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Site Fidelity, Dispersal, and Movements of Radio-Implanted Northern Pike in Minto Lakes, 1995 - 1997

by

Stafford M. Roach

February 1998

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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by

Stafford M. Roach
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Stafford M. Roach
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599,USA

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ABSTRACT

To improve stock assessment techniques, radiotelemetry was used to examine site fidelity, movements, and dispersal of Minto Lakes northern pike. Locations of 68 northern pike in Minto Lakes were examined from the spring of 1995 to the spring of 1997. Proportions of radio-implanted northern pike located within Minto Lakes area ranged from 0.33 (SE = 0.07) to 0.92 (SE = 0.03). Proportions that returned to Minto Lakes for spawning from one year to the next was 0.68 (SE = 0.07) from 1995 to 1996 and 0.79 (SE = 0.08) from 1996 to 1997. The proportion of radio-implanted northern pike that did not return to Minto Lakes for spawning in 1996, but returned in 1997 was 0.67 (SE = 0.13). In both years of the study there was movement into and out of Minto Lakes during the ice-free months except between June and July. The period between June and July was also the least active period during the ice-free months of the study. Maximum clumping of radio-implanted northern pike occurred shortly before overwintering movements. Proportions that overwintered in Minto Lakes were 0.36 (SE = 0.06) in 1995 - 1996 and 0.33 (SE = 0.07) in 1996 – 1997. In both years of the study, more than 50% of radio-implanted northern pike that moved out of Minto Lakes for overwintering moved out after December. Of the radio-implanted northern pike that moved back into Minto Lakes for spawning in 1996, peak movement occurred between April 24 and May 7. Males ≤ 585 mm FL, however, began moving into the area before April 24 and continued after May 7. All males and females > 585 mm FL moved into Minto Lakes for spawning between April 24 and May 7. Considering the assumption of a closed population, the results of this radio-tracking study support the conclusion that the Minto Lakes area is suitable for within year but not between year or between season mark-recapture experiments. Within-season estimates of abundance for the Minto Lakes area of Minto Flats may be less susceptible to bias from site infidelity than between season or between year estimates. Investigators may minimize bias due to movement into and out of the study area by conducting single-year mark-recapture experiments after the spawning period up until July. Furthermore, samples taken after spawning may reduce sex and length bias associated with spring movements of northern pike.

Key Words: northern pike, *Esox lucius*, Minto Flats, Minto Lakes, radiotelemetry, radio-tracking, seasonal movements, overwintering, dispersal, fidelity.

INTRODUCTION

Alaska Department of Fish and Game conducted mark-recapture experiments in Minto Flats from 1987 through 1991 (Burkholder 1989, 1990, 1991; Hansen and Burkholder 1992). Generally, sampling events concentrated on the channels and sloughs near the Minto Lakes area[1] of Minto Flats (hereafter referred to just as Minto Lakes) and investigators conducted these experiments during spring or fall movements. The designs of these between-season and between-year mark-recapture experiments were contingent upon either, 1) marked fish being distributed throughout Minto Flats during the recapture; or, 2) the fidelity of northern pike to Minto Lakes from one season or one year to the next. In the first case the estimate would be germane to Minto Flats and in the second to Minto Lakes only. These studies, however, were abandoned after 1991 because investigators suspected that neither assumption was valid for between-year or between-season experiments.

Little is known about the fidelity of northern pike to Minto Lakes from one season or one year to the next. Hallberg (1984) and Burkholder and Bernard (1994) used radiotelemetry to describe fall and winter distributions of Minto Flats northern pike, however premature failure of radio tags kept them from examining fidelity to Minto Lakes. Even though Frost and Kipling (1967) suggested that Windermere Lake northern pike repeatedly returned to the same area for spawning, preliminary analysis of Minto Flats tagging data indicated that some but not all

[1] In some reports this area is part of what is referred to as Minto Flats Area I.

northern pike returned to Minto Lakes for spawning between years. Similarly, Franklin and Smith (1963) observed that northern pike in Minnesota did not demonstrate fidelity to spawning areas.

In addition to site fidelity, there are questions regarding biased sex and length composition in spring and fall northern pike samples from Minto Lakes. Investigators have reported biased sex and length composition in other systems when samples were taken in spring or fall. Casselman (1975) reported that male and female northern pike exhibited biannual peaks of availability to the gear, resulting in inherent sampling error. Males were relatively more abundant in spring and fall. He suggested that composition bias was related to differential timing of movements to spawning and overwintering areas by sex and not necessarily related to locality or method of capture. Neumann and Willis (1995) reported that males moved into and out of spawning areas faster than females and entered spawning areas first. They found that a higher percentage of males were captured during the spawning period, which indicated greater activity of males during this time. These studies suggest that northern pike are more likely to have the same probability of capture by length and sex after spawning and before fall movements.

Before 1996, abundances and compositions of Minto Flats northern pike were estimated from samples taken when large numbers of fish could be captured during spring and fall movements. Pierce (1997), however, suggested that abundance and length composition estimates might not be valid if derived by focusing on a particular fish behavior to enhance sample size. He demonstrated that failure to meet assumptions of equal-catchability resulted in large differences in population estimates. By keying on fish behavior for samples, some fish potentially have a greater capture probability than others, which causes population estimates to be biased low.

RESEARCH OBJECTIVES

This study examined locations of Minto Lakes northern pike from the spring of 1995 to the spring of 1997 using radio-telemetry techniques. The goal of this study was to determine the suitability of mark-recapture experiments for this area based upon the timing of movements and site fidelity. Objectives relating to between year spawning-site fidelity, northern pike movements within and out of Minto Lakes, and the timing of movements were investigated. Specific objectives[2] were to:

1) estimate the proportion of northern pike, which moved into Minto Lakes in early May 1995, that were found within Minto Lakes on May 16, May 24, and the middles of June, July, August, September, October, and December 1995;

2) estimate the proportion of northern pike, which moved into Minto Lakes in early May 1995, that were found within Minto Lakes by April 8, April 24, May 7, and May 15, 1996; and,

3) estimate the proportion of northern pike that were found outside Minto Lakes during the April and May 1996 tracking events, but which were found within Minto Lakes during the middle of May 1997.

[2] Some tracking dates are different than specified in the original plan due to logistic considerations.

In addition to these objectives, the dispersal, wintering locations, and distances moved of Minto Lakes northern pike were described to help improve population assessment work. Knowing the behavior of Minto Lakes northern pike is critical to the design of future mark-recapture experiments.

DESCRIPTION OF STUDY AREA

Minto Flats is located approximately 50 km west of Fairbanks, Alaska within the Tanana River drainage (Figure 1). 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 2). Except for the Tanana River, these rivers are slow flowing and meandering. The Tanana River is a large glacial river that delineates the southern boarder of the flats and is the primary water source for Swanneck and Grassy sloughs. The lakes of Minto Flats are generally shallow and contain large areas of dense aquatic vegetation. Summer habitat for northern pike in Minto Flats covers approximately 6,000 ha (Holmes and Pearse 1987). These investigators identified Minto Lakes as a primary northern pike spawning and summer feeding area within Minto Flats. In recent years, the majority of northern pike sport fishing in Minto Flats effort has occurred in Minto Lakes. In addition to northern pike, least cisco *Coregonus sardinella*, humpback whitefish *C. pidschian*, broad whitefish *C. nasus*, sheefish *Stenodus leucichthys*, Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, longnose suckers *Catostomus catostomus*, blackfish *Dallia pectoralis*, slimy sculpin *Cottus cognatus*, and lake chub *Couesinus plumbeus* are found in Minto Flats. Chinook salmon *Oncorhynchus tshawytscha* and chum salmon *O. keta* pass through parts of Minto Flats during migrations to and from spawning areas in the upper Chatanika River.

METHODS

Alaska Department of Fish and Game personnel captured northern pike during late April and early May 1995 near the "Caches"[3] (Figure 2), as they moved up Goldstream Creek from over-wintering areas to spawning areas associated with Minto Lakes. Radio transmitters were surgically implanted into 68 of these fish, which were selected by sex and length over an eight-day period (Table 1). Radiotelemetry was used to locate, track movements, and determine dispersal of radio-tagged northern pike to help determine if northern pike migrating into Minto Lakes in the spring are suitable for obtaining an unbiased population estimate using mark-recapture techniques.

[3] The "Caches" are a common landmark near the entrance to Minto Lakes, which northern pike pass when moving in or out of Minto Lakes.

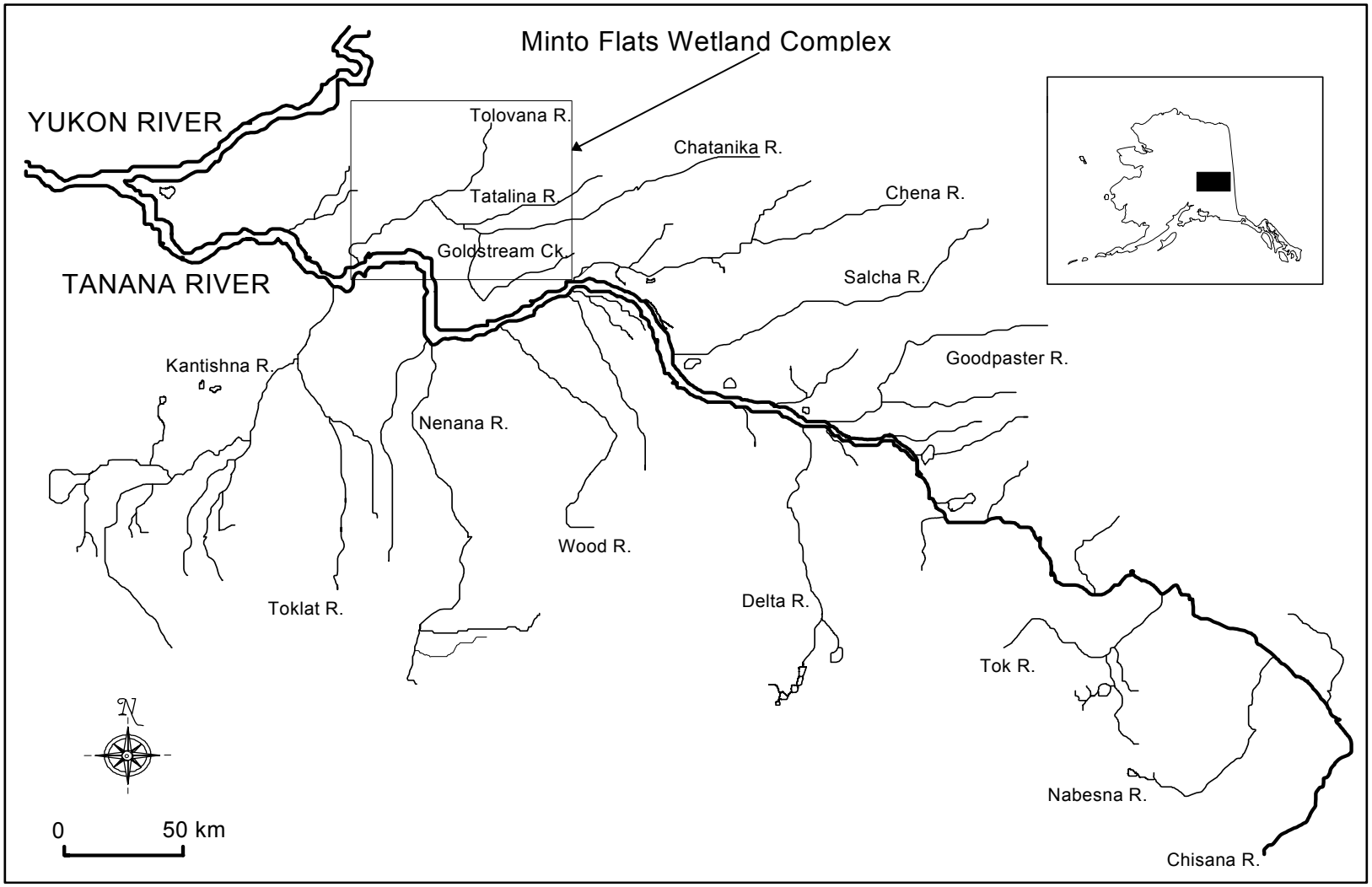

Figure 1.–Tanana River drainage.

4

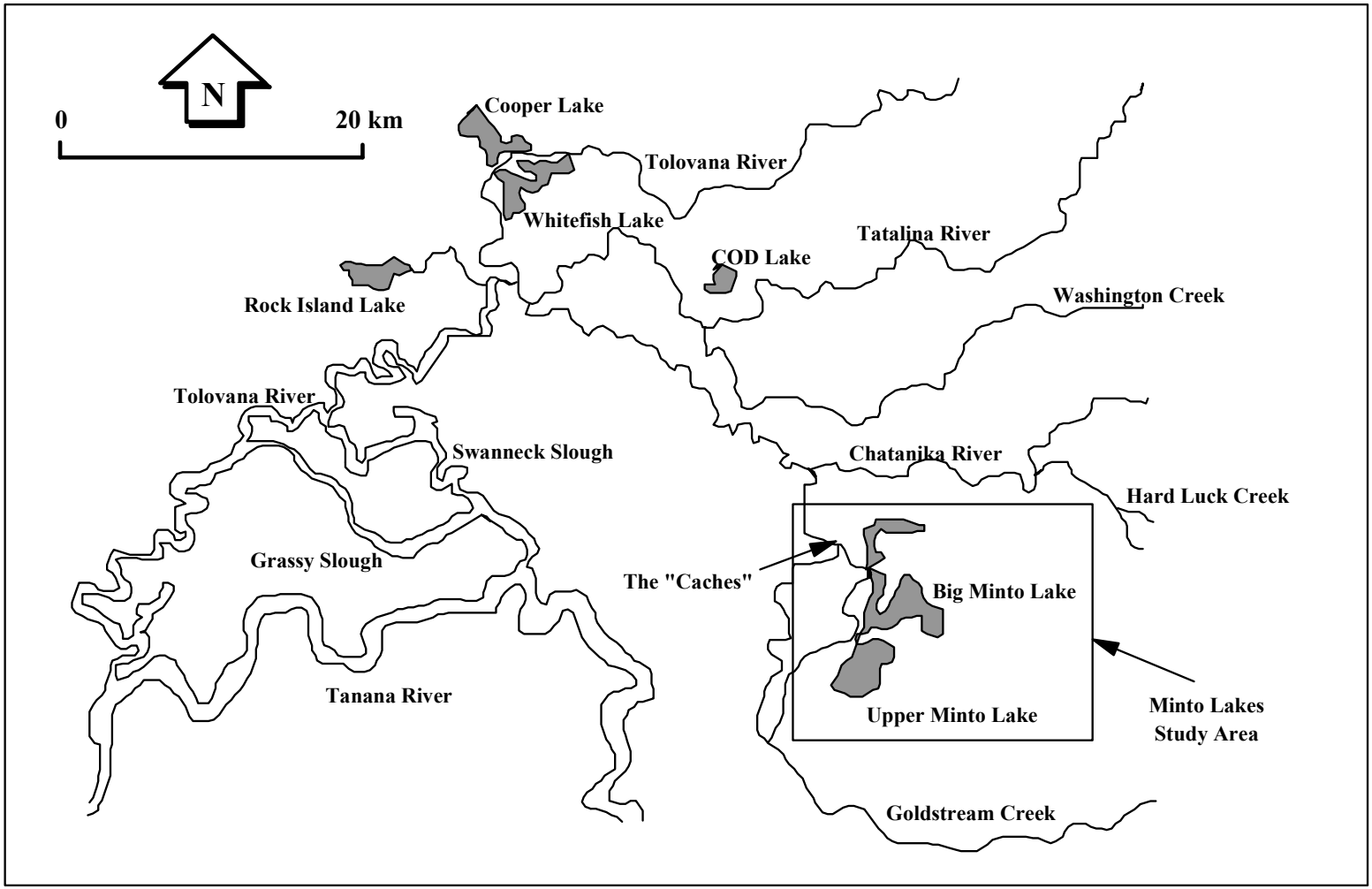

Figure 2.–Minto Flats wetland complex.

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Table 1.–Numbers of northern pike implanted with radio tags by length category, sex, and date.

Length (FL mm)	Sex	Numbers of Northern Pike: Month and Day (1995) 4/27	4/28	4/29	4/30	5/1	5/2	5/3	5/4	Total
400 - 449	M	1	1	1	0	0	1	0	0	4
	F	0	0	0	0	0	0	0	0	0
450 - 499	M	1	2	1	1	0	3	0	0	8
	F	0	2	0	1	1	0	0	0	4
500 - 599	M	1	3	2	1	1	2	4	0	14
	F	1	2	2	2	0	3	0	0	10
600 - 699	M	0	0	0	1	2	2	2	4	11
	F	2	0	0	1	5	2	0	3	13
≥ 700	M	0	0	0	0	0	0	0	1	1
	F	0	0	1	0	1	0	1	0	3
Total	M	3	6	4	3	3	8	6	5	38
	F	3	4	3	4	7	5	1	3	30

DESCRIPTION OF RADIO TRANSMITTERS

The radio transmitters (model CHP-4P) used in this study were manufactured by Telonics Incorporated[4]. Each radio transmitter was formatted with a unique frequency between 148.000 and 148.990 MHz. The expected life of each transmitter was 24 months at 35 beeps per minute. The length of each was 4.8 cm, diameter 1.5 cm, and air weight less than 25 g. Each was hermetically sealed with a wax-dip coating. Telonics Incorporated fitted each radio transmitter with a TA-5LT (0.10 cm diameter; 45 cm length) flexible whip antenna.

PROCEDURES FOR IMPLANTING RADIO TRANSMITTERS

Radio transmitters were surgically implanted in 38 mature male and 30 mature female northern pike captured by hoop traps and gill nets. Sex was determined by the presence of milt or eggs. Radio transmitters were placed in the coelomic cavity through a 2 to 3 cm incision along the linea alba, anterior to the pelvic girdle following procedures outlined by Hart and Summerfelt 1975. Suture material was 3-0 PDS*II violet monofilament (polydioxanone) with an attached CP-1 cutting needle. Three to five sutures were used to close the incision, topical antibacterial powder Furacin® manufactured by Norden Laboratories[5] was applied to the incision, and tissue

[4] Telonics Incorporated, Mesa, AZ.

[5] Norden Laboratories, Incorporated, Lincoln, NE.

adhesive Vetbond™ manufactured by 3M[6] was applied over the sutures. The outlet incision for the trailing antenna was posterior to the pelvic girdle similar to the method described by Ross (1982). During the surgical procedure, fresh water was periodically poured over the gills of each northern pike. Radio-tagged northern pike were released after a short recovery period and after regaining equilibrium.

PROCEDURES FOR LOCATING RADIO-IMPLANTED NORTHERN PIKE

A Telonics TR-2 with an attached TS-1 scanner-programmer or Lotek[7] SRX_400 telemetry receiver was used to locate radio signals from radio-tagged northern pike. Signals were received with a directional 5-element Yagi antenna mounted on the wing strut of a Cessna 185 aircraft with a 9-dBd gain. For each locating event, up to ten hours flying time was used to locate radio-tagged northern pike. Simple triangulation was used to determine latitude and longitude of each radio signal. Once the receiver picked up a signal the pilot determined direction by strength of the signal. The pilot then flew a transect in the direction of strongest signal until there was a reduction in signal strength, circled back on a second transect that was approximately a right angle to the first, again adjusting direction by strength of the signal until the second transect crossed the first. When uncertain or for weak signals, this process was repeated until the location was narrowed down to an area approximately a quarter of a square kilometer. Latitude and longitude determined by a Trimble Navigation[8] Global Positioning System (GPS) TNL2000A, was recorded for the location of each radio signal. The locations of each radio-tagged fish were plotted on maps of the Minto Flats area derived from a USGS 1:63,360 map overlaid with a grid of latitude and longitude. Water levels fluctuated throughout the study period; therefore, some fish shown on maps were outside the main water bodies as depicted by the maps.

Mortality of radio-implanted fish was determined by recovery of radio tag or lack of movement over four consecutive tracking events. Evenson (1993) determined that actual river locations of radio-implanted burbot were within 0.5 km of locations determined from the air using the same aircraft and signal-receiving configuration used in this study. Given this accuracy, the estimated location of a dead fish may change up to 1 km from one tracking event to the next without actually moving. For this study, radio-implanted northern pike were determined dead when estimated movements were less than 1 km for four consecutive tracking events with no subsequent movement. Even though arbitrary, fish that did not move for less than four consecutive tracking events were considered alive based on the sedentary nature of northern pike. Diana (1979) reported that northern pike in Lac Ste. Anne, Alberta were inactive over 80% of the time and movements were sporadic. A northern pike determined dead at the end of this study was removed from the analysis beginning with the first tracking event in which no movement was determined.

DATA ANALYSIS

The proportion of radio-implanted northern pike located within Minto Lakes of Minto Flats during each tracking event was considered an estimate of the proportion of northern pike that

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[6] 3M Animal Care Products, St. Paul, MN.

[7] Lotek Engineering Incorporated, Newmarket, Ontario, Canada.

[8] Trimble Navigation, Seattle, WA.

were within Minto Lakes at the time of tracking. Proportions and standard errors were estimated as:

$$\hat{p} = \frac{x}{n}, \text{ and} \tag{1}$$

$$SE[\hat{p}] = \sqrt{\frac{\hat{p}(1-\hat{p})}{n-1}} \tag{2}$$

where: $\hat{p}$ = the proportion of northern pike that were located in Minto Lakes;

x = the number of northern pike located in the Big Minto Lake area; and,

n = the total number of northern pike located.

Green's index (Ludwig and Reynolds 1988) was used to describe the dispersal of radio-implanted northern pike found within Minto Lakes during each tracking event. The adjusted variance-to-mean ratio was examined for the number of radio-implanted northern pike located in each square unit of a 12 x 6 grid overlain on Minto Lakes for each tracking event. Values of 0 indicate random dispersal and values of 1 indicate maximum clumping (i.e., all individuals found in a single square unit). Green's index was computed as:

$$GI = \frac{\left(s^2 / \bar{x}\right) - 1}{n-1} \tag{3}$$

where: $\bar{x}$ = the mean number of radio-implanted northern pike found within a square of the grid;

s^2 = the variance; and,

n = the number of radio-implanted northern pike located within the grid.

In addition, straight-line distances between consecutive locations were used to describe movement of radio-implanted northern pike. Straight-line distances each fish moved between two consecutive locations were calculated as:

$$SLD = \sqrt{\left(\left(lat_i - lat_{i-1}\right) * 112\text{ km}\right)^2 + \left(\left(long_i - long_{i-1}\right) * 48\text{ km}\right)^2} \tag{4}$$

where: lat_i = the latitude of the i^{th} location in degrees;

$long_i$ = the longitude of the i^{th} location in degrees;

112 km $\approx$ the distance of one degree of latitude; and,

48 km $\approx$ the distance of one degree of longitude near the 65th parallel.

RESULTS

Radio tags were surgically implanted in 38 male and 30 female northern pike during late April and early May 1995. Radio tags were implanted in northern pike over eight days and distributed across length categories (Table 1). Fork lengths of radio-implanted northern pike ranged from 413 to 829 mm FL, males from 413 to 804 mm FL, and females from 456 to 829 mm FL. All radio-implanted northern pike were released in good condition and moved to spawning locations after surgery. Locations for radio-implanted northern pike were recorded on 19 different occasions between May 1995 and May 1996 (Appendix A). All 68 radio-implanted northern pike remained alive through the middle of June 1995 and 47 remained alive throughout the duration of the study (Table 2). Anglers reported harvesting five radio-implanted northern pike between two months and 16 months after surgery and described these fish as healthy and captured along with other northern pike. The remaining 15 radio-implanted northern pike were removed from the study as determined dead because of lack of movement.

Table 2.–Numbers of radio-implanted northern pike alive and numbers located by date of tracking, sex, and length category.

Date (m/d/yr)	Numbers of Radio-Implanted Northern Pike Alive and (Located)				
	Total	Males		Females	
		400-585 mm	586-850 mm	400-585 mm	586-850 mm
5/16/95	68 (66)	24 (24)	14 (12)	13 (13)	17 (17)
5/24/95	66 (63)	23 (23)	14 (11)	13 (13)	16 (16)
6/14/95	66 (64)	23 (22)	14 (14)	13 (13)	16 (15)
7/10/95	62 (60)	23 (22)	13 (13)	12 (12)	14 (13)
8/16/95	60 (58)	22 (21)	12 (12)	12 (12)	14 (13)
9/13/95	59 (53)	22 (20)	12 (12)	12 (11)	13 (10)
10/24/95	59 (52)	22 (20)	12 (12)	12 (11)	13 (09)
12/12/95	59 (51)	22 (19)	12 (11)	12 (14)	14 (09)
3/7/96	59 (56)	22 (21)	12 (11)	12 (14)	13 (12)
4/8/96	54 (49)	20 (20)	10 (8)	12 (14)	12 (09)
4/24/96	53 (44)	20 (16)	10 (8)	11 (13)	12 (09)
5/7/96	51 (47)	20 (17)	9 (9)	11 (10)	11 (11)
5/15/96	50 (44)	20 (20)	9 (7)	11 (9)	10 (08)
6/10/96	48 (37)	19 (16)	8 (4)	11 (10)	10 (07)
7/1/96	48 (42)	19 (17)	8 (6)	11 (11)	10 (08)
8/26/96	47 (43)	18 (17)	8 (6)	11 (11)	10 (09)
12/9/96	47 (36)	18 (13)	8 (7)	11 (9)	10 (07)
3/4/97	47 (43)	18 (17)	8 (7)	11 (11)	10 (08)
5/12/97	47 (42)	18 (18)	8 (8)	11 (8)	10 (08)

FIDELITY TO MINTO LAKES

Over the two-year study, proportions of radio-implanted northern pike located within Minto Lakes ranged from 0.33 (SE = 0.07) to 0.92 (SE = 0.03). The proportions located in Minto Lakes remained relatively constant from the middle of June through the middle of August in both 1995 and 1996. Proportions overwintering in Minto Lakes were 0.36 (SE = 0.06) in 1995 - 1996 and 0.33 (SE = 0.07) in 1996 - 1997 (Figure 3). There was no significant difference between proportions of males and females that remained in Minto Lakes during each winter ($Z = 1.17$; P = 0.24 and $Z = 0.73$; P = 0.46).

After spawning in 1995, 15 of 68 radio-implanted northern pike left Minto Lakes before the end of October. Eleven left before the middle of June (three of these also returned before the middle of June) and four after the middle of July (two of which returned before the end of October), but none left the area between the middle of June and the middle of July (Figure 4). After spawning in 1996, three of 30 left between the first of July and the end of August, but none earlier (Figure 4).

Proportions of radio-implanted northern pike that returned to Minto Lakes for spawning from one year to the next was 0.68 (SE = 0.07) from 1995 to 1996 and 0.79 (SE = 0.08) from 1996 to 1997 (Table 3). Proportions of radio-implanted northern pike returning to Minto Lakes for spawning after one year (1995 to 1996 and 1996 to 1997) was not significantly different between years ($Z = 1.23$; P = 0.22). There was no significant difference between proportions of males and females that returned to Minto Lakes for spawning after one year (1995 – 1996; $Z = 0.16$; P = 0.88; and 1996 - 1997 $Z = 1.31$; P = 0.19). The proportion of radio-implanted northern pike that did not return to Minto Lakes for spawning in 1996, but returned in 1997 was 0.67 (SE = 0.13).

DISPERSAL AND MOVEMENTS

Green's index indicated that the relative dispersal of radio-implanted northern pike within Minto Lakes varied from random to clumped. Maximum clumping occurred in October 1995 (GI = 0.052; $d = 8.40$), December 1995 (GI =0.042; $d = 4.48$), and December 1996 (GI = 0.067; $d = 4.33$). Dispersal was most random the first of July 1996 (GI = 0.004; $d = 0.57$; Figure 5). For radio-implanted northern pike, the least active one-month period during the ice-free months was between June and July in both 1995 (average distance moved = 2.52 km; SD = 2.04) and 1996 (average distance moved = 2.90 km; SD = 2.14; Figure 6).

In both years of the study, movements out of Minto Lakes for overwintering were not completed until after December (Figure 4). More than 50% of the radio-implanted northern pike that left Minto Lakes, left after December in both years (for the winter 1995 – 1996 males > 585 mm Fl did not follow this pattern; Figure 7). Of 33 radio-implanted northern pike that left Minto Lakes between September 1995 and March 1996, 55% left after December 1995 (Figure 7). Of 16 radio-implanted northern pike that left Minto Lakes between late August 1996 and March 1997, 75% left after December 1996 (Figure 8). The winter distribution of radio-implanted northern pike varied between years (Figures 9 – 12). Radio-implanted northern pike moved further up the Chatanika by March 1996 (Figure 10) than March 1997 (Figure 12).

Of radio-implanted northern pike that overwintered outside of Minto Lakes, movements back into Minto Lakes for spawning began after the first week in March 1996 and continued up to May 15. Peak movements to spawning areas occurred between April 24 and May 7 (Figure 13).

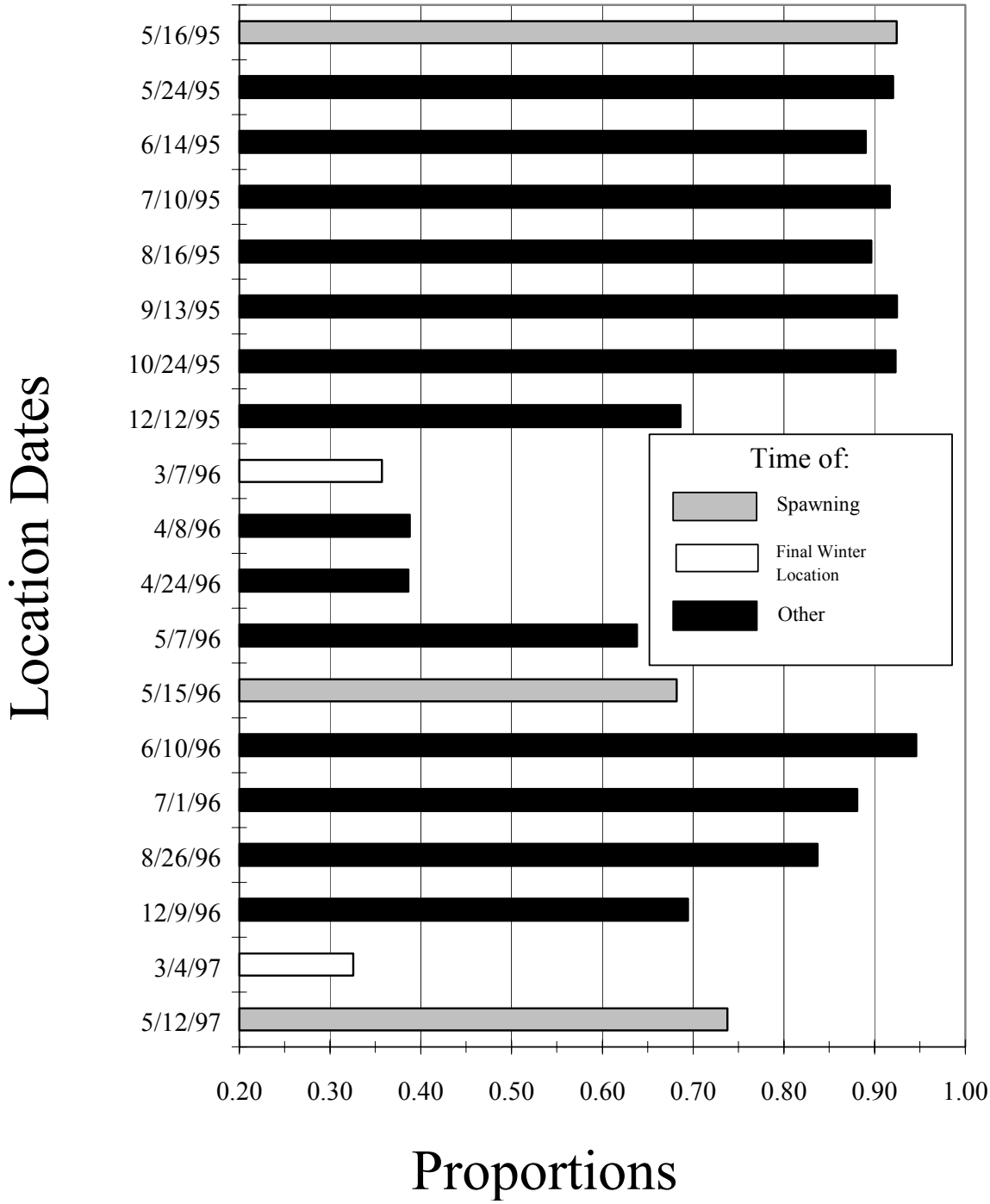

Figure 3.–Proportions of radio-implanted northern pike located within Minto Lakes at each tracking.

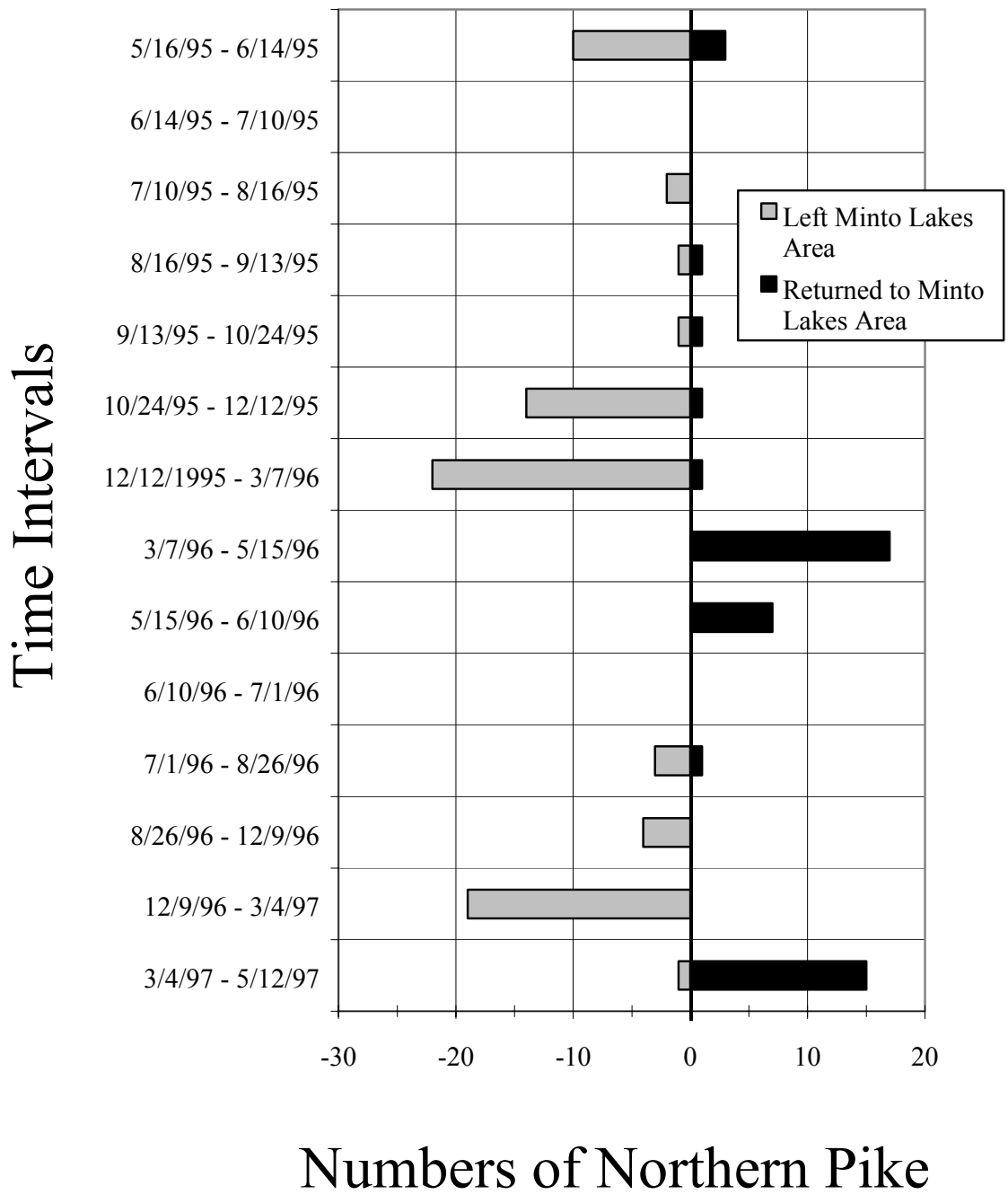

Figure 4.–Numbers of radio-implanted northern pike that left Minto Lakes and numbers that returned during the study period.

Table 3.–Proportions and standard errors of radio-implanted northern pike that returned to Minto Lakes for spawning by year.

Years Spawned in Minto Lakes	Proportions and (SE) that Returned			
	1996		1997	
1995	0.68	(0.07)	0.74	(0.07)
1996	-	-	0.79	(0.08)

Of the radio-implanted northern pike that moved back into Minto Lakes for spawning in 1996 from overwintering locations in the Chatanika River, males ≤ 585 mm FL moved in first with larger males and females following after April 24. Both male and female fish ≤ 585 mm FL moved into Minto Lakes for spawning after May 7 (Figure 14).

DISCUSSION

The behavior of radio-implanted northern pike was similar to northern pike not implanted with radio tags. All radio-implanted northern pike moved from the location of surgery to locations consistent with known spawning habitat. The five radio-implanted northern pike harvested by anglers were caught along with other northern pike and reported healthy with no sign of infection or fungus near the incision. Cook and Bergersen (1988) suggested that radio-implanted northern pike that responded to angling indicated normal behavior.

Radiotelemetry data from this study demonstrated that the northern pike population found in Minto Lakes changes throughout the year and that there is high but not complete fidelity to Minto Lakes spawning areas between years. Northern pike are more clumped shortly before movements to overwintering locations and during overwintering than other times of the year. Most movement into and out of Minto Lakes occurs in relation to spawning and overwintering but movement also occurs outside of these times. Northern pike enter spawning areas over several weeks and leave Minto Lakes summer areas over several months. This study suggests that the timing of movements into Minto Lakes for spawning differs by size of the fish. Large northern pike move in over a shorter period than small northern pike.

Considering the assumption of a closed population, the results of this radio-tracking study support the conclusion that Minto Lakes is suitable for within year but not between year or between season northern pike mark-recapture experiments. This study also supports the suspicions of Burkholder and Bernard (1994) that movement out of and into the study area may bias estimates of abundance for northern pike when mark-recapture experiments are conducted during spring and fall movements. Even though 0.68 to 0.79 of the northern pike that spawned in Minto Lakes in one year returned the next year to spawn, the spawning population changed each of the two years of the study. Furthermore, during the open-water period there was both movement into and movement out of the Minto Lakes. This lack of fidelity suggests that between season and between year estimates of abundance from sampling Minto Lakes would be biased high when applied to just Minto Lakes and biased low when applied to all of Minto Flats.

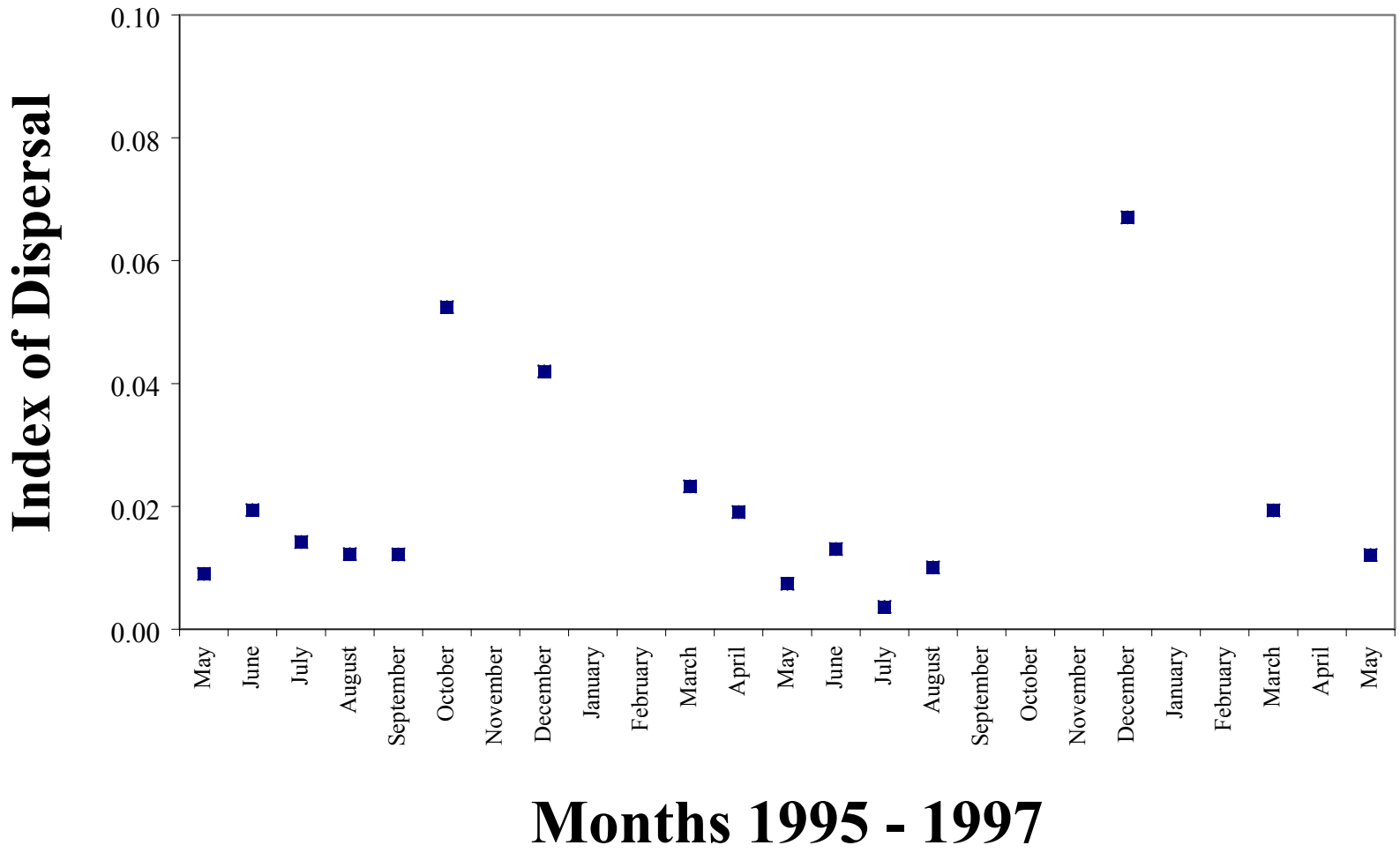

Figure 5.–Green's index of dispersal (0.00 for random; 1.00 for maximum clumping) for radio-implanted northern pike in Minto Lakes by month.

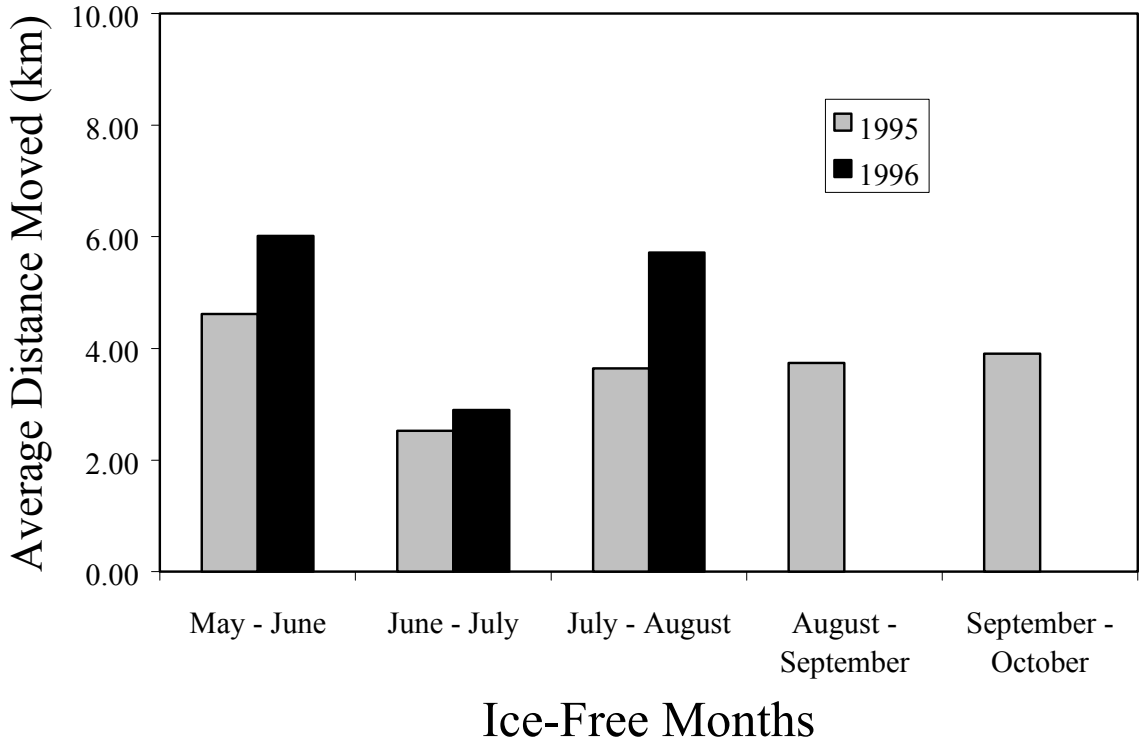

Figure 6.–Average straight-line distance that radio-implanted northern pike moved within Minto Lakes during one-month intervals during ice-free months in 1995 and 1996.

Within-season estimates of abundance for Minto Lakes may be less susceptible to bias from site infidelity than between season or between year estimates. In each of the two years of this study radio-movements of implanted northern pike indicated that the population remained relatively stable after spawning prior to July. Investigators may minimize bias due to movement into and out of the study area by conducting single-year mark-recapture experiments during this period. Furthermore, samples taken after spawning may reduce sex and length bias associated with spring movements of northern pike. Differential movement of radio-implanted northern pike into Minto Lakes for spawning by size and sex supports the conclusion of Casselman (1975) and Neumann and Willis (1995) that sampling during the time of spawning may result in biased estimates of length and sex composition.

Marking the incoming population near the "Caches" as fish move into Minto Lakes for spawning may be a suitable alternative if the recapture event occurs after spawning movements and before July in the same year. Since some fish overwinter in Minto Lakes, all fish would not be susceptible to marking using this approach. For success, in either situation investigators would have to ensure that marked and unmarked fish have similar probabilities of capture during at least one of the events. This study suggests that Minto Lakes northern pike are more likely to have the same probability of capture after spawning prior to July.

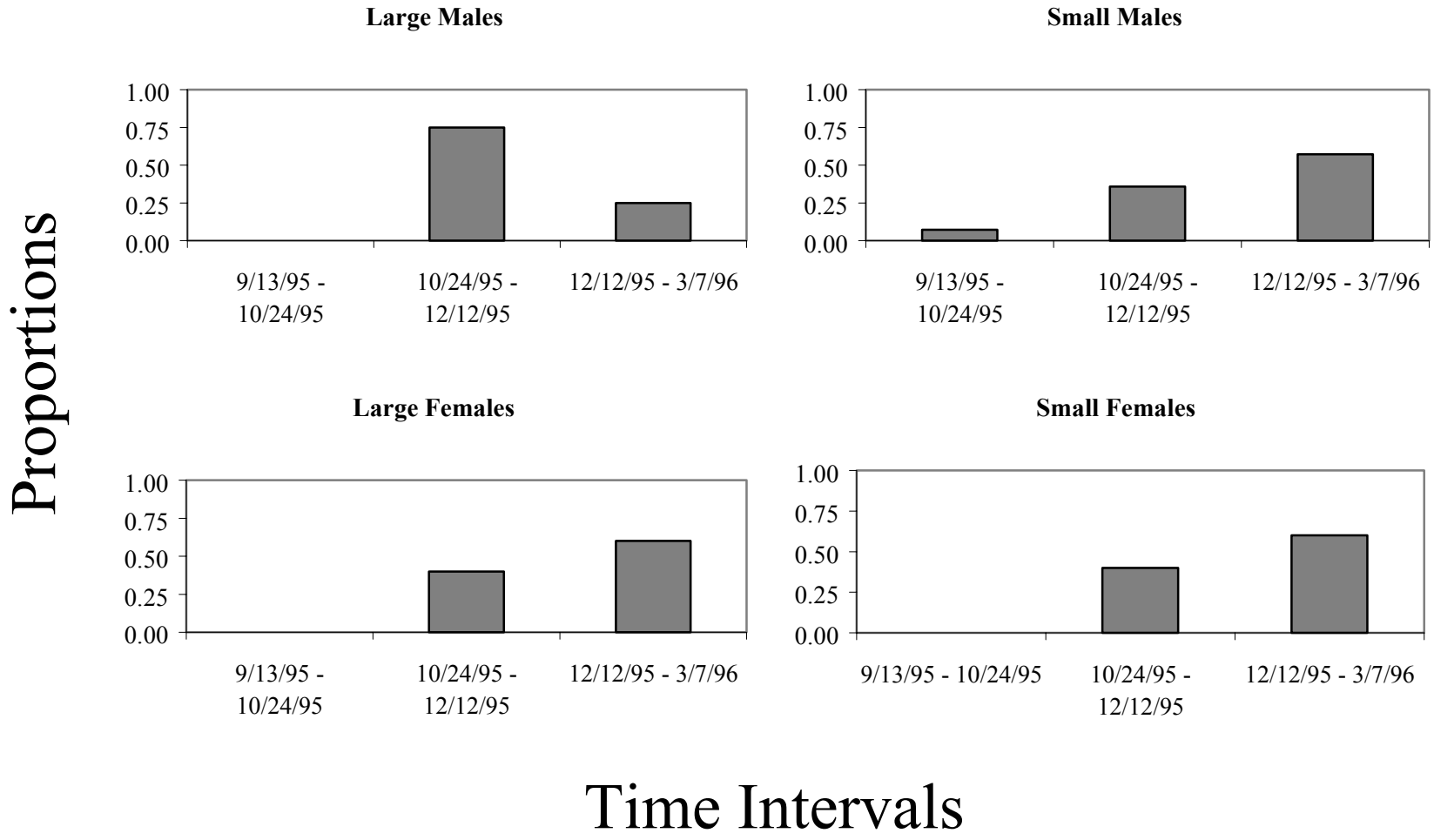

Figure 7.–Proportions of female and male radio-implanted northern pike that moved out of Minto Lakes for overwintering by time interval and size during the winter 1995 – 1996 (large > 585 mm FL; small ≤ 585 mm FL).

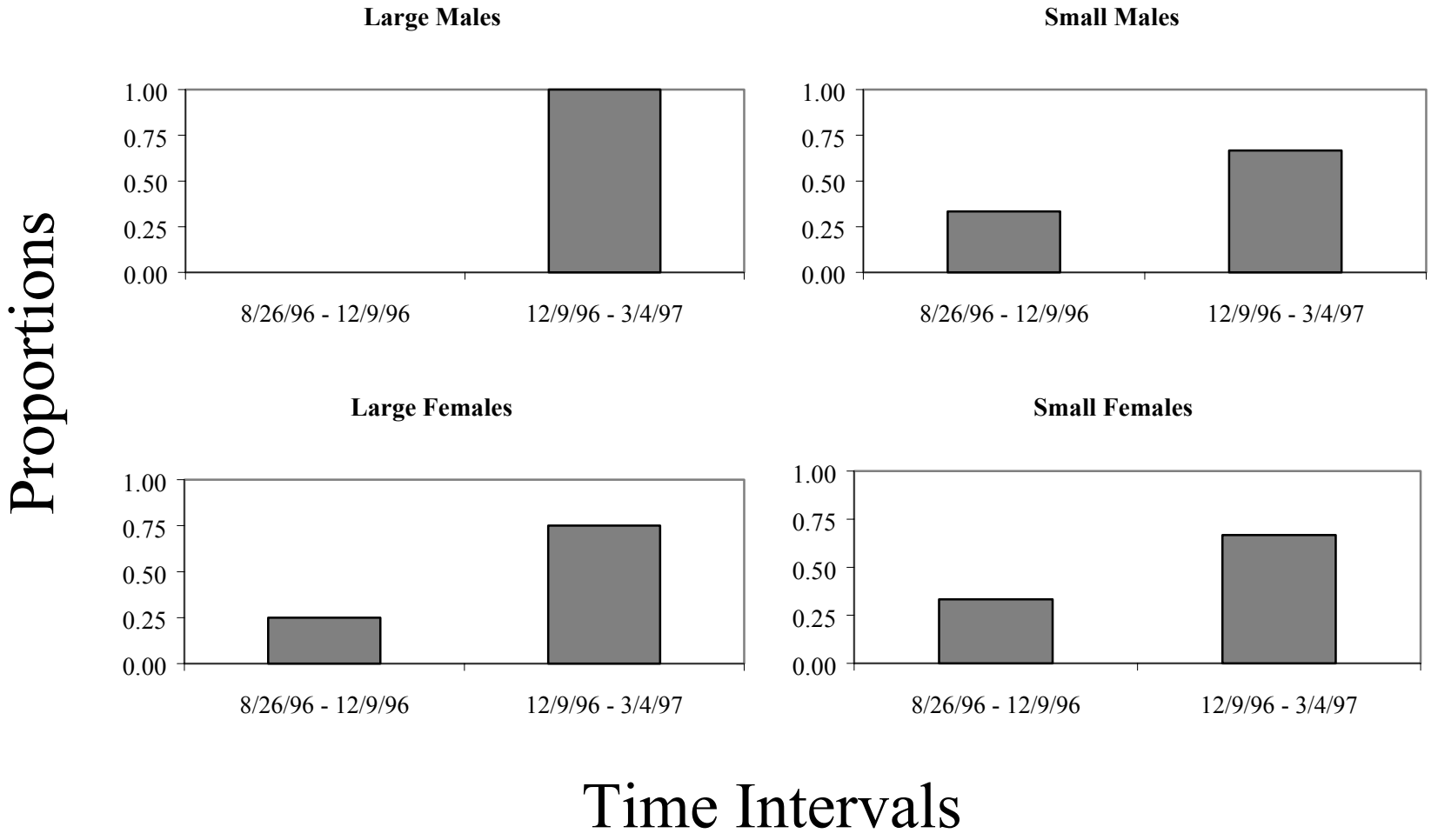

Figure 8.–Proportions of female and male radio-implanted northern pike that moved out of Minto Lakes for overwintering by time interval and size during the winter 1996 – 1997 (large > 585 mm FL; small ≤ 585 mm FL).

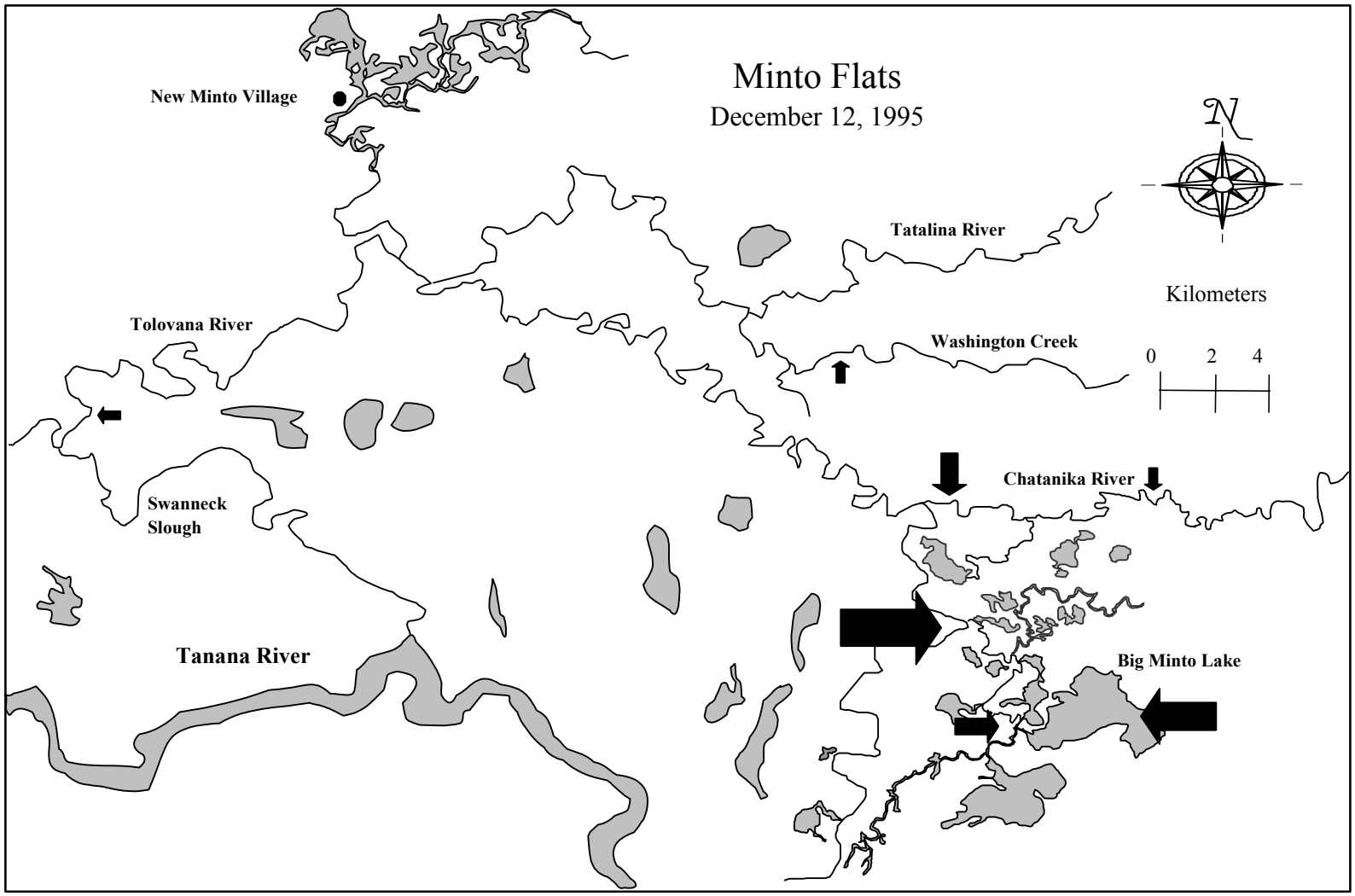

Figure 9.–Relative distribution of radio-implanted northern pike in Minto Flats on December 12, 1995 (indicated by the magnitude of the arrows).

18

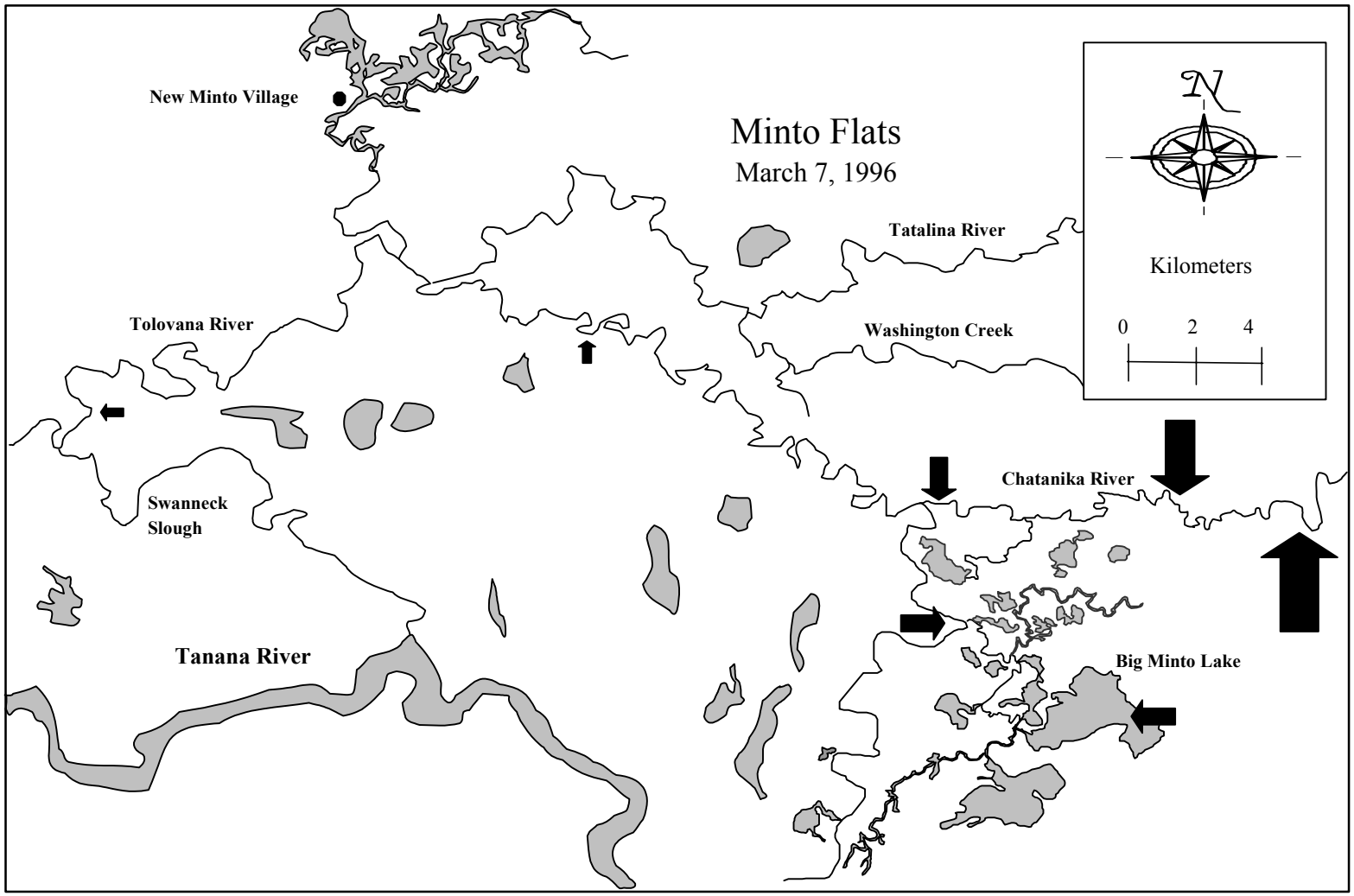

Figure 10.–Relative distribution of radio-implanted northern pike in Minto Flats on March 7, 1996 (indicated by the magnitude of the arrows).

19

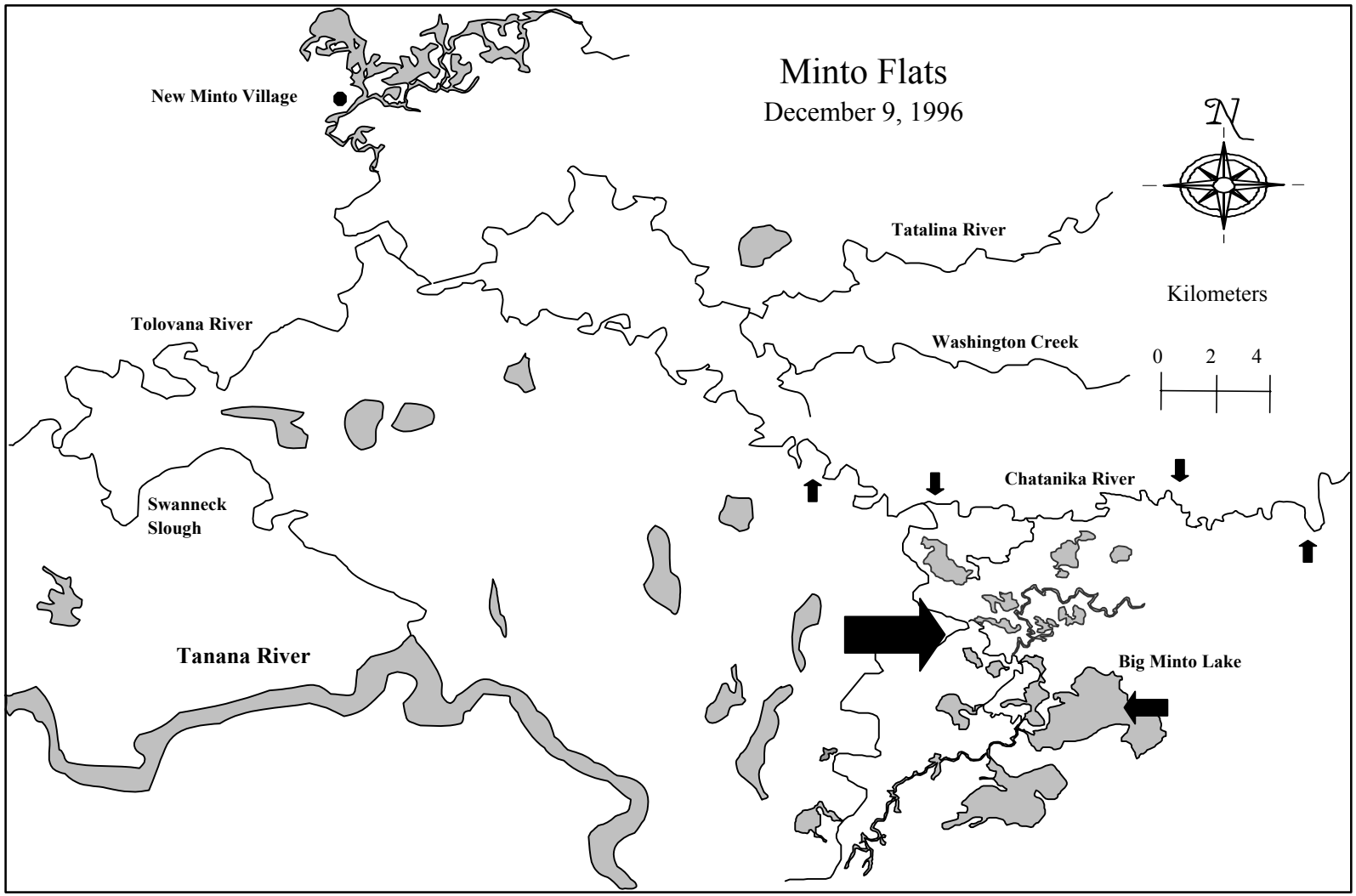

Figure 11.–Relative distribution of radio-implanted northern pike in Minto Flats on December 9, 1996 (indicated by the magnitude of the arrows).

20

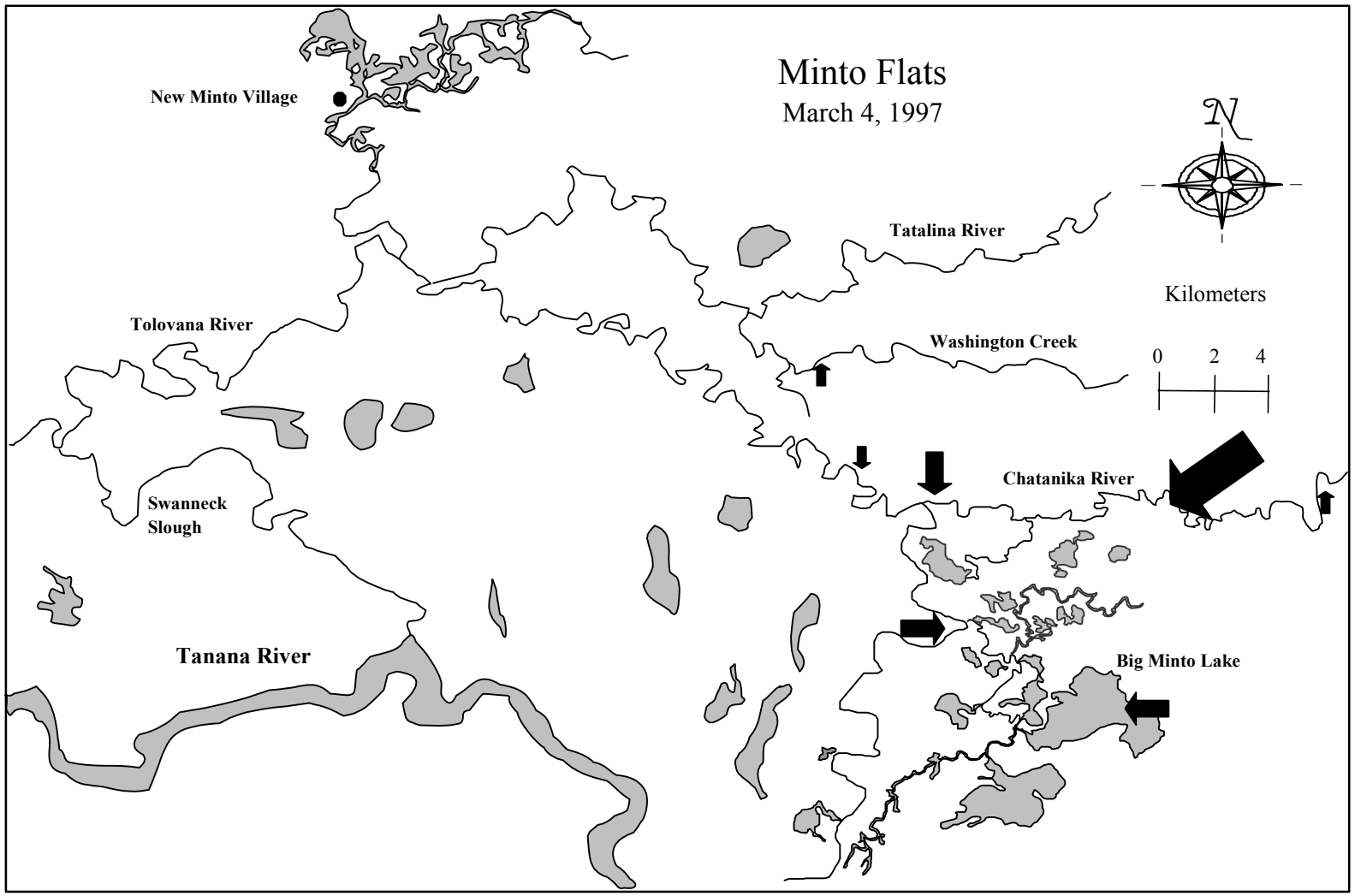

Figure 12.–Relative distribution of radio-implanted northern pike in Minto Flats on March 4, 1997 (indicated by the magnitude of the arrows).

21

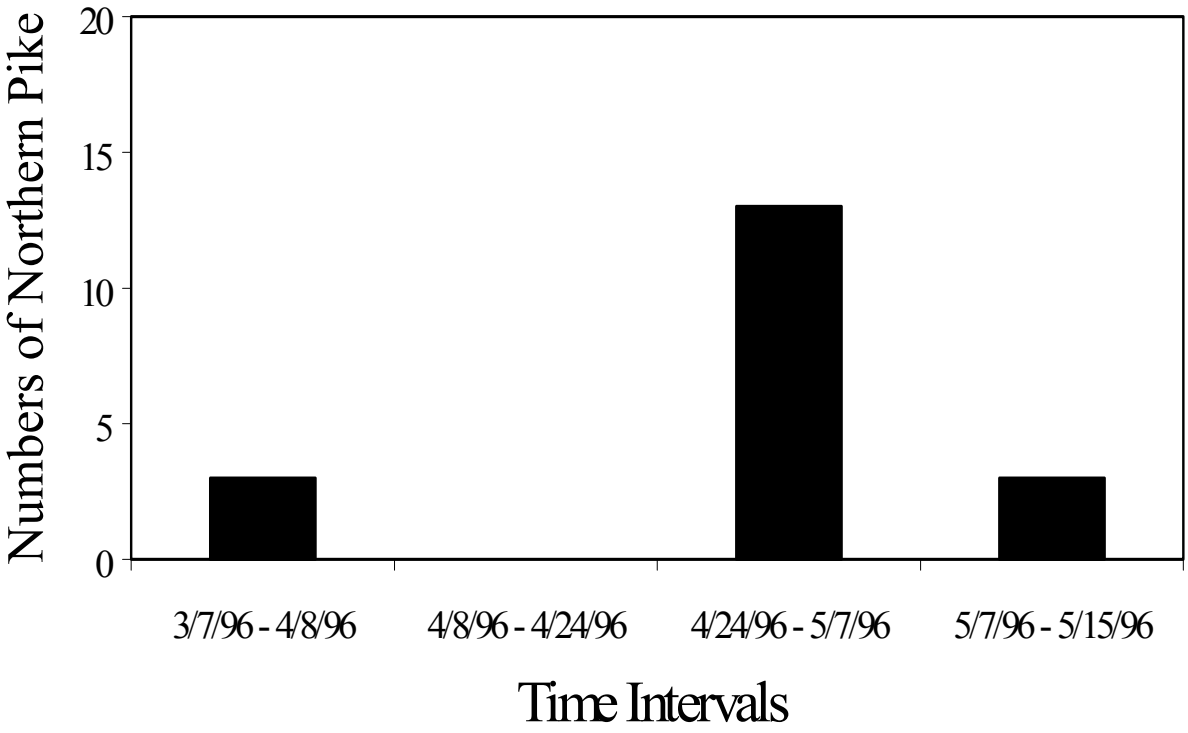

Figure 13.–Numbers of radio-implanted northern pike that moved from overwintering locations into Minto Lakes for spawning by time interval.

ACKNOWLEDGMENTS

The author appreciates and is thankful for information gained from the hard work of those who worked on Minto Flats northern pike projects preceding this work, specifically Jerry Hallberg, Fred DeCicco, Alan Burkholder, and Gary Pearse. Additional thanks is given to Gary Pearse for his piloting skills, advice on radio-tracking methods, and thoughts concerning the biology of northern pike. Thanks is also given to Fred Andersen and Peggy Merritt for supervisory support and encouragement and Mike Wallendorf for biometric review. In addition, I thank Matt Evensen for help with implanting the radio tags and Jim Fish, Doug Fleming, Tom Taube, and Mike Wallendorf for help with the tracking flights. The U. S. Fish and Wildlife Service provided partial funding for this study through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under project F-10-11, Job 3-4(c).

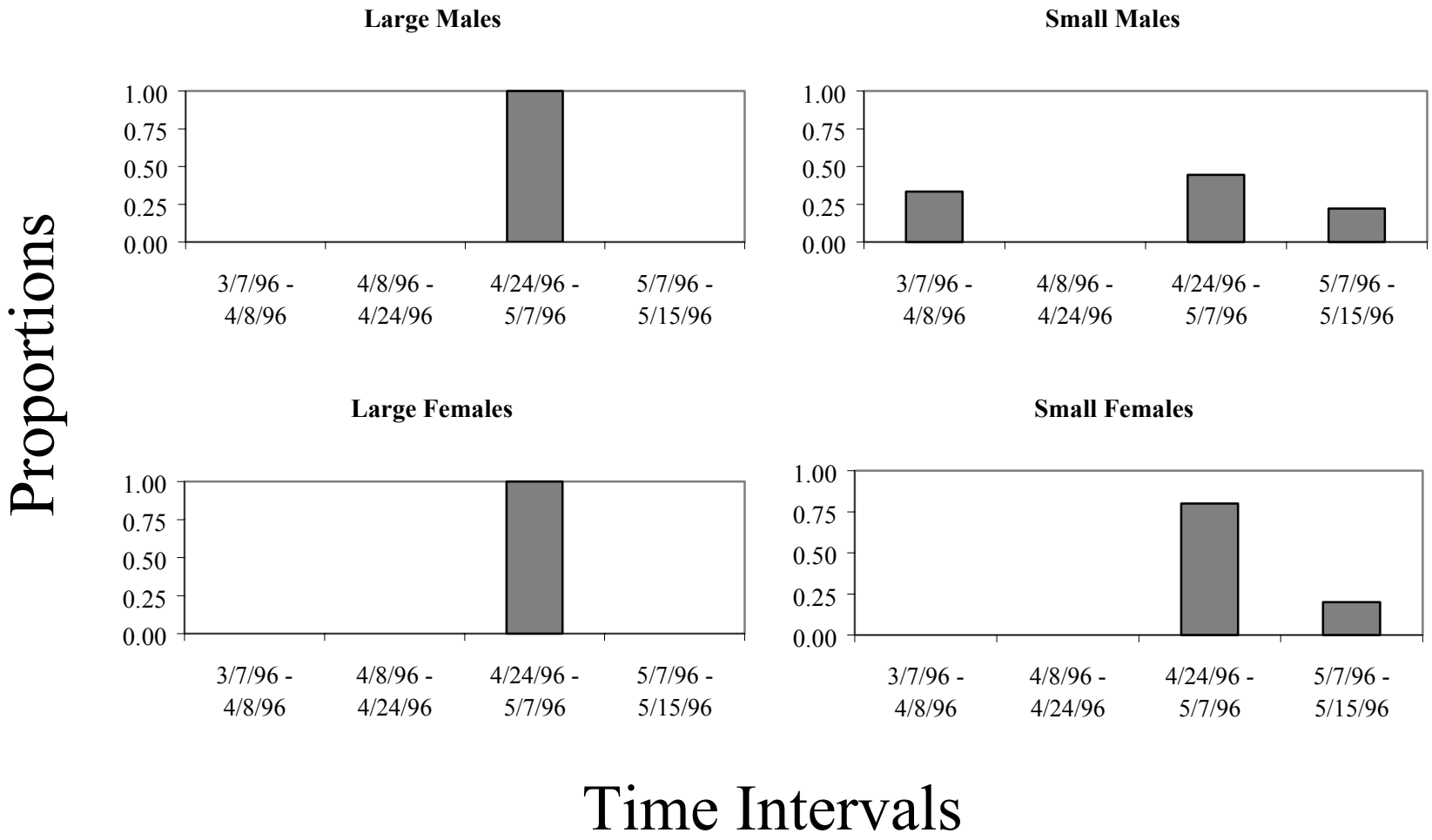

Figure 14.–Proportions of female and male radio-implanted northern pike that moved from overwintering locations into Minto Lakes for spawning by time interval and size (large > 585 mm FL; small ≤ 585 mm FL).

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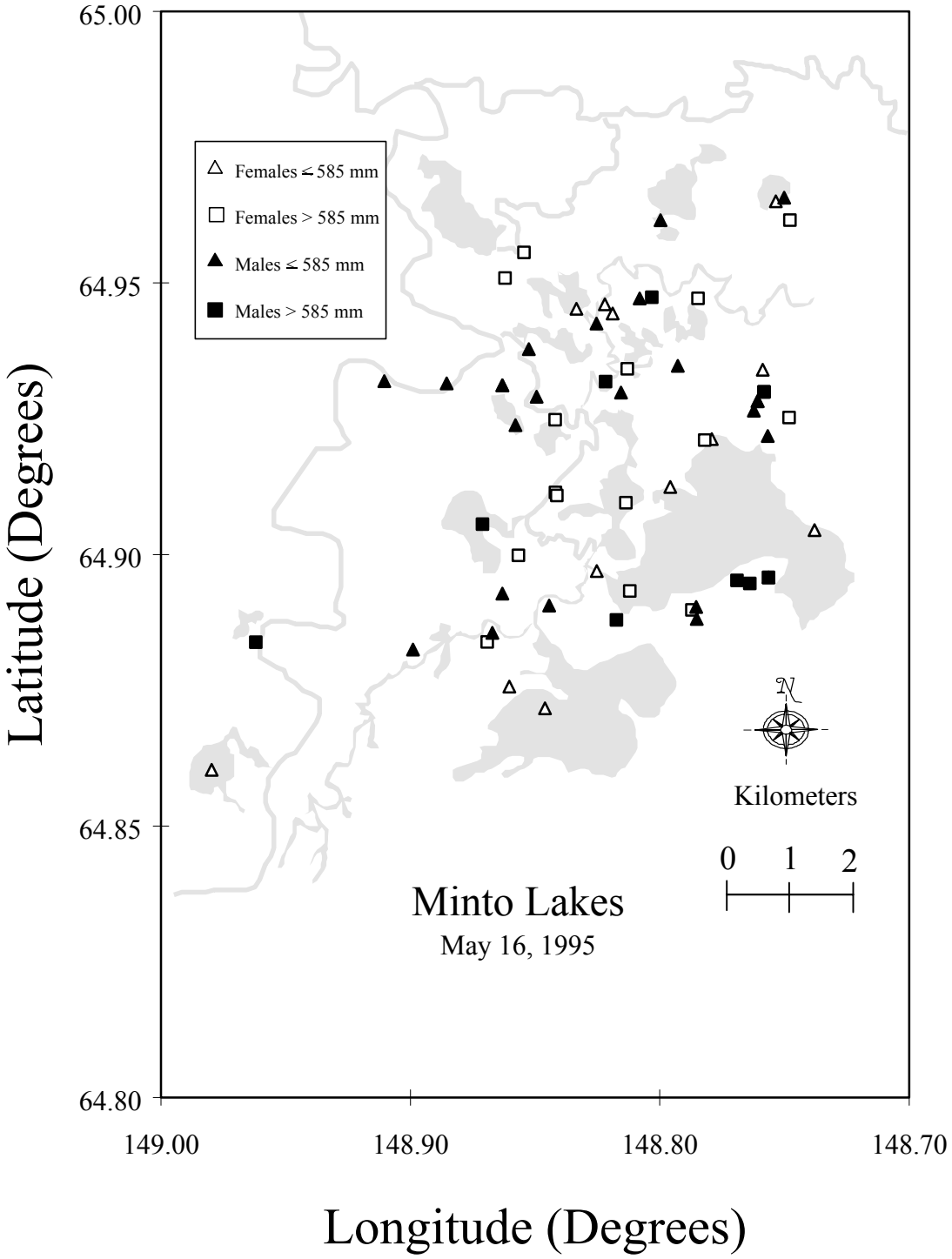
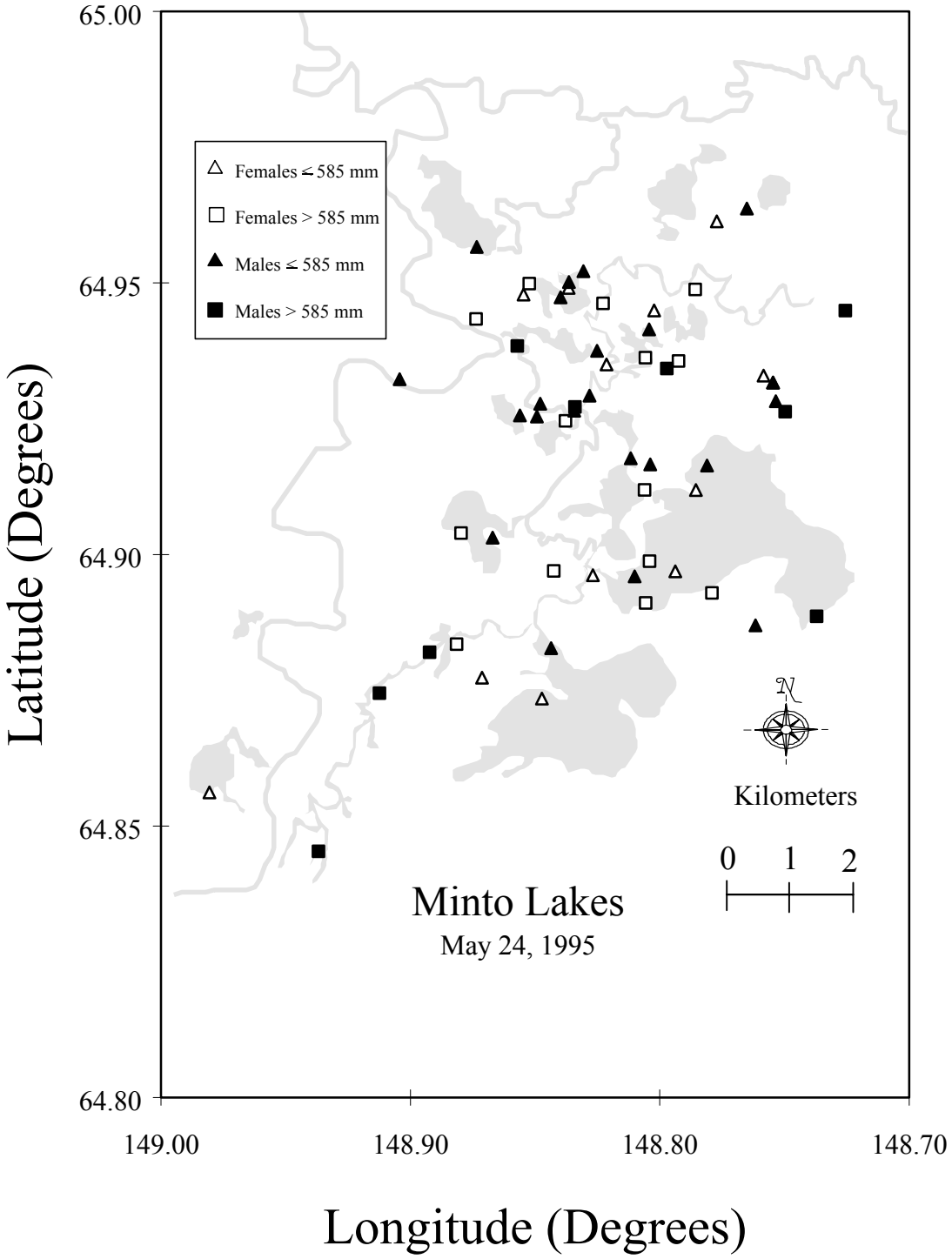
APPENDIX A

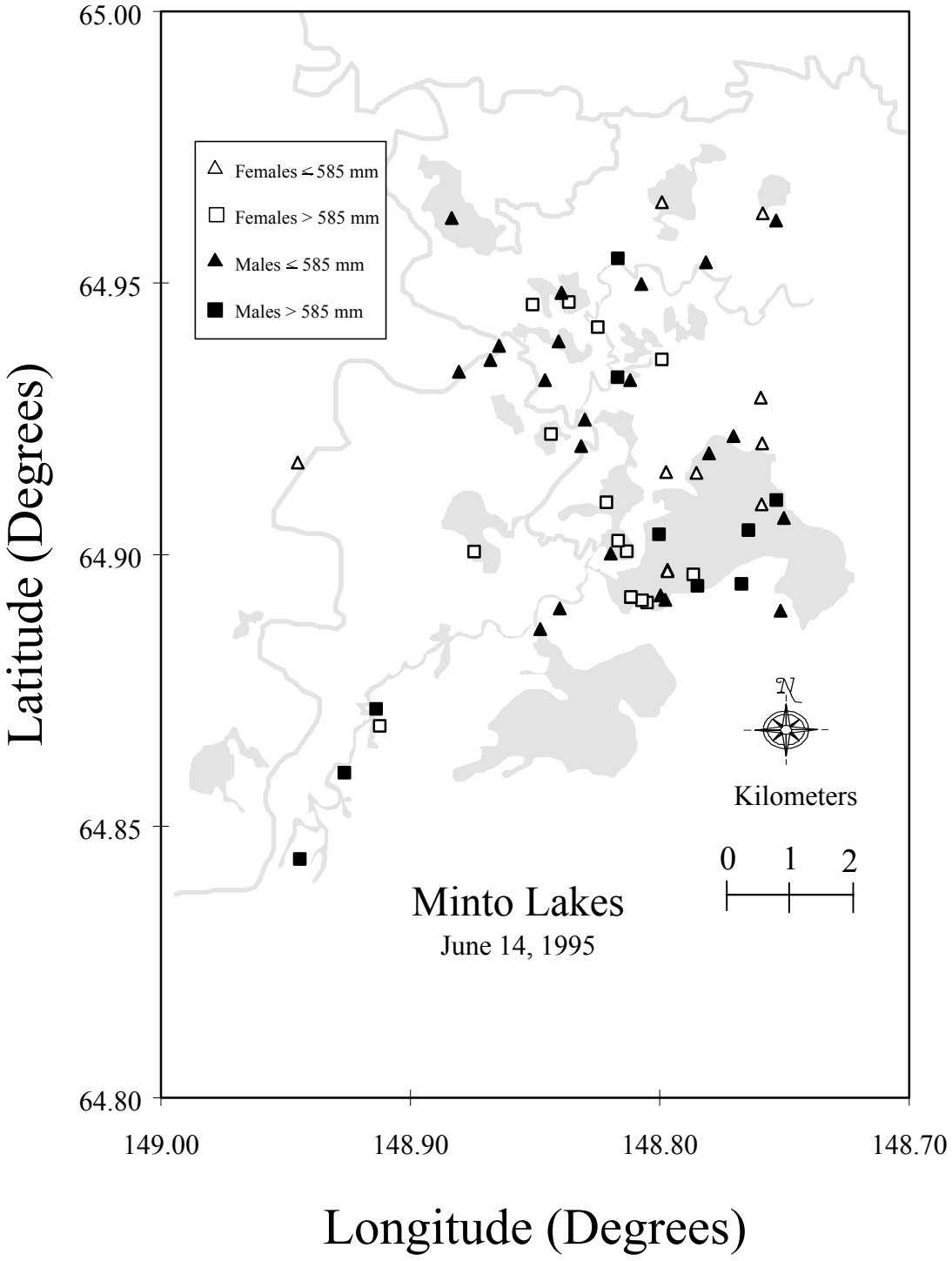
Minto Lakes Radio-Tracking Locations



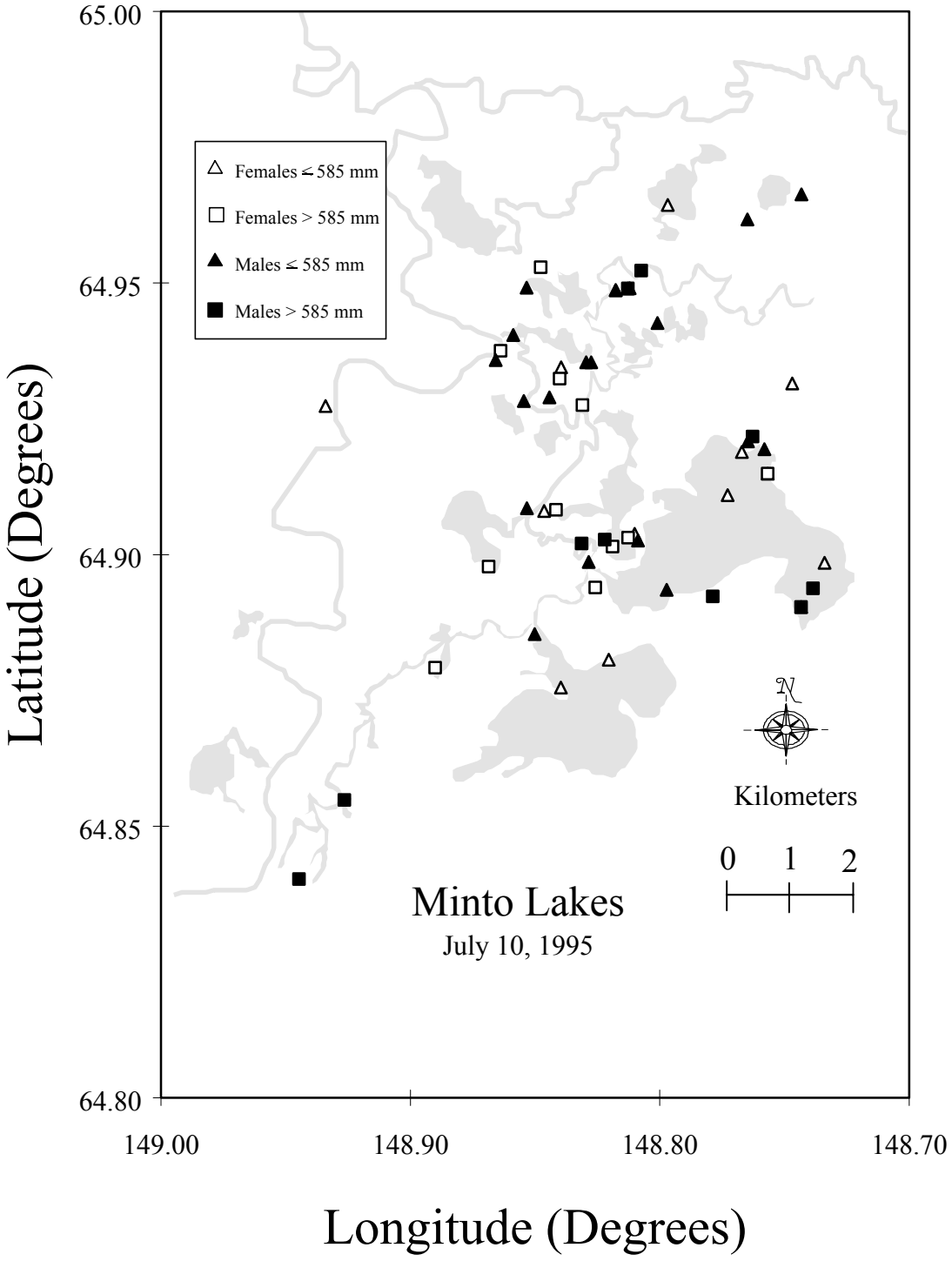
Appendix A1.–Locations of 61 radio-implanted northern pike found in Minto Lakes by latitude and longitude on May 16, 1995 (five additional were located outside of Minto Lakes and not depicted).



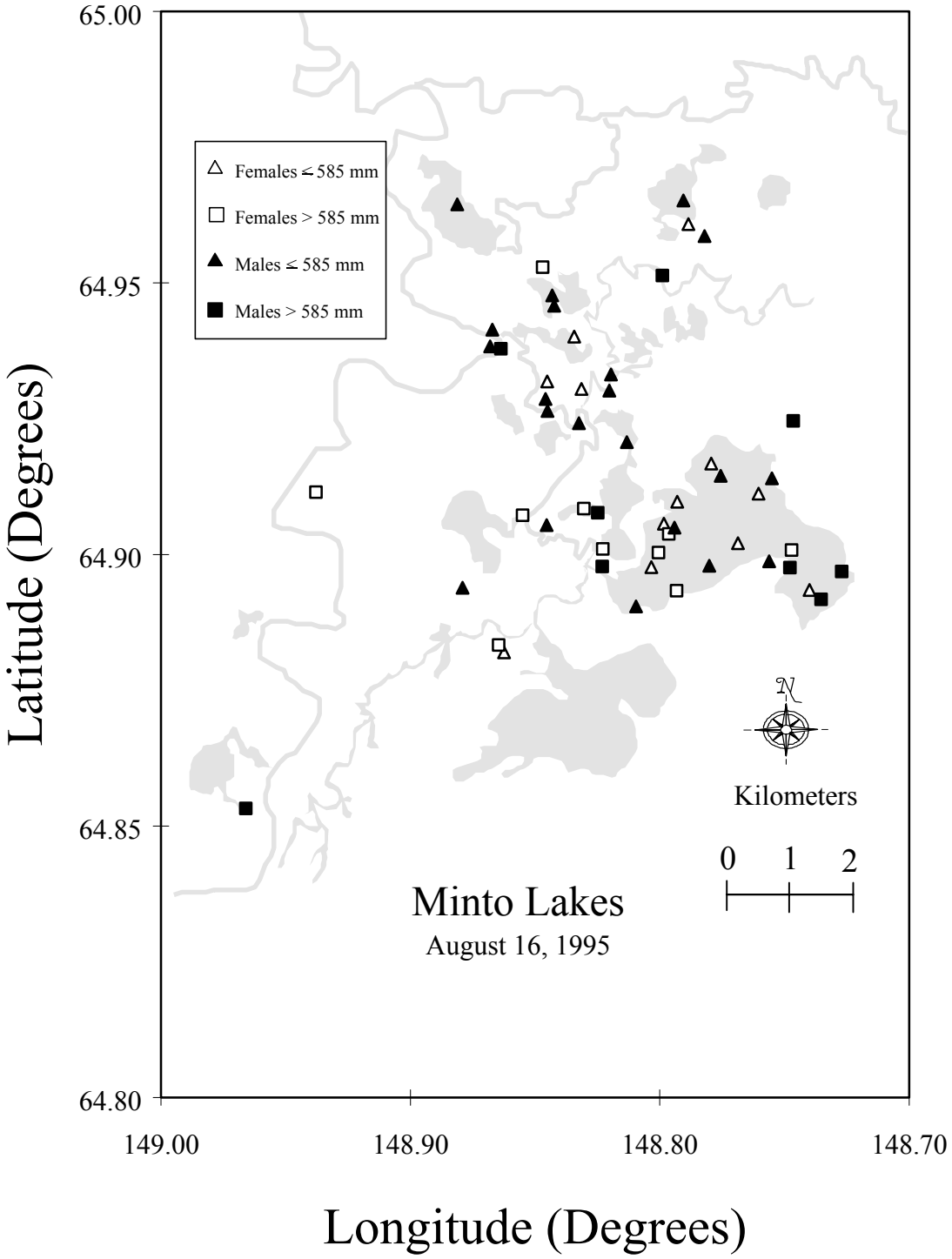
Appendix A2.–Locations of 58 radio-implanted northern pike found in Minto Lakes by latitude and longitude on May 24, 1995 (five additional were located outside of Minto Lakes and not depicted).



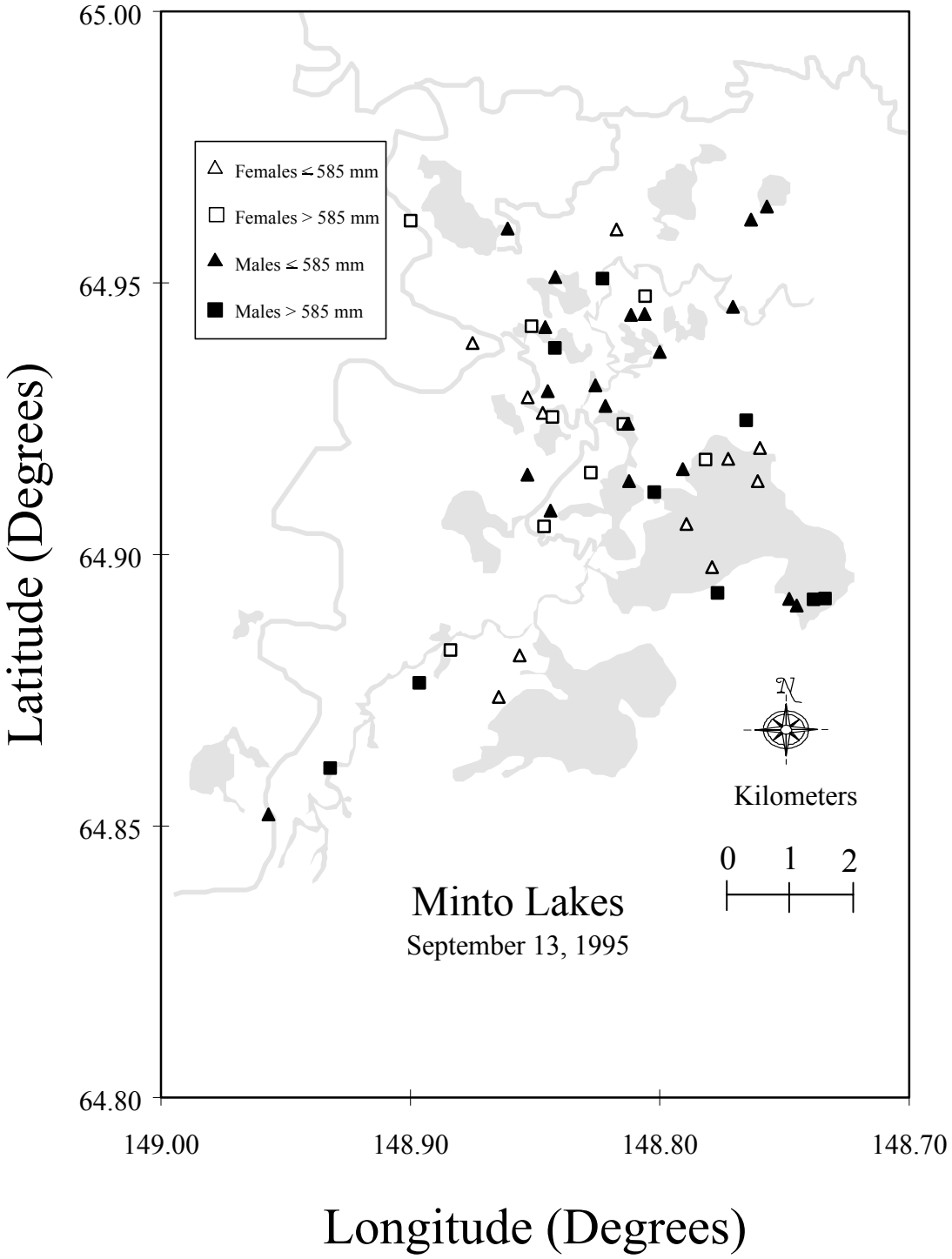
Appendix A3.–Locations of 57 radio-implanted northern pike found in Minto Lakes by latitude and longitude on June 14, 1995 (seven additional were located outside of Minto Lakes and not depicted).



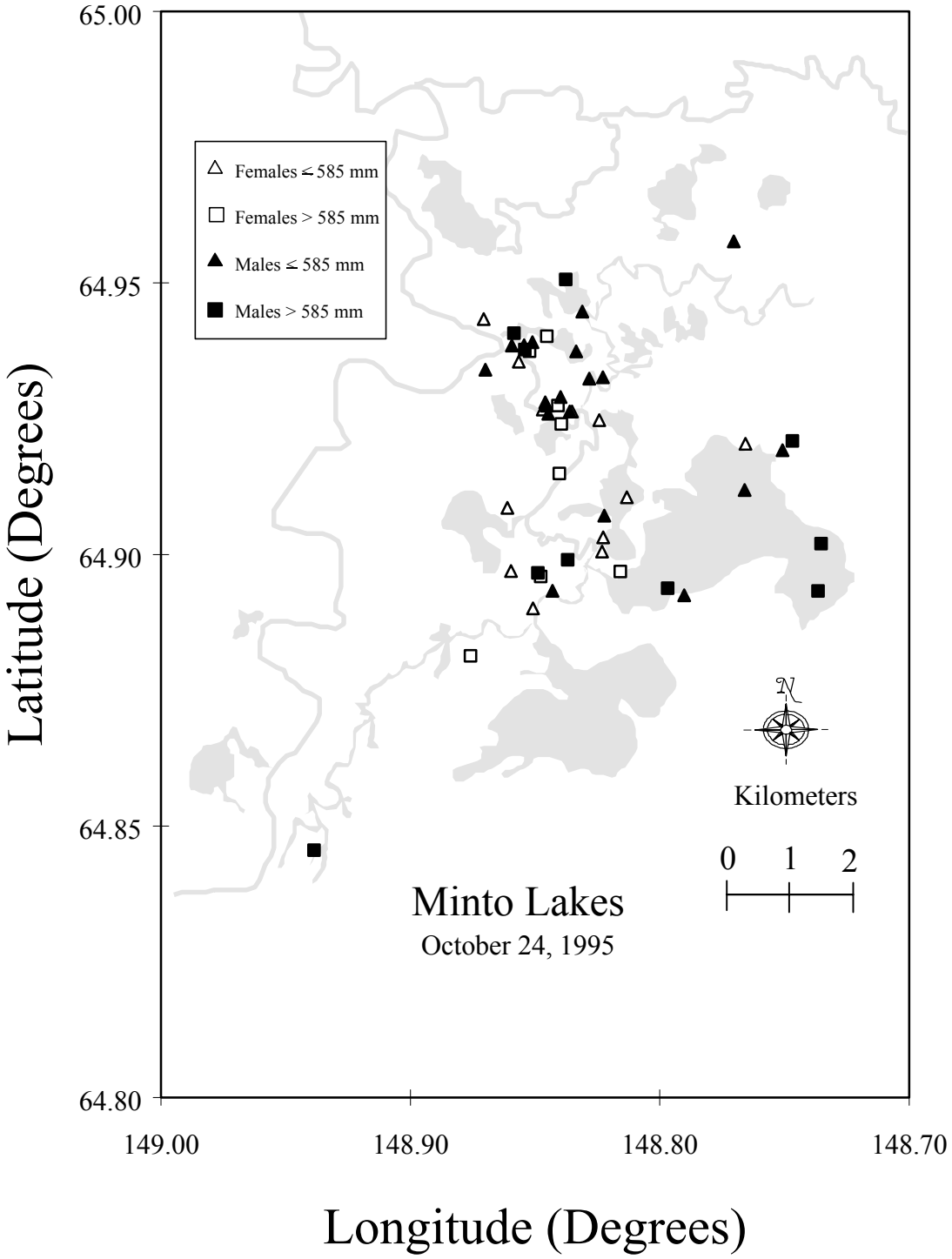
Appendix A4.–Locations of 55 radio-implanted northern pike found in Minto Lakes by latitude and longitude on July 10, 1995 (five additional were located outside of Minto Lakes and not depicted).



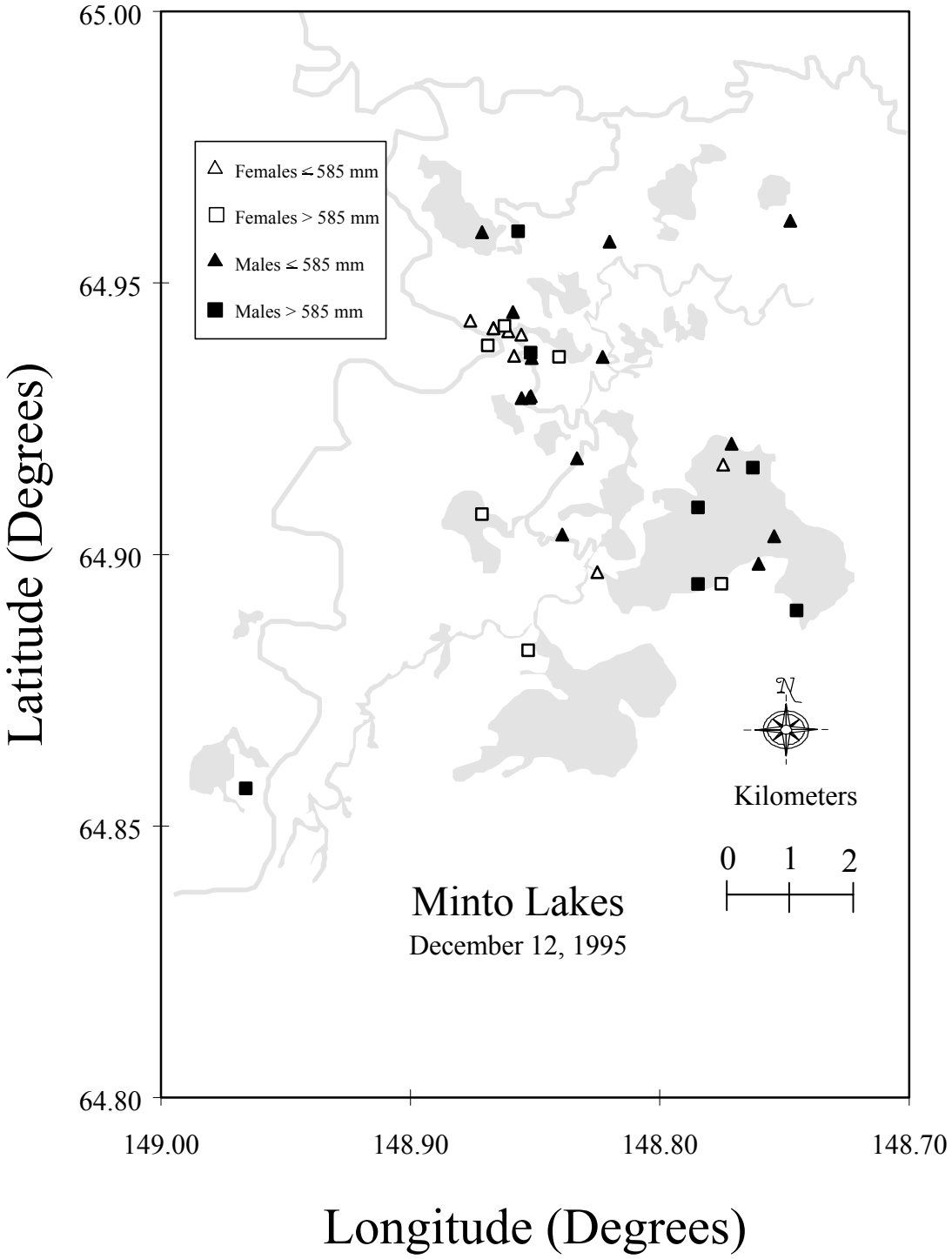
Appendix A5.–Locations of 52 radio-implanted northern pike found in Minto Lakes by latitude and longitude on August 16, 1995 (six additional were located outside of Minto Lakes and not depicted).



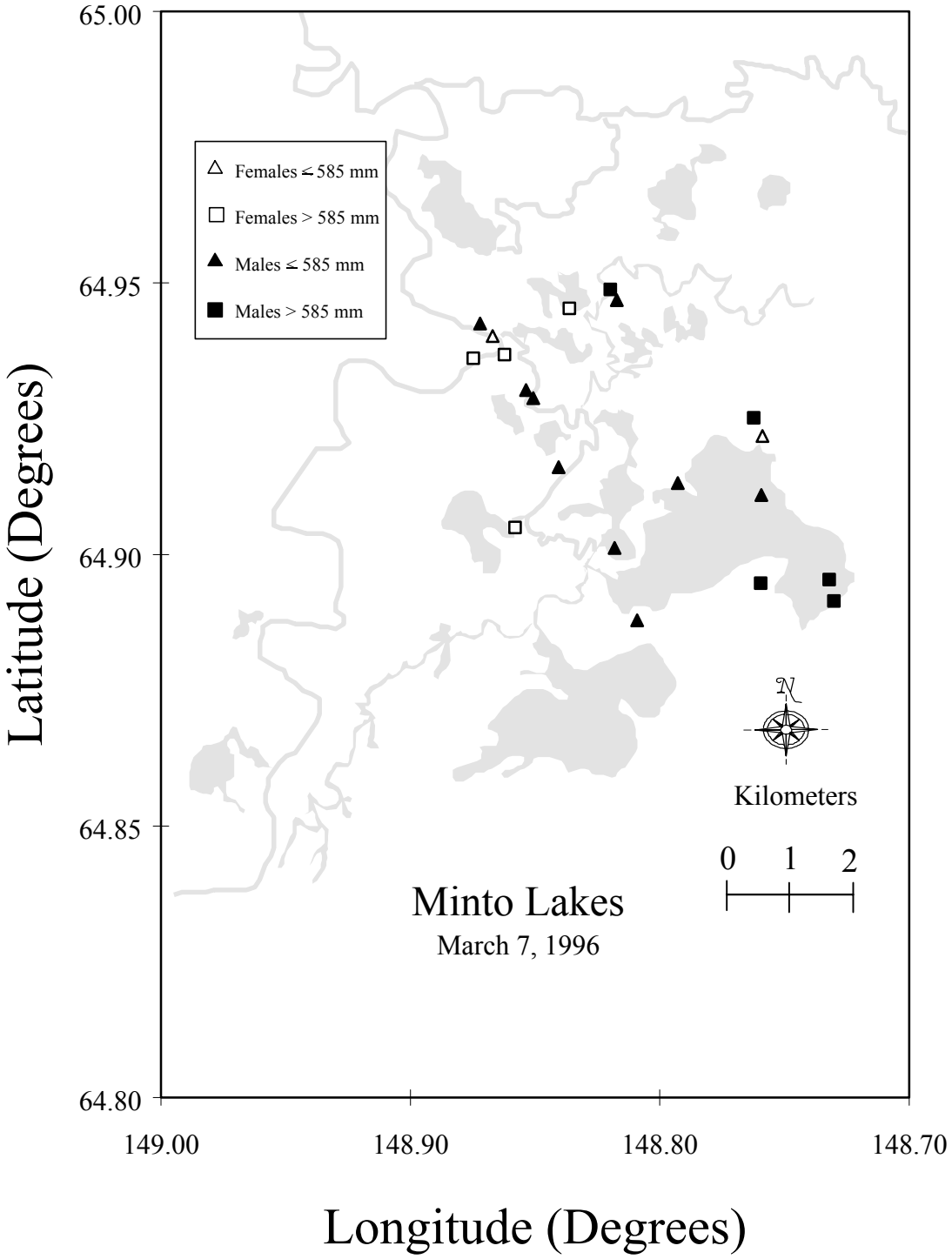
Appendix A6.–Locations of 49 radio-implanted northern pike found in Minto Lakes by latitude and longitude on September 13, 1995 (four additional were located outside of Minto Lakes and not depicted).



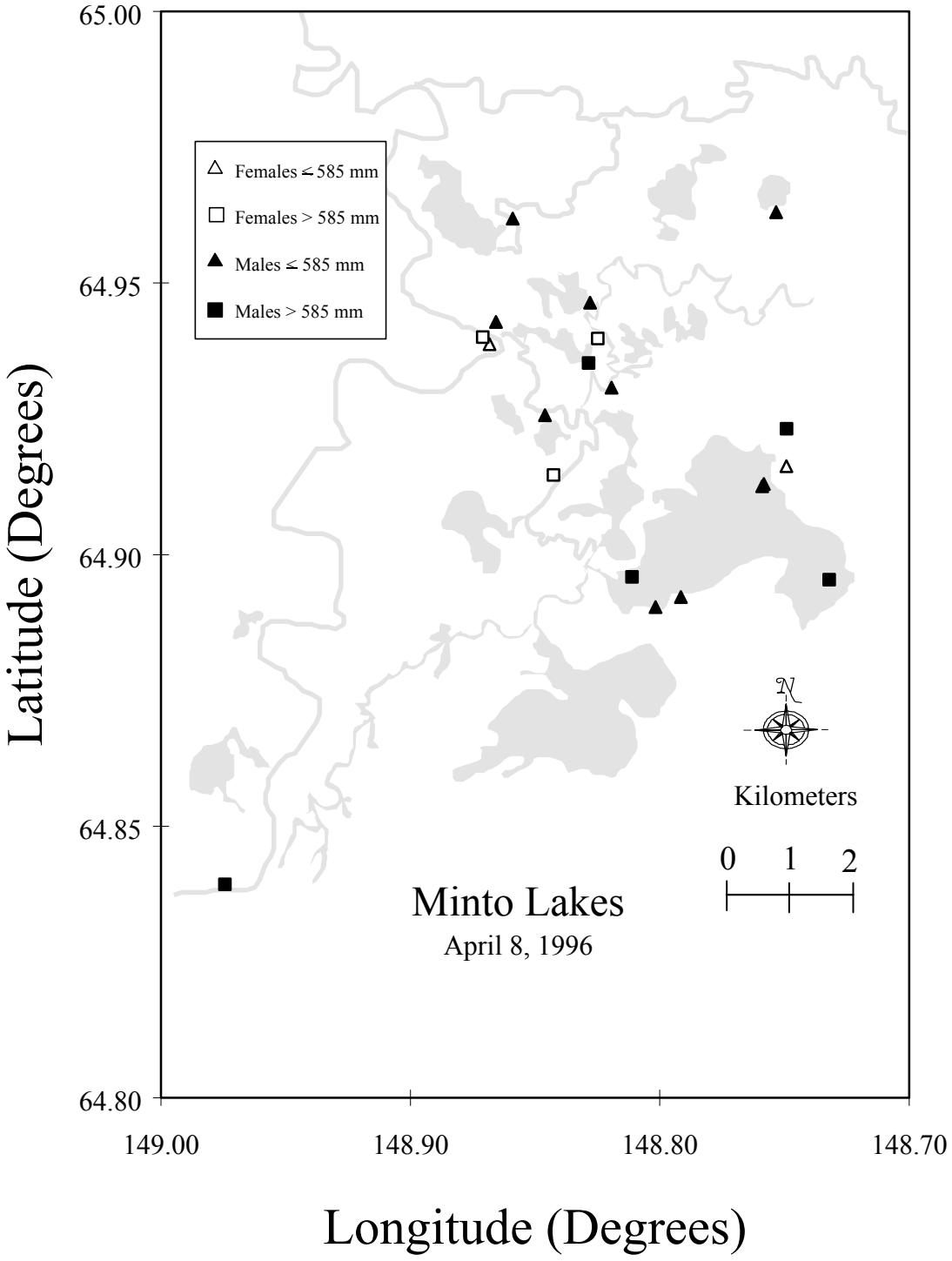
Appendix A7.–Locations of 48 radio-implanted northern pike found in Minto Lakes by latitude and longitude on October 24, 1995 (four additional were located outside of Minto Lakes and not depicted).



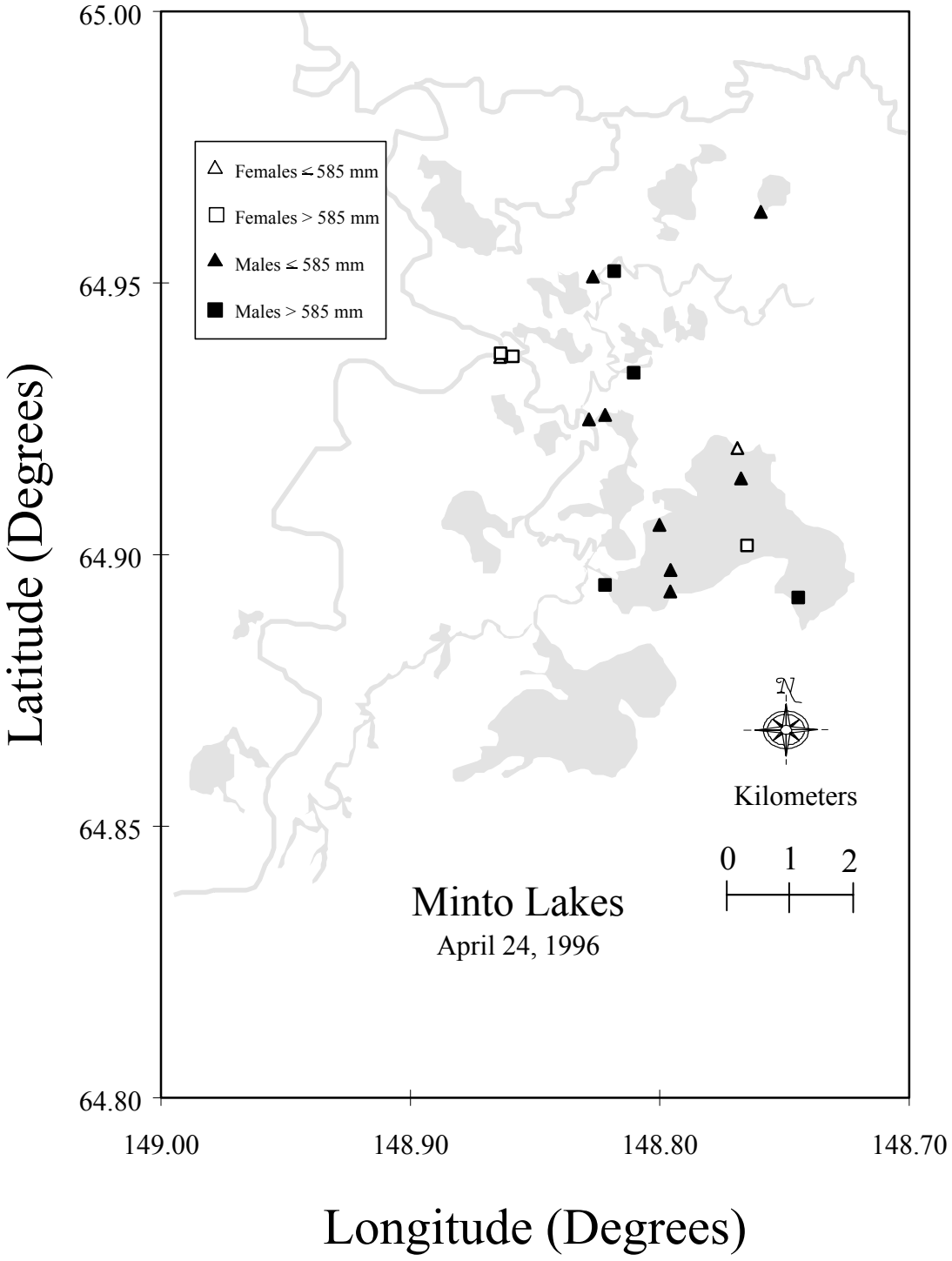
Appendix A8.–Locations of 35 radio-implanted northern pike found in Minto Lakes by latitude and longitude on December 12, 1995 (16 additional were located outside of Minto Lakes and not depicted).



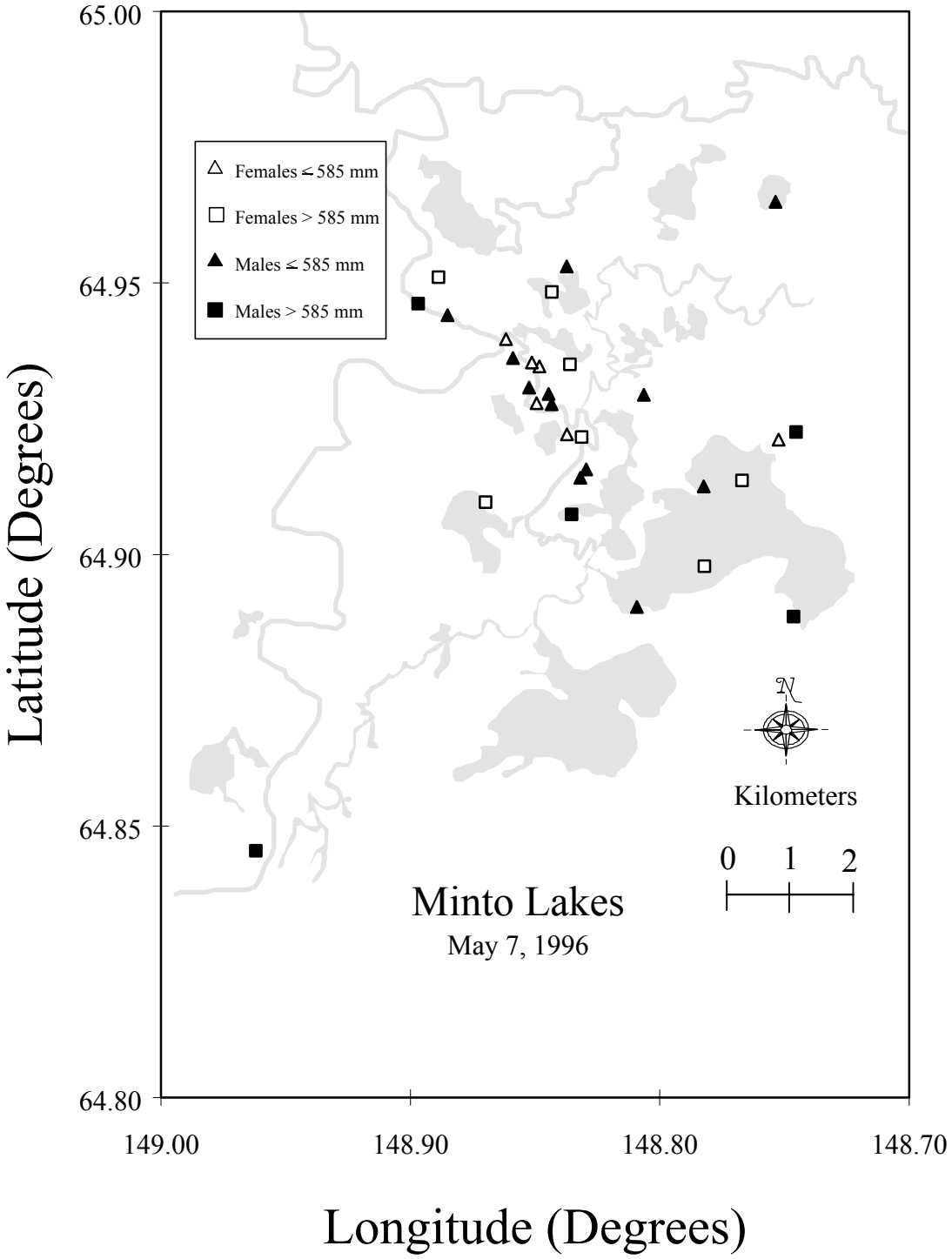
Appendix A9.–Locations of 20 radio-implanted northern pike found in Minto Lakes by latitude and longitude on March 7, 1996 (36 additional were located outside of Minto Lakes and not depicted).



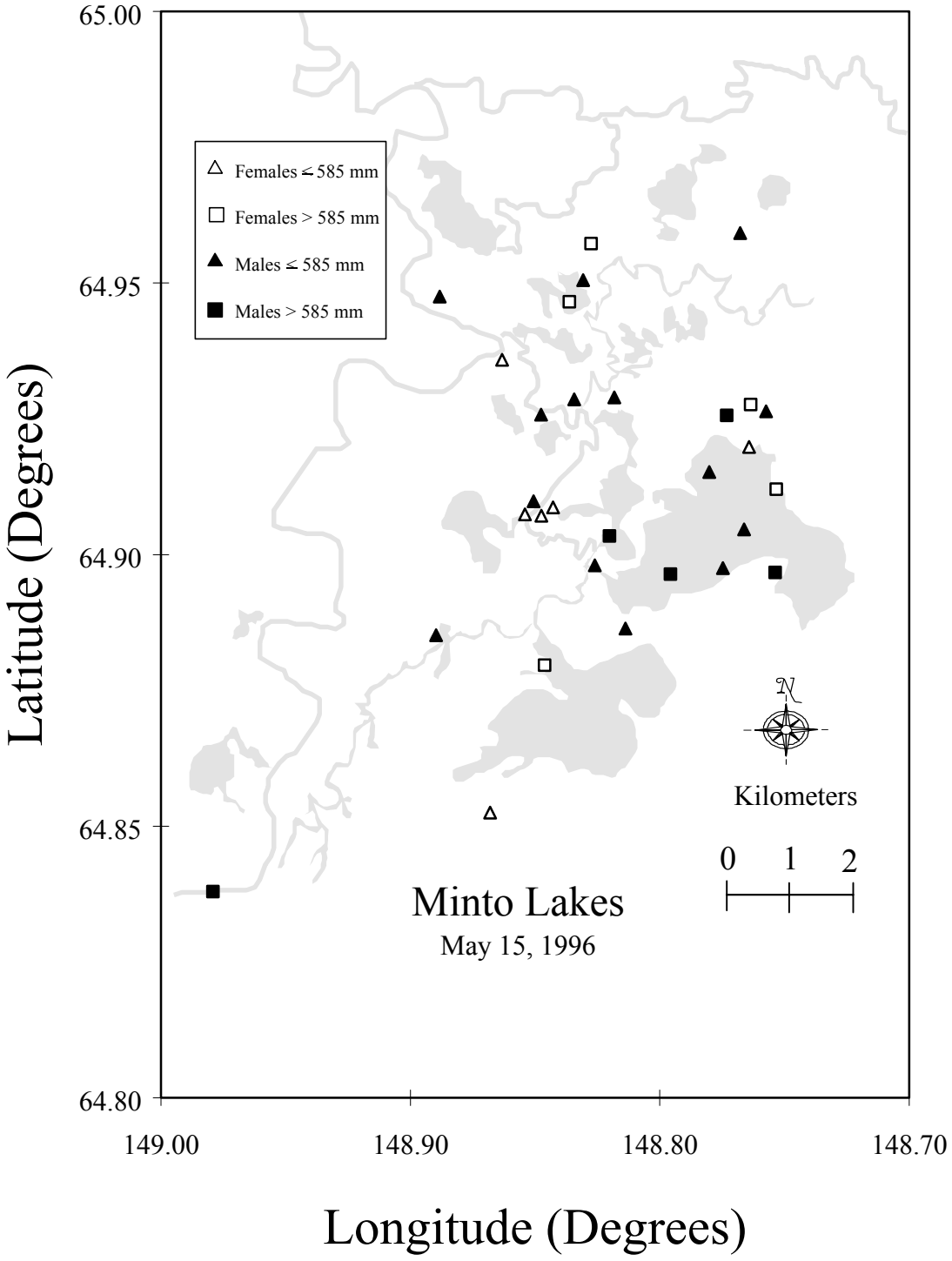
Appendix A10.–Locations of 19 radio-implanted northern pike found in Minto Lakes by latitude and longitude on April 8, 1996 (30 additional were located outside of Minto Lakes and not depicted).



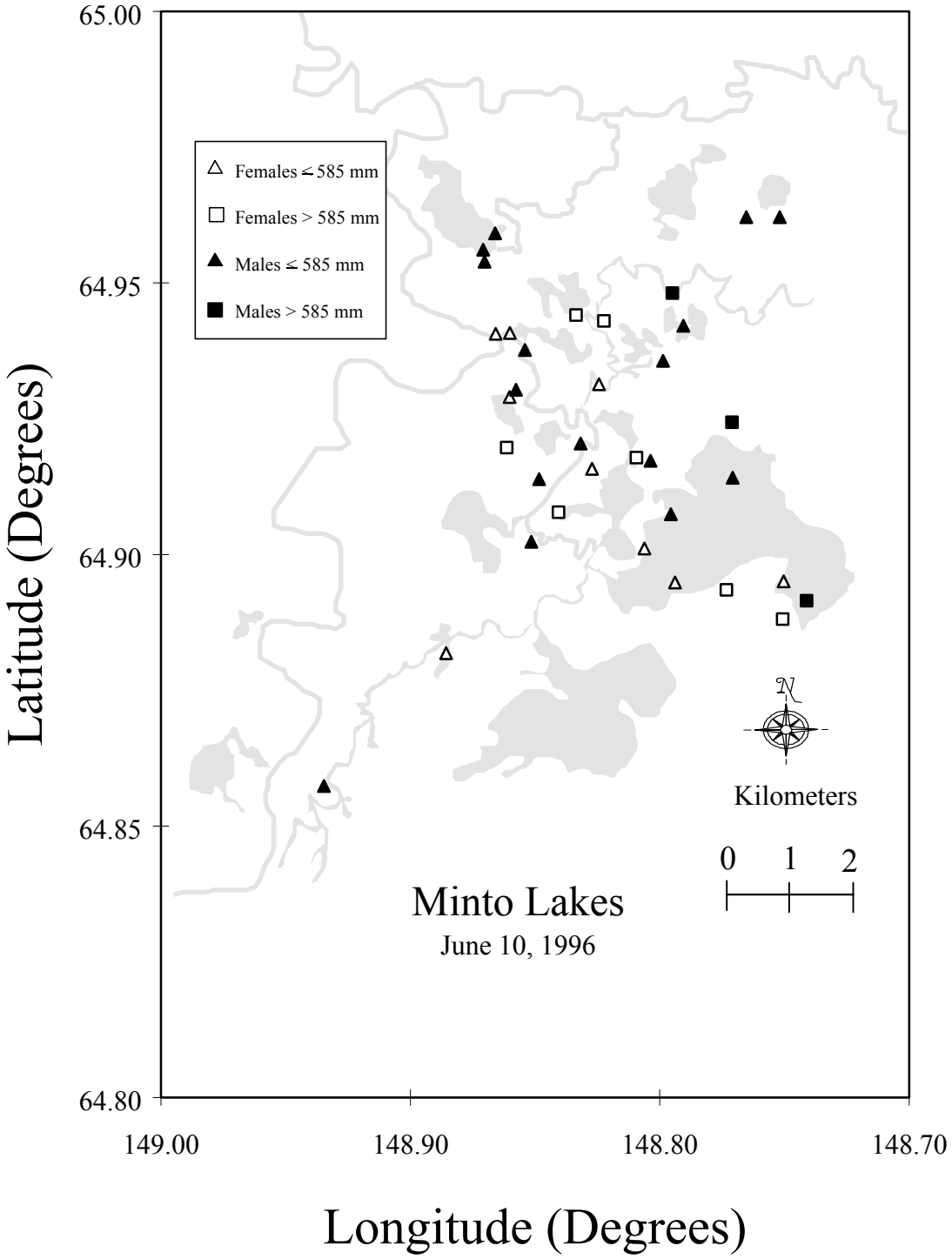
Appendix A11.–Locations of 17 radio-implanted northern pike found in Minto Lakes by latitude and longitude on April 24, 1996 (27 additional were located outside of Minto Lakes and not depicted).



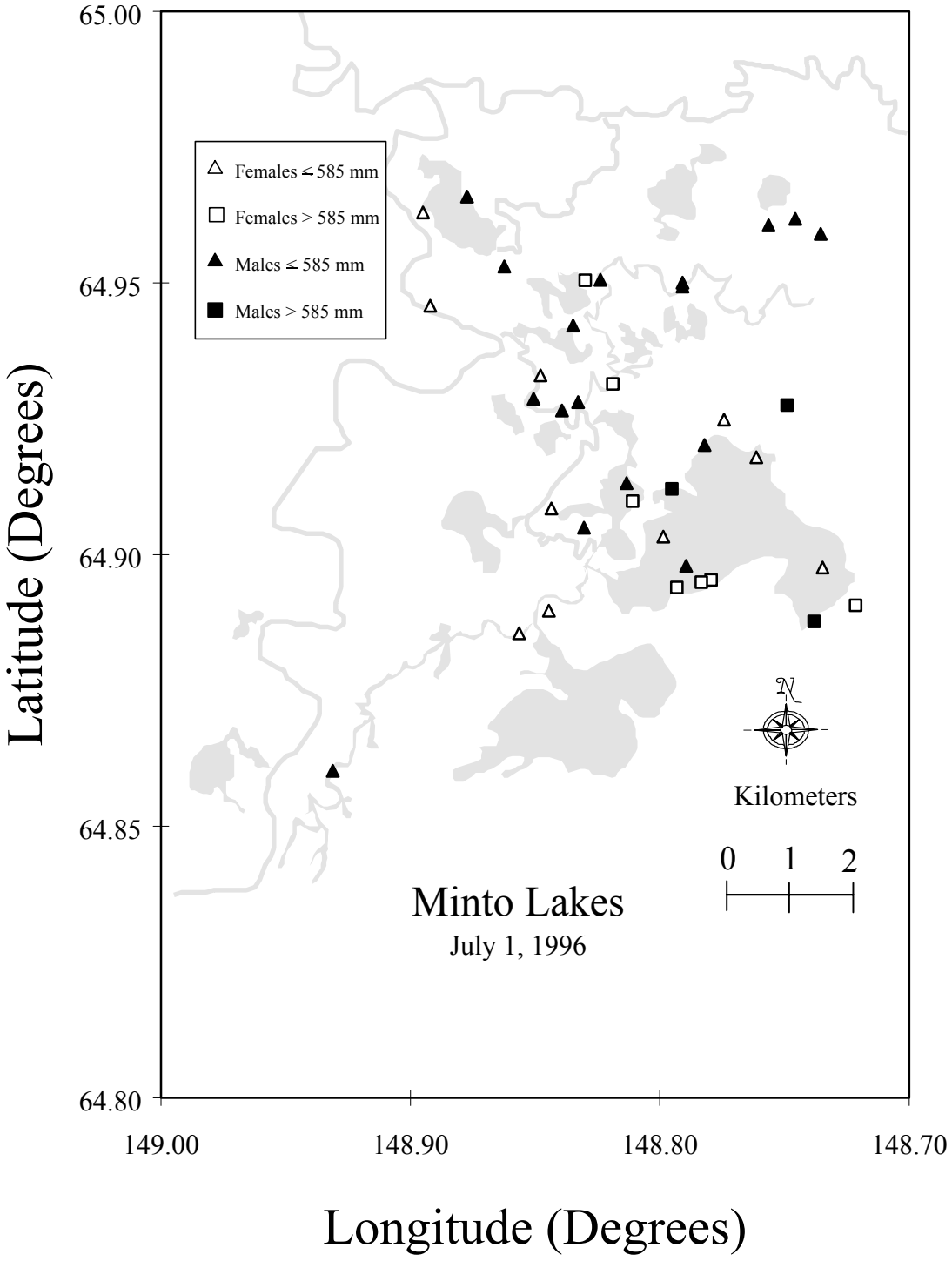
Appendix A12.–Locations of 30 radio-implanted northern pike found in Minto Lakes by latitude and longitude on May 7, 1996 (17 additional were located outside of Minto Lakes and not depicted).



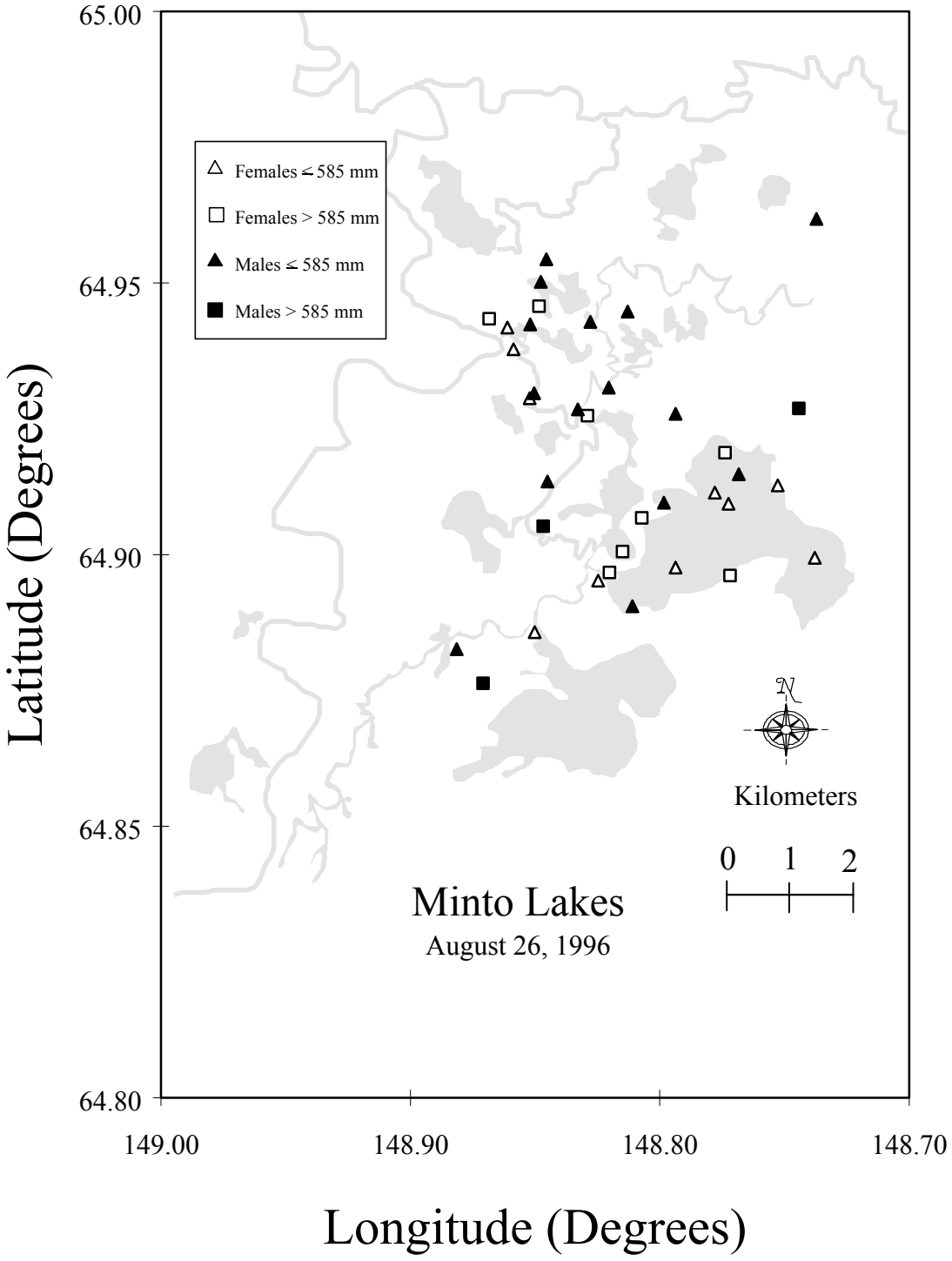
Appendix A13.–Locations of 30 radio-implanted northern pike found in Minto Lakes by latitude and longitude on May 15, 1996 (14 additional were located outside of Minto Lakes and not depicted).



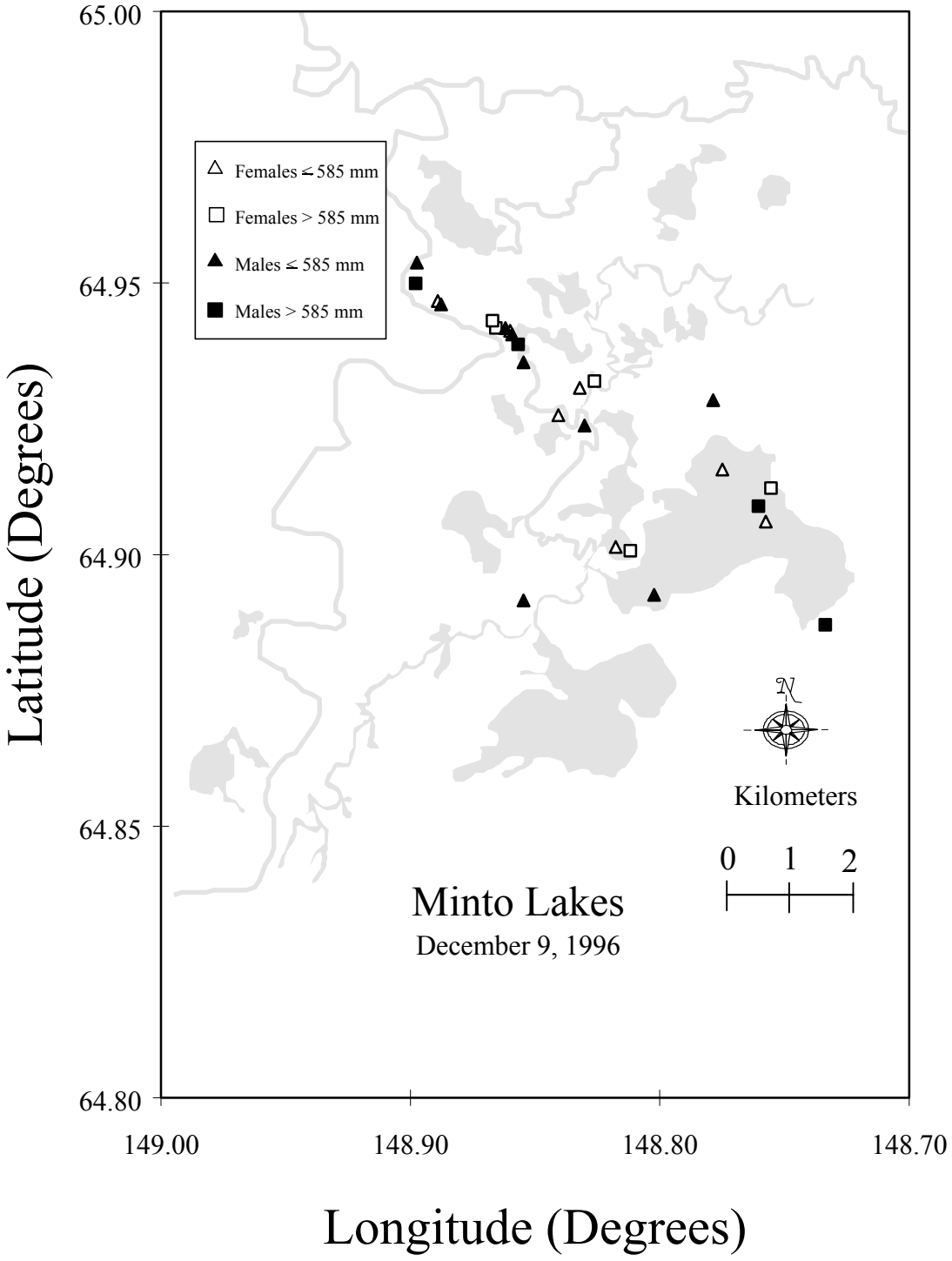
Appendix A14.–Locations of 35 radio-implanted northern pike found in Minto Lakes by latitude and longitude on June 10, 1996 (two additional were located outside of Minto Lakes and not depicted).



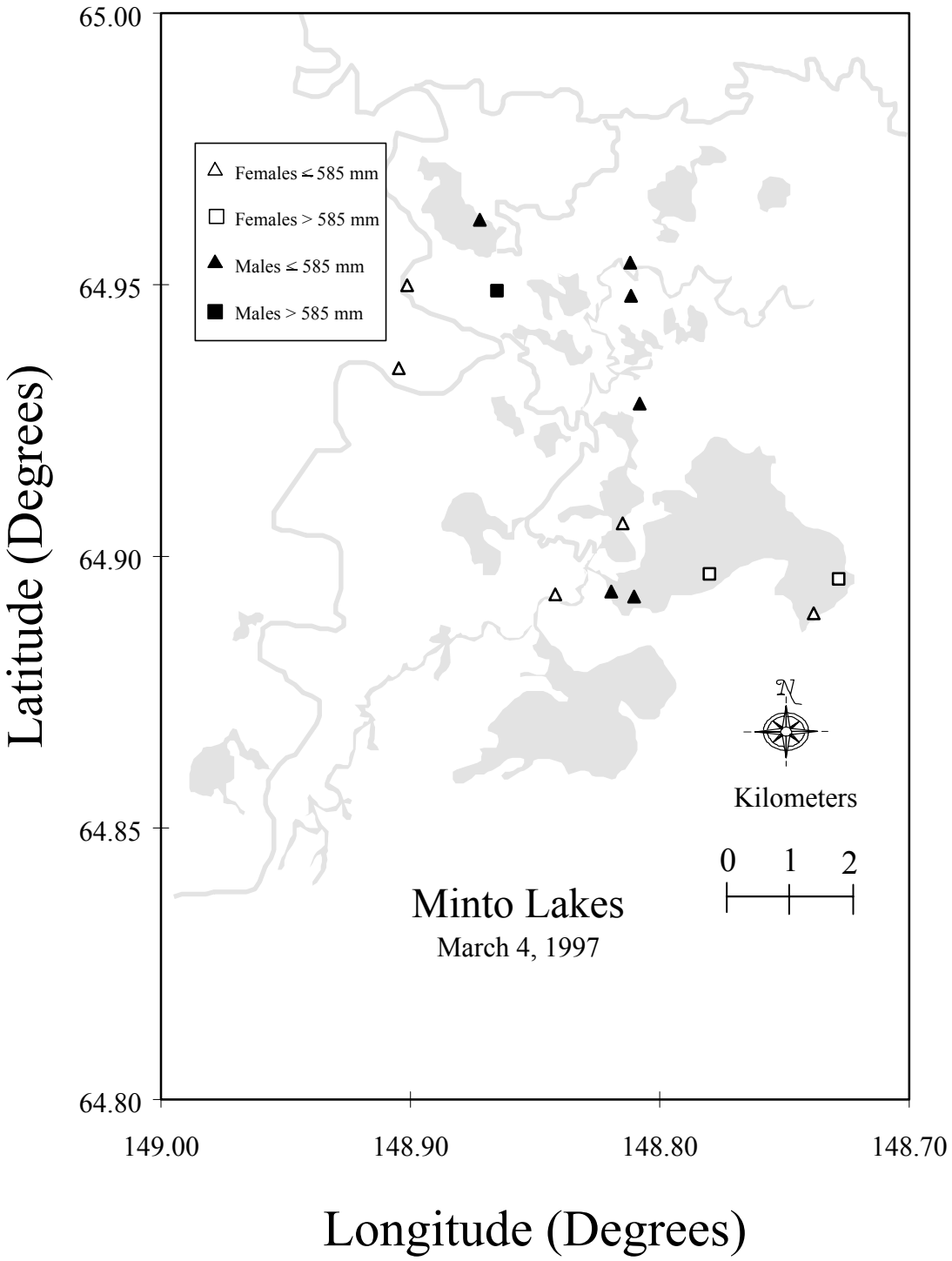
Appendix A15.–Locations of 37 radio-implanted northern pike found in Minto Lakes by latitude and longitude on July 1, 1996 (five additional were located outside of Minto Lakes and not depicted).



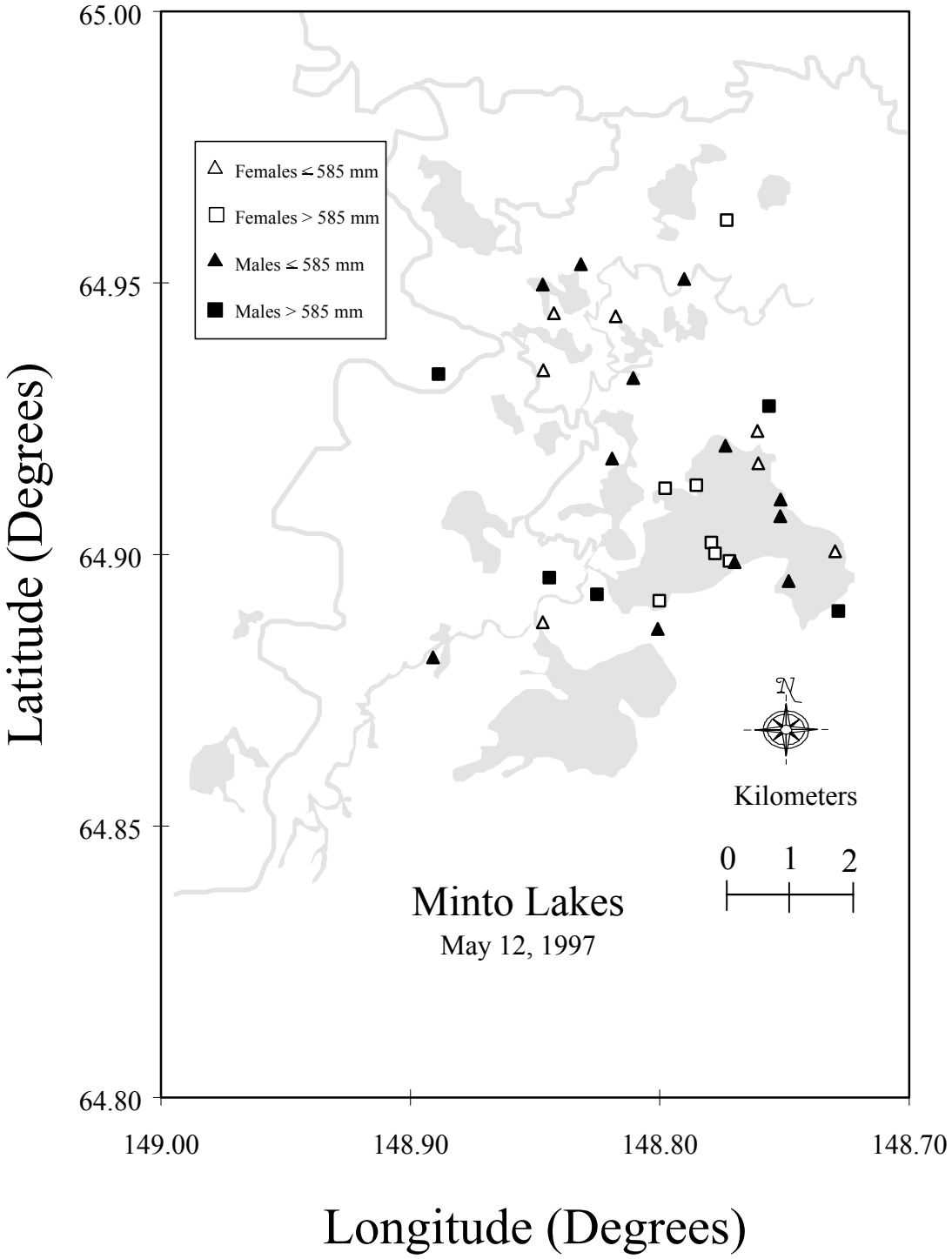
Appendix A16.–Locations of 36 radio-implanted northern pike found in Minto Lakes by latitude and longitude on August 26, 1996 (seven additional were located outside of Minto Lakes and not depicted).



Appendix A17.–Locations of 25 radio-implanted northern pike found in Minto Lakes by latitude and longitude on December 9, 1996 (11 additional were located outside of Minto Lakes and not depicted).



Appendix A18.–Locations of 14 radio-implanted northern pike found in Minto Lakes by latitude and longitude on March 4, 1997 (29 additional were located outside of Minto Lakes and not depicted).



Appendix A19.–Locations of 31 radio-implanted northern pike found in Minto Lakes by latitude and longitude on May 12, 1997 (11 additional were located outside of Minto Lakes and not depicted).