Fishery Data Series No. 20-16

Movement Patterns of Northern Pike in Alexander Lake

by

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May 2020

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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MOVEMENT PATTERNS OF NORTHERN PIKE IN ALEXANDER LAKE

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ABSTRACT

In 2011, the Alaska Department of Fish and Game (ADF&G) began a long-term invasive northern pike (*Esox lucius*) suppression program in side-channel sloughs of Alexander Creek. To determine if Alexander Lake, at the headwaters of this system, served as a significant source of northern pike to Alexander Creek or other adjacent watersheds, a northern pike movement study was conducted on Alexander Lake between 2011 and 2013 using radiotelemetry. A total of 125 mature northern pike were captured in Alexander Lake and a total of 25 were captured in Alexander Creek; all fish were surgically implanted with radiotransmitter tags. During this study, few radiotagged northern pike migrated into the creek, and no radiotagged northern pike left the system. All northern pike that left the lake were later captured downstream in gillnets by northern pike suppression crews and dispatched. The telemetry project indicated that northern pike movements out of Alexander Lake were not detrimental to ADF&G's suppression efforts. Between 2014 and 2016, ADF&G planned to investigate whether juvenile northern pike movements differed from those observed for mature northern pike, but this question could not be answered because juveniles did not recruit to the sampling gear.

Key words: Northern pike, *Esox lucius,* radiotelemetry, radio tags, seasonal movements, migration, seasonal distributions, Susitna River drainage, invasive species

INTRODUCTION

BACKGROUND

Northern pike (*Esox lucius*) are native throughout much of Alaska but do not naturally occur south and east of the Alaska Range (Figure 1). Invasive northern pike, which are predatory fish, pose a significant threat to salmon habitats in Southcentral Alaska (ADF&G 2007), and its presence has coincided with the loss of several fisheries across the region, including the heavily impacted Alexander Creek in the Susitna River drainage[1].

Based on anecdotal accounts, the first introduction of northern pike to the Susitna River drainage was probably by an air charter operator to the Yentna River drainage (Bulchitna Lake, Lake Creek drainage) in the late 1950s, and from there, northern pike subsequently spread throughout the Susitna River drainage via natural migration and further illegal stockings. Based on reports from local residents, northern pike are believed to have been illegally introduced to Alexander Lake in the late 1960s, although there was no harvest record of them prior to 1985 (Mills 1986). Anecdotal accounts from Alexander Creek area residents suggest that dispersal of northern pike from the lake to the lower river occurred slowly over a 30-year period. The first documented catch of northern pike in the lower Alexander Creek drainage (river kilometer [RKM] 0–1) was in the mid-1990s. Today, northern pike are widespread throughout the system.

Prior to 2000, Alexander Creek was one of the most productive Chinook salmon (*Oncorhynchus tshawytscha*) systems in the entire Northern Cook Inlet (NCI) area. During its productive years (1980–1999), this system experienced an average of 13,700 angler-days of sport fishing effort per year (Oslund et al. 2017a: page 70). During that same period, an average of 2,872 Chinook salmon were harvested annually (Oslund et al. 2017a: page 112). Since the late 1990s, the populations of multiple fish species have been reduced in the Alexander Creek drainage, including Chinook salmon, which last achieved the escapement goal in 2005 (Oslund et al. 2017a, 2017b). This culminated in the Alaska Board of Fisheries designating Alexander Creek's Chinook salmon as a "stock of concern" (SOC) in 2011. Because of poor runs, the Chinook salmon sport fishery has been closed to harvest since 2008. Aerial surveys have been flown on Alexander Creek annually

[1] Yanusz, R., and D. Rutz. 2009. Alexander Creek/Lake White Paper. Available at https://www.adfg.alaska.gov/static-sf/Region2/pdfpubs/Alexander_King_White_Paper.pdf (accessed 10/10/2019).

since 1979 and have shown a distinct change in Chinook salmon spawner distribution patterns (D. Rutz, Fishery Biologist, ADF&G, personal observation). Since 1992, Chinook salmon spawners have disappeared from the tributaries upstream of Alexander Lake, and since about 1998, they have disappeared from much of the mainstem Alexander Creek (i.e., both upstream and downstream of the Sucker Creek confluence; Figure 2). In addition, harvest of coho salmon (*O. kisutch*) has been below the historical (1980–1999) average of 1,531 since 2005 (Oslund et al. 2017a: pages 126–127), and the once popular and abundant rainbow trout (*O. mykiss*) and Arctic grayling (*Thymallus arcticus*) fisheries were also closed to harvest in 1996 (Whitmore and Sweet 1998). Despite these fisheries becoming catch-and-release, catch rates have declined over the past 20 years for both species (Oslund et al. 2017a). Northern pike establishment in Alexander Creek is believed to be the primary factor resulting in these declines.

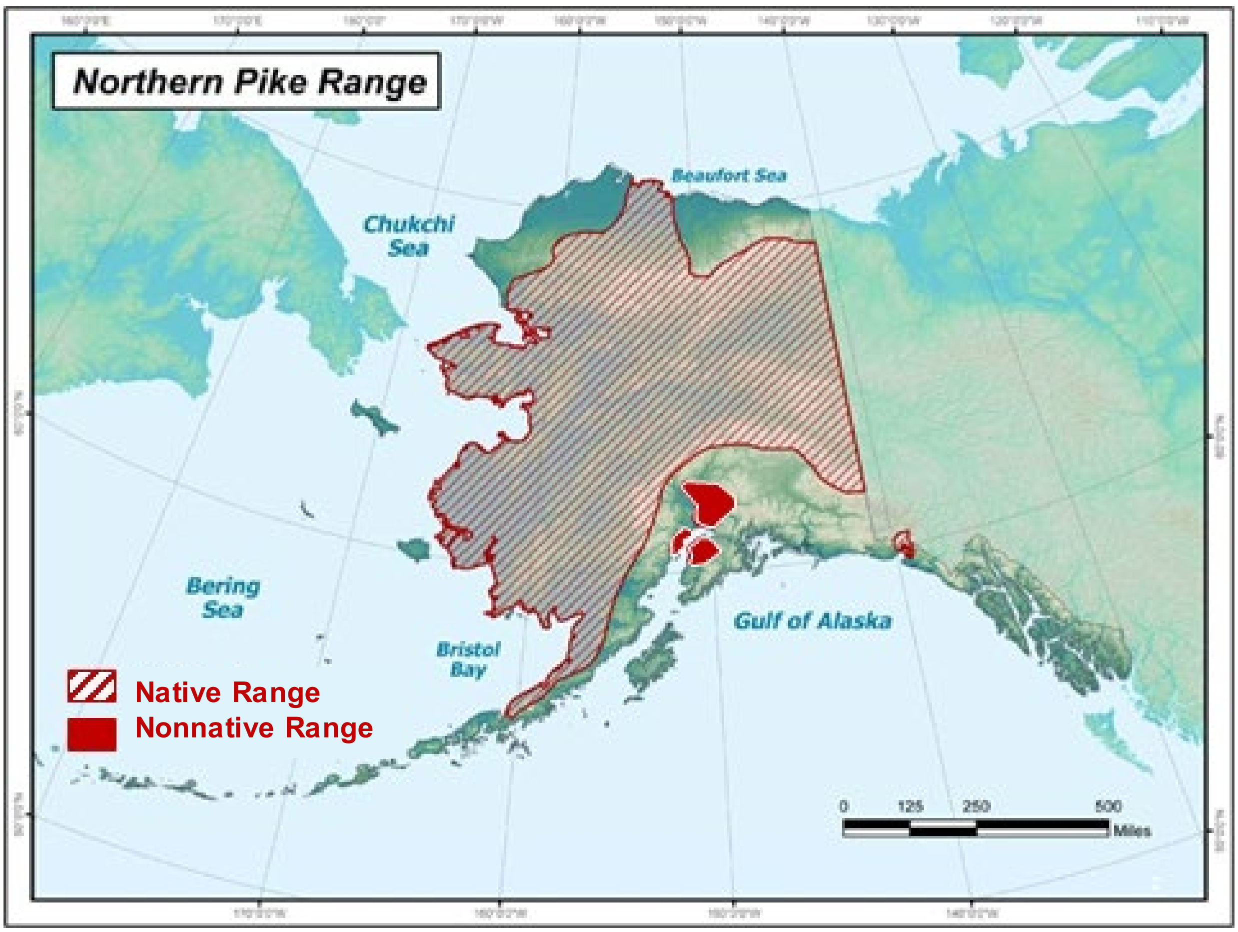

Figure 1.–Distribution of native and nonnative northern pike in Alaska.

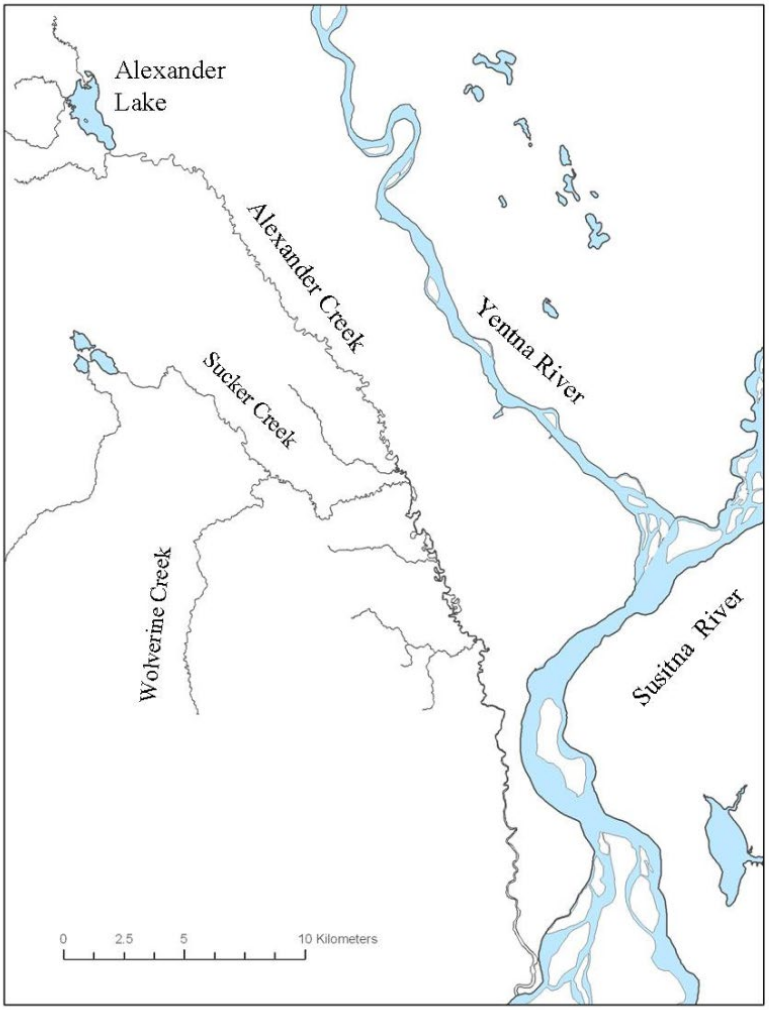

Figure 2.–Map of the Alexander Creek drainage.

NORTHERN PIKE MOVEMENT PROJECT

The mission of the Alaska Department of Fish and Game (ADF&G) Division of Sport Fish (SF) is "to protect and improve the state's recreational fisheries resources," and a crucial objective of the SF strategic plan is to "minimize impacts of invasive species on fish stocks, recreational fisheries, and fish habitat." To reduce northern pike abundance and increase salmonid productivity and sport fishing opportunities within the Alexander Creek drainage, ADF&G initiated a long-term northern pike suppression program in 2011 (Rutz et al. 2020). Crews intensively gillnet side-channel sloughs of Alexander Creek annually during the northern pike spawning period.

The primary goals of the Alexander Creek northern pike suppression project are to restore the quality of salmon rearing habitat by annually reducing the number of mature northern pike in the backwater sloughs of the creek and secondly, to restore sport fishing opportunities. However, there is a prolific population of northern pike in Alexander Lake at the headwaters of the creek. Past Susitna River drainage studies have documented radiotagged northern pike moving within and between drainages in the Susitna River (Rutz 1996, 1999). One critical question before suppression could begin was whether this strategy of focusing suppression in Alexander Creek sloughs could be effective without northern pike suppression in Alexander Lake, which would be a much more expensive endeavor. To address this question, a northern pike movement study was conducted between 2011 and 2013 using radiotelemetry to identify movement patterns of northern pike between Alexander Lake and Alexander Creek. If significant movement of northern pike was found to occur between Alexander Lake and Alexander Creek, the strategy of focusing suppression in the side-channel sloughs of Alexander Creek would probably be ineffective in increasing salmonid survival because recruitment of northern pike from Alexander Lake could replace those removed in gillnets from the creek. It was important to determine this prior to implementation of the suppression project because suppression would have to be more logistically complex and probably cost prohibitive.

OBJECTIVES

1) Estimate the proportion of all mature northern pike residing in Alexander Lake that migrate at least once annually to Alexander Creek from 15 July 2011 to 30 June 2013 such that the estimated proportion is within 15 percentage points of the true value 95% of the time.
2) Calculate the catch per unit effort (CPUE) of young of the year and 1-year-old northern pike captured in fyke nets downstream of the outlet of Alexander Lake and estimate the proportion of this catch that migrates to Alexander Creek sloughs between 7 May 2014 and 30 September 2016.

METHODS

STUDY AREA

Alexander Lake is approximately 356-hectares and shallow with a mean depth of about 1.2 meters. It is vegetated throughout and is located at the headwaters to Alexander Creek, which flows into the west side of the Susitna River approximately 13 river kilometers (RKM) upstream from where the Susitna River drains into Cook Inlet. The creek's length is approximately 66 RKM from its headwaters at the lake to its confluence with the Susitna River (Figure 2). Alexander Creek's mainstem can be characterized as a tannin stained, low gradient, slow velocity, meandering channel with a large portion of the river comprising dense vegetative mats. This drainage encompasses hundreds of square miles and is composed of interconnecting shallow lakes and ponds, vast expanses of adjacent wetlands and marshes, and numerous backwater side-sloughs and oxbow channels that are typically shallow stagnant waters with low flows containing dense aquatic vegetation, all of which provide optimum spawning and rearing habitat for northern pike (Inskip 1982; Rutz 1996), which are currently well distributed throughout.

STUDY DESIGN

Overview

This study is one of the first comprehensive investigations of northern pike movement patterns within an open system outside of its native range in Alaska. Northern pike movements have been described in areas of the state where northern pike naturally occur (Taube and Lubinski 1996; Roach 1998; Chythlook and Burr 2002). Besides anecdotal information from floy-tag recoveries or small-scale studies of northern pike movements in the Susitna River drainage (Rutz 1996, 1999), little information is available describing the distribution and movement patterns of Alaska's invasive northern pike populations and in particular, the invasive population in the Alexander Creek system. Results from this study were used to assess whether northern pike suppression in the Alexander Creek system by gillnetting slough channels located adjacent to the mainstem of

Alexander Creek could be effective. Furthermore, these results can be used to inform future northern pike control efforts or eradication projects.

Radiotelemetry Assessment of Northern Pike Movements in Alexander Creek (*Objective 1*)

Spatial and temporal movement patterns of invasive northern pike in the Alexander Creek drainage were assessed through radiotelemetry techniques with the main emphasis on determining the number of radiotagged northern pike in Alexander Lake that emigrated into the creek or other adjacent waters. During July of 2011, 150 northern pike greater than 440 mm fork length were surgically implanted with F1845 Advanced Telemetry Systems[2] (ATS) radio transmitters using standard surgical procedures (Ross and Kleiner 1982; Summerfelt and Smith 1990). Radio transmitters were 42 mm in length, 17 mm in diameter, and weighed about 14 g with a 30 cm external whip antenna and a battery capacity of approximately 693 days (1.9 years). In addition, each of the radiotagged northern pike were tagged with a sequentially numbered T-bar floy tag. A total of 125 fish were captured and radiotagged in the lake (primary objective) and 25 were captured and radiotagged in the creek (to observe movement patterns; Appendix A1). All northern pike that were tagged were captured using hook and line. After tags were surgically implanted, the fish were measured and then held in an aerated recovery tank until they recuperated enough to be released back to their original capture location. The 125 northern pike captured in the lake were collected throughout the northern region of the lake. Northern pike captured in Alexander Creek were either captured near the outlet of Alexander Lake (RKM 64) or near the creek's confluence with the Susitna River (RKM 1.6–5.0). Modal surgery time was 6 minutes per fish. All fish were released in good health and appeared active prior to their release.

Radiotagged northern pike were tracked monthly from July 2011 through June 2013 using a combination of aerial tracking surveys and stationary receivers. It was expected that approximately half of radiotagged northern pike would survive the entire 2-year study (Taube and Lubinski 1996; Roach 1998). Detailed records of the tag numbers and movement distances were kept and monitored for all tagged northern pike. There were 6 separate frequencies used for the 150 implanted radio tags. All frequencies were within the 150.000–151.999 MHz range. Effort was made to ensure these frequencies did not conflict with any other ongoing radiotelemetry studies. Each frequency had 25 different transmission patterns ("pulse codes"), resulting in 150 uniquely identifiable transmitters (radio tags). Because northern pike can remain sedentary for long periods of time, the transmitters included mortality indicators. Movements of radiotagged fish were monitored through a combination of repeated aerial surveys and 3 stationary receiving towers.

A single-engine Piper PA-12 fixed-wing aircraft was used to conduct a total of 24 aerial surveys. Surveys were conducted to detect general distribution and major northern pike movements. During aerial surveys, a Yagi antenna was mounted on each wing strut with the antenna oriented forward and slightly downward and with the elements vertical to maximize the reception. Both antennas were connected by antenna cable, which was then attached to the receivers. Two ATS Model 4500 radio receivers with internal GPS receivers were programmed to continuously scan all frequencies and create a log of detected tags and their latitude and longitude. Flight tracking surveys were scheduled to take place monthly between September and March, twice in April, weekly during

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2 Product names used in this publication are included for completeness and do not constitute product endorsement.

May, and twice a month between June and August. Actual surveys flown were dependent on weather and pilot availability.

Stationary receivers were installed at the mouth of Alexander Lake (RKM 64), near the confluence of Alexander Creek and Sucker Creek (RKM 37), and approximately 5 RKM upstream of the confluence of Alexander Creek with the Susitna River (Figure 3). Tracking stations consisted of an ATS 4500 receiver and self-contained power system. Radiotagged fish within reception range of the stations were identified and recorded. Recorded information included the date and time the fish was present at the site, the signal strength, and the location of the fish in relation to the station (upstream or downstream of the tower). Information on tracking station operations (i.e., voltage levels for the station components and whether the reference transmitter at the site was properly recording) was also documented. A field crew traveled to each of the 3 stationary receivers once per month during the open water season from early May through September to manually download data. Receivers were generally pulled from their tower location from October through early May of each year to avoid freezing and breakage of crystalline data display boards in the receivers.

The proportion of northern pike leaving Alexander Lake was estimated to determine whether northern pike migrate from the lake into the creek or into other drainage systems. The proportion of northern pike leaving Alexander Lake was estimated as follows:

$$\hat{p} = \frac{s_t}{n} \tag{1}$$

where

s_t = the number or radio tags detected leaving Alexander Lake,

n = the total number of radio tags originally deployed in the lake, and

$\hat{p}$ = the proportion of northern pike leaving the lake.

This assumes that tagged northern pike represent a random sample of all mature northern pike in Alexander Lake and that the process of catching and tagging these fish did not influence their survival rates or migratory behaviors. For those northern pike that exited the lake, the maximum downstream distance of each fish was measured to the nearest kilometer to document the spatial extent of these movements. The movements of all radiotagged northern pike were mapped in ArcMap 10.2 to illustrate the extent of the movements observed and to visually represent any seasonal movement patterns (Appendices B1–B21).

Assessment of Juvenile Northern Pike Emigrating from Alexander Lake into the Creek (*Objective 2*)

To qualitatively investigate if juvenile northern pike were emigrating from the lake into the creek, 2 fyke nets were installed adjacent to each bank of the outlet of Alexander Lake with the cod ends facing in the downstream position and the open end (catch end) facing upstream. The modified fyke nets measured 0.9 m by 1.5 m long with 6 mm square mesh nylon netting on five 3 m aluminum hoops with finger-style throats on the second and third hoops and with attached 4 m leads. Fyke nets were fished from 20 May to 20 June 2014, 19 May to 30 June 2015, and 15 May to 10 September 2016. Nets were checked daily when field crews were present and opportunistically thereafter.

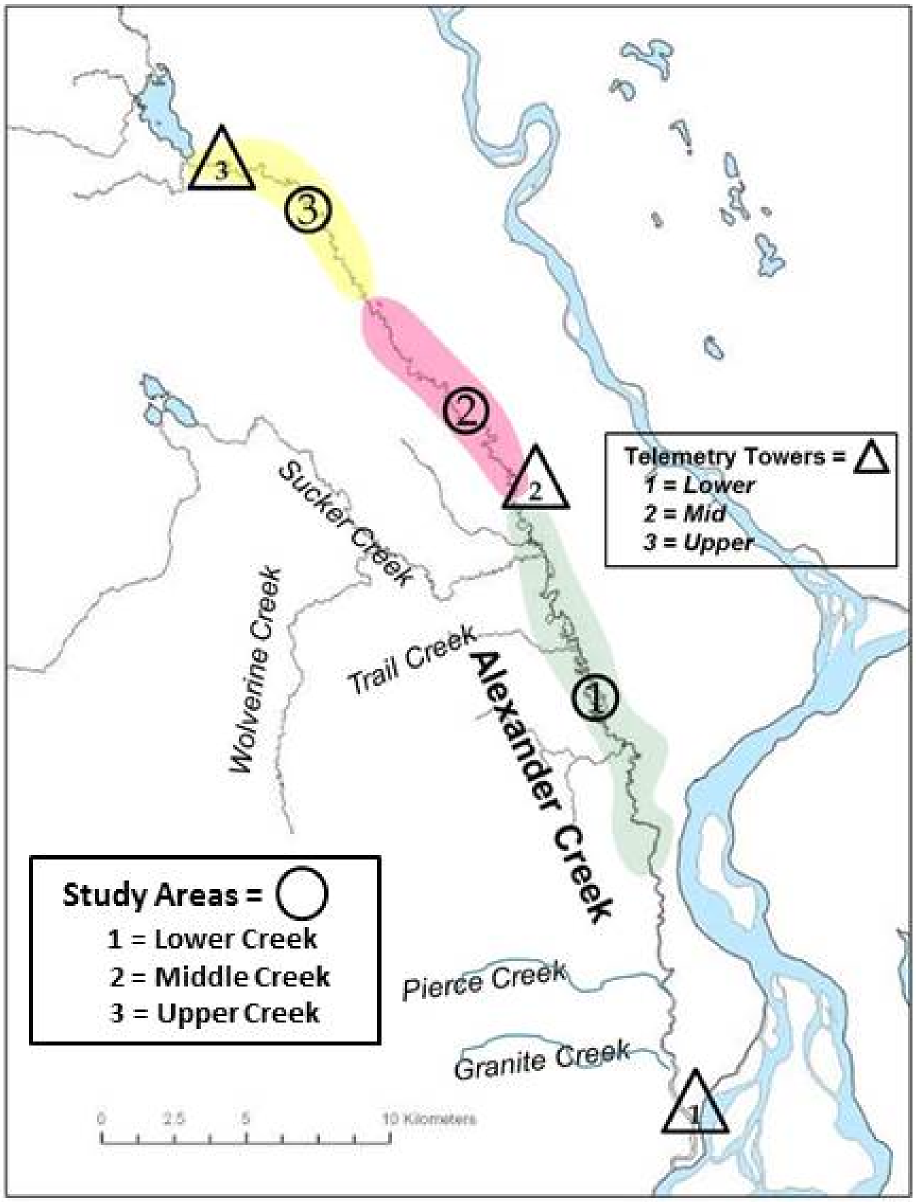

Figure 3.–Map of the Alexander Creek drainage, tributaries, study reaches, and radiotelemetry tower locations.

RESULTS

RADIO TELEMETRY ASSESSMENT OF NORTHERN PIKE MOVEMENTS IN ALEXANDER CREEK (*OBJECTIVE 1*)

A total of 150 northern pike were captured and surgically implanted with radio tags between 6 July and 26 July 2011 (Appendix A1). All tagged northern pike were transmitting live signals and in good condition at the time of their release. Tagged northern pike ranged in length from 440 mm to 786 mm, averaging 529 mm. Of the 150 tagged northern pike, 125 were tagged in the lake and 25 in the creek. Of the tagged northern pike that left the lake, no movements at all were observed or documented through either aerial tracking or locations from stationary receivers until April of 2012. Only 8 of the 125 radiotagged northern pike (465–650 mm, mean 548 mm) exited the lake, and all 8 did so between mid-April and early May (Table 1). Movements of these fish from the lake occurred for both study years (2012–2013) prior to stationary towers being operational in the spring, so radio locations of these fish were based on aerial surveys alone.

Table 1.–Capture habitat, frequency and tag number, location of recapture, and minimum distance traveled from the original tagged location for radiotagged northern pike, 2011–2013.

Initial capture habitat	Fish no.	Frequency tag no.	Tag date	Recapture date	Slough no. (recapture)	Minimum distance traveled (RKM)
Lake						
	28	151.823-2	6 Jul 2011	9 May 2012	20	22.5
	30	151.823-4	6 Jul 2011	14 May 2012	27	19.3
	32	151.823-6	7 Jul 2011	27 May 2012	48	5.6
	33	151.823-8	6 Jul 2011	31 May 2013	1	48.3
	39	151.823-15	6 Jul 2011	9 May 2012	40.5	7.2
	47	151.862-23	7 Jul 2011	2 Jun 2012	37	9.9
	129	151.902-3	8 Jul 2011	11 Jun 2012	39	9.7
	143	151.902-19	7 Jul 2011	13 Jun 2013	18	25.7
Creek						
	7	151.802-6	7 Jul 2011	29 May 2012	48	5.6
	22	151.802-23	7 Jul 2011	18 May 2012	2	17.7

By May 2012, only 101 of the original 125 tags from the lake-tagged fish remained viable (continued to broadcast live signals). Of the original 125 lake-tagged fish, 4 were never located during any of the aerial tracking events or by the stationary towers. It's assumed that either the radios malfunctioned, they were immediately caught by anglers and not reported, or they left the system before stationary receivers were operational. Fifteen of the fish displayed successive mortality signals: 2 were either captured and not reported by anglers or the radiotransmitters eventually malfunctioned, and 3 were confirmed to have been caught by anglers (Table 2). During 2012, of the 101 lake-tagged fish remaining, 6 (5.9%) migrated from the lake into the creek. By May 2013, only 68 of the original 125 radio tags remained viable, with 40 of the original tagged fish displaying mortality signals. Of the 68 fish remaining, only 2 (3%) left the lake. All radiotagged northern pike that were documented exiting the lake were captured in gillnets in the creek downstream of the lake by ADF&G northern pike suppression crews, either in the spring of 2012 or 2013 (Table 2).

Table 2.–Fate of 125 radiotagged Alexander Lake northern pike by number and percent, 2012 and 2013.

Fate of radiotagged lake northern pike	Year		Total
	2012	2013	
Remaining live tags	101 (81%)	68 (54%)	NA
Never located	4 (3%)	4 (3%)	4 (3%)
Mortalities	15 (12%)	40 (32%)	55 (44%)
Radio malfunction or angler harvest	2 (2%)	7 (6%)	9 (7%)
Known angler harvest	3 (2%)	6 (5%)	9 (7%)
Caught in gillnets	6 (5%)	2 (2%)	8 (6%)
Percent exiting lake	6%	3%	7%

Note: NA means not applicable.

Of the fish that left the lake, the farthest known downstream distance from initial capture site was recorded for fish number 33 (151.823-8; Table 1). This fish was captured, tagged, and released in northeast Alexander Lake. It mainly resided in the southern portion of the lake and then moved downstream a distance of approximately 48.3 RKM where it was captured by an ADF&G gillnet crew in the most downstream slough targeted on June 9, 2013 (Appendix B1). The second farthest downstream movement recorded was for lake-tagged fish number 143 (151.902-19). This fish was tagged in northwest Alexander Lake and resided in proximity to its original capture site prior to exiting the lake in the spring of 2013. It then traveled downstream a distance of 25.7 RKM before being captured by ADF&G crews in a slough in June 2013 (Appendix B2).

Fish number 28 (151.823-2) was tagged in the northwest area of the lake and was located throughout the lake during most tracking events. In the spring of 2012, this fish left the lake and was captured by ADF&G gillnet crews in a slough, having traveled 22.5 RKM from its original location of capture (Appendix B3). Fish number 30 (151.823-4) was also captured and tagged in the northwest section of Alexander Lake; however, this fish had a more localized range, at least while residing in the lake, spending most of its time in the southernmost area of the lake and then exiting the lake in April or May 2012 and traveling 19.3 RKM downstream prior to being captured by ADF&G gillnetting crews in May of 2012 (Appendix B4). The remaining 4 radiotagged fish that left the lake either displayed localized ranges or displayed a more widespread dispersal prior to exiting the lake (Appendices B5–B8). All 4 of these fish were recovered by ADF&G sampling crews in sloughs less than 10 RKM from the lake outlet. A radio signal from 1 additional lake-tagged fish (151.862-19) was received that would have located it approximately 20 RKM downstream; however, this fish was considered a mortality prior to leaving the lake, and all signals received downstream were mortality signals (Appendix B9).

Most (95%) of the northern pike that were tagged in the lake did not leave the lake. Habitual distribution of lake-residing northern pike demonstrated 3 distinct spatial patterns: localized (utilizing a specific area of the lake) or lake-wide distribution, but most of the lake-tagged northern pike demonstrated movement patterns somewhere in between the two. Examples of lake northern pike displaying more localized distribution patterns include fish numbers 40 (151.823-16), 96 (151.862-22), and 99 (151.862-26) (Appendices B10–B12), whereas examples of northern pike showing lake-wide ranges are fish numbers 139 (151.902-14), 26 (151.823-0), and 101 (151.882-0) (Appendices B13–B15).

Of the 25 northern pike that were radiotagged in the creek, 10 (one of which was a lake-caught fish that was tagged and accidentally transported downstream and released) were tagged within 5 RKM of the creek confluence with the Susitna River, and 15 were caught and tagged within

1 RKM of the outlet of Alexander Lake (Appendix A1, Figure 2). Of the 25 northern pike that were radiotagged in Alexander Creek, only 6 remained alive throughout the duration of the telemetry study, 12 succumbed to what we assumed to be natural mortality, 5 were either caught by anglers or subject to battery failure, and 2 were caught in gillnets by field sampling crews (Table 3). Of the 15 fish that were implanted with radio tags in the upper river (near the outlet of Alexander Lake), 6 survived the duration of the study, 8 died from natural mortality during the study, and 1 either had a radiotag battery failure or was caught by an angler. The northern pike that were tagged near the outlet of Alexander Lake generally migrated into the lake for most of the year but did not move more than 5 or 6 RKM. The typical movement of upper creek-tagged fish is shown by fish number 18 (151.802-19; Appendix B16). Of the 10 fish radiotagged in the lower river, 2 were caught in gillnets, 4 succumbed to natural mortality, and 4 were either caught by anglers, the radio transmitter failed, or the fish left the system before stationary receivers were operational in the spring (Table 3).

Table 3.–Fate of Alexander Creek radiotagged northern pike that were captured, tagged, and released in the upper and lower sections of the creek, 2011–2013.

Area tagged	Number of fish tagged	Total natural mortality	Live for duration of study	Caught by angler or battery failure	Caught in gillnet
Lower creek	10	4	0	4	2
Upper creek	15	8	6	1	0
Total	25	12	6	5	2

The greatest known movement of a northern pike captured, tagged, and released in the lower creek was for fish number 7 (151.802-6; Appendix B17). The last observed downstream location of this fish was on 13 May 2012 when it was located near RKM 19, approximately 17.7 RKM from its capture site; the next survey was flown on 27 May 2012, and that same fish was found nearly 42 RKM upstream of its previous location. Within a 14-day timespan, the total distance fish number 7 moved from location of capture to its last tracked location was nearly 60 RKM. Three of the fish radiotagged in the lower creek, numbers 9 (151.802-9), 21 (151.802-22), and 22 (151.802-23), generally moved throughout a 16 RKM reach of the lower river and appeared to migrate upstream to RKM 16, most likely to spawn given the timing of their migrations (Appendices B18–B20). Other lower creek-tagged fish generally moved less than 5 RKM from the location of their original tagging site.

Of note, 1 creek-tagged fish, number 23 (151.802-24), was actually caught in the lake on 26 July 2011 and was transported downstream, tagged, and released on that same day. The release location was lower Alexander Creek, approximately 3.2 RKM upstream of the confluence with the Susitna River. This fish migrated approximately 64 RKM back upstream and into the lake by 13 September 2011 and remained, for the most part, in the middle section of the lake for the duration of the study (Appendix B21).

ASSESSMENT OF JUVENILE NORTHERN PIKE EMIGRATING FROM ALEXANDER LAKE INTO THE CREEK (*OBJECTIVE 2*)

Despite measures to capture juvenile northern pike from 2014 through 2016, no juvenile northern pike were observed by staff or captured in fyke nets that were strategically placed at the outlet of Alexander Lake for all 3 study years (2014–2016).

DISCUSSION AND RECOMMENDATIONS

DISCUSSION

During this study, no major northern pike movement patterns out of Alexander Lake into Alexander Creek or adjacent water bodies were observed. This was an important question with ramifications for the entire northern pike suppression strategy in this system. If this study showed that a significant portion of the lake-tagged northern pike exited the lake to rear or spawn in the creek, suppression efforts would have needed to expand to include the lake, and this would have been both a costly and potentially controversial endeavor. Prior to this study, little information was available on the movement of Alexander Creek northern pike. Preliminary radiotelemetry data from the 1990s demonstrated that northern pike can move more than 10 km within a year, and movement can occur between tributaries in the Susitna River drainage (Rutz 1996). Information from Floy-tagged northern pike that were captured and tagged in Alexander Lake and recovered in gillnets during a pilot study in 2009 and 2010 (Oslund and Ivey 2010) indicated that a least some of Alexander Lake's northern pike population migrated from the lake into the creek, but there was no knowledge on the extent or magnitude of this movement. In addition, northern pike have been captured in ADF&G fishwheels in both the Yentna and Susitna River mainstems (unpublished data on file with ADF&G Division of Sport Fish, Palmer, contact Sam Ivey). These are large, glacial, high-velocity river systems that do not support northern pike habitat within their mainstems, so it is likely that northern pike utilize these rivers as migration corridors to seek suitable habitat elsewhere in the drainage. Northern pike have also been caught in commercial setnets in the saline waters of Upper Cook Inlet (UCI) (personal communication with UCI setnetters). However, the findings of this study demonstrated that only a small percentage of radiotagged northern pike left Alexander Lake (about 6%), and all that were documented doing so were captured in ADF&G northern pike suppression gillnets downstream in Alexander Creek sloughs. This not only demonstrated the effectiveness of the suppression project but validates that the timing of suppression activities coincides with the timing of northern pike migration into the creek for those northern pike that do move out of the lake. However, this assumes that radiotagged lake northern pike display similar survival and movement behavior patterns to all northern pike in the lake.

Earlier investigations have attempted to estimate the population size of northern pike in Alexander Lake. The complexity of the habitat makes population estimation difficult, but this earlier work suggested that the northern pike population in the lake could exceed 13,000 fish (36/hectare) (Rutz 1999; Oslund and Ivey 2010) for fish greater than 300 mm. Using this estimate as a starting point and applying the proportion of radiotagged northern pike that migrated from Alexander Lake, it is conceivable that approximately 772 (95% CI 260–1,417) northern pike leave Alexander Lake annually during the spring spawning period each year. Catches in suppression gillnets in Alexander Creek sloughs have ranged from 997 (2017) to 3,987 (2011) since suppression efforts began (Rutz et al. 2020). Although lake-originating northern pike probably contribute to some of these catches, evidence from the telemetry study does not suggest this occurs at levels detrimental to the northern pike suppression strategy but does suggest that most northern pike exiting the lake probably succumb to spring gillnetting, thus substantially reducing that portion of the lake's northern pike population attempting to spawn downstream.

Information from the telemetry study has already benefited the northern pike suppression program by identifying how northern pike use open systems outside their native range. This study also demonstrated that, at least between 2011 and 2013, there was no observed movement of radiotagged northern pike from Alexander Creek into other Susitna River drainage systems or watersheds; however, there is no way of knowing if those radiotagged northern pike that were caught in the gillnets would have remained in the system. Radio locations of overwintering Alexander Lake and Alexander Creek northern pike were used to direct anglers to areas of the lake and creek where the overwintering population was more abundant and therefore might increase angler chances of harvesting northern pike during the ice-covered months. This, however, did not result in any increase in angler harvest of radiotagged northern pike.

Though the telemetry study showed no major migration of adult northern pike from the lake, it did not address whether juvenile northern pike had similar movement patterns. Larsen (1966) documented that the recruitment of age-0+ northern pike into Danish trout streams did not result from spawning in the river but from bogs, wetlands, and lakes, and from migration downstream from sloughs or backwater areas into the streams. Forney (1968) found that young northern pike seemed to locate the outlet of the lake by swimming parallel to the shore until they detected an outlet current. Sepulveda et al. (2013) documented very low levels of cannibalism in Alexander Creek, and this has been corroborated through ADF&G's northern pike suppression data (Rutz et al. 2020). However, in Alexander Lake, where few to no other fish of other species remain, cannibalism rates on smaller northern pike may be higher. Northern pike are known to be highly opportunistic in their feeding and exhibit a high degree of trophic plasticity, which allows them to exploit available prey sources, even when these resources are not preferred prey (Mann 1985; Sepulveda et al. 2013). It is unknown if differences in cannibalism rates between lake and creek habitats influences movement patterns of juvenile northern pike, but this could be an area warranting further study. However, no northern pike juveniles were captured or observed leaving the lake for any of the study years. Juvenile northern pike are notoriously difficult to sample because the habitat they occupy consists primarily of marshes or shallow water with submerged and emergent vegetation, and these fish tend not to recruit well to sampling gear (Bry 1996; Casselman 1996; Pierce et al. 2007). Given that, it is plausible that the lack of juvenile northern pike captured in our fyke nets could be because of gear failure; however, given that no juvenile pike were observed by staff during this investigation at or near the lake outlet, it is also plausible that juvenile pike may not be migrating out of the lake in detectable numbers. Due to this uncertainty, this question remains and will warrant further investigation.

Another complication in assessing movement of northern pike out of Alexander Lake is that an invasive aquatic plant (common water weed, *Elodea candensis,* referred to as elodea) was discovered in Alexander Lake in 2014. At that time, elodea was only present in a 16-hectare section of the lake, but by 2016, it had increased exponentially and covered approximately 283 hectares, or about 70% of the entire surface area of the lake. Between 2016 and 2017, Alexander Lake was treated with herbicides 3 times but thus far the treatments have been unsuccessful in eradicating elodea. Presently, elodea occupies approximately 90% of the lake. Plans are being developed to remove this invasive species. However, the present distribution of elodea in Alexander Lake has tremendous potential to affect movement patterns of northern pike in the system. This radiotelemetry study occurred before the elodea invasion. Because elodea has spread in such a short time throughout most of the lake and formed extensive areas of dense vegetative mats, large northern pike may now be displaced due to habitat encroachment by this aquatic plant and there may be increased migration of large fish out of the lake as a result. Diana (1979) found that large-sized northern pike preferred vegetative zones, though Grimm (1983) found large-sized northern pike to be less dependent upon aquatic vegetation. However, given the density of elodea in Alexander Lake, it has been evident to field crews and local fishermen in the last few years that large-sized northern pike were noticeably absent from these dense elodea mats, perhaps because maneuverability and visual foraging opportunities are severely restricted. Displacement of northern pike by elodea could be a possible explanation for recent increases in catches of northern pike in nearby sloughs by suppression crews (Rutz et al. 2020). Frost and Kipling (1967) report that northern pike in Windermere Lake, UK spawn in areas where vegetation includes elodea. It is possible that the presence of elodea in Alexander Lake may increase spawning habitat from spring flooded meadows to a larger portion of the lake proper and create even more optimal habitat for juvenile northern pike. Juvenile northern pike occupy areas of dense aquatic vegetation (Bregazzi and Kennedy 1980; Inskip 1982; Malley and Brown 1983). Therefore, it is likely that although elodea may displace larger-sized northern pike from some areas, smaller northern pike would be well suited to this dense elodea growth. This change in habitat structure in the lake could potentially explain the lack of juvenile northern pike found in fyke nets at the lake outlet during 2014–2016 because this was the time when elodea was rapidly expanding in the lake and altering the habitat. Therefore, it is recommended that ADF&G continue to monitor Alexander Lake in the future to understand how this habitat change is affecting northern pike distribution.

RECOMMENDATIONS

The northern pike movement study in the Alexander Creek system was a very important component of the larger initiative to begin long-term northern pike suppression in Alexander Creek. Although the initial information provided by this study helped established ADF&G's suppression strategies, recent changes in the habitat of Alexander Lake now call into question the contemporary value of the original project results reported here. On a positive note, significant progress is underway to plan effective eradication of elodea from the Alexander system. It is recommended that ADF&G remain engaged with partners on this effort because it has direct ramifications for protecting almost a decade of effort and investment in Alexander Creek northern pike suppression. Furthermore, although undertaking a new radio telemetry study is not currently financially feasible, more qualitative attempts to look at changing movement patterns of larger northern pike are warranted. Recommendations include using ADF&G crews that are stationed at the Alexander Lake outlet for the suppression project to intentionally fish Alexander Lake via hook and line after suppression activities in the creek cease for the day. All northern pike caught by this method could be implanted with Passive Integrated Transmitter (PIT) tags. Tag numbers and GPS coordinates would be recorded. Then, during regular northern pike suppression netting, all captured fish could be scanned for tags to look for downstream movements of these fish. If a higher proportion of PIT-tagged fish are recovered than observed from the results of the telemetry study reported here, it would indicate that movement patterns in the system shifted after elodea infestation. In addition, efforts should continue to look for juvenile northern pike migration from Alexander Lake. If PIT-tagged or juvenile northern pike are found leaving the lake at greater rates than previously understood, the outcome of these observations would be that ADF&G reconsider some level of northern pike suppression in Alexander Lake in the future and begin developing plans and budgets to accommodate this expansion.

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APPENDIX A: RADIOTAG DEPLOYMENT IN ALEXANDER CREEK DRAINAGE

Appendix A1.–Alexander Creek drainage northern pike radio tag deployment, July 2011.

Fish number	Date	Capture area [a]	Habitat	Surgery time (minutes)	Length (mm)	Frequency	Pulse code
1	10 Jul	UC	Creek	5	495	151.802	0
2	10 Jul	UC	Creek	5	564	151.802	1
3	19 Jul	UC	Creek	5	521	151.802	2
4	26 Jul	LC	Creek	5	590	151.802	3
5	26 Jul	LC	Creek	5	621	151.802	4
6	25 Jul	LC	Creek	5	640	151.802	5
7	25 Jul	LC	Creek	5	583	151.802	6
8	19 Jul	UC	Creek	5	518	151.802	8
9	14 Jul	LCC	Creek	6	564	151.802	9
10	19 Jul	UC	Creek	5	527	151.802	11
11	19 Jul	UC	Creek	5	501	151.802	12
12	19 Jul	UC	Creek	5	552	151.802	13
13	10 Jul	UC	Creek	5	610	151.802	14
14	14 Jul	LCC	Creek	5	476	151.802	15
15	26 Jul	LC	Creek	5	612	151.802	16
16	10 Jul	UC	Creek	5	449	151.802	17
17	10 Jul	UC	Creek	5	522	151.802	18
18	19 Jul	UC	Creek	5	498	151.802	19
19	19 Jul	UC	Creek	5	440	151.802	20
20	19 Jul	UC	Creek	5	482	151.802	21
21	26 Jul	LC	Creek	5	588	151.802	22
22	26 Jul	LC	Creek	5	641	151.802	23
23	26 Jul	LC	Creek	5	594	151.802	24
24	19 Jul	UC	Creek	5	516	151.802	26
25	19 Jul	UC	Creek	5	452	151.802	75
26	6 Jul	NW	Lake	8	486	151.823	0
27	7 Jul	NW	Lake	8	515	151.823	1
28	6 Jul	NW	Lake	9	504	151.823	2
29	6 Jul	NW	Lake	7	449	151.823	3
30	7 Jul	NW	Lake	6	468	151.823	4
31	6 Jul	NW	Lake	8	495	151.823	5
32	7 Jul	NW	Lake	8	650	151.823	6
33	6 Jul	NW	Lake	6	465	151.823	8
34	7 Jul	NW	Lake	8	501	151.823	9
35	7 Jul	NW	Lake	8	576	151.823	11
36	6 Jul	NW	Lake	5	515	151.823	12
37	6 Jul	NW	Lake	8	467	151.823	16
38	7 Jul	NW	Lake	10	507	151.823	14
39	6 Jul	NW	Lake	6	620	151.823	15
40	6 Jul	NW	Lake	8	508	151.823	16
41	7 Jul	NW	Lake	5	485	151.823	17
42	7 Jul	NW	Lake	8	440	151.823	18
43	6 Jul	NW	Lake	8	512	151.823	19
44	6 Jul	NW	Lake	10	565	151.823	20
45	6 Jul	NW	Lake	7	556	151.823	21

-continued-

Fish number	Date	Capture area [a]	Habitat	Surgery time (minutes)	Length (mm)	Frequency	Pulse code
46	6 Jul	NW	Lake	6	503	151.823	22
47	7 Jul	NW	Lake	7	523	151.823	23
48	6 Jul	NW	Lake	10	501	151.823	24
49	6 Jul	NW	Lake	8	500	151.823	26
50	7 Jul	NW	Lake	8	543	151.823	75
51	8 Jul	NW	Lake	10	510	151.842	0
52	8 Jul	NW	Lake	7	533	151.842	1
53	8 Jul	NW	Lake	4	468	151.842	2
54	8 Jul	NW	Lake	7	553	151.842	3
55	8 Jul	NW	Lake	6	501	151.842	4
56	8 Jul	NW	Lake	6	560	151.842	5
57	8 Jul	NW	Lake	9	587	151.842	6
58	8 Jul	NW	Lake	9	461	151.842	8
59	8 Jul	NW	Lake	7	505	151.842	9
60	8 Jul	NW	Lake	7	561	151.842	11
61	8 Jul	NW	Lake	4	518	151.842	12
62	8 Jul	NW	Lake	9	507	151.842	13
63	8 Jul	NW	Lake	6	506	151.842	14
64	8 Jul	NW	Lake	6	555	151.842	15
65	8 Jul	NW	Lake	6	568	151.842	16
66	8 Jul	NW	Lake	7	539	151.842	17
67	8 Jul	NW	Lake	9	522	151.842	18
68	8 Jul	NW	Lake	8	476	151.842	19
69	8 Jul	NW	Lake	4	522	151.842	20
70	8 Jul	NW	Lake	7	518	151.842	21
71	8 Jul	NW	Lake	5	513	151.842	22
72	8 Jul	NW	Lake	9	504	151.842	23
73	8 Jul	NW	Lake	9	544	151.842	24
74	8 Jul	NW	Lake	7	509	151.842	26
75	8 Jul	NW	Lake	6	558	151.842	75
76	7 Jul	NW	Lake	7	583	151.862	0
77	7 Jul	NW	Lake	9	489	151.862	1
78	7 Jul	NW	Lake	7	540	151.862	2
79	7 Jul	NW	Lake	5	469	151.862	3
80	7 Jul	NW	Lake	6	531	151.862	4
81	7 Jul	NW	Lake	6	479	151.862	5
82	7 Jul	NW	Lake	7	510	151.862	6
83	7 Jul	NW	Lake	7	502	151.862	8
84	7 Jul	NW	Lake	6	557	151.862	9
85	7 Jul	NW	Lake	7	502	151.862	11
86	7 Jul	NW	Lake	7	529	151.862	12
87	7 Jul	NW	Lake	8	527	151.862	13
88	7 Jul	NW	Lake	7	456	151.862	14
89	7 Jul	NW	Lake	7	542	151.862	15
90	7 Jul	NW	Lake	6	489	151.862	16

-continued-

Fish number	Date	Capture area [a]	Habitat	Surgery time (minutes)	Length (mm)	Frequency	Pulse code
91	7 Jul	NW	Lake	7	666	151.862	17
92	7 Jul	NW	Lake	7	512	151.862	18
93	7 Jul	NW	Lake	6	444	151.862	19
94	7 Jul	NW	Lake	8	555	151.862	20
95	7 Jul	NW	Lake	9	535	151.862	21
96	7 Jul	NW	Lake	7	474	151.862	22
97	7 Jul	NW	Lake	8	489	151.862	23
98	7 Jul	NW	Lake	9	543	151.862	24
99	7 Jul	NW	Lake	5	532	151.862	26
100	7 Jul	NW	Lake	5	486	151.862	75
101	9 Jul	W	Lake	5	545	151.882	0
102	9 Jul	W	Lake	5	520	151.882	1
103	9 Jul	E	Lake	5	573	151.882	2
104	9 Jul	E	Lake	5	484	151.882	3
105	9 Jul	E	Lake	5	570	151.882	4
106	9 Jul	N	Lake	5	567	151.882	5
107	9 Jul	N	Lake	5	506	151.882	6
108	9 Jul	W	Lake	5	480	151.882	8
109	9 Jul	W	Lake	5	528	151.882	9
110	9 Jul	N	Lake	5	474	151.882	11
111	9 Jul	N	Lake	5	550	151.882	12
112	9 Jul	N	Lake	5	564	151.882	13
113	9 Jul	W	Lake	5	484	151.882	14
114	9 Jul	N	Lake	5	556	151.882	15
115	9 Jul	N	Lake	5	494	151.882	16
116	9 Jul	N	Lake	5	475	151.882	17
117	9 Jul	E	Lake	5	547	151.882	18
118	9 Jul	E	Lake	5	574	151.882	19
119	9 Jul	E	Lake	5	534	151.882	20
120	9 Jul	N	Lake	5	568	151.882	21
121	9 Jul	N	Lake	5	503	151.882	22
122	9 Jul	E	Lake	5	537	151.882	23
123	9 Jul	E	Lake	5	650	151.882	24
124	9 Jul	E	Lake	5	514	151.882	26
125	9 Jul	N	Lake	5	523	151.882	75
126	8 Jul	NE	Lake	6	607	151.902	0
127	8 Jul	NE	Lake	4	598	151.902	1
128	8 Jul	NE	Lake	6	477	151.902	2
129	8 Jul	NE	Lake	5	528	151.902	3
130	8 Jul	NE	Lake	5	571	151.902	4
131	8 Jul	NE	Lake	7	479	151.902	5
132	8 Jul	NE	Lake	6	482	151.902	6
133	8 Jul	NE	Lake	5	546	151.902	7
134	8 Jul	NE	Lake	3	464	151.902	8
135	8 Jul	NE	Lake	5	497	151.902	9

-continued-

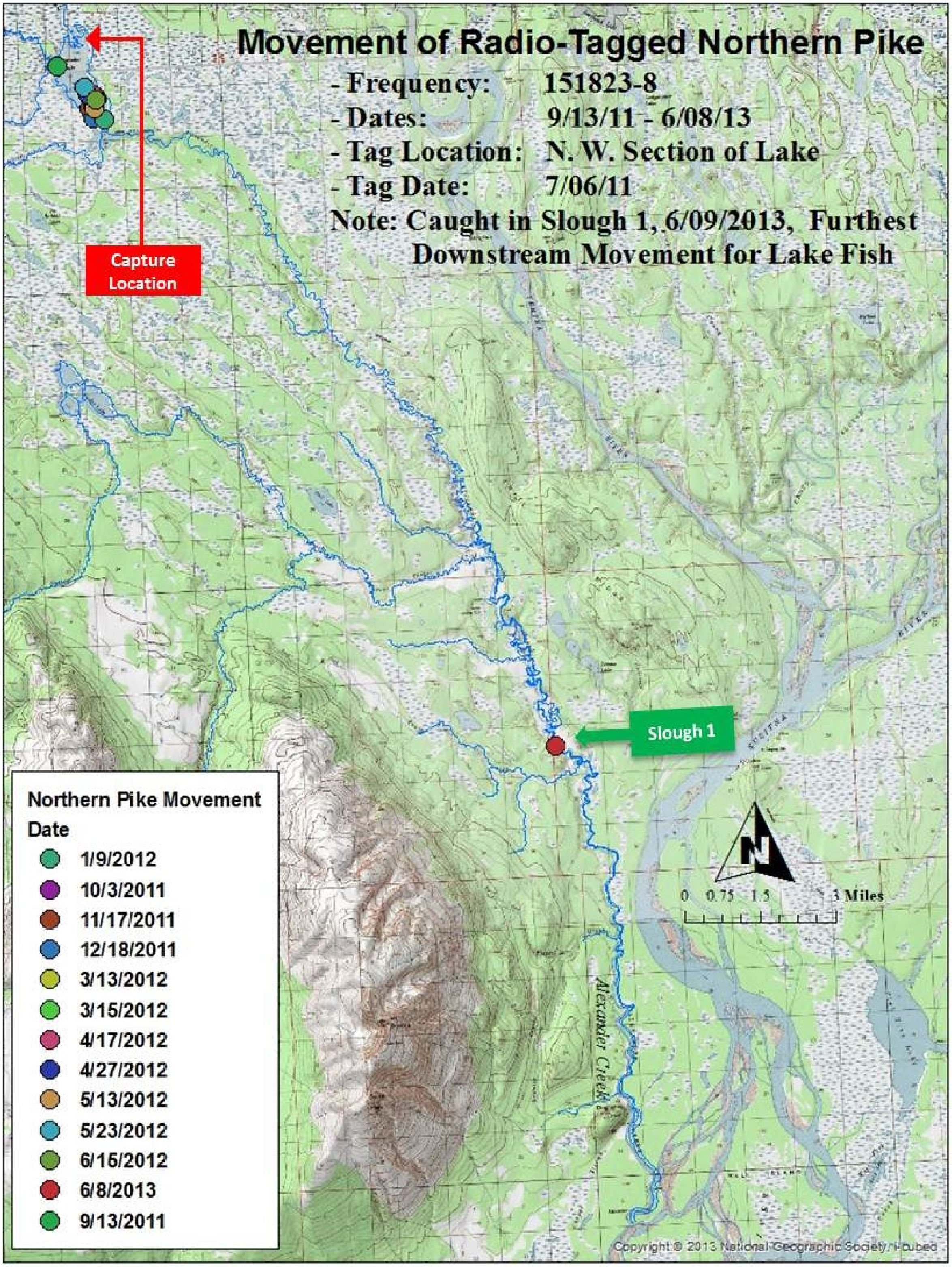
Appendix A1.–Page 4 of 4.

Fish number	Date	Capture area [a]	Habitat	Surgery time (minutes)	Length (mm)	Frequency	Pulse code
136	8 Jul	NE	Lake	6	460	151.902	11
137	8 Jul	NW	Lake	6	541	151.902	12
138	8 Jul	NE	Lake	7	464	151.902	13
139	8 Jul	NE	Lake	7	499	151.902	14
140	8 Jul	NE	Lake	7	602	151.902	15
141	8 Jul	NE	Lake	8	786	151.902	16
142	8 Jul	NE	Lake	5	537	151.902	18
143	8 Jul	NE	Lake	6	622	151.902	19
144	8 Jul	NE	Lake	7	688	151.902	20
145	8 Jul	NE	Lake	5	558	151.902	21
146	8 Jul	NE	Lake	5	537	151.902	22
147	8 Jul	NE	Lake	6	552	151.902	23
148	8 Jul	NW	Lake	6	519	151.902	24
149	8 Jul	NE	Lake	4	508	151.902	26
150	8 Jul	NE	Lake	5	482	151.902	75

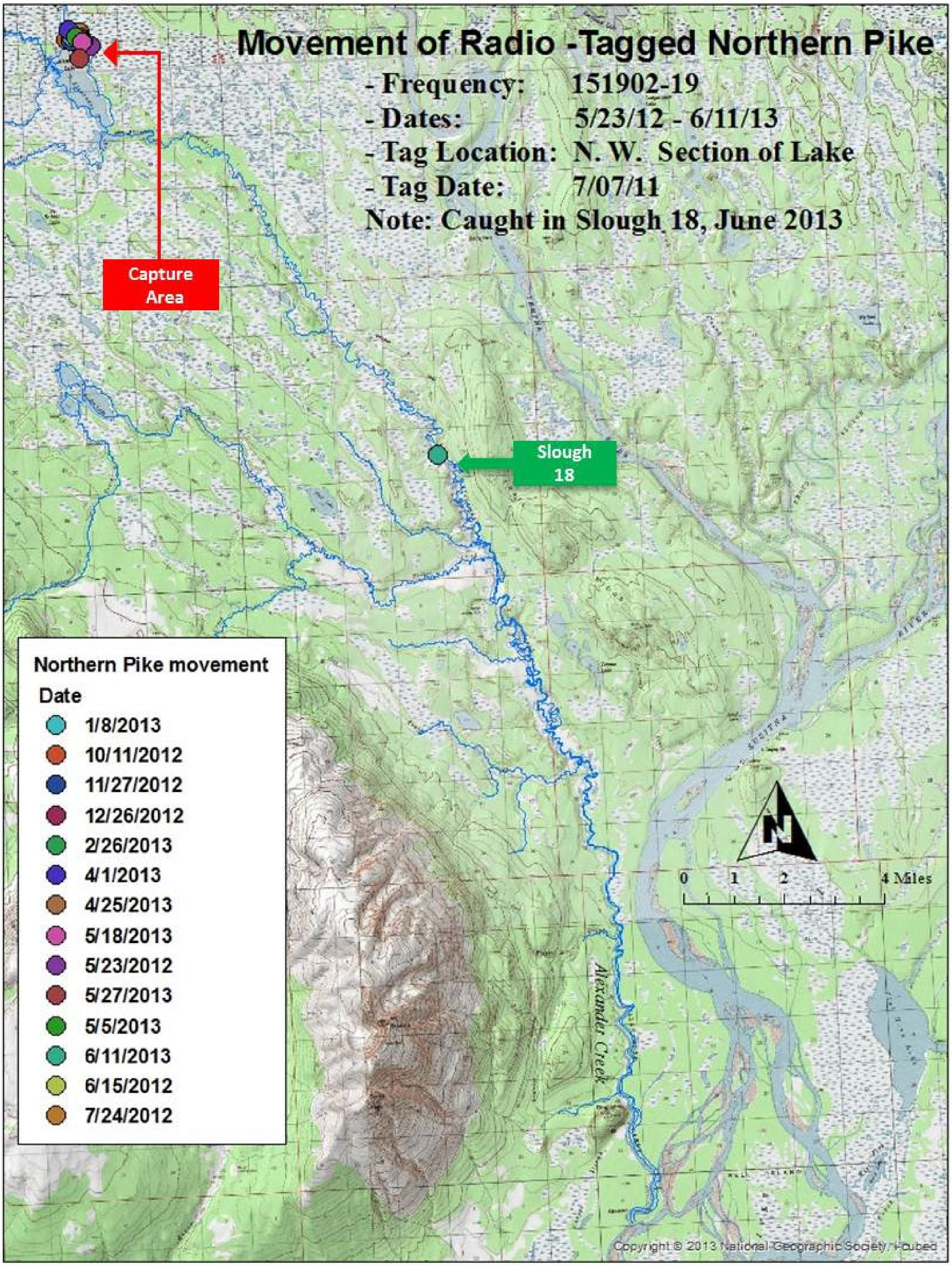
[a] For creek habitat, LC means lower creek, 4.8 km upstream of the Alexander Creek confluence with the Susitna River; UC means upper creek near lake outlet; and LCC means lower creek within 1.6 km of the confluence of Alexander Creek and the Susitna River. For lake habitat, capture locations are indicated by cardinal directions from the center of the lake, i.e., north (N), northeast (NE), east (E), northwest (NW), and west (W).

APPENDIX B: MOVEMENTS OF LAKE-TAGGED NORTHERN PIKE IN ALEXANDER CREEK DRAINAGE

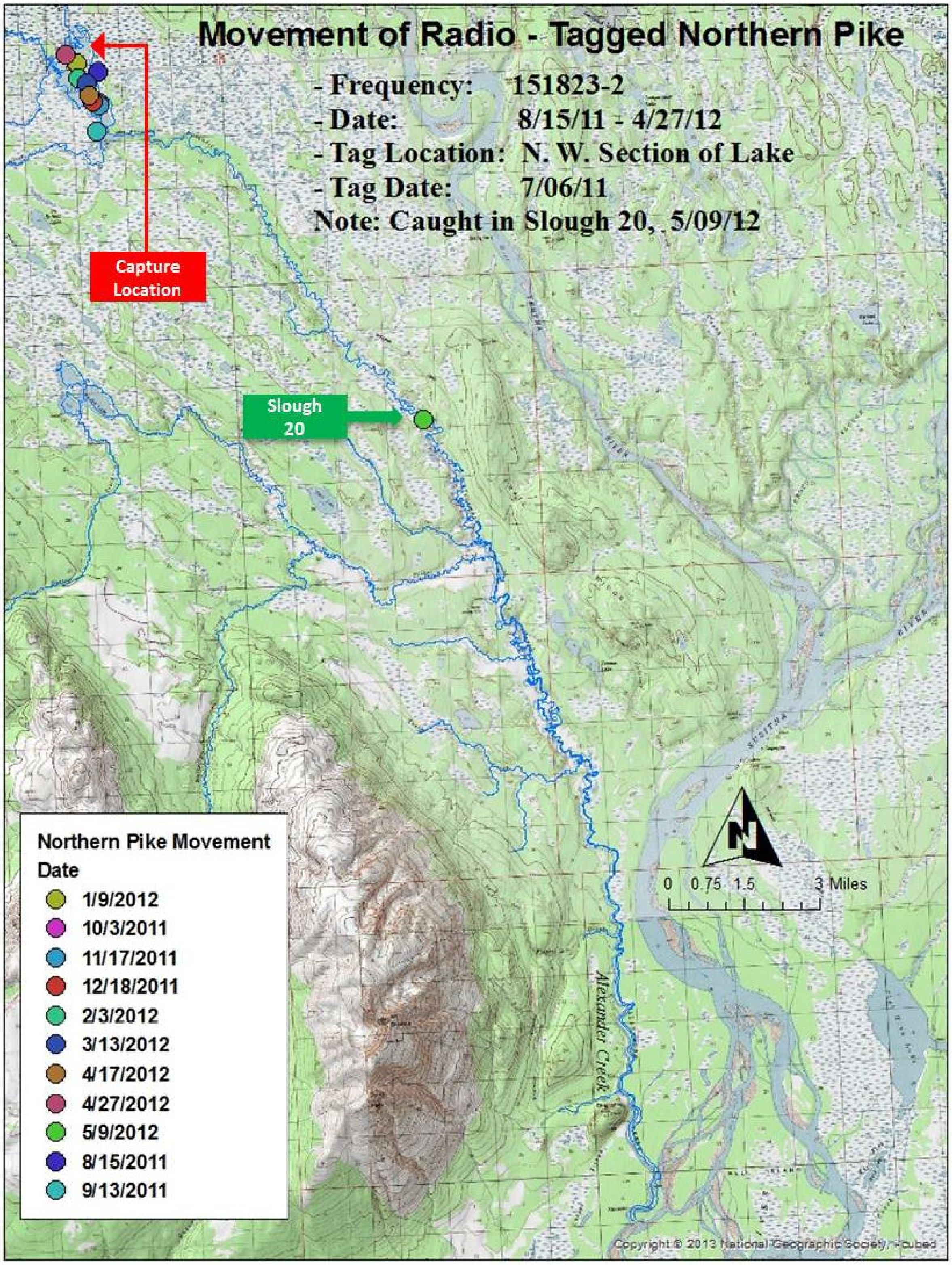
Appendix B1.–Movements of lake-tagged northern pike number 33 (151.823-8) in Alexander Creek drainage, September 2011–June 2013.



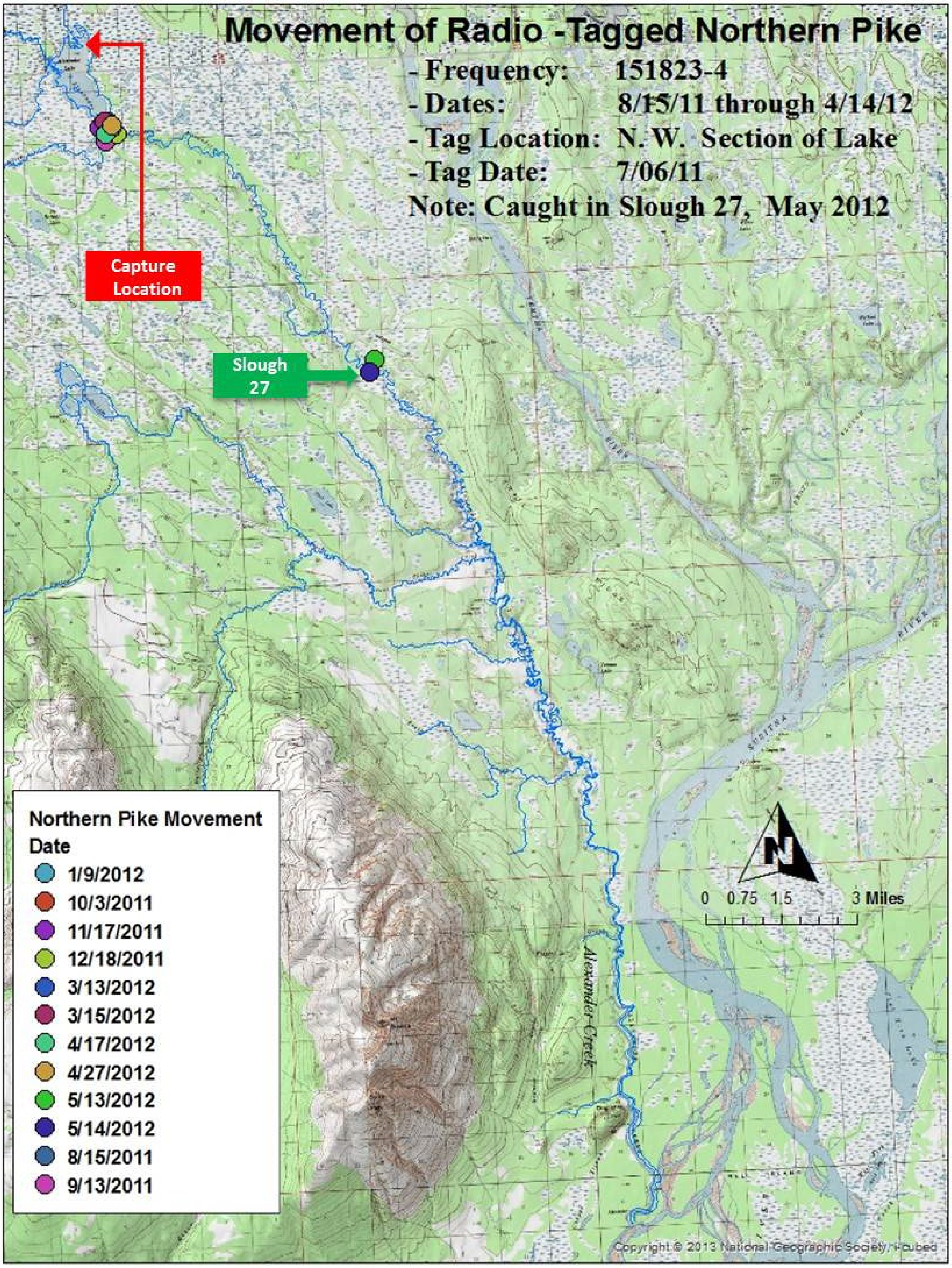
Appendix B2.–Movements of lake-tagged northern pike number 143 (151.902-19) in Alexander Creek drainage, May 2012–June 2013.



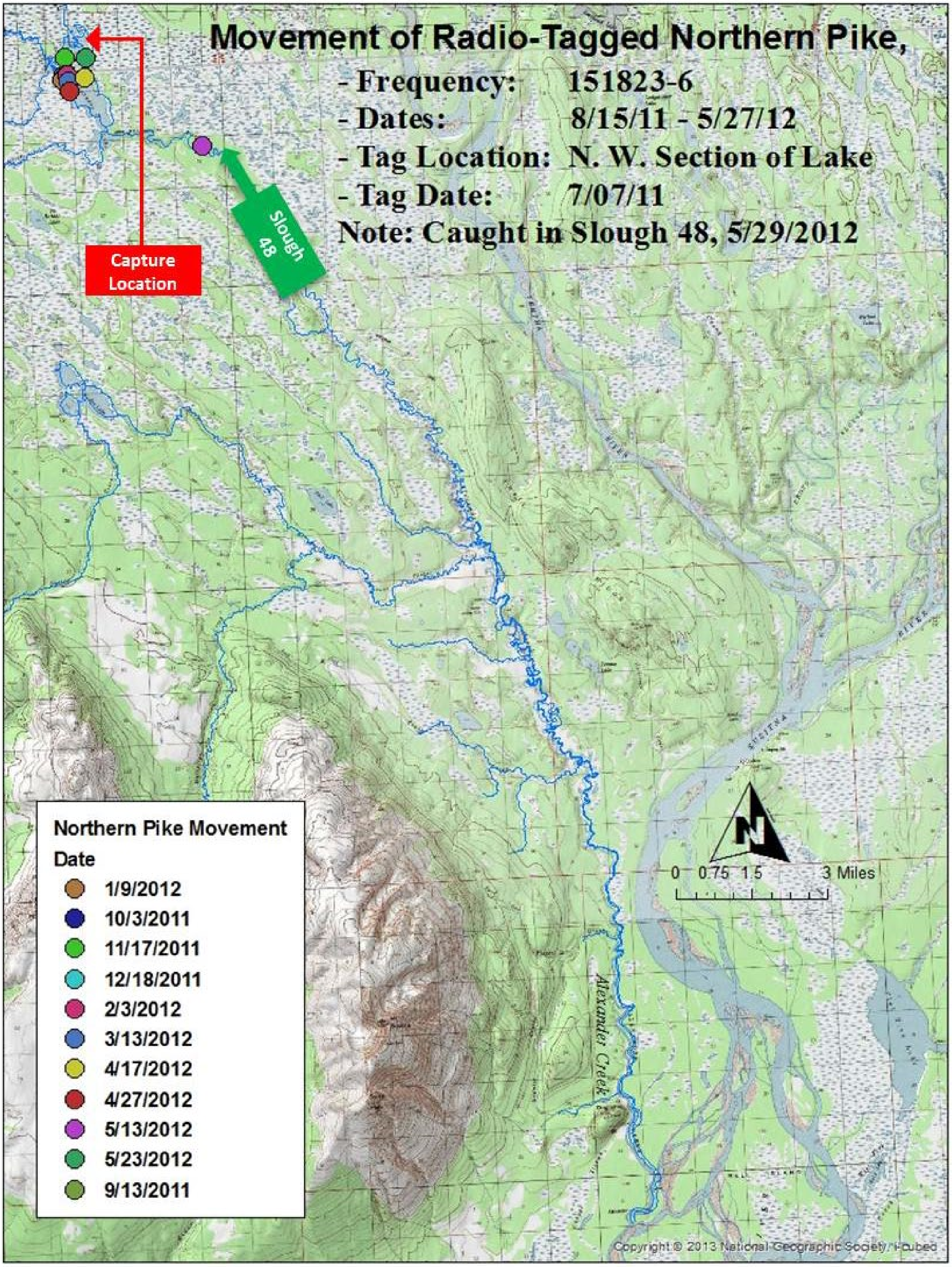
Appendix B3.–Movements of lake-tagged northern pike number 28 (151.823-2) in Alexander Creek drainage, August 2011–April 2012.



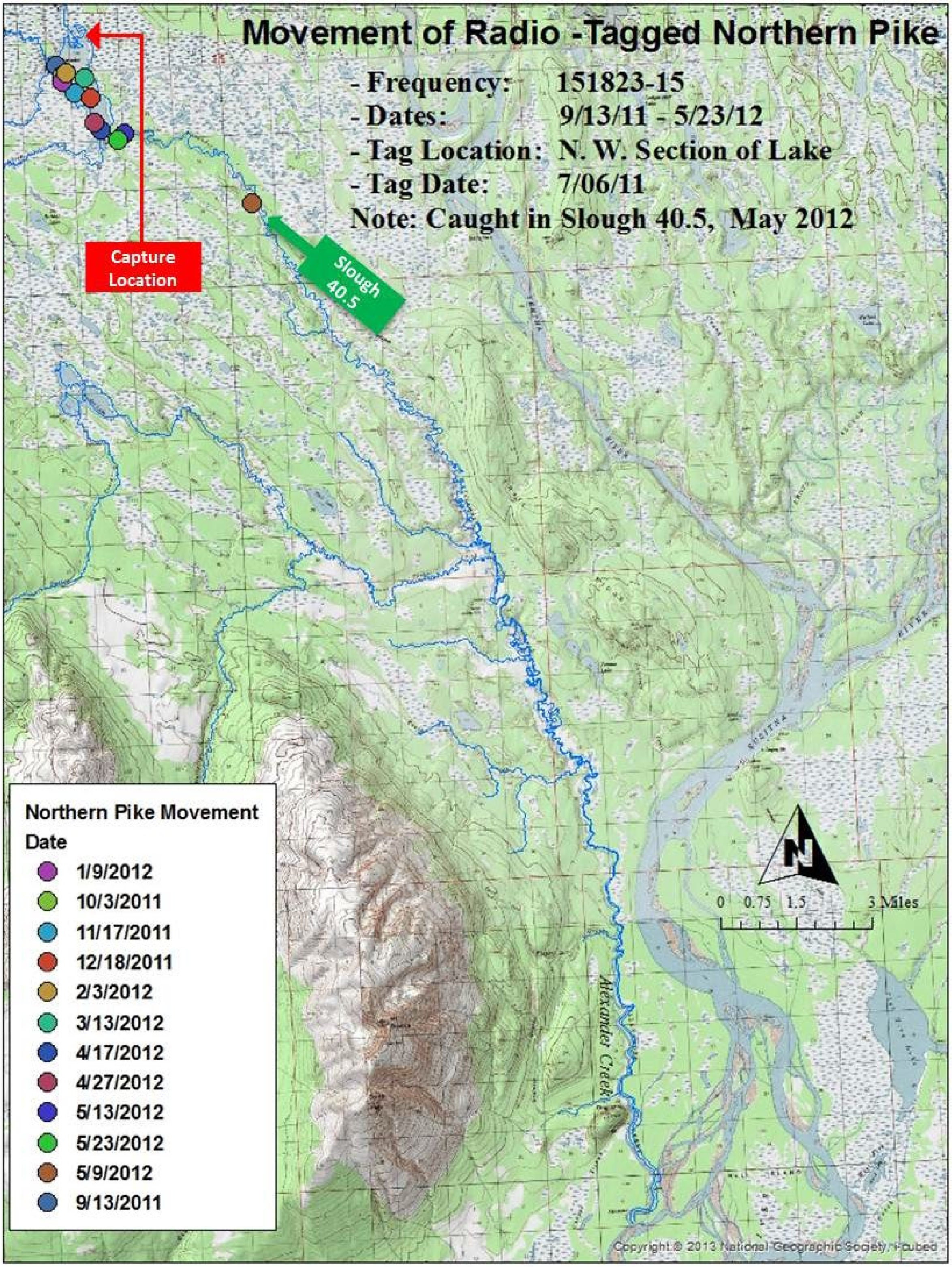
Appendix B4.–Movements of lake-tagged northern pike number 30 (151.823-4) in Alexander Creek drainage, August 2011–April 2012.



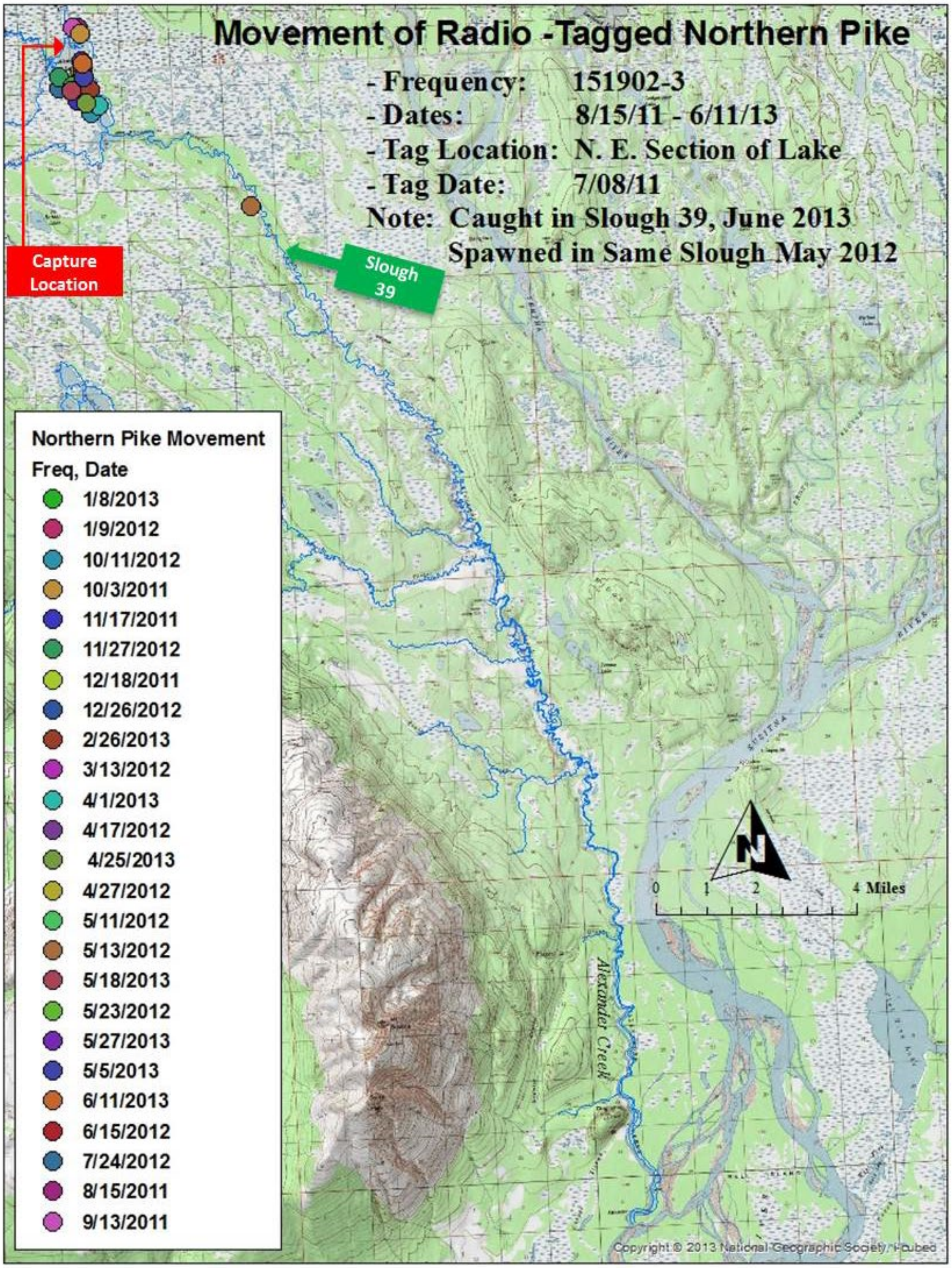
Appendix B5.–Movements of lake-tagged northern pike number 32 (151.823-6) in Alexander Creek drainage, August 2011–May 2012.



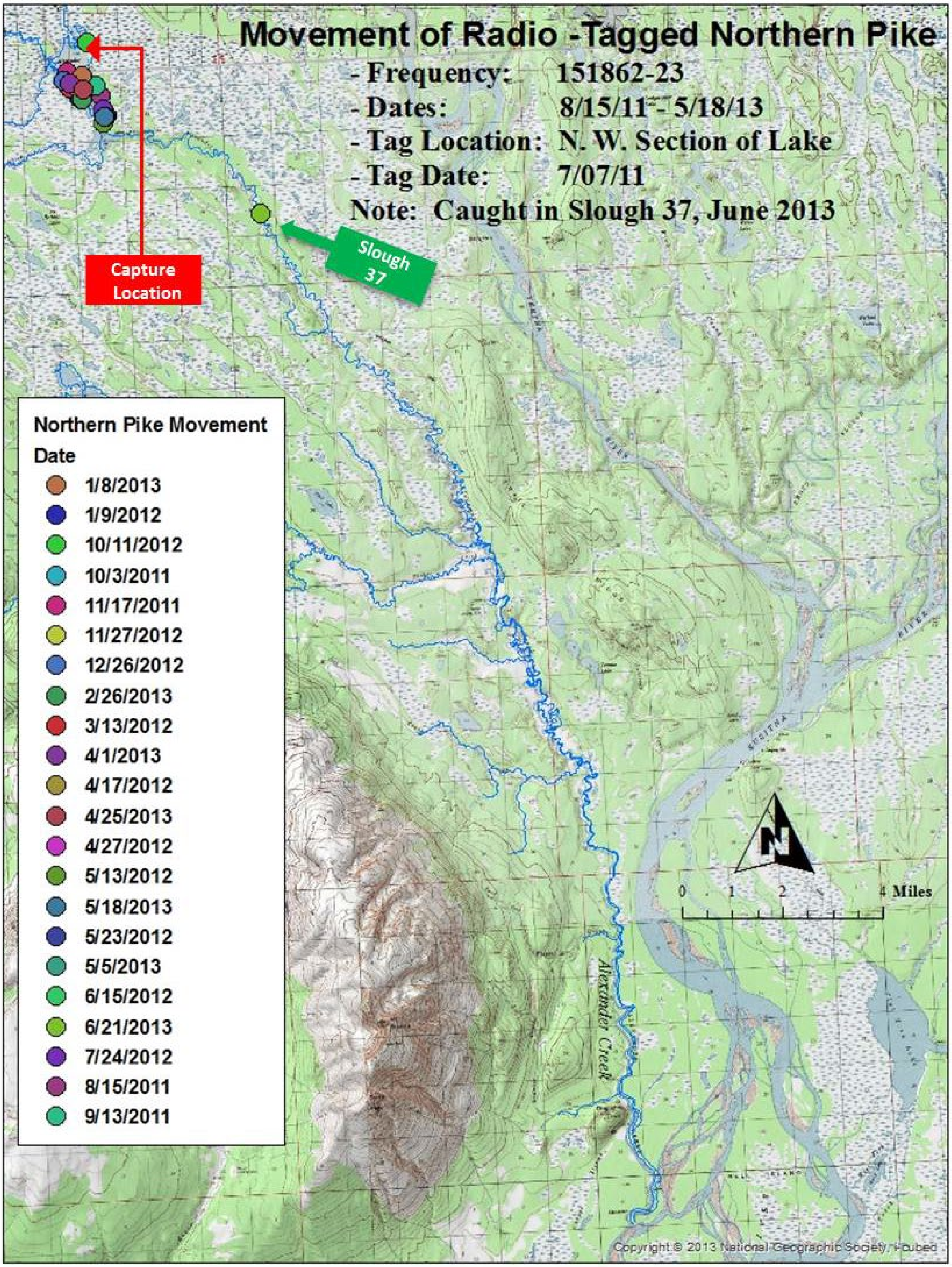
Appendix B6.–Movements of lake-tagged northern pike number 39 (151.823-15) in Alexander Creek drainage, September 2011–May 2012.



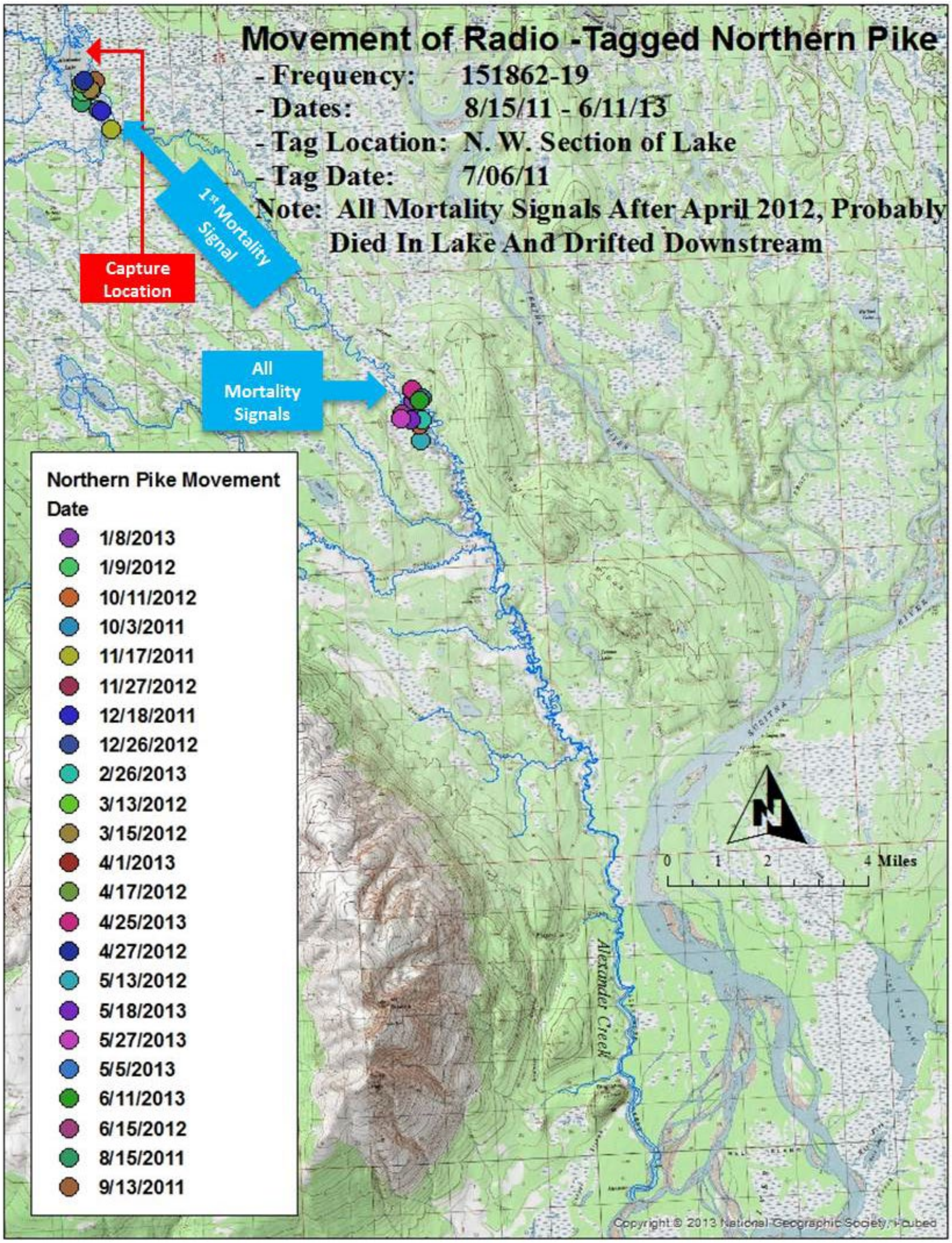
Appendix B7.–Movements of lake-tagged northern pike number 129 (151.902-3) in Alexander Creek drainage, August 2011–June 2013.



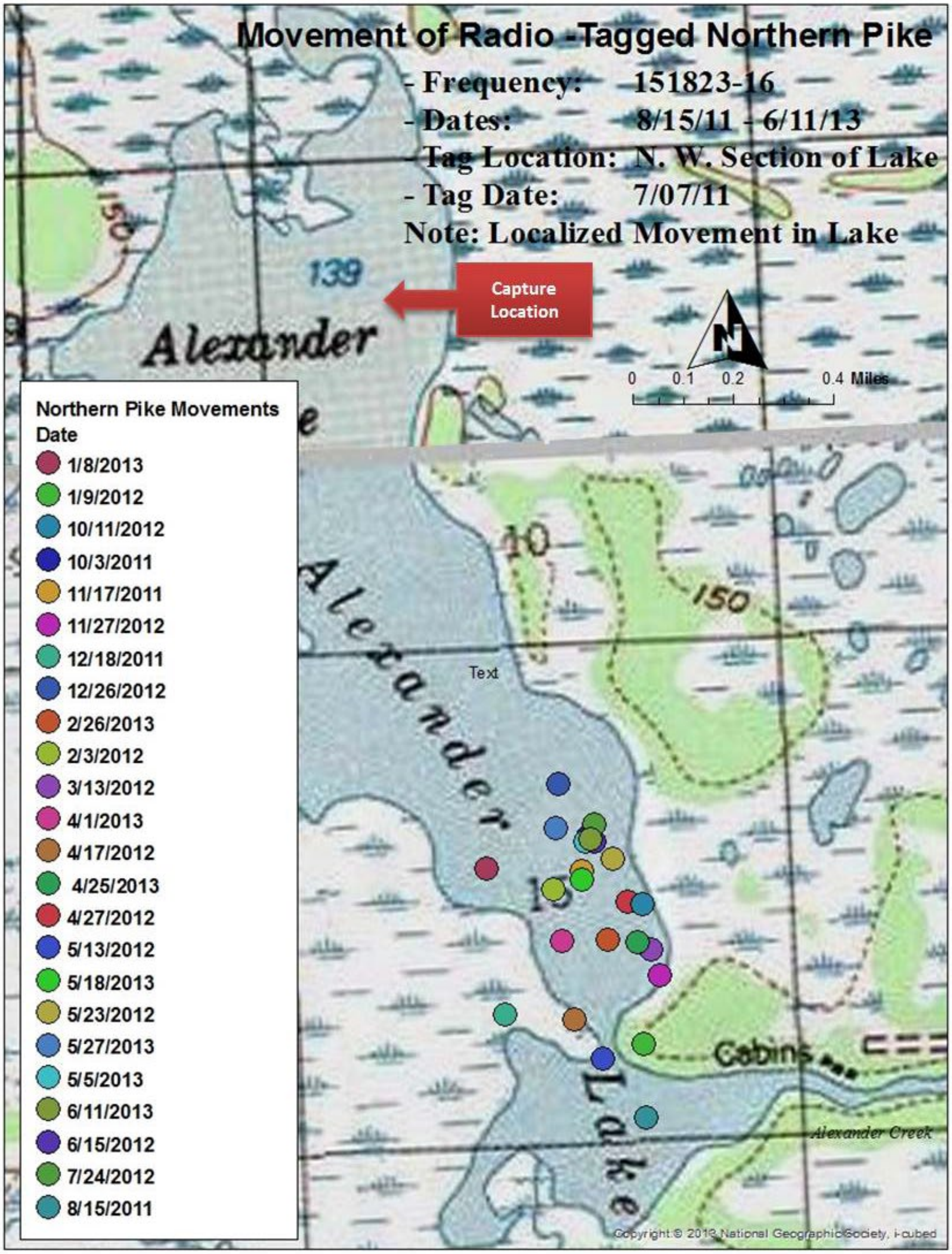
Appendix B8.–Movements of lake-tagged northern pike number 97 (151.862-23) in Alexander Creek drainage, August 2011–May 2013.



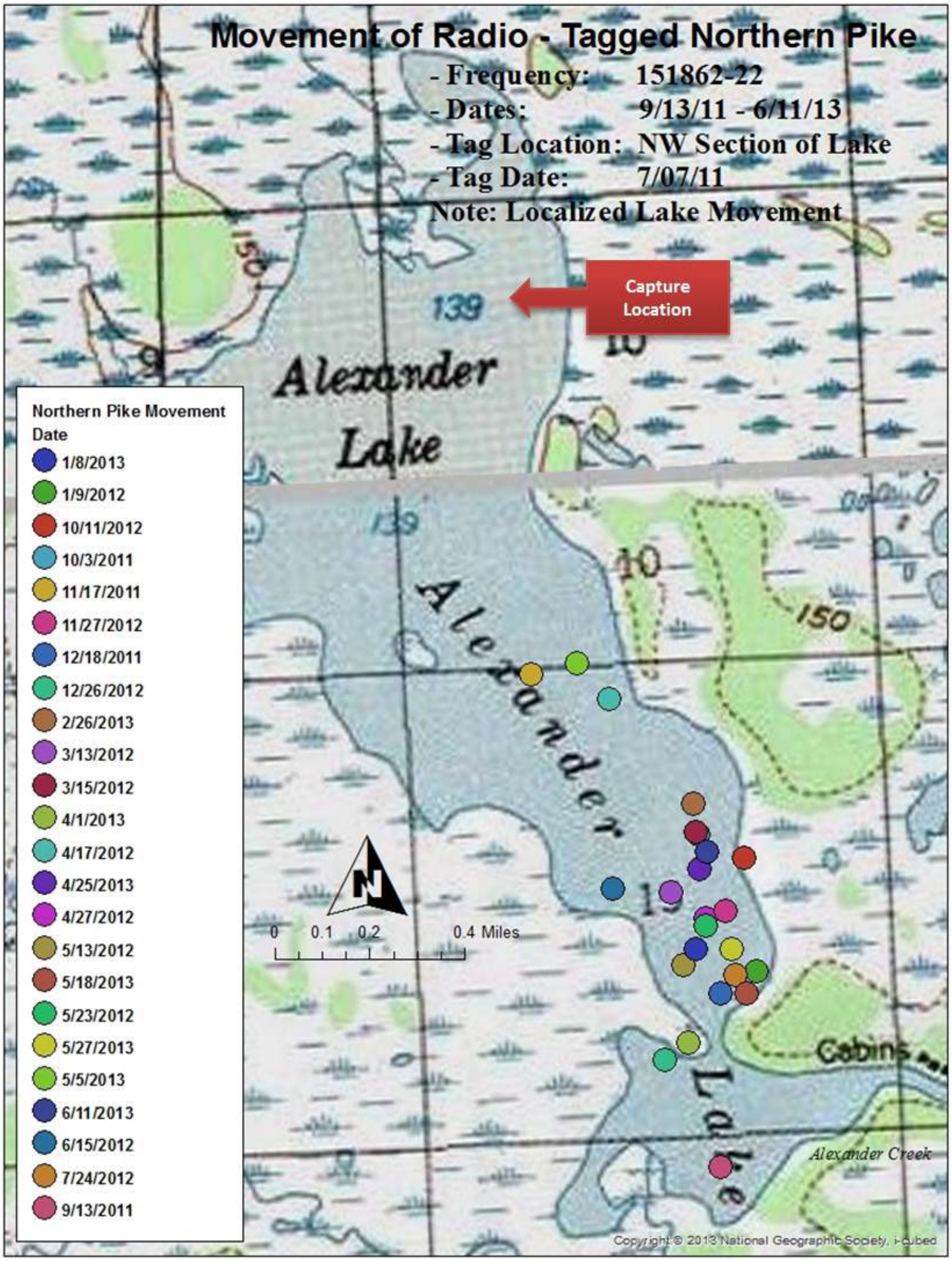
Appendix B9.–Movements of lake-tagged northern pike number 92 (151.862-19) in Alexander Creek drainage, August 2011–June 2013.



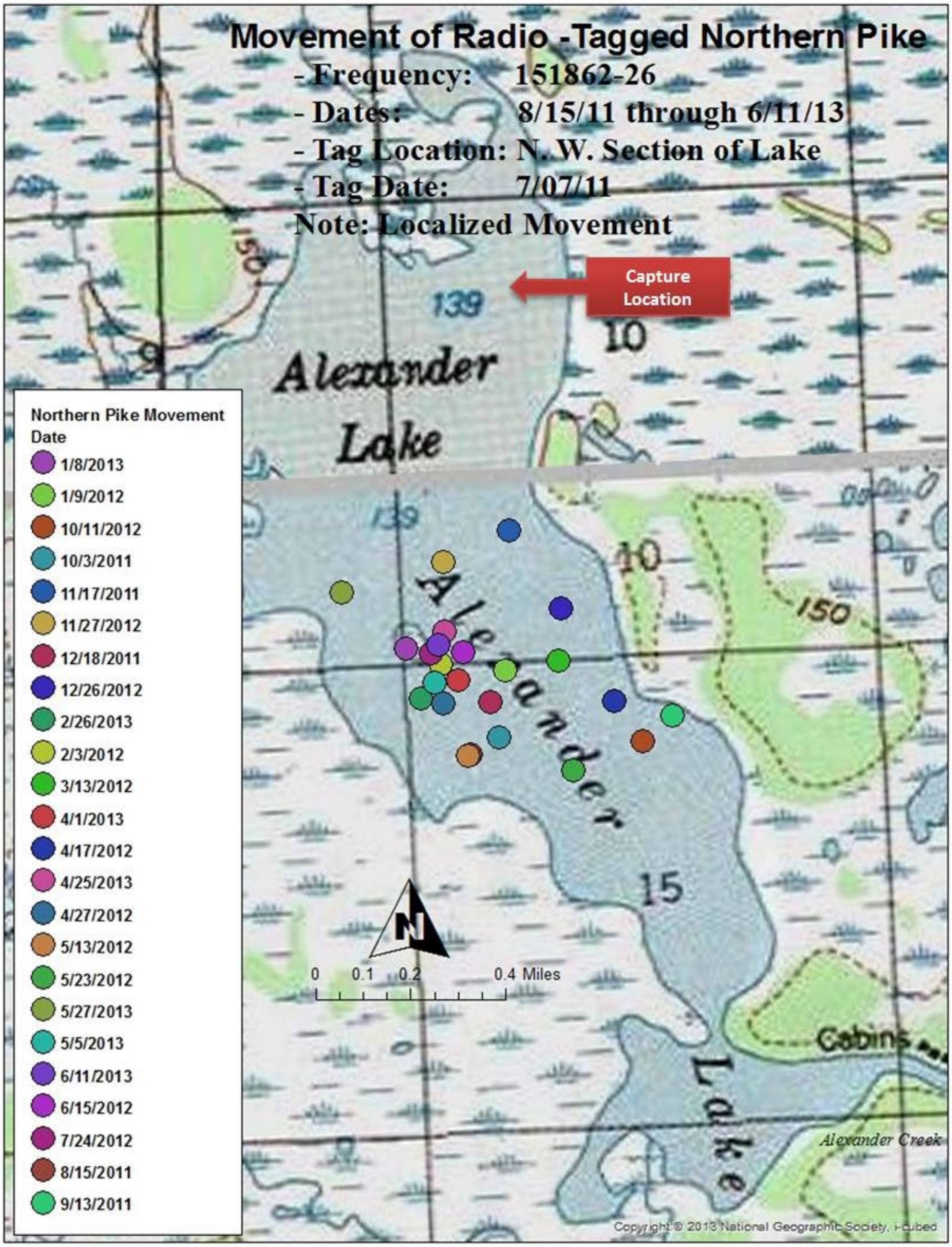
Appendix B10.–Movements of lake-tagged northern pike number 40 (151.823-16) in Alexander Creek drainage, August 2011–June 2013.



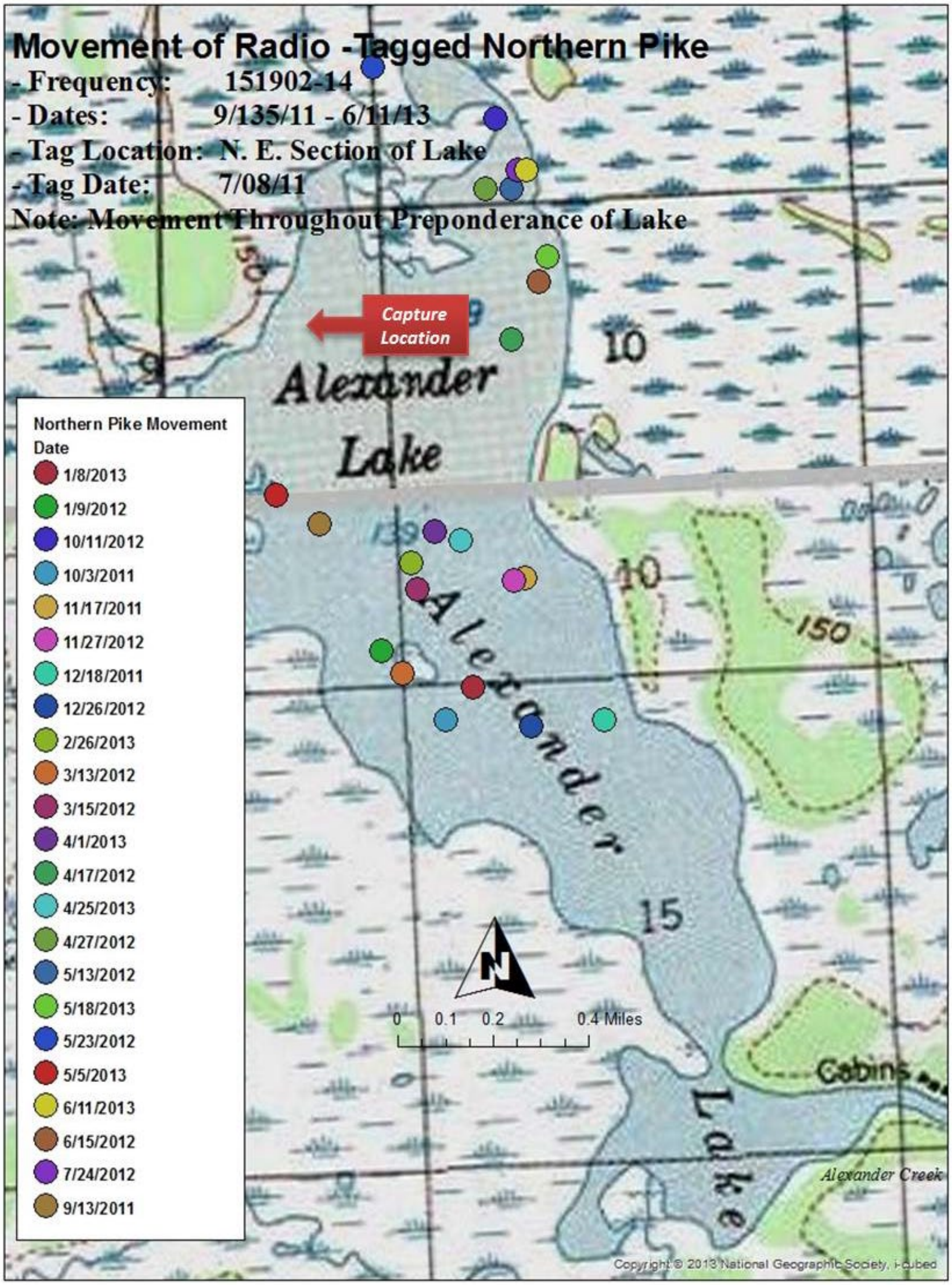
Appendix B11.–Movements of lake-tagged northern pike number 96 (151.862-22) in Alexander Creek drainage, September 2011–June 2013.



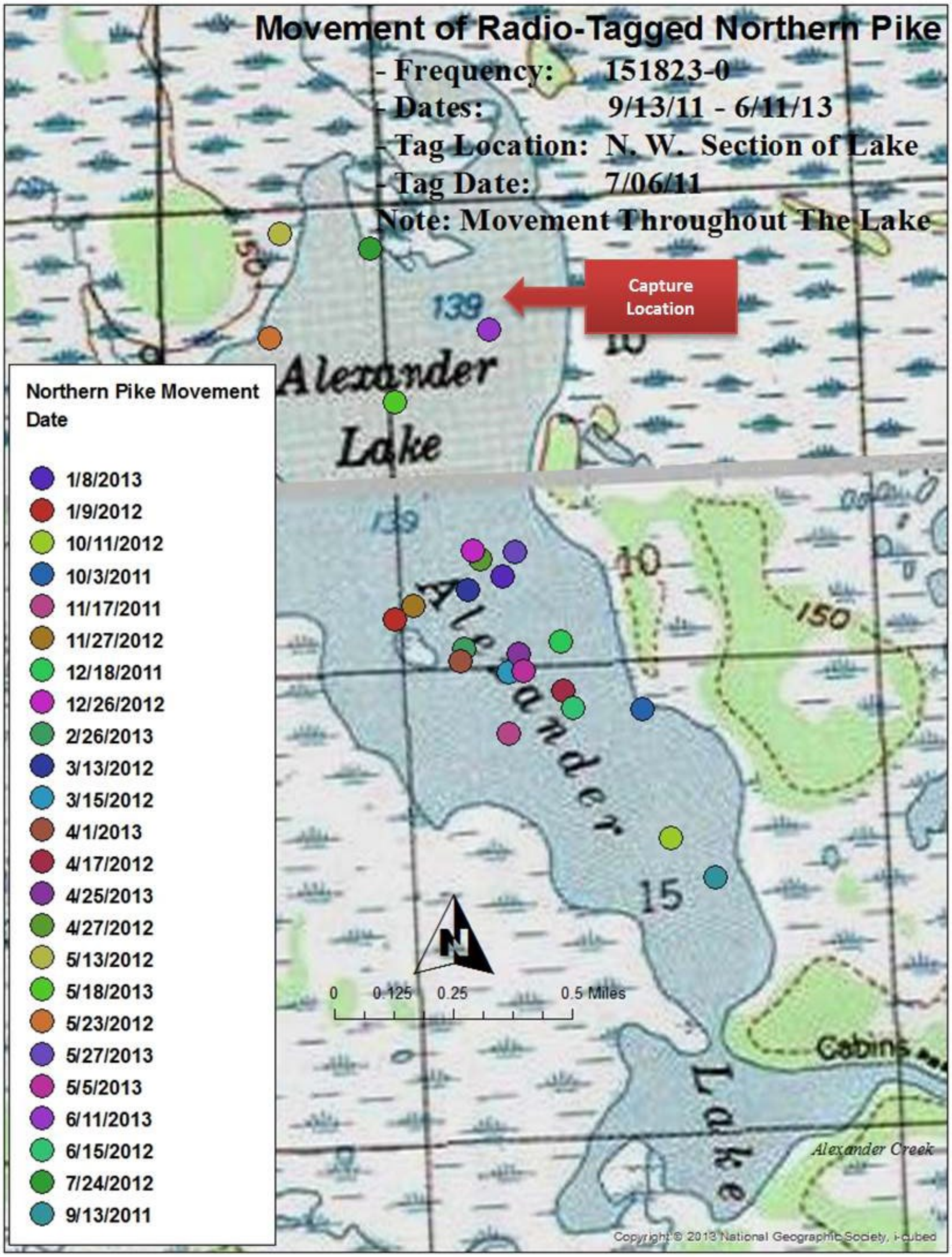
Appendix B12.–Movements of lake-tagged northern pike number 99 (151.862-26) in Alexander Creek drainage, August 2011–June 2013.



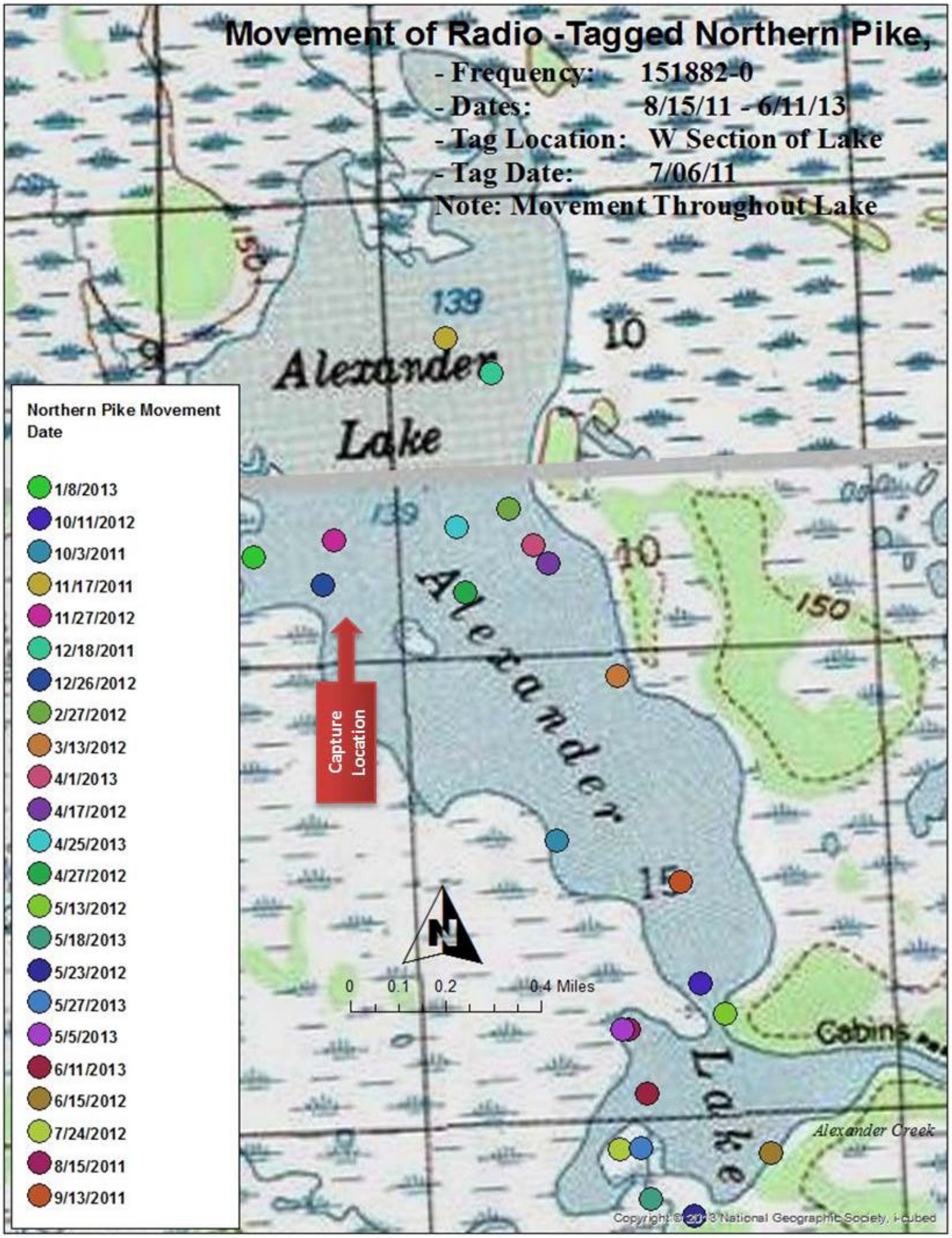
Appendix B13.–Movements of lake-tagged northern pike number 13 (151.902-14) in Alexander Creek drainage, September 2011–June 2013.



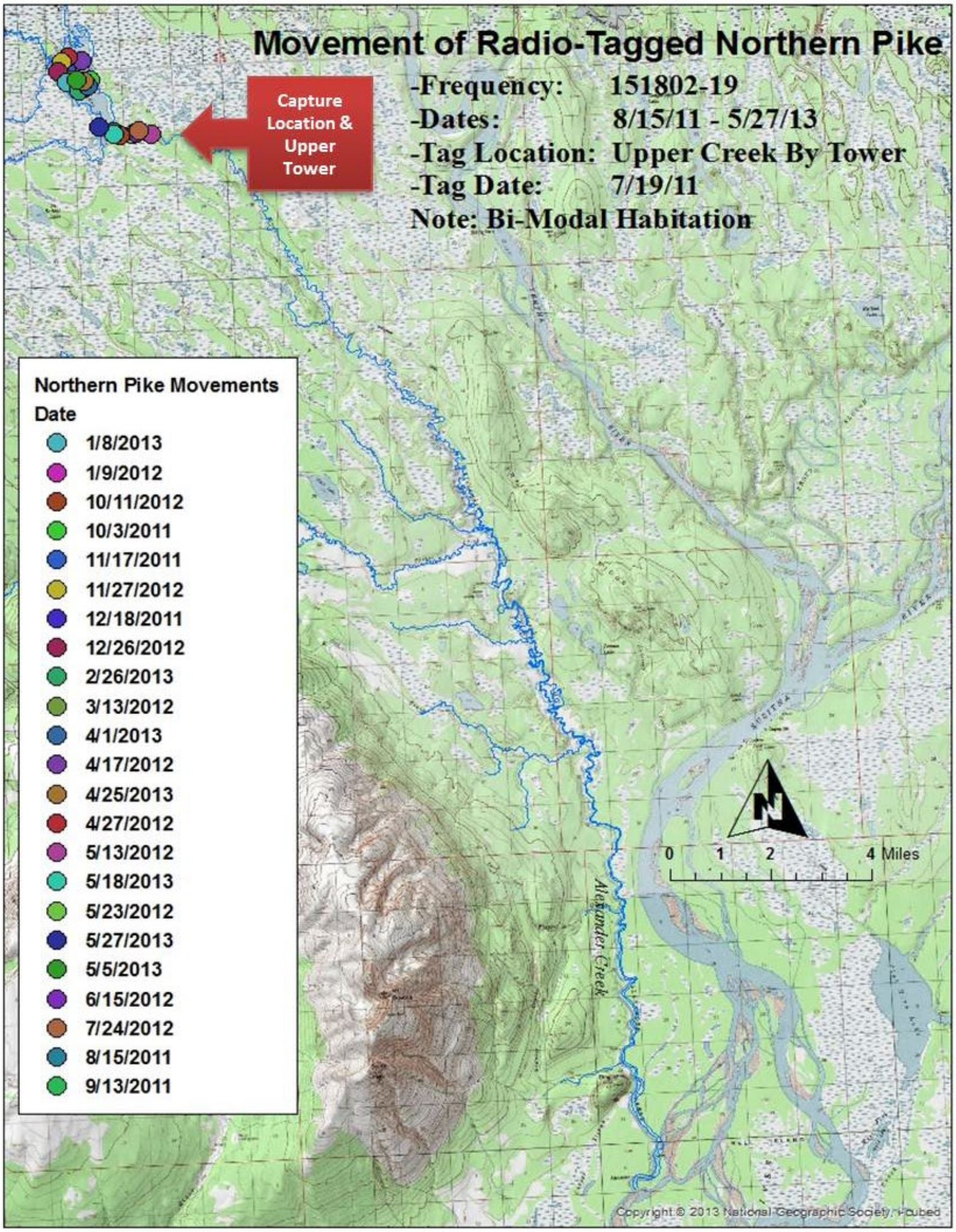
Appendix B14.–Movements of lake-tagged northern pike number 26 (151.823-0) in Alexander Creek drainage, September 2011–June 2013.



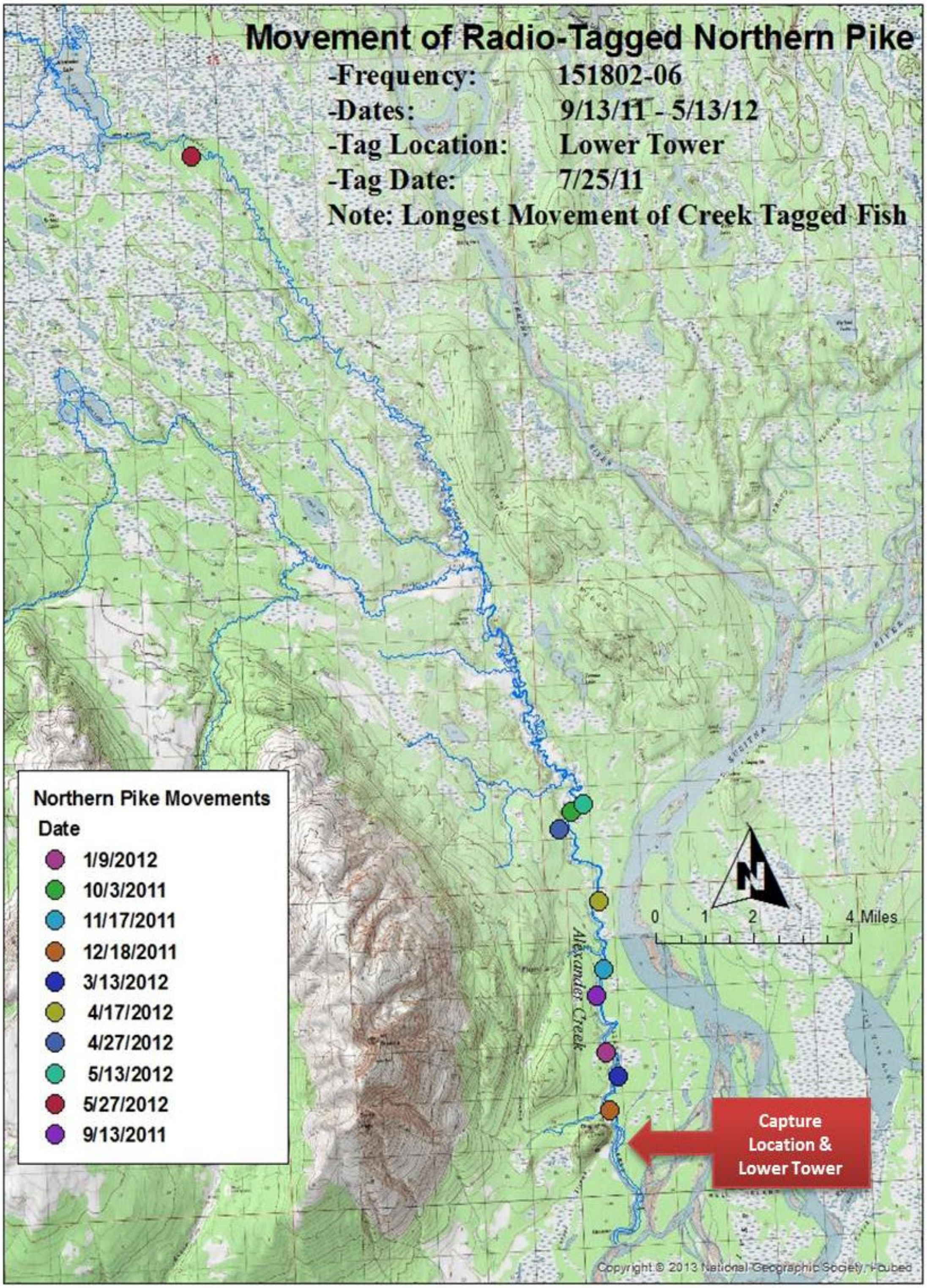
Appendix B15.–Movements of lake-tagged northern pike number 101 (151.882-0) in Alexander Creek drainage, August 2011–June 2013.



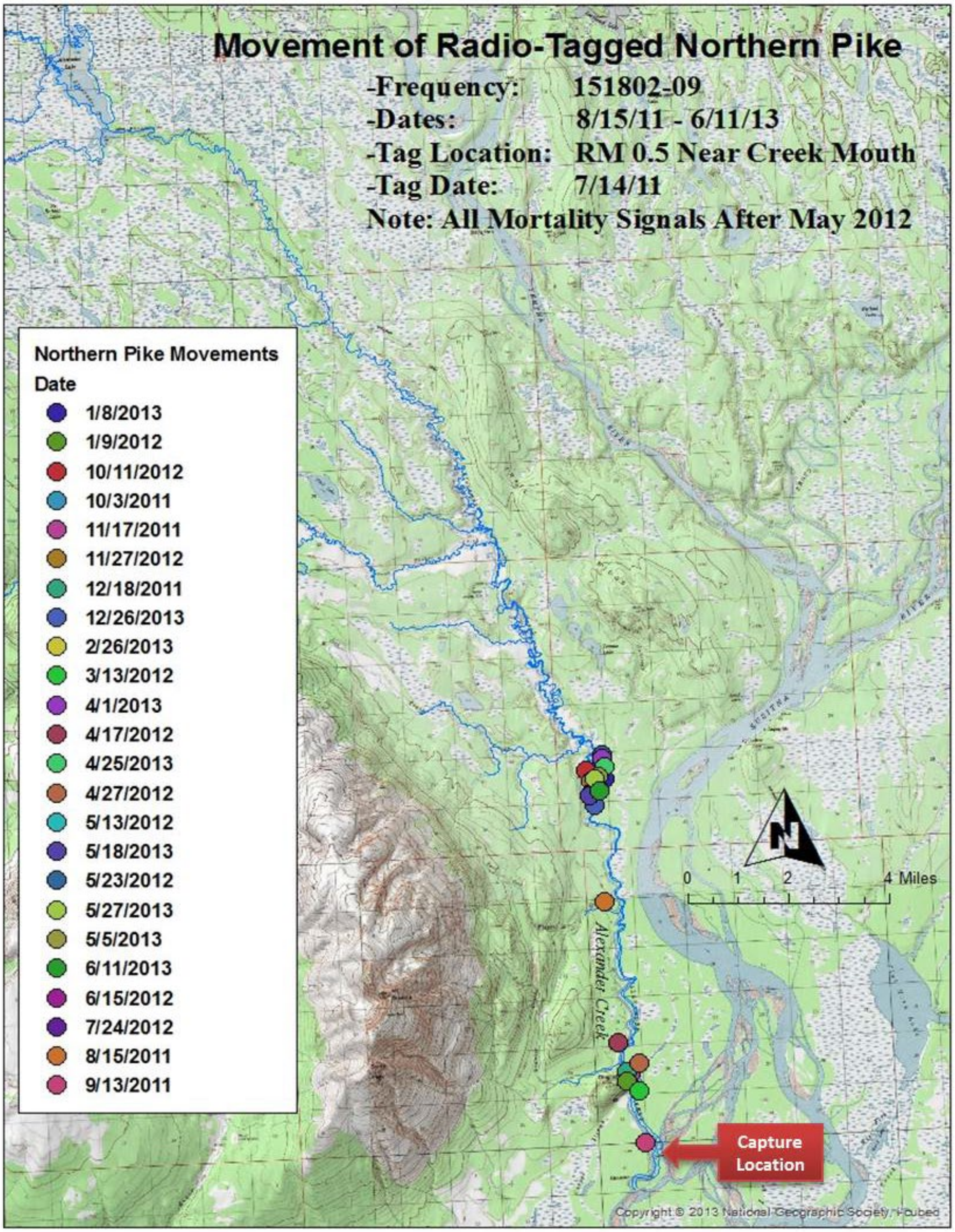
Appendix B16.–Movements of creek-tagged northern pike number 18 (151.802-19) in Alexander Creek drainage, August 2011–May 2013.



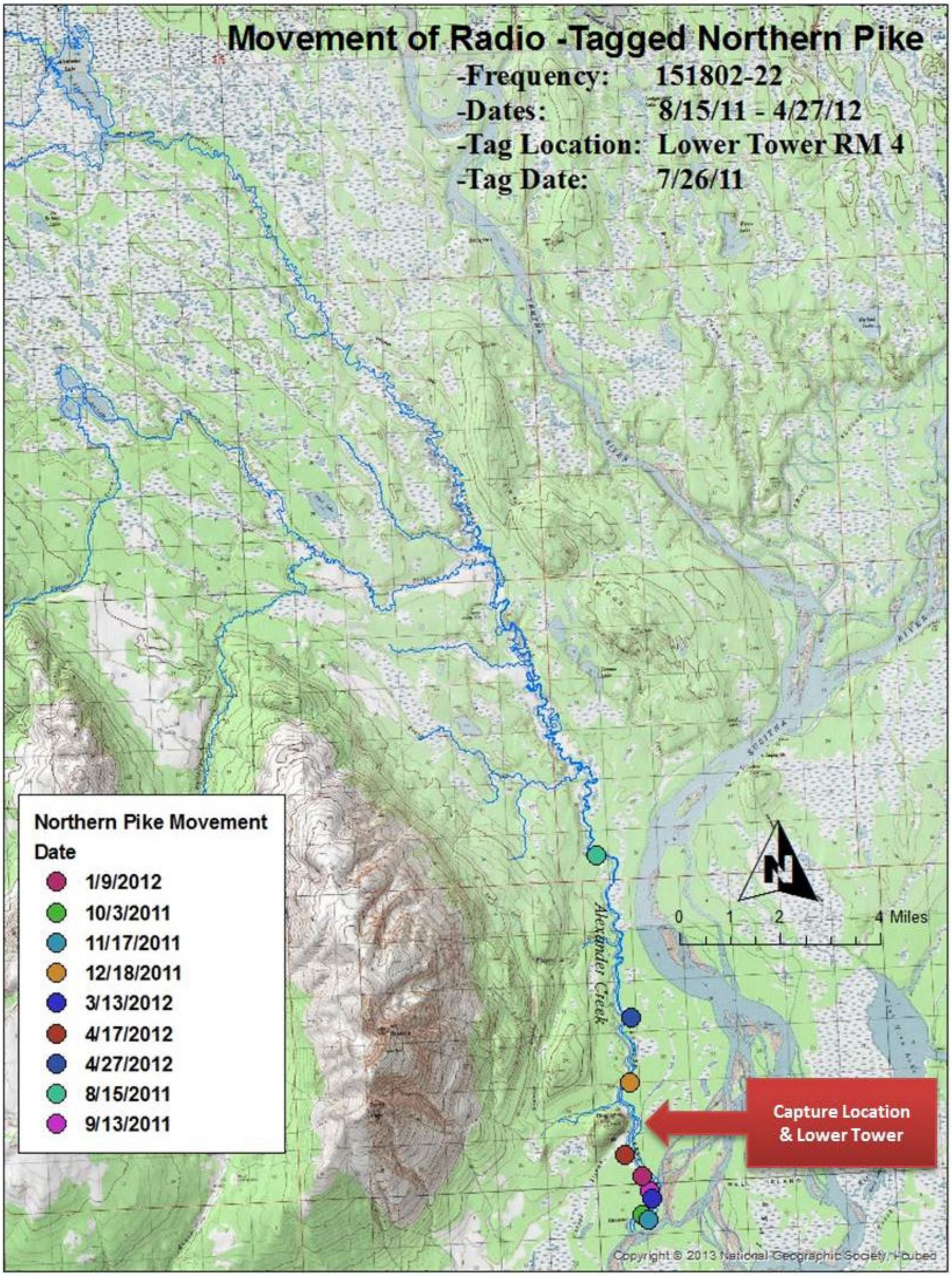
Appendix B17.–Movements of creek-tagged northern pike number 17 (151.802-06) in Alexander Creek drainage, September 2011–May 2012.



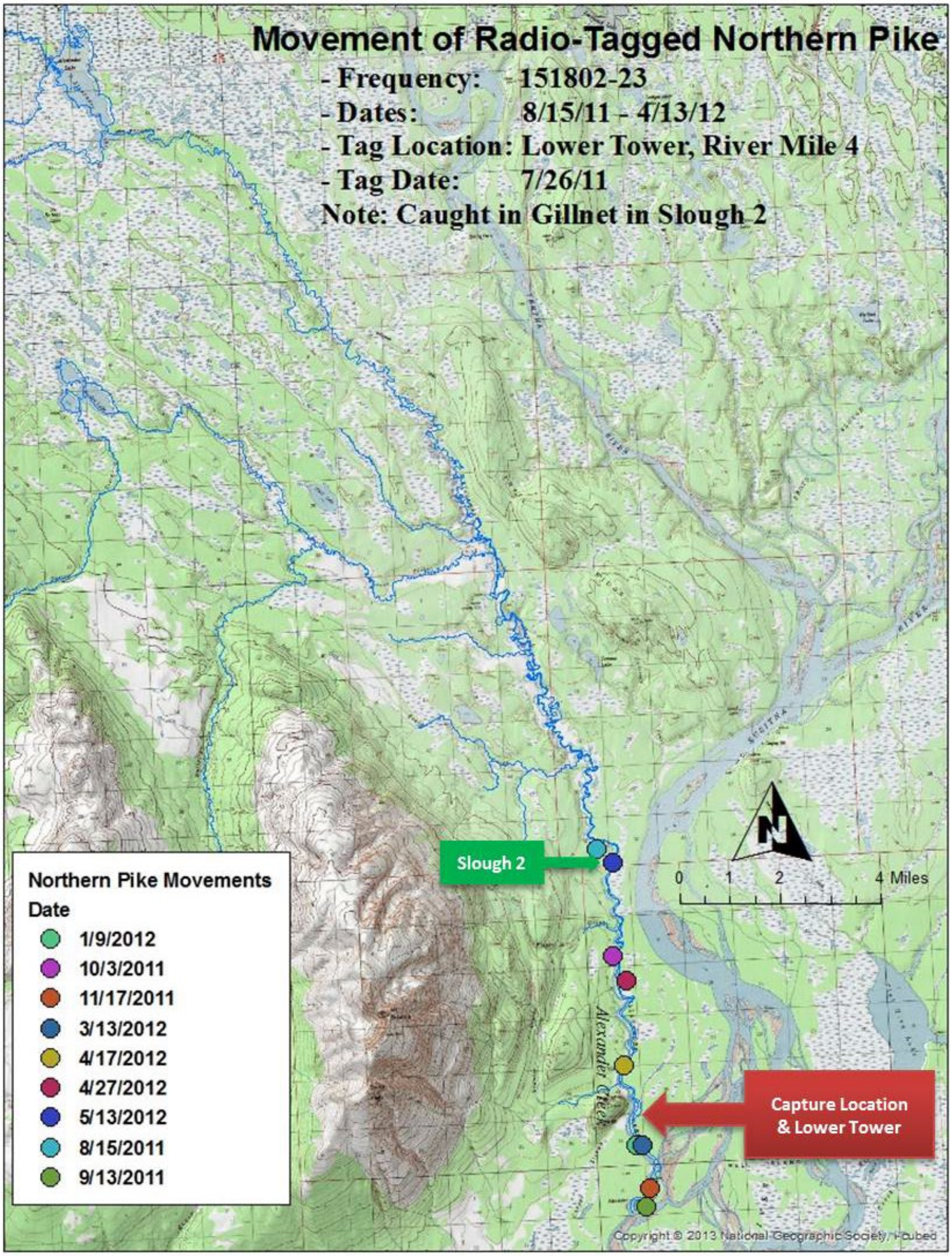
Appendix B18.–Movements of creek-tagged northern pike number 9 (151.802-09) in Alexander Creek drainage, August 2011–June 2013.



Appendix B19.–Movements of creek-tagged northern pike number 21 (151.802-22) in Alexander Creek drainage, August 2011–April 2012.



Appendix B20.–Movements of creek-tagged northern pike number 22 (151.802-23) in Alexander Creek drainage, August 2011–April 2012.



Appendix B21.–Movements of lake-caught northern pike number 23 (151.802-24), transferred, tagged, and released in the lower creek in Alexander Creek drainage, September 2011–April 2012.