed-DC electrical barrier (Smith-Root, Inc., Vancouver, Washington) was first used at the site in 1989. It was successful at blocking sea lamprey but did not allow the upstream passage of non-target species (Tom Rozich, MDNR, personal communication). The current barrier was completed in 1999, and has been modified with state-of-the-art pulsators and electronics, as well as a pumped-source pool-and-weir fish ladder. The fish ladder is constructed with walls of corrugated steel sheet piling, and is 1.2 m wide and about 19.5 m in length. Removable weirs separate 3 pools. Because the electrical barrier does not create an impoundment, water must be pumped into the fish ladder. One pump delivers water to a false weir at the top of the channel at 12 cfs, creating a 20-30 cm head over the removable weirs, and a larger pump is used to create an attracting flow (25 cfs) closer to the entrance of the

Figure 1. Location of the Pere Marquette River in Michigan.

ladder. Upon entering the passage, fish must navigate the series of four weirs before being returned to the river upstream of the barrier via a 30.5 cm PVC tube. In 2001, a net was placed over the exit end of the tube to allow observers to count and examine passing fish.

The barrier was in operation from 21 March-30 June 2000 and 5 April-30 June 2001. The normal operating procedure for the electrical barrier is to run continuously for the duration of the sea lamprey spawning migration. However, this protocol was not followed during part of the 2000 field season. A damaged pump prevented the circulation of water through the fish ladder from 31 March to 8 April, so the electrical field was turned off between the hours of 10:00 and 16:00 to allow fish passage. Several radio-tagged fish passed over the electrical barrier during this time, thereby compromising the design of the study. Additionally, at the conclusion of the 2000 field season, stray voltage from the barrier was discovered near the entrance to the fish ladder. It is believed that this condition may have existed throughout the period of operation and was corrected for the 2001 field season.

The area of study (Figure 2) extended from the mouth of the Pere Marquette River upstream to Bowman Bridge (48 km). Much of the river within this area has a stream gradient of less than 1 meter per kilometer and is characterized by slow runs and deep pools. Generally, streams best suited for trout reproduction have a gradient ranging from 1.9-13 meters per kilometer (Hay-Chmielewski et al. 1985). In the Pere Marquette, much of this higher quality spawning habitat occurs near and upstream of Bowman Bridge. Therefore, it is likely that fish that were successful in passing through the fish ladder would continue their migration upstream past Bowman Bridge.

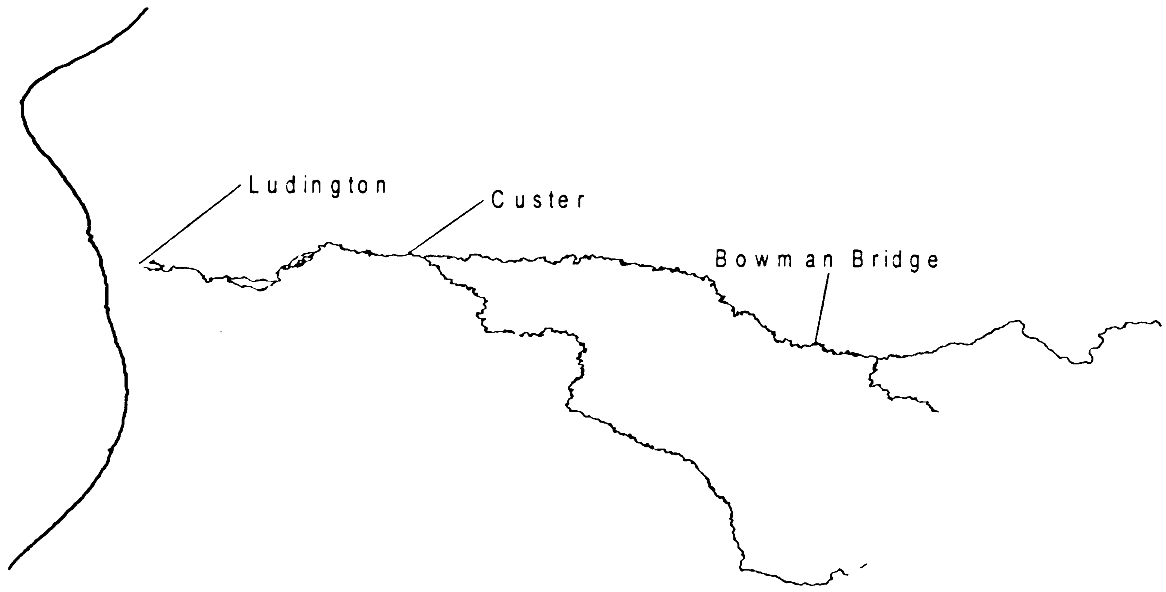


Figure 2. Location of the study site on the Pere Marquette River, MI.

METHODS

I captured steelhead in trap nets near the mouth of the Pere Marquette River, and by hook and line fishing near the mouth, as well as directly below the barrier. I fished the nets continuously for approximately 25 days each year, and checked them daily for the presence of steelhead. In order to minimize mortality, I only selected those fish measuring 50 cm or more in length, migrating upstream, and appearing in good physical condition for the study.

I implanted digitally encoded radio transmitters (Lotek Engineering, Inc., Model MCFT-7A; 16 x 83 mm, 12.8g in water) into 113 steelhead (56 in 2000 and 57 in 2001). I anesthetized the fish in a 15-gallon tank of tricaine methane sulfonate (MS-222), outfitted them with a transmitter and an external T-type tag (Floy Tag Co.), and transferred them to a recovery tub prior to releasing the fish at the point of capture. I released all fish caught in the trap nets approximately 200 m upstream of the nets in order to minimize recapture. I released fish caught by angling at the location of their capture. In 2000, I surgically implanted radio transmitters using methods similar to Hart and Summerfelt (1975). The entire procedure, from induction of anesthesia to release took approximately 15 minutes to complete. In response to concerns that the surgical procedure might alter behavior, I used an alternative implant method, gastric insertion, in 2001. In 2001, I surgically implanted transmitters into the peritoneal cavity of 24 fish, and used gastric insertion of transmitters for 33 fish. I executed gastric implants by inserting the transmitter through the esophagus and into the stomach of an anesthetized fish. The antenna extended out the fish's mouth, and was bent to trail along the fish's side (Ted Bjornn, University of Idaho, personal communication).

I monitored stream temperature and stream discharge for the duration of both sampling seasons. I obtained stream discharge data from the U. S. Geological Survey for the gaging station at Scottville, and monitored stream temperature at the barrier site in Custer and at the net site in Ludington by means of Onset Hobo electronic thermographs.

Monitoring movement

I monitored movements of the radio-tagged steelhead from the time of tag implantation until the end of the upstream spawning run. I used Lotek SRX-400 receivers at two fixed (base) stations, and one portable station to monitor fish movement. I used a portable receiver equipped with a boat-mounted Yagi antenna (Lindsay Inc., Lindsay, Ontario) to locate radio-tagged fish between Custer and Pere Marquette Lake, and to ensure that the radio transmitters were functioning prior to implantation. The primary base station was located at the barrier site in Custer. I equipped the site with a recording receiver, and a Digital Spectrum Processor (DSP-500) with a fast antenna switching option. The DSP-500 is a digital coprocessor that provides frequency discrimination using real-time analysis. This allowed for simultaneous scanning of multiple antennas and frequencies. The receiver logged all data into memory, which I downloaded daily. I used seven antennas at this station in order to detect the movement of fish near the barrier (Figure 3). I mounted one aerial Yagi antenna approximately 70 m downstream of the barrier (A1), and another aerial Yagi 30 m upstream (A7) of the barrier. I used these two antennas to detect the direction of travel, along with the times of arrival and departure in the reception area. I placed three submerged antennas (A2, A3,

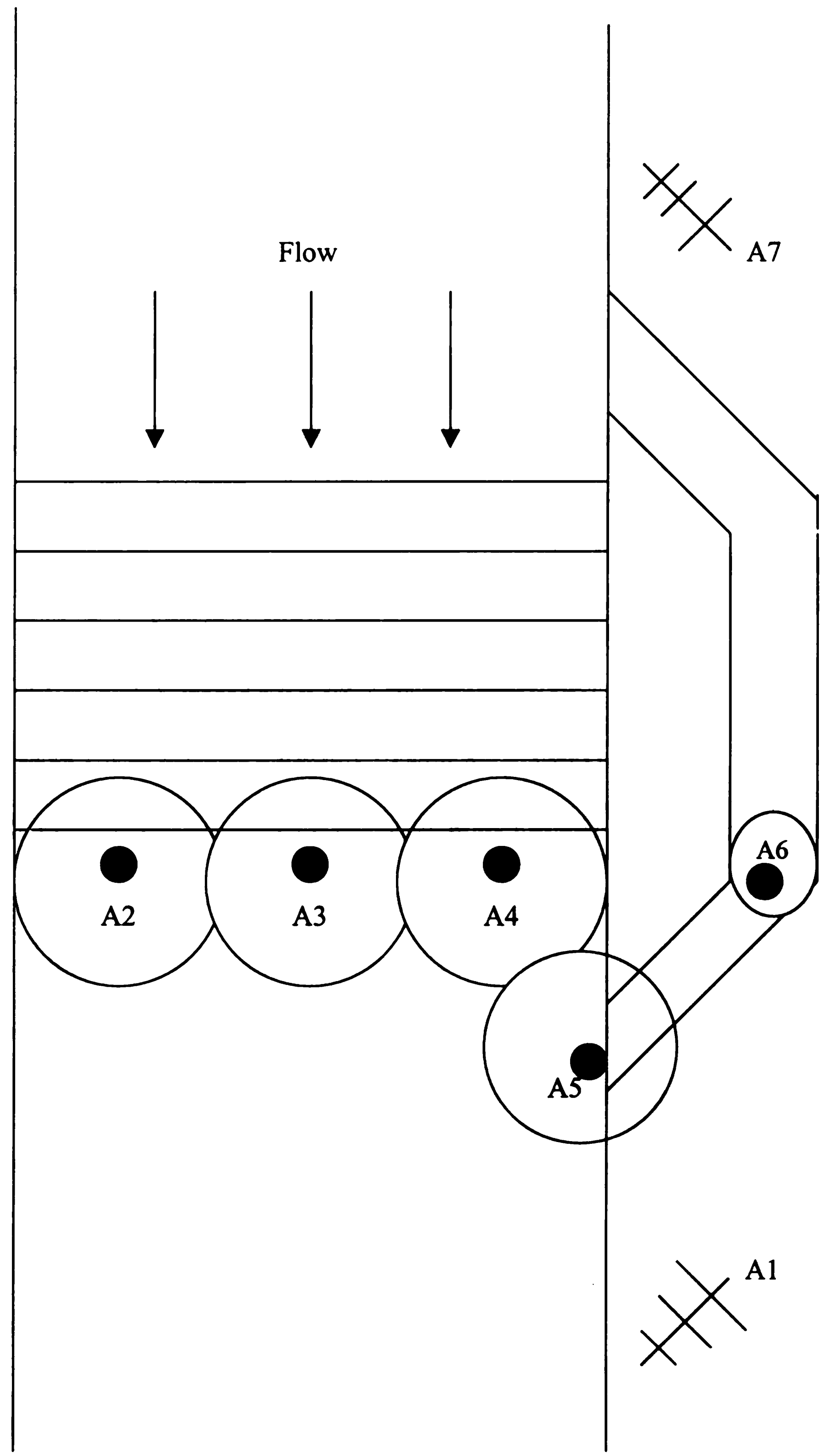


Figure 3. Antenna arrangement at the electrical barrier site in Custer, MI.

and A4) across the face of the barrier, another at the mouth of the fish passage (A5), and one within the ladder (A6). The submerged antennas allowed me to monitor fish as they encountered and attempted to negotiate the barrier and the fish passage structure. I constructed submerged antennas using RG-58 coaxial cable, and left approximately 20 cm of center wire exposed at the end. I calibrated the SRX/DSP unit to determine the reception area of the seven antennas. I positioned the aerial antennas at a 45° angle to the riverbank (directed away from the barrier) to achieve greater range, and to avoid possible overlap with underwater antennas. Areas of overlap in the underwater reception cells ensured that a fish could not swim between antennas without being detected (Figure 3). The second base station was located about 2 km upstream of Bowman's Bridge. I equipped this station with a recording receiver (SRX-400) housed in an environmental chamber. I used an LA51 solar panel with a 12-volt deep-cycle battery and photovoltaic charge controller (Kyocera, Arvada, CO) to supply power to this remote site. I mounted two aerial Yagi antennas approximately 80 m apart to detect direction of movement, and the date and time of arrival and departure of tagged fish.

I obtained movement data of untagged fish from the United States Fish and Wildlife Service, which was in charge of operating the barrier. This data included the number of steelhead ascending the ladder on each date of barrier operation, as well as time of passage.

Data analysis

I divided the river into three sections for data analysis. Section A was the stretch of river from Pere Marquette Lake upstream to the detection limit of A1 at the electrical barrier (20 km). I did not include the fish tagged in the vicinity of the barrier in the analysis of section A. I determined the timing of migration and arrival at Custer by using the dates and times of capture and first detection at the barrier, respectively. The detection zone of the telemetry equipment located at the barrier served as Section B. I calculated the time difference between first detection at the barrier and last detection on the upstream antenna to determine time of passage. Conversely, I calculated downstream time of passage as the fish moved downstream through the array. I included the fish tagged at the barrier in downstream time of passage as well as percent passage, but excluded them from upstream time of passage. Section C extended from the upstream detection limit of A7 to Bowman Bridge, which covers a river distance of approximately 28 km. I included all radio-tagged fish that ascended the fish ladder and continued their migration upstream to Bowman Bridge in the analysis of this section.

I considered a fish to have passed the barrier when it moved upstream of antenna seven, was captured upstream, recorded on the Bowman Bridge receiver or, in the case of radio failure, when the barrier attendant observed the fish in the capture net on the upstream tube.

I determined the activity levels of tagged fish in the vicinity of the barrier by dividing the number of times a fish switched from one antenna to another, by the total time spent at the barrier before ascending or before swimming downstream and not returning. I did not include fish that were tagged at the barrier in this analysis of activity. I only carried out a detailed analysis of movement downstream and through the barrier for the 2001 field season. Barrier operations, broken antenna moorings, and a non-functioning antenna (A2) in 2000 made further analysis impractical.

For all statistical analysis, I first tested for equality of variance. If variance was equal, I used a pooled t-test, and if variances were unequal, I used Satterthwaite's approximation. I used Fisher's Exact Test to compare differences in percent passage between gastrically and surgically implanted fish, males and females, and barrier passage between fish tagged in Ludington and those tagged at the barrier. I performed all statistical tests using $\alpha=0.05$.

RESULTS

Timing of migration

I captured steelhead in trap nets from 3 March to 28 March, 2000, with many of the fish being caught during the week of 18 March to 24 March (Figure 4). I captured all fish when water temperature was 3°C or warmer, and captured 65% of the fish when water temperature was at least 7°C. Radio-tagged steelhead arrived at the Custer reception area (Section B) from 1 March to 15 April, and most of the arrivals occurred over a one-week period from 22 March to 30 March.

In the 2001 field season, I captured steelhead in trap nets from 14 March to 16 April (nets were not fished from 20 March to 1 April), and all fish were caught when water temperature exceeded 2.5° C (Figure 5). I captured seventy-two percent of the fish when the water temperature was 7° C or warmer. The daily catch was generally 1-3 fish per night with the exception of 20 fish being captured on 8 April. It was during this and the next two days that the majority of the tagged fish arrived at the Custer barrier site.

Water temperature (Figure 6) and discharge (Figure 7) were very different between the 2000 and 2001 study periods. In 2000, water temperature fluctuated greatly, but warmed much earlier than in 2001. The temperature was consistently above 4°C after 4 March 2000, whereas the river did not reach these temperatures until 30 March in 2001. The river did, however, reach a higher water temperature during the capture portion of the 2001 field season (11.2°C) than it did in 2000 (9.5°C). Discharge steadily decreased

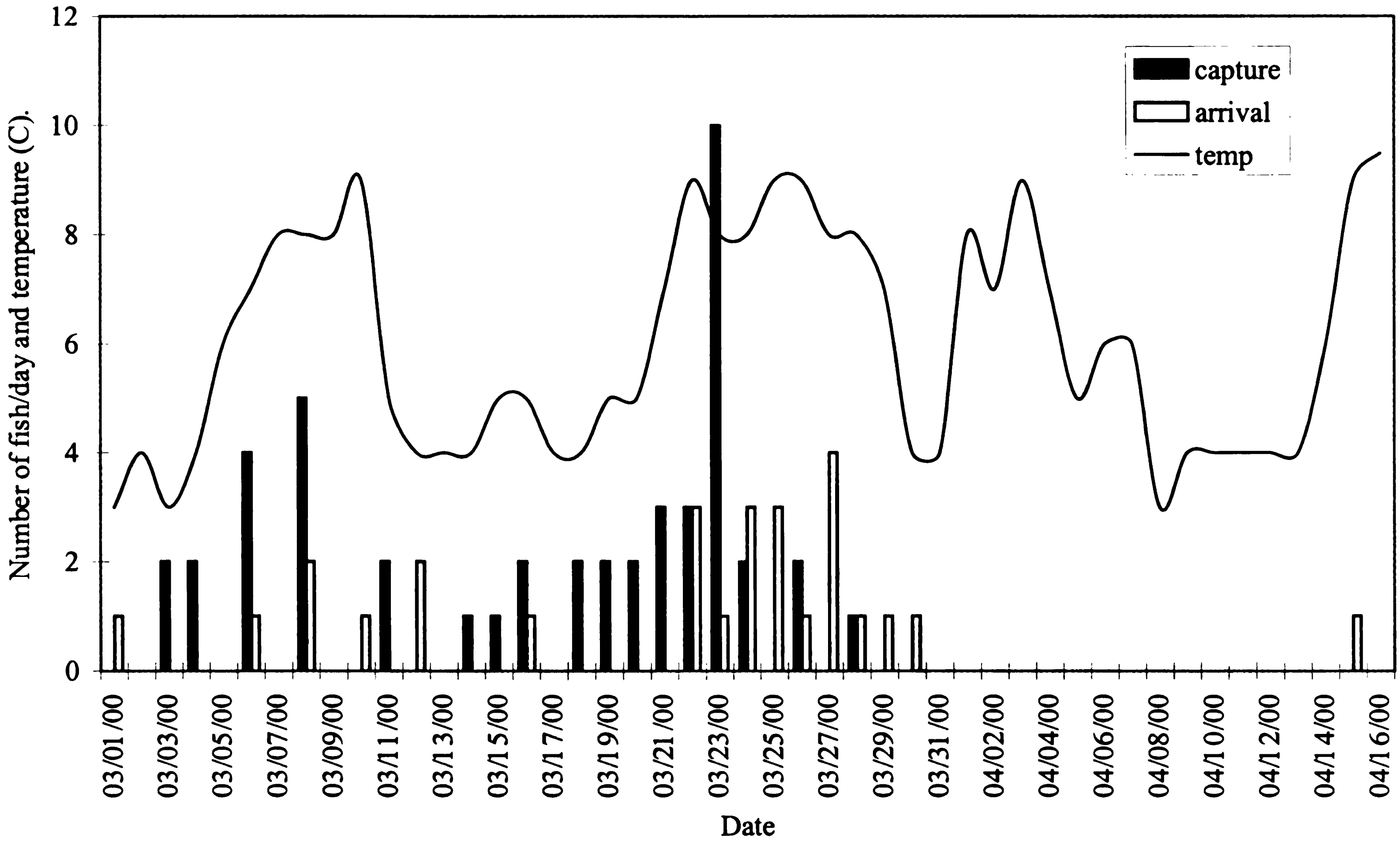


Figure 4. Daily catch of steelhead in fyke nets in Ludington, and daily arrival of tagged steelhead, and water temperature at the Custer station, Spring 2000.

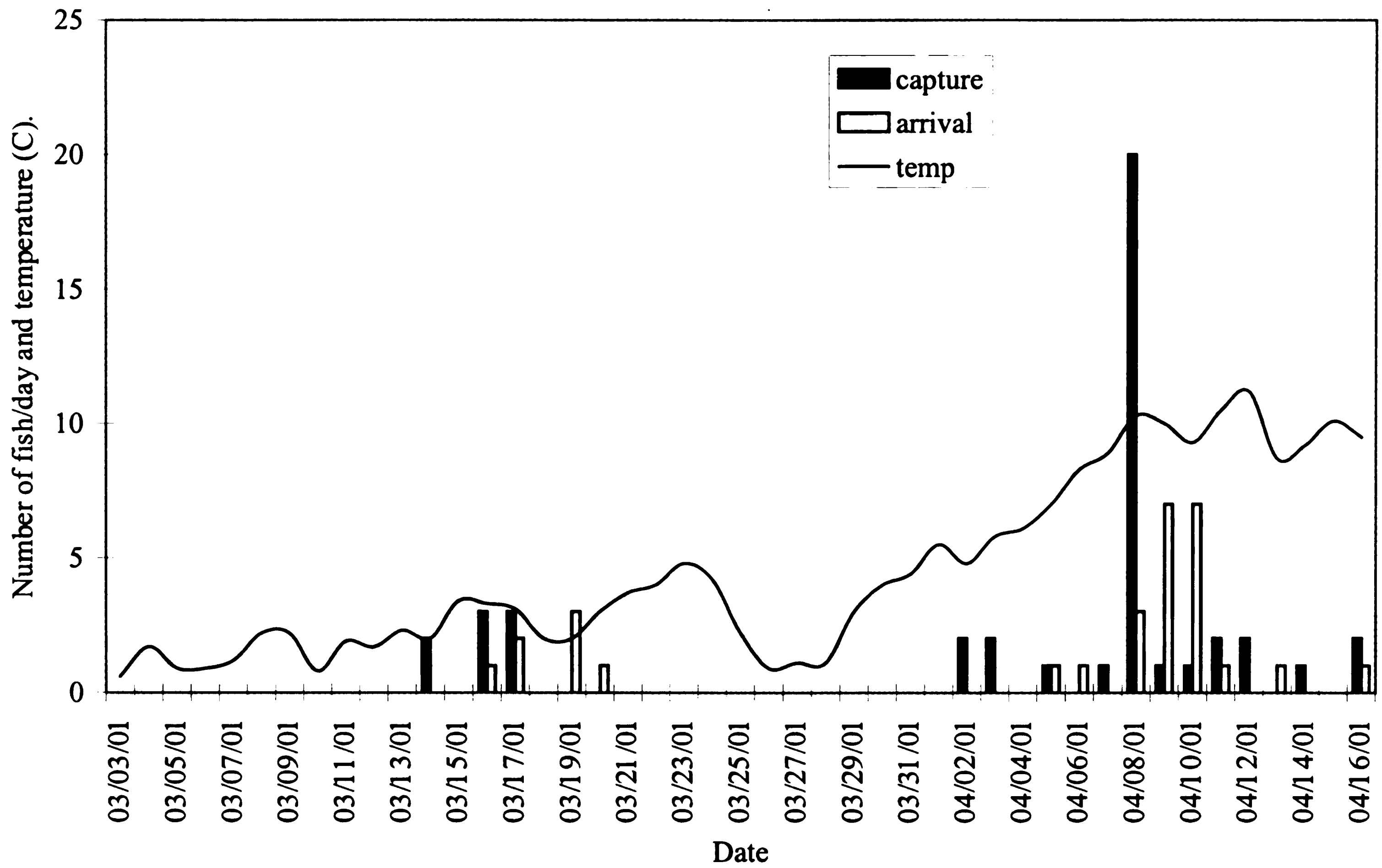


Figure 5. Daily catch of steelhead in fyke nets in Ludington, and daily arrival of tagged steelhead, and water temperature at the Custer station, Spring 2001.

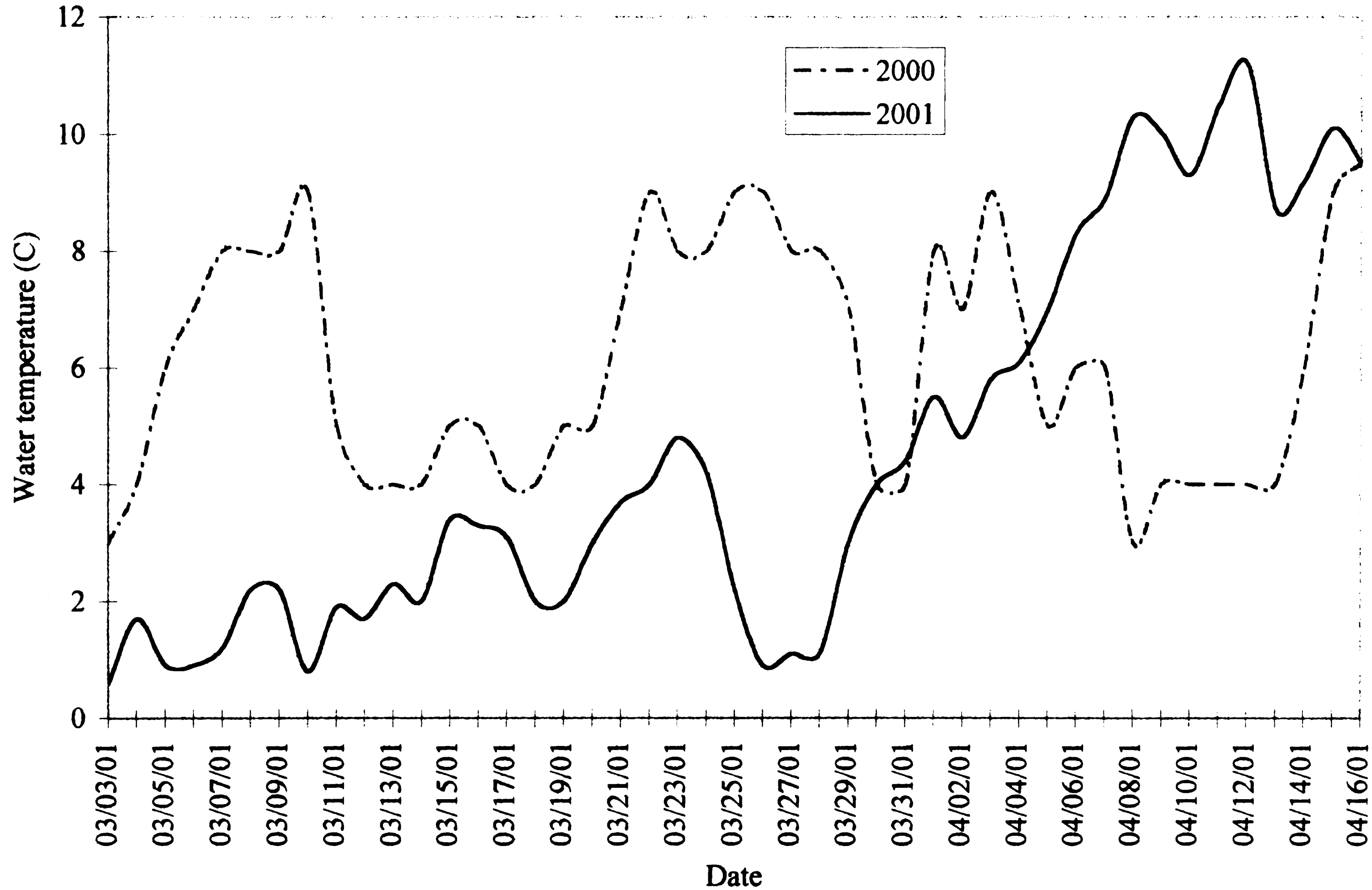


Figure 6. Water temperature at the Custer station, Spring 2000 and 2001

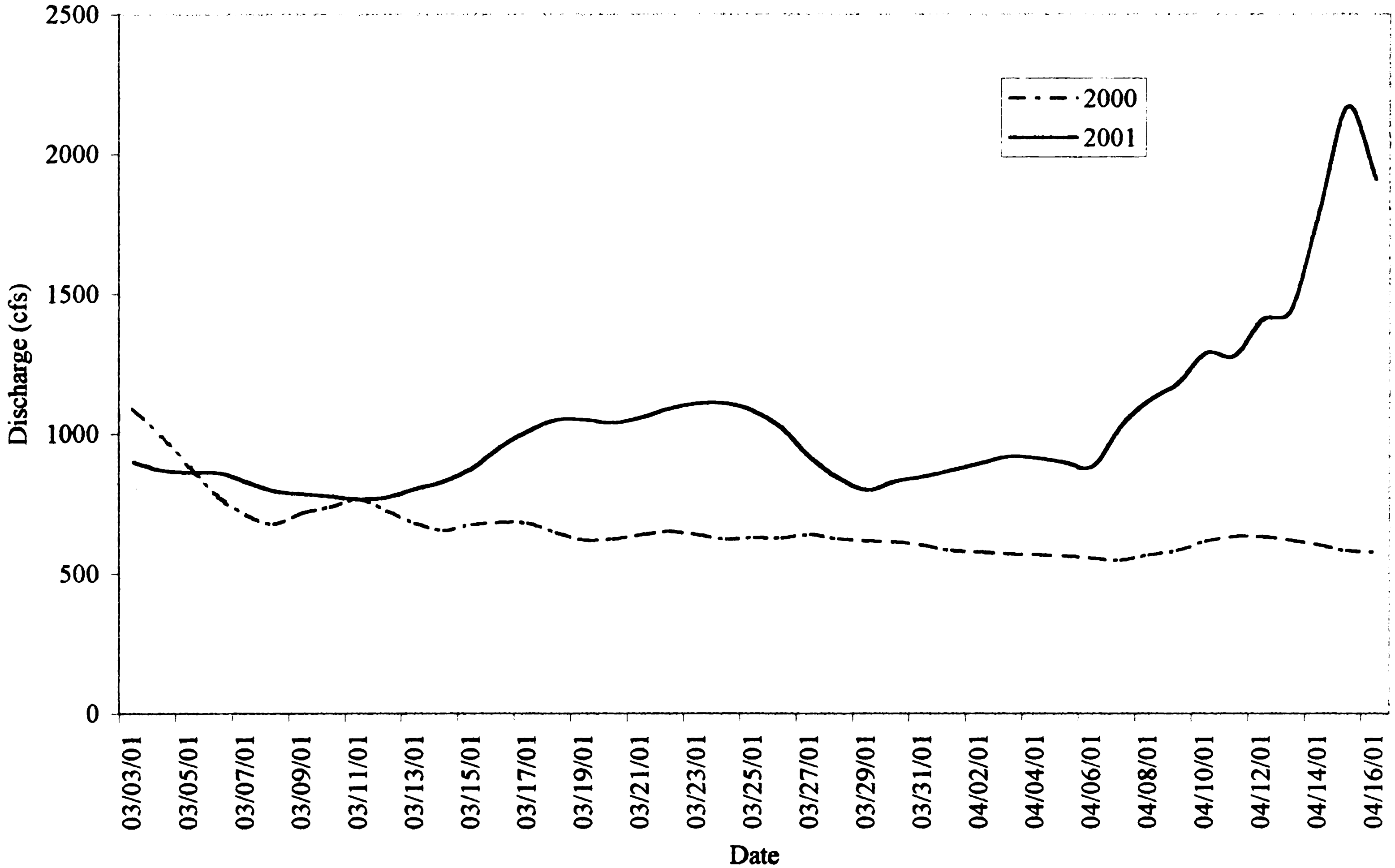


Figure 7. Discharge at the U.S Geological Survey gauge station in Scottville, MI, Spring 2000 and 2001.

throughout the 2000 study period, but increased during the 2001 season. In 2000, discharge was highest on 1 March (1176 cfs) and rapidly fell until 8 March. It then remained between 567 cfs and 767 cfs through the rest of the field season. Conversely, discharge in 2001 was generally increasing, and reached its maximum (2170 cfs) at the end of the capture period. The minimum discharge was 767 cfs.

<u>Percent passage</u>

In spring 2000, I implanted radio transmitters into 44 steelhead at Ludington. Twenty-seven (61%) were detected at the Custer receiver. Five of these 27 fish passed through the section before the barrier began operation (21 March). I tagged twelve more steelhead directly below the barrier, three of which moved downstream and remained stationary. Thirty-one tagged fish were actively seeking passage around the barrier at some time during the study period. Seventeen of these steelhead were able to pass upstream of the barrier during the period when the grid was de-energized. Only 1 (3%) fish ascended the ladder when the barrier was fully operational. Of the fish tagged in Ludington that never reached Custer, two were recaptured in other rivers. One was caught by an angler in the Sable River, a Lake Michigan tributary whose mouth is about 9.5 km north of the Pere Marquette River, and the other was captured at the Little Manistee River egg collection weir (MDNR), approximately 34 km north. I found nine fish after tagging that were never detected at the barrier, and failed to locate six other fish after tag implantation.

In 2001, I radio-tagged 43 steelhead at Ludington. Thirty-two (74% total, 69% surgical, 78% gastric) of these fish were detected at Custer. Of the 32 tagged fish that arrived at Custer, nine passed before the barrier began operation (5 April). I tagged an additional 14 steelhead, one of which remained stationary after release (and presumably died or expelled its transmitter), just below the barrier. Thirty-six fish were assumed healthy and actively seeking passage around the barrier. At least twenty-four (67%) of these fish were able to ascend the ladder. The successful passage of 19 of these fish was recorded on the Custer receiver, and five were accounted for by other means. Two of the 5 successful fish were detected at Custer and at Bowman Bridge, but the Custer receiver did not detect their passage through the fishway. Another of the five fish was captured by an angler upstream of Custer, and its transmitter was nonresponsive. Barrier personnel handled and recorded floy tag numbers from one steelhead with an unresponsive transmitter, and one that had regurgitated its transmitter. The twelve fish that did not ascend the ladder were either located downstream (7 fish), or were not relocated (5 fish). Of the eleven fish tagged in Ludington that never reached the barrier at Custer, three were never located. One was recaptured by an angler in Cooper Creek, a small tributary to Lake Michigan, the mouth of which is about 28 km north of the Pere Marquette, and another was caught by a charter boat in August, about 31 km offshore from Frankfort, MI. Six of the tags remained stationary, and did not reach Custer through the end of the study period.

Males and females were equally successful at ascending the fish ladder (males=69% passage, females=65% passage). There was no significant difference ($t=1.83$, $df=31$, $P=0.08$) between the size of fish that ascended the fish ladder (3.4 kg, SE=0.18) and those that did not (3.9 kg, SE=0.35). Additionally, there was no significant difference between percent passage of gastrically tagged fish (74% passage) and surgically tagged fish (54% passage) (Fishers Exact Test, $P=0.14$).

Of the fish that I tagged immediately downstream of the weir, 85% succeeded in passing through the fishway and 57% of the fish that were tagged at Ludington were successful. These proportions were not significantly different (Fisher's Exact Test, p=0.086), however, the sample size is relatively small.

Rate of ascent to Custer

The mean (median in parentheses) time from tag implantation in Ludington to first detection at the Custer receiver station in 2000 was 151.2 hours (103.2 hours) (n=27,SE= 26.4 h, range 24-456 h). Steelhead that I radio-tagged in Ludington in 2001 were detected at the Custer station in a mean time of 76.8 hours (38.4 hours)(n=29, SE=21.6 h, range=16.8-604.8 h), which was significantly faster than in 2000 (t=2.31, df=54, P=0.02). There was no significant difference in time of passage between surgically and gastrically implanted fish in 2001 (t=0.62, df=20, P=0.54).

Rate of bypassing weir

In 2001, tagged and untagged fish exhibited similar patterns in their timing of migration through the fish ladder (Figure 8), suggesting normal behavior of radio-tagged fish. The first radio-tagged fish entered and ascended the ladder on 10 April when the water temperature was 9.5°C (Figure 9). Most fish, both tagged and untagged, moved upstream through the ladder when water temperature was above 9°C, and remained stable or was on the increase. Eighteen tagged fish ascended the ladder upon first entry, while three ascended on their second entry into the passage. Detailed movements were not available for three fish due to tag loss or failure.

The first approach to the electrical barrier was equally distributed across the river width. Six fish first encountered the weir along the north side of the river (A2), six fish

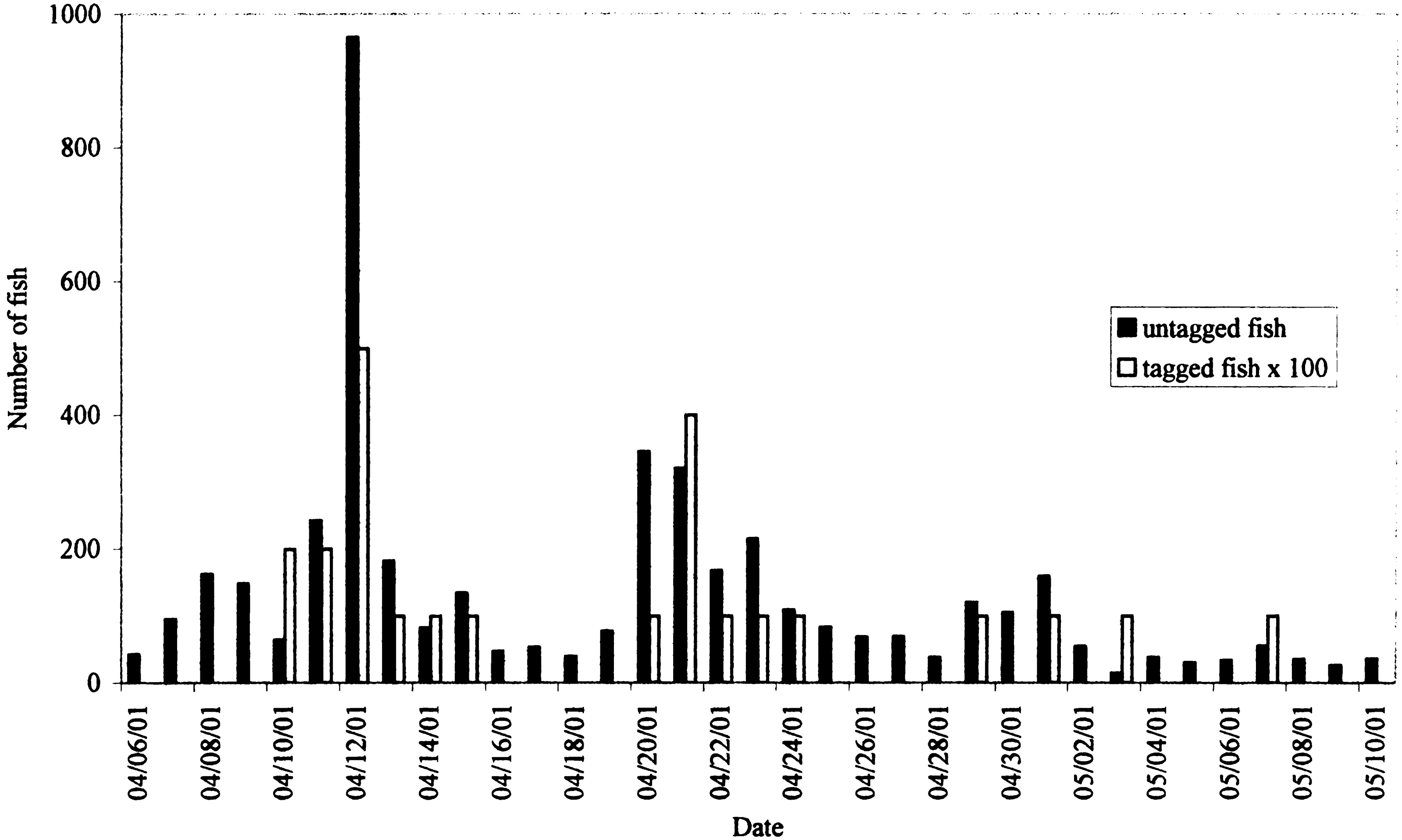


Figure 8. Number of tagged (x100) and untagged fish ascending the fish ladder in Custer, MI, Spring 2001.

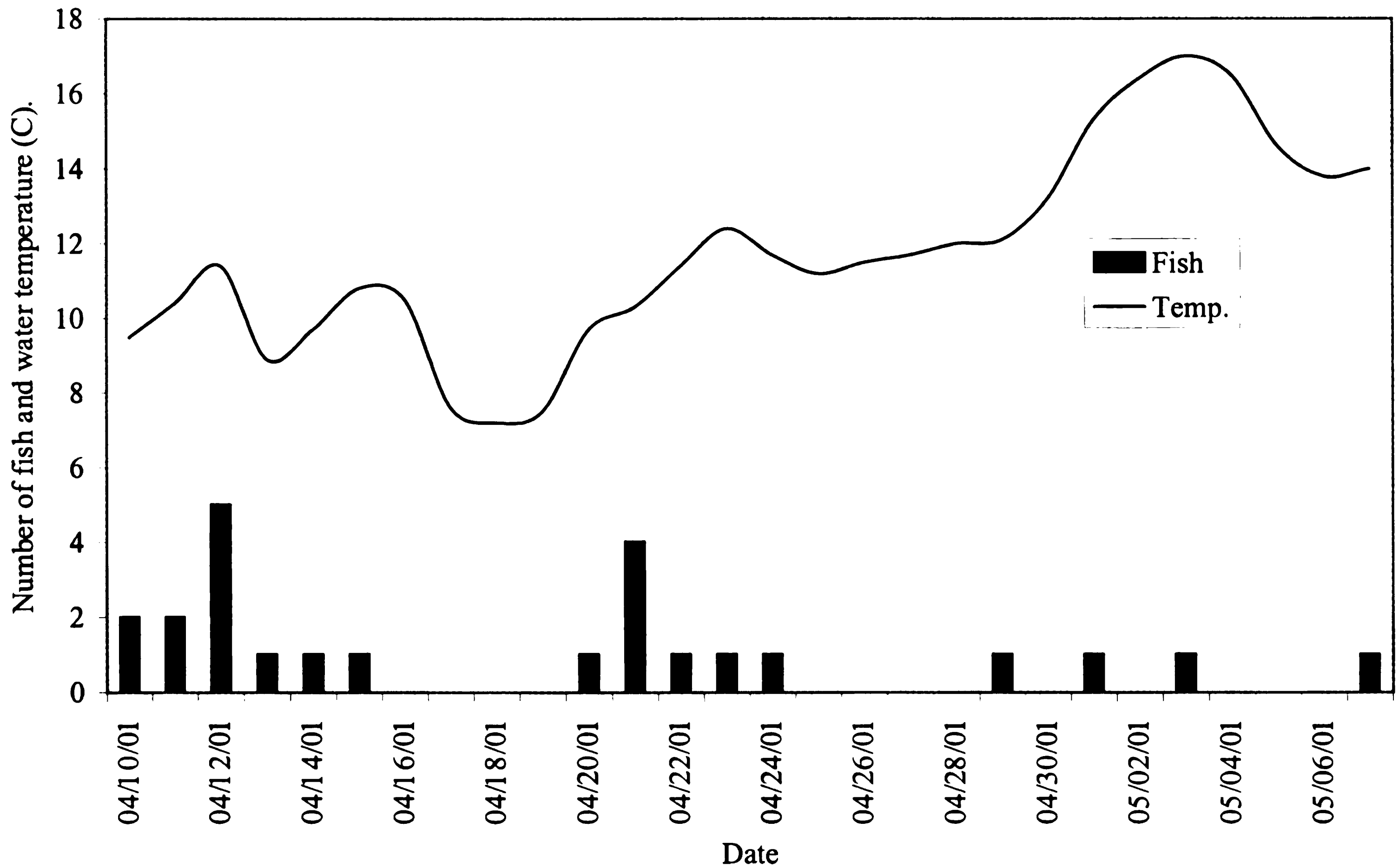


Figure 9. Number of tagged steelhead passing through the fish ladder and water temperature at the Custer station, Spring 2001.

encountered it in the middle of the river (A3), and nine fish encountered it along the south side of the river (four at A5, five at A5).

Activity of tagged fish in the vicinity of the barrier ranged from 0.3-21.5 antenna switches per hour (sph). Fish that passed the barrier appeared to be more active (7.1 sph) than those fish that did not pass (3.5 sph), although the difference was not statistically significant (t=-1.21, df=16, P=0.24). Gastrically tagged fish (6.5 sph) and surgically tagged fish (2.8 sph) were equally as active in their search for passage (t=1.73, df=15, P=0.10).

Tagged fish arrived at the Custer station at all times of the day, with 62% arriving during daylight hours and 38% arriving in the dark (Figure 10). Approximately 58% of the 24-hour period at this time of year was daylight. Most (88%) tagged fish that passed through the barrier section before the barrier was operating (5 April) moved in the dark (Figure 11). Most (86%) tagged fish that ascended the ladder during weir operation moved during daylight hours.

The time it took for the tagged steelhead to pass through the weir site (Section B) in 2000 depended on the operation of the barrier. The fish that arrived before the barrier was turned on (21 March) passed through the section relatively quickly, with a mean time of 1.0 hour (n=4, SE=0.35 h, range=0.43 to 2 h). Once the barrier was operating, only one steelhead successfully navigated its way through the fish passage and around the barrier, and it did not pass until 511.2 hours after its arrival at the barrier. Many of the steelhead passed through the section from 31 March to 8 April, when the electrical field was turned off between 10:00 and 16:00 to allow fish passage. The mean time of passage during this period was 105 hours (136 hours)(n=11, SE=20.2 h, range=1 to 171 h).

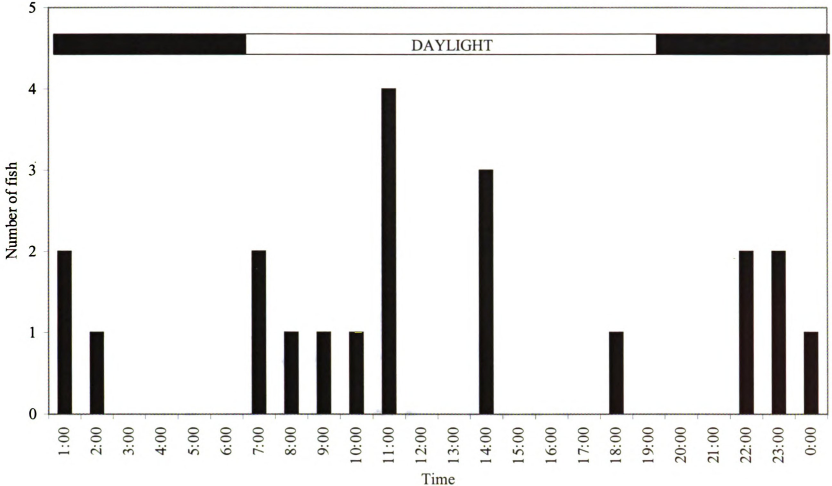


Figure 10. Number of tagged steelhead arriving at Custer and time of arrival, Spring, 2001.

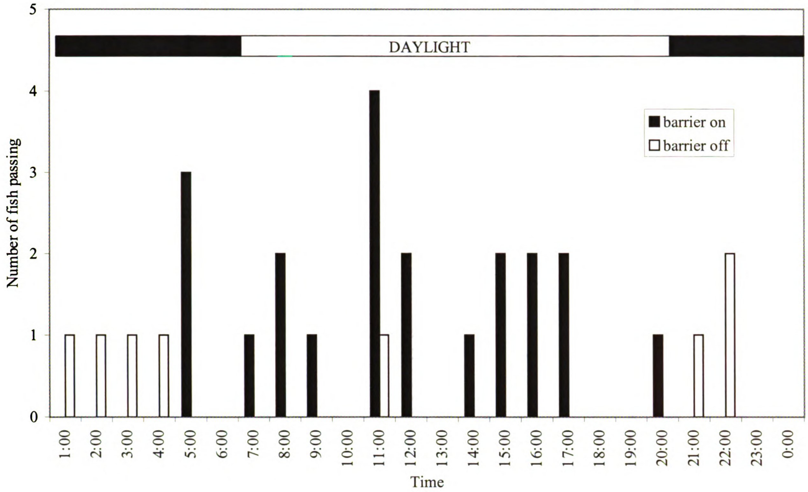


Figure 11. Number of tagged steelhead passing the barrier at Custer before (barrier off) and during (barrier on) weir operation, Spring 2001.

In 2001, fish that arrived before the barrier was energized passed through the section quickly, with a mean time of 0.78 hours (n=9, SE=0.43 h, range=0.17-4 h). Steelhead that arrived after 5 April were present for a mean of 184.4 hours (108 hours)(n=10, SE=55.2 h, range=28.8-576 h) before ascending the ladder. Upon entering the fish ladder, fish were able to navigate their way through the structure (entrance to return tube) in a mean time of 0.62 hours (0.58 hours) (n=15, SE=0.08 h, range=0.08-1.05 h). A total of three tagged fish (12.5%) fell back through the electrical field before ascending the ladder for a second, and in one case, third time.

Rate of ascent to spawning site

The Bowman Bridge base station was inoperable for most of the 2000 field season due to malfunctioning equipment. Only one fish was recorded at this site, making the passage from Custer to Bowman in 120 hours. In 2001, tagged fish arrived at Bowman Bridge in a mean of 84 hours (median = 48 hours)(n=6, SE=28.8 h, range=38.4-228 h) after passing the electric barrier.

Fish moving downstream over the weir during normal operation in 2000 took a mean time of 7.3 hours (median=7 hours) (n=7, SE=2.1 h, range=2.2 to 17.1 h). In 2001, steelhead that moved downstream after the spawning period passed through the barrier in a mean time of 37 hours (23.5 hours) (n=5, SE=14.1 h, range=2.6-87 h). All of these fish passed through the electric field.

DISCUSSION

Adult steelhead entered the Pere Marquette River nearly two weeks earlier in 2000 than in 2001. In both years, fish appeared to be triggered to migrate when water temperature was steady or increasing, with the peak of activity occurring when water temperatures exceeded 7°C. Differences between years are most likely the result of between year variation in stream temperature and discharge (Workman et al., in press). Additionally, most of the upstream migration during both years occurred within the last two weeks of March and the first two weeks of April, which is typical according to previous studies on the Pere Marquette River (Workman 2001).

Some steelhead left the Pere Marquette River after being tagged in both years of the study, which may occur when tagging anadromous species near the mouth of a river (Eiler 1990, Webb 1990). The steelhead in the present study may have been homing to a geographical area rather than specifically to the Pere Marquette, which can occur when streams are close together and similar in chemical and physical condition (Biette et al. 1980).

The percentage of radio-tagged steelhead reaching the barrier site in Custer after being surgically implanted in Ludington was comparable between years, and similar to an earlier study (57% in 1997, 63% in 1998)(Workman 2001). Movement rates, activity levels at the barrier, and percent passage did not differ between surgically implanted steelhead and gastrically implanted steelhead. However, the faster, less invasive method of gastric implant may be practically significant, and would be recommended for future research.

At least 67% of radio-tagged steelhead ascended the fish passage during the 2001 field season. While this percentage falls short of the proposed goal (70%), it should be considered a minimum estimate of passage. It is known that 24 fish ascended the fish ladder, but it is also known that there was a certain degree of equipment failure. The Custer receiver contained incomplete records of two radio-tagged fish that are known to have passed the weir. These fish were detected on the Bowman Bridge receiver and their passage could have been missed during the process of downloading data from the Custer receiver. Two radios failed after implantation (one was handled by barrier personnel and one was captured upstream by an angler), and one fish regurgitated a radio before ascending and being captured in the upstream net. Of the 24 fish that were confirmed moving upstream through the ladder, only 14 were handled by barrier personnel. Because three tagged fish were never located after implantation, and the fate of seven more is unclear, it is possible that one or more of these fish might have passed the barrier undetected.

Radio-tagged steelhead traveled faster through all three sections in 2001 than in 2000. Fish most likely moved faster due to the difference in water temperature between years, which has been found to be the dominant factor in triggering upstream migration in Pere Marquette River steelhead (Workman et al., in press). In 2000, a larger number of fish were tagged when water temperature was below 7°C. In 2001, many steelhead were tagged when water temperature exceeded 9.5°C, and based on previous studies it is clear that the propensity to migrate increases dramatically with increasing water temperatures (Workman et al., in press).

Water temperature also appears to be a factor in the upstream movement of steelhead through the fish passage. No radio-tagged steelhead, and few untagged steelhead ascended the ladder at temperatures below 9°C. Gowans et al. (1999) reported similar behavior of Atlantic salmon (*Salmo salar*) moving through a fish ladder.

Faster movement rates through section B in 2001, which includes the fish passage, are most likely the result of the improved barrier operations (correcting stray voltage problems near the entrance of the fish ladder). While fish were able to find passage around the barrier in 2001, the effect of the delay on individual steelhead is unclear. Bjornn et al. (1998) found that chinook salmon that took extended periods of time (twice the median) to ascend ladders on the Snake River were less likely to reach spawning areas. Fish in the Snake River, however, must travel much greater distances than steelhead in the Pere Marquette. Furthermore, mean delays were shorter than those reported in similar studies of salmonids by Gowans (1999) (14.8 days) and by Laine (1995) (14 days), but median delay was longer than that reported by Bjornn et al. (1998) (0.25-0.86 days).

Passage times through section C are difficult to compare between years due to the small sample sizes. If tagged fish did, indeed, move faster in 2001, the difference may again be explained by Workman's temperature based model. Alternatively, salmonids have also been found to migrate faster once ascending a dam to compensate for the delay incurred below the dam (Bjornn et al. 1998). A larger sample would be necessary to evaluate this in the present study.

The fish ladder was an effective passage for steelhead around the barrier once the fish located its entrance, and fish moved through the ladder relatively quickly upon entrance. However, fish were quite active in seeking passage before finally entering the ladder. It is clear that the process of finding the entrance to the ladder, rather than the process of ascending the ladder, led to the increased time spent by fish in the area downstream of the barrier during barrier operation. It has previously been suggested that fish must become acquainted with the entrance to a fish ladder before actually ascending (Laine 1995).

Tagged steelhead mainly ascended the ladder during daylight hours, supporting the idea that salmonids may rely heavily upon light to navigate such obstacles (Banks, 1969). Fish ladder data also confirms this for untagged fish, as nearly 70% passed in daylight. Similar diel patterns have been observed in chinook salmon (Bjornn et al.1998), Atlantic salmon (Gowans 1999), and steelhead (Chapman 1941, Jan Sapak, MDNR, personal communication) migrating through fish ladders.

Passage times of tagged steelhead migrating downstream through the barrier was longer, in both years of the study, than before the operation of the barrier (11 minutes)(Workman 2001). This may be caused by stray voltage on the upstream side of the barrier. Stray voltage on the upstream side may also be blamed for the 12% fallback rate. Rather than being released upstream of the electrical field, some fish falling from the return tube were dropped directly into stray voltage, and subsequently washed back downstream.

Based on this study, it appears that once fish locate and enter the fish ladder, they are able to complete passage above the weir quickly. However, some factors caused a delay of >180 hours in their efforts to locate the entrance to the fish ladder or to enter it. Most upstream movement through the ladder can be expected during the latter part of

March to the end of April, during daylight hours, and when water temperatures reach 9°C. It is also apparent that minor flaws in the operation of the electrical barrier and fish ladder can have a significant effect on the movement of steelhead. It is important to monitor for and to eliminate stray voltage from the barrier that may block access to the fish ladder.

CHAPTER 2: AN ANGLER SURVEY ON THE PERE MARQUETTE RIVER, MICHIGAN

ABSTRACT

I conducted an angler survey on the Pere Marquette River, MI in order to characterize the spring recreational fishery. The Pere Marquette is a free flowing coastal stream that experiences anadromous runs of native and introduced species. I designed this study to document all anglers, including those fishing for steelhead and suckers. My study area consisted of 17 sampling sites located from Baldwin downstream to Ludington on the mainstem of the river. The section is open to year round fishing and includes a seven mile long stretch designated as a catch-and-release "flies only" area.

I found that anglers fishing the Pere Marquette from public access sites during the spring months of 2000 and 2001 most often targeted steelhead, and effort totaled an average of 110,000 hours per spring. This is a dramatic increase in effort since the time of the last angler survey, nearly twenty years ago (22,228 hours per spring). Anglers caught an average of 18,074 steelhead, 7,504 brown trout, and 24,029 suckers per spring. Most anglers fishing for suckers were from local counties, while those pursuing steelhead typically traveled greater distances. Anglers who targeted steelhead were most numerous at upstream sites, particularly between Green Cottage and Gleason's Landing, and anglers who targeted suckers were most numerous at the three downstream sites.

INTRODUCTION

The Pere Marquette River is one of the last remaining free flowing coastal streams in Michigan. It is a state "Natural River" and a national "Wild and Scenic River" and is highly regarded by anglers for its resident and anadromous fish populations. The Pere Marquette is believed to be the first river in North America to be stocked with brown trout (MacCrimmon and Marshall 1968), and the historical significance of trout and salmon to the fishery has been well documented (Kruger 1985). The salmonid fishery is nationally renowned and provides a significant contribution to local economies; however, there are at least 40 other species of fish that inhabit the river, some of which also contribute to the recreational fishery (MR 1998). Heavy angling pressure occurs in the spring when large numbers of native and introduced species make spawning migrations into the river from Lake Michigan. It is widely known that many of the anglers are targeting steelhead, but it is apparent that suckers are also an important species (Aaron Snell, personal observation).

The goal of this study is to describe the spring recreational fishery on the Pere Marquette River. Nelson et al. (1998) conducted a recreational use survey on the mainstem, and Nelson and Smith (1998) give a detailed description of use patterns and current management issues, but did not explore the fishery in detail. Kruger (1985) conducted a year long angler survey on the upper mainstem of the Pere Marquette, which lies in an area designated as a Michigan "Blue Ribbon" trout stream, but no other creel survey work has been done since then. I designed the present study to estimate total effort, catch per effort, and total catch on the entire maintstem of the Pere Marquette River from 23 February-29 April, 2000 and 2001.

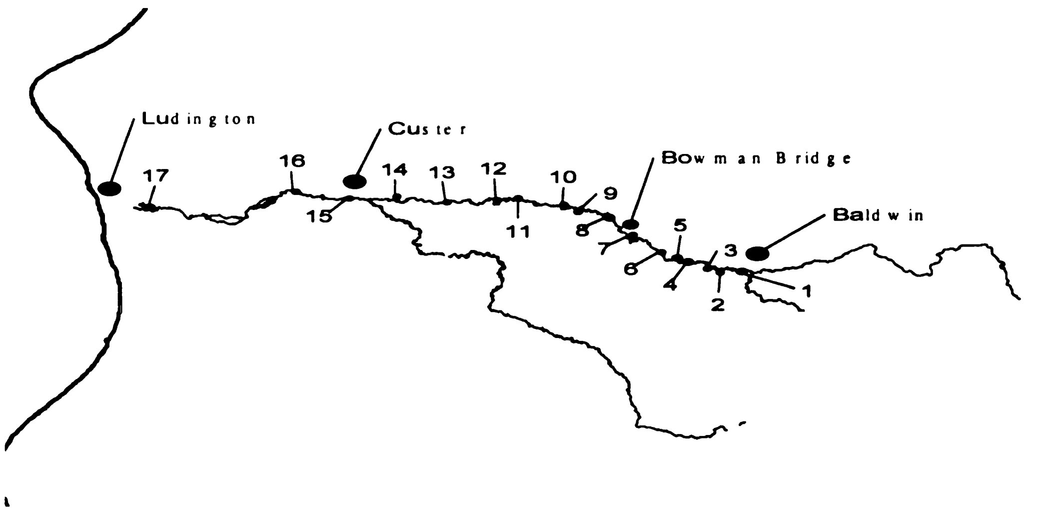
STUDY SITE

The Pere Marquette River is located along the eastern shoreline of Lake Michigan in west central Michigan (Figure 12). The watershed encompasses an area of 1956 km^2 and contains 612 lineal km of streams. From the headwaters near Chase to Pere Marquette Lake in Ludington, the Pere Marquette River courses a distance of about 154 km (MDNR/IFR 1998). A large percentage of the riparian lands along the river are privately owned, limiting public access to commercial or government maintained sites (Table 1). This study focused on seventeen sampling sites located on the mainstem of the Pere Marquette from Baldwin downstream to Ludington (Figure 13).

Like many free-flowing rivers, the habitat in the Pere Marquette River changes as it winds its way from its headwaters to Lake Michigan. In general, river gradient is steep in the upper watershed and gradually decreases as the river nears its mouth. The upper mainstem, near Baldwin, is characterized by relatively shallow water and numerous riffle areas that attract large numbers of spawning fish. The river is easily waded, yet provides sufficient access to canoes or boats. Downstream of Gleason's Landing, much of the river has a stream gradient of less than 1 meter per kilometer and is characterized by slow runs and deep pools (MDNR/IFR 1998). Mid-stream sites (Bowman Bridge to Maple Leaf) offer limited access to wading anglers and several areas of suitable spawning habitat. Downstream sites (Walhalla Bridge to Twin Bridges) are primarily accessed by boat or from shore.

Currently, Michigan sport fishing regulations allow year-round fishing on the

Figure 12. Location of the Pere Marquette River in Michigan.



See Table 1. For site names

Figure 13. Location of the seventeen sampling sites on the Pere Marquette River, MI for the angler survey.

Table 1. Sampled public access sites on the mainstem of the Pere Marquette River from Baldwin downstream to Ludington.

Site #	County	Agency	Name	Type
1	Lake	MDNR	M-37	Watercraft/Wading
2	Lake	Unknown	72nd St	Wading
3	Lake	USFS	Green Cottage	Watercraft/Wading
4	Lake	USFS	Clay Banks	Wading
5	Lake	USFS	Jorgenson's	Wading
6	Lake	USFS	Gleason's	Watercraft/Wading
7	Lake	USFS	Bowman Bridge	Watercraft/Wading
8	Lake	USFS	Rainbow Rapids	Watercraft/Wading
9	Lake	MDNR	Sulak	Watercraft/Wading
10	Lake	USFS	Upper Branch	Watercraft/Wading
11	Lake	Unknown	Ackerson's	Wading
12	Lake	USFS	Maple Leaf	Wading
13	Lake	MDNR	Walhalla Bridge	Watercraft/Wading
14	Mason	USFS	Indian Bridge	Watercraft/Wading
15	Mason	MDNR	Custer Bridge	Watercraft
16	Mason	MDNR	Scottville Bridge	Watercraft
17	Mason[1]	MDNR	U.S. 31	Watercraft
17	Mason[1]	Unknown	Sutton's Landing	Watercraft

USFS-United States Forest Service; MDNR-Michigan Department of Natural Resources.
[1] included in the "Twin Bridges" site.

mainstem of the Pere Marquette River from Lake Michigan upstream to M-37 in Baldwin. Most tributaries are closed to fishing from 1 October through the last Saturday in April to protect spawning fish. Additional regulations include a "flies-only" catch-and-release section between M-37 and Gleason's Landing, and a restriction that limits the use of motorized watercraft to the portion of river downstream of Indian Bridge.

METHODS

I patterned this roving survey after those used by the Michigan Department of Natural Resources (MDNR) and it consisted of two separate sampling components: interviews of angling trips and counts of anglers (Lockwood 1999). The survey followed a stratified design and the data I collected represents angling characteristics for each of the sampling sites during specific calendar and daily periods. The study focused on the entire mainstem, during a 10-week period in the spring of 2000 and 2001, and was designed to quantify all public-access angling. I selected the seventeen sampling sites based on patterns of previous use (Nelson et al. 1998) and personal observation. I selected sampling dates and times by dividing the 10-week sampling period into blocks of two weeks. Within each two-week block, I randomly selected three weekdays (Monday-Friday) and three weekend days. I then assigned a sampling time to each of the three weekdays and three weekend days. A morning (700-1200), afternoon (1200-1700), and evening (1700-2200) time block were all represented once during the week and once during the weekend.

During each of the sampling periods, I used "count-while-interviewing" progressive vehicle counts to estimate effort at each of the 17 sampling sites (Pollock et al. 1994). I randomized the starting point and direction of travel (Neuhold and Lu 1957), and used checkpoints along the route to stay on schedule, thereby eliminating potential bias (Wade et al. 1991). In addition to the number of vehicles present at each site, I recorded the date, day of the week, count start time, count end time, starting site, and direction of travel on the data sheet (Appendix A). I tallied vehicles into four categories:

Michigan vehicles, Michigan vehicles with trailer, out-of-state vehicles, and out-of-state vehicles with trailer. I also recorded the state of residence for all out-of-state travelers.

Angler use was restricted during a portion of the 2001 sampling season due to inclement weather. Residual snow and ice storms closed Sulak until 3/11, Ackerson's until 3/22, and Jorgenson's and Maple Leaf until 3/25. Additionally, these sites were only accessible by 4-wheel drive on some sampling dates. Twin Bridges was closed for approximately half of the 2000 season due to road construction.

I conducted angler interviews during and after the car counts at each of the 17 sampling sites. All anglers interviewed fished for a minimum of 0.5h (Pollock et al. 1997). I interviewed most anglers while they were actively fishing; however, anglers were sometimes met at the completion of their trip. Therefore, I recorded both complete and incomplete-trip interviews on forms patterned after those used by the MDNR (Appendix B). For the purpose of this study, I considered steelhead and rainbow trout to be the same species, and recorded all species of sucker into one general category. In an effort to avoid angler party size bias, I recorded information by individual angler rather than by angling party (Lockwood 1997).

Summary parameters

I used the following formulas to calculate the summary parameters for estimates of effort, catch per effort, and total catch. Formulas marked with an asterisk (*) and all variance estimates are from Lockwood et al. (1999). I developed the other formulas for use in this study.

Total Effort:

Car hours*:

$\beta = Fc$

where,

β = estimated total number of car-hours from progressive counts

F = fishable hours in a stratum

c = total number of cars counted

Angler hours*:

$E = \beta\bar{a}$

where,

E = estimated angler hours

a = number of anglers in a party

Boat vs. shore hours:

$$M = \frac{T}{V}$$

where,

M = proportion of angler hours fished from a boat

T = total number of trailers counted per section.

V = total number of vehicles counted per section.

Angler trips*:

$$\bar{t} = \frac{\sum_{i=1}^{k} t_i}{k} \qquad \mathcal{E}_p = \frac{E}{\bar{t}}$$

where,

ε = estimated angler trips

t = length of fishing trip

k = total number of anglers interviewed

Targeted effort[1]:

$$D = \sum_{1}^{17} s\left[\left(\frac{k_{Hs}}{k_{cs}}\right) E_s\right]$$

$$J = E - D$$

where,

D = estimated effort targeted at steelhead

k_{Hs} = number of anglers interviewed at site s targeting steelhead

k_{cs} = number of anglers interviewed at site s targeting suckers

J = estimated effort targeted at suckers

[1]Only 2000 data was used for estimation at the Custer site, due to low number of 2001 interviews. The low number of interviews was caused by difficulty in accessing fishermen.

Catch per effort*:

Incomplete trips:

$$\bar{r}_p = \frac{\sum_{i=1}^{k_p} \left(c_{pi} / h_{pi} \right)}{k_p}$$

where,

c = total catch of a particular species by angler i

h = total angler hours fished by angler i

Complete trips:

$$\bar{r}_p = \frac{\bar{c}_p}{\bar{h}_p}$$

$$\text{Catch per effort } (R) = \frac{Incomplete(\bar{r}) + Complete(\bar{r})}{2}$$

Total catch:

$$C = RE$$

where,

R = appropriate catch rate estimator

RESULTS

I counted a total of 2,044 vehicles in 2000 and 1,948 in 2001 (Table 2). Green Cottage and Gleason's Landing were the most used sites, with 37% of the total number of vehicles counted at these two sites alone. Custer was the third busiest site in both years of the study.

The estimated number of total angler hours (± 2 standard errors) was consistent during both years of the study. In 2000, anglers spent 110,435 (9,844) hours on the river, while in 2001 effort was estimated to be 109,626 (10,694) hours. Much of the effort (58% in 2000, 57% in 2001) was concentrated in the "flies only" section which offers high accessibility and a large number of spawning fish (Figure 14). Fishing effort was evenly distributed over the weekday (57,036 angler hours) and weekend (53,399 angler hours) strata during the 2000 season; however, more effort was applied during the weekdays in 2001 (65,314 angler hours on weekdays, 44,313 angler hours on weekends). The division of angler hours between boat and shore anglers was similar between years, as well as regions of the river. In 2000, 19% of the anglers fishing in the "flies only" section fished from a boat and in 2001, 22% fished from a boat. Downstream of Gleason's Landing, 20% of the anglers fished from a boat in 2000, and 25% fished from a boat in 2001.

The estimated number of angler trips (± 2 standard errors) in 2000 was 18,410 (3,006) for steelhead and 4,114 (1,158) for suckers. In 2001, the number of angler trips was similar at 18,015 (4,171) steelhead trips, and 4,116 (1,170) trips targeting suckers. A total of 81.7% of the fishing trips targeted steelhead in 2000, as compared to 81.4% in

Table 2. Total number of vehicles counted at each Pere Marquette River access site during the 2000 and 2001 sampling seasons.

	Number of vehicles	
Site	2000	2001
M-37	90	107
72nd Street	144	105
Green Cottage	428	393
Clay Banks	116	93
Jorgenson's	68	67
Gleason's Landing	328	335
Bowman Bridge	51	47
Rainbow Rapids	63	78
Sulak	133	94
Upper Branch	98	96
Ackerson's	28	26
Maple Leaf	93	91
Walhalla Bridge	54	63
Indian Bridge	54	58
Custer	174	142
Scottville	97	108
Twin Bridges	25	45
Total	2044	1948

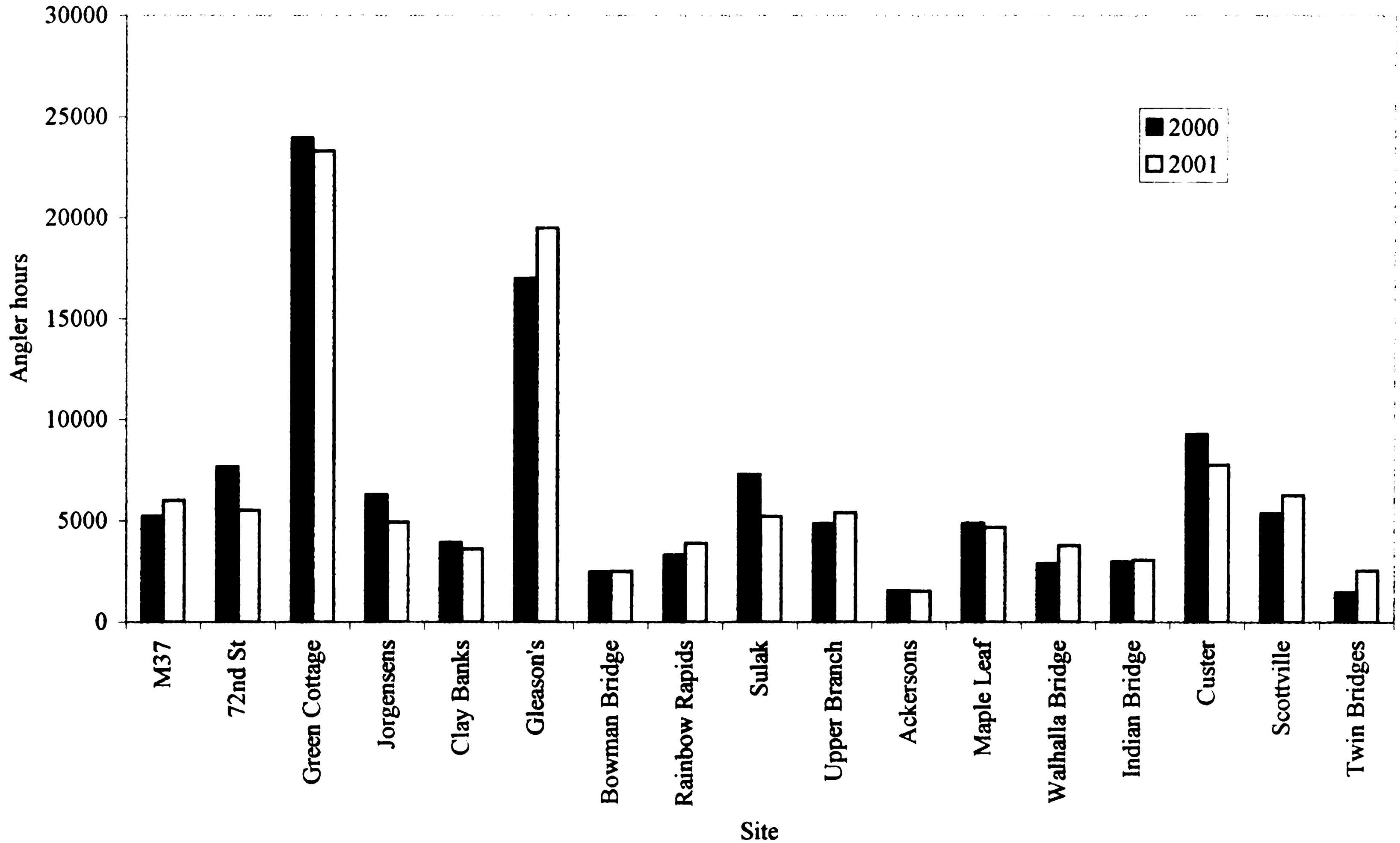


Figure 14. Estimated total effort at each study site on the Pere Marquette River, MI, Spring 2000 and 2001.

2001. Trip lengths were about 2 hours longer for steelhead anglers than for sucker anglers. This meant that 87.5% (96,652 hours in 2000, 95,839 hours in 2001) of the actual total effort was spent fishing for steelhead. In both years of the study, anglers interviewed in the "flies-only" section, and several midstream sites targeted only steelhead (Figures 15 and 16). At downstream sites, such as Indian Bridge, Custer, and Scottville, a greater proportion of the effort targeted suckers.

Catch rates varied greatly between species (Table 3). Sucker anglers caught only suckers, and had the highest catch per effort in both years of the study. The lowest catch per effort was for brown trout, which were caught regularly by anglers targeting steelhead. Catch rates were similar between years for all species of fish, although there appears to be a reduction in 2001 for steelhead and suckers. This possible reduction can most likely be attributed to the large estimated variances. Based on these estimates of catch per effort, the total catch (± 2 standard errors) for 2000 was 19,427 (±10,025) steelhead, 6,766 (±3,817) brown trout, and 33,166 (±225,860) suckers (Figure 17). In 2001, the total catch was estimated to be 16,676 (±12,152) steelhead, 8,242 (±10,325) brown trout, and 14,891 (±40,886) suckers (Figure 17).

The majority of anglers fishing on the Pere Marquette River were residents of Michigan, although license plates from 29 other states or provinces were observed (Table 4). Interview data suggest that anglers targeting steelhead were likely to travel greater distances to the Pere Marquette than those anglers targeting suckers. Interviews of anglers fishing for steelhead represented thirty-six Michigan counties. In 2000, about 36% of steelhead anglers were from Mason or Kent counties (Table 5). In 2001, about 34% of anglers interviewed were from Kent or Oakland counties. Sucker anglers, meanwhile, represented only 13 counties within Michigan. Most (76% in 2000, 70% in 2001) anglers targeting suckers were from Lake or Mason county.

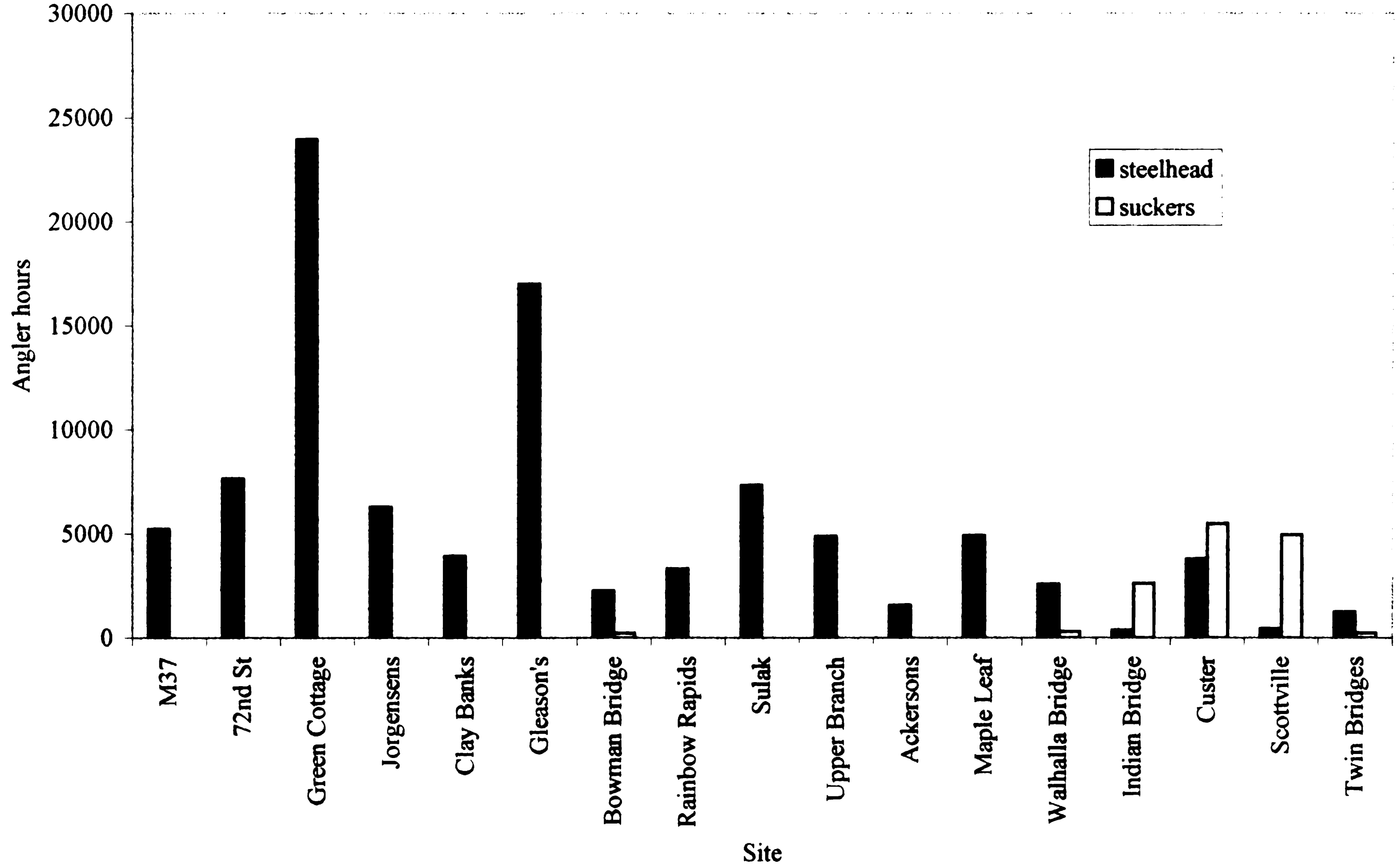


Figure 15. Estimated targeted effort at each sampling site on the Pere Marquette River, MI, Spring 2000.

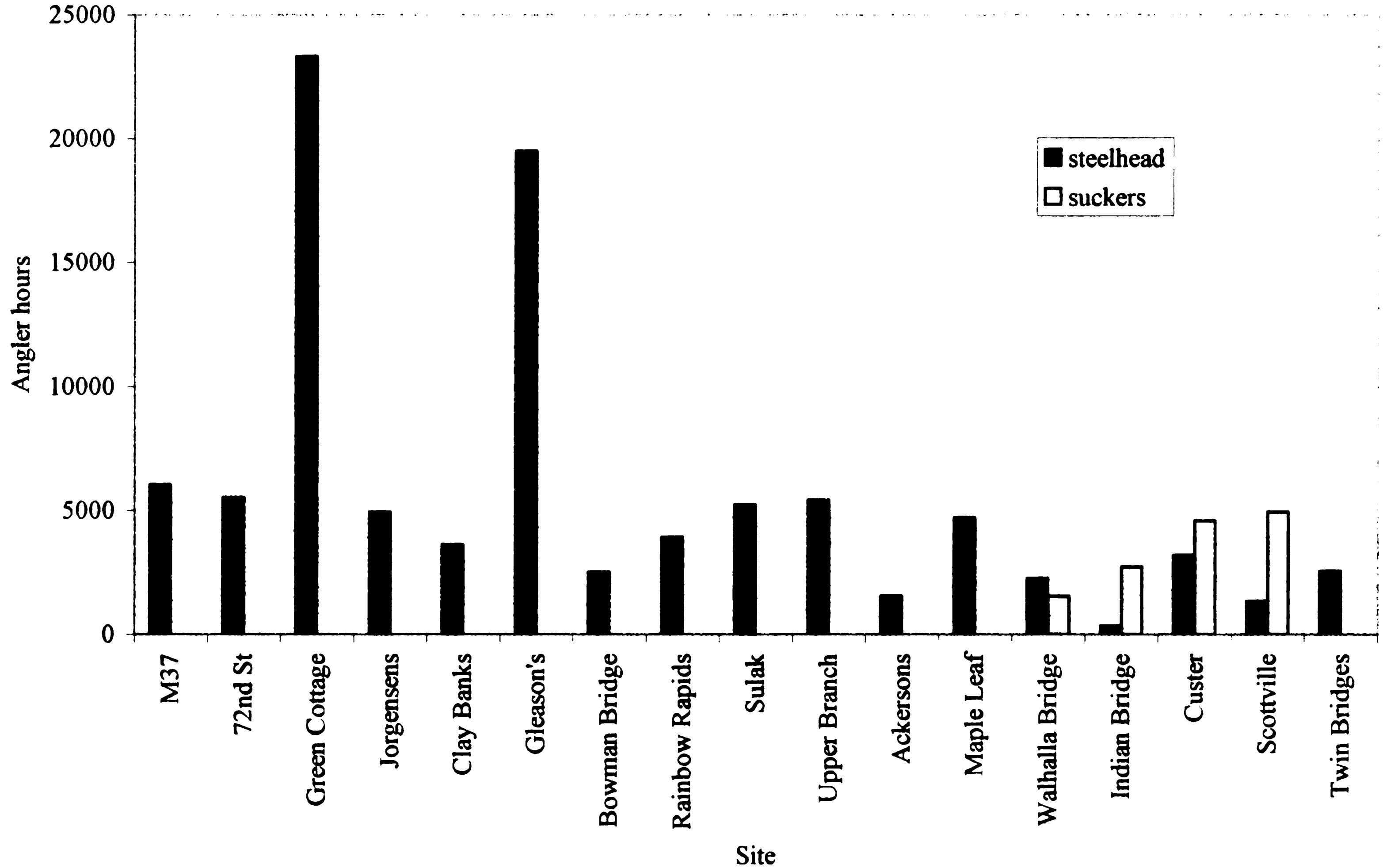


Figure 16. Estimated targeted effort at each sampling site on the Pere Marquette River, MI, Spring 2001.

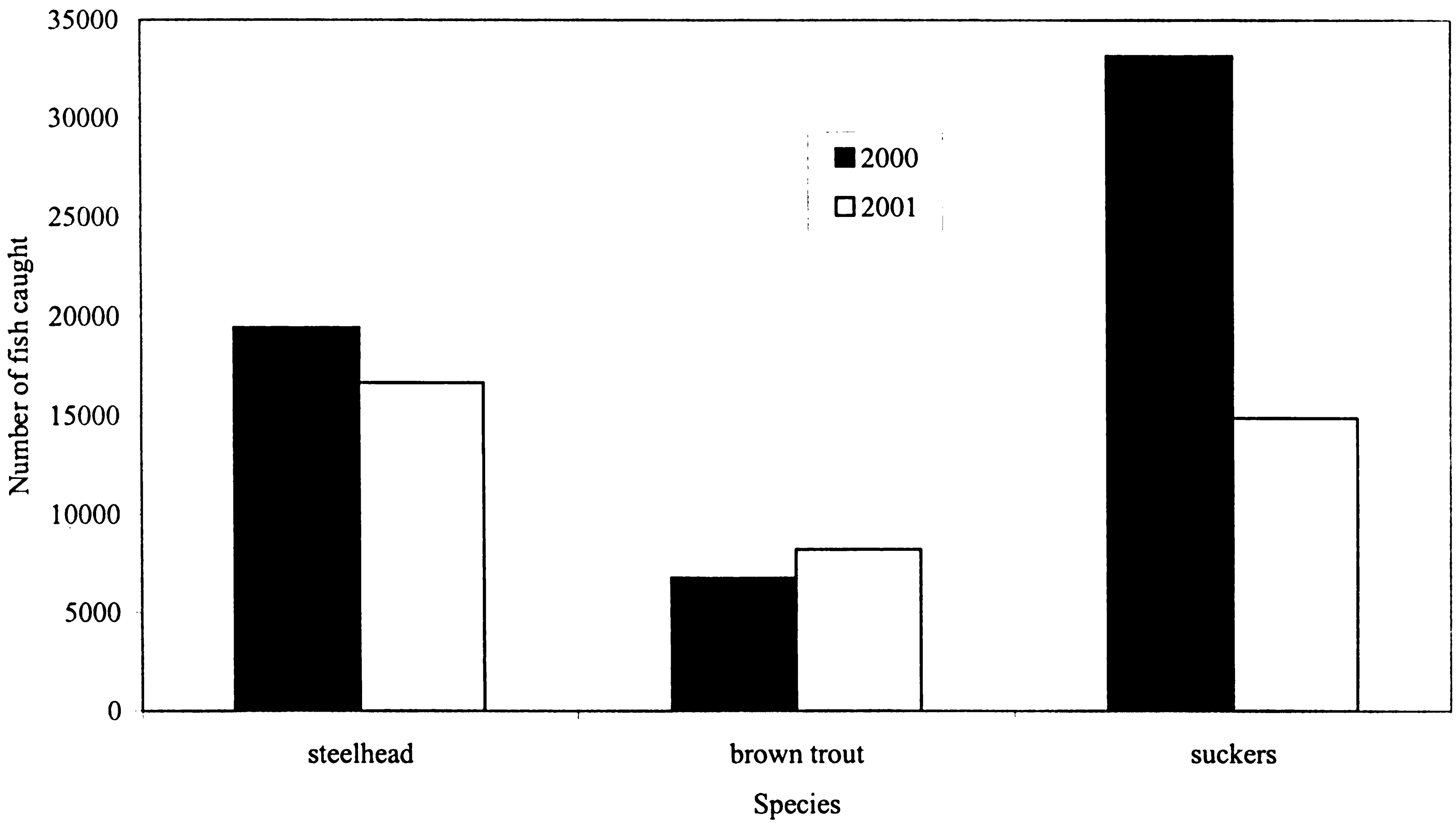


Figure 17. Estimated total number of fish caught on the Pere Marquette River, MI during the 2000 and 2001 sampling seasons.

Table 3. Catch per effort (fish/hour) estimates for anglers fishing on the Pere Marquette River, MI, Spring 2000 and 2001 (±2 standard errors).

	2000			2001		
Target	steelhead	suckers	brown trout	steelhead	suckers	brown trout
steelhead	0.201	0.028	0.070	0.174	--	0.086
	(0.089)	(0.036)	(0.034)	(0.112)	--	(0.094)
suckers	--	2.210	--	--	1.080	--
	--	(2.036)	--	--	(0.360)	--

Table 4. Percentage of anglers fishing the Pere Marquette River in 2000 and 2001, based on vehicle counts, by state or province of residence.

Residence	2000	2001
Michigan	93.1%	91.9%
Alabama	--	0.05%
Arkansas	0.04%	--
California	--	0.05%
Colorado	0.15%	0.46%
Georgia	0.04%	0.10%
Idaho	0.15%	0.21%
Illinois	2.25%	2.67%
Indiana	1.66%	1.33%
Iowa	0.15%	0.31%
Kentucky	0.10%	--
Maryland	--	0.05%
Minnesota	0.04%	0.05%
Mississippi	--	0.05%
Missouri	0.04%	--
Montana	0.29%	0.21%
New Hampshire	--	0.10%
New York	--	0.05%
North Carolina	0.04%	--
Ohio	1.61%	1.39%

Table 4 continued (page 2).

Residence	2000	2001
Ontario	0.04%	0.10%
Pennsylvania	--	0.21%
Tennessee	--	0.10%
Texas	--	0.05%
Vermont	--	0.05%
Virginia	--	0.05%
West Virginia	0.15%	0.05%
Wisconsin	0.04%	0.36%
Wyoming	0.04%	--
Sample Size	2044	1948

Table 5. Percentage of Michigan anglers interviewed while fishing for steelhead and suckers on the Pere Marquette River during 2000 and 2001 by county of residence.

	2000		2001	
Residence	Steelhead	Suckers	Steelhead	Suckers
Allegan	--	1.72%	--	--
Barry	0.80%	--	--	--
Bay	--	--	3.75%	--
Branch	--	--	1.25%	--
Calhoun	--	--	1.25%	--
Clare	2.40%	--	1.25%	--
Clinton	0.80%	--	1.25%	--
Crawford	0.80%	--	--	--
Eaton	0.80%	--	--	--
Emmet	0.80%	--	--	--
Genesee	2.40%	--	1.25%	--
Grand Traverse	1.60%	--	--	--
Gratiot	1.60%	--	--	--
Ingham	4.80%	--	--	--
Isabella	0.80%	--	2.50%	--
Jackson	--	--	1.25%	--
Kent	15.20%	--	16.25%	--
Lake	5.60%	18.97%	3.75%	24.24%
Lapeer	--	--	1.25%	3.03%
Livingston	--	--	1.25%	--

Table 5 continued (page 2).

	2000		2001	
Residence	Steelhead	Suckers	Steelhead	Suckers
Macomb	1.60%	--	1.25%	3.03%
Manistee	0.80%	3.44%	1.25%	3.03%
Mason	20.80%	56.90%	8.75%	45.45%
Mecosta	7.20%	1.72%	6.25%	--
Midland	2.40%	--	3.75%	--
Monroe	0.80%	--	3.75%	--
Montcalm	0.80%	--	--	--
Muskegon	4.80%	12.07%	6.25%	9.09%
Newaygo	2.40%	--	--	3.03%
Oakland	5.60%	--	17.50%	--
Oceana	1.60%	3.45%	1.25%	3.03%
Osceola	--	--	--	3.03%
Ottawa	4.80%	--	1.25%	3.03%
Saginaw	1.60%	--	3.75%	--
Shiawasee	--	--	1.25%	--
St. Joseph	--	--	1.25%	--
Washtenaw	0.80%	--	--	--
Wayne	5.60%	1.72%	6.25%	--
Sample size	125	58	80	33

DISCUSSION

The results of this study show that steelhead are, in fact, the principal species targeted in the spring fishery on the Pere Marquette River. Steelhead anglers can be found along the entire length of the river, but the highest density of anglers is in the "flies only" section. Sucker fishing, while only accounting for about 15% of the total effort, attracts mostly local anglers who spend nearly 14,000 hours on the lower portion of the river.

Also apparent from the results of this study and from Nelson et al. (1998) is that the Pere Marquette River has experienced dramatic changes in angler use over the past two decades. In 1982-83, anglers spent an estimated annual total of 74,294 hours fishing the section of river between M-37 and Rainbow Rapids, with approximately 30% of the effort taking place from February to April (Kruger 1985). During 2000 and 2001, this same section of river experienced an average of 69,584 angler hours from late February to late April alone. Kruger (1985) found that anglers fishing the "flies only" section made a total of 2,281 trips during the months of April and May. In my ten-week sampling period, anglers made an average of 12,012 trips to the "flies only" section. Additionally, Kruger (1985) reported that, between March and May, only about 1% of the effort in the "flies only" section was applied by boat anglers. In the two years of the present study, boat anglers applied an average of about 20% of the effort in the "flies only" water, which is probably an underestimate based on the method of calculation used. While it is difficult to make direct comparisons to Kruger (1985) due to methodological differences, it is clear that the number of anglers fishing the Pere Marquette has grown substantially in the past twenty years. Increased use is likely the result of many factors, including management for anadromous species and an increasing human population in the watershed. Interestingly, the users of the Pere Marquette River cite overcrowding as the most negative aspect of their trip (Nelson and Smith 1998).

Even with the large increase in total effort over this time period, the catch per effort for steelhead has increased (0.05 fish/hour during spring months in 1983 (Kruger 1985)). Both mandatory and voluntary catch-and-release fishing allow the same fish to be caught multiple times, and undoubtedly contribute to high catch rates and associated total catch. Catch rates of sucker fishermen proved to be difficult to accurately estimate due to large variances. These large variances can be attributed primarily to the low numbers of interviews collected. Additionally, the variance associated with sucker fishing is higher because the catch of suckers per angler (zero to 41 fish) was much more variable than the catch of steelhead per angler (zero to 6 fish).

From the results of this study, it is clear that the amount of angler effort has increased substantially on the Pere Marquette River. Most of this pressure comes from fishermen that travel from areas outside of the watershed to pursue steelhead in the upper reaches of the river. Sucker fishermen account for about 15% of the total effort, and are typically local anglers that fish the lower portions of the river.

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APPENDIX A

Date:___/___/___ Start time:______ a p End time:______ a p

Day of week:____ Start site (#):____

	Michigan			Out-of-state		
	cars	trailers	notes	cars	trailers	notes
1. M-37						
2. 72nd St						
3. Green Cottage						
4. Clay Banks						
5. Jorgenson's						
6. Gleason's Landing						
7. Bowman Bridge						
8. Rainbow Rapids						
9. Sulak						
10. Upper Branch						
11. Lower Branch						
12. Ackerson's						
13. Maple Leaf						
14. Walhalla Bridge						
15. Indian Bridge						
16. Custer						
17. Scottville						
18. Twin Bridges						

NOTES:

APPENDIX B

COMPLETED TRIP ANGLER PARTY INTERVIEW FORM

Party interview ID#____	Date: ___ ___ ___	Site:______________
Angler ID#_____	Day of week:_____	Interview time:_____ a p
Anglers in party: _______	Length of trip: _______	Mode: boat shore
Target species:__________	State of residence:____	County of residence:_____

Catch

Species	kept	released	Species	kept	released
Suckers	___	___	Steelhead	___	___
Longnose	___	___	Brown trout	___	___
White	___	___	Northern pike	___	___
Redhorse spp.	___	___	__________	___	___
Rock bass	___	___	__________	___	___

Party interview ID#____	Date: ___/___/___	Site:______________
Angler ID#_____	Day of week:_____	Interview time:_____ a p
Anglers in party: _______	Length of trip: _______	Mode: boat shore
Target species:__________	State of residence:____	County of residence:_____

Catch

Species	kept	released	Species	kept	released
Suckers	___	___	Steelhead	___	___
Longnose	___	___	Brown trout	___	___
White	___	___	Northern pike	___	___
Redhorse spp.	___	___	__________	___	___
Rock bass	___	___	__________	___	___