Fishery Manuscript No. 94-1

Movements and Distribution of Radio-Tagged Northern Pike in Minto Flats

by

Alan Burkholder

and

David R. Bernard

May 1994

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY MANUSCRIPT NO. 94-1

MOVEMENTS AND DISTRIBUTION OF RADIO-TAGGED NORTHERN PIKE IN MINTO FLATS[1]

By

Alan Burkholder
and
David R. Bernard

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

May 1994

[1] This investigation was partially financed by the Federal Aid in Sport fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-8, Study C, Job No. 3-1.

The Fishery Manuscripts series was established in 1987 for the publication of technically oriented results of several year's work undertaken on a project to address common objectives, provide an overview of work undertaken through multiple projects to address specific research or management goal(s), or new and/or highly technical methods. Fishery Manuscripts are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

ABSTRACT

Radio telemetry was used to study the movements of northern pike *Esox lucius* in Minto Flats. Ninety-eight northern pike were surgically implanted with high frequency (150-152 MHz) transmitters during the fall of 1987. Tracking was conducted with a fixed-wing aircraft during 10 tracking periods between September, 1987 and September, 1988. Northern pike radio-tagged throughout Minto Flats during the fall of 1987 segregated into four overwintering groups. About 70% of the radio tags implanted in the fall of 1987 were assumed to have failed prematurely and unexpectedly by April 1988. The highest median velocities for most northern pike for each overwintering group were achieved prior to December, 1987. In general, median velocities progressively decreased throughout the winter (December through April). No differences between the velocities of male and female or small and large radio-tagged northern pike for a given overwintering group were detected. Differences between the velocity of male and female northern pike for a given tracking period were only detected in three of 28 comparisons. Differences between the velocity of small and large northern pike for a given tracking period were only detected in two of 25 comparisons. An additional 20 northern pike were radio-tagged at one of the overwintering sites in March, 1988. Dispersal from this overwintering site was not detected until May. Northern pike located throughout the remaining tracking periods (after May) moved very little.

KEY WORDS: northern pike, *Esox lucius*, Minto Flats, radio telemetry, seasonal movements, overwintering.

INTRODUCTION

Next to Arctic grayling *Thymallus arcticus*, northern pike *Esox lucius* is the most sought after indigenous sport fish species in interior Alaska (Mills 1992). Between 75% and 90% of the annual harvest of northern pike in Alaska comes from the Tanana River drainage. Minto Flats has supported the largest sport fishery for northern pike in Alaska in 12 of the last 16 years (Mills 1979 - 1993). From 1981-1984 the average sport harvest in Minto Flats was 2,279 northern pike. However, in 1985, a new sport fishery developed on a concentration of overwintering northern pike in the Chatanika River. This fishery resulted in an increase in the estimated sport harvest from 2,349 northern pike in 1984 to 4,665 fish in 1985, and 4,903 in 1986. Angler reports and limited creel survey sampling (Holmes and Burkholder 1988) indicated that a large proportion of the harvest from this new fishery was prespawning females.

In addition, a subsistence fishery for northern pike by the indigenous people of Minto Flats exists. Throughout the 1980s subsistence fishing for northern pike occurred near the present village site (New Minto) and at historically used sites in the eastern portions of Minto Flats (Andrews 1988). Gill nets are used to catch northern pike throughout the open-water period and hook-and-line techniques are primarily used to capture fish through the ice. Estimated harvest of northern pike in the subsistence fishery for the years 1983 through 1992 has been reported as high as 3,003 in 1983 (Andrews 1988) and as low as 10 in 1986 (Holder Memorandum[1]).

Radio telemetry has been used to describe movement patterns of northern pike over time and to describe distribution of northern pike in relation to various habitats (Chapman and McKay 1984a, 1984b; Cook and Bergersen 1988; Diana 1980; Diana et al. 1977; Malinin 1969, 1970, 1971; Poddubnyi et al. 1970; and Ross and Winter 1981). Pearse and Clark (1992) and Roach (1993) related distribution of radio-tagged northern pike in Volkmar and Harding lakes in interior Alaska to sampling strategies in mark-recapture experiments to estimate abundance. DosSantos et al. (1988) was able to track five northern pike over the course of two years in the lower Flathead River impoundment system in Montana. Information concerning movement and distribution of northern pike throughout an entire year in river systems without impoundments is lacking. Hallberg (1984) and Behrends and West (1987) described fall and winter distributions of a few radio-tagged northern pike in two open river systems, Minto Flats and the Tetlin Wildlife Refuge, respectively.

The objective of our study was to describe the distribution of radio-tagged northern pike in Minto Flats throughout the course of a year. The intent was to identify critical habitat (overwintering areas) and relate movements and distributions of these radio-tagged northern pike to sampling strategies for estimation of age composition and size of populations of northern pike in Minto Flats.

---

[1] Holder, Russ. 4/27/93. Memorandum. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, 1300 College Road, Fairbanks, Alaska 99701.

Study Area

Minto Flats is located approximately 50 km west of Fairbanks, Alaska. It is a 200,000 ha area of marsh and lakes interconnected by numerous sloughs and five rivers: the Chatanika, Goldstream, Tatalina, Tolovana, and Tanana (Figure 1). With the exception of the Tanana River, these rivers are slow flowing and meandering. The Tanana is a large glacial river that delineates the southern border of the flats and is the primary water source for Swanneck and Grassy sloughs. The lakes are generally shallow and contain large areas of dense aquatic vegetation. Summer habitat for northern pike in Minto Flats covers of an estimated 6,000 ha (Holmes and Pearse 1987). Minto Flats is populated during the ice-free months with northern pike, least cisco, *Coregonus sardinella*; humpback whitefish, *C. pidschian*; broad whitefish, *C. nasus*; sheefish, *Stenodus leucichthys*; Arctic grayling; burbot, *Lota lota*; longnose suckers, *Catostomus catostomus*; blackfish, *Dallia pectoralis*; and lake chub, *Couesius plumbeus*. Chinook salmon, *Oncorhynchus tshawytscha* and chum salmon, *O. keta* pass through this area during their respective migrations to and from spawning areas in the upper Chatanika River. Little is known concerning the winter distribution of these fish.

METHODS

Description of Radio Tags and Tagging Methodology

Radio transmitters were 70 mm long, 20 mm in diameter, weighed approximately 27 g in air, and had a life expectancy of 12 months (manufactured by Wildlife Materials Inc., Route 1, Carbondale, IL). Since fish generally should not be equipped with transmitters that weigh more than 2% in air of the fish's weight out of water (Winter 1983), only fish that weighed 1,350 g or more were used in this study. Each transmitter operated on a discrete frequency between 150 and 152 MHz, enabling fish to be identified by their individual frequency.

Radio transmitters were surgically implanted in the coelomic cavity of 98 northern pike captured between August 28 and October 6, 1987. Surgery followed procedures similar to those reported in Ross (1982). Fish were captured throughout Minto Flats with gill nets, traps, and hook and line. External characteristics described by Casselman (1974) were used to determine the sex of tagged fish. An additional 20 transmitters were implanted in northern pike caught through the ice with hook and line gear in the Chatanika River during mid March, 1988. The only difference in the surgical procedure was that it was conducted in a heated tent to prevent freezing of body tissue. The temperature inside the surgical tent was kept slightly above 0^0C. Sex was not determined for these fish.

Tracking of Radio-Tagged Fish

Location of tagged northern pike was monitored 10 times from September 1987 through September 1988 from a Cessna 185 aircraft equipped with a TR-2 receiver, a TS-1 scanner, and a RA-2AK antenna mounted on the strut (Telonics, Telemetry Electronics Consultants, 932 E. Impala Ave, Mesa, AZ). Flights were parallel to stream courses and transects were flown for lakes at 130 km/h and 150 - 300 m above the ground. When a signal was received, the gain was decreased on the receiver and low altitude crossing flights were made.

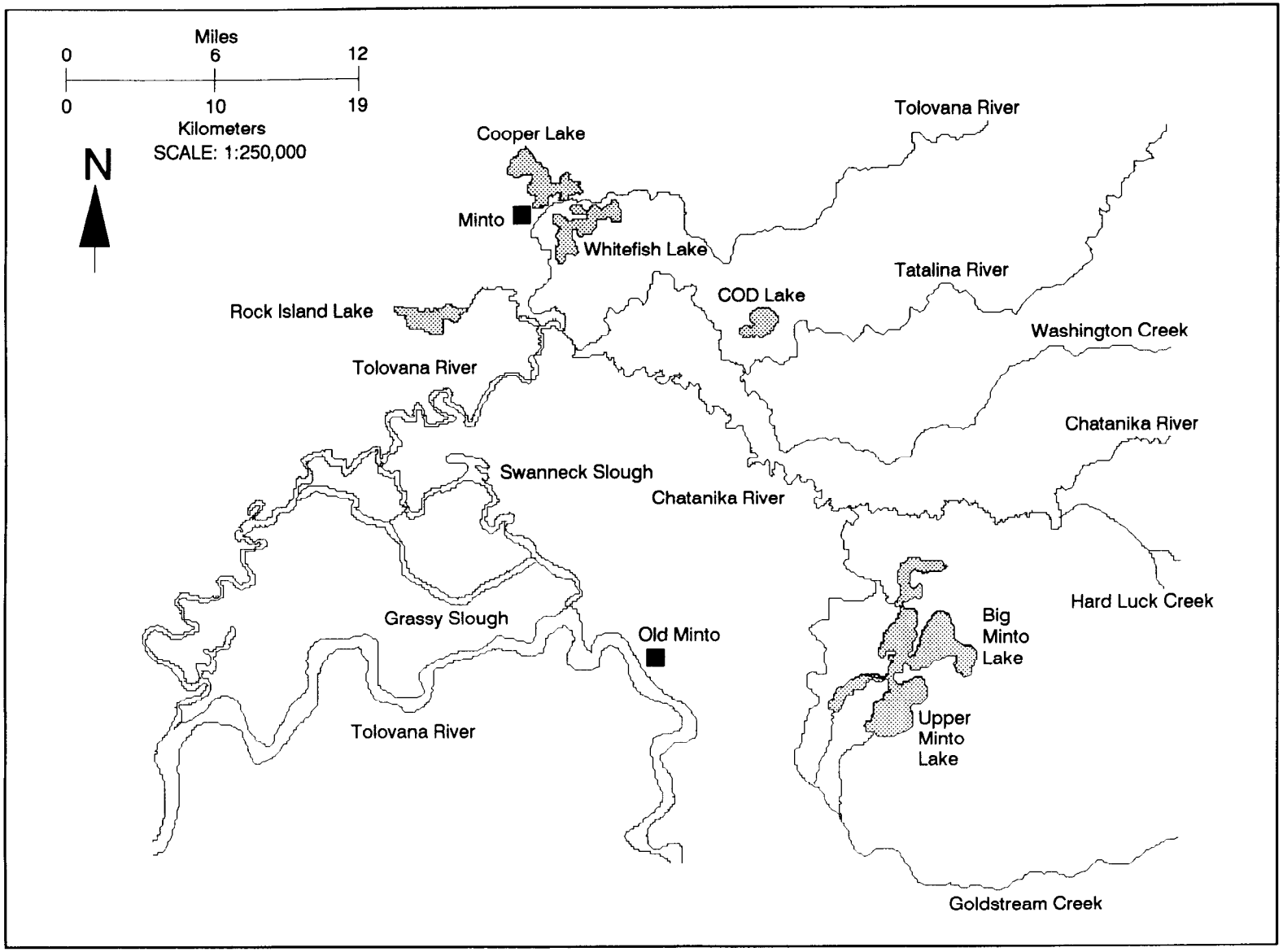

Figure 1. Minto Flats study area.

Location of the strongest signal was then plotted on a 1:63,360 USGS map. Loran C coordinates (longitude and latitude) and a narrative description for each fish location were also recorded.

A tracking period was defined as the time interval corresponding to a completed search for all tags. Due to the size of the area, aircraft availability, and weather conditions, the average tracking period lasted about 7 days (range 1 - 13 days). The average flight time per tracking period was 11.5 hours (range, 5-20 hours). A flight altitude of around 250 m appeared to be optimal for the number of frequencies that could be scanned versus the accuracy of location.

Data Analysis

Distributions of radio-tagged northern pike were analyzed graphically. Fish were grouped by where they overwintered from January through April (Chatanika River, Goldstream drainage, middle Tolovana River or lower Tolovana/Tanana River). The distribution of each overwintering group was then plotted for each tracking period, illustrating convergence to and dispersal from a particular overwintering site.

Mann-Whitney tests (Zar 1984) were used to test the null hypothesis of no difference between the median velocities of male and female as well as small and large radio-tagged northern pike for an overwintering group and for an overwintering group by tracking period. Velocity was defined as the minimum distance (m) by water between consecutive relocations divided by elapsed time (d) between these observations.

Significance of seasonal differences in median velocity between males vs. females and large vs. small northern pike were tested by contrasting the number of instances when one group had a higher median velocity than another. If there had been no seasonal differences between groups, medium velocity of one group would be expected to be greater than median velocity for the other in half the tracking periods. Only those tracking periods in which three fish were located were used in these contrasts.

Floy Tags

Information from radio-tagged northern pike was supplemented with data from other northern pike tagged in 1987 and 1988 with individually numbered anchor tags [see Holmes and Burkholder (1988) for details]. Recaptured northern pike were grouped by where they were originally marked in the spring of 1987 (5/19 - 7/3). The distribution of each group was then plotted for fall of 1987 (9/9 - 10/13), spring of 1988 (5/12 - 6/30), and fall of 1988 (9/14 - 9/30).

RESULTS

Movements of Radio-Tagged Fish

Of the 98 fish implanted with radio transmitters in the fall of 1987, five were never located, two were located in Minto Village (harvested) and one was located on land (assumed dead). Two fish were initially located near their release locations (Tatalina River and Cooper Lake), and all consecutive

locations were the same; these fish were assumed to have died. A third fish was released in the Chatanika River, moved to the upper Tolovana, remained there, and was assumed to have died. No movement detected between consecutive sightings in concert with no overwintering by other tagged fish in these areas was the basis for assuming that these fish had died. One of the 20 fish tagged in the Chatanika River in March 1988 was never located.

Radio-tags implanted in August and September 1987 failed prematurely and unexpectedly by early April 1988. On average, 93% of the 87 radio-tagged northern pike released in 1987 (located at least once and assumed to represent live fish) were located during October through March. Only 31% of these fish were located in April, 6% in May, 11% in June and 1% in July. None of the fish tagged in the fall of 1987 were located after the July tracking period. It is unlikely that 69% of the tagged fish moved out of Minto Flats sometime between the March and April tracking periods and therefore not located. So it is assumed that the low percentages of sightings after the March tracking period were due to failure of radio tags. This premature failure of radio-tags precluded the ability to fully track northern pike to their spawning areas.

Relocated fish can be segregated into four groups according to where they spent the winter: the Chatanika River, the Goldstream drainage, the middle Tolovana River, and the lower Tolovana/Tanana River. No differences were detected between the length distributions of these overwintering groups of northern pike (Anderson-Darling K-Sample test, $T_{akn} = 1.04$, $P > 0.10$) (Figure 2). Forty-three (50%) overwintered in the Chatanika River (16 males and 27 females). Fish in this overwintering group were tagged throughout Minto Flats (Figure 3). During September and October some fish from this group were still located outside of the Chatanika River (Figure 3). By December all fish that were located were in the Chatanika River (Figure 3). No fish were located outside of the Chatanika River until May (Figure 3). During June only three fish were located. Two were located in Big Minto Lake and the other was located in the Minto lakes channel.

Sixteen (18%) northern pike (eight males and eight females) tagged in the fall of 1987 overwintered in the Goldstream drainage. Most of these fish (12) were tagged in the vicinity of Minto lakes (Figure 4); the remaining fish were tagged downstream of Minto lakes. During the tracking periods most of the fish in this group were located near Minto lakes (Figure 4). Only one fish in this group was located (in Big Minto Lake) after spring breakup (breakup occurred between the April and May tracking periods; Figure 4).

Nine (10%) northern pike (four males and five females) tagged in the fall of 1987 overwintered in the middle Tolovana River. Six of these fish were tagged in this area and the others were tagged in the Tatalina River and Rock Island Slough (Figure 5). No fish tagged in the eastern portion of Minto Flats overwintered in this area. The six fish tagged around Grassy and Swanneck sloughs were tagged after the September tracking period was completed. Consequently, only one fish from this group was located during September (Figure 5). Most of the fish in this group were located in the middle section of the Tolovana River from October through April (Figure 5). One of the fish tagged around Grassy Slough was located in the Chatanika River during October (Figure 5). This same fish was latter located in the lower section of Swanneck Slough during March and April (Figure 5). The only fish located

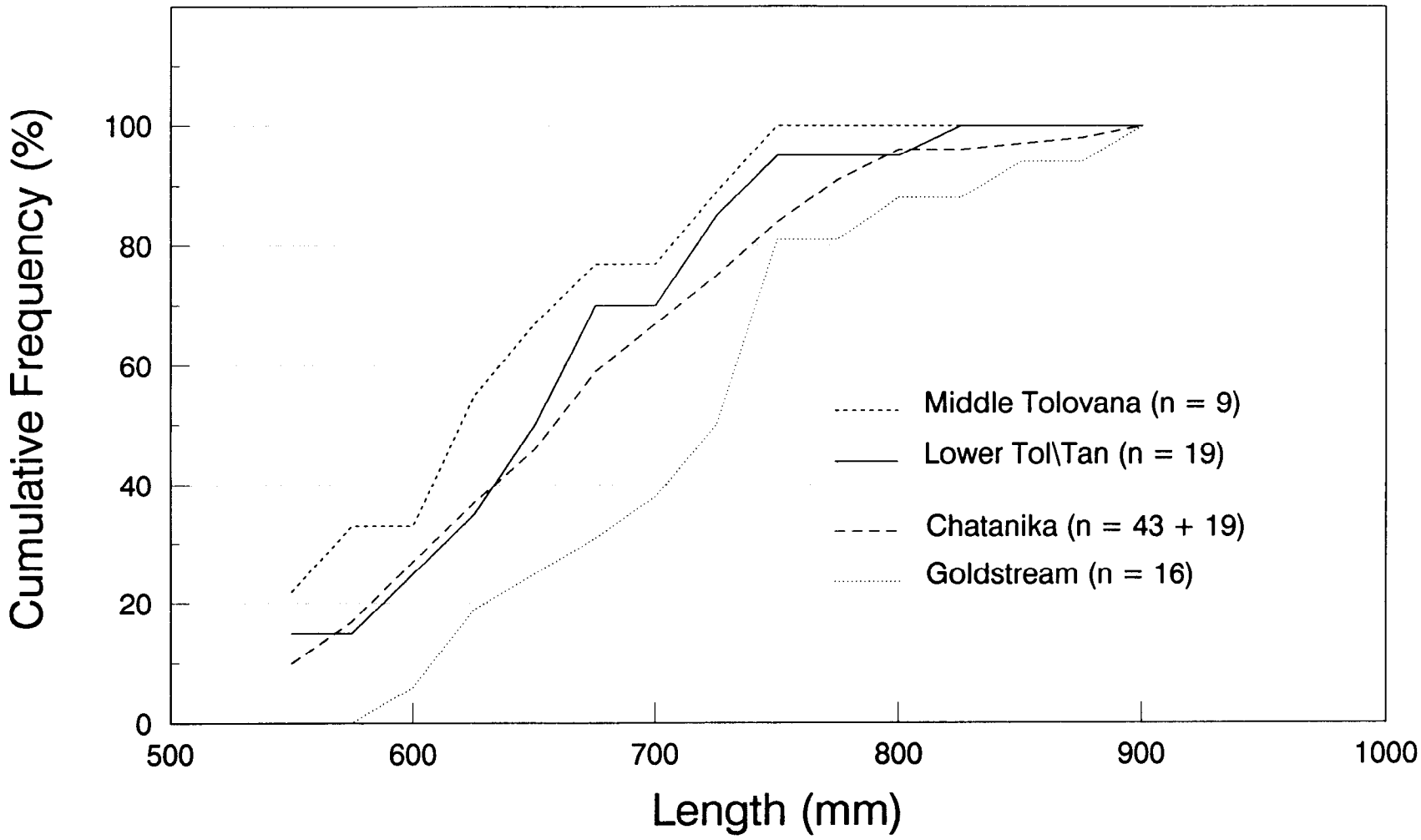

Figure 2. Cumulative length frequency (mm) for overwintering groups of northern pike radio-tagged in Minto Flats.

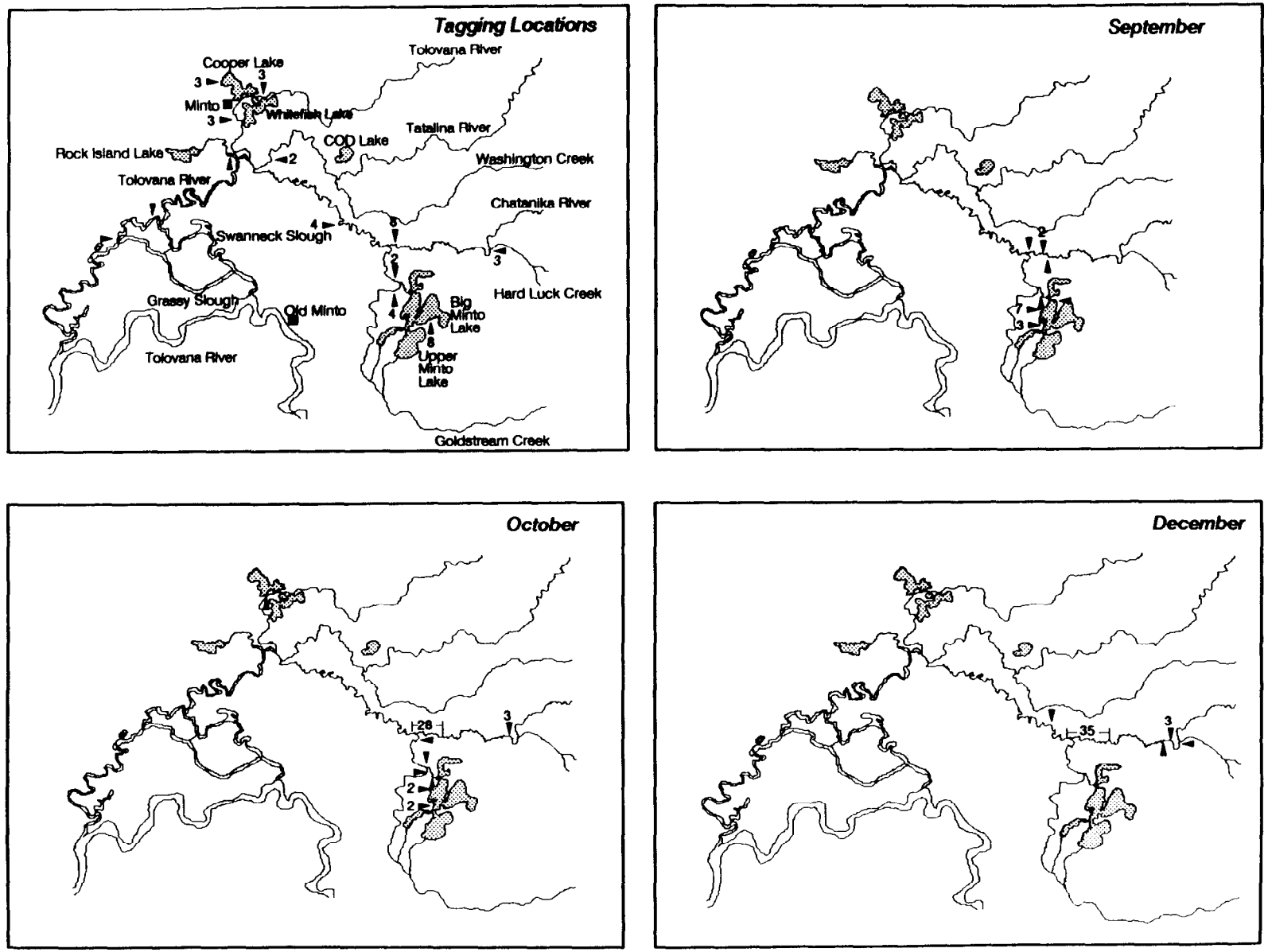

Figure 3. Tagging locations and distributions (September 1987 through May 1988) of radio-tagged northern pike that overwintered in the Chatanika River. When more than one fish was found at each location, the number is listed near each marker or within brackets.

-continued-

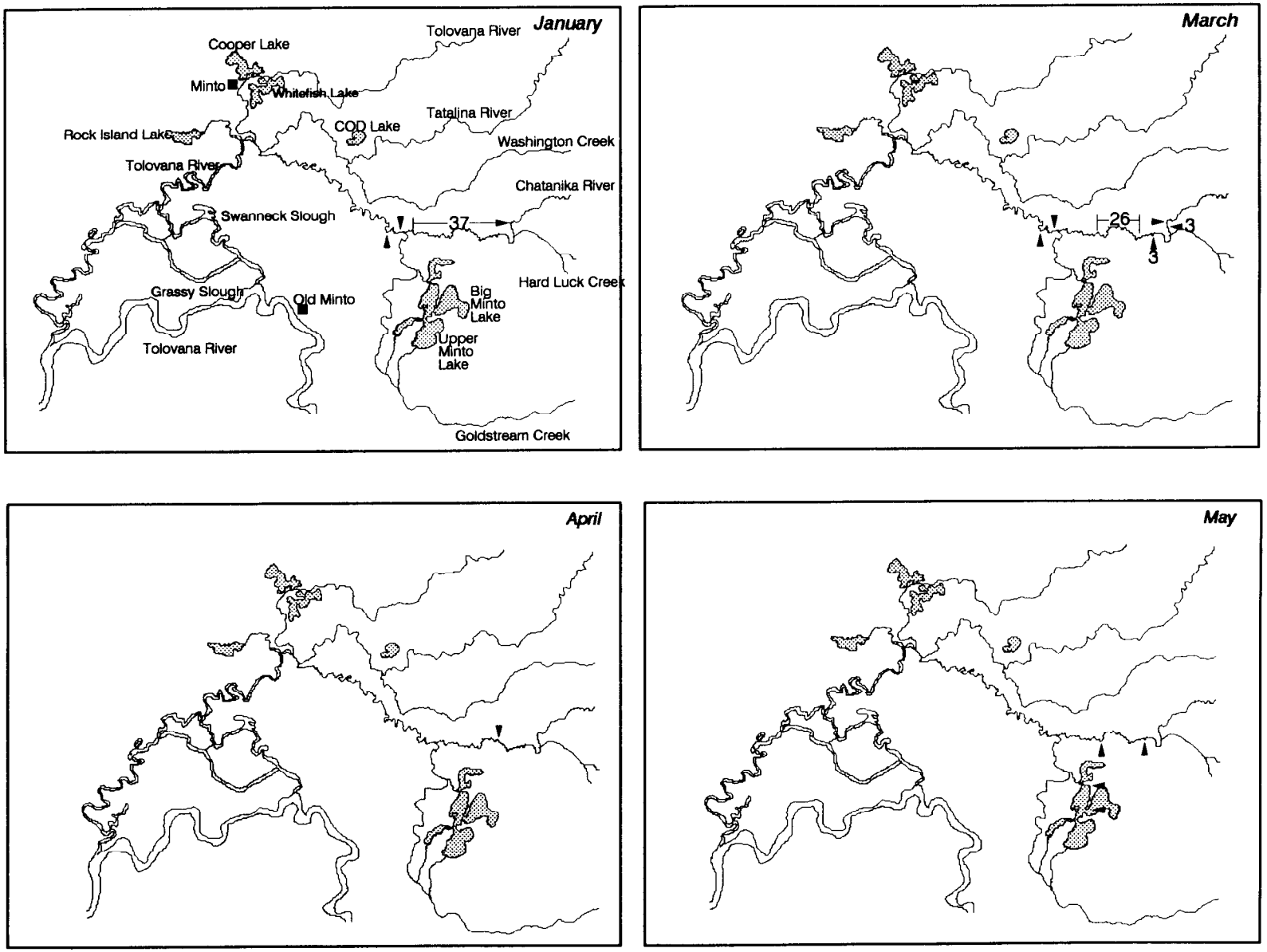

Figure 3. (Page 2 of 2).

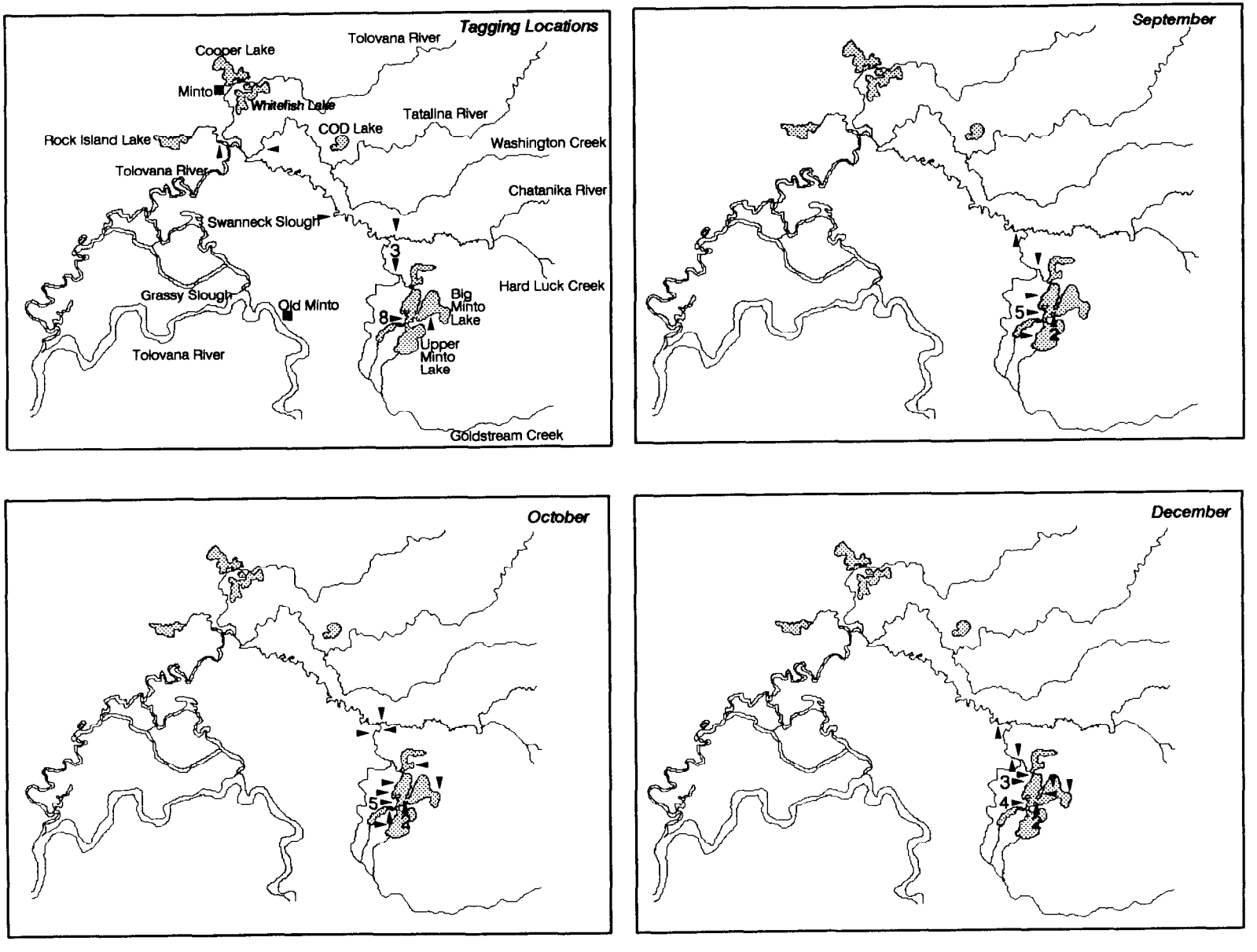

Figure 4. Tagging locations and distributions (September 1987 through May 1988) of radio-tagged northern pike that overwintered in the Goldstream drainage. When more than one fish was found at each location, the number is listed near each marker or within brackets.

-continued-

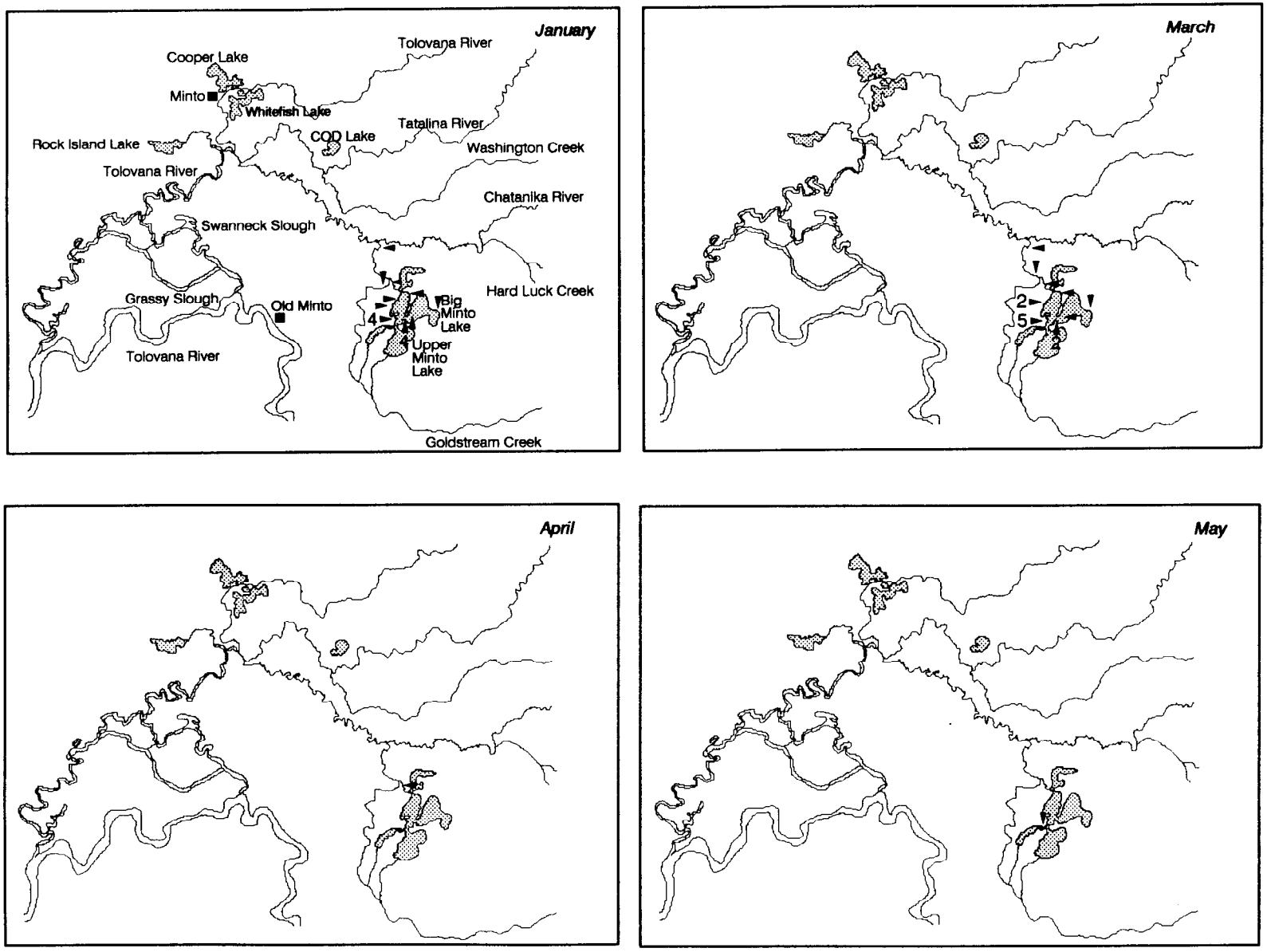

Figure 4. (Page 2 of 2).

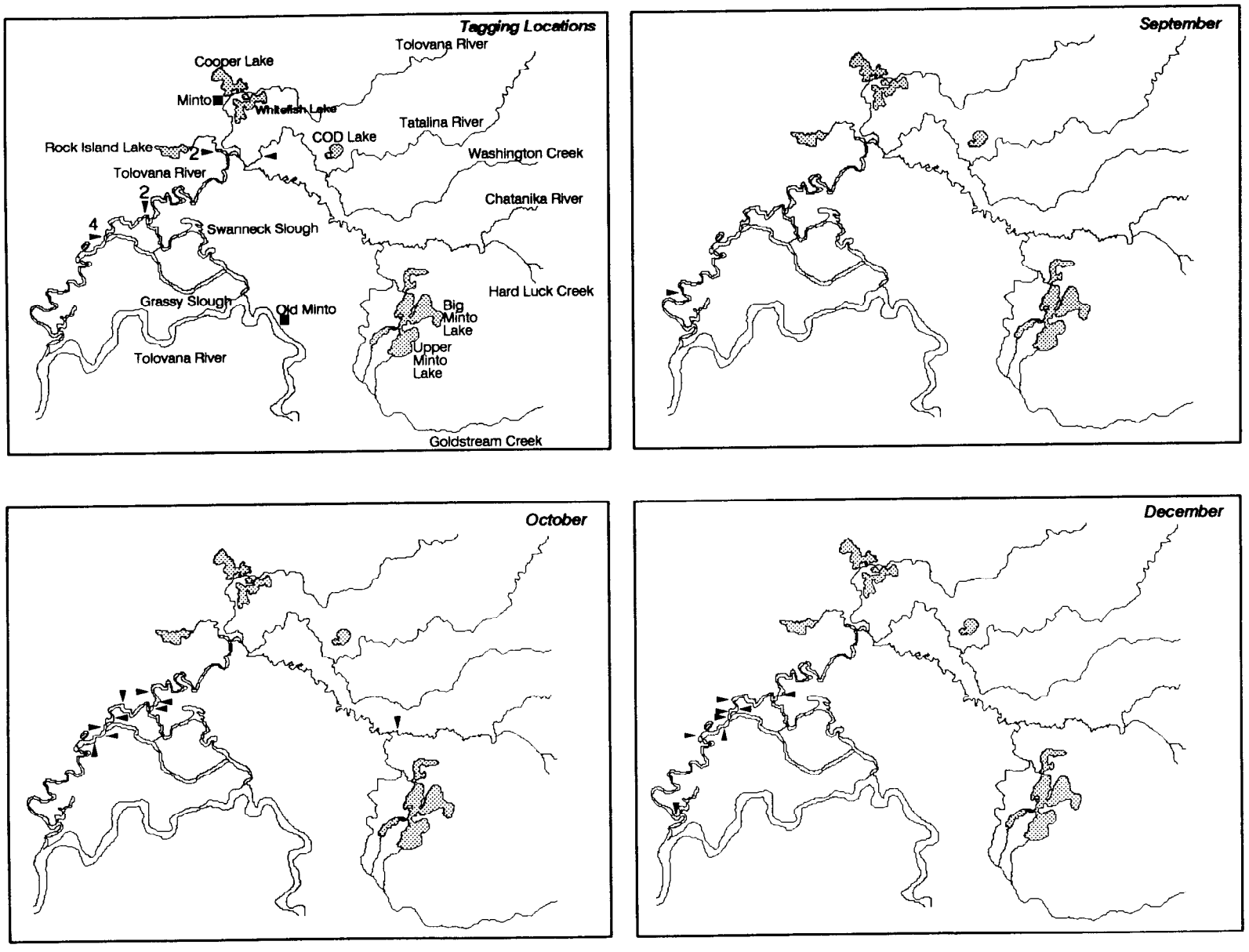

Figure 5. Tagging locations and distributions (September 1987 through June 1988) of radio-tagged northern pike that overwintered in the middle Tolovana River. When more than one fish was found at each location, the number is listed near each marker or within brackets.

-continued-

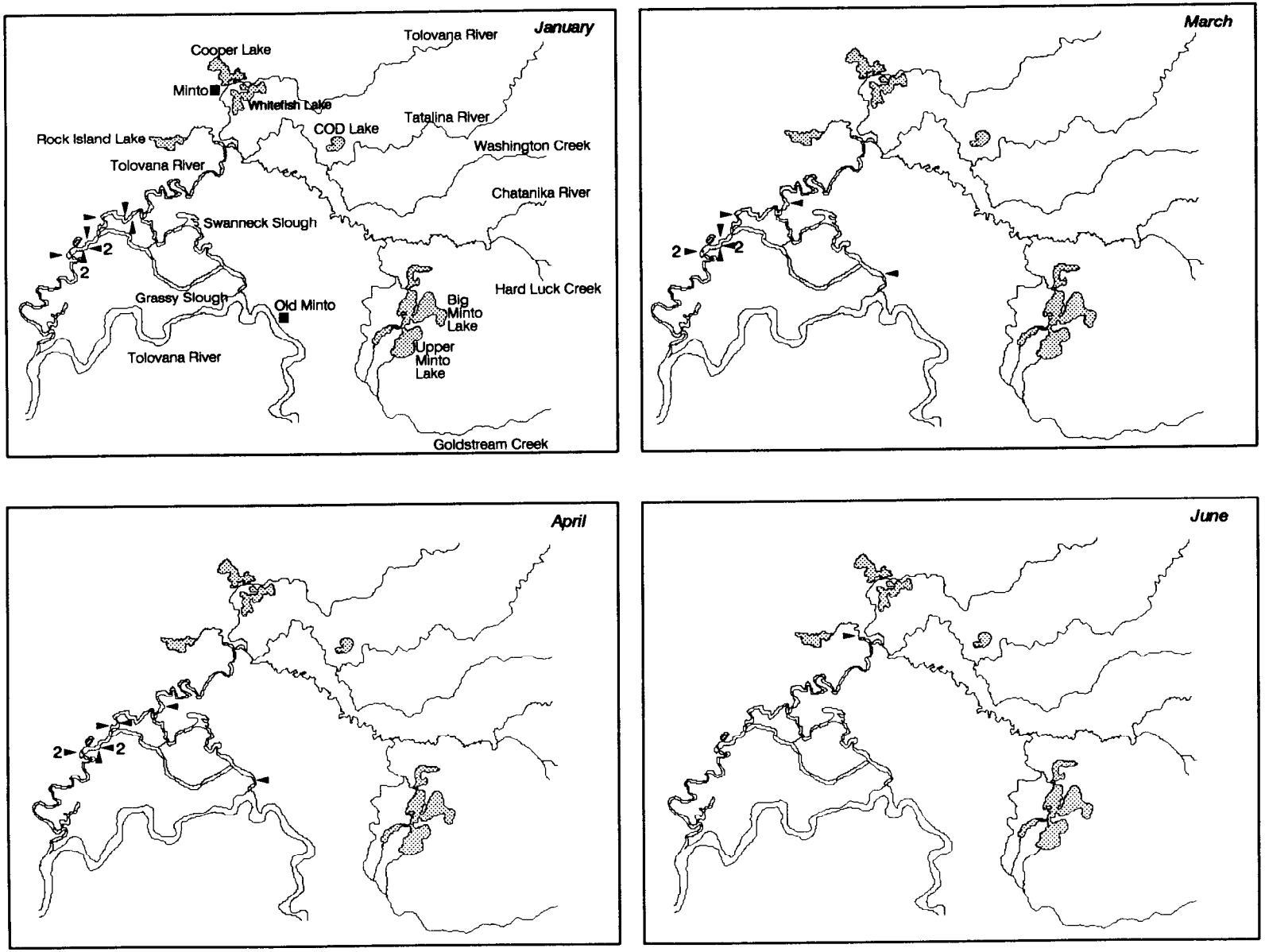

Figure 5. (Page 2 of 2).

after breakup was found in Rock Island Slough (Figure 5). This fish was originally tagged near Grassy Slough.

Nineteen (22%) northern pike (five males and 14 females) tagged in the fall of 1987 overwintered near the mouth of the Tolovana River and in the Tanana River. The tagging distribution of this group was similar to that of the middle Tolovana overwintering group, albeit some fish in this group were tagged in the vicinity of Minto Village (Figure 6). Again no fish tagged in the eastern portion of Minto Flats overwintered in this area. Only two fish were located during September (Figure 6). However, 12 of the fish in this group were not tagged until after this tracking period had been completed. By October, fish had begun moving downstream with some individuals moving out of the Tolovana River into the Tanana River (Figure 6). This trend continued throughout the next two tracking periods (Figure 6). During March and April, fish located in the Tolovana River were more widely distributed whereas the northern pike that overwintered in the Tanana River remained stationary during this time period (Figure 6). Fish located after breakup were distributed throughout Minto Flats. None of the northern pike that overwintered in the Tanana River downstream of the Tolovana River were located after April. The two fish that moved to the Minto lakes, one from the Tanana River near old Minto Village and the other from the lower Tolovana River, traveled at least 130 km and 140 km, respectively (Figure 6).

Northern pike fitted with radio tags in the Chatanika River in March 1988 remained in the Chatanika River until breakup (Figure 7). By May the majority of fish were located near Minto lakes. Fish were also located in the Chatanika and Tatalina rivers, near the confluence of the Chatanika and Tolovana rivers, and the lakes around Minto Village (Figure 7). This spring distribution is quite similar to the fall tagging distribution of fish that overwintered in the Chatanika River (Figures 3 and 7). The obvious difference is that none of the fish tagged in March were located below the confluence of the Chatanika and Tolovana rivers. Northern pike located throughout the remaining tracking periods moved very little (Figure 7).

The highest median velocities for most northern pike for each overwintering group were achieved prior to December (Figures 8 and 9). In general, median velocities of male and female northern pike progressively decreased throughout the winter (December though April). Significant differences ($P \leq 0.05$) between the median velocity of male and female northern pike for a given tracking period were only detected in three of the 28 comparisons (Appendices A1 through A5). No differences between the velocities of male and female northern pike for a given overwintering group were detected (Appendices A6 and B1). Median velocities of male and female northern pike increased, after breakup. Differences between the velocity of small and large northern pike for a given tracking period were only detected in two of the 25 comparisons (Appendices C1 through C5). No differences between the velocities of small and large northern pike for a given overwintering group were detected (Appendices B1 and C6). The highest median velocities for small and large northern pike that overwintered in the Chatanika River occurred after breakup. In general, median velocities of small and large northern pike progressively decreased throughout the winter tracking periods (December though April). Velocities of small and large northern pike increased, after breakup. Velocities of small and large northern pike in the Chatanika River overwintering group progressively decreased after May. This trend of high

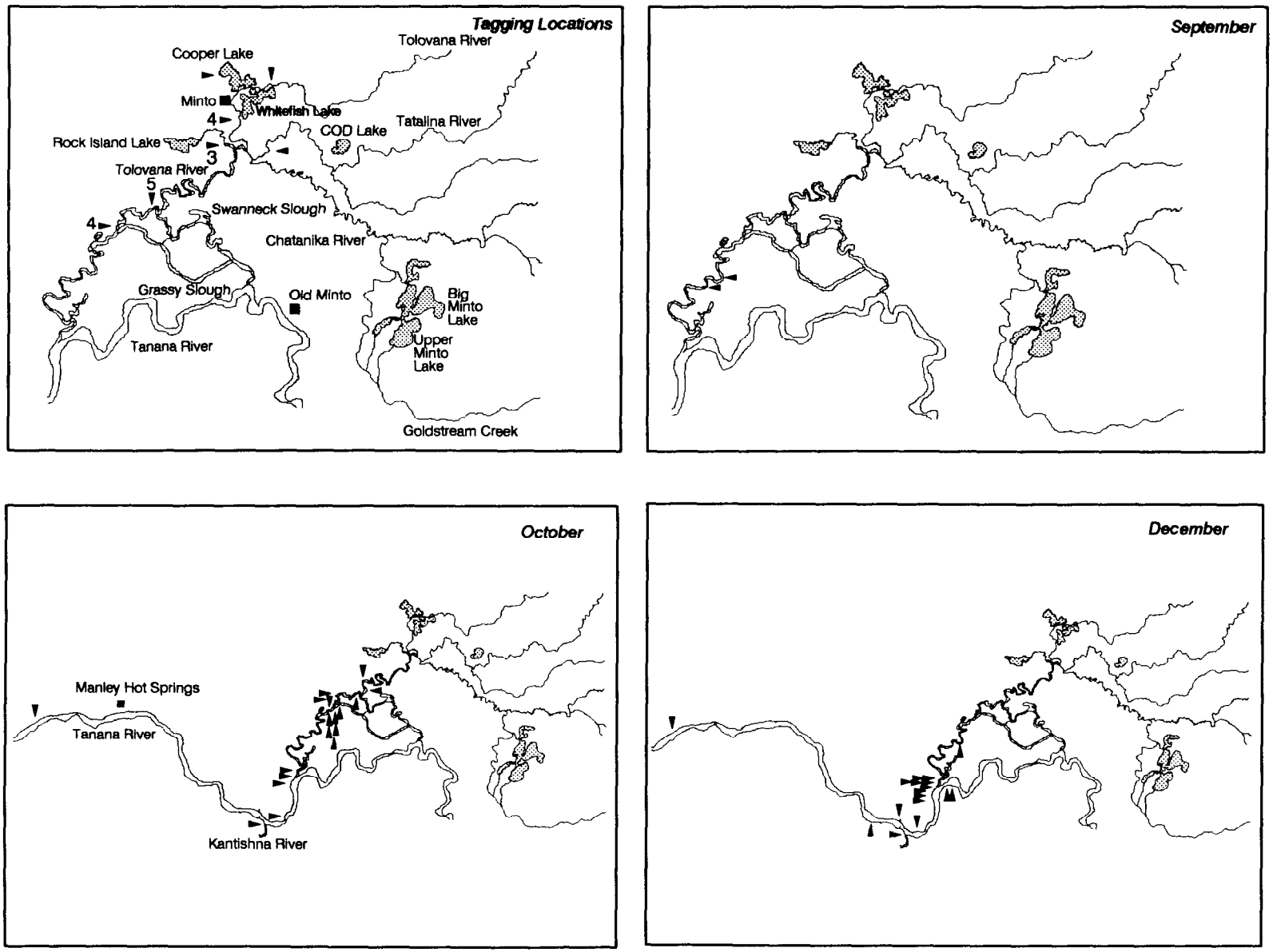

Figure 6. Tagging locations and distributions (September 1987 through June 1988) of radio-tagged northern pike that overwintered in the lower Tolovana and Tanana rivers. When more than one fish was found at each location, the number is listed near each marker or within brackets.

-continued-

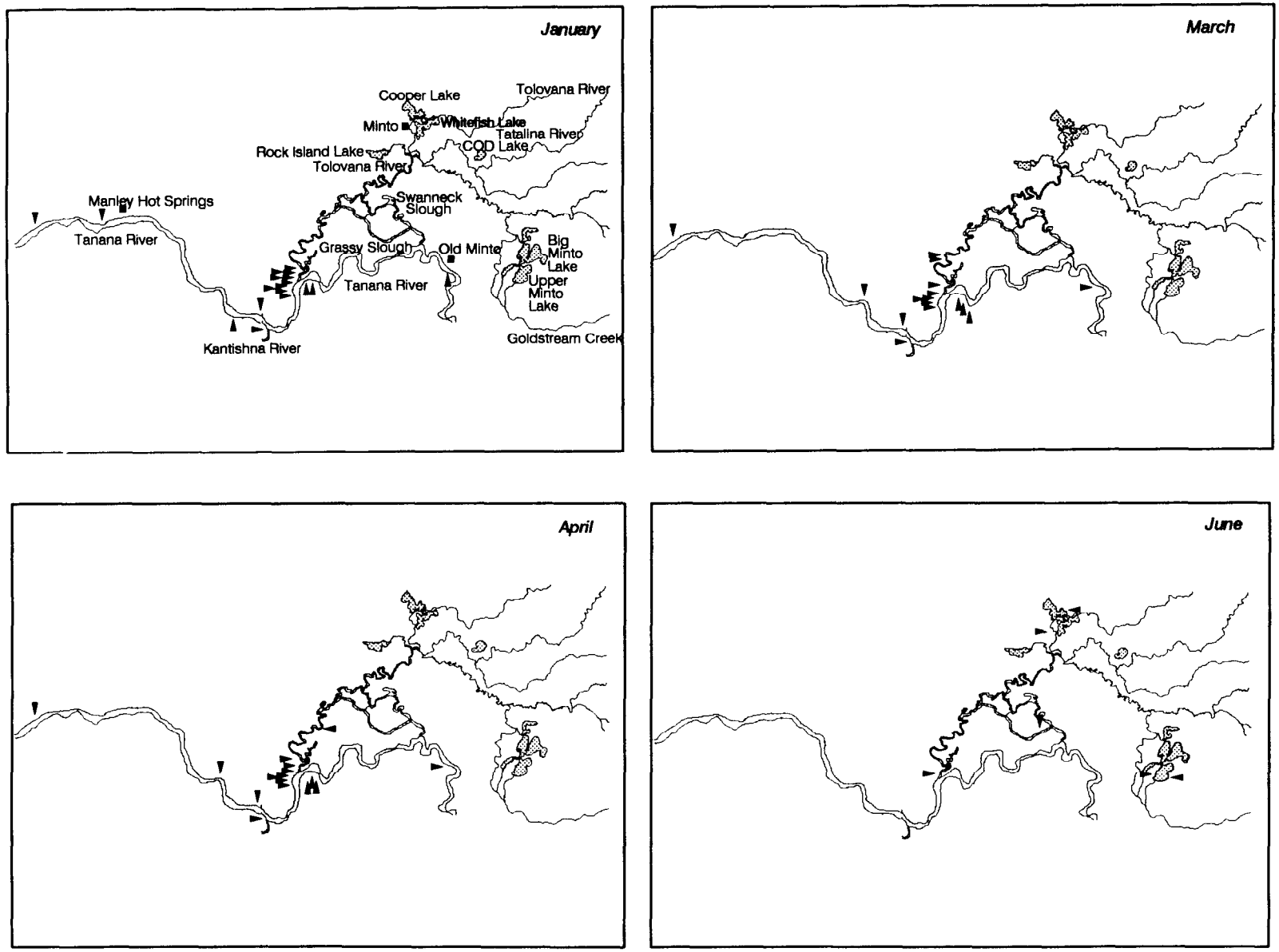

Figure 6. (Page 2 of 2).

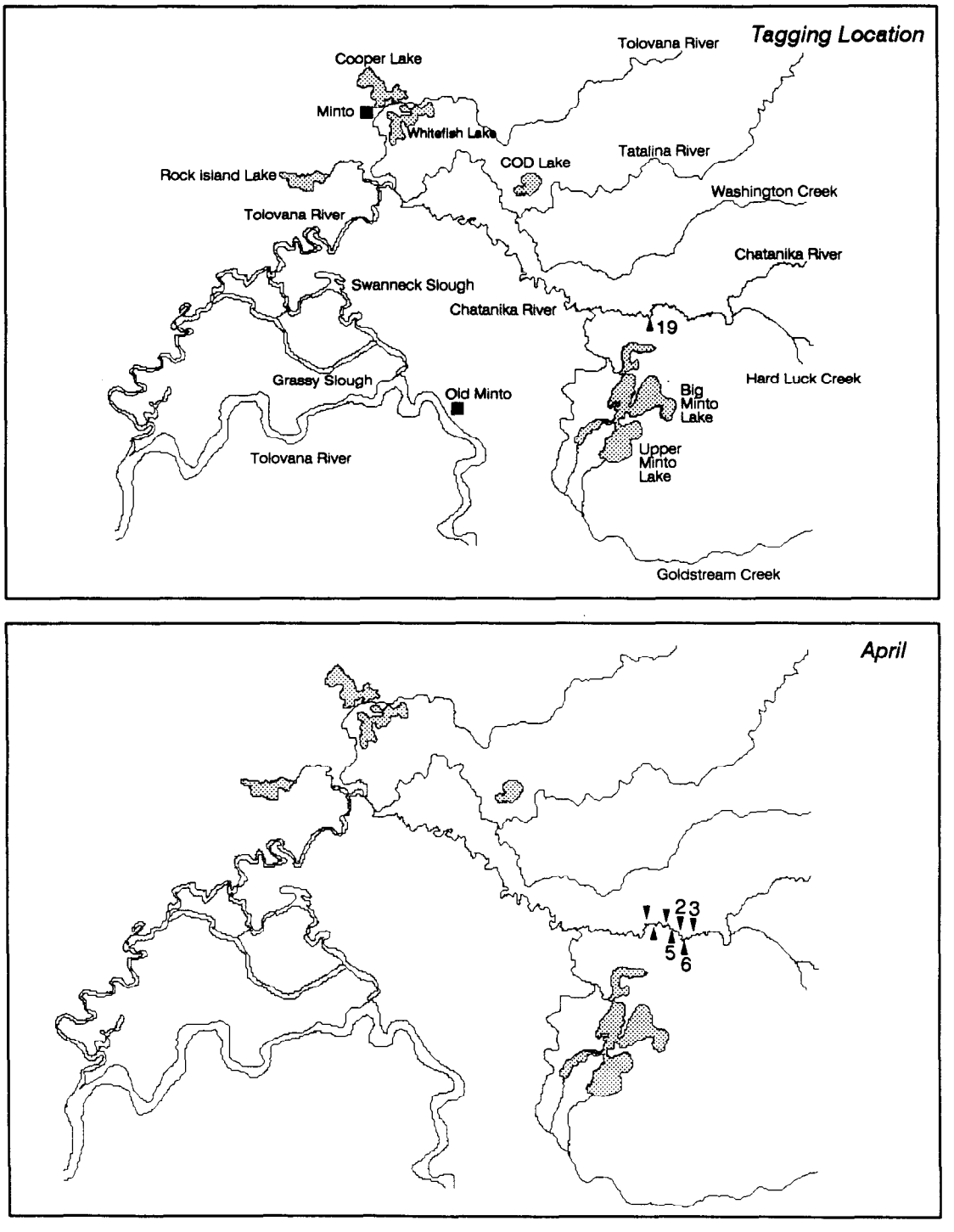

Figure 7. Tagging location and distributions (May through September, 1988) of northern pike radio-tagged in the Chatanika River in March 1988. When more than one fish was found at each location, the number is listed near each marker or within brackets.

-continued-

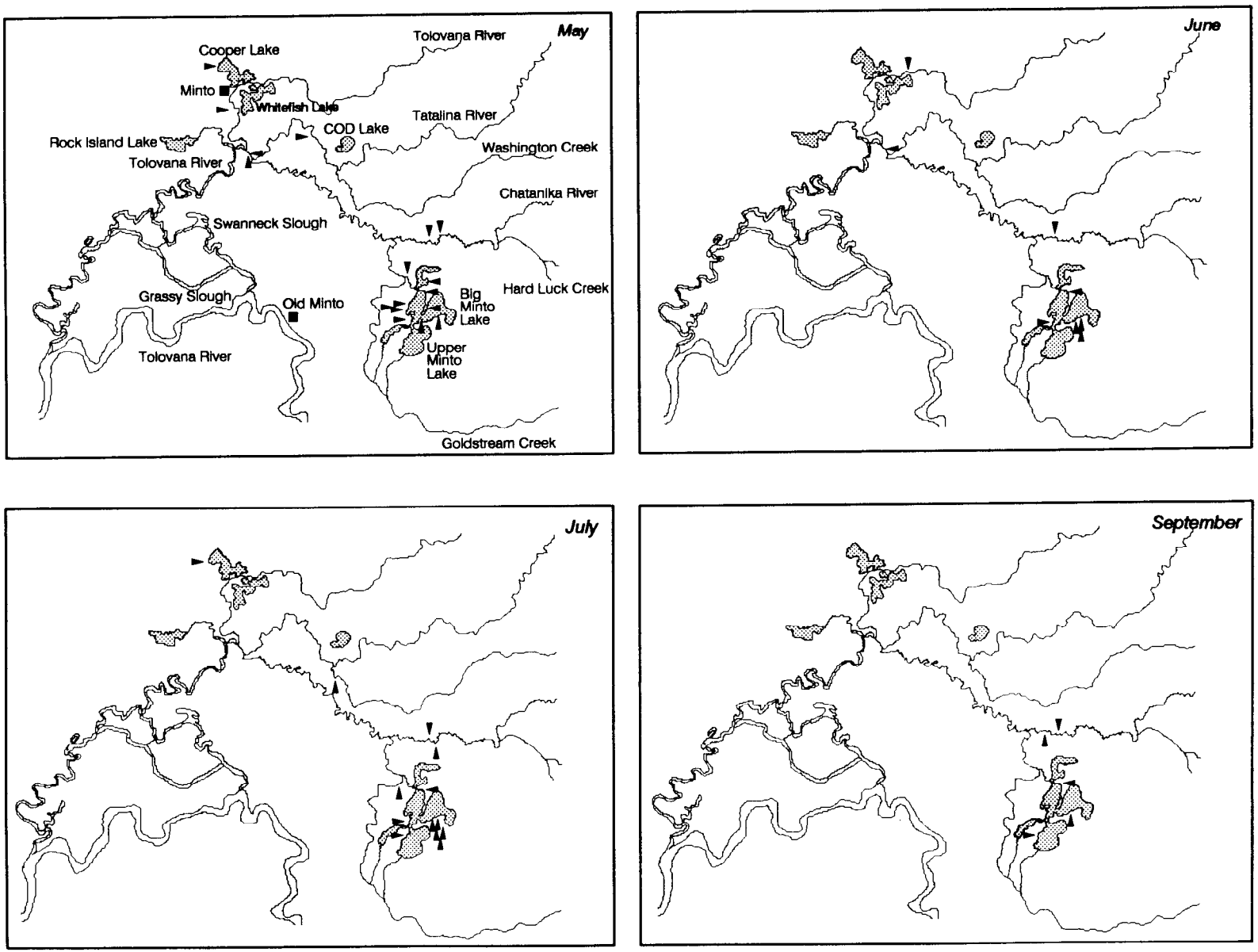

Figure 7. (Page 2 of 2).

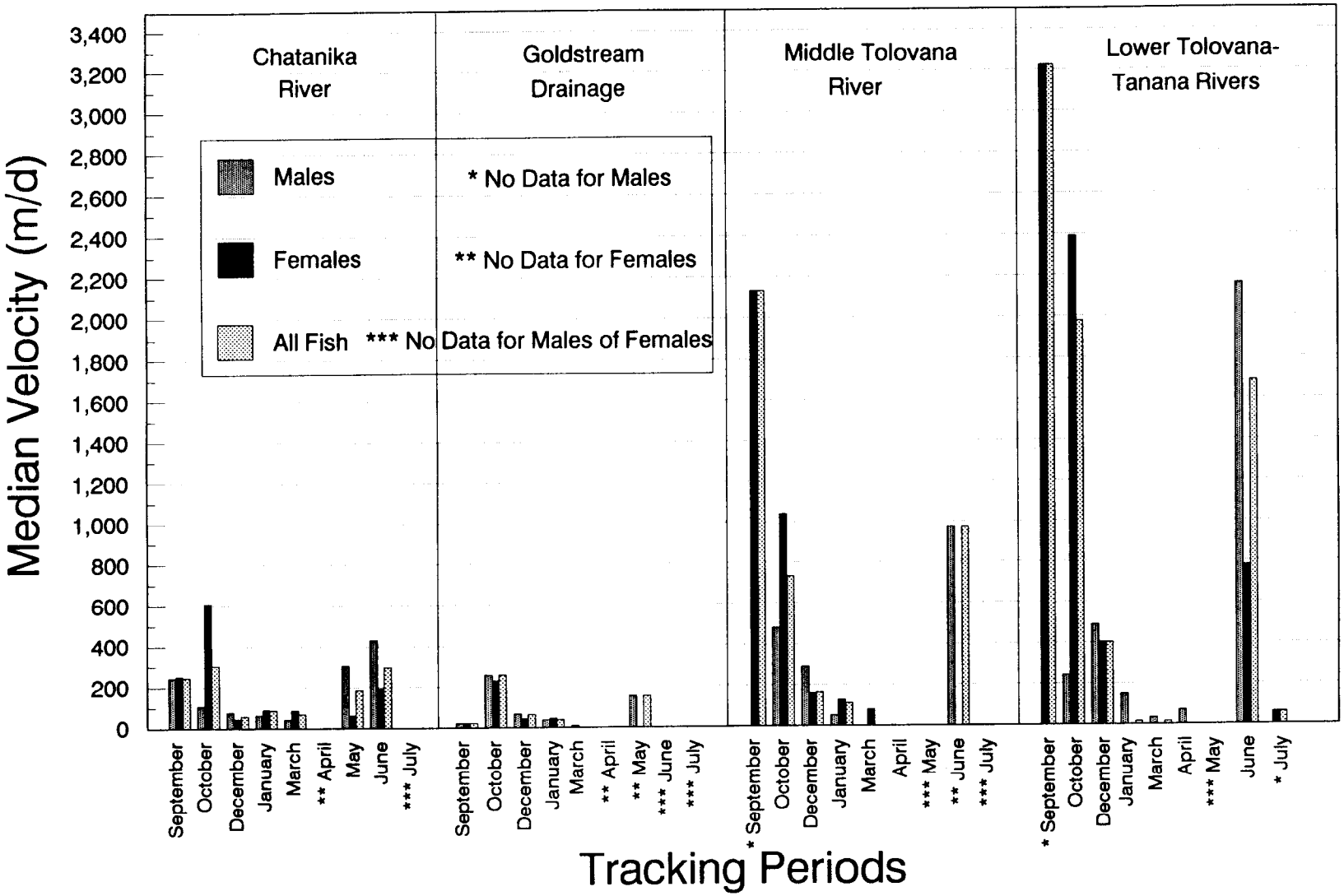

Figure 8. Median velocities for male and female northern pike radio-tagged that overwintered in the Chatanika River, Goldstream drainage, middle Tolovana River and the lower Tolovana and Tanana rivers.

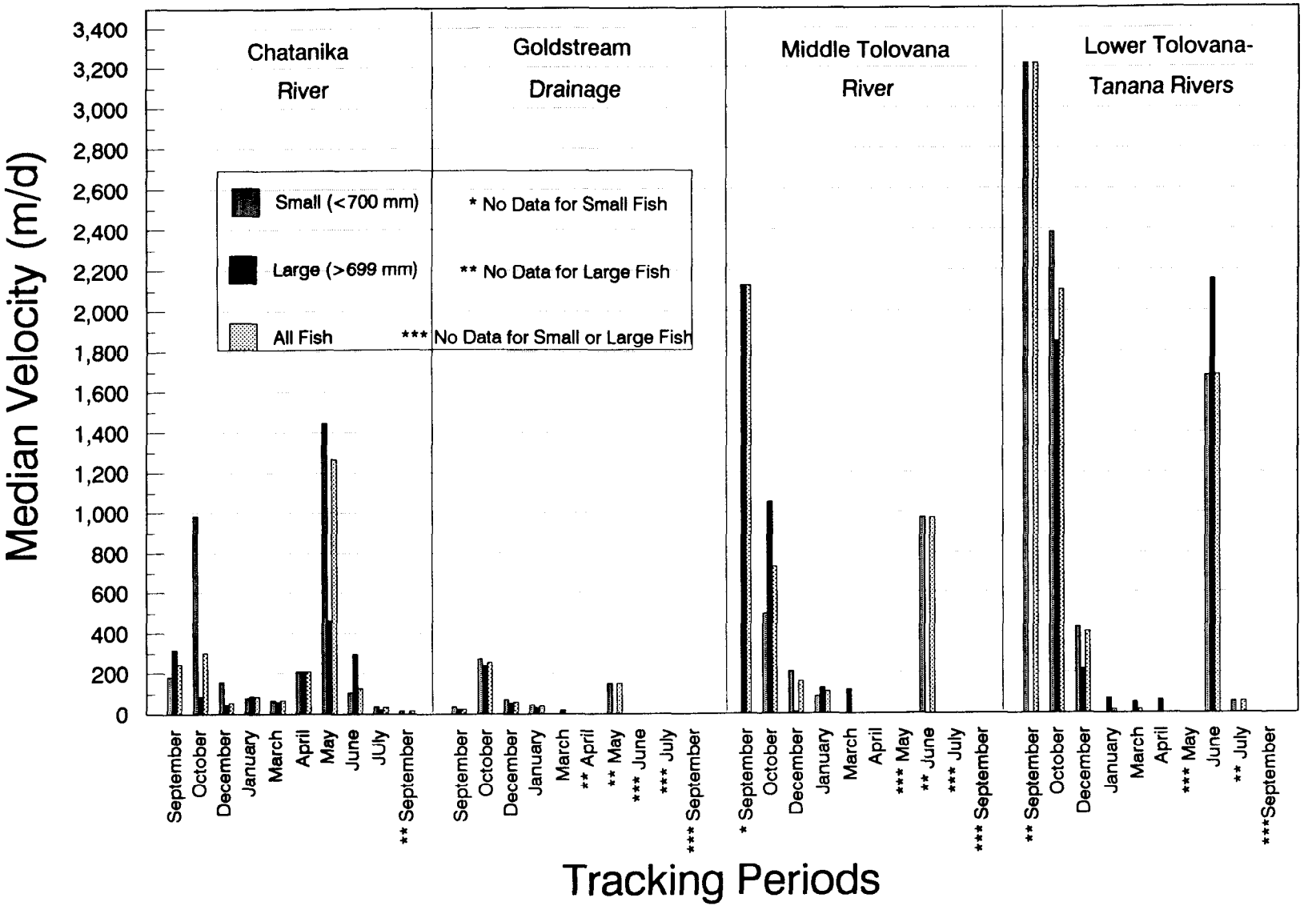

Figure 9. Median velocities for small (<700 mm) and large (>699 mm) northern pike radio-tagged that overwintered in the Chatanika River, Goldstream drainage, middle Tolovana River and the lower Tolovana and Tanana rivers.

velocity after breakup followed by low velocity during the summer was also apparent for the lower Tolovana and Tanana rivers overwintering group.

Movements of Floy-Tagged Fish

About 4% of the northern pike marked in the spring of 1987 were recaptured during the spring of 1988 and of these fish, about 77% were recaptured in the same areas as where they were marked. Northern pike floy-tagged near Minto lakes (spring 1987) in general were recaptured in the lakes the following spring and recaptured in Goldstream and the Chatanika River during the fall of 1987 and fall of 1988 (Figure 10). The fall distributions were very similar during both 1987 and 1988. It is important to note that northern pike were not sampled in Big and Upper Minto lakes during either the fall of 1987 or 1988 (Figure 11). Northern pike marked in the Tatalina River (Figure 12) were recaptured during the fall of 1987 and fall of 1988 in Goldstream Creek, as well as the upper Tolovana River during the fall of 1988. During the spring of 1988 northern pike were recaptured in the Tatalina River and Rock Island Slough (Figure 12). Fish marked in the upper Tolovana River (Figure 13) were recaptured in the same area as well as in the Chatanika River in the fall of 1987 (Figure 13). One northern pike was recaptured in Rock Island Slough during the fall of 1988. One northern pike marked in Rock Island Slough was recaptured in the upper Tolovana River during the fall of 1987 (Figure 14). Most of the recaptured fish in this group were caught in Rock Island Slough during the spring of 1988. Fish recaptured in the fall of 1988 were found in the Tolovana River below its confluence with the Chatanika River (Figure 14). Only one out of 10 northern pike fish marked in the lower Tolovana River (spring 1987) was recaptured during any of the subsequent sampling events. This fish was recaptured the following spring down stream of where it was marked.

With the exception of one fish recaptured in the Tatalina River in the fall of 1987, fish tagged in the Minto lakes and lake channels were generally recaptured in the same areas the following year. In the spring they were in the lake channels and Minto lakes and in the fall they were in Goldstream Creek and the Chatanika River. These results are complementary to the telemetry results for fish radio-tagged in these areas. Fish in the other floy tag groups move greater distances to and from overwintering areas so therefore where a fish is recaptured a year later would not be expected to be as consistent as for a northern pike tagged in the Minto lakes and channels where movement to and from overwintering sites is considerably shorter.

DISCUSSION

We found no evidence that implanted radio tags affected behavior of northern pike, although there was evidence of some early failures of radio tags implanted in 1987. During this study the incisions of two tagged northern pike examined in May 1988 appeared to be well healed. No visible sign of infection or fungus as a result of the surgical procedure was evident. Three northern pike located within 14 d after surgery moved from 64 km to 112 km upstream. At least two tagged northern pike were caught by anglers. Cook and Bergersen (1988) indicated that northern pike healed well after surgery, responded to angler lures, grew in size, were active and showed no signs of stress during visual observations, all of which were assumed to indicate

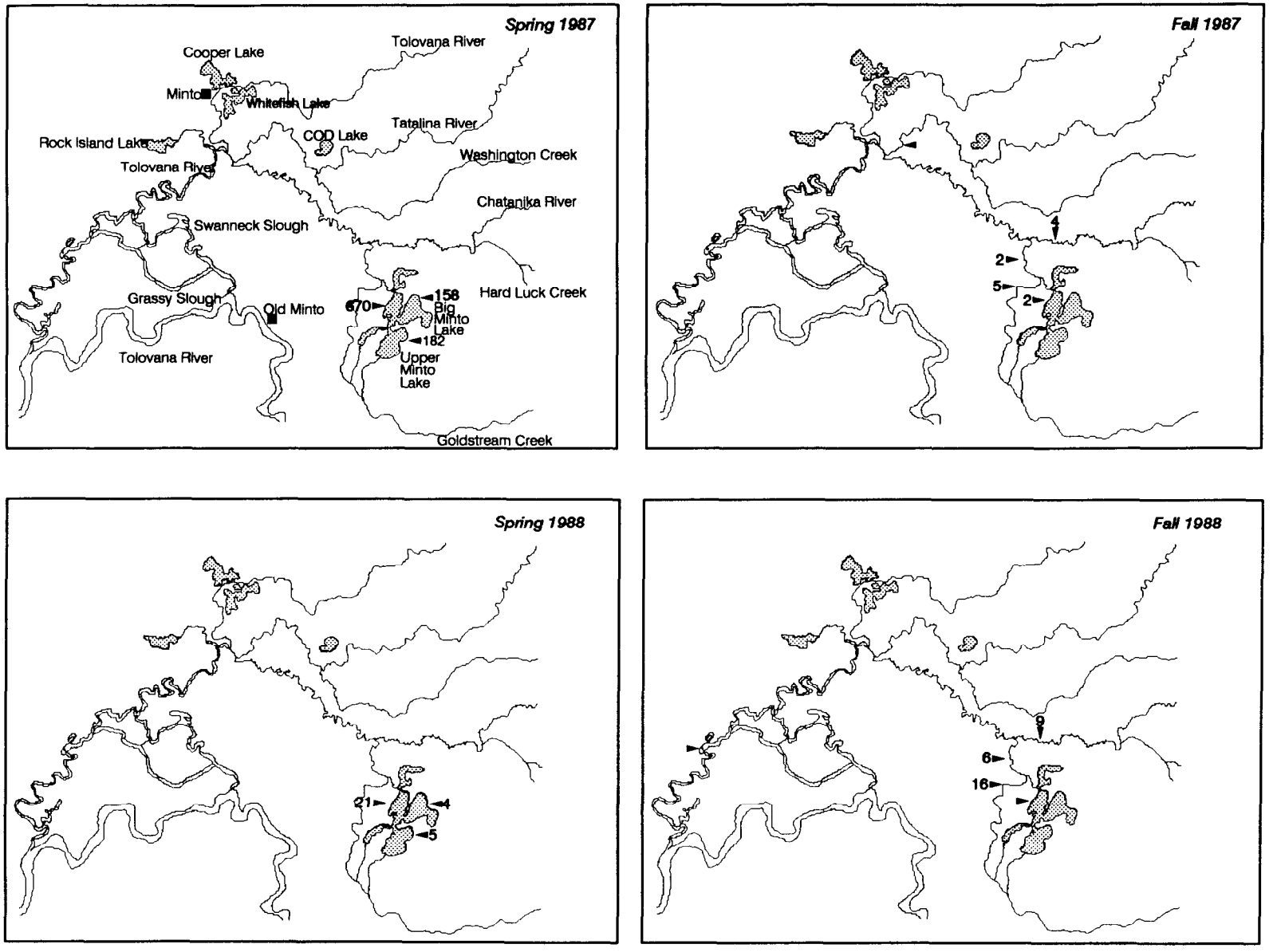

Figure 10. Seasonal distributions of recaptured northern pike marked with Floy tags in the Minto lakes and channels during the spring of 1987. When more than one fish was found at each location, the number is listed near each marker or within brackets.

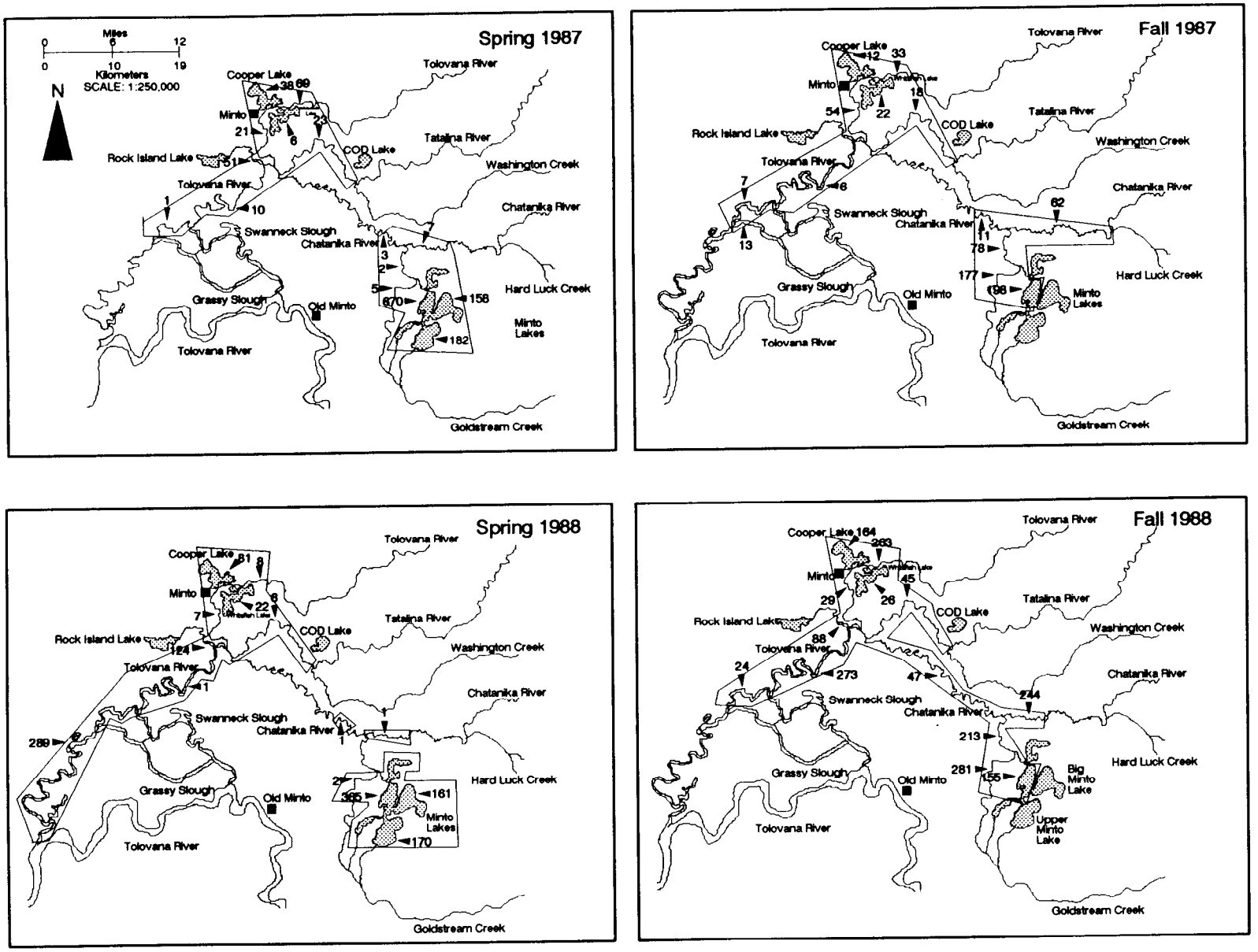

Figure 11. Areas and numbers of northern pike sampled during spring 1987, fall 1987, spring 1988, and fall 1988 in Minto Flats. When more than one fish was found at each location, the number is listed near each marker or within brackets. Sampling locations are marked with inclusion in rectangle.

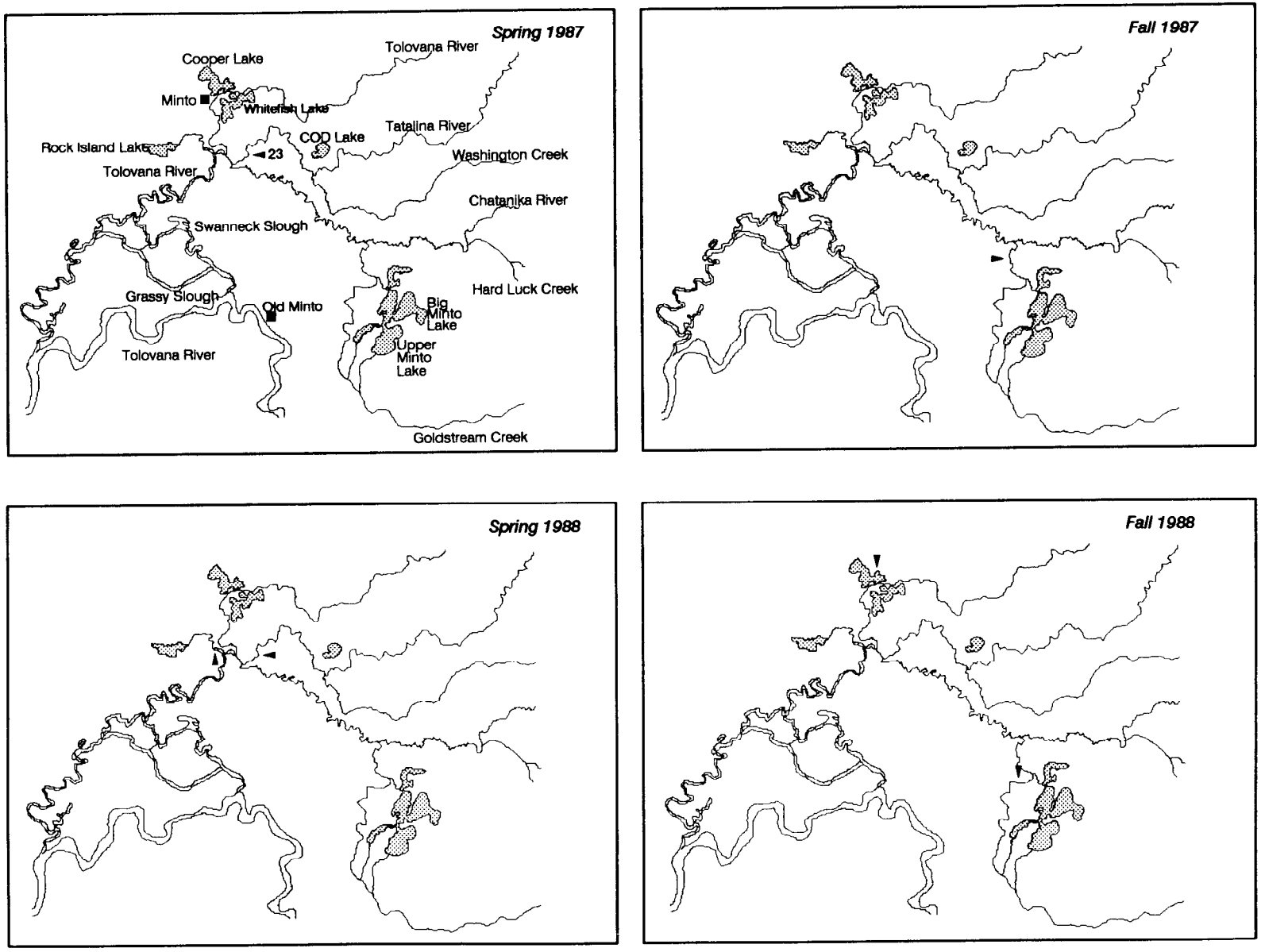

Figure 12. Seasonal distributions of recaptured northern pike marked with Floy tags in the Tatalina River during the spring of 1987. When more than one fish was found at each location, the number is listed near each marker or within brackets.

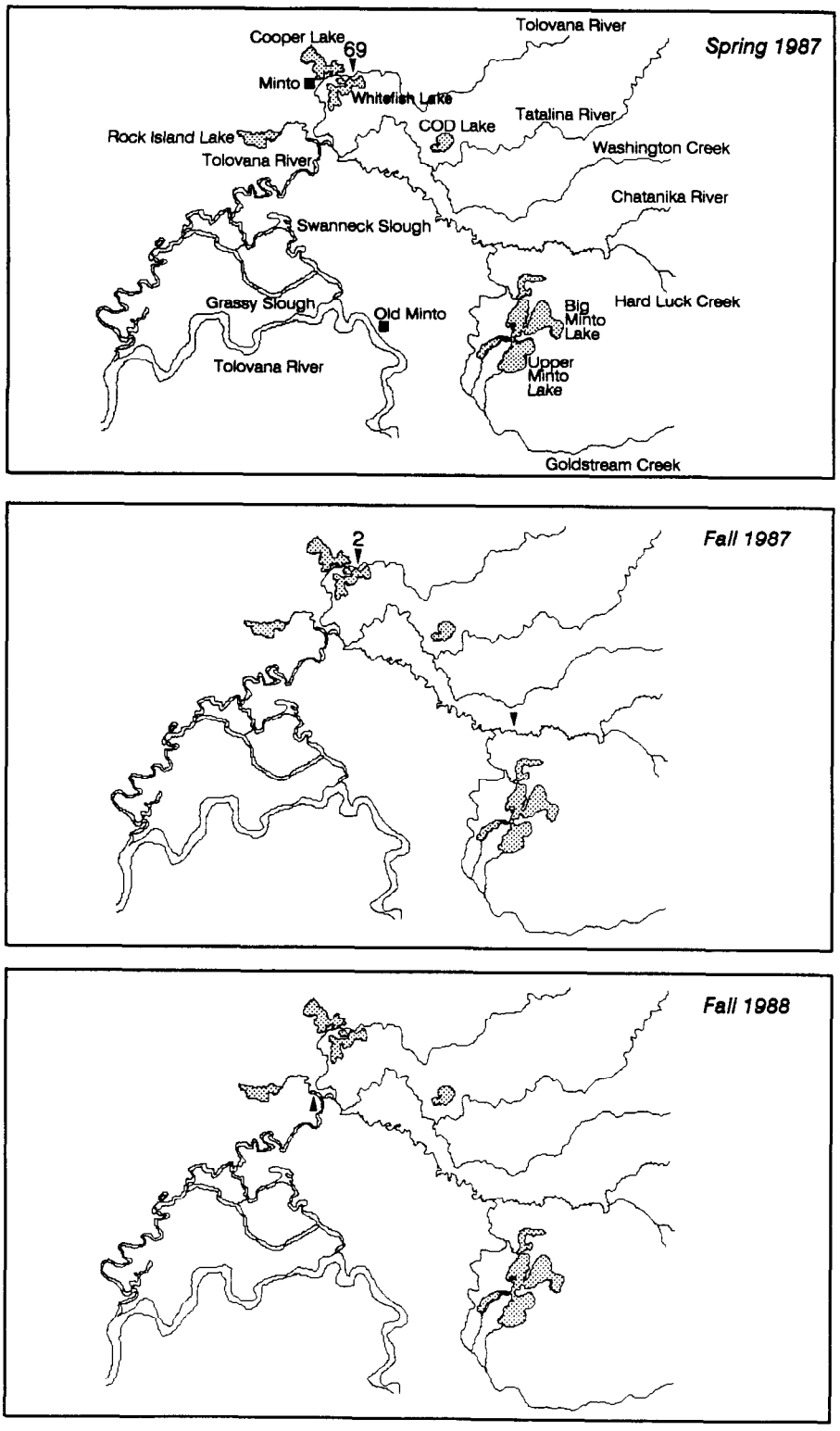

Figure 13. Seasonal distributions of recaptured northern pike marked with Floy tags in the upper Tolovana River during the spring of 1987. When more than one fish was found at each location, the number is listed near each marker or within brackets.

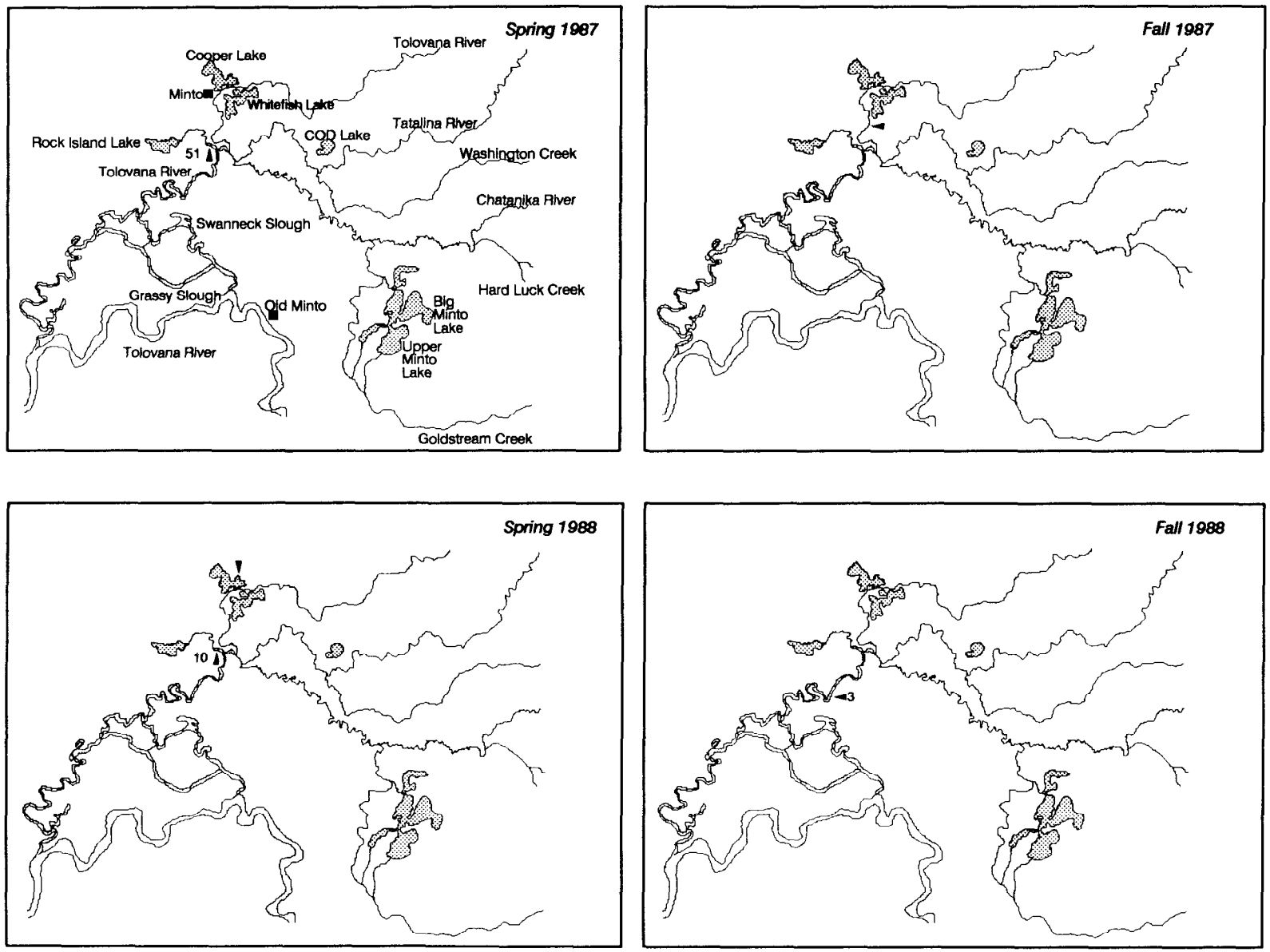

Figure 14. Seasonal distributions of recaptured northern pike marked with Floy tags in Rock Island Slough during the spring of 1987. When more than one fish was found at each location, the number is listed near each marker or within brackets.

normal behavior. However, there is a potential for fish inactivity of up to 5 d after implantation of radio tags (Diana 1980).

The four northern pike implanted with radio transmitters in September 1982 by Hallberg (1984) and released into Minto Flats moved similarly to fish released in this study (Figure 15), as did nine fish released in the upper Tanana drainage in 1985 (Behrends and West 1987). Three of the fish radio-tagged by Hallberg (1984) overwintered in the same areas (Swanneck Slough, Tanana and Chatanika rivers) as fish tagged in 1987. The other fish overwintered in Grassy Slough (Figure 15). Hallberg (1984) reported that all four fish exhibited strong movements in early October, which corresponded with ice formation and in general movement progressively declined between December and March. Behrends and West (1987) had similar results for nine northern pike radio-tagged in a wetlands complex near Northway Alaska. Seven of these fish left either small streams or lakes as freeze up occurred to overwinter in the Chisana River (a glacial river), one overwintered in a lake, and one was not located during the winter. Through the winter, all fish remained essentially sedentary (Behrends and West 1987).

It is assumed that the overwintering distribution of northern pike in Minto Flats is primarily a function of dissolved oxygen levels. In shallow lakes where oxygen is greatly reduced during the winter, northern pike can readily survive minimum oxygen concentrations of 0.3 mg/l (2% air saturation) and some northern pike have been captured alive in stationary gear at oxygen concentrations of 0.04 mg/l (0.3% air saturation) (Casselman 1978). Although northern pike are extremely tolerant of low winter oxygen, they can detect and avoid low oxygen concentrations in lakes (Casselman 1978). Roguski (1967), Cheney (1972), and Hallberg (1984) found dissolved oxygen concentrations of <1 ppm and little or no water in numerous areas of Minto Flats during the winter. One of the fish that was assumed to have died during the course of this study was located in the Tolovana River between the mouth of the Chatanika River and Rock Island Slough. Cheney (1972) and Hallberg (1984) reported dissolved oxygen concentrations of 0.5 ppm (2/27/68) and 0.8 ppm (2/16/73) at the mouth of the Chatanika River and the Tolovana River near Rock Island Slough, respectively. Cheney (1972) reported dissolved oxygen concentrations of 5.5 ppm (2/27/68) for the mouth of the Tolovana River and 4.5 ppm (3/26/71) below the confluence of the Tolovana River and Swanneck Slough. Hallberg (1984) reported dissolved oxygen concentrations of 4.2 ppm (2/16/83) below the confluence of the Tolovana River and Grassy Slough and 8.0 ppm (3/14/83) near the first bluff downstream of the confluence of the Tolovana and Tanana rivers. These documented areas of high dissolved oxygen concentrations in Minto Flats correspond to overwintering locations of northern pike implanted with radio transmitters in our study.

Sampling Implications and Recommendations

Spring and fall are probably the best times of the year to sample northern pike in Minto Flats with passive gear since northern pike are more active (moving from and to overwintering areas) at these times. Sampling northern pike in Minto Flats with active gear (electrofishing) has been most successful in late fall just prior to freeze up. But, because some northern pike leave Minto Flats in the fall and some enter Minto Flats in the spring, the probability of getting an unbiased estimate of abundance from a short-term mark-recapture experiment during either one of these times (fall or spring) is

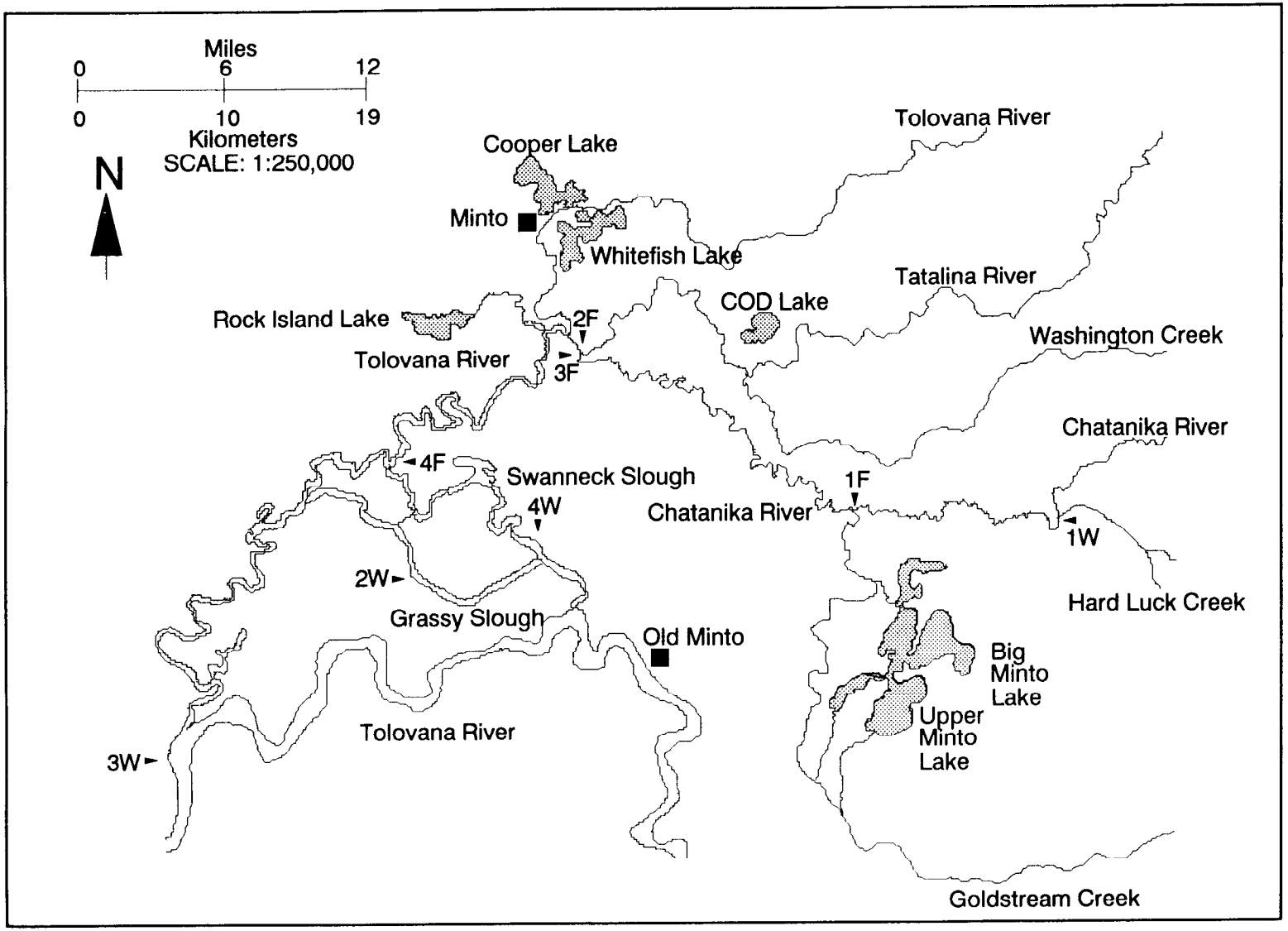

Figure 15. Fall and winter locations of four northern pike implanted with radio transmitters in Minto Flats, 1980 (Hallberg 1982). When more than one fish was found at each location, the number is listed near each marker or within brackets.

low. Northern pike are capable of moving long distances. Moen and Henegar (1971) reported movement of up to 322 km for a northern pike in Lake Oahe, South and North Dakota. Of the 14 radio-tagged northern pike (16%) that left Minto Flats to overwinter in the Tanana River, only three were located after breakup, even though all three were located in Minto Flats. Under these conditions (emigration-immigration), the abundance of northern pike in Minto Flats at a given time could be estimated with a long-term mark-recapture experiment based on a mathematical model developed for open populations.

ACKNOWLEDGEMENTS

Thanks to John Clark and Jim Reynolds for assisting with the design and implementation of this project. The authors are grateful for assistance with field work from Gary Pearse, James Reynolds, Fred DeCicco, Bob Murphy, Tim McKinley, Matt Evenson, Jerry Hallberg, and John Clark. Thanks to John Clark and Peggy Merritt for editing this report and thanks to Sara Case for finalizing this document.

LITERATURE CITED

Andrews, E. 1988. Use of fish and wildlife in Minto, Alaska. Alaska Department of Fish and Game Technical Paper No. 137, Juneau.

Behrends, W. D. and R. L. West. 1987. Seasonal movements of northern pike in the Chisana River. U.S. Fish and Wildlife Service. Fairbanks, Alaska.

Casselman, J. M. 1974. External sex determination of northern pike, *Esox lucius* Linnaeus. Transactions of the American Fisheries Society 103(2):343-347.

———. 1978. Effects of environmental factors on growth, survival, and exploitation of northern pike. American Fisheries Society, Special Publication 11:114-128.

Chapman, C. A., and W. C. Mackay. 1984a. Direct observation of habitat utilization by northern pike. Copeia 1984:258-262.

_____. 1984b. Versatility in habitat use by a top predator, *Esox lucius* L. Journal of Fish Biology 25:109-115.

Cheney, W. L. 1972. Life histories of northern pike in the Tanana river drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972, Project F-9-4, 13 (R III):1-30.

Cook, M. F., and E. P. Bergersen. 1988. Movements, habitat selection, and activity periods of northern pike in Eleven Mile Reservoir, Colorado. Transactions of the American Fisheries Society 117:495-502.

Diana, J. S. 1980. Daily activity pattern and swimming speeds of northern pike (*Esox lucius*) in Lac Ste. Anne, Alberta. Canadian Journal of Fisheries and Aquatic Sciences 37:1454-1458.

LITERATURE CITED (Continued)

Diana, J. S., W. C. Mackay, and M. Ehrman. 1977. Movements and habitat preference of northern pike (*Esox lucius*) in Lac Ste. Anne, Alberta. Transactions of the American Fisheries Society 106:560-565.

DosSantos, J. M., J. E. Darling, and D. Cross. 1988. Lower Flathead fisheries study, main river and tributaries, Volume II. Bonneville Power Administration, Division of Fish and Wildlife, Portland OR.

Hallberg, J. E. 1984. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters-Fairbanks District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25 (G-III-H):50-84.

Holmes, R. A. and A. Burkholder 1988. Movements and stock composition of northern pike in Minto Flats. Alaska Department of Fish and Game, Fisheries Data Series No. 53, Juneau.

Holmes, R. A. And G. A. Pearse 1987. Northern pike stock status and regulatory concerns in the Arctic Yukon Kuskokwim Region. Alaska Department of Fish and Game Report to the Alaska board of Fisheries.

Malinin, L. K. 1969. Uchastki obitaniya instinkt vozvroskcheniya ryb [Home range and homing instinct of fish.] Zoologichesskii Zhurnal 48:381-391. Translated from Russian: Fisheries Research Board of Canada Translation Series 2050.

_____. 1970. Use of ultrasonic transmitters for tagging bream and pike. Biologiya Vnutrennykh Vod Informatsionii Byulleten 8:75-78. Translated from Russian: Fisheries Research Board of Canada Translation Series 2146.

_____. 1971. Home range and actual paths of fish in the river pool of the Rybinsk Reservoir. Biologiya Vnutrennykh Vod Informatsionii Byulleten 22:158-166. Translated from Russian: Fisheries Research Board of Canada Translation Series 2282.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979 Project F-9-11, 20 (SW-I-A).

_____. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A).

_____. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

_____. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

———. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A).

———. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A).

———. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A).

———. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A).

———. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-86, Project F-10-1, 27(RT).

———. 1987. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

———. 1988. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

———. 1989. Alaska statewide sport fisheries harvest report. Alaska department of Fish and Game, Fisheries Data Series No. 122, Juneau.

———. 1990. Harvest and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

———. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

———. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

———. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Moen, T., and D. Henegar. 1971. Movement and recovery of tagged northern pike in Lake Ohae, South and North Dakota, 1964-68. American Fisheries Society Special Publication 8:85-93.

Pearse, G. A. and J. H. Clark. 1992 Movements and distributions of radio-tagged northern pike in Volkmar Lake. Alaska Department of Fish and Game, Fishery Data Series No. 92-28, Anchorage.

Poddubnyi, A. G., L. K. Malinin, and V. V. Gaiduk. 1970. Experiment in telemetric observations under ice of the behavior of wintering fish. Biologiya Vnutrennykh Vod Informatsionii Byulleten 6:65-70. Translated from Russian: Fisheries Research Board of Canada Translation Series 1817.

Roach, S. M. 1993. Movements and distribution of radio-tagged northern pike in Harding Lake. Alaska Department of Fish and Game, Fishery Data Series No. 93-12, Anchorage.

Roguski, E. 1967. Inventory and cataloging of the sport fish and sport fish waters in the interior. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1966-1967, Project F-5-R-8, 9 (17-B):231-246.

Ross, M. J. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish Culturist 44(1):41-43.

Ross, M. J., and J. D. Winter. 1981. Winter movements of four fish species near a thermal plume in northern Minnesota. Transactions of the American Fisheries Society 110:14-18.

Winter, J. D. 1983. Underwater biotelemetry. Pages 371-396 in L. Nielsen and D. Johnson, editors. Fisheries Techniques. American Fisheries Society. Southern Printing Company, Inc. Blacksburg, Virginia.

Zar, J. H. 1984 Biostatistical Analysis. 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

APPENDIX A

Appendix A1. Mean velocity and median velocity between tracking periods of radio-tagged male and female northern pike that overwintered in the Chatanika River.

Tracking Period	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	males	539	278	6	244	Z = -0.05
through	females	1044	544	10	251	P = 0.96
9/30/87	combined	855	353	16	245	
10/12/87	males	454	178	14	108	Z = 1.40
through	females	1363	407	26	606	P = 0.16
10/23/87	combined	1045	278	40	304	
12/3/87	males	184	65	16	76	Z = -0.48
through	females	179	41	25	46	P = 0.63
12/8/87	combined	181	35	41	57	
1/26/88	males	94	24	15	64	Z = 0.46
through	females	109	20	24	89	P = 0.64
2/2/88	combined	103	15	39	86	
3/14/88	males	81	24	14	43	Z = 1.16
through	females	118	27	21	86	P = 0.24
3/15/88	combined	103	19	35	68	
4/8/88	males	0		1	0	
through	females					
4/15/88	combined	0		1	0	
5/3/88	males	304		1	304	
through	females	319	273	3	61	
5/13/88	combined	315	193	4	183	
6/3/88	males	430		1	430	
through	females	193	103	2	193	
6/15/88[a]	combined	272	99	3	296	

[a] No northern pike in this group were located after 6/15/88.

Appendix A2. Mean velocity and median velocity between tracking periods for radio-tagged male and female northern pike that overwintered in the Goldstream drainage.

Tracking Period	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	males	23	9	4	23	Z = 0.41
through	females	245	211	7	23	P = 0.68
9/30/87	combined	164	134	11	23	
10/12/87	males	465	238	8	256	Z = 0.05
through	females	394	145	8	229	P = 0.96
10/23/8	combined	430	135	16	256	
12/3/87	males	83	30	8	66	Z = 0.21
through	females	128	61	8	43	P = 0.83
12/8/87	combined	106	33	16	62	
1/26/88	males	46	20	8	38	Z = 0.48
through	females	45	12	8	45	P = 0.63
2/2/88	combined	46	11	16	38	
3/14/88	males	30	19	8	9	Z = -0.19
through	females	14	7	7	0	P = 0.85
3/15/88	combined	23	10	15	0	
4/8/88	males	0		1	0	
through	females					
4/15/88	combined	0		1	0	
5/3/88	males	150		1	150	
through	females					
5/13/88[a]	combined	150		1	150	

[a] No northern pike in this group were located after 5/13/88.

Appendix A3. Mean velocity and median velocity between tracking periods of radio-tagged male and female northern pike that overwintered in the middle section of Tolovana River.

Tracking Period	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	males					
through	females	2128		1	2128	
9/30/87	combined	2128		1	2128	
10/12/87	males	481	100	4	478	Z = 1.34
through	females	3334	2593	5	1038	P = 0.18
10/23/87	combined	2066	1456	9	730	
12/3/87	males	275	72	4	288	Z = -1.59
through	females	85	44	4	155	P = 0.11
12/8/87	combined	180	53	8	161	
1/26/88	males	76	45	4	51	Z = 1.35
through	females	247	134	5	124	P = 0.18
2/2/88	combined	171	79	9	110	
3/14/88	males	0	0	4	0	Z = 2.01
through	females	99	41	5	79	P = 0.04
3/15/88	combined	55	28	9	0	
4/8/88	males	34	34	4	0	Z = -0.17
through	females	9	9	5	0	P = 0.87
4/15/88	combined	20	15	9	0	
5/3/88	males					
through	females					
5/13/88	combined					
6/3/88	males	973		1	973	
through	females					
6/15/88[a]	combined	973		1	973	

[a] No northern pike in this group were located after 6/15/88.

Appendix A4. Mean velocity and median velocity between tracking periods of radio-tagged male and female northern pike that overwintered in the lower Tolovana and Tanana rivers.

Tracking Period	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	males					
through	females	3222	1354	2	3222	
9/30/87	combined	3222	1354	2	3222	
10/12/87	males	1144	651	5	241	Z = 1.38
through	females	2321	446	13	2387	P = 0.17
10/23/87	combined	1944	381	18	1978	
12/3/87	male	433	142	4	487	Z = -0.28
through	females	385	101	13	402	P = 0.78
12/8/87	combined	397	82	17	402	
1/26/88	males	443	240	5	146	Z = -2.12
through	females	69	39	13	0	P = 0.03
2/2/88	combined	173	79	18	15	
3/14/88	males	58	33	4	32	Z = -1.10
through	females	70	38	12	0	P = 0.27
3/15/88	combined	67	29	16	15	
4/8/88	males	101	59	4	67	Z = -1.27
through	females	34	16	12	0	P = 0.20
4/15/88	combined	50	19	16	0	
5/3/88	males					
through	females					
5/13/88	combined					
6/3/88	males	2023	171	3	2154	Z = -1.75
through	females	848	462	3	776	P = 0.08
6/15/88	combined	1435	343	6	1683	
7/26/88	males					
through	females	59		1	59	
7/27/88[a]	combined	59		1	59	

[a] No northern pike in this group were located after 7/27/88.

Appendix A5. Mean velocity and median velocity between tracking periods of all radio-tagged male and female northern pike.

Tracking Period	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	males	332	181	10	115	Z = 0.88
through	females	1036	353	20	178	P = 0.38
9/30/87	combined	802	248	30	177	
10/12/87	males	572	145	31	241	Z = 2.18
through	females	1643	341	52	825	P = 0.03
10/23/87	combined	1243	227	83	497	
12/3/87	males	201	42	32	92	Z = -0.62
through	females	217	37	50	65	P = 0.53
12/8/87	combined	211	28	82	84	
1/26/88	males	134	44	32	46	Z = -0.13
through	females	102	20	50	69	P = 0.90
2/2/88	combined	115	21	82	64	
3/14/88	males	53	14	30	26	Z = 1.20
through	females	87	17	45	36	P = 0.23
3/15/88	combined	73	12	75	34	
4/8/88	males	54	28	10	0	Z = -0.66
through	females	26	12	17	0	P = 0.51
4/15/88	combined	36	13	27	0	
5/3/88	males	227	77	2	227	
through	females	319	273	3	61	
5/13/88	combined	282	153	5	150	
6/3/88	males	1494	348	5	1683	Z = -1.88
through	females	586	301	5	296	P = 0.06
6/15/88	combined	1040	265	10	874	
7/26/88	males					
through	females	59		1	59	
7/27/88[a]	combined	59		1	59	

[a] No northern pike in this group were located after 7/27/88.

Appendix A6. Mean velocity and median velocity throughout all tracking periods for overwintering groups of radio-tagged male and female northern pike.

Overwintering Location	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
Chatanika River	males	232	50	68	75	Z = 1.30
	females	511	117	111	104	P = 0.19
	combined	405	76	179	90	
Goldstream Drainage	males	138	56	38	34	Z = 0.22
	females	167	53	38	30	P = 0.83
	combined	153	38	76	32	
Middle Tolovana River	males	211	59	21	91	Z = 0.38
	females	863	545	25	110	P = 0.70
	combined	551	298	46	100	
Lower Tolovana and Tanana	males	655	182	25	161	Z = -1.78
	females	672	147	69	63	P = 0.08
	combined	667	118	94	102	
Combined	males	275	43	152	73	Z = 0.53
	females	537	89	243	86	P = 0.60
	combined	436	57	395	77	

APPENDIX B

Appendix B1. Sign tests comparing mean and median velocities of radio-tagged northern pike for sex and size[a] categories of overwintering groups.

Overwintering Group	Category	Sign Test for Mean Velocity	Sample Size	Sign Test for Median Velocity	Sample Size
Chatanika River	male/female	P = 0.19	5	P = 0.19	5
	small/large	P = 0.50	7	P = 0.50	7
Goldstream Drainage	male/female	P = 0.50	5	P = 0.31	4
	small/large	P = 0.69	4	P = 0.31	4
Middle Tolovana River	male/female small/large	P = 0.50	5	P = 0.31	4
Lower Tolovana and Tanana Rivers	male/female	P = 0.34	6	P = 0.11	6
	small/large	P = 0.34	6	P = 0.34	6
All Groups Combined	male/female	P = 0.50	7	P = 0.34	6
	small/large	P = 0.36	8	P = 0.14	8

[a] Small (550 - 699 mm FL), Large (>699 mm FL)

APPENDIX C

Appendix C1. Mean velocity and median velocity between tracking periods of radio-tagged small[a] and large[b] northern pike that overwintered in the Chatanika River.

Tracking Period	Size Category	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	small	1011	842	5	184	Z = 0.28
through	large	783	377	11	317	P = 0.78
9/30/87	combined	855	353	16	245	
10/12/87	small	1793	590	17	958	Z = -1.93
through	large	491	138	23	86	P = 0.05
10/23/87	combined	1045	278	40	304	
12/3/87	small	245	64	18	157	Z = -1.26
through	large	131	35	23	46	P = 0.21
12/8/87	combined	181	35	41	57	
1/26/88	small	91	13	16	80	Z = -0.10
through	large	112	24	23	88	P = 0.92
2/2/88	combined	103	15	39	86	
3/14/88	small	89	19	15	68	Z = 0.08
through	large	115	30	20	60	P = 0.93
3/15/88	combined	103	19	35	68	
4/8/88	small	188	19	19	208	
through	large	208		1	208	
4/15/88	combined	189	18	20	208	
5/3/88	small	1707	270	17	1448	Z = -1.84
through	large	496	358	4	463	P = 0.07
5/13/88	combined	1500	245	21	1270	
6/3/88	small	188	81	7	106	Z = 0.85
through	large	279	70	4	298	P = 0.40
6/15/88	combined	221	57	11	127	
7/26/88	small	45	11	12	36	
through	large	20		1	20	
7/27/88	combined	43	10	13	34	
9/14/88	small	23	8	5	16	
	large					
	combined	23	8	5	16	

[a] Small (550 - 699 mm FL)
[b] Large (>699 mm FL)

Appendix C2. Mean velocity and median velocity between tracking periods of radio-tagged small[a] and large[b] northern pike that overwintered in the Goldstream drainage.

Tracking Period	Size Category	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	small	34	11	2	35	
through	large	193	164	9	23	
9/30/87	combined	164	134	11	23	
10/12/87	small	576	379	5	274	Z = 0.00
through	large	363	111	11	238	P = 1.00
10/23/87	combined	430	135	16	256	
12/3/87	small	91	43	5	75	Z = 0.00
through	large	112	45	11	57	P = 1.00
12/8/87	combined	106	33	16	62	
1/26/88	small	58	30	5	45	Z = -0.06
through	large	40	10	11	30	P = 0.95
2/2/88	combined	46	11	16	38	
3/14/88	small	10	7	5	0	Z = 0.68
through	large	29	15	10	17	P = 0.50
3/15/88	combined	23	10	15	0	
4/8/88	small	0		1	0	
through	large					
4/15/88	combined	0		1	0	
5/3/88	small	150		1	150	
through	large					
5/13/88	combined	150		1	150	
6/3/88	small					
through	large					
6/15/88[c]	combined					

[a] Small (550 - 699 mm FL)
[b] Large (>699 mm FL)
[c] No northern pike in this group were located after 6/15/88.

Appendix C3. Mean velocity and median velocity between tracking periods of radio-tagged small[a] and large[b] northern pike that overwintered in the middle Tolovana River.

Tracking Period	Size Category	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	small					
through	large	2128		1	2128	
9/30/87	combined	2128		1	2128	
10/12/87	small	2355	1890	7	495	
through	large	1055	17	2	1055	
10/23/87	combined	2066	1456	9	730	
12/3/87	small	237	52	6	208	
through	large	9	9	2	9	
12/8/87	combined	180	53	8	161	
1/26/88	small	184	103	7	86	
through	large	127	3	2	127	
2/2/88	combined	171	79	9	110	
3/14/88	small	37	31	7	0	
through	large	118	39	2	119	
3/15/88	combined	55	28	9	0	
4/8/88	small	25	19	7	0	
through	large	0		2	0	
4/15/88	combined	20	15	9	0	
5/3/88	small					
through	large					
5/13/88	combined					
6/3/88	small	973		1	973	
through	large					
6/15/88[c]	combined	973		1	973	

[a] Small (550 - 699 mm FL)
[b] Large (>699 mm FL)
[c] No northern pike in this group were located after 6/15/88.

Appendix C4. Mean velocity and median velocity between tracking periods of radio-tagged small[a] and large[b] northern pike that overwintered in the lower Tolovana and Tanana rivers.

Tracking Period	Size Category	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	small	3222	1354	2	3222	
through	large					
9/30/87	combined	3222	1354	2	3222	
10/12/87	small	2058	506	9	2387	Z = -0.44
through	large	1930	601	9	1852	P = 0.66
10/23/87	combined	1994	381	18	2104	
12/3/87	small	495	118	9	427	Z = -1.50
through	large	286	107	8	217	P = 0.13
12/8/87	combined	397	82	17	402	
1/26/88	small	57	48	9	0	Z = 1.39
through	large	288	144	9	73	P = 0.17
2/2/88	combined	173	79	18	15	
3/14/88	small	25	21	8	0	Z = 1.29
through	large	108	52	8	55	P = 0.20
3/15/88	combined	67	29	16	15	
4/8/88	small	17	12	8	0	Z = 1.68
through	large	84	33	8	67	P = 0.09
4/15/88	combined	50	19	16	0	
5/3/88	small					
through	large					
5/13/88	combined					
6/3/88	small	1151	532	3	1682	Z = 0.87
through	large	1721	473	3	2154	P = 0.38
6/15/88	combined	1435	343	6	1683	
7/26/88	small	59		1	59	
through	large					
7/27/88[c]	combined	59		1	59	

[a] Small (550 - 699 mm FL)
[b] Large (>699 mm FL)
[c] No northern pike in this group were located after 7/27/88.

Appendix C5. Mean velocity and median velocity between tracking periods of all radio-tagged small[a] and large[b] northern pike.

Tracking Period	Size Category	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
9/23/87	small	1285	633	9	184	Z = -1.00
through	large	594	228	21	138	P = 0.32
9/30/87	combined	802	248	30	178	
10/12/87	small	1800	443	38	730	Z = -1.83
through	large	773	163	45	403	P = 0.07
10/23/87	combined	1243	227	83	497	
12/3/87	small	283	46	38	207	Z = -2.58
through	large	149	30	44	56	P = 0.01
12/8/87	combined	211	28	82	84	
1/26/88	small	96	24	37	63	Z = 0.39
through	large	130	33	45	62	P = 0.70
2/2/88	combined	115	21	82	64	
3/14/88	small	52	12	35	17	Z = 1.45
through	large	92	19	40	51	P = 0.15
3/15/88	combined	73	12	75	34	
4/8/88	small	111	18	35	89	Z = -0.78
through	large	80	29	11	45	P = 0.43
4/15/88	combined	104	15	46	84	
5/3/88	small	1621	269	18	1378	Z = -1.75
through	large	620	358	4	463	P = 0.08
5/13/88	combined	1439	241	22	1214	
6/3/88	small	522	194	11	127	Z = 1.27
through	large	897	344	7	430	P = 0.20
6/15/88	combined	668	178	18	356	
7/26/88	small	46	10	13	38	
through	large	20		1	20	
7/27/88	combined	44	9	14	36	
9/14/88	small	23	8	5	16	
	large					
	combined	23	8	5	16	

[a] Small (550 - 699 mm FL)
[b] Large (>699 mm FL)

Appendix C6. Mean velocity and median velocity throughout all tracking periods for overwintering groups of radio-tagged small[a] and large[b] northern pike.

Overwintering Location	Sex	Mean Velocity (m/day)	Standard Error	Number of Fish Located	Median Velocity (m/day)	Mann - Whitney Test
Chatanika River	small	590	107	131	149	Z = -1.82
	large	287	53	110	90	P = 0.07
	combined	452	64	241	115	
Goldstream Drainage	small	162	86	24	40	Z = 0.10
	large	148	41	52	30	P = 0.92
	combined	153	38	76	32	
Middle Tolovana River	small	589	388	35	91	Z = 0.37
	large	432	208	11	124	P = 0.71
	combined	551	298	46	101	
Lower Tolovana and Tanana	small	689	169	49	59	Z = 0.67
	large	643	167	45	146	P = 0.50
	combined	667	118	94	102	
Combined	small	567	89	239	96	Z = -1.28
	large	335	47	218	76	P = 0.20
	combined	456	52	457	89	

[a] Small (550 - 699 mm FL)
[b] Large (>699 mm FL)