Regional Operational Plan No. ROP.SF.3F.2022.03

Lake Trout Movement and Spawning Locations within the Tangle Lakes System

by

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May 2022

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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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LAKE TROUT MOVEMENT AND SPAWNING LOCATIONS WITHIN THE TANGLE LAKES SYSTEM

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SIGNATURE PAGE

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Project leader(s):	Corey Schwanke*, Fishery Biologist II*
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Approval

Title	Name	Signature	Date
Project Leader	Corey Schwanke		
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ABSTRACT

This study will use telemetric procedures to describe movement and locate spawning areas of lake trout *Salvelinus namaycush* within the 4 interconnected Tangle Lakes (Upper, Round, Shallow and Lower). A total of 100 radio tags will be deployed among the 4 lakes: 10 tags in Upper Tangle, 30 tags in Round Tangle, 20 tags in Shallow Tangle and 40 tags in Lower Tangle. Periodic aerial and boat tracking flights will take place from June through October 2022. The radio tags will shut off from November 2022 to March 2023 and surveys will resume at the same general schedule from April 2023 to October 2023. During mid-to-late September 2022, boat tracking will occur at night with spotlights to document spawning aggregations of lake trout in all 4 lakes.

Keywords: lake trout, Tangles Lakes, telemetry, distribution, spawning areas

PURPOSE

Lake trout *Salvelinus namaycush* support important recreational fisheries in Alaska. Lake trout are relatively long lived and are slow to mature meaning they can easily be over exploited when not managed conservatively (Martin and Olver 1980). In the Tanana River drainage, the most popular fishery for lake trout occurs in the Tangle Lakes system. The Tangle Lakes system is comprised of 4 lakes (Upper, Round, Shallow, and Lower Tangle) that are all connected by various reaches of the Tangle River (Figure 1) and Landlocked Tangle Lake, which is not connected to the system. The Denali Highway intersects the lakes between Upper and Round Tangle Lakes near Mile Post 21. The interconnected lakes vary in size from 140 to 200 ha and vary morphometrically from predominately long and shallow to circular and deep. Two other nearby lakes, Glacier Lake and Landmark Gap Lake, drain into the Tangle Lakes through separate small streams. All 7 lakes contain lake trout. In addition to lake trout, other species found in the Tangle Lakes include burbot *Lota lota*, Arctic grayling *Thymallus arcticus*, round whitefish *Prosopium cylindraceum*, humpback whitefish *Coregonus clupeaformis*, and longnose sucker *Catostomus catostomus*.

Due to concerns of overexploitation, the harvest limit for lake trout in the Tangle Lakes was reduced in 1987 from 12 fish per day, only 2 of which could be 20 inches or larger, to 1 fish per day ≥18 in in total length. The regulation was changed to 1 lake trout of any size in 2008. The latest 5-year mean of catch and harvest is 1,085 and 282, respectively (Table 1). ADF&G considers release mortality when estimating exploitation with the conservative assumption that 10% of all released fish die. Total angler-based mortality is estimated annually as the sum of harvest and estimated release mortality, with estimated release mortality being 10% of the difference between catch and harvest. The 5-year mean of estimated angler-based mortality from Tangle Lakes is 362.

Lake trout inhabit deep water and typically occur in low densities; consequently, stock assessment research is difficult and costly, particularly in large or remote lakes, and may result in biased or imprecise estimates. In the absence of updated stock assessments to determine sustained yields, the lake area (LA) model developed by Evans et al. (1991) has been applied to Alaskan interior lakes to determine if annual harvests for lake trout exceed the estimated yield potential (YP). The model estimates the total mass of fish that can be sustainably harvested from a lake based on its surface area. Applying the LA model to Tangle Lakes when considering the 4 lakes combined (one intermixing population of lake trout), sustained yield is estimated as 408 kg/year (Burr 2006). Burr (2006) also estimated mean weight of lake trout of all sizes from Tangle Lakes to be approximately 1.7 kg, meaning an estimated 235 fish can be sustainably harvested from the Tangle Lakes combined. The difficulty with this notion is that just because the lakes are connected does not mean that they should be considered a single population. If the lakes were treated as individual populations (complete closure among them), and their YPs estimated individually and then summed, the result would be a YP of about 600 kg/year, or approximately 353 total fish. As previously stated, ADF&G estimates that the most recent 5-year mean of angler-based mortality in the Tangle Lakes combined is 362 fish, well above YP if treated as a single population, but only slightly above YP if each lake has a separate population.

The notion of whether to treat the Tangle Lakes system as a single population, or multiple populations has been previously examined. Scanlon (2010) radiotagged 40 lake trout from the interconnected Tangle Lakes in 2004 and tracked them for about 24 months to evaluate mixing and try to find spawning areas. A total of 20 fish were radiotagged in Lower Tangle, 7 in Shallow Tangle, 12 in Round Tangle and 1 in Upper Tangle. Low sample sizes constrained results, but the main conclusions of the study were that lake trout do periodically mix between Round and Shallow Tangle Lakes, and that mixing between Lower Tangle Lake and other lakes is very limited. Scanlon (2010) documented no mixing of fish between Upper Tangle Lake and the other lakes, but sample sizes were very small. Secondary results of this study included the confirmation of a single spawning area in Round Tangle Lake, a suspicion that an undocumented spawning area(s) exists in Lower Tangle Lake, and suspicion that some spawning may have been occurring in the Tangle River above Lower Tangle Lake.

Studies prior to Scanlon (2010) are limited. Burr (1989) estimated an abundance of 211 lake trout ≥250 mm FL (SE = 33) in Upper Tangle Lake. In an attempt to identify spawning locations in 1991, Burr (1992) sampled 22 fish in Round Tangle Lake and 18 in Shallow Tangle Lake during the spawning season. He also documented spawning lake trout in the same area on Round Tangle Lake that Scanlon (2010) verified, and he suspected a spawning area in Lower Tangle based on high catch rates of ripe fish from a single gillnet set. Of particular interest, one of the fish Burr (1992) tagged in Upper Tangle Lake was later recaptured in nearby Glacier Lake. The movement of this fish indicated that flows in Rock Creek were, at one time, sufficient to serve as a migration corridor between Glacier and Tangle Lakes, but the degree of exchange between these lakes is uncertain. However, based on observations by Burr (1987), the flows in Rock Creek were very low during mid-summer and appeared to prohibit any fish passage. Because of the distance between the lakes and the observed low flows, it is unlikely that any meaningful exchange occurs between the 2 lakes. The likelihood of exchange between Landmark Gap and Tangle Lakes appears far less because the stream is small and intermittent in nature, with a steep descent (approximately 400 ft over 10 miles), which very likely serves as a barrier to upstream passage of adult-sized fish.

The primary goals of this project are to assess mixing among the 4 interconnected lakes to better understand if they should be treated as separate or combined populations, to better assess spawning areas among all 4 lakes, and to collect information to help design an abundance estimation study to better understand population dynamics and the effects of current exploitation rates. General catch rates, length composition of the population, locations of spawning areas, and movement among lakes are all important factors when designing a mark-recapture experiment.

OBJECTIVES

The objectives of the Tangle Lakes lake trout study are to:

1) Describe the seasonal (June 2022–October 2023) distributions of mature-sized lake trout ≥450 mm FL radiotagged in the interconnected Tangle Lakes during spring 2022 with an emphasis on movement among lakes; and,
2) Identify spawning areas of lake trout in the interconnected Tangle Lakes in September 2022.

METHODS

Study Area

The Tangle Lakes system is comprised of 4 interconnected lakes: Upper (141.6 ha), Round (156.2 ha), Shallow (129.5 ha), and Lower Tangle (192.7 ha). Landlocked Tangle Lake shares the same last name, but as implied in the name, is not connected to the other 4. Glacier Lake and Landmark Gap Lake do share the same drainage, but are spatially separated and connected by relatively small creeks. All 7 lakes have lake trout present. All radiotagging will take place in the 4 interconnected Tangle Lakes, but occasional aerial surveys will be flown over Glacier and Landmark Gap Lakes.

Study Design

Overview

This study will document the seasonal distribution of lake trout, as related to mixing, among the 4 interconnected lakes in the Tangle Lakes system (Figure 1). A total of 100 radio tags will be deployed in spring 2022 into mature sized (≥450 mm FL) lake trout. Fish will be tracked with airplane, boat, and fixed-tracking stations. An emphasis on tracking will be placed in late September in an attempt to verify previously documented spawning areas and document undiscovered spawning areas.

Fish Capture

Lake trout will be captured during 2 approximate time periods: 4–10 April and then from 10–25 June. Lower Tangle Lake can be difficult to access in summer because of a stretch of shallow rocky water, so radio tags will be deployed in that lake in April 2022. The other 3 lakes have easy open water access and will be sampled in June 2022.

A total of 40 radio tags are allocated for Lower Tangle Lake. A crew of 6 people will access the lake via snowmachine and use hook-and-line gear to capture lake trout. Specific gear will consist of spoons, tube jigs, and swim shads, all tipped with bait.

The remaining 60 tags (20 for Shallow, 30 for Round, and 10 for Upper) will be deployed in June 2022. The dates are dependent on ice-out, but it is anticipated sampling will commence around 10 June and conclude by 25 June. Two or three 2-person crews will capture and tag lake trout from boats using hook-and-line gear and baited jug lines. Sampling with hook-and-line will primarily consist of trolling or casting spoons and vertically jigging soft baits such as tube jigs and swim shads. Hookless jug lines, which have been used successfully in other lake trout projects (Scanlon 2010; Schwanke and Albert 2019), will be deployed throughout the lake. Approximately 20 jug lines will be available for use. Jug lines will be constructed from a 45-cm section of PVC pipe encased in marine foam with a 10- to 20- m section of braided line hanging from the bottom of the foam float. A 15- to 25-cm piece of bait (herring or whitefish) will be tied to the line with a noose knot, and the bottom will be weighted with a 28- to 85-gram sinker. Jug lines will be opportunistically set on the windward side of the lake to minimize the chance of washing ashore and additional weight may be added if considerable drifting occurs. Jug lines will be checked daily. Captured fish will be gently guided into a rubber meshed dip net and placed in a tub filled with fresh water. Entanglement nets (2.54-mm bar mesh gill nets) will also be used if sample sizes cannot be achieved using only angling and jug lines. Nets will be soaked for approximately 10- to 20-min depending on water temperature and the condition of captured fish. Extreme care will be taken to minimize mortalities and gillnets will be closely monitored, fish will be removed from the net immediately upon capture, holding tubs will be filled with fresh water before lake trout are removed from the net, and a rubber meshed dip net will be used to transfer fish from the water to the boat.

All captured fish throughout this study will be temporarily placed in a tote or cooler to examine their health (i.e., make sure they are not bleeding or injured in any other way). Surgeries will follow within 10 minutes of this inspection.

Sample Size

Lake trout telemetry studies are limited within ADF&G, and Scanlon (2010) did not use radio tags with mortality sensors, so there is little species-specific information to predict survival rates with this study. Survival rates for this study will be estimated from recent studies on other species with the same/similar staff (Schwanke 2015; Schwanke and Tyers 2019). Based on these studies, it is expected that at least 80% of the fish will survive the first two weeks after surgery, at least 70% of the radiotagged fish will survive to mid-summer (2022), and at least 60% will survive to spawning in September 2022. It is then anticipated that at least 40% will survive to the following summer (2023) and likely the final spawning period.

Between Scanlon (2010) and Burr (1992), an important spawning area was documented in Round Tangle Lake and 2 spawning areas were suspected in Lower Tangle Lakes. For sample size planning, we assume that 2 other spawning areas exist bringing the total number of spawning areas to 5. We also have to assume that every spawning area will have a different probability of the population utilizing them. A simulation was performed where each of the 5 potential spawning areas had the following probabilities of the lake trout population utilizing them: 9%, 9%, 18%, 27%, and 36%. Under this scenario, and assuming that 50 of the 60 lake trout assumed to be alive during the fall surveys will be located, the chance that a spawning area would not be identified is less than 2%. Regardless of what the true number of spawning areas are and their use by the population, deploying 100 radio tag gives us an exceptional chance of identifying all the major spawning areas. Lastly, a sample size of 60 live tracked fish tracked during any period will provide proportion estimates in the data analysis section that are within 12 percentage points of the true values 90% of the time.

Telemetric Procedures

Standardized telemetry practices will be employed during the spring 2022 sampling events. Each lake trout will be anesthetized using Aqui-S 20E and implanted with a radio tag following surgical methods detailed by Brown et al. (2002). The tags will be Lotek MCFT-2EM tags individually coded from 1–100 on frequency 150.400 MHz. They are programmed to beep every 5–6.5 seconds, are programmed to be turned off from 1 November 2022 through 30 March 2023, then beep continuously until the batteries die sometime in early winter 2023. This will encompass 2 full open water seasons (summer of 2022 and 2023) and 2 spawning periods. All radio tags have motion detectors to help decipher mortalities.

Tracking flights will be conducted using a fixed-wing aircraft or boat with a Lotek SRX 1200 receiver. It is anticipated that most surveys will be aerial, but boat-based surveys will be conducted and evaluated for effectiveness. Receivers will be equipped with an internal GPS that will record time and location data during each survey. Over a 19-month period, approximately 16 surveys will be conducted. All surveys will coincide within 2-time blocks when the tags are beeping: June 2022 through October 2022 and again from April 2023 through October 2023. Probable dates of surveys are listed in the *Schedule and Reports* section of this plan.

A series of 3 ground-based tracking stations will be set up between the 4 interconnected lakes (Figure 2). Lotek SRX 600 receivers will be used along with a power source (two 12-volt batteries and a solar panel), an antenna switch box, a SunSaver solar controller and 2 five-element Yagi antennas. The electrical components will be stored in a locked metal box at the site. The stations will be in operation from late-May through 1 November 2022 and 2023 and will be inspected and downloaded every 4–6 weeks.

Spawning Area Evaluation(s)

In mid-September 2022, an aerial survey will be flown to look for concentrations of fish. Using this information, radiotagged fish will be tracked at night with a boat when lake trout move onto spawning beds. When a single, or preferably a group, of radiotagged lake trout is located in a potential spawning area (i.e., favorable water depth, substrate type), visual inspection of fish behavior and the site will be made using high-powered, submersible lights and hand-held spotlights. If a group of radiotagged fish is detected with the receiver but cannot be seen due to either muddy or deep water, entanglement nets (2.54-mm bar mesh gillnets) will be set to confirm spawning. Peak spawning is believed to occur during the last week of September, but sampling will occur between the dates of 20 September and 5 October. Depending on the level of success (are there still questions on spawning locations) of the 2022 sampling and if sample sizes of live radiotagged fish are adequate in 2023, spawning area investigations may be repeated in September 2023.

Data Collection and Reduction

For each lake trout captured and radiotagged in 2022, data collected will include: 1) date, 2) gear type, 3) measurement of fish length to the nearest 1 mm FL, 4) location (which lake and GPS coordinates in WGS84 decimal-degrees); and, 5) radio tag frequency and code.

During all aerial surveys, the receiver (Lotek SRX 1200) will automatically record date, time, and location (GPS decimal-degree, Datum WGS84) of radiotagged fish. The data will be downloaded and saved as a text file. All data related to radiotelemetry will be integrated into one master Excel spreadsheet compatible with ArcGIS® software. All available information for each radiotagged fish will be recorded in a single row in a worksheet.

It is anticipated that "periods" of time will exist where movement is more pronounced than others. For example, pre-and post-spawning movements among lakes is anticipated. If this is ultimately a true occurrence, mixing will be consolidated and summarized into "periods" of time (vs. on a survey-by-survey basis).

Data Analysis

For each survey and time period, fates will be assigned to each located radiotagged fish and will consist of 2 components: a location label and a subscript to the location label indicating whether the fish was alive or dead. The location label will be defined as: Upper Tangle Lake (UT), Round Tangle Lake (RT), Shallow Tangle Lake (ST), and Lower Tangle Lake (LT). The subscripts will be defined as:

1) Alive (A)- a fish with an active code and has shown movement since its previous locations
2) Non-fishing mortality (NFM) – a fish located within the lake but was judged to be dead at the time of the survey being conducted. Such fish could be located washed up on shore or found floating on the surface, otherwise, this fate may not be determined until the completion of the study and movement trends are analyzed. Fish with this fate will not be used for calculating proportions for tracking surveys subsequent to the survey it was deduced as or known to be dead;
3) Fishery Mortality (FM) – a fish that was reported harvested within the lake of origin. Fish with this fate will not be used in movement analyses for surveys subsequent to the survey it was deduced as or known to be dead; and,
4) If a fish was not found during a survey, its location symbol will be AL (at large).

Given the general movement characteristics of lake trout, it may be difficult to precisely define a fate or a time of death. Unlike stream-resident species such as Dolly Varden, Arctic grayling and Chinook salmon, lake trout may spend considerable time in water too deep to be located during radiotracking surveys. This may lead to relatively long periods of time where the "AL" fate has been assigned to a fish. The NFM fates will be assigned to a fish whose radio tag emits an inactive code, and/or when no movement is observed by that fish over periods during which substantial movement was observed for other fish, such as during pre-spawning, post-spawning, and break-up.

Fish tracked during the spawning period will be further categorized by denoting whether the fish was located on a verified spawning area (SA) or not on a verified spawning area (NotSA). Each spawning area will be numbered (i.e., SA1, SA2, etc.…) and the appropriate designation will be assigned to the subscript at the completion of the study. A fate history will be prepared for each radiotagged lake trout (Appendix A1).

Many movement scenarios are possible, making a prescriptive analytical procedure impractical. Instead, analytical methods that are expected to be useful will be described with example applications provided. To begin with, maps will be used to denote spawning areas and locations of radiotagged lake trout during relevant time periods. Fate data will be analyzed to assess the degree of inter-lake movement between time periods of interest using contingency tables and chi-square tests, and by estimating the proportion of fish that moved based on the movements of the radiotagged fish. Of particular interest are movements among lakes between spawning periods, movements between mid-summer and spawning, movement among spawning areas between spawning periods, and movement during the mid-summer periods. The contingency tables and related chi-square tests will be analogous to the test for complete mixing used to test for consistency of the Petersen estimator (Seber 1982). An s-by-(t+1) contingency table will be constructed as will the contingency table for the pooled version of this test (Seber 1982). Numbers of radiotagged fish with unknown fate during the second period will be recorded in column t+1 (i.e., analogous to "not observed" during the second event of a two-event mark-recapture experiment).

To further describe movements, the proportion of fish moving among lakes or among spawning areas between periods of interest will be estimated from the movement of radiotagged fish as follows:

$$\hat{p}_{moved} = \frac{x_{moved}}{n} \qquad (1)$$

$$var(\hat{p}_{moved}) = \frac{\hat{p}_{moved}(1-\hat{p}_{moved})}{n-1} \qquad (2)$$

where:

$\hat{p}_{moved}$ = the proportion of lake trout that moved at least once among lakes (or spawning areas) between the periods of interest;

x_{moved} = all radiotagged fish whose location label (or spawning area identifier) changed between periods of interest (does not include AL fish, or fish with NFM or FM subscripts); and,

n = includes x_{moved} and fish whose location label did not change between periods (does not include AL fish, or fish with NFM or FM subscripts).

Radiotracking station data, and to a lesser degree multiple surveys during a single period, will be examined to assess within period movement. Of particular interest is movement during the mid-summer period while fish are most vulnerable to harvest. The proportion of fish changing lakes at least once will be calculated as:

$$\hat{p}_{moved,i} = \frac{x_{moved,i}}{n_i} \qquad (3)$$

$$var(\hat{p}_{moved,i}) = \frac{\hat{p}_{moved,i}(1-\hat{p}_{moved,i})}{n_i-1} \qquad (4)$$

where:

$\hat{p}_{moved,i}$ = the proportion of lake trout that changed lakes at least once during the period of interest; i;

$x_{moved,i}$ = all radiotagged fish whose location label changed at least once during the period of interest, i, (does not include AL fish, or fish with NFM or FM subscripts); and,

n_i = includes $x_{moved,i}$ and fish whose location label did not change during the period of interest, i, (does not include AL fish, or fish with NFM or FM subscripts).

Equations 1–4 may also be used to estimate the proportion of lake trout that moved at least two or more times during or between periods of interest.

SCHEDULE AND DELIVERABLES

Dates of sampling events, milestones, and other activities are summarized in the following table. Most surveys will be aerial, but some will be by boat.

Date(s)	Sampling Activity/Milestone
4 April 2022	Complete Operational Plan
4–10 April 2022	Radiotag 40 lake trout in Lower Tangle Lake
15–25 April 2022	Install tracking stations
10–25 June	Radiotag 20 lake trout in Shallow, 30 in Round and 10 in Upper Tangle Lakes
End of June 2022	1st tracking survey
Mid-July 2022	2nd tracking survey
Mid-August 2022	3rd tracking survey
Mid-Sept–10 October	4th, 5th , and 6th tracking surveys (spawning)-look for spawning fish
Late October	7th tracking survey
November 2022	Retrieve tracking stations
1 April 2023	Redeploy tracking stations
Mid-April 2023	8th tracking survey
Mid-May 2023	9th tracking survey
Mid-June 2023	10th tracking survey
Mid-July 2023	11th tracking survey
Mid-August 2023	12th tracking survey
Mid-Sept–10 October	13th, 14th , and 15th tracking surveys (spawning)-look for spawning
Late October	16th final tracking survey
November 2023	Retrieve tracking stations
February 2024	Data analyses complete
December 2024	FDS Report complete

RESPONSIBILITIES

List of Personnel and Duties:

ADF&G

Corey Schwanke:	Fishery Biologist II;	Overall supervision of project. Coordinate sampling schedules with project personnel. Organize telemetry surveys, analyze data, and prepare reports with technical assistance.
April Behr:	Fishery Biologist III;	Supervise project leader and review all reports.
Jiaqi Huang:	Biometrician IV;	Assist in preparation of statistical design of field investigation for operational plan, and review data analysis and final report.
Matt Albert:	Fishery Biologist II;	Assist with lake trout capture and tagging
Laura Gutierrez:	Fishery Biologist II;	Assist with lake trout capture and tagging
Brian Collyard:	F&W Tech IV;	Assist with lake trout capture and tagging
Joe Spencer:	F&W Tech III;	Assist with lake trout capture and tagging
Mike Willard:	F&W Tech III;	Assist with lake trout capture and tagging
Matt Stoller:	F&W Tech III;	Assist with lake trout capture and tagging
Clint Wyatt:	F&W Tech III;	Assist with lake trout capture and tagging

BLM

Tim Sundlov: Fisheries Biologist;	Assist with lake trout capture and tagging

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TABLES AND FIGURES

Table 1.–Estimated catch, harvest, and angler mortality of lake trout from Tangle Lakes, 2003–2020.

Year	Catch	Harvest	Harvest w/ 10% Release Mortality
2003	1,631	505	618
2004	825	270	326
2005	1,781	224	380
2006	895	272	334
2007	1,580	383	503
2008	541	190	225
2009	1,140	333	414
2010	3,266	640	903
2011	1,216	300	392
2012	1,222	161	267
2013	590	401	420
2014	801	206	266
2015	1,121	72	177
2016	1,049	374	442
2017	851	205	270
2018	195	0	20
2019	700	316	354
2020	2,630	516	727
5-year average (2016–2020)	1,085	282	362
10-year average (2011–2020)	1,038	255	333

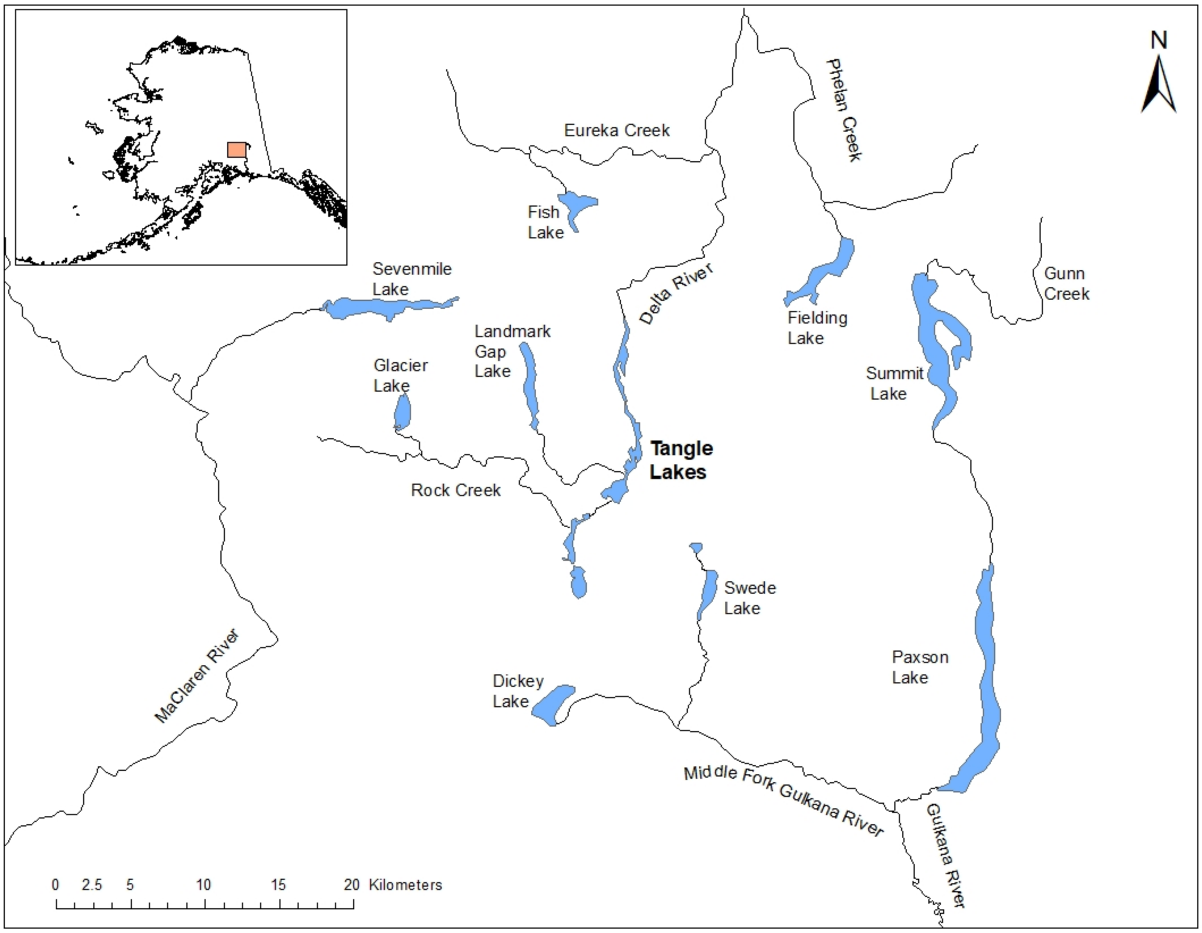

Figure 1.–Map depicting the location of Tangle Lakes.

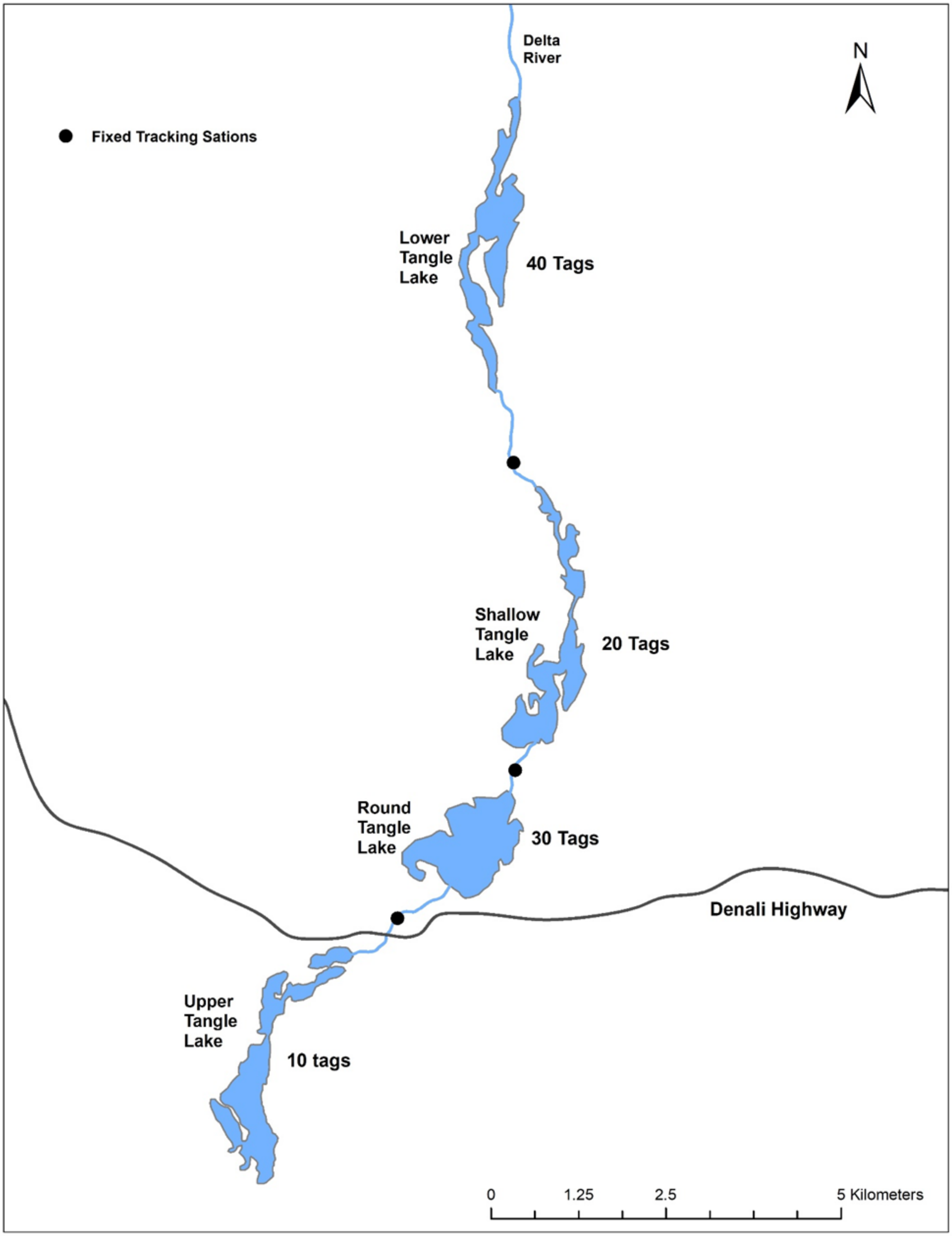

Figure 2.–Map of Tangle Lakes with proposed radio tag deployment distribution and the location of the 3 fixed-tracking station locations.

APPENDIX A

Appendix A1.–Example of assignment of fates for radiotagged lake trout. Descriptions of fates are given in the Data Analysis section.

	Tracking Period						
Tag	Midsummer 22	Prespawning 22	Spawning 22	Postspawning 22	Winter 22-23	Spring 23	Midsummer 23
1	AL	UT_a	UT_{SA2}	UT_a	AL	AL	ST_a
2	UT_a	UT_a	AL	UT_a	UT_a	UT_a	UT_{FM}
3	AL	UT_a	UT_{SA1}	UT_a	UT_a	UT_a	RT_a
4	RT_a	RT_a	RT_{SA4}	AL	RT_{FM}	Removed	Removed
5	RT_a	RT_a	RT_{SA4}	RT_a	RT_a	UT_a	UT_{FM}
6	UT_a	UT_a	ST_{SA5}	RT_a	RT_a	UT_a	UT_a
7	ST_a	ST_a	ST_{NotSA}	ST_a	ST_a	ST_a	ST_a
8	RT_a	ST_a	ST_{SA2}	ST_a	ST_a	ST_a	RT_a
9	LT_a	LT_a	LT_{SA2}	AL	AL	AL	LT_a
10	LT_a	LT_{NFM}	Removed	Removed	Removed	Removed	Removed