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Time-Lapse Video Recording**

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Estimates of Fish Passage on the St. Joseph River in 1993 Using Time-Lapse Video Recording

James L. Dexter, Jr.

*Michigan Department of Natural Resources
P.O. Box 355
Plainwell, MI 49080*

and

Neil D. Ledet

*Indiana Department of Natural Resources
6889 N. State Road 327
Orland, IN 46776*

Abstract.—Monitoring of total fish passage at the Berrien Springs, Niles, and South Bend dams was accomplished from 16 February through 9 December 1993 using time-lapse video recording. This was the first complete year of monitoring at all three dam sites since completion of the five fish ladders on the lower St. Joseph River in 1992. Total passage of fish varied from 29,993 at the Berrien Springs dam to 10,106 at the South Bend dam. Warmwater and coolwater species accounted for 6.9% of the total observations at the Berrien Springs and Niles dams. Members of the sucker family accounted for over 67% of warmwater and coolwater fish passage. No enumeration of these species was attempted at the South Bend ladder. Potamodromous salmonines comprised 94.4% of all observations at the three facilities. Steelhead and chinook salmon were the most prevalent species passed, respectively. Approximately 25% of the total ladder movements at all three facilities occurred at night (2000 to 0800 EST). The South Bend ladder showed the highest night-time usage, as occurred in 1992. Evaluation of the accuracy of video readers and video recordings compared to manual counts showed no significant differences. Fish passage at the Berrien Springs ladder was considerably higher in 1993 compared to previous years. However, this was most likely due to the extended open ladder period. Distribution of salmonines throughout the available 63 miles of river was not evenly distributed as we thought might occur. The use of video time-lapse photography proved to be a good method for estimating returns of salmonines and passage of resident river species. With video, filming can take place continuously, improving fish passage, identification and counting in order to help meet program management goals.

The St. Joseph River, located in southwest Michigan and northwest Indiana, is the third largest river basin in Michigan. It drains a watershed of approximately 2,600 square miles

in Michigan and 1,685 square miles in Indiana. The average discharge (measured at the river mouth in St. Joseph, Michigan) is 4,598 cubic feet per second. The river is 306 miles long and

has an additional 1,641 miles of tributary streams (Brown 1944). The St. Joseph River is designated as a top quality warmwater system in Michigan. The river has hosted runs of salmonines from Lake Michigan since the inception of the salmonine stocking program in the late 1960s. Even though it is classified as a warmwater system, the river does support a high quality population of coolwater species. Prior to the first dam being constructed in Niles in 1868, the St. Joseph River hosted a variety of potamodromous species that had free access to the entire river length. Species included: lake sturgeon *Acipenser fulvescens*, whitefish *Coregonus clupeaformis*, muskellunge *Esox masquinongy*, and lake trout *Salvelinus namaycush*.

In 1975, Michigan constructed a fish ladder at the Berrien Springs dam which expanded fishing opportunities for potamodromous trout and salmon some 33 miles upstream from Lake Michigan to the Buchanan Dam (Figure 1). Based on the success of this project, the Michigan Department of Natural Resources (MDNR), the Indiana Department of Natural Resources (IDNR), and the U.S. Fish and Wildlife Service (USFWS) began discussions to further develop and manage this fishery. An environmental impact statement (James et al. 1980) was developed and presented to the public in 1980. This \$15 million dollar interstate project called for the construction of fish passage facilities at the Buchanan, Niles, South Bend and Mishawaka dams enabling spawning runs of trout and salmon to migrate from Lake Michigan 63 miles upstream to the Twin Branch Dam in Mishawaka, Indiana. This plan also called for the construction of a coldwater fish hatchery in Indiana (Richard Clay Bodine State Fish Hatchery) to provide fish for Indiana's river stocking commitment. To date, all four ladders and the hatchery have been completed. Minor modifications to the original Berrien Springs ladder continue to be made to improve its efficiency. Migrating salmonines had unimpeded access to the lower 63 miles of the St. Joseph River for the first time during fall 1992. Monitoring fish passage by both states started in September 1992 and includes most months of the year.

Fish passage at the Berrien Springs dam has been estimated each year since 1977. Prior to 1992, the Berrien Springs facility included a resting pool at the top of the ladder, with several boards (stop logs) to control water flow and fish passage. The ladder operator would remove boards in the morning and evening and manually count each passed fish by species.

Presently, the Berrien Springs, Niles, South Bend and Mishawaka fish ladders have underground fish viewing (counting) rooms with windows located along the ladder wall. Fish migrating through these ladders are directed within 16 to 20 inches of the window by an angled aluminum crowder grate or by the narrowing of the concrete ladder chamber. A sloped metal ramp at the bottom of the ladder chamber and subsurface grates have also been installed where necessary to direct fish toward the center of the window for viewing. A fish-viewing room was built above ground at the Buchanan fish ladder. At this facility, an angled steel grate forces fish within 12 inches of the water surface for viewing. Fish counts are not immediately planned for the Buchanan and Mishawaka fish ladders.

In 1988 a formal written agreement between the states of Michigan and Indiana was developed to serve as a management framework for the program (Anonymous 1988). This agreement, signed by the Directors of the MDNR and IDNR, included monitoring the returns of adult salmonines from Lake Michigan. The Berrien Springs, Niles, and South Bend fish ladders are primary counting locations at this time. The Berrien Springs dam, 23 river miles upstream from the mouth, is the first dam encountered by returning adult salmonines. The Niles dam is located 19 river miles upstream of Berrien Springs. It is the last dam salmonines encounter before entering Indiana's portion of the St. Joseph River. The South Bend dam is an additional 14 river miles above Niles and is the first dam salmonines encounter in Indiana (Figure 1).

Chinook salmon *Oncorhynchus tshawytscha* have been stocked by Indiana in the St. Joseph River since 1984, and Skamania-strain steelhead *Oncorhynchus mykiss* since 1985. The majority of these stockings occur in Indiana waters of the St. Joseph River, five dams

upstream of Lake Michigan. The MDNR has stocked fall- and spring-run steelhead (Little Manistee River strain), chinook salmon, coho salmon *Oncorhynchus kisutch*, and brown trout *Salmo trutta* in the river since the early 1970s. These were stocked between the Berrien Springs dam and Lake Michigan. Stocking targets for the river (both states combined) are 175,000 spring yearling Skamania steelhead; 50,000 fall fingerling Skamania; 50,000 spring yearling Michigan-strain steelhead; 580,000 spring fingerling chinook salmon; and 15,000 spring yearling brown trout. Appendix 1 contains all stocking information on the St. Joseph River for both states since 1984.

The main objective of this project was to continue to determine the number, times of movement, and species of fish, both of river residents and potamodromous salmonines, that utilized the Berrien Springs, Niles and South Bend fish ladders in 1993. Other tasks performed during the 1993 monitoring period included: 1) estimating relative contribution by strain (Skamania and Little Manistee River) for steelhead utilizing the Berrien Springs and South Bend fish ladders, 2) comparing fish passage estimates from the 48- and 72-h taping mode against manual counts, 3) determining the accuracy of fish passage estimates between various tape readers, 4) determining the effectiveness of using attraction water to improve fish passage and 5) determining the effectiveness of altering the baffle system in the upper pool of the Berrien Springs fish ladder to improve fish passage past the viewing window.

Methods

We monitored fish passage through the Berrien Springs, Niles and South Bend fish ladders using identical, Super VHS time-lapse video recording equipment. Video tape recording was conducted at the Berrien Spring ladder from 16 February through 30 April and from 18 June through 25 November 1993. Recording at Niles ran from 16 February through 30 April and from 18 June through 9 December. At South Bend, video recording was conducted from 16 February through 31 May and from 17 June through 9 December. The

seasonal periods not monitored are generally considered low movement periods for salmonines. Table 1 lists the days and times during the monitoring period that recording was not conducted and the reasons recording was not conducted.

Equipment specifications, recording modes, viewing window dimensions, and lighting specifications are outlined in our 1992 report (Dexter and Ledet 1994). Modifications since 1992 included the addition of an adjustable bank of eight, 150-watt flood lights in the Berrien Springs viewing room. This track mounted bank of lights on the ceiling was positioned approximately 3 feet from the viewing window. In addition, cold weather ballasts were added to the fluorescent lights in the backlighting panel at the Niles ladder, while a backlighting diffuser panel and two permanent, 300-watt lights were added to the South Bend fish viewing system.

Tapes were reviewed by fisheries personnel experienced in identification of fishes. The equipment used for viewing allowed the tape reader to control playback speed and tape direction. Tapes could be played one frame at a time in either direction to permit fish identification as needed. Fish passage was tabulated on an hourly basis and entered into a database for analysis. This information was used to estimate passage by: four-hour periods (i.e., 0000 to 0400 Eastern Standard Time (EST)), day, week, month and season. For periods where recordings were missed, estimates were made by averaging fish passage by species for the same time period 2 d before and 2 d after the missed time period.

To determine strain of steelhead that used the Berrien Springs and South Bend fish ladders, fisheries personnel assigned each steelhead viewed on the video tape a strain designation based on body shape, fin clips or both.

The accuracy of using time-lapse taping to estimate fish passage was determined by fisheries personnel manually counting fish passing the viewing window over a designated time period, and comparing this number with the number determined from viewing the tape for the same period. This was conducted at the Berrien Springs and Niles ladders, for both the 48- and 72-h recording modes. Similar

comparisons were conducted at the South Bend ladder using the 48-h mode only.

We also tested the accuracy of two different people reading the same tapes, and the same person reviewing a tape twice. Differences in fish counts between readers and between manual counts and video tape estimates were tested using a pairing design t-test (Remington and Schork 1970, Snedecor and Cochran 1989). Alpha was set at 0.05.

The addition of attraction water at the Niles ladder was tested for its ability to improve fish passage. Attraction water was initiated and run until the screen became plugged by debris, which prevented attraction water flow. Control gates for attraction water were then shut down in order to self clean, and then restarted within a few days. Dates and times of attraction water flow were recorded. At the Berrien Springs fish ladder, permanent cement baffles located in the first pool above the viewing window were removed and replaced with wooden baffles that could be altered. Testing there included varying the heights and configuration of the baffles to determine if certain flow patterns could improve fish movement past the viewing window.

Results

Fish Passage

Total fish passage at all three ladders in 1993 ranged from 29,993 at Berrien Springs to 10,166 at South Bend (Table 2). The Berrien Springs ladder was operated a total of 234 d, Niles 242 d, and South Bend 261 d. Fish counts at Berrien Springs were up considerably compared to historic passage (Figure 2). Higher passage was observed for steelhead and chinook salmon, possibly a result of extended ladder operation and higher than normal spring river discharge. This was the first year of full operation during the summer months. Daily fish passage at each dam can be found in Appendix 3-5. Due to failure of video recorders and manpower limitations, we estimated 0.5%, 0.4%, and 6.0% of the passage at the Berrien Springs, Niles, and South Bend ladders, respectively.

Potamodromous salmonines comprised 94.41% of all fish passed at the three ladders. Steelhead were the most numerous species passed at each of the ladders, while chinook salmon were the second most common. Suckers (Catostomidae), walleye *Stizostedion vitreum*, smallmouth bass *Micropterus dolomieu*, channel catfish *Ictalurus punctatus*, common carp *Cyprinus carpio*, alewife *Alosa pseudoharengus*, and rock bass *Ambloplites rupestris* represented the remaining 6.8% of the observations. Warmwater and coolwater species were not tabulated for the South Bend ladder due to personnel time limitations.

Steelhead

The first steelhead entered the Berrien Springs ladder on 3 March, 15 d after opening. A total of 20,604 steelhead passed through this ladder during the 1993 season. The highest monthly passage occurred in August (Table 3), the lowest in November (excluding the partial month of February). During the sampling period there were 39 d when no steelhead passed. An average of 88 steelhead passed per day. Spring steelhead passage at this ladder was significantly higher in 1993 compared to previous years of passage (Figure 3).

On 22 March, the first steelhead was observed moving through the Niles ladder. A total of 7,995 steelhead passed through the Niles ladder during the sampling period. The highest monthly passage occurred in September, the lowest in November (excluding partial months, Table 3). During the sampling period there were 79 d when no steelhead passed. An average of 33 steelhead passed per day.

The first steelhead to move through the South Bend ladder was observed on 6 March. (Steelhead which passed all dams in fall 1992 could move anytime in the spring, hence the possibility existed for earlier movements through the ladders). A total of 6,987 steelhead passed through the South Bend ladder during the sampling period. The highest monthly passage occurred in September, the lowest in May (excluding partial months, Table 3). During the sampling period, there were 87 d when no

steelhead passed. An average of 27 steelhead passed per day of operation.

In the fall, Skamania and Little Manistee River steelhead were identified from video tape recordings based on body shape and fin clips. The first Little Manistee River steelhead appeared in the Berrien Springs ladder on October 1. Skamania movement slowed to a trickle as the Little Manistee River strain peaked in mid to late October (Figure 4). No strain identification was conducted at the Niles ladder. At the South Bend ladder, the first Little Manistee River strain steelhead was not observed until 3 November. Of the 93 steelhead that passed the South Bend ladder between 3 November and the 9 December closure, 24 (26%) were classified as Little Manistee River strain.

Peak time period for steelhead movement occurred between 0800 and 2000 EST for all three ladders (Table 4). The South Bend ladder exhibited the highest tendency for night movement (36%), while the Berrien Springs and Niles ladder exhibited the lowest amounts of night movement (29%). Our video counts showed that 39% and 34% of the steelhead passed at the Berrien Springs ladder also passed the Niles and South Bend ladders, respectively (Figure 5).

Chinook Salmon

Chinook salmon were first observed in the Berrien Springs ladder on 25 July. A total of 7,491 chinook salmon passed through the Berrien Springs ladder July through November (Table 5). Approximately 8% of the chinook salmon passed at Berrien Springs consisted of young-of-the-year (8-10 in) fish that originated from Indiana's spring stockings. These fish were uniquely fin clipped and easily identified at this ladder. Identification of these fish was more difficult at Niles and South Bend due to the speed at which these fish passed the win-

dow. September had the highest chinook salmon passage, and July the lowest. During the chinook salmon migration, 25 July through 19 November, an average of 64 chinook salmon passed through the Berrien Springs ladder each day. There were 17 d during this time when no chinook were observed at the Berrien Springs ladder. The 1993 chinook salmon migration was considerably larger than previous years, and contributed most of the difference in fall passage totals (Figure 6).

The first chinook salmon was observed using the Niles ladder on 4 September, 41 d after the first was seen at Berrien Springs. During migration, the highest chinook salmon passage occurred in September, while the lowest was in November (Table 5). Once the migration reached this ladder, there were 13 d when none passed through (up to the end of the migration on 14 November). An average of 49 chinook salmon passed through the ladder each day from the start of the migration.

A total of 3,025 chinook salmon utilized the South Bend ladder. The first chinook salmon was recorded on 6 September, 33 h after the first chinook was observed passing through the Niles fish ladder. October and November accounted for the highest and lowest monthly passage, respectively (Table 5). There were 7 d during the migration when no chinook salmon passage occurred at the South Bend ladder (up to the end of the migration on 21 November). An average of 39 chinook salmon passed through the ladder each day from the start of the migration.

The peak time period of chinook salmon movement occurred between 0800 and 2000 EST for all three ladders (Table 4). The South Bend ladder exhibited the highest tendency for night movement (33%), while the Berrien Springs ladder exhibited the lowest amount of night movement (13%). Video counts showed that 47% of the chinook salmon that passed through the Berrien Springs ladder also moved through the Niles ladder. Only 40% of the chinook salmon that migrated through the Berrien Springs ladder also passed through the South Bend ladder (Figure 7).

Coho Salmon

Coho salmon were observed passing through the Berrien Springs ladder from 5 August through 21 October, and a total of 447 passed through this ladder. Most coho salmon passed in September, while the least number passed in August (Table 6). There were 27 d when no coho salmon passed. An average of seven coho salmon passed through the ladder each day during their migration.

The first coho salmon passed the Niles ladder on 13 September, 39 d after the first one appeared at Berrien Springs. The coho migration through this ladder continued through 28 October. The highest monthly passage was in September (Table 6). There were 13 d when no coho salmon passed, while an average of three passed through the ladder each day during their migration.

A total of 146 coho salmon moved through South Bend ladder, the same number as in 1992. The first was observed at South Bend on 13 September, only 4 h after the first one was observed at the Niles ladder. The majority of coho salmon moved through this ladder in September, followed by the lowest number in October (Table 6). There was only one day when no coho salmon were observed during their run period (13 September - 16 October). An average of four passed through the ladder each day during their run.

Peak time periods for movement of coho salmon occurred between 0800 and 2000 EST for all three ladders (Table 4). Once again, the South Bend ladder exhibited the highest tendency for night passage (39%), while the Berrien Springs ladder exhibited the lowest amount of night movement (17%). Our video counts showed that 31% of the total number of coho salmon that passed through the Berrien Springs ladder passed the Niles ladder, and that 33% of the Berrien Springs total passed through South Bend (Figure 8).

Brown Trout

Brown trout were observed moving through the Berrien Springs ladder between 18 June through 23 November. A total of 771 brown

trout passed through this ladder (Table 7). There was a large movement of brown trout immediately following the opening of the ladder on 18 June. However, the largest movement occurred in September, with the lowest movement in winter (Table 7). There were 56 d when no brown trout passed. An average of five brown trout passed through the ladder each day during their migration.

A brown trout was first observed at the Niles ladder on 6 July, although it was the only one observed until 17 September. A total of 205 brown trout passed through this ladder through 22 November, the last observation. September had the highest passage, while August had none (Table 7). There were 93 d when no brown trout passed this ladder. An average of two brown trout passed through the ladder each day during their migration.

Only eight brown trout passed through South Bend fish ladder, five in September, two in October and one in November. Obviously, during most days of operation no brown trout passed this ladder.

Peak time periods for movement of brown trout occurred between 0800 and 2000 EST at all three ladders (Table 4). The Niles ladder exhibited the highest tendency for night movement (28%), while none of the eight brown trout observed at South Bend ladder moved at night. Our video counts showed that 27% of the total brown trout passage at the Berrien Springs ladder passed the Niles ladder, and only 1% of the Berrien Springs total passed through the South Bend ladder (Figure 9).

Ladder Usage by Daily Time Period

Daily movement of salmonines through the fish ladders occurred mainly during the daylight hours (0800 to 2000 EST). Approximately 25% of total ladder movements occurred at nighttime (2000 to 0800 EST) which is the same amount we observed during fall 1992. The highest nighttime salmonine movement occurred at South Bend in 1993: 36% for steelhead, 33% for chinook salmon, and 39% for coho salmon. This also was similar to the movement observed 1992.

Steelhead passage peaked at all three ladders during the late morning period (0800 to 1200 EST). This was 4 h earlier than peak movement at Berrien Springs and Niles during fall 1992, but the same for South Bend. Chinook salmon passage peaked at the Berrien Springs ladder in the late afternoon period (1600 to 2000 EST), and at Niles and South Bend in the late morning period (same time periods as fall 1992). In 1993, coho salmon movement peaked at Berrien Springs in the late afternoon period, and in the late morning period at Niles and South Bend. This was similar to 1992, with the exception of South Bend which peaked in the early afternoon in 1992. Brown trout passage peaked at Berrien Springs in the late afternoon period, and at Niles and South Bend in the late morning period. This too was similar to 1992, with the exception of Niles which had a brown trout peak in the early afternoon period in 1992.

Other Species

For the first time since we have operated the Berrien Springs ladder (1977), lake trout (8) were observed using the fish ladder (Table 2). All of the lake trout moved through in October. During our first year of summer operation, we also passed a total of 672 warmwater and coolwater fishes at Berrien Springs and 2,390 at Niles. A total of 67% of this passage was comprised of sucker species, including white sucker *Catostomus commersoni*, quillback carpsuckers *Carpionodes cyprinus*, longnose sucker *Catostomus catostomus*, and redbreasted sunfish *Moxostoma* spp. No attempt was made to keep track of individual species of sucker. Channel catfish were the second most common warmwater or coolwater species to use the fish ladders, representing 18% of the non-salmonine passage. Most catfish and suckers were passed at the Niles ladder. Carp were passed more frequently at Niles, while smallmouth bass passed in about equal numbers at both ladders. Only 28 walleye were observed at Berrien Springs and Niles ladders. Seven alewife passed the Berrien Springs ladder, and one rock bass moved through the Niles ladder.

Downstream Ladder Passage

We estimated downstream ladder passage at Berrien Springs and Niles ladders. Very few fish of any species utilized the ladder for downstream passage. Downstream passage numbers and species are included in Appendix 2.

Evaluation of Accuracy of Video Readers and Video Recording

We tested the accuracy of two different video tape readers. Two tapes, 48- and 72-h modes, from Berrien Springs and Niles were used. We also tested the accuracy of our full time tape reader by having these tapes read twice. No significant differences were found in any of the tests conducted (whole tape tests, Table 8). We then tested the accuracy of manually counting fish to the video tape recording. No significant differences could be found in these tests either, which were conducted for both the 48- and 72-h recording modes (Table 8).

Discussion

Potamodromous fish passage at Berrien Springs in 1993 was considerably higher than passage in previous years (Figure 2, 3, and 6). Chinook passage in the St. Joseph River was relatively strong, while runs elsewhere appeared down. Michigan's stocking rates for chinook salmon in the St. Joseph River have increased since 1988, due to the additional river miles available through ladder construction. However, the catch and catch rates in 1993 for Michigan waters of the Great Lakes were the lowest ever recorded (Rackozy and Svoboda 1995), and runs statewide were minimal. The overall run strength of chinook salmon, as determined by ladder counts at Berrien Springs, appears related to ladder operation and is not out of the ordinary.

Spring passage of steelhead was the largest seen to date on the St. Joseph River. However, the high number of fish passed was not unusual considering the number stocked annually.

Fishing effort and access to the river during the spring season was severely hampered by high water levels for the entire migration. The additional discharge, 3-4 times higher than normal over the majority of the spring (Smithburger, Indiana and Michigan Power Company, personal communication), severely hampered fishing success and fishing access, and appeared to encourage steelhead to migrate further upstream. Ladders being open 24 hours a day is also considered a contributing factor to the overall spring steelhead passage.

The 1993 steelhead run occurred in five distinct peaks (Figure 5). The first peak in the spring appeared to be made up primarily of Little Manistee River fish. However, we have no enumeration of the stock origin at this time. During the fall, steelhead strains could be accurately determined by visual characteristics observed during tape viewing. However, as fish mature these characteristics became less distinguishable. To determine steelhead relative abundance, the Berrien Springs and South Bend ladder fish traps will be operated during the 1994 and 1995 spring monitoring period to supplement data collected during the creel survey.

The second, third, and fourth peaks (Figure 5) were all Skamania steelhead, while the last peak was a mixture, as described in the results. Skamania steelhead moved through the Berrien Springs fish ladder within 2 h after opening the ladder in mid June. At that time, we were not aware that Skamania steelhead had entered the river.

Returning Skamania steelhead appear to be cued by a combination of both the river and Lake Michigan water temperatures. The first steelhead movement in June barely reached the Niles ladder before river temperatures rose above 72 F, which appeared to eliminate Skamania movement. When temperatures reach 72 F or above, we have observed these fish concentrating in the cooler waters of incoming tributaries, typically holding in the St. Joseph River at the mouths of these waters (presumably to conserve energy and reduce stress). The third peak of the year (the largest) occurred in August and suffered the same fate as the first Skamania run in June. River temperatures soared quickly after the run began, and most of the fish that

passed Berrien Springs never made it to Indiana. Once temperatures cooled, the last wave of Skamania came in, and more fish did migrate through to Indiana.

Chinook and coho salmon tended to be more distributed in their run strengths over the fall, but did exhibit definite peaks (Figures 7 and 8). The earliest migrating fish of both species showed up at Berrien Springs during the first two weeks in August. It is not known what percentage of the chinook that passed Niles into Indiana were actually stocked in Indiana. However, fish observed in the creel and sampled from the South Bend ladder fish trap will address this issue. All coho salmon returns are presumably from a 1992 net-pen project at St. Joseph (rearing of 217,000 fall fingerlings), or were stray fish. While the number passed was relatively low compared to chinook salmon and steelhead, coho salmon passage in 1993 was higher than any year since 1981. Coho salmon reared in net pens from a 1990 release at the port of St. Joseph showed no positive benefit to the river fishery in 1992 (Dexter and Ledet 1994).

The run of brown trout in the St. Joseph River was good in 1993. Only 15,000 yearling browns are stocked annually at the port of St. Joseph; over 750 were counted as they ascended the Berrien Springs ladder. Most of these fish primarily moved through the three ladders in daylight, contrary to previous studies of movements of stream-dwelling brown trout (Clapp et al. 1990, Hudson 1993). These fish always attract anglers and create excitement when they are caught. It is not uncommon to have several brown trout that exceed 15 pounds captured by anglers below Berrien Springs dam. We were very surprised at the strength of brown trout passage in June, which was previously unknown. Once these fish pass Berrien Springs, our video counts show that they have a very strong tendency to remain in Michigan's portion of the river.

Fish passage counts at the Berrien Springs ladder have been made by the same operator since 1977. On several occasions prior to 1992, manual counts were made at the Berrien Springs ladder through the night. On each occasion, counts were sufficiently low to surmise that most passage occurred in daylight hours. Our

data also show that the majority of passage occurs during daylight hours (0800 and 2000 EST). However, a significant proportion of the 1993 run did take place during the night, similar to that observed in 1992 (Dexter and Ledet 1994). This information suggests that it would be beneficial to operate the ladders on a 24-h basis in order to assure good passage and document movement trends.

Use of video time-lapse photography proved to be a good method for estimating returns of salmonines. In past years, fish were passed only when the ladder operator was on site to conduct manual counts. Now, time-lapse filming and ladder operations can take place continuously, improving fish passage and counting capabilities. However, reading the tapes can be time consuming, depending on how many fish are on a tape and the recording mode used. In 1993, tape reading ranged from 2-20 hours per tape.

In January 1993, we modified each ladder with metal ramps at the bottom of the viewing window to direct fish up into the window for viewing. A gap of seven inches existed between the bottom of the window and the ladder floor, which may have allowed smaller fish to pass undetected (Dexter and Ledet 1994). Once installed, this ramp also improved video recording of the entire fish which facilitated identification.

Our fish passage totals did have one small discrepancy. Nine more coho were counted at South Bend than at Niles. We do not believe this is a result of missing fish at Niles, rather the misidentification of fish species in the 8-12 inch range. This size group coincides with young-of-the-year chinook salmon and small jack coho salmon.

We also attempted to determine the effectiveness of using attraction water to improve fish movement through the Niles fish ladder. Limited manpower and environmental factors prevented this task from being completed.

The Berrien Springs ladder was modified prior to the 1993 spring operation. This modification consisted of removing cement baffle walls in the first pool above the viewing window and replacing them with wooden timbers that we could adjust. Hydraulic

conditions in this area of the ladder appeared to delay fish movement past the viewing window. Migrating fish hesitated, and moved back and forth in front of the window before continuing upstream and out of the ladder. On occasion, individual fish remained in front of the viewing window for up to a week. This caused serious analysis problems. Several possible configurations with the adjustable timber walls have been tried to improve fish movement past the window. However, none showed any positive benefits. Additional modifications to this chamber will be made in 1994, which may include a reduction of the available cross section of the ladder to increase water velocities.

Movement of salmonines, especially steelhead, throughout the 63 miles of available river did not occur as anticipated. Our data show that the majority (more than 60%) of the salmonines that migrated through the Berrien Springs ladder didn't continue on to Niles, much less to Indiana. Although this is partially a function of fluctuating water temperatures, it does not explain why so many Skamania that used the Berrien Springs ladder in August did not later ascend the river once water temperatures became more favorable. Homing, or lack thereof, is a possible cause. The Dowagiac River is the largest tributary to the St. Joseph River, with its confluence approximately 1/2 mile below the Niles dam. The Dowagiac River probably did not hold all of these Skamania, as fishing success would have been outstanding and reflected in the creel survey. The goal of the St. Joseph River Trout and Salmon Plan is to provide high quality fishing opportunities in the lower 63 miles of the St. Joseph River. Part of the initial evaluation of the plan includes a policy to leave ladders open during the migration (rather than close ladders to concentrate fish for anglers), and monitoring to determine how returning trout and salmon distribute themselves in the project area. To date, returns have not been as high as expected and the movement of trout and salmon from above Berrien Springs into Indiana is disappointing. Angler effort has also been unevenly distributed throughout the 63 miles. However, Cole and Ward (1994) suggested that distributing resources unevenly over sites would produce the highest angler benefit.

Passage of warmwater and coolwater species was considered low and not tabulated prior to 1992. However, once the ladders were operated during the summer months the movement of warmwater and coolwater species increased. Sucker, catfish, carp and smallmouth bass commonly used the ladders. We were surprised by the low number of walleye that utilized the ladders, considering the excellent walleye fishery present in the lower Michigan waters of the St. Joseph River. For the first time, alewife were seen moving through the Berrien Springs ladder and could present management implications.

In addition to estimating fish passage, tasks to accomplish in 1994 include continuing

modifications to the flow regime at Berrien Springs to facilitate improved fish passage in front of the viewing window and assessing stock origins for steelhead trout and chinook salmon.

Acknowledgments

The authors wish to thank the many Michigan and Indiana Department of Natural Resources personnel who worked hard to complete this project. John Clevenger Sr. and Peggy Dorsey read most of the tapes, while various management technicians, hatchery and creel census personnel also labored to assist in ladder operations.

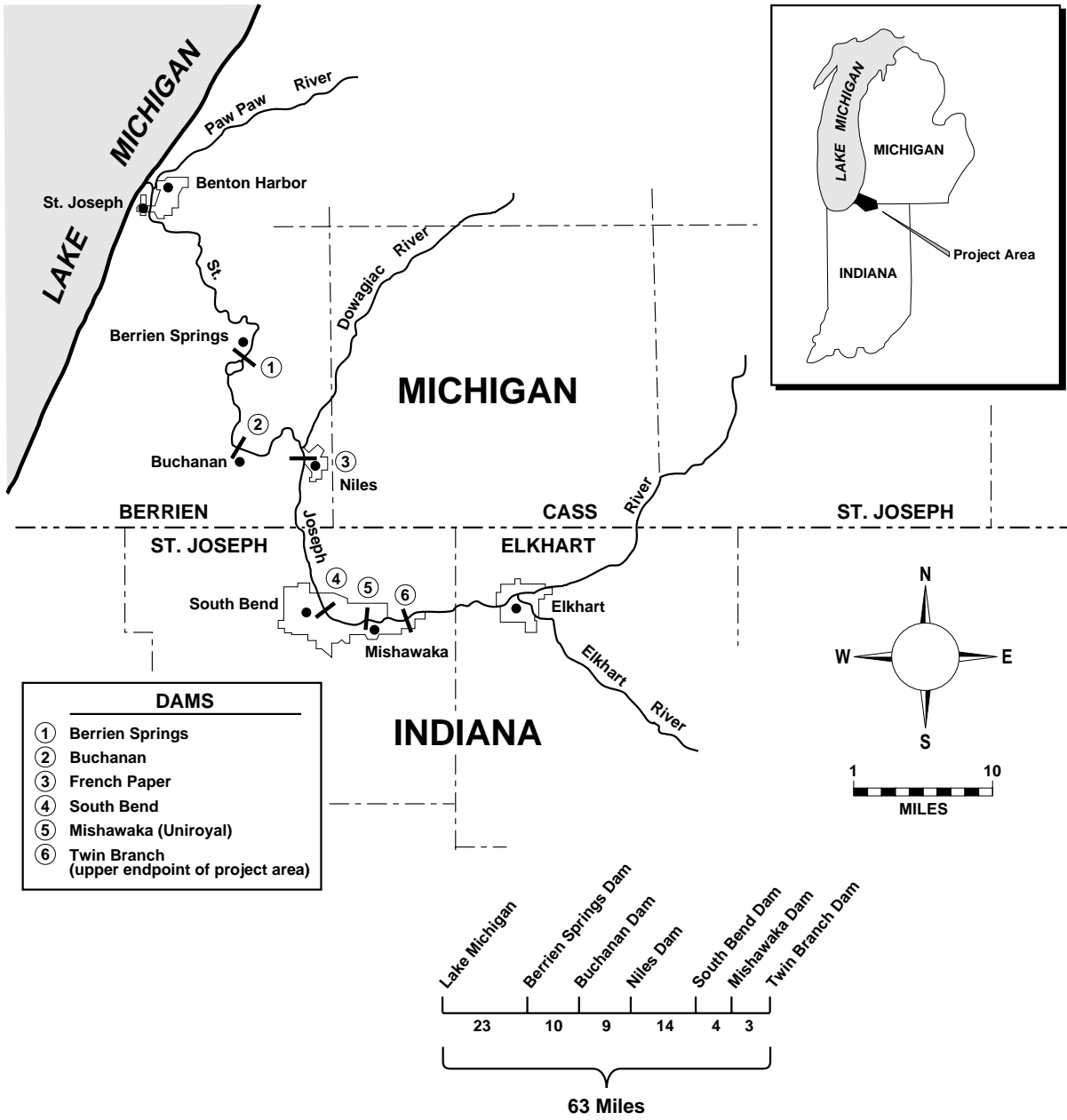


Figure 1.—A map of the project area.

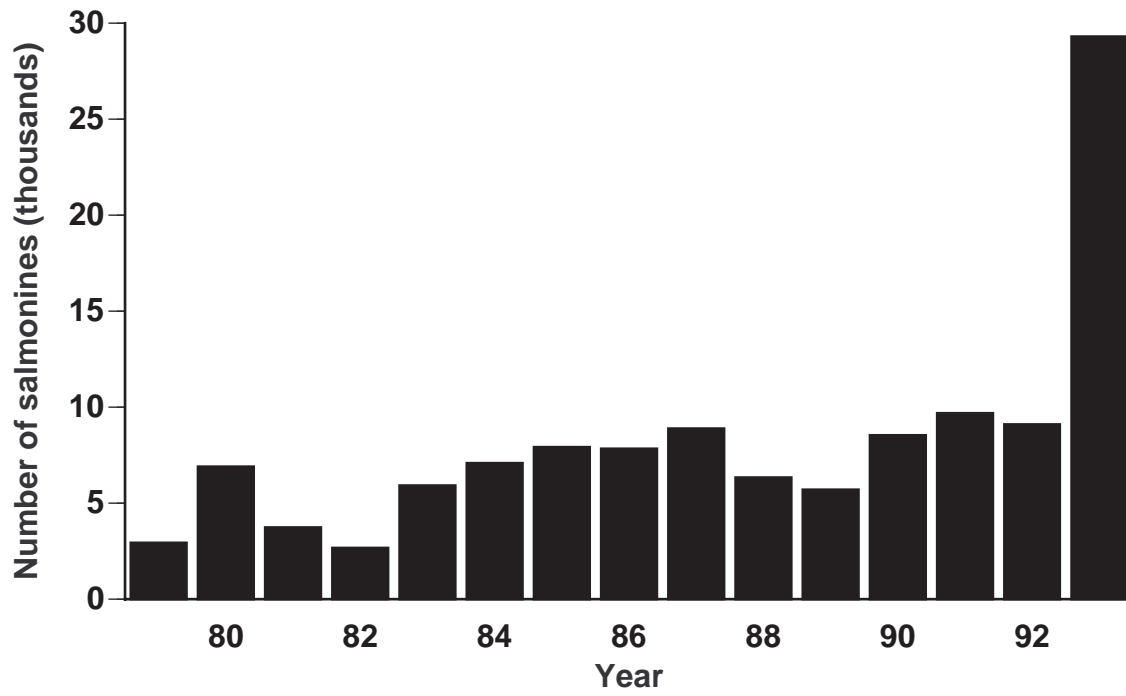


Figure 2.—Total passage of all salmonines at the Berrien Springs fish ladder, 1979 through 1993.

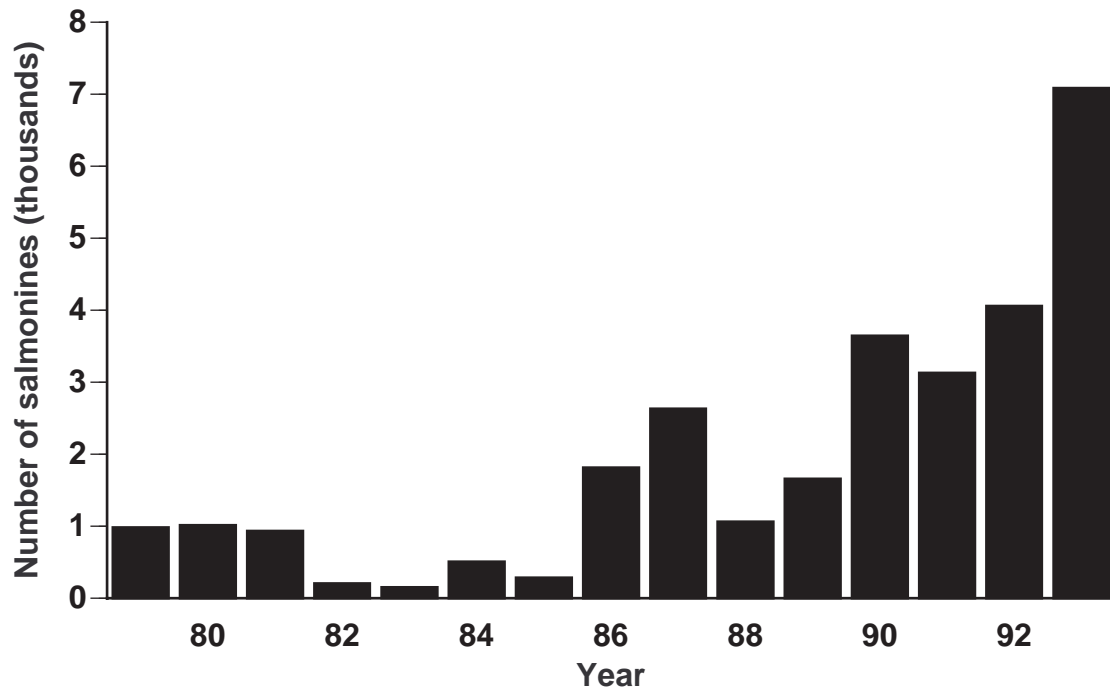


Figure 3.—Total Spring steelhead passage at the Berrien Springs fish ladder from 1979 through 1993.

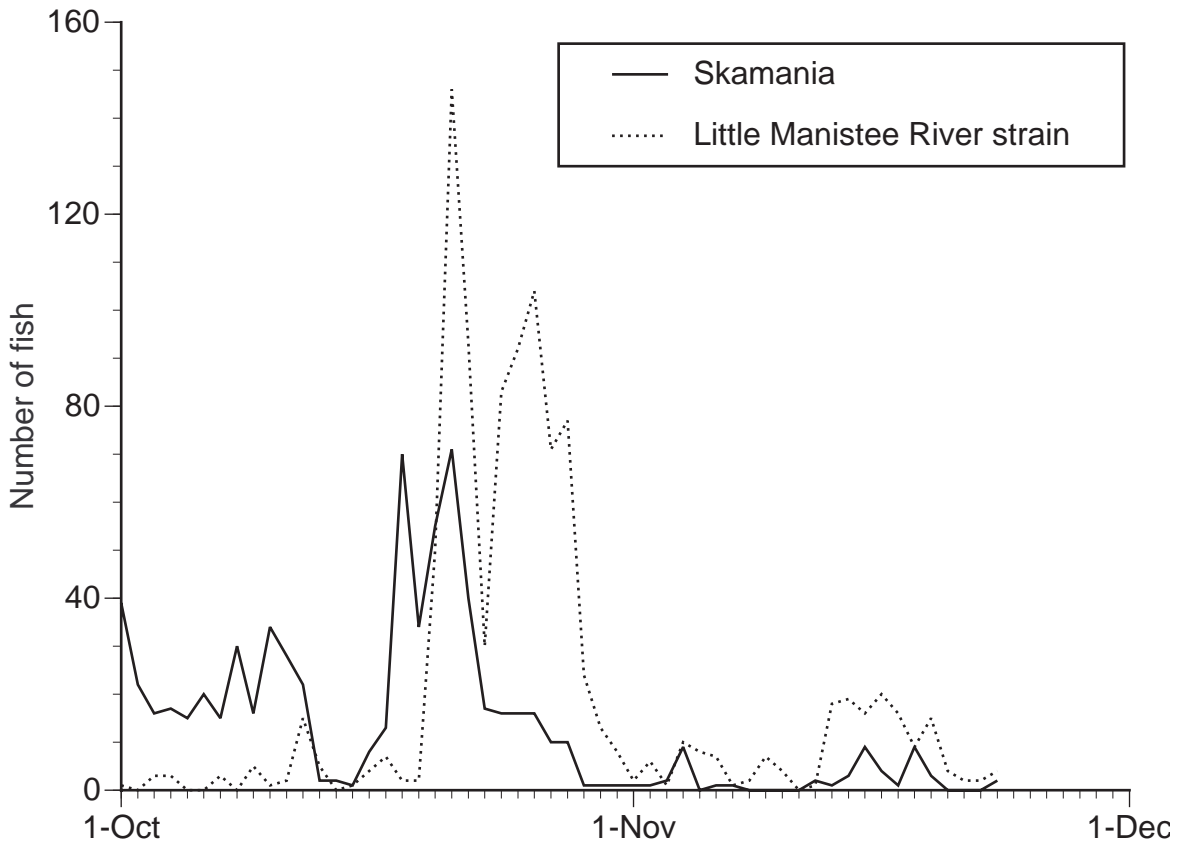


Figure 4.—Daily passage of skamania and Little Manistee River steelhead at the Berrien Springs fish ladder, October through closure 1993.

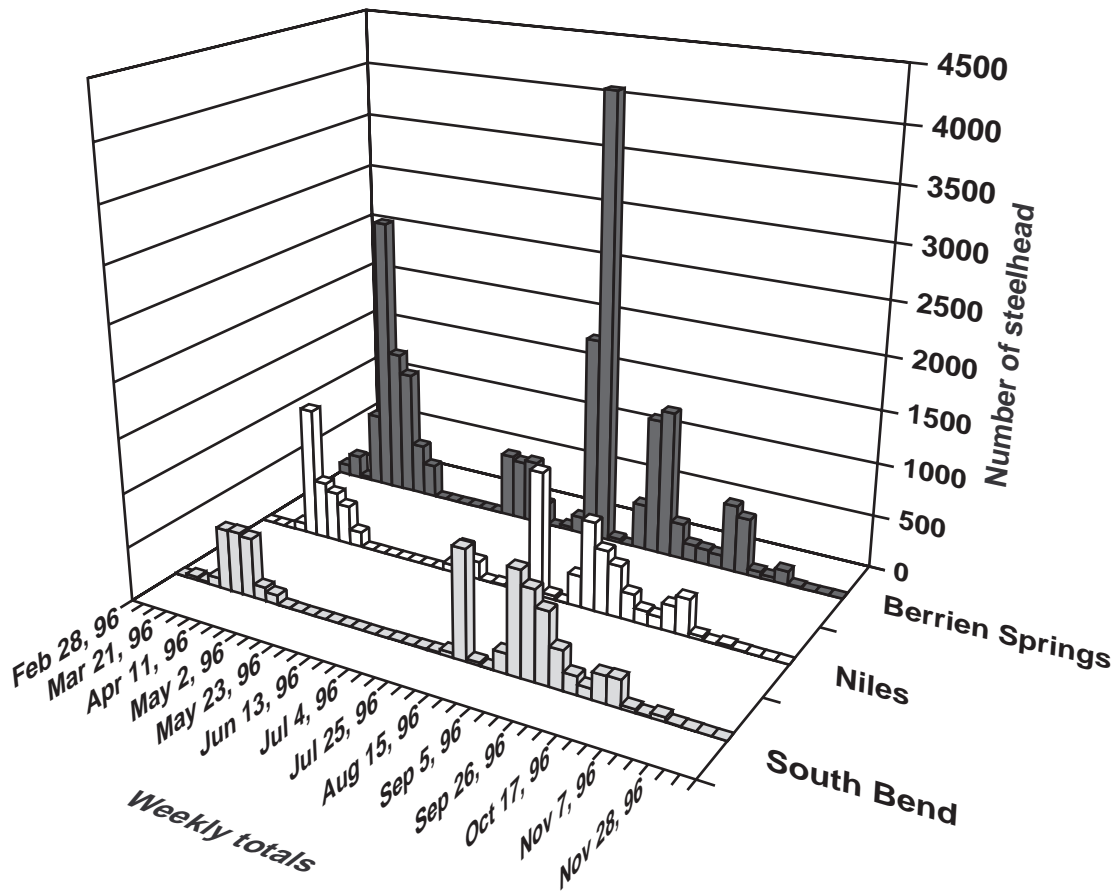


Figure 5.—Weekly steelhead passage as estimated for Berrien Springs, Niles, and South Bend fish ladders, 1993.

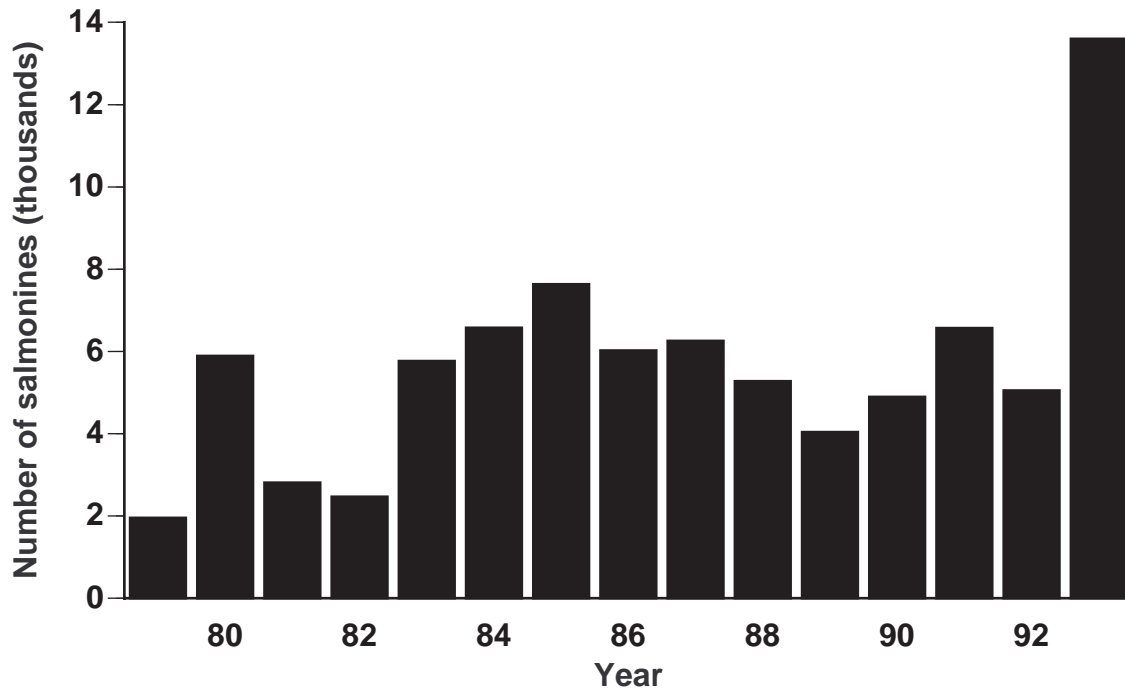


Figure 6.—Total fall passage of all salmonines as estimated at the Berrien Springs fish ladder, 1979 through 1993.

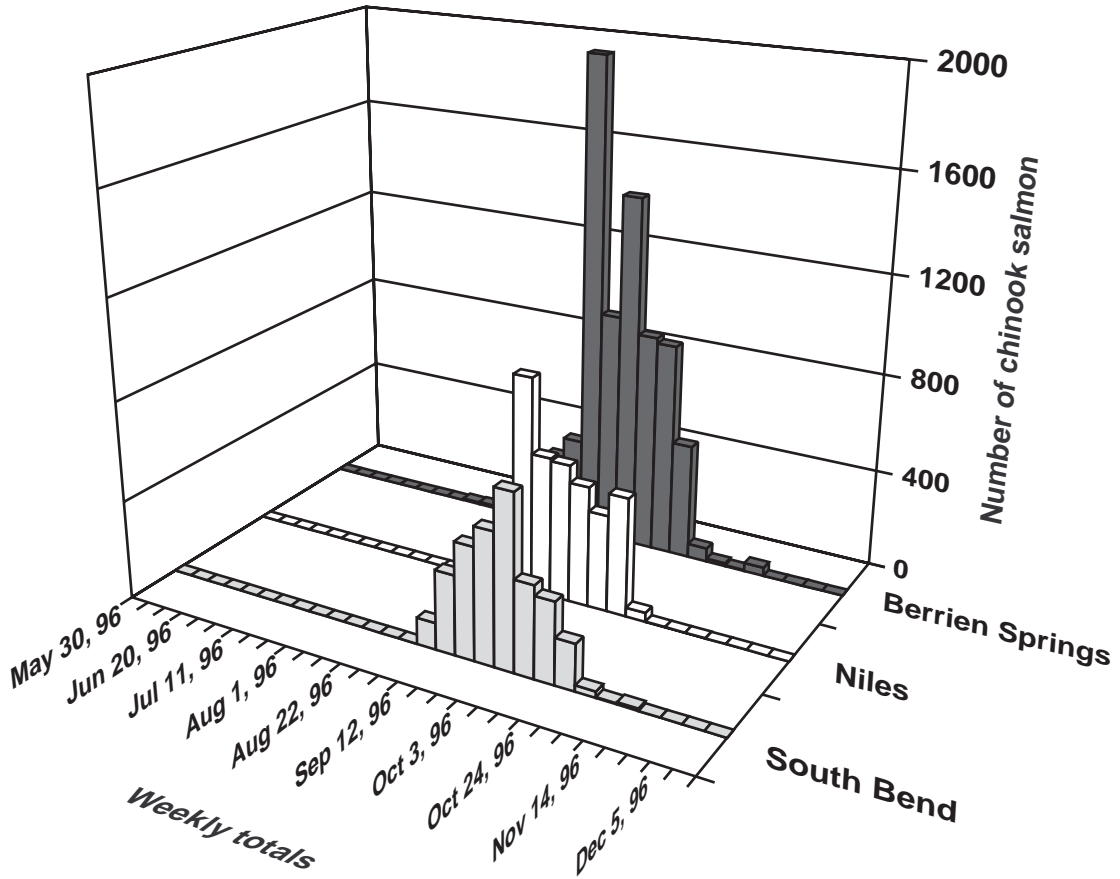


Figure 7.—Weekly chinook salmon passage as estimated for Berrien Springs, Niles, and South Bend fish ladders, 1993.

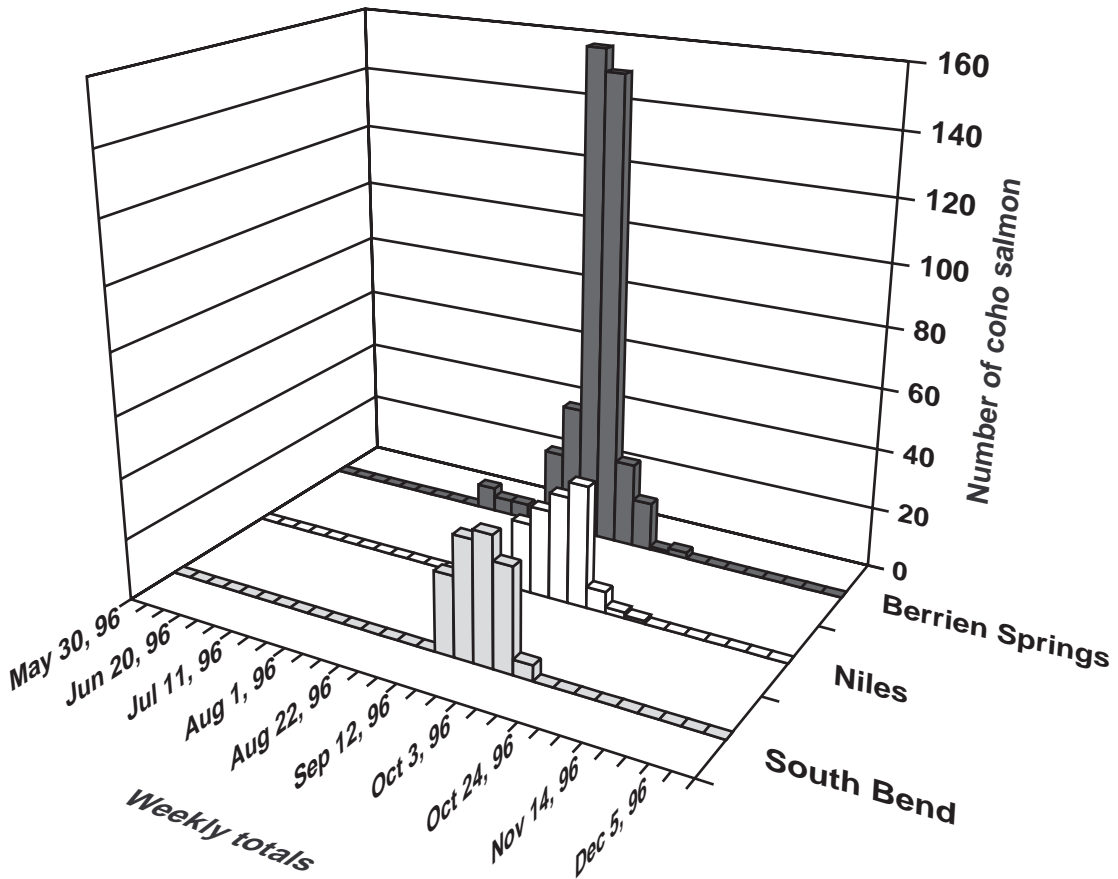


Figure 8.—Weekly coho salmon passage as estimated for Berrien Springs, Niles, and South Bend fish ladders, 1993.

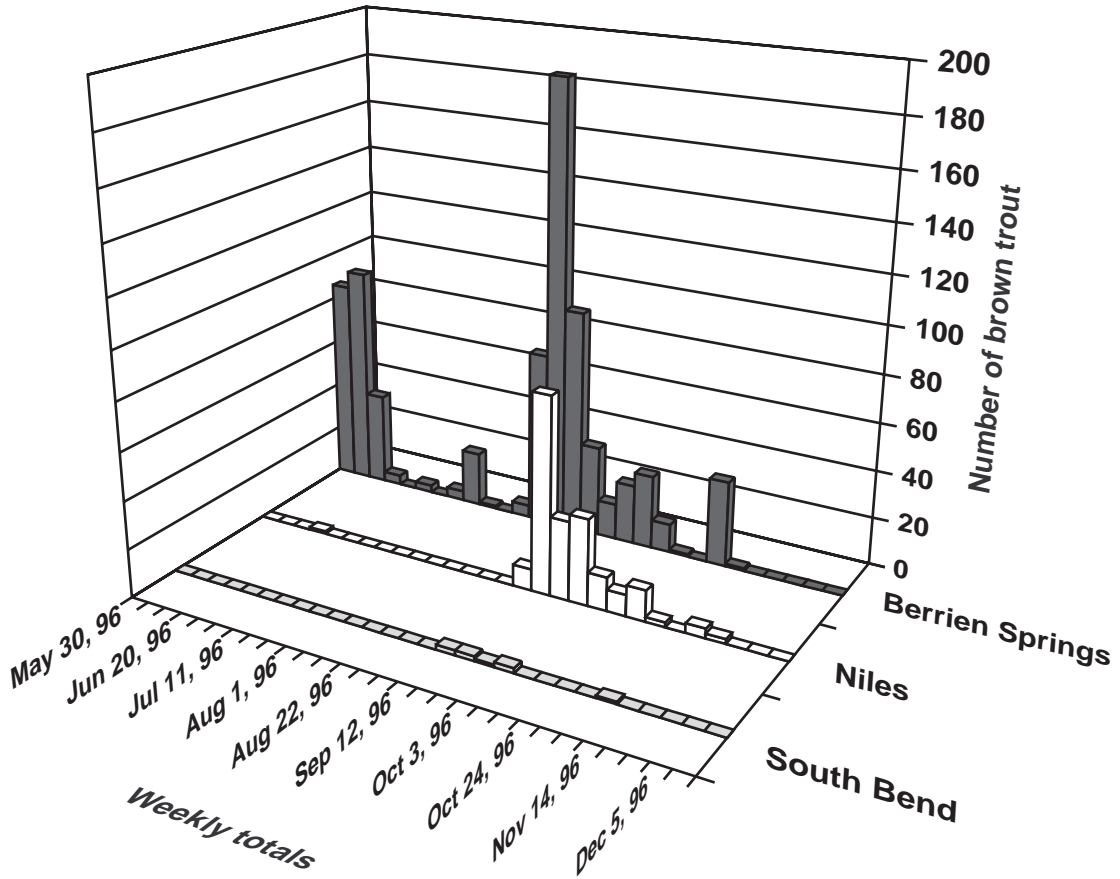


Figure 9.—Weekly brown trout passage as estimated for Berrien Springs, Niles, and South Bend fish ladders, 1993.

Table 1.—Time periods and dates where no recording took place at each ladder in 1993. Estimates were made for these periods.

Ladder and Date	Down Time (h)	Reason
Berrien Springs		
18 Feb	2	Power outage
9 Apr	2	Power outage
19 Jun	8	Power outage
13-14 Oct	16	Bad tape
25 Nov-09 Dec		Equipment stolen
Niles		
27-28 June	14	Bad tape
South Bend		
11-13 Mar	43	Limited manpower
27-29 Mar	48	Limited manpower
26-28 Apr	44	Limited manpower
2-3 May	20	Limited manpower
17 Aug	24	Limited manpower
3 Sept	10	Limited manpower
17-19 Sept	44	Limited manpower
4 Nov	24	Limited manpower
12-14 Nov	43	Limited manpower
16-17 Nov	21	Limited manpower
26-27 Nov	24	Limited manpower
7-8 Dec	24	Limited manpower

Table 2.—Upstream fish passage at the Berrien Springs, Niles, and South Bend dams as determined by video time-lapse recording for all seasons, 1993. Species other than salmonines were not counted at South Bend.

Species	Berrien Springs	Niles	South Bend
Steelhead	20,604	7,995	6,987
Chinook salmon	7,491	3,523	3,025
Coho salmon	447	137	146
Brown trout	771	205	8
Lake trout	8		
Walleye	11	17	
Smallmouth bass	106	93	
Channel catfish	58	508	
Carp	13	190	
Suckers	477	1,581	
Alewife	7		
Rock Bass		1	
Total	29,993	14,250	10,166

Table 3.—Steelhead passage by month at the Berrien Springs, Niles, and South Bend fish ladders, 1993.

Month	Berrien Springs	Niles	South Bend
February	0	0	0
March	2,949	767	481
April	4,137	2,062	1,573
May	closed	closed	4
June	1,409	115	0
July	758	419	25
August	6,111	1,319	1,092
September	3,511	2,344	2,911
October	1,506	915	810
November	223	54	91
December	closed	0	0
Total	20,604	7,995	6,987

Table 4.—Percent of salmonine passage during daytime (0800 to 2000) at each fish ladder during 1992 and 1993.

	Berrien Springs		Niles		South Bend	
	1992	1993	1992	1993	1992	1993
Steelhead	82	71	80	71	77	64
Chinook salmon	71	87	85	77	66	67
Coho salmon	79	83	89	77	71	61
Brown trout	69	75	75	72	82	100
Average	75	79	82	74	74	73

Table 5.—Chinook salmon passage by month at the Berrien Springs, Niles, and South Bend fish ladders, 1993.

Month	Berrien Springs	Niles	South Bend
February	0	0	0
March	0	0	0
April	0	0	0
May	closed	closed	0
June	0	0	0
July	7	0	0
August	71	0	0
September	4,666	1,856	1,225
October	2,698	1,664	1,764
November	49	3	36
December	closed	0	0
Total	7,491	3,523	3,025

Table 6.—Coho salmon passage by month at the Berrien Springs, Niles, and South Bend fish ladders, 1993.

Month	Berrien Springs	Niles	South Bend
February	0	0	0
March	0	0	0
April	0	0	0
May	closed	closed	0
June	0	0	0
July	0	0	0
August	18	0	0
September	404	69	93
October	25	68	53
November	0	0	0
December	closed	0	0
Total	447	137	146

Table 7.—Brown trout passage by month at the Berrien Springs, Niles, and South Bend fish ladders, 1993.

Month	Berrien Springs	Niles	South Bend
February	0	0	0
March	0	0	0
April	0	0	0
May	closed	closed	0
June	193	0	0
July	32	1	0
August	28	0	0
September	384	112	5
October	96	85	2
November	38	7	1
December	closed	0	0
Total	771	205	8

Table 8.—Comparisons of accuracy between readers, between replicates for one reader, and between video tape and manual counting. No significant differences were detected at $\alpha = 0.05$.

Mode	Comparison	Mean	Variance	Calculated t
48 hour	Reader 1 vs. replicate	-1.25	5.896	-0.515
	Reader 1 vs. 2	-1.75	10.229	-0.547
	Replicate vs. 2	-0.50	0.750	-0.577
72 hour	Reader 1 vs. replicate	-2.00	12.000	-0.577
	Reader 1 vs. 2	-4.25	3.562	-2.252
	Replicate vs. 2	-2.25	11.896	-0.652
48 hour	Manual counter 1 vs. tape	-0.50	0.117	-1.464
72 hour	Manual counter 1 vs. tape	-0.60	0.060	-2.450

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Report approved by Paul W. Seelbach
James S. Diana, Editor
Alan D. Sutton, Graphics
Barbara A. Diana, Word Processor

Appendix 1.–Fish stocking records for the St. Joseph River in Berrien County, Michigan and St. Joseph County, Indiana , 1984-1993. Many fish were marked or fin clipped with the following patterns: f = fingerling, AD = adipose, OX = oxytetracycline, y = yearling, DO = dorsal, RP = right pectoral, pp = Paw Paw River, LP = left pectoral, RV = right ventral, LV = left ventral.

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Steelhead-MI (winter)	17,500y	40,000y	53,230y	57,975y	55,797yAD	35,172yAD	34,274yAD	51,374y	49,557y	51,813y
MI (summer)	10,000pp	5,000pp	10,000pp	9,608pp	6,400pp 6,623AD	8,673ppAD 19,334AD	7,011ppAD 13,806AD	6,400pp	9,300pp	7,800pp
Steelhead-IN(summer) (Skamania strain)		165,996LV 60,608LP	168,520RV 91,405BV	175,976LV 48,905LPRV	172,262LV 53,883BP	175,786BV 38,282ADLP	176,810LP 44,632BV	130,823RP 1,328ADRP	129,222LP 47,829ADLP	130,274RP 50,238ADRP
Rainbow trout										
Brown trout	15,000y 20,000f	13,000y	15,000y	14,900y	15,000y	15,000y	15,000y	14,688y	14,697y	14,900y
Lake trout	30,000ADRV 30,000ADLV	83,750RP	54,800RV		120,000LP	150,000LV				
Chinook salmon-MI	250,020f	190,000f	221,060f	204,961f	200,000f	400,000f	307,982FOX 96,582	205,183FOX 104,851AD	251,796FOX 102,748ADOX	260,215FOX 21,882ADOX
Chinook salmon-IN	523,023f	407,013f	357,939RP	258,474LP	377,528	86,858ADRV	153,590BV	148,267LV	60,888ADLP 112,890ADRP	82,372ADLV 83,770ADRV
Coho salmon							291,044y		217,721y	
Walleye (fingerling (fry)	92,621 3,030,000	161,564 3,000,000	159,676 1,137,500	106,124 1,843,000	148,242 3,600,000	112,403 3,000,000	**none	127,018	86,002	103,402

**no stocking to enable a check for natural reproduction.

Appendix 2.—Species, number, and date of movement downstream through the Berrien Springs and Niles ladders, 1993.

	Number	Date(s)
Berrien Springs		
Channel catfish	2	24 April
Bullhead	1	19 June
Steelhead smolts	11	3 & 16 July
Suckers	1	19 July, 3 August, 8 August
Niles		
Suckers	1	8 & 23 April, 22 November

Appendix 3.—Daily fish counts at the Berrien Springs ladder in 1993.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Feb 1										0	
Feb 2										0	
Feb 3										0	
Feb 4										0	
Feb 5										0	
Feb 6										0	
Feb 7										0	
Feb 8										0	
Feb 9										0	
Feb 10										0	
Feb 11										0	
Feb 12										0	
Feb 13										0	
Feb 14										0	
Feb 15										0	
Feb 16										0	36
Feb 17										0	35
Feb 18										0	32
Feb 19										0	32
Feb 20										0	33
Feb 21										0	34
Feb 22										0	34
Feb 23										0	33
Feb 24										0	32
Feb 25										0	31
Feb 26										0	33
Feb 27										0	32
Feb 28										0	34
Mar 1										0	34
Mar 2										0	35
Mar 3	1									1	37
Mar 4	11									11	37
Mar 5	24									24	36
Mar 6	63									63	36
Mar 7	39									39	39
Mar 8	33									33	40
Mar 9	89									89	39
Mar 10	44								1	45	38
Mar 11	6									6	38
Mar 12	3									3	36
Mar 13	4									4	36
Mar 14										0	35
Mar 15	1									1	34
Mar 16										0	37

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Mar 17	9									9	36
Mar 18	3									3	34
Mar 19	10									10	36
Mar 20	3									3	37
Mar 21	5									5	38
Mar 22	20									20	39
Mar 23	92									92	41
Mar 24	104									104	41
Mar 25	110									110	42
Mar 26	193									193	42
Mar 27	174									174	43
Mar 28	284									284	45
Mar 29	201									201	46
Mar 30	694							2		696	47
Mar 31	729							5		734	50
Apr 1	402									402	49
Apr 2	327							2		329	47
Apr 3	26									26	45
Apr 4	26									26	44
Apr 5	169									169	44
Apr 6	114									114	45
Apr 7	224									224	45
Apr 8	358									358	48
Apr 9	179									179	49
Apr 10	311						1			312	49
Apr 11	285									285	49
Apr 12	244									244	48
Apr 13	151									151	49
Apr 14	161									161	50
Apr 15	161									161	51
Apr 16	125									125	50
Apr 17	71									71	
Apr 18	68									68	52
Apr 19	72									72	52
Apr 20	30									30	51
Apr 21	58									58	50
Apr 22	84									84	57
Apr 23	69									69	52
Apr 24	109									109	53
Apr 25	95									95	54
Apr 26	76									76	55
Apr 27	44									44	55
Apr 28	50									50	56

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Apr 29	41								1	42	58
Apr 30	7									7	58
May 1										0	
May 2										0	
May 3										0	
May 4										0	
May 5										0	
May 6										0	
May 7										0	
May 8										0	
May 9										0	
May 10										0	
May 11										0	
May 12										0	
May 13										0	
May 14										0	
May 15										0	
May 16										0	
May 17										0	
May 18										0	
May 19										0	
May 20										0	
May 21										0	
May 22										0	
May 23										0	
May 24										0	
May 25										0	
May 26										0	
May 27										0	
May 28										0	
May 29										0	
May 30										0	
May 31										0	
Jun 1										0	
Jun 2										0	
Jun 3										0	
Jun 4										0	
Jun 5										0	
Jun 6										0	
Jun 7										0	
Jun 8										0	
Jun 9										0	
Jun 10										0	

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Jun 11										0	
Jun 12										0	
Jun 13										0	
Jun 14										0	
Jun 15										0	
Jun 16										0	
Jun 17										0	
Jun 18	285			52		2	4		11	354	72
Jun 19	321			34		3	2	1	75	436	72
Jun 20	237			23		28	5		55	348	71
Jun 21	146			7		40	3		24	220	70
Jun 22	40			14		5			8	67	71
Jun 23	56			15		2	3		65	141	72
Jun 24	55			25		2			53	135	73
Jun 25	17			5		1	4		20	47	73
Jun 26	18			4	1	1	5		43	72	
Jun 27	51			6		9	3		32	101	75
Jun 28	25			3	1	1	10		9	49	73
Jun 29	40			3			3		6	52	73
Jun 30	119			2			1		1	123	70
Jul 1	140			12					2	154	69
Jul 2	95			5					1	101	69
Jul 3	127			8						135	70
Jul 4	97			2					1	100	72
Jul 5	83			1			1			85	73
Jul 6	16						1			17	74
Jul 7	3						1		9	13	75
Jul 8	1				1	1	1		27	31	77
Jul 9	3				1	3			7	14	78
Jul 10	1			1	1	1	1			5	78
Jul 11					2		1	1		4	78
Jul 12						1				1	77
Jul 13									2	2	76
Jul 14					1	1			1	3	76
Jul 15	2								1	3	76
Jul 16										0	75
Jul 17	1					1			1	3	76
Jul 18									1	1	76
Jul 19	2			2	1	1				6	76
Jul 20	7									7	75
Jul 21	2						1		1	4	74
Jul 22	2			1	1				1	5	73
Jul 23	3									3	73

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Jul 24	16									16	75
Jul 25	24	2								26	75
Jul 26	4						1		3	8	75
Jul 27	8					1	1			10	74
Jul 28								1	2	3	76
Jul 29	2							1		3	76
Jul 30	11									11	75
Jul 31	108	5							1	114	74
Aug 1	289	4				1			1	295	74
Aug 2	41				1				1	43	74
Aug 3	60							1		61	74
Aug 4	49									49	74
Aug 5	187	4	8	3						202	73
Aug 6	314			1				1		316	72
Aug 7	975	2								977	
Aug 8	898	4		5						907	71
Aug 9	1332	21	4	12						1369	71
Aug 10	782	1		4						787	71
Aug 11	458	7								465	71
Aug 12	413	3	1	2						419	73
Aug 13	261	11								272	73
Aug 14	21	3								24	76
Aug 15	4	1	5					4		14	76
Aug 16	13	7						2	1	23	75
Aug 17	12	3		1						16	75
Aug 18	2									2	75
Aug 19										0	76
Aug 20										0	
Aug 21										0	
Aug 22										0	
Aug 23										0	
Aug 24										0	
Aug 25										0	
Aug 26										0	
Aug 27										0	
Aug 28										0	
Aug 29										0	
Aug 30										0	
Aug 31										0	
Sep 1										0	
Sep 2										0	
Sep 3	128	76	4	1						209	71
Sep 4	302	232	22	4						560	

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Sep 5	398	167	5	5						575	
Sep 6	389	71	13	30						503	69
Sep 7	140	38	1	19						198	68
Sep 8	42	13		1						56	67
Sep 9	1	1								2	67
Sep 10	183	51	5	4						243	65
Sep 11	124	50	19	14						207	65
Sep 12	70	25	16	14						125	64
Sep 13	25	12	6	1						44	65
Sep 14		1		1						2	67
Sep 15	314	697	42	45						1098	66
Sep 16	616	824	44	74						1558	63
Sep 17	249	301	43	41						634	63
Sep 18	103	109	9	11						232	63
Sep 19	80	53	8	10						151	62
Sep 20	100	122	46	35						303	62
Sep 21	61	199	16	14						290	61
Sep 22	39	213	49	4						305	60
Sep 23	24	316	27	15						382	61
Sep 24	21	34	6	9						70	61
Sep 25	9	14	1	7						31	62
Sep 26	13	104	4	2						123	60
Sep 27	11	45	4	6						66	59
Sep 28		10								10	58
Sep 29	2	29								31	57
Sep 30	66	859	14	17						956	56
Oct 1	40	235	4	8						287	55
Oct 2	24	160	2	5						191	55
Oct 3	19	73		2						94	55
Oct 4	20	106	6	3						135	55
Oct 5	15	382	2	2						401	53
Oct 6	20	78	3	2						103	54
Oct 7	18	79		2						99	56
Oct 8	30	94	3	1						128	57
Oct 9	21	84	2	3						110	57
Oct 10	35	311		8						354	55
Oct 11	30	214		7						251	54
Oct 12	37	169		4						210	54
Oct 13	7	44								51	52
Oct 14	2	37								39	51
Oct 15	2	11	1							14	52
Oct 16	12	89		6						107	53
Oct 17	20	145		2			1			168	54

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Oct 18	72	115		3				1		191	54
Oct 19	36	75		4						115	54
Oct 20	106	54		11			3			174	54
Oct 21	217	35	2	4		1				259	54
Oct 22	133	32		3			1			169	53
Oct 23	47	19		4						70	52
Oct 24	99	9		1						109	52
Oct 25	108	10		2						120	52
Oct 26	120	18								138	53
Oct 27	81	9		4						94	52
Oct 28	87	6		2						95	50
Oct 29	25	1		3						29	50
Oct 30	14	3								17	49
Oct 31	9	1								10	44
Nov 1	3	2								5	44
Nov 2	7	1		1						9	45
Nov 3	3	3								6	45
Nov 4	19	4								23	45
Nov 5	8	1								9	46
Nov 6	8									8	45
Nov 7	2									2	43
Nov 8										0	42
Nov 9	2									2	42
Nov 10	4									4	43
Nov 11	7									7	43
Nov 12	3	1								4	43
Nov 13	19	3								22	44
Nov 14	22	3								25	45
Nov 15	25	14		7						46	45
Nov 16	24	7		9						40	45
Nov 17	17			2						19	45
Nov 18	18	8		6						32	45
Nov 19	18	2		11						31	44
Nov 20	4			1						5	43
Nov 21	2									2	42
Nov 22	2									2	42
Nov 23	6			1						7	44
Nov 24										0	43
Nov 25										0	
Nov 26										0	
Nov 27										0	
Nov 28										0	
Nov 29										0	

Appendix 3.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Nov 30										0	
Dec 1										0	
Dec 2										0	
Dec 3										0	
Dec 4										0	
Dec 5										0	
Dec 6										0	
Dec 7										0	
Dec 8										0	
Dec 9										0	
Dec 10										0	
Dec 11										0	
Dec 12										0	
Dec 13										0	
Dec 14										0	
Dec 15										0	
Dec 16										0	
Dec 17										0	
Dec 18										0	
Dec 19										0	
Dec 20										0	
Dec 21										0	
Dec 22										0	
Dec 23										0	
Dec 24										0	
Dec 25										0	
Dec 26										0	
Dec 27										0	
Dec 28										0	
Dec 29										0	

Appendix 4.–Daily fish counts at the Niles ladder in 1993.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Feb 1										0	
Feb 2										0	
Feb 3										0	
Feb 4										0	
Feb 5										0	
Feb 6										0	
Feb 7										0	
Feb 8										0	
Feb 9										0	
Feb 10										0	
Feb 11										0	
Feb 12										0	
Feb 13										0	
Feb 14										0	
Feb 15										0	
Feb 16										0	36
Feb 17										0	35
Feb 18										0	32
Feb 19										0	32
Feb 20										0	33
Feb 21										0	34
Feb 22										0	34
Feb 23										0	33
Feb 24										0	32
Feb 25										0	31
Feb 26										0	33
Feb 27										0	32
Feb 28										0	34
Mar 1										0	34
Mar 2										0	35
Mar 3										0	37
Mar 4										0	37
Mar 5										0	36
Mar 6										0	36
Mar 7										0	39
Mar 8										0	40
Mar 9										0	39
Mar 10										0	38
Mar 11										0	38
Mar 12										0	36
Mar 13										0	36
Mar 14										0	35
Mar 15										0	34
Mar 16										0	37

Appendix 4.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Mar 17										0	36
Mar 18										0	34
Mar 19										0	36
Mar 20										0	37
Mar 21										0	38
Mar 22	1									1	39
Mar 23										0	41
Mar 24	2									2	41
Mar 25	25									25	42
Mar 26	16							1		17	42
Mar 27	35									35	43
Mar 28	91									91	45
Mar 29	128									128	46
Mar 30	177								1	178	47
Mar 31	292								2	294	50
Apr 1	300									300	49
Apr 2	124								3	127	47
Apr 3	116							3	31	150	45
Apr 4	56								9	65	44
Apr 5	54								1	55	44
Apr 6	44									44	45
Apr 7	57									57	45
Apr 8	96									96	48
Apr 9	138								2	140	49
Apr 10	95									95	49
Apr 11	79								1	80	49
Apr 12	76									76	48
Apr 13	42									42	49
Apr 14	67									67	50
Apr 15	67									67	51
Apr 16	97									97	50
Apr 17	42								1	43	
Apr 18	30									30	52
Apr 19	27									27	52
Apr 20	67									67	51
Apr 21	94									94	50
Apr 22	51								1	52	57
Apr 23	53								2	55	52
Apr 24	47								12	59	53
Apr 25	39							1	26	66	54
Apr 26	40								10	50	55
Apr 27	30								3	33	55
Apr 28	22								20	42	56
Apr 29	12									12	58

Appendix 4.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Apr 30										0	
May 1										0	
May 2										0	
May 3										0	
May 4										0	
May 5										0	
May 6										0	
May 7										0	
May 8										0	
May 9										0	
May 10										0	
May 11										0	
May 12										0	
May 13										0	
May 14										0	
May 15										0	
May 16										0	
May 17										0	
May 18										0	
May 19										0	
May 20										0	
May 21										0	
May 22										0	
May 23										0	
May 24										0	
May 25										0	
May 26										0	
May 27										0	
May 28										0	
May 29										0	
May 30										0	
May 31										0	
Jun 1										0	
Jun 2										0	
Jun 3										0	
Jun 4										0	
Jun 5										0	
Jun 6										0	
Jun 7										0	
Jun 8										0	
Jun 9										0	
Jun 10										0	
Jun 11										0	
Jun 12										0	

Appendix 4.–Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Jun 13										0	
Jun 14										0	
Jun 15										0	
Jun 16										0	
Jun 17										0	
Jun 18										0	
Jun 19										0	
Jun 20										0	
Jun 21	2						39	18	113	172	70
Jun 22	33					8	59	20	203	323	71
Jun 23	5					1	54	14	196	270	72
Jun 24	15					1	36	7	165	224	73
Jun 25	6					2	34	4	95	141	73
Jun 26	6					2	16	3	37	64	
Jun 27	7					3	12	3	34	59	75
Jun 28	4						4		23	31	73
Jun 29	15					3	14		47	79	73
Jun 30	22								9	31	70
Jul 1	33						7	1	22	63	69
Jul 2	93					1	3		20	117	69
Jul 3	107					1	2	1	10	121	70
Jul 4	108					1	9		31	149	72
Jul 5	44					3	11		48	106	73
Jul 6	12			1		1	8		28	50	74
Jul 7	1					3	7		50	61	75
Jul 8						3	6		28	37	77
Jul 9						6	38	31	55	130	78
Jul 10							46	19	32	97	78
Jul 11					1	4	25	10	12	52	78
Jul 12							27	3	7	37	77
Jul 13						1	6	2	11	20	76
Jul 14						2	2		4	8	76
Jul 15					1	4	3		8	16	76
Jul 16	1					2	2	1	6	12	75
Jul 17	1					3	1		12	17	76
Jul 18	2					3	3		12	20	76
Jul 19	1					1	3	2	22	29	76
Jul 20	3					4	2	2	12	23	75
Jul 21	1				2	4	1	2	11	21	74
Jul 22	1					1	1		5	8	73
Jul 23						1	2	1		4	73
Jul 24	1				1	1	1	2	2	8	75
Jul 25	4				2	4	3		11	24	75
Jul 26	3					2	2		6	13	75

Appendix 4.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Jul 27	3					1	3	1	1	9	74
Jul 28						2	3			5	76
Jul 29					1	1		2	3	7	76
Jul 30					1					1	75
Jul 31							1			1	74
Aug 1								1	2	3	74
Aug 2	1					1			1	3	74
Aug 3	2					1	3		1	7	74
Aug 4	2					1			4	7	73
Aug 5	9				1	1	1	1	3	16	72
Aug 6	27				1	1			4	33	
Aug 7	61					1		1	8	71	71
Aug 8	138				3	1	3	1	5	151	71
Aug 9	334				1		2		4	341	71
Aug 10	256								3	259	71
Aug 11	203								5	208	73
Aug 12	160								5	165	73
Aug 13	50								1	51	76
Aug 14	21							4		25	76
Aug 15	11							6		17	75
Aug 16	25					1				26	75
Aug 17								1		1	75
Aug 18					1	2		1		4	76
Aug 19					1			1	3	5	
Aug 20	1						1	1		3	
Aug 21								3		3	
Aug 22	1					1		1	1	4	
Aug 23								1		1	
Aug 24	1									1	
Aug 25	1							2	1	4	
Aug 26								1	4	5	
Aug 27						1		2	1	4	
Aug 28						1		2	1	4	
Aug 29	1								1	2	
Aug 30	12							1		13	
Aug 31	2							1	2	5	
Sep 1	18						1			19	
Sep 2	29						1	1		31	
Sep 3	93							1	1	95	71
Sep 4	134	1						1		136	
Sep 5	175	16							4	195	
Sep 6	155	8								163	69
Sep 7	167	37								204	68
Sep 8	164	41								205	67

Appendix 4.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Sep 9	100	6								106	67
Sep 10	37	3								40	65
Sep 11	23	5								28	65
Sep 12	53	20								73	64
Sep 13	64	22	2							88	65
Sep 14	68	25	1							94	67
Sep 15	25	146	3							174	66
Sep 16	39	266	8							313	63
Sep 17	119	224	2	3						348	63
Sep 18	222	171	7	6						406	63
Sep 19	125	85	4	6						220	62
Sep 20	88	56	6	21						171	62
Sep 21	48	29	6	13						96	61
Sep 22	61	77	1	8						147	60
Sep 23	47	102	5	15						169	61
Sep 24	43	114	2	6						165	61
Sep 25	68	106	5	13						192	62
Sep 26	55	98	7	8						168	60
Sep 27	35	27	3	8						73	59
Sep 28	41	93	2	4						140	58
Sep 29	23	48	2							73	57
Sep 30	25	30	3	1						59	56
Oct 1	8	117	7	1						133	55
Oct 2	65	145	11	11						232	55
Oct 3	21	86	4	4						115	55
Oct 4	11	50	1	1						63	55
Oct 5	10	13		2						25	53
Oct 6	19	87	6	9						121	54
Oct 7	27	75	23	10						135	56
Oct 8	28	121	5	9				1		164	57
Oct 9	13	57	1	1						72	57
Oct 10	12	63	1	4						80	55
Oct 11	12	52	3	2						69	54
Oct 12	37	97	2	3						139	54
Oct 13	16	60		1						77	52
Oct 14	9	41		2						52	51
Oct 15	9	43								52	52
Oct 16	15	37	1	2						55	53
Oct 17	32	127		2						161	54
Oct 18	15	91	1	1						108	54
Oct 19	22	135		1						158	54
Oct 20	19	53		3						75	54
Oct 21	49	30		1						80	54
Oct 22	68	37	1							106	53

Appendix 4.–Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Oct 23	39	10		1						50	52
Oct 24	28	10		2						40	52
Oct 25	41	4		1						46	52
Oct 26	60	12		3						75	53
Oct 27	86	4		2						92	52
Oct 28	73	6	1	4						84	50
Oct 29	38									38	50
Oct 30	19	1		1						21	49
Oct 31	14			1						15	44
Nov 1	7									7	44
Nov 2	6									6	45
Nov 3	7									7	45
Nov 4	2									2	45
Nov 5		1		1						2	46
Nov 6										0	45
Nov 7		1								1	43
Nov 8										0	42
Nov 9										0	42
Nov 10										0	43
Nov 11										0	43
Nov 12										0	43
Nov 13	3									3	44
Nov 14	4	1		2						7	45
Nov 15	5									5	45
Nov 16	6			1						7	45
Nov 17	3									3	45
Nov 18	1			1						2	45
Nov 19	3									3	44
Nov 20	1									1	43
Nov 21										0	42
Nov 22	2			2						4	42
Nov 23	1									1	44
Nov 24										0	43
Nov 25	1									1	42
Nov 26	1									1	43
Nov 27										0	
Nov 28										0	39
Nov 29										0	39
Nov 30										0	
Dec 1										0	39
Dec 2	1									1	38
Dec 3										0	40
Dec 4										0	40
Dec 5											

Appendix 4.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Dec 6										0	
Dec 7										0	42
Dec 8										0	41
Dec 9										0	40
Dec 10										0	40
Dec 11										0	
Dec 12										0	
Dec 13										0	
Dec 14										0	
Dec 15										0	
Dec 16										0	
Dec 17										0	
Dec 18										0	
Dec 19										0	
Dec 20										0	
Dec 21										0	
Dec 22										0	
Dec 23										0	
Dec 24										0	
Dec 25										0	
Dec 26										0	
Dec 27											
Dec 28											
Dec 29											
Dec 30											
Dec 31											

Appendix 5.—Daily fish counts at the South Bend ladder in 1993.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Feb 1										0	
Feb 2										0	
Feb 3										0	
Feb 4										0	
Feb 5										0	
Feb 6										0	
Feb 7										0	
Feb 8										0	
Feb 9										0	
Feb 10										0	
Feb 11										0	
Feb 12										0	
Feb 13										0	
Feb 14										0	
Feb 15										0	
Feb 16										0	36
Feb 17										0	35
Feb 18										0	32
Feb 19										0	32
Feb 20										0	33
Feb 21										0	34
Feb 22										0	33
Feb 23										0	32
Feb 24										0	31
Feb 25										0	33
Feb 26										0	32
Feb 27										0	34
Feb 28										0	
Mar 1										0	
Mar 2										0	
Mar 3										0	
Mar 4										0	
Mar 5										0	36
Mar 6	3									3	36
Mar 7	1									1	39
Mar 8	3									3	40
Mar 9	7									7	39
Mar 10	6									6	38
Mar 11	5									5	38
Mar 12	4									4	36
Mar 13	5									5	36
Mar 14	1									1	35
Mar 15										0	34

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Mar 16	1									1	37
Mar 17	6									6	36
Mar 18	2									2	34
Mar 19	2									2	36
Mar 20	3									3	37
Mar 21	2									2	38
Mar 22	3									3	39
Mar 23	4									4	41
Mar 24										0	41
Mar 25	7									7	42
Mar 26	14									14	42
Mar 27	55									55	43
Mar 28	61									61	45
Mar 29	64									64	46
Mar 30	112									112	47
Mar 31	110									110	50
Apr 1	81									81	49
Apr 2	66									66	47
Apr 3	79									79	45
Apr 4	79									79	44
Apr 5	67									67	44
Apr 6	52									52	45
Apr 7	54									54	45
Apr 8	62									62	48
Apr 9	118									118	49
Apr 10	147									147	49
Apr 11	94									94	49
Apr 12	96									96	48
Apr 13	79									79	49
Apr 14	54									54	50
Apr 15	73									73	51
Apr 16	96									96	50
Apr 17	64									64	
Apr 18	17									17	52
Apr 19	7									7	52
Apr 20	9									9	51
Apr 21	3									3	50
Apr 22	31									31	57
Apr 23	34									34	52
Apr 24	25									25	53
Apr 25	30									30	54
Apr 26	21									21	55
Apr 27	16									16	55

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Apr 28	12									12	56
Apr 29	1									1	58
Apr 30	6									6	58
May 1	1									1	
May 2	1									1	
May 3										0	
May 4										0	
May 5										0	
May 6	2									2	
May 7										0	
May 8										0	
May 9										0	
May 10										0	
May 11										0	
May 12										0	
May 13										0	
May 14										0	
May 15										0	
May 16										0	
May 17										0	
May 18										0	
May 19										0	
May 20										0	
May 21										0	
May 22										0	
May 23										0	
May 24										0	
May 25										0	
May 26										0	
May 27										0	
May 28										0	
May 29										0	
May 30										0	
May 31										0	
Jun 1										0	
Jun 2										0	
Jun 3										0	
Jun 4										0	
Jun 5										0	
Jun 6										0	
Jun 7										0	
Jun 8										0	
Jun 9										0	

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Jun 10										0	
Jun 11										0	
Jun 12										0	
Jun 13										0	
Jun 14										0	
Jun 15										0	
Jun 16										0	
Jun 17										0	
Jun 18										0	72
Jun 19										0	72
Jun 20										0	71
Jun 21										0	70
Jun 22										0	71
Jun 23										0	72
Jun 24										0	73
Jun 25										0	73
Jun 26										0	
Jun 27										0	75
Jun 28										0	73
Jun 29										0	73
Jun 30										0	70
Jul 1										0	69
Jul 2										0	69
Jul 3										0	70
Jul 4										0	72
Jul 5										0	73
Jul 6										0	74
Jul 7	3									3	75
Jul 8										0	77
Jul 9										0	78
Jul 10										0	78
Jul 11										0	78
Jul 12										0	77
Jul 13										0	76
Jul 14										0	76
Jul 15										0	76
Jul 16	1									1	75
Jul 17	2									2	76
Jul 18	2									2	76
Jul 19										0	76
Jul 20	3									3	75
Jul 21										0	74
Jul 22										0	73

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Jul 23	1									1	73
Jul 24	2									2	75
Jul 25	4									4	75
Jul 26	4									4	75
Jul 27										0	74
Jul 28	3									3	76
Jul 29										0	76
Jul 30										0	75
Jul 31										0	74
Aug 1										0	74
Aug 2										0	74
Aug 3	1									1	74
Aug 4										0	73
Aug 5	1									1	72
Aug 6	18									18	71
Aug 7	22									22	71
Aug 8	50									50	71
Aug 9	164									164	71
Aug 10	285									285	73
Aug 11	222									222	73
Aug 12	155									155	76
Aug 13	75									75	76
Aug 14	52									52	75
Aug 15	6									6	75
Aug 16	17									17	75
Aug 17	4									4	76
Aug 18										0	
Aug 19										0	
Aug 20										0	
Aug 21	1									1	
Aug 22										0	
Aug 23										0	
Aug 24	2									2	
Aug 25	1									1	
Aug 26										0	
Aug 27										0	
Aug 28										0	
Aug 29										0	
Aug 30	7									7	
Aug 31	9									9	
Sep 1	11									11	
Sep 2	19									19	
Sep 3	59									59	71

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Sep 4	78									78	
Sep 5	110									110	
Sep 6	160	4								164	69
Sep 7	138	27								165	68
Sep 8	171	34								205	67
Sep 9	186	23								209	67
Sep 10	138	5								143	65
Sep 11	49	14								63	65
Sep 12	75	10								85	64
Sep 13	80	45	1							126	65
Sep 14	59	34	1	1						95	67
Sep 15	125	43	8	1						177	66
Sep 16	185	65	6							256	63
Sep 17	139	48	3							190	63
Sep 18	155	74	7							236	63
Sep 19	144	67	6							217	62
Sep 20	141	55	7	1						204	62
Sep 21	126	70	9	1						206	61
Sep 22	83	47	2							132	60
Sep 23	72	65	4							141	61
Sep 24	47	76	7							130	61
Sep 25	50	71	4							125	62
Sep 26	93	105	6							204	60
Sep 27	53	40	4	1						98	59
Sep 28	40	59	6							105	58
Sep 29	68	87	8							163	57
Sep 30	57	57	4							118	56
Oct 1	31	45	7							83	55
Oct 2	15	138	7							160	55
Oct 3	22	149	6							177	55
Oct 4	27	137	9							173	55
Oct 5	27	72	5							104	53
Oct 6	25	111	6							142	54
Oct 7	24	98	4							126	56
Oct 8	24	63	1							88	57
Oct 9	18	68	3	2						91	57
Oct 10	15	40	1							56	55
Oct 11	21	58	1							80	54
Oct 12	25	68	1							94	54
Oct 13	10	76	1							87	52
Oct 14	2	37								39	51
Oct 15	16	50								66	52
Oct 16	8	38	1							47	53

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Oct 17	14	50								64	54
Oct 18	5	52								57	54
Oct 19	30	79								109	54
Oct 20	26	50								76	54
Oct 21	77	48								125	54
Oct 22	35	25								60	53
Oct 23	58	22								80	52
Oct 24	82	41								123	52
Oct 25	30	13								43	52
Oct 26	75	26								101	53
Oct 27	33	25								58	52
Oct 28	23	42								65	50
Oct 29	4	22								26	50
Oct 30	5	18								23	49
Oct 31	3	3								6	44
Nov 1	8	3								11	44
Nov 2	2	2								4	45
Nov 3	5	2								7	45
Nov 4	4	5								9	45
Nov 5	6	8								14	46
Nov 6	5	3								8	45
Nov 7	1	1		1						3	443
Nov 8	2	2								4	42
Nov 9	1	1								2	42
Nov 10	1									1	43
Nov 11	1									1	43
Nov 12	2									2	43
Nov 13	4									4	44
Nov 14	5									5	45
Nov 15	8	2								10	45
Nov 16	8	3								11	45
Nov 17	7	2								9	45
Nov 18	3									3	45
Nov 19	9	1								10	44
Nov 20	2									2	43
Nov 21	1	1								2	42
Nov 22										0	42
Nov 23										0	44
Nov 24	2									2	43
Nov 25	1									1	42
Nov 26	1									1	43
Nov 27										0	
Nov 28	1									1	39

Appendix 5.—Continued.

Date	Rainbow trout	Chinook salmon	Coho salmon	Brown trout	Walleye	Small-mouth bass	Channel catfish	Carp	Sucker	Total	Temp
Nov 29										0	39
Nov 30										0	39
Dec 1										0	
Dec 2	1									1	38
Dec 3										0	40
Dec 4										0	40
Dec 5										0	
Dec 6										0	42
Dec 7										0	41
Dec 8										0	40
Dec 9										0	40
Dec 10										0	
Dec 11										0	
Dec 12										0	
Dec 13										0	
Dec 14										0	
Dec 15										0	
Dec 16										0	
Dec 17										0	
Dec 18										0	
Dec 19										0	
Dec 20										0	
Dec 21										0	
Dec 22										0	
Dec 23										0	
Dec 24										0	
Dec 25										0	
Dec 26										0	
Dec 27										0	
Dec 28										0	
Dec 29										0	
Dec 30										0	
Dec 31										0	