Special Publication No. 22-07

Soldotna Creek Drainage Invasive Northern Pike Eradication, 2014–2017, and Restoration, 2015–2019

by

Rob Massengill

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

SPECIAL PUBLICATION NO. 22-07

SOLDOTNA CREEK DRAINAGE INVASIVE NORTHERN PIKE ERADICATION, 2014–2017, AND RESTORATION, 2015–2019

by
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ABSTRACT

During 2014–2017, the Alaska Department of Fish and Game implemented a series of chemical treatments (rotenone) to remove invasive northern pike (*Esox lucius*) from the Soldotna Creek drainage, a Kenai River tributary. The treatments included 7 lakes and ponds, 22 miles of streams, and over 144 acres of wetlands. Northern pike eradication success was assessed by posttreatment sampling of rotenone concentration, gillnet surveys, caged sentinel fish response, and environmental DNA (eDNA) sampling. Taken together, these assessments suggested all northern pike were removed from the drainage. During 2015–2019, native fish populations were actively restored to the western branch of the drainage where natural recolonization would be difficult due to fish pathway challenges by collecting and relocating native fish from other parts of the drainage where natural recolonization can quickly occur. The total number of native fish relocated to the western branch of the drainage included 4,545 juvenile rainbow trout (*Oncorhynchus mykiss*), 4,837 juvenile Dolly Varden (*Salvelinus malma*), 49,271 juvenile coho salmon (*O. kisutch*), 32,850 unspecified stickleback (largely *Gasterosteus aculeatus*), and 3,694 sculpins (Family Cottidae). Based on assessment of pre- and posttreatment minnow trapping and gillnet surveys, it appears native fish have reestablished throughout the drainage where rotenone had been applied.

Keywords: Kenai Peninsula, Soldotna Creek drainage, rotenone, northern pike, *Esox lucius*, chemical treatment, restoration, invasive species, eradication, Kenai River drainage

INTRODUCTION

Northern pike (*Esox lucius*) is an apex freshwater predator native to Alaska north and west of the Alaska Range, but is considered invasive in southcentral Alaska (ADF&G 2007; Figure 1). Northern pike are believed to have been first introduced to Alaska's southcentral region in the 1950s and are now widely dispersed in many Southcentral Alaska drainages due to natural dispersion and additional introductions. Invasive northern pike are implicated in the decline of native fisheries throughout the region (Rutz 1999; Patankar et al. 2006; Sepulveda et al. 2013; Sepulveda et al. 2015; Glick and Willette 2016). There is strong evidence that northern pike prefer soft finned juvenile salmonids (*Oncorhynchus* spp.) over other available prey species in southcentral Alaska (Patankar et al. 2006; Sepulveda et al. 2013). Consumption of native juvenile salmonids by introduced northern pike has also been observed elsewhere in the northwestern United States (Rich 1992; McMahon and Bennett 1996; Schmetterling 2001; Muhlfeld et al. 2008). In Southcentral Alaska, prey of invasive northern pike may be particularly vulnerable because they evolved in the absence of these predators whereas in interior Alaska, native northern pike share an evolutionary history with their prey, which evolved adaptations for predator avoidance (Oswood et al. 2000). Prevalent shallow lake morphology throughout much of Southcentral Alaska offers limited deepwater refugia for northern pike prey because northern pike typically occupy habitat that is shallow and vegetated (Inskip 1982; Cook and Bergersen 1988; Massengill 2014a, 2014b; Dunker et al. 2018).

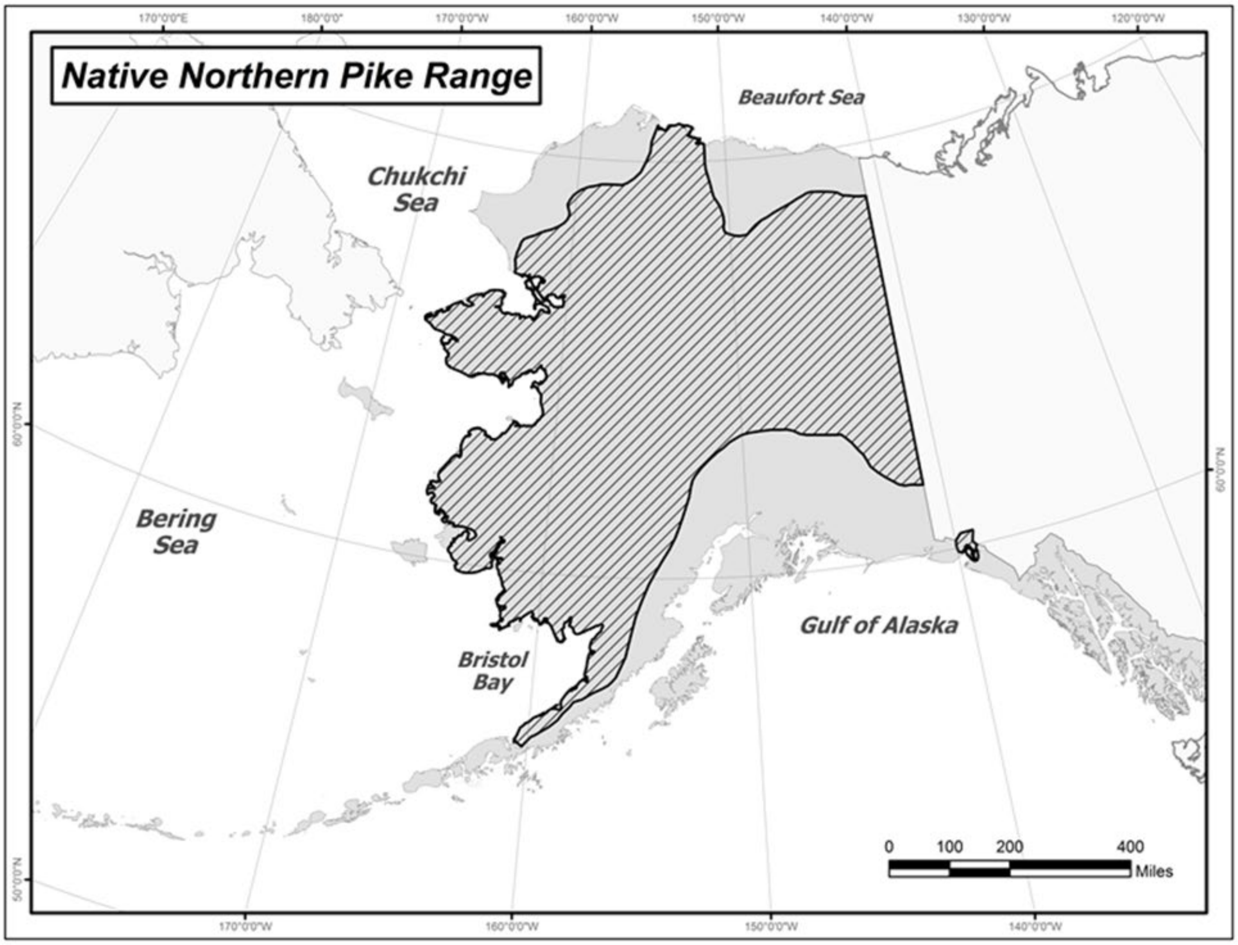

Figure 1.–Native range of northern pike (*Esox lucius*) in Alaska.

Source: Morrow (1980).

The introduction of northern pike to the Kenai Peninsula is believed to have first occurred at Derks Lake in the Soldotna Creek drainage during the early 1970s (ADF&G unpublished[1]). Northern pike have since spread, often with human aid, and self sustaining populations have been detected in 24 Kenai Peninsula waterbodies including Soldotna Creek (Figure 2). Eleven of these northern pike populations were detected since 2000; however, the dates for these introductions are mostly unknown. Northern pike predation has reduced or eliminated existing fish populations from most Kenai Peninsula waters invaded by northern pike (Begich and McKinley 2005; Begich 2010;. Massengill 2010; McKinley 2013; Massengill 2014a, 2014b, 2017). Northern pike pose an immense threat to Kenai Peninsula freshwater sport fish, particularly those species sharing similar habitat preferences as northern pike. Northern pike prefer low gradient, vegetated, and relatively shallow habitat like that found in the Moose River drainage, a Kenai River tributary, and the Swanson River drainage. This type of habitat also serves as rearing habitat for salmonids like coho salmon (*Oncorhynchus kisutch*) and as habitat to all life stages of rainbow trout (*O. mykiss*) (ADF&G 2007). It is probable that if northern pike become established in critical salmonid rearing habitats like these, dramatic losses to salmonid populations will occur.

1 Report titled Northern Pike (*Esox lucius*) in the Soldotna Creek System, anonymous author, available at the Soldotna ADF&G Office.

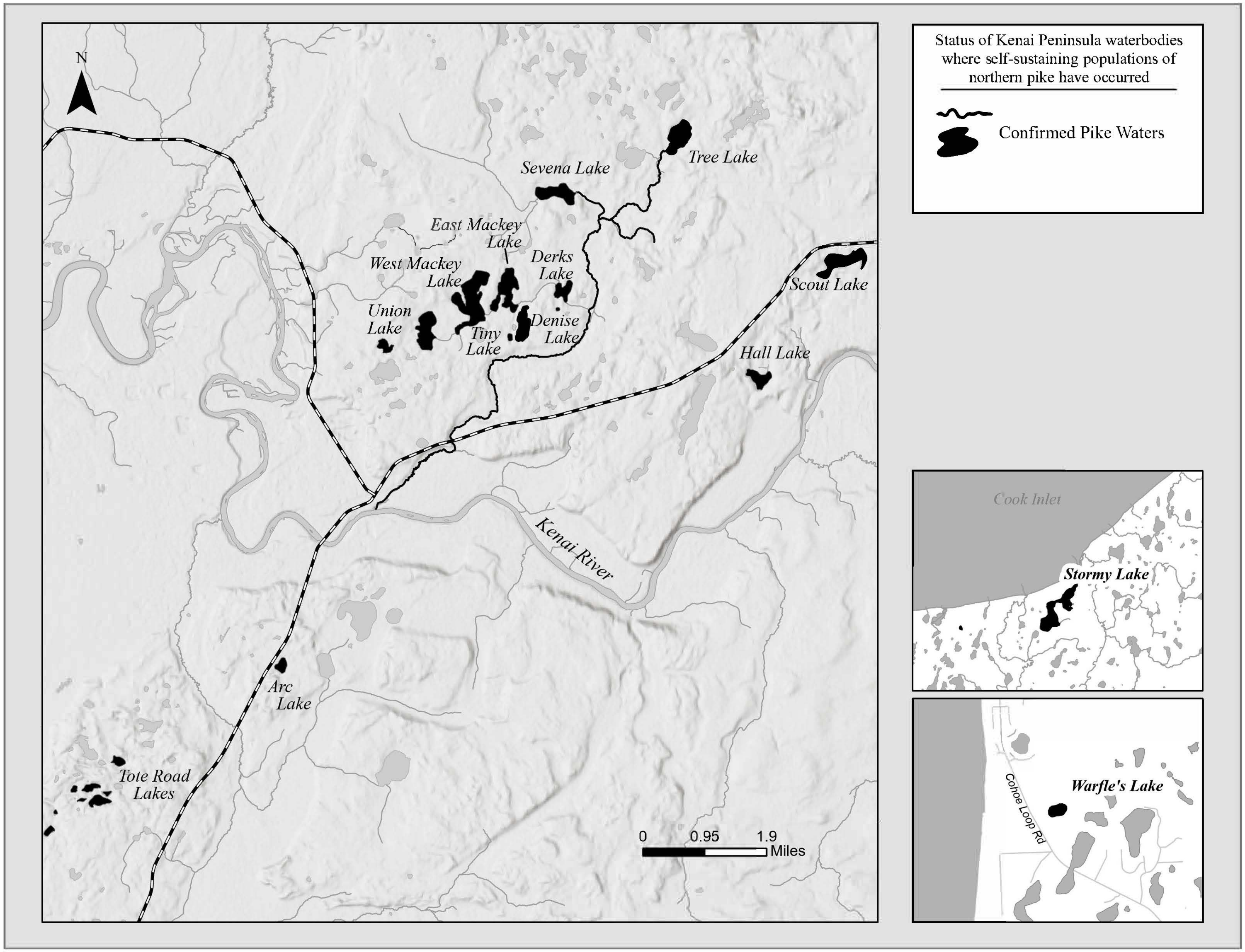

Figure 2.–Kenai Peninsula waterbodies where self-sustaining populations of northern pike have been identified, 1970s–2019.

Recent observations from the Kenai River are concerning. Several northern pike were observed via video weir entering the Kenai River from Soldotna Creek between 2009 and 2010 (Gates and Boersma 2011). Although extremely rare, anglers reporting in the Alaska Department of Fish and Game (ADF&G) Statewide Harvest Survey (SWHS) have caught northern pike from the Kenai River. However, these reports of northern pike catches in the Kenai River are unconfirmed and some may be the result of species misidentification. SWHS estimates indicate that no northern pike were caught in the Kenai River drainage in the 2017 and 2018.[2]

Substantiated reports of northern pike occurring in the Kenai River drainage outside of Soldotna Creek include an angler who, in 1995, provided ADF&G with a photo of a northern pike caught from Engumen Lake, an open lake within the Moose River drainage, but no sport fish catches have been confirmed since. A dead northern pike was found by an Alaska State Park ranger near the mouth of the Moose River in 2007, and another dead northern pike was recovered by an ADF&G biologist near the Russian River mouth in the late 1990s (Bruce King, retired Fisheries Biologist, ADF&G, Soldotna, personal communication). Despite numerous sampling efforts by ADF&G and the United States Fish and Wildlife Service (USFWS) in the Moose River drainage, no northern pike have been captured there. These efforts include Moose River weir passage observations from 1992 through 2007 (ADF&G, Division of Sport Fish, Soldotna, unpublished data), a 2001 ADF&G netting survey of multiple lakes in the east fork of the Moose River (Tim McKinley, Fisheries Biologist, ADF&G, Soldotna, personal communication), and a wintertime angling survey conducted by the USFWS (Palmer and Tobin 1996). To date, there is no evidence that a self-sustaining northern pike population exists anywhere in the Kenai River drainage beyond the Soldotna Creek drainage.

The economic and ecological importance of salmonids to the Kenai Peninsula and Southcentral Alaska cannot be overstated. Southcentral Alaska sport and commercial fisheries alone provide an economic output annually valued at about $2.0 billion (Southwick Associates Inc. et al. 2008; McDowell Group 2020[3]). Salmon are also a keystone species that drive trophic nutrient and energy exchanges vital to the area's ecosystem (Hilderbrand et al. 2004; Rinella et al. 2013). The Kenai River drainage supports the largest salmon and trout fisheries on the Kenai Peninsula (Begich et al. 2017). To protect native freshwater fisheries on the Kenai Peninsula from potential northern pike predation, it is imperative that all invasive northern pike populations on the Kenai Peninsula be removed. At the start of this project, the Soldotna Creek drainage contained what was believed to be the largest population of invasive northern pike on the Kenai Peninsula and was considered one of the biggest threats to native fish in the Kenai River drainage prompting the ADF&G Division of Sport Fish Region II Invasive Northern Pike Planning Team to rate the Soldotna Creek drainage as the highest priority threat of all Kenai Peninsula northern pike populations (Appendix A1).

The Soldotna Creek drainage encompasses 119 km^2 and enters the Kenai River near river mile (RM) 22 (35.4 river kilometers). The drainage includes dozens of lakes, ponds, and small tributaries. Northern pike have been identified in a total of 11 waterbodies (10 lakes and ponds, and Soldotna Creek; Figure 3). Two of these waterbodies (Tree Lake and Denise Lake) lost their

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[2] Alaska Sport Fishing Survey database [Internet]. 1996–present. Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited March 2020). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

[3] http://www.mcdowellgroup.net/wp-content/uploads/2020/01/mcdowell-group_asmi-economic-impacts-report-jan-2020-1.pdf (Accessed October 2020).

northern pike populations sometime after 2002 by unknown causes, although winterkill is suspected for Tree Lake.

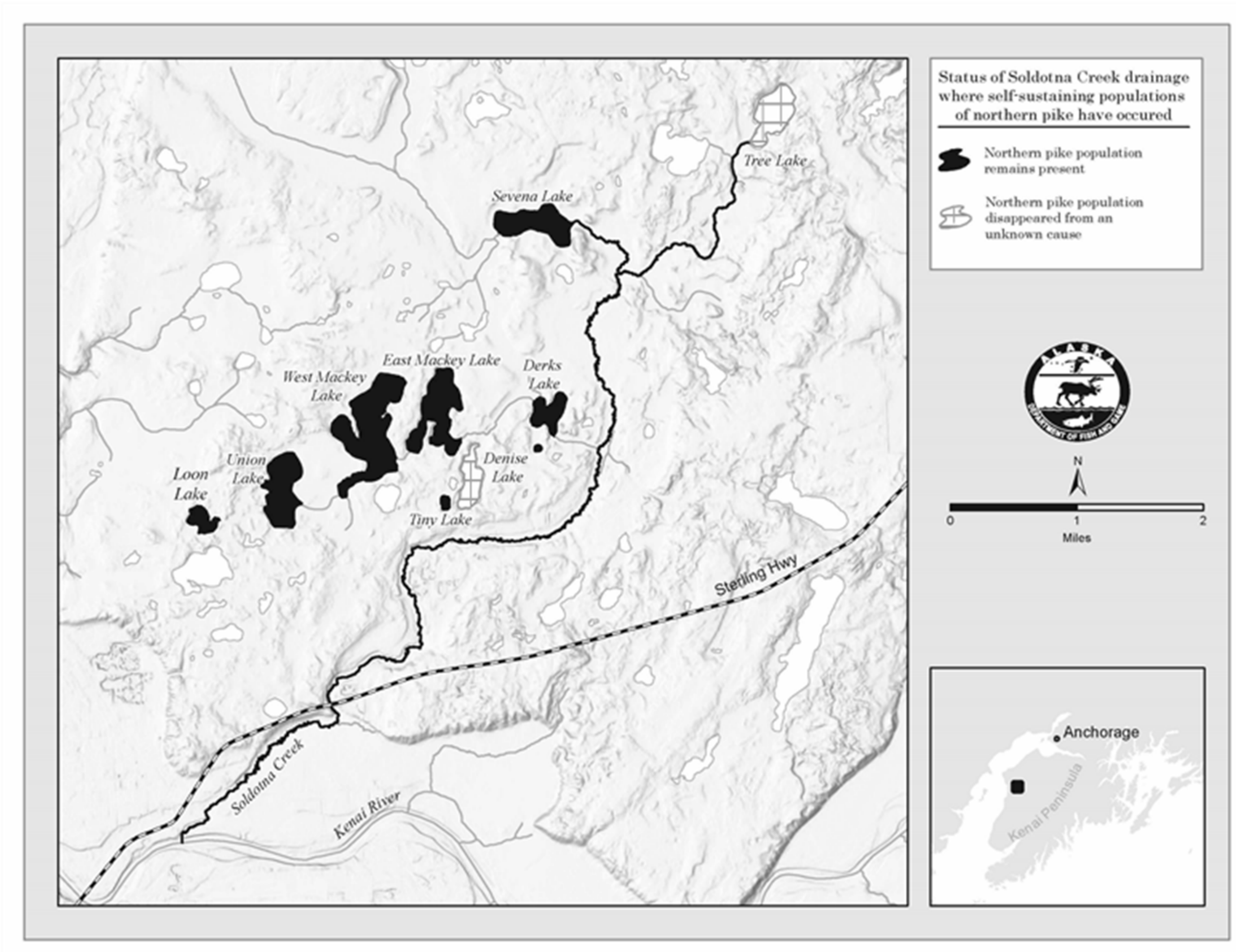

Figure 3.–Map of Soldotna Creek drainage showing the status of northern pike waters.

Note: Two northern pike populations (Tree Lake and Denise Lake populations) disappeared from unknown causes prior to 2014.

During the 2000s, fish assemblage and distribution data were collected in the Soldotna Creek drainage via northern pike removal projects and a USFWS video weir operated in Soldotna Creek in 2009 and 2010 (Begich 2010; McKinley and Fleischman 2010; Gates and Boersma 2011; Massengill 2011). Fish surveys conducted in the Soldotna Creek drainage in 2001 and in 2013 indicated native fish had been extirpated by northern pike in the western branch of the drainage. The eastern branch of the drainage consists of Sevena Lake, other headwater lakes, and the mainstem Soldotna Creek. Native fish populations were found to be severely depressed in Sevena Lake but remained robust in the mainstem of Soldotna Creek where suitable northern pike habitat is very limited. Native fish species affected by northern pike predation in the Soldotna Creek drainage include rainbow trout, Dolly Varden (*Salvelinus malma*), coho salmon, and stickleback (largely *Gasterosteus aculeatus* with rarer *Pungitius pungitius*; unspecified in most cases).

Beginning in 2008, the ADF&G Kenai Peninsula northern pike control program shifted focus from mostly mechanical removal methods to chemical treatments. Initial eradication efforts targeted landlocked lakes (Massengill 2014a, 2014b). By 2012, ADF&G successfully conducted a chemical eradication effort of the Stormy Lake drainage, a large and complex anadromous waterbody within the Swanson River drainage (Massengill 2017). In 2012, ADF&G conducted public scoping to vet the options for addressing the northern pike problem in the Soldotna Creek drainage. Following public input, ADF&G chose chemical eradication (rotenone treatment) as the most cost effective means to eradicate the northern pike population. This report describes the restoration of the Soldotna Creek drainage, which to date, is the largest effort to eradicate invasive northern pike and restore native fish habitat in Alaska.

OBJECTIVES

The goal of this project was to restore the fish habitat of the Soldotna Creek drainage.

Primary Objective

Eradicate the invasive northern pike population in the Soldotna Creek drainage.

Secondary Objectives

1) Conduct public scoping for eradicating northern pike from the Soldotna Creek drainage.
2) Collect physical, biological, and water quality data from the drainage prior to treatment.
3) Fulfill all permitting and authorization obligations required for the eradication effort including National Environmental Protection Agency [NEPA] compliance.
4) Install stream barriers to partition the drainage into sections.
5) Chemically treat the drainage with a piscicide (rotenone).
6) Deactivate rotenone treated waters, if needed, prior to discharging into the Kenai River.
7) Monitor the drainage after treatment, including an evaluation of removal success, documenting when rotenone deactivation occurs, and determining when water quality and the amount of fish forage are sufficient for the reintroduction of native fish.
8) Reintroduce and restore the distribution of native fish in the Soldotna Creek drainage to that which was historically present prior to the introduction of northern pike.

METHODS

CLEARANCES FOR TREATMENT

Various regulatory and landowner permits were required for this project and are summarized below. Original documents are available at the ADF&G Soldotna office.

Federal Level Approval

1) An environmental assessment for the Soldotna Creek drainage restoration was submitted to the United States Fish and Wildlife Service (USFWS) on 4 June 2014. A Finding of No Significant Impact (FONSI) was issued on 27 August 2014. The environmental assessment can be viewed online (accessed November 2020) at the following: https://www.adfg.alaska.gov/static/species/nonnative/invasive/rotenone/pdfs/soldotna_creek_drainage_restoration_project_environmental_assessment.pdf.

State Level Approvals

1) An Alaska Department of Environmental Conservation (DEC) Pesticide Use Permit (PUP) was issued on 22 May 2014.
2) An electronic Notice of Intent (eNOI) was submitted by ADF&G to the DEC Alaska Pollution Discharge Elimination System (APDES) program. The permit request was approved on 6 September 2013. The eNOI permit number is #AKG870004 and it required certification by the ADF&G Statewide Invasive Species Program Leader. ADF&G also completed a Pesticide Discharge Management Plan (PDMP), an eNOI requirement. Both the eNOI approval and PDMP are archived in the ADF&G Soldotna Office.
3) An Alaska Department of Natural Resources (DNR) Land Use Permit (LUP) was issued on 13 May 2015.
4) Multiple ADF&G Fish Resource Permits were obtained (SF-2014-071, SF-2016-055, SF-2016-056, SF-2016-239, and SF-2018-202). These were needed for native fish collections, relocations, and for bioassay in the Soldotna Creek drainage. These permits were approved between 26 February 2014 and 28 June 2018.
5) Multiple ADF&G Fish Transport Permits (14A-0039, 14A-0040, 15A-0016, 15A-0018, 15A-0019, 15A-0020, 15A-0021, 15A-0022, 15A-0023, 15A-0024, 15A-0025, 15A-0026, 15A-0027, 15A-0028, and 16A-0019). These were needed for native fish restoration and sentinel fish or bioassay purposes. These permits were approved between 1 September 2014 and 1 March 2017.
6) Multiple ADF&G Fish Habitat Permits (FH 13-V-0311 through FH13-V-0019; FH18-V-0094 and FH18-V-0099) were issued between 11 October 2013 and 26 June 2018. These permits allowed for the installation and maintenance of temporary fish barriers in the Soldotna Creek drainage.
7) A Salamatof Native Association Land Use Permit (2015-62) was issued 20 October 2015 to allow treatment related activities on Salamatof lands during the Area 2 treatment.
8) Written approval was given by the Kenaitize Native Association via email on 30 September 2015 to allow treatment related activities on Kenaitize lands during the Area 2 treatment.
9) A Cook Inlet Regional Inc. (CIRI) Land Use permit (2014-006) was issued on 1 April 2014 to allow treatment related activities on CIRI lands during the project.
10) Written approval by the ADF&G Division of Sport Fish Director allowing the use rotenone for the Soldotna Creek drainage restoration project, per AS 16.35.200, was received via email on 18 July 2014.
11) Written approval by the Alaska Board of Fisheries to allow the use of rotenone for the Soldotna Creek drainage restoration project, per AS 16.35.200, was received on 19 September 2014.
12) A Pesticide-Use Permit Emergency Exemption was issued by DEC on 14 August 2017 that allowed ADF&G to conduct an emergency rotenone treatment at Loon Lake.
13) Multiple Soldotna Borough Landfill Disposal Approvals (U2014-7, U2016-7, U2017-6, L2016-3, L2016-4, and L2017-5) were obtained between 29 August 2014 and 8 May 2018. These were required to dispose of various pesticide contaminated waste generated by this project.

Public Scoping and Notices

A list of the public scoping meetings, notices, and media generated for the Soldotna Creek drainage restoration project are provided below:

1) Public meetings to solicit input on the Soldotna Creek drainage restoration alternatives were held on 3 occasions in March 2012 at the Kenai National Wildlife Refuge's Environmental Education Center. The meetings were advertised with an ADF&G news release on 8 March 2012 (accessed November 2020): https://www.adfg.alaska.gov/sf/EONR/index.cfm?ADFG=region.NR&NRID=1580. Also, 447 notices were mailed to property owners proximate to the Soldotna Creek drainage and dozens of other stakeholders were notified by email or phone.
2) ADF&G gave a presentation on 3 March 2012 to the ADF&G Soldotna Area Advisory Committee on the issue of invasive northern pike in the Soldotna Creek drainage, alternative strategies to the address the issue, and permitting requirements.
3) ADF&G contracted a planner (Stantec, formerly USKH) who conducted 25 stakeholder interviews in March 2012 to gather input from organizations and individuals identified by ADF&G as having a specific interest or concern about invasive northern pike in the Soldotna Creek drainage.
4) Public notices for the Soldotna Creek drainage restoration DEC PUP application were printed in the Peninsula Clarion on 2 consecutive days (20–21 April 2014).
5) Public notices for the Soldotna Creek drainage restoration Environmental Assessment (EA) were printed in the Peninsula Clarion on 2 consecutive days (20–21 April 2014).
6) Hand delivered notices were provided to all lakeside residences in the western branch of Soldotna Creek drainage on 25–28 March 2014 to inform of the public commenting period for the DEC PUP application and Environmental Assessment.
7) Public notice handouts announcing the public commenting period for the Soldotna Creek drainage restoration DEC PUP and EA were provided at the Soldotna Sport Show held at the Soldotna Sports Complex in May 2014.
8) The Peninsula Clarion newspaper published articles about the Soldotna Creek drainage invasive pike issue and ADF&G restoration plans on 20 September 2014 and 24 March 2016 (accessed November 2020, links follow, respectively): https://www.peninsulaclarion.com/news/pike-killing-project-approved-for-the-soldotna-creek-drainage/ and https://www.peninsulaclarion.com/news/fish-and-game-targets-soldotna-creek-for-summer-pike-eradication/.
9) ADF&G gave a presentation to the Soldotna City Council on 23 March 2016 to update the Council of ongoing efforts to remove invasive northern pike from the Soldotna Creek drainage.
10) ADF&G news release announcing the June 2016 rotenone treatment of the Soldotna Creek drainage (accessed November 2020): https://www.adfg.alaska.gov/sf/EONR/index.cfm?ADFG=region.NR&Year=2016&NRID=2263.
11) ADF&G provided multiple mailed and hand delivered notices to landowners in the Soldotna Creek drainage between October 2013 and January 2018 to apprise landowners of project milestones.

12) ADF&G held a public meeting at the State Forestry Headquarters in Soldotna to inform landowners and the public of the outcome of the completed Soldotna Creek Restoration project and native fish reintroduction efforts on 1 February 2018.

PROJECT PLANNING DATA COLLECTION

Lake Mapping and Partitioning

To plan for chemical treatments, bathymetric maps and water volume estimates were generated for the lakes and ponds containing invasive northern pike. The bathymetry data were collected using a boat mounted Lowrance HDS 7 Touch depth finder–chart plotter with a depth sounding transducer. The Lowrance HDS 7 Touch unit simultaneously records data at a user selected "ping rate" of 5 per second. We followed mapping guidelines by ciBiobase, a cloud based map processing service provided by Contour Innovations LLC, including keeping the boat speed less than 20 miles per hour (mph) or below a speed that prevents cavitation near the depth transducer. Most commonly, boat speeds while surveying were less than 5 mph. Data were typically collected by first surveying near lake perimeter as close to shore as possible followed by a second pass more offshore (about 7 meters) from the initial pass. Subsequent surveying was done by traveling straight line transects spaced less than 10 m apart and orientated parallel with the longest straight line distance of the waterbody or bay being surveyed. Transect swaths were visually monitored on the Lowrance HDS 7 Touch screen while the survey was in progress.

Once a survey was completed, all data records were uploaded to ciBioBase for processing that corrects erroneous data and interpolates the data using algorithms to generate bathymetry maps, processed depth data records, volume estimates, and vegetation reports.

It is important to have volume estimates of lake sections (partitions) to allow for planning a more even distribution of rotenone during the application. To compute lake partition volume estimates, processed depth, location, and lake outline data were input into ArcGIS, which was used to make a digital elevation model (DEM) of the lake bottom surface using the TOPO to Raster command. The lake outline was digitized manually from imagery layers produced by the Kenai Peninsula Borough that were already orthorectified and georeferenced. An ArcGIS tool called "Surface Volume" calculated the projected area, surface area, and volume of a surface relative to a given reference plane. A custom GIS software tool was used to take user supplied lake partition polygons and associated lake depth grid data to compute area and volume for lake partitions (personal communication, Jason Graham, ADF&G Analyst/Programmer, Anchorage, Alaska).

Water Quality

We collected monthly water quality data from all northern pike occupied lakes for 1 year before and 1 year after their respective rotenone treatments. Water temperature, pH, dissolved oxygen, and specific conductivity data were collected using a Quanta Hydrolab. Water quality data were collected in 1-meter increments from the lake bottom to the surface at a single site located near the deepest part of each lake. Turbidity data were measured to the nearest 0.1 meter of visibility to the naked eye using a secchi disc at the same location where water quality data were collected.

Stream Discharge and Travel Rates

Monthly stream discharge measurements were collected from Soldotna Creek and selected tributaries for 1 year in advance of the first rotenone treatment to provide information for initial project planning. Stream discharge was also collected, as needed, immediately before the rotenone treatments and afterwards to help assess the need for rotenone deactivation to avoid impacts to aquatic life outside the treatment area. Equipment used to collect stream discharge measurements included a Price Pygmy current meter (magnetic head) attached to a Scientific Instruments wading rod with an electronic AquaCount display screen mounted on it. Stream discharge was collected in accordance with the ADF&G Statewide Aquatic Resources Coordination Unit training course titled "How to Measure Stream Discharge." Monthly pretreatment discharge measurements were collected between April 2006 and April 2017. Subsequent discharge measurements collected just prior to and following rotenone treatments occurred between 23 September 2014 and 22 June 2017.

Stream travel rate is used when planning stream rotenone treatments to determine spacing for rotenone drip stations along a stream. In cooperation with ADF&G, the Kenai Watershed Forum (KWF) conducted a study to estimate Soldotna Creek stream travel rates in 5 reaches that encompass the entire mainstem of Soldotna Creek. The KWF used a salt release in the stream's headwaters and subsequent downstream salinity detections to estimate stream travel rate. A summary of methods is provided in Appendix A2. This study was funded by an award granted by the Kenai Peninsula Fish Habitat Partnership.

Northern Pike Distribution and Reduction

Since the early 2000s, gillnetting surveys have been used to define the distribution of northern pike in the Soldotna Creek drainage and to reduce their abundance (Begich and McKinley 2005; Begich 2010; Massengill 2010, 2011; McKinley 2013). The project presented here conducted pretreatment gillnetting to assess current northern pike distribution in the drainage. Most netting focused on small lakes and ponds with potential surface water connections to known northern pike lakes. Lakes netted during the 2013–2017 period included Cisca Lake, Derks Lake, Derks Pond, East Mackey Lake, Halfhorn Lake, Loon Lake, No Banjo Lake, Sevena Lake, Tree Lake, Union Lake, and West Mackey Lake (some lake names are unofficial; Figure 4).

It was also deemed beneficial to lower northern pike abundance with intensive under ice gillnetting during the winter of 2013/2014 in most lakes associated with the western branch of Soldotna Creek drainage and during the winter of 2016/2017 at Sevena Lake. Nets were set in the lakes as they froze and were removed in the spring as ice-out occurred. Northern pike removal prior to rotenone treatments was intended to reduce the number of decaying carcasses that might cause a public nuisance after treatment and perhaps reduce northern pike reproductive success and proliferation of young-of-year inhabiting wetlands that were difficult to treat.

The gillnets were constructed of variable mesh gillnets paneled with six 20-foot sections of ¾ in, 1 in, 1¼ in, 1½ in, 1¾ in, and 2 in stretch monofilament mesh. Each net was 120 feet in length and 6 feet in depth with a braided polypropylene floating line and sinking lead line. Generally, nets were fished in a hockey stick pattern in nearshore vegetated habitat with one end tethered to shore using a wood survey stake. The net was then stretched perpendicular to the shoreline until reaching the edge of an offshore weedline, then stretched parallel along the weedline edge until the net was fully deployed.

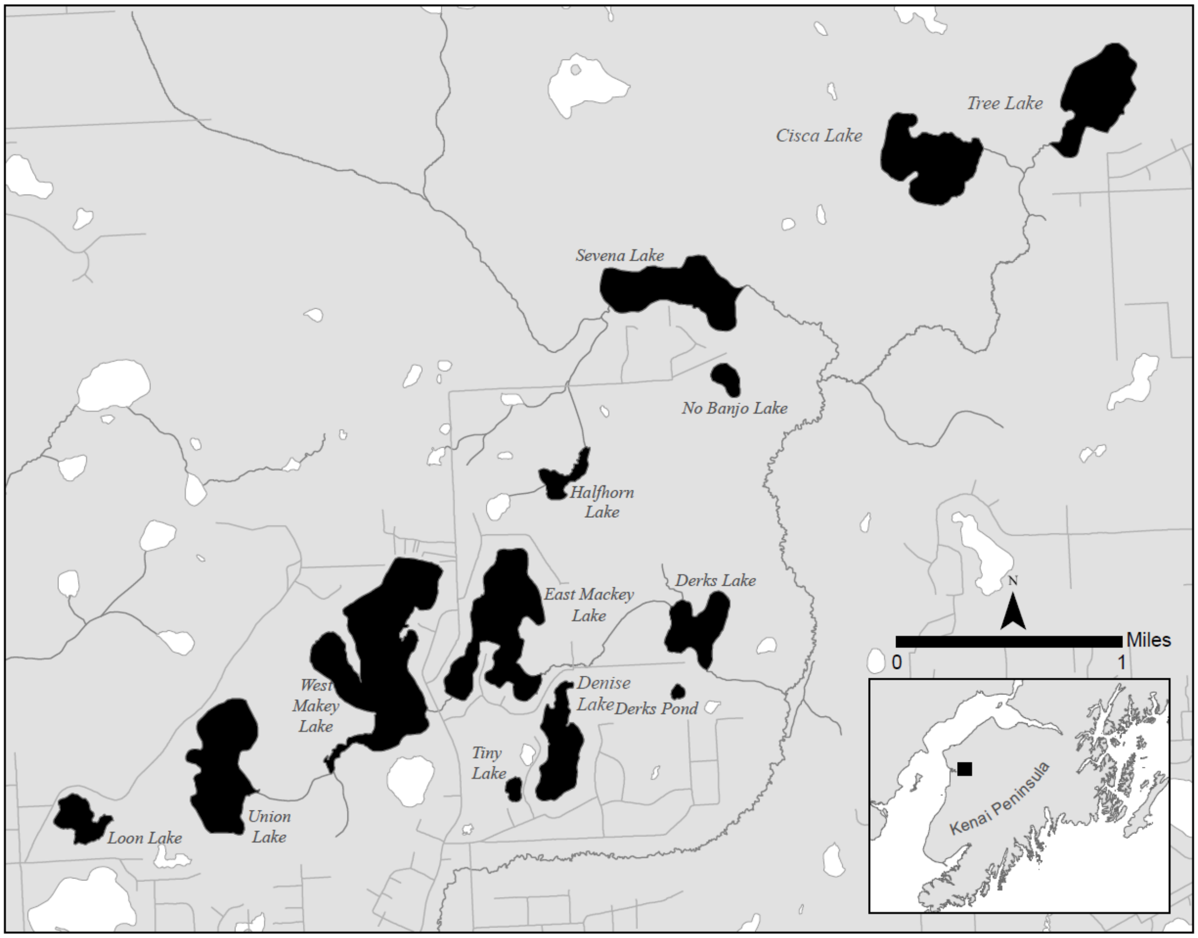

Figure 4.–Map of lakes fished with gillnets (black fill), 2010 and 2017.

BIOASSAYS

Bioassays using juvenile salmonids were conducted to determine the minimum effective dose (MED) of rotenone required for the rotenone treatments following the criterion that the MED is the concentration that achieves 100% mortality after 8 hours of exposure (Finlayson et al. 2010). Finlayson et al. (2010) recommended that the target rotenone concentration be at least double the MED to account for environmental and biotic factors (including organic load, pH, turbidity, temperature, sunlight intensity, and water depth) that can impede rotenone's effectiveness. For example, if a bioassay indicates a MED of 50 parts per billion (ppb), the target treatment concentration should be at least 100 ppb (2 × 50 ppb = 100 ppb).

Juvenile coho salmon, rather than northern pike, were collected from Soldotna Creek for the bioassays because it is difficult to catch northern pike of appropriately small size (larger fish would probably exceed the recommended 1 g fish per liter of water; Finlayson et al. 2010). Coho salmon may have a higher tolerance to rotenone than northern pike (Marking and Bills 1976), so concentrations fatal to coho salmon were expected to kill northern pike.

For each bioassay, 4–6 fish (110 mm fork length [FL]) were placed in a plastic bucket filled with 20 L of lake water. Added to each bucket was a preselected amount of a liquid rotenone formulation (CFT Legumine) or powder formulation (Fish Toxicant Powder) according to directions provided in Finlayson et al. (2010). The bioassays tested the active ingredient (rotenone) across a range of concentrations ranging from 0 ppb (control) to 200 ppb using the amounts of rotenone premixture (rotenone product diluted with water) found in Table 1. The elapsed time was recorded when fish were observed becoming impaired (i.e., unable to remain orientated, excessive surface gulping, immobile except for gilling, or death defined by lack of gill movement). Water temperature and dissolved oxygen data were recorded in the bioassay containers using a Quanta Hydrolab to confirm if water temperature and dissolved oxygen levels had remained sustainable.

Table 1.–Reference table for amount of rotenone product premix added to various bioassay container volumes to achieve desired concentrations.

	Bioassay container volume	
	10 liter (L)	20 liter (L)
Target concentration in ppb[a]	Milliliters (mL) of premix[b]	Milliliters (mL) of premix[b]
12.5	2.5	5
25	5	10
50	10	20
100	20	40
200	40	80

[a] Target concentration refers to amount of rotenone (not total product), in parts per billion.

[b] Premix consists of 1 mL of liquid pesticide product or 1 mg of powdered rotenone product, containing 5% rotenone, added to one liter of water. An adjustment must be made for how much product is required for the premix if the assayed rotenone concentration is different than 5% rotenone (see Appendices B1 and B2 for product labels).

CALCULATING AMOUNT OF PRODUCT REQUIRED

A combination of rotenone formulations (liquid and powdered) was used to treat the Soldotna Creek drainage. Liquid formulations were used exclusively to treat flowing waters as dictated by product labeling, and a mix of liquid and powder formulations was used to treat most of the lakes. In some instances, only liquid formulations were applied to lakes. Cost savings was a factor in utilizing the powder formulation. The liquid formulation contains additives to emulsify and disperse the rotenone, which improves mixing, and it is considered safer for applicators because of lower inhalation risk compared to powdered products; however, liquid formulations are significantly more costly. Powdered formulations were primarily used in open offshore lake applications. The amount of liquid and powdered rotenone formulations needed to treat each waterbody was calculated based on bioassay results, the volume of each waterbody, and consideration of environmental variables that might affect the duration and potency of rotenone (Finlayson et al. 2010). In the western branch of Soldotna Creek drainage, roughly 30–40% of each lake was treated with liquid formulation and the remainder with powder formulation. Sevena Lake was only treated with liquid formulation.

Example calculations for determining the amount of rotenone product to apply are provided below using a hypothetical target concentration of 0.8 ppm of product (which is equivalent to 40 ppb active rotenone). The actual combined product target concentration varies based on the discretion of the certified applicator informed by the bioassay results, environmental conditions, and the potential risk for rotenone to move outside the treatment area.

Lake Treatment

Liquid Rotenone Formulation Example

The number of gallons of liquid CFT Legumine product (G_p) required to treat a hypothetical 400 acre-feet lake at a target concentration of 0.8 ppm (product), equivalent to 40 ppb active ingredient (rotenone), was calculated from the product label (Appendix B1) in this manner:

$$G_p = 0.\overline{333} \times D_c \times V_e \tag{1}$$

where

$0.\overline{333}$	=	gallons of CFT Legumine product required to treat 1 acre-foot of water at 1.0 ppm (per product label; Appendix B1),
D_c	=	desired target concentration (0.8 ppm) of CFT Legumine, and
V_e	=	estimated volume (400 acre-feet) for hypothetical Lake X.

Therefore, it follows that for a desired target concentration of 0.8 ppm for 400 acre-feet,

$G_p = 0.\overline{333} \times 0.8 \times 400 = 106.6$ gallons of CFT Legumine are needed.

Powdered Rotenone Formulation Example

The number of pounds of Prentox Prenfish Rotenone Fish Toxicant Powder (P_p) required to treat a hypothetical 400 acre-feet at a target concentration of 0.8 ppm (product) was calculated from the product label (Appendix B2) in this manner:

$$P_p = 2.7027 \times D_c \times V_e \tag{2}$$

where

2.7027	=	pounds of Prentox Fish Toxicant Powder product required to treat 1 acre-foot of water at 1.0 ppm (per product label; Appendix B2),
D_c	=	desired target concentration (0.8 ppm) of Prentox Fish Toxicant Powder, and
V_e	=	estimated volume (400 acre-feet) for hypothetical Lake X.

It therefore follows that for a desired target concentration of 0.8 ppm for 400 acre-feet,

$P_p = 2.7027 \times 0.8 \times 400 = 866.3$ pounds of Prentox Fish Toxicant Powder.

To compensate for the difference between the assayed rotenone concentration listed on the Prentox Prenfish Rotenone Fish Toxicant Powder container (6.3%) and the concentration used in the product label directions (5%), an adjustment was required. The adjustment multiplied a coefficient to the 866.3 pounds of product originally calculated. The coefficient was derived by dividing the assayed rotenone concentration percentage used in product label directions (5%) by the assayed rotenone concentration listed on the product container (6.3%) as follows: $5 \div 6.3 = 0.794$.

Therefore, the pounds of product needed to achieve the target concentration of 0.8 ppm for 400 acre-feet would be adjusted as follows:

$P_p = 866.3 \times 0.794 = 687.5$ pounds of Prentox Prenfish Rotenone Fish Toxicant Powder

Creek Treatment

CFT Legumine Liquid Toxicant Example

Only liquid rotenone formulations can be applied to flowing waters (Finlayson et al. 2010). The stream application utilizes multiple drip stations that are spaced no less than 1 hour or no more than 2 hours apart in stream travel distance (Finlayson et al. 2010). Hence, drip station placement and the rotenone application rate are based on stream discharge and stream travel rates for a reach of stream.

The volume of liquid rotenone required at a single drip station be calculated for flowing waters. For example, using the milliliters (mL) of undiluted liquid CFT Legumine formulation (X_s) required per minute for a single drip station applying rotenone in a creek with a discharge 2.0 cubic feet per second (ft^3/s) or stream travel rate 0.25 mph, a 0.8 ppm of liquid product per minute is calculated as follows:

$$X_s = (1.692 \times F \times C) \tag{3}$$

where

1.692	=	formula constant (Finlayson et al. 2010)
F	=	flow of the stream in cubic feet per second, and
C	=	desired rotenone product concentration in parts per million (ppm).

It follows that for a flow rate (F) of 2 ft^3/s and a desired rotenone concentration of 0.8 ppm, $X_s = 1.692 \times 2 \times 0.8 = 2.7$ mL of undiluted rotenone per minute

The amount of CFT Legumine (X_m) required for multiple drip stations in a 4,500-foot section of the same stream, where discharge and travel rates remain equal, where the drip stations will operate 480 minutes, and each drip station is equally spaced at a distance equal to 1 hour of stream travel, can be calculated as follows:

$$X_m = X_s \times M \times D \tag{4}$$

where,

M	=	number of minutes of treatment duration = 480 minutes
D	=	number of drip stations needed to treat the stream to achieve a 1-hour stream travel rate interval between drip stations and calculated as follows:

$$D = (F_s/T_r)/S_h \tag{5}$$

where

F^s	=	feet of stream (lineal feet) to be treated = 4,500 feet
T_r	=	travel rate of stream = 0.25 feet per second
S_h	=	seconds in an hour = 3,600 seconds

resulting in $D = (4500/0.25)/3600 = 5$ drip stations.

Therefore, the amount (mL) of CFT Legumine needed to treat the 4,500-foot section of the example stream for (480 minutes) using 5 drip stations is

$X_t = 2.7 \times 480 \times 5 = 6{,}480$ mL (or about 6.48 L).

TREATMENT STRATEGIES

Overview

The large scale and challenging logistics involved with treating the Soldotna Creek drainage with rotenone and restoring native fish populations required dividing the drainage into 2 treatment sections. Area 1 consists of the western branch of the Soldotna Creek drainage including Union Lake, West Mackey Lake, East Mackey Lake, Derks Lake, Derks Pond, Loon Lake, and some wetlands and tributaries directly connected to these waters (Figure 5). Area 2 includes the entirety of the Soldotna Creek mainstem, Tree Creek, Sevena Lake, and other tributaries not in Area 1 (Figure 6). Several rotenone treatments were planned over a 3-year period (2014–2017). Area 1, excluding Loon Lake, was treated once in 2014. Loon Lake was treated separately in 2017 under emergency conditions because northern pike were unexpectedly detected in 2017 and their presence created an immediate threat to the integrity of this project due to its potential connectivity to other Area 1 waters during rare high water events. Area 2 was treated twice, once in 2016 and again in 2017; however, the 2017 treatment was restricted to just Sevena Lake and its tributaries. A series of temporary fish barriers near the terminus of Area 1 (Derks Lake outlet) was installed to prevent between-Area fish movement until the entire project was completed.

Drainagewide fish distribution was garnered mostly from work done under other projects. These projects included ADF&G northern pike assessment and control projects and a USFWS video weir operated in Soldotna Creek (Begich 2010; McKinley and Fleischman 2010; Gates and Boersma 2011; Massengill 2011). Additional netting, minnow trapping, and eDNA surveys were conducted opportunistically by ADF&G to supplement our understanding of fish distribution in the drainage (Soldotna ADF&G office, unpublished data[4]).

Gillnet and minnow trapping surveys done by previous projects indicated most Area 1 native fish species were extirpated by northern pike predation by 2001, if not earlier. In Area 2, native fish populations generally remained robust in the mainstem of Soldotna Creek but were at low relative abundance in Sevena Lake where northern pike were most prevalent.

A general timeline for select project tasks was as follows:

2013: Pretreatment northern pike abundance reduction using under-ice gillnets in Areas 1 and 2.

2014: Treat northern pike waterbodies from Area 1 in October using rotenone.

2015: During the open water season, capture as many native fish of all species as feasible from Area 2 and relocate them to Area 1.

2016: Treat northern pike waterbodies from Area 2 in June using rotenone.

2017: Repeat northern pike removal efforts in Area 2 in June as deemed necessary.

2016–2018: Continue native fish restoration efforts by relocating fish from Area 1 to Area 2.

The timing of the Area 1 treatment during fall was chosen to take advantage of lake thermocline changes (fall turnover) to aid in mixing the rotenone in the drainage's deepest lakes. A cold water treatment was expected to slow the deactivation of rotenone and increase the likelihood all northern pike would eventually be exposed to the piscicide. Mid- to late June treatments were planned for Area 2 to allow most juvenile coho salmon smolt and overwintering adult steelhead (*O. mykiss*) to

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[4] Report titled Northern Pike (*Esox lucius*) in the Soldotna Creek System, anonymous author, available at the Soldotna ADF&G Office

emigrate before treatment and to avoid impacting adult coho salmon and steelhead returning in late summer and fall.

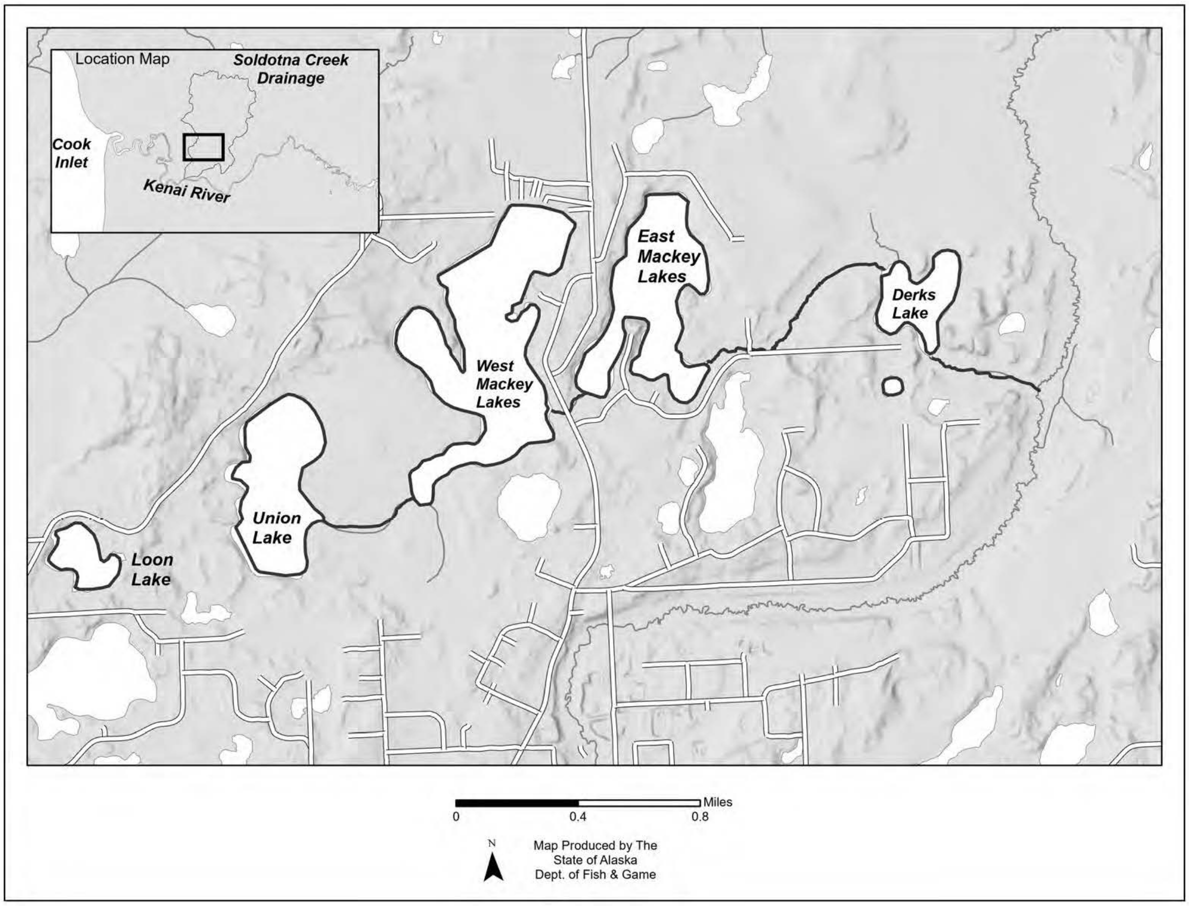

Figure 5.–Map of treatment areas in Area 1 of the Soldotna Creek drainage.

Note: Bold lines on main map indicate Area 1 treatment areas. Insert shows main map (rectangle) with respect to Soldotna Creek drainage outlined in bold.

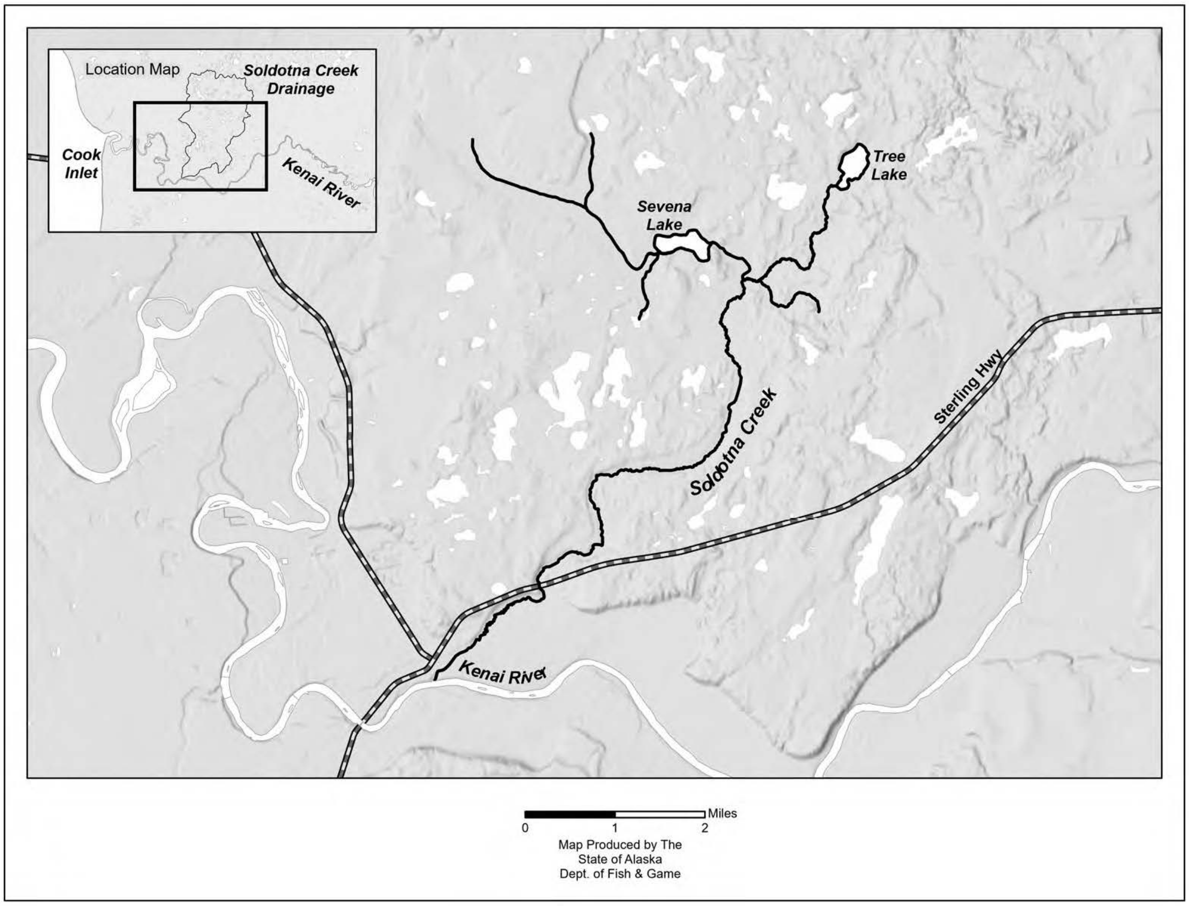

Figure 6.–Map of treatment areas (bold dark lines) in Area 2 of the Soldotna Creek drainage.

LIQUID ROTENONE APPLICATION TECHNIQUES

Boat Application

CFT Legumine (Appendix B1) is a liquid rotenone product containing additives that improve its emulsion and diffusion in water. We planned to use it to treat areas where mixing could be impeded (e.g., weedy shoreline areas, deep water >30 ft), and to a lesser degree, open lake surfaces.

We applied CFT Legumine primarily with 2 outboard powered boats and 1 airboat. All liquid rotenone application boats required 2 applicators per boat, one to operate the boat and another to operate the pumping apparatus. All application outboard boats were equipped with gas-powered semi-closed pumping apparatuses consisting of a Honda trash pump with intake and discharge hoses. Premixing occurred within the pump apparatuses by way of merged intake lines wherein a large diameter (2-inch) intake line drew lake water from behind the boat transom while a smaller intake line (¼- to ¾-inch diameter) drew CFT Legumine from the product container. Both the piscicide and water were drawn, mixed, and discharged by the pumping apparatus. A valve lever on the CFT Legumine intake line was used to control the rate of withdrawal from the container.

One application boat had a discharge hose with the option to discharge piscicide with a spray turret for long distance spraying (approximately 15 m) or to deploy a pair of 20-foot long, 1.5-inch diameter submersible well pipes for deep subsurface water applications (>5 m depth; Figure 7).

Each well pipe was secured to the gunnel near the boat's transom using adjustable sleeve mounts that allowed the pipes to rotate up or down in the water column. A tandem spreader bar attached near the distal ends of each well pipe helped to keep the pipes spaced apart and to stabilize when deployed below the water surface. One end of a cable was connected to the center of the pipe spreader and the other end was attached to a winch-mounted boom on the boat's bow. The winch could be hand cranked to raise or lower the well pipes.

Figure 7.–Outboard application boat with hand-operated spray turret and a deep-water application apparatus.

An electronic depth finder (Garmin GPSMAP 440s FishFinder) was used by outboard boat applicators for monitoring the application of both liquid and powdered rotenone formulations by tracking application swaths, boat speed, and lake depth. A printed reference chart (Appendix C1) allowed boat operators to adjust boat speed in relation to observed water depths to promote even distribution of the rotenone. Generally, applicators would first apply piscicide to the outermost perimeter of an area and work their way inward by making increasingly smaller concentric loops while maintaining approximately 30-foot distances between application swaths.

An airboat applied CFT Legumine to wetlands and shallow lake depths (<3 ft) that were difficult to navigate by outboard boat without fouling a propeller or causing undesirable sediment disturbance that could bind with the rotenone, decreasing its effectiveness. The airboat was equipped with a 12-volt battery-powered pump system (model LP45 made by Superior Industries, LLC) and discharged piscicide with a handheld spray gun. This pumping system included a 45-gallon mixing tank where the CFT Legumine was premixed with lake water before application.

Aerial Application

Aerial application was required to treat the largest and most remote wetlands in the drainage's headwaters and to spot treat smaller hard to access wetlands throughout the corridor of Soldotna

Creek within Area 2. ADF&G contracted a private helicopter service (Cline Air Services, LLC [Central Valley Helicopters], Ellensburg, Washington) to treat up to 144 surface acres of wetlands by helicopter. An Enstrom F28F helicopter was used that was equipped with a sprayer and boom system and had GPS tracking and mapping capabilities. The pilot was provided treatment area maps with detailed instructions on where the aerial application was needed and how much product to use. A reconnaissance flight with the pilot and a certified applicator was done prior to starting the aerial application to ensure the treatment plan and flight plan was well understood by the pilot. Per product label directions and helicopter contractor recommendations, specific helicopter application methods and equipment requirements were adhered to (Appendix C2). Helicopter operations were based at a field near a private airstrip located about 1.3 km southeast of Derks Lake. This region of the drainage is lightly populated and centrally situated within the drainage.

All-Terrain Vehicle [ATV] Application

A modified ATV (Yamaha Grizzly 500 EPS) equipped with J-Wheelz (wheel add-on devices designed to increase floatation) was used to apply piscicide in wetland areas. A custom built 12-volt powered ATV sprayer from Superior Industries LLC, hose reel, and 50 ft of spray hose were mounted on the ATV. The sprayer included a 25-gallon mixing tank where the piscicide was premixed with water. This ATV sprayer was instrumental in accessing and treating wetlands in Area 1 that were too shallow and heavily vegetated for an airboat to operate in. The addition of J-Wheelz to the ATV greatly increased its floatation and reduced trampling damage to vegetation.

Backpack Application

Backpack applicators were used to spot treat shallow marshy nearshore areas where water mixing was poor or where boats or the ATV could not operate (e.g., floating bogs, seeps, small creeks). Backpack applicators premixed CFT Legumine with site water in the backpack's tank in a 2:100 volume to volume ratio of CFT Legumine to water (Finlayson et al. 2010). A few tablespoons of rhodamine dye were sometimes added to the backpack's mixing tank to aid applicators in distinguishing treated areas from untreated areas.

Drip Station Application

Drip stations were used to treat the majority of Soldotna Creek, Tree Creek, and some tributaries of Sevena Lake. Drip stations were spaced apart a distance approximately equal to 1–2 hours of stream travel time. Stream travel estimates for different reaches of Soldotna Creek were provided by the Kenai Watershed Forum and described in Appendix A2.

Each drip station consisted of a 12-volt battery-powered variable speed peristaltic pump made by Control Company. Each drip station pumped undiluted CFT Legumine through a silicon tube that was suspended directly over the creek. Drip rates were calibrated and monitored by periodically collecting the piscicide discharge over a 1-minute period in a graduated cylinder to measure the volume and then making appropriate adjustments by using the controller knob on the pump or by selecting a different diameter discharge tube to adjust drip rate as needed. Drip rates were checked at least hourly, and the operation of each drip station was planned to last a minimum of 4 hours.

Caged juvenile coho salmon served as sentinel fish to monitor the effectiveness of the stream treatment in real time. Sentinel fish were typically placed just upstream of the next downstream drip station to verify the effectiveness of each drip station. For the farthest downstream drip station of the series, a sentinel fish was placed downstream near the terminus of the treatment area for that day.

Powdered Rotenone Application Techniques

Powdered Rotenone Boat Application

Prentox Fish Toxicant Powder was applied to lakes in areas greater than 50 yards offshore. The powdered rotenone was premixed with water within the pump system to form a slurry prior to discharge (Finlayson et al. 2010). The pump system included a 13-horsepower high-pressure Gorman-Rupp water pump. The pump had a 2-inch water intake line and a 1.5-inch discharge line. The discharge line on the pump was fitted with an inline 1.5-inch inner diameter cast iron chemical eductor made by Scot Pump. The eductor utilizes the Venturi effect of water flowing through a restriction to create a vacuum capable of siphoning liquid or powdered piscicide into the body of the eductor via a siphon line. The mixing ratio of the water and powdered rotenone needed to create a slurry was controlled by a breather valve fitted in the siphon line that decreased the siphon's suction as needed.

We utilized 2 boats equipped in this manner for much of the Area 1 lake treatments and for the 2016 treatment of Sevena Lake (Area 2). Each powder application boat required at least 2 applicators. Ideally, one applicator operated the boat, another applicator handled the piscicide siphon line and probe that was placed in the piscicide container, and if available, a third applicator broke up any clumped powdered piscicide by pounding on the side of the piscicide container with a bat to break the clumps into smaller chunks, which greatly reduced clogging of the siphon line and probe clogging. A printed reference chart (Appendix C3) allowed boat operators to adjust boat speed in relation to observed water depths to ensure an even distribution of the piscicide. We adjusted the powder application equipment to apply about 5 pounds of powdered rotenone per minute.

Sand-Gelatin-Rotenone Mixture Ball Application

Mixture balls containing sand, gelatin, and powdered rotenone were used to treat wetland seepages feeding into Soldotna Creek and smaller tributaries. The mixture balls consisted of a ratio of 1 pound of sand to 1 pound of rotenone to 2 ounces of unflavored gelatin. The ingredients were mixed and moistened with water until a consistency was achieved that allowed the mixture to be formed into balls that held together, and then each ball was covered in cheesecloth. Ball sizes ranged from 1 pound or larger as needed. Approximately 1 pound of this mixture will treat 0.5 ft^3/s of flowing water at 18 ppb for 12 hours (Finlayson et al. 2010). The mixture balls were tied with cotton string to the middle of 3-foot long wooden survey stakes that were pushed by hand into the stream substrate until the mixture balls were submerged midway in the water column.

Rotenone Deactivation

Rotenone must be deactivated before it leaves the treatment area to prevent harm to nontarget organisms. Deactivation of rotenone can occur through several mechanisms. Exposure to warm temperatures and sunlight are the factors that most influence the rate of natural degradation (Loeb and Engstrom-Heg 1970; Engstrom-Heg 1972; Gilderhus et al. 1986; Ware 2002; ODFW 2008). Rotenone released into relatively warm water (about 15°C) is expected to fully detoxify within 2–4 weeks (Dawson et al. 1991). Through hydrolysis, the primary degradation metabolite of rotenone is rotenolone (Thomas 1983), and rotenolone is considered an order of magnitude less toxic than rotenone (Ling 2003). The final degradation products of rotenone are carbon dioxide and water.

Dilution can also decrease rotenone concentrations to nondetectable levels (defined as less than 2.0 ppb rotenone). Finlayson et al. (2010) provide an example of how to estimate the dilution of rotenone after 2 streams mix and only 1 is treated with rotenone. Based on their example, we can calculate the concentration of rotenone when treated and untreated streams mix as follows:

$$C = D \times R \tag{6}$$

where R is the rotenone concentration of the treated stream in parts per billion (ppb) and D is the dilution factor:

$$D = T_S/U_S \tag{7}$$

where

T_S = discharge of the treated stream in cubic feet per second,

U_S = discharge of the untreated stream in cubic feet per second.

Applying this formula, we modeled the rotenone concentration that might be present in the Kenai River from rotenone introduced by the Soldotna Creek drainage outlet creek treated at 40 ppb of rotenone. To consider the maximum concentration of rotenone that could result, this model assumed that the discharge of Soldotna Creek was at a historical high (44.1 ft^3/s observed in 2006; Massengill 2011) and the Kenai River discharge (which is measured about 1 mile downstream of the Soldotna Creek mouth) was at a historical low (minimum monthly mean 2,561 ft^3/s observed May through July 2001–2012[5]). This scenario provided a rotenone concentration estimate of 0.69 ppb, which is conservative because the rotenone concentration after mixing under average discharge rates would be far less. This model shows that without any chemical deactivation occurring prior to mixing, the concentration in the Kenai River would be less than 1.0 ppb.

In situations where rotenone could travel outside the treatment area at a concentration of 2.0 ppb or greater, potassium permanganate ($KMnO_4$) must be applied to deactivate the rotenone before it leaves the treatment area. Chemical deactivation of rotenone using $KMnO_4$ is typically accomplished after about 30 minutes of mixing between the two compounds using ratios of 1.0–1.5 parts rotenone to 1.0–2.0 parts $KMnO_4$ (Finlayson et al. 2010).

As a precautionary measure, preparations were made to chemically deactivate the rotenone, if needed, in the downstream reaches of both Area 1 and Area 2 during their respective treatments to protect native fish residing downstream. To apply the $KMnO_4$, a rotenone deactivation station was installed in Area 1 just below the outlet of Derks Lake in the fall of 2014. Likewise, a pair of deactivation stations were installed in tandem 800 stream-meters upstream of the Soldotna Creek's confluence with the Kenai River for the 2016 treatment of Area 2. In 2017, tandem deactivation stations were installed 5.7 km (river kilometers) below Sevena Lake. The 2017 Area 2 deactivation stations were moved further upstream from the 2016 location because the treatment was limited to Sevena Lake and this location was the nearest logistically feasible location to install one.

Deactivation stations were composed of an Acrison model 105-C/2 volumetric feeder with a 2 cubic foot supply hopper. The feeder was powered by a portable gas powered Honda 2000 generator. The $KMnO_4$ feed rate was adjustable (between 0.032 and 0.25 cubic feet per hour) with a motor controller or by selection of the feeder's auger size. During operation, deactivation stations

[5] Source: https://waterdata.usgs.gov/ak/nwis/uv/?site_no=15266300&PARAmeter_cd=00065,00 (downloaded on 8/9/13).

were continuously monitored either by direct onsite monitoring or by remote monitoring using a satellite alarm system that sent a phone call to a preselected contact if operation failed.

To first determine if chemical deactivation was warranted, we relied on caged sentinel fish (juvenile coho salmon) responses. Sentinel fish were placed just above each deactivation site, and in one or more downstream areas where rotenone treated water mixed with untreated water.

Operation of a deactivation station could be stopped periodically at the judgement of the certified applicator to assess the response of sentinel fish in downstream areas where treated and untreated water mixed. Deactivation was permanently halted if the nearest downstream sentinel fish were free of rotenone effects (i.e., mortality, rolling, imbalance, or gasping after 24 hours without deactivation; Finlayson et al. 2010). Deactivation was immediately resumed if sentinel fish began showing rotenone stress symptoms during this period, so constant monitoring was required.

Deactivation of rotenone using $KMnO_4$ is a time dependent reaction and is affected by variables influencing background oxygen demand of the creek such as temperature, electrolytes, organics, and exposure time (Engstrom-Heg 1972; Finlayson et al. 2010). As contact time is shortened, the ratio of $KMnO_4$ to rotenone needs to increase to achieve a proportional benefit. For example, at 60 minutes of contact time in distilled water, the ratio of $KMnO_4$ to rotenone should be 1:1, whereas the ratio should be about 2:1 if the contact time is shortened to 30 minutes.

$KMnO_4$ deactivation is a dynamic operation that requires applicators to use judgment in selecting the initial $KMnO_4$ target concentration and to monitor its effectiveness based on the response of caged sentinel fish held downstream and by periodically measuring the $KMnO_4$ concentration in the creek (Finlayson et al. 2010). For simplicity, a residual level of about 1 ppm $KMnO_4$ is desired at the end of the neutralization zone (the stream stretch below the deactivation station where $KMnO_4$ interacts with rotenone) because this level is not toxic to fish during short term exposure and is easily visible to the unaided eye (Engstrom-Heg 1972; Finlayson et al. 2010). The concentration of $KMnO_4$ in parts per million was easily estimated in the field using the DPD (N, N-diethyl-p-phenylenediamine sulfate) method for measuring total chlorine. The chlorine value can be determined by a color wheel provided by the chlorine kit then converted to an approximate potassium permanganate value by multiplying the chlorine value by a coefficient of 0.89 (Finlayson et al. 2010). Measuring the $KMnO_4$ concentration during deactivation station operation typically occurred 3 or more times daily. Below are example calculations used to determine the application of $KMnO_4$ to the Soldotna Creek drainage to neutralize an existing rotenone concentration of 50 ppb (1 ppm of liquid rotenone formulation).

Calculating the Amount of $KMnO_4$ Example

To determine the desired concentration (Y) of $KMnO_4$ needed to neutralize the rotenone in Soldotna Creek, the following equation is utilized:

$$Y = A + B + C \tag{8}$$

where

A = ppm of $KMnO_4$ needed for the natural $KMnO_4$ demand of the creek,

B = ppm of $KMnO_4$ needed for a contact time of 30 minutes where the concentration of rotenone formulation is 1.0 ppm,

C = ppm of $KMnO_4$ desired as a residual in the creek after deactivation.

Therefore, if A = 1, B = 2, and C = 1 (determined by stream characteristic investigations), then Y = 2 + 2+ 1, or 4 ppm of $KMnO_4$.

To determine the application rate (SF) of crystalized $KMnO_4$, the following equation was utilized per Finlayson et al. (2010):

$$SF = Y \times 1.7 \times Q \tag{9}$$

where

SF	=	flow of solid $KMnO_4$ crystals (g/min),
Y	=	desired $KMnO_4$ concentration in creek (5.0 ppm) and,
Q	=	stream discharge in cubic feet per second.

Therefore, if stream discharge Q = 25 ft^3/s, then SF = 4 ppm × 1.7 × 25 ft^3/s = 170 g/min $KMnO_4$.

To convert the desired $KMnO_4$ application rate of 170 g/min to volumetric units, we utilize the following conversions:

1 lb = 453.6 g

1 ft^3 $KMnO_4$ = 89 lb $KMnO_4$

1 ft^3 $KMnO_4$ = 89 lb $KMnO_4$ × 453.6 g/lb = 40,370.4 g $KMnO_4$

1 ft^3 = 28,316.8 mL

1 mL $KMnO_4$ = (1 ÷ 28,316) ft^3 $KMnO_4$ = (40,370.4 ÷ 28,316.8) g $KMnO_4$ = 1.43 g $KMnO_4$.

Therefore, the estimated $KMnO_4$ application rate converted to volume (mL/min) is as follows:

170 g/min $KMnO_4$ ÷ 1.43 g/mL = 118.9 mL/min $KMnO_4$.

As the rotenone concentration in the outlet creek decreases over time due to cessation of the rotenone application, natural degradation, and dilution processes, the demand for $KMnO_4$ for neutralization decreases accordingly so deactivation operators must rely on periodic testing of the downstream residual $KMnO_4$ to make appropriate adjustments to the application of $KMnO_4$.

TREATMENT SUCCESS EVALUATION

Rotenone Sampling

Water and sediment samples were collected immediately before and periodically after each rotenone treatment to verify the peak concentration and persistence of rotenone. Rotenolone concentration (a less toxic rotenone degradation byproduct) was likewise monitored in 2014 and 2015, when laboratory services were available to analyze rotenolone; however, beyond 2015, rotenolone was not analyzed because no laboratory was found that had rotenolone analysis capability. For each treatment, we generally sampled the same lake, sediment, and well locations for all sampling events; all sample site locations are shown in Figure 8. Sampling continued after each treatment until rotenone concentrations were determined to be less than 2.0 ppb or caged sentinel fish responses showed no observable effects after 24 hours of exposure to treated waters. Samples collected in 2017, associated with the Loon Lake and Sevena Lake treatments, were only analyzed for rotenone because we were unable to find a laboratory that could provide the analytic capability to determine rotenolone content.

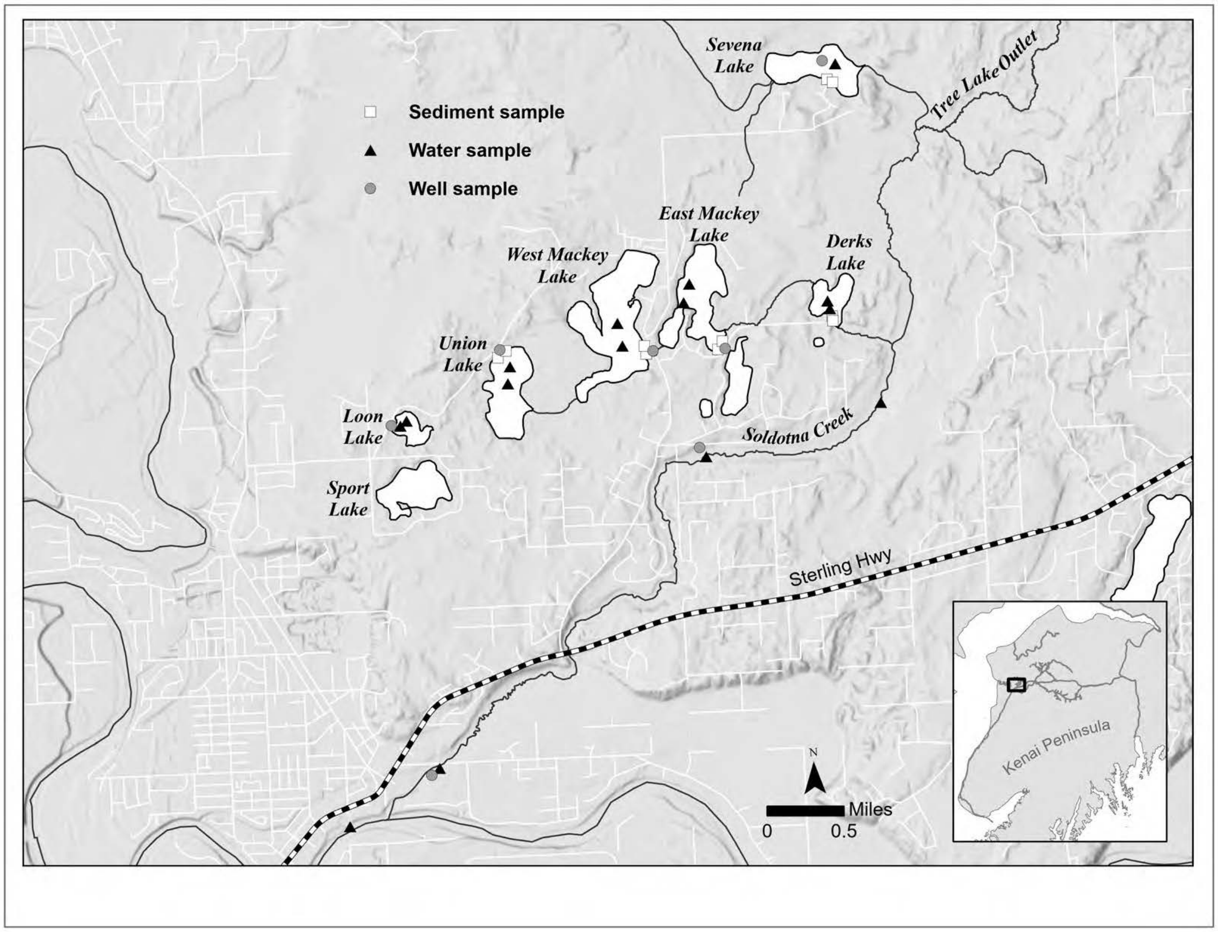

Figure 8.–Soldotna Creek drainage sediment, surface water, and well water sampling sites, 2014–2017.

Pretreatment sampling entailed collecting a single surface water sample and a single sediment sample from each lake. Posttreatment sampling within the first month after treatment was designed to collect water samples from at least 2 locations and a sediment sample from 1 location within each lake. The additional water sample was desired to better assess the mixing of rotenone shortly after its application. Sediment sampling was discontinued about 1 month after treatment because rotenone has low mobility in soil and binds strongly to organics, posing less ecological concern and need for monitoring. Lake water sampling greater than 1 month posttreatment was scaled back to a single composite surface water sample (50:50 mix from 2 locations) collected from each lake during each sampling event. Sampling locations were preselected.

When 2 samples were collected, each lake water sample was a composite of equal amounts of water collected from the 2 different locations from similar depth strata. For instance, a shallow composite sample represented a sample collected from near surface waters from 2 discrete locations from the same lake; similarly, composite deepwater samples were also collected this way. Shallow samples were collected 1 m below the lake surface and deep samples were collected at least midway down in the water column near the deepest lake areas. Water was collected by lowering a 2.2-liter Kemmerer sampling tube to the desired depth and activating the capture mechanism. Water was transferred from the Kemmerer sampling tube to a 1-liter amber colored glass sample jar. Stream water samples were collected by hand by directly filling a 1-liter amber glass bottle in the stream at locations selected at the discretion of the project biologist.

Lake and stream sediment samples were collected by combining equal amounts of sediment from 2 nearshore submerged sites within the same vicinity (less than 10 meters apart) using a shovel or hand trowel. Samples were transferred to an amber colored 250 mL glass jar. In most instances, a single sediment sample was collected from each treated lake during each sampling event for both the Area 1 and Area 2 treatments. Likewise, a single sediment sample was collected from Soldotna Creek during each sampling event associated with the 2016 and 2017 Area 2 treatments.

When sentinel fish in Soldotna Creek became impaired following the Area 1 treatment and chemical deactivation was warranted, additional water samples were collected from the Derks Lake outlet creek and from Soldotna Creek to assess rotenone concentrations. One or more stream water samples were collected from Soldotna Creek during each sampling event associated with the 2016 Area 2 treatment. One Soldotna Creek water sample was collected during each sampling event associated with the 2017 Area 2 treatment.

On lakes with adjacent residences, a representative private well water sample was collected periodically to determine if rotenone entered the ground water. Similarly, when Soldotna Creek was treated with rotenone in 2016, 2 private wells next to the creek corridor were sampled before and after treatment. Well water testing continued until the rotenone in each treatment area fully degraded.

Upon collection, all samples were immediately labeled, placed into cold storage, and express shipped with chain-of-custody paperwork within 48 hours to a laboratory for analysis. Samples collected for the 2014 and 2016 rotenone treatments were analyzed for both rotenone and rotenolone by the California Department of Fish and Game Water Pollution Control Lab in Rancho Cordova, California. Samples collected in 2017 were analyzed for rotenone by North Coast Laboratories, LTD in Arcata, California.

Posttreatment Gillnet Surveys

Treatment success was primarily determined from gillnets used to remove northern pike from the drainage's lentic waters. We strove to apply enough netting effort to achieve an estimated 80% probability of detecting a northern pike population of 4 individuals in each waterbody. Details on estimating the netting effort to achieve the desired precision criteria are found in Appendix D1.

Most lakes were evaluated with gillnets set during fall ice-up after treatment. Nets were fished continuously without monitoring under the ice until removal at ice-out the following spring. Exceptions to the under-ice netting strategy were implemented at our discretion based on safety and bycatch concerns. All gillnets were set in vegetated nearshore areas that are typically preferred by northern pike. The gillnets were the same design as those described earlier.

Sentinel Fish

Caged juvenile coho salmon served as sentinel fish to test the effectiveness of treatments in real time in both lentic and lotic waters. Juvenile coho salmon were collected from Soldotna Creek for the bioassays and acted as a surrogate for northern pike because it is difficult to catch northern pike of appropriate size (larger fish would probably exceed the recommended 1 g fish per liter of water; Finlayson et al. 2010). Coho salmon have a higher tolerance to rotenone than northern pike (Marking and Bills 1976), so concentrations fatal to coho salmon should effectively kill northern pike as well. These fish were suspended in small cages at various depths in multiple locations dispersed throughout each treated lake and just upstream of each drip station in Soldotna Creek and Tree Creek and in several smaller tributaries of Soldotna Creek and Sevena Lake. At least 3 fish were placed in each cage. The fish were monitored periodically during each Area's treatment to verify lethality.

Fyke Nets and Screen Traps

Fyke nets and screen traps were placed in creeks to serve multiple purposes for this project. Their primary purpose was to prevent or reduce movement of northern pike within the drainage. Some fyke nets were intended to reduce access to wetland spawning habitat yet others were intended to collect dead or rotenone impaired fish in Soldotna Creek during rotenone treatment. Rotenone killed and impaired fish carried downstream and collected by the fyke nets in Soldotna Creek served both to gauge the lethality of the rotenone treatment and to provide samples of fish indicative of the species present, including northern pike. Four fyke nets and 2 screen traps were installed in Area 1 streams and 11 fyke nets were installed in Area 2 streams, including Soldotna Creek (Figure 9).

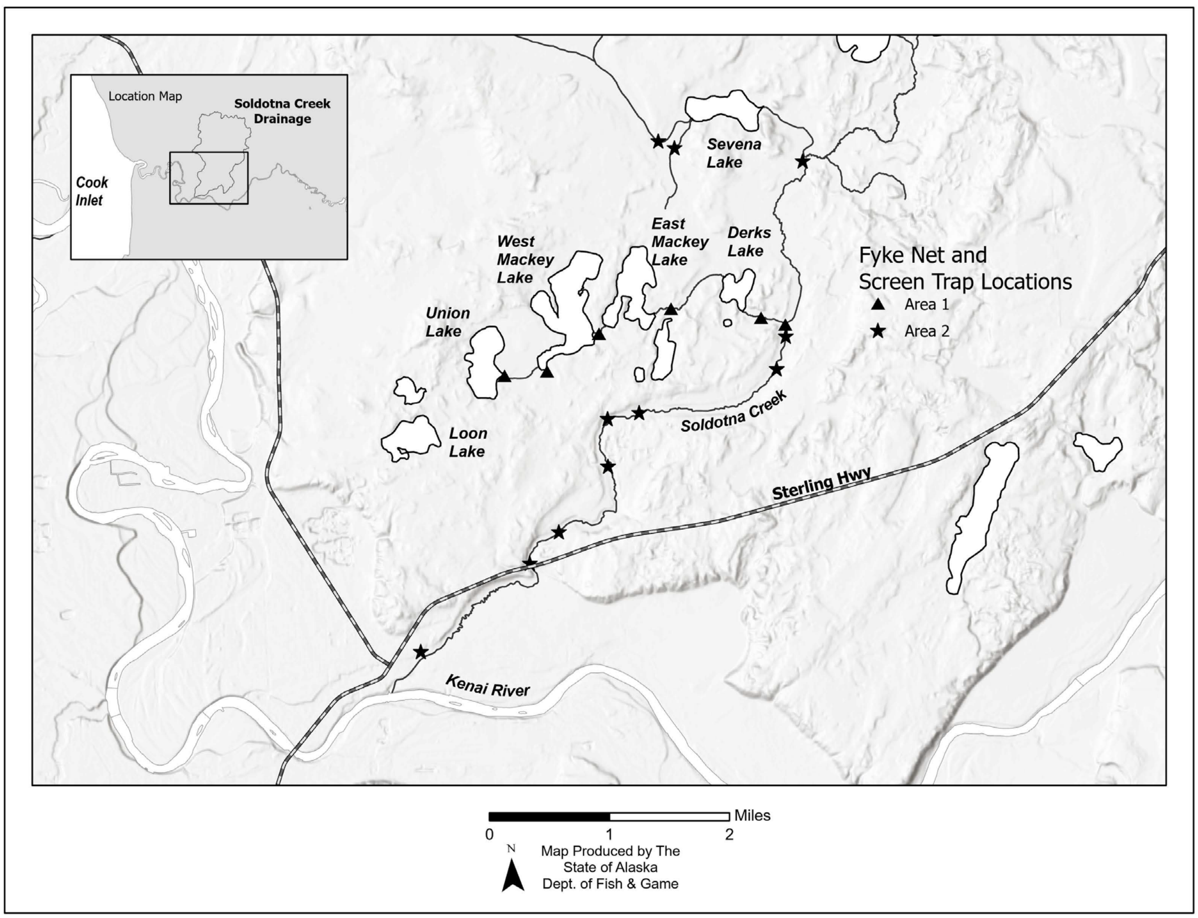

Figure 9.–Fyke net locations in Soldotna Creek, June 2016.

The Area 1 fyke nets and screen traps were installed prior to the start of the rotenone treatment in 2014 and remained in place until the entire project was completed in 2018. Likewise, the Area 2 fyke nets were installed prior to the rotenone treatment, and many were maintained in place until the entire project was completed in 2018. All fyke nets installed in the mainstem of Soldotna Creek were removed just after treatment completion to allow for movement of recolonizing native fish.

We utilized an assortment of fyke net designs and sizes, but most were manufactured by Duluth Nets. These fyke nets consisted of a series of rectangular metal frames covered with ⅛-inch knotless mesh. The fyke entrance frame ranged from 2 to 3 ft in width and had 8 to 12 ft mesh wings attached to the sides of the entrance. Some fyke nets had internal throats at each frame segment and others had just 1 throat near its entrance. The length of the fyke net was typically 12 ft. Fyke nets were given a green coating by the manufacturer to help protect the mesh from sun damage and to make them less conspicuous. The fyke nets were extended into position by securing them to metal fence posts driven into the stream bed. To reduce animal damage, fabric fyke nets that operated long term were surrounded with polycoated metal poultry fencing.

The Derks Lake outlet creek served as the boundary separating Area 1 from Area 2. Two screen traps were placed in this outlet and served to prevent northern pike from reentering Area 1 after treatment. These screen traps were robust and constructed of angled aluminum frame panels. The largest of the 2 screen traps, placed near the outlet of Derks Lake, was composed of panels measuring 4 ft high and 10 ft long covered with ¼-inch stainless steel screen. These panels had a 1 ft flap of Vexar (plastic screen) extending below the bottom of the frame that served to seal the panel bottom to the stream substrate when sandbags were laid atop the flap. Four panels were used to make this screen trap and were arranged so that 2 panels created each side of a 2-sided V-shaped barrier with a 4 ft distance between the 2 panels on the upstream end that reduced to a 1 ft width between the panels on the downstream end, which was covered with perforated aluminum plate (Figure 10). A smaller yet similar screen trap was placed several hundred yards downstream of the larger screen trap nearest the Derks Lake outlet where the creek was narrower and more channelized, this screen trap served as a redundant barrier to prevent pike movement between Areas 1 and 2.

In addition to the 2 screen traps in the Derks Lake outlet creek, a vertical drop barrier (perched culvert) was installed in a beaver dam just upstream of the upper Derks Lake block net to further reduce the chance that northern pike could move from Area 2 to Area 1 (Figure 11). This vertical barrier maintained about a 1 ft vertical drop year-round and a plywood panel mounted below the water at the downstream end of the culvert prevented formation of a deep plunge pool. A screened basket mounted below the culverts outflow also served to prevent fish from jumping upstream.

Figure 10.–Screen trap in the Derks Lake outlet creek just downstream of a vertical drop barrier.

Figure 11.–Perched culvert used as a vertical drop barrier at the Derks Lake outlet.

eDNA sampling

Environmental DNA (eDNA) sampling methods were implemented to assess the efficacy of this methodology in detecting northern pike presence both before and after rotenone treatment of Area 1. Multiple 1-liter composite water samples ($N = 85$) were collected from the 4 Area 1 lakes prior to the 2014 rotenone treatment (22–24 September 2014) at an average sampling intensity of 1 sample per 1.9 surface hectares. Posttreatment sampling ($N = 179$) occurred between 14–28 May 2015, following spring ice-out and turnover, which occurred the 1st and 2nd weeks of May, at an average sampling intensity of 1 sample per 0.9 surface hectares.

Water samples were filtered at the Soldotna ADF&G limnology lab to concentrate the eDNA. The resultant filtrate samples were analyzed for northern pike eDNA by the USFWS Conservation Genetics Laboratory in Anchorage, Alaska. Details on the eDNA methods and results are reported by Dunker et al. (2016).

BIOLOGICAL MONITORING

Invertebrate Surveys

Macroinvertebrate and zooplankton surveys were conducted to identify taxonomic diversity present in the Soldotna Creek drainage both before and after treatment. Representative waterbodies selected for surveying included West Mackey Lake (Area 1; Figure 12), Sevena Lake (Area 2;

Figure 13), and Soldotna Creek (Area 2; Figure 14). A minimum of 1 pretreatment and 1 posttreatment sampling survey was planned for each representative lake, with additional surveys in Soldotna Creek being optional. Pretreatment and posttreatment surveys were conducted at the same locations and during similar seasonal periods. All sampling locations were recorded with a handheld GPS to ensure repeat site selection. At each sampling site, all captured invertebrates were combined into a single glass jar filled with denatured ethanol and labeled with the date, site location, and gear type.

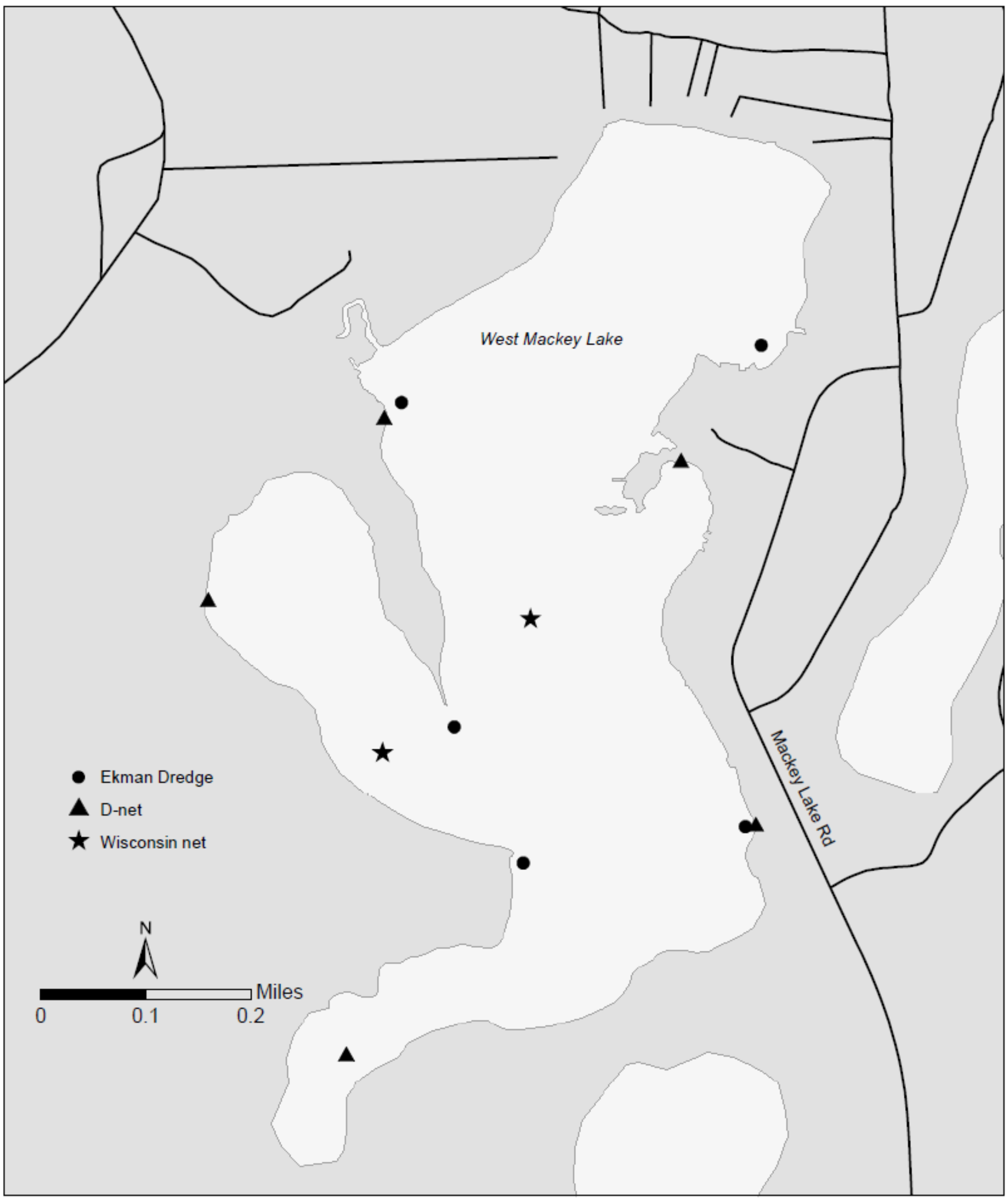

Figure 12.–West Mackey Lake invertebrate sampling sites by gear type, 2014–2015.

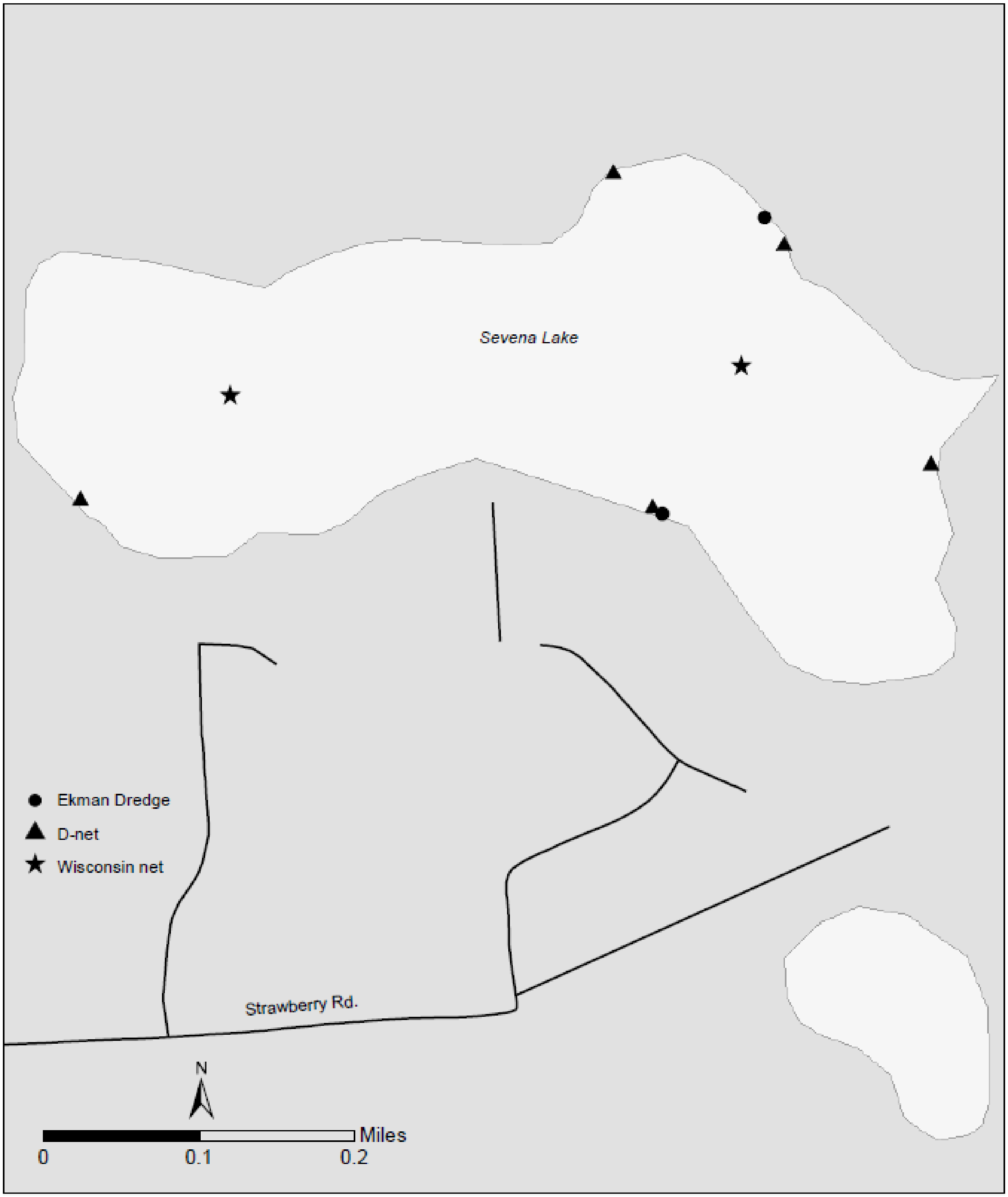

Figure 13.–Sevena Lake invertebrate sampling sites by gear type, 2015–2016.

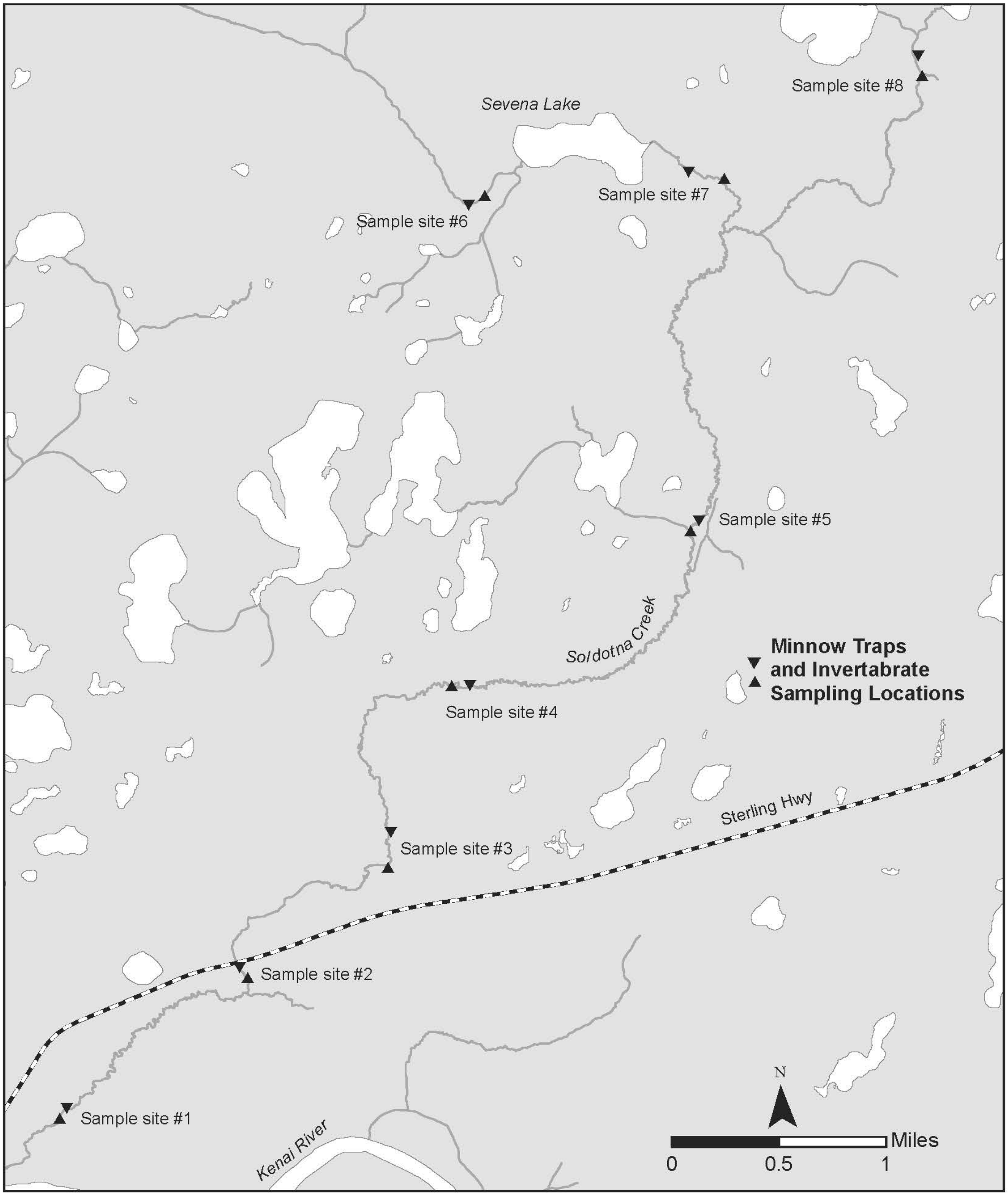

Figure 14.–Map of invertebrate and minnow trapping sites in the flowing waters of the Soldotna Creek drainage.

Note: Paired black triangles represent sampling sites (1–8) where 2 minnow traps were fished (1 upstream and 1 downstream relative to each other); invertebrate samples were collected using D-nets between each pair of triangles.

During each lake sampling survey, zooplankton collections were made with replicate vertical tows (from bottom of the lake to surface) using a 0.5 m diameter Wisconsin net with 153 µm mesh at 2 different sites in locations near maximum lake depth. The net was lowered to near the lake bottom with a hand line and then retrieved at a rate of 1 m every 2 seconds. As the net was retrieved, captured zooplankton concentrated in the net bottom inside a screened PVC collection bucket. At the surface, the bucket was detached, and captured zooplankton were transferred to a collection jar. Zooplankton samples were generally resolved to the order or family level using illustrations found in Bachmann (1973) and taxonomic keys found in Pennak (1989).

During each lake sampling survey, benthic macroinvertebrates were collected using a 9-inch Ekman bottom grab sampler to collect bottom organisms from 5 offshore sites. The Ekman sampler was deployed from an anchored outboard motorboat in 5 to 10 feet of water. Collected sediment was screened to filter out invertebrates, which were removed from the screen with tweezers.

Handheld D-nets were used to sample lake invertebrates along vegetated nearshore areas (<0.6 m in depth) in 5 locations per lake. The mainstem of Soldotna Creek was also surveyed for macroinvertebrates with D-nets. The D-net was swept back and forth through submerged vegetation for 30 seconds. Visual observations of freshwater mussels and snails were done opportunistically in nearshore areas. All collected macroinvertebrates were identified to the order, suborder, or family level as feasible, using keys by Pennak (1989), Voshell (2002), and Merrit and Cummins (1984).

Fish Surveys

Lake Gillnetting

Posttreatment gillnetting to assess native fish was mostly conducted 1 or more years after treatment to determine distribution and CPUE data in all treated lakes except Loon Lake, which is restocked annually with hatchery fish and never supported native salmonid populations. Gillnetting was done periodically between 2015 and 2019, which allowed time for native fish populations to reestablish following extirpation by northern pike in Area 1 and by the rotenone treatment in Sevena Lake. The gillnets were identical to those described in the *Northern Pike Distribution and Reduction* section. At this stage of the project, gillnetting effort was intentionally low to reduce impacts to sensitive rebuilding native fish populations, and fish lengths were usually just collected from mortalities to reduce handling impacts to live fish. Netting effort was subjectively applied to lakes and varied according to observed catch rates, human recreational use, and waterfowl activity on the lake. However, in the case of Derks Lake, which had positive posttreatment detections of northern pike eDNA, gillnetting effort was greatly increased to determine whether these detections were the result of living northern pike.

Soldotna Creek Minnow Trapping

Pretreatment and posttreatment minnow trapping surveys were conducted in Soldotna Creek, Tree Creek, and a tributary of Sevena Lake to document representative species presence and CPUE-based index of abundance. Minnow trapping CPUE comparisons (pretreatment versus posttreatment) were used to assess potential treatment associated changes in species distribution and abundance. For each species and trapping site, we subtracted the pretreatment CPUE from the posttreatment CPUE taken during similar temporal periods (summer or fall) to determine posttreatment change in CPUE for species at each site. Summing the CPUE changes for all sites by species yielded a drainagewide change in CPUE, indicating the relative change in abundance before and after treatment.

Eight locations in total were selected for minnow trapping, representing the diversity of stream habitats found throughout the drainage (Figure 14). At each location, 2 minnow traps baited with salmon roe were fished simultaneously less than 100 m of each other. All minnow traps were fished for 30 minutes, which was sufficient time to capture a representative sample for our purpose, and the entire catch was identified to species before being released. All salmonids were measured for FL. There was a minimum of 2 pretreatment and 2 posttreatment surveys. Standardized sampling protocols for utilizing minnow trapping CPUE as an index of abundance (CPUE was assumed proportional to density) were adopted so that similar trapping conditions between pretreatment and postreatment surveys could be carried out (Statewide Aquatic Resources Coordination Unit 2016).

The minnow traps were cylindrical galvanized wire cages about 18 inches in length with inverted funnel entrances at both ends. Minnow traps were set parallel to stream flow next to woody debris or in heavy vegetation that provided fish cover. Bait (commercially produced cured salmon roe) was placed in a small, perforated plastic container and suspended with wire inside the middle of the trap.

CPUE was calculated as follows:

$$CPUE = \frac{c}{e} \tag{10}$$

where

c = number of a species captured in a single trap,

e = units of time (1 unit = 30 minutes).

Because all minnow traps were fished for 30 minutes, which is defined as 1 "unit of time," individual minnow trap catch and CPUE values are identical.

Lake Minnow Trapping

In addition to pretreatment and posttreatment stream minnow trapping surveys, 7 of the largest lakes in the Soldotna Creek drainage were surveyed with minnow traps before and after treatment. The pretreatment survey, conducted in 2001 (McKinley 2013), documented the presence or absence of native fish species in all the lakes known or suspected to have northern pike. Loon Lake and Derks Pond were not included in the 2001 minnow trap survey. Posttreatment minnow trapping surveys during 2017–2019 included all known northern pike lakes in the drainage, including Loon Lake and Derks Pond. For each lake surveyed, a minimum of 5 minnow traps baited with salmon eggs were fished continuously for at least 30 minutes. Minnow traps were fished in shallow water (<3 ft) in nearshore weedy areas.

FISHERY RESTORATION

Native Fish Relocation

Drainagewide native fish restoration was accomplished by 2 methods. The first was for native fish to naturally recolonize the drainage after treatment when all northern pike had been eradicated and all temporary fish barriers removed. Native fish (i.e., juvenile salmonids, sculpin [unspecified, Family Cottidae], lamprey [unspecified, Family Petromyzontidae], and stickleback) migrating from the Kenai River were expected to be the primary recolonizing native fish in Area 2. Adult returns of sea-run spawning fish to Soldotna Creek (eulachon [*Thaleichthys pacificus*], coho salmon, steelhead, and Pacific lamprey [*Entosphenus tridentatus*]) were also expected to aid in restoration.

The restoration of native fish to Area 1 presented a unique challenge because natural migration of native fish into this area would likely be hampered by the ephemeral nature of the streams linking this western branch of the drainage to Soldotna Creek. There are also human made barriers that could pose challenges to fish movement in the drainage; such barriers include a perched culvert in the creek linking West Mackey Lake and East Mackey Lake and an earthen and concrete barrier at the outlet of East Mackey Lake. Both barriers have a vertical drop of about 1 foot, depending on water conditions, that can potentially impede upstream fish movement.

The 2014 rotenone treatment of Area 1 created an area within the drainage that was pike free and subsequently provided a safe place to relocate native fish collected from Area 2. Relocation of native fish served to reestablish native fish in Area 1 and prevent the loss of some fish that might otherwise be exposed to rotenone during the 2016 and 2017 treatment in Area 2.

Native fish were collected from Area 2 primarily by minnow trapping the mainstem of Soldotna Creek and Sevena Lake although other gear types were used with minimal success. Soldotna Creek minnow trapping, for fish restoration purposes, began in 2015 and continued through 2019 and was done opportunistically during the open water periods in all years. Backpack electrofishing in Soldotna Creek was done during the summer of 2015 using a 3-person team. The electrofishing team was composed of 1 person who operated a Smith-Root LR-24 electrofisher, a 2nd person who used a handheld dipnet to collect fish that elicited taxis toward the anode, and a 3rd person who carried supplies including the collected fish in a 5-gallon pail. Electrofishing proved less efficient at collecting fish than minnow trapping.

Sevena Lake was the only lake in the drainage posed for rotenone treatment that still harbored remnant populations of adult rainbow trout and Dolly Varden. During midsummer of 2015, 1–2 gillnets were opportunistically fished in Sevena Lake near the mouth of a clear, cool, shallow, spring-fed water tributary to collect adult Dolly Varden and rainbow trout that appeared to be seeking refuge there from thermal related stress. Within a few days, it appeared we had collected most of the available fish based on visual surveys of the creek. Overall, minnow trapping proved the most productive and efficient method for collecting native salmonids, stickleback, and sculpin, so it became the standard native fish collection method for the duration of the project. None of the used gear types proved successful in capturing a significant number of lamprey.

The minnow trapping locations varied but most of the effort was concentrated in the road accessible lower third of Soldotna Creek. Typically, teams of minnow trappers roved the creek corridor and fished minnow traps baited with salmon roe. Traps were checked and relocated periodically throughout the day and often left overnight to be checked the following morning. Survey flagging was used to help identify trap locations.

Captured fish were held in 5-gallon pails filled with creek water and hand transported to submerged live boxes (55-gallon plastic drums ventilated profusely with ¼-inch holes) tethered to fenceposts driven into the stream bottom. Live boxes were maintained at multiple locations in Soldotna Creek at convenient locations with easy access to the creek. Before placing fish in the live boxes, the catch was identified to species and counted. Within 1–3 days of collection, all fish were removed from the live boxes and transported to their release site in an aerated "livewell" mounted in the back of a truck. The livewell was an insulated fish tote with a 50-gallon capacity, and aeration was supplied by a 12-volt air pump externally mounted in the bed of the truck and which supplied air to airstones placed inside the livewell. At the release site, fish were transported by hand in pails to the lake and released.

There was no set limit to the number of native fish relocated to Area 1 because many of these fish would otherwise be lost during the Area 2 treatments. We tried to maintain similar stocking densities for each species we released into the 4 largest Area 1 lakes (Union Lake, West and East Mackey Lakes, and Derks Lake), which also represented the lakes where native fish had been historically present prior to the northern pike invasion.

Assessment of Native Fish Recovery

Minnow Trapping Survey

As described in the *Fish Surveys* section, pretreatment and posttreatment minnow trapping in Soldotna Creek and some associated tributaries would serve to describe native fish distribution, relative abundance based on CPUE, and length (FL) data.

Gillnetting Survey

Posttreatment gillnetting to assess native fish presence, CPUE, and to collect length data (FL) was done at Union Lake, West Mackey Lake, East Mackey Lake, Derks Lake, and Sevena Lake. To prevent significantly impacting recovering native fish populations, netting effort was typically moderated and limited to 4 or fewer gillnets per lake for approximately 24 hours of fishing effort per net based on the discretion of the project leader. The gillnetting methods adhered to that already described in other sections.

RESULTS

WATER BODY PHYSICAL AND CHEMICAL CHARACTERIZATION

Lake Mapping and Partitioning

Bathymetric data were collected at East Mackey Lake, West Mackey Lake, Union Lake, Sevena Lake, and Derks Lake during June and July of 2013. Bathymetric data were collected in October 2014 for Derks Pond and July 2017 for Loon Lake. Bathymetric maps were produced for all lakes treated with rotenone except for Derks Pond, which only had its volume estimated because it is small and did not need partitioning for rotenone treatment. All bathymetric maps are found in Appendices E1–E6; these maps also show the boundaries of the lake sections used for calculating how much rotenone was required to apply to each lake section. A summary of the water volume of each lake section and the amount of rotenone product applied to each section is listed in Table 2. Orange buoys tethered to weights were placed in the lakes along section boundaries to aid boat applicators during the rotenone treatment.

Table 2.–Summary of the amount of rotenone applied to the Soldotna Creek drainage during 2014–2017.

Treatment area	Waterbody	Application date	Lake section	Surface acres	Acre-feet	Percent (%) of lake volume	CFT Legumine applied (gal)	Prentox Fish Toxicant Powder applied (lb)
Area 1	Derks Lake[a]	10/9/2014	1	4.8	54.2	11.9	6.5	59
			2	9.8	130.3	28.6	15.4	143
			3	6.8	75.5	16.6	9.0	83
			4	10.7	159.6	35.0	19.4	175
			5	4.7	36.1	7.9	4.3	40
			Lake total	36.9	455.6	100.0	54.5	500
			Other[b]	NA	NA	NA	10.0	5
			Grand total	36.9	455.6	100.0	64.5	505
	East Mackey Lake	10/8/2014	1	16.8	151.0	16.1	18.1	233
			2	24.6	362.3	38.7	43.5	559
			3	7.0	41.2	4.4	4.9	64
			4	11.7	181.2	19.3	21.6	279
			5	15.9	114.3	12.2	13.7	176
			6	13.5	53.4	5.7	6.4	82
			7	9.1	33.8	3.6	4.1	52
			Lake total	98.6	937.2	100.0	112.3	1,445
			Other[b]	NA	NA	NA	4.0	13
			Grand total	98.6	937.2	100.0	116.3	1,458
	West Mackey Lake	10/7/2014	1	38.9	253.8	20.8	30.2	414
			2	24.0	148.7	12.2	18.0	243
			3	25.5	187.5	15.4	21.0	306
			4	23.6	166.6	13.7	21.1	271
			5	27.4	163.2	13.4	18.5	266
			6	29.9	300.2	24.6	36.0	490
			Lake total	169.3	1220.1	100.0	144.8	1,990
			Other[b]	NA	NA	NA	22.5	0
			Grand total	169.3	1220.1	100.0	167.3	1,990

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Table 2.–Page 2 of 3.

Treatment area	Waterbody	Application date	Lake section	Surface acres	Acre-feet	Percent (%) of lake volume	CFT Legumine applied (gal)	Prentox Fish Toxicant Powder applied (lb)
Area 1 (cont.)	Union Lake	10/6/2014	1	18.5	88.3	12.3	10.6	138
			2	13.4	181.3	25.2	21.8	280
			3	11.1	135.9	18.9	16.3	210
			4	18.5	142.7	19.9	17.2	221
			5	21.8	170.3	23.7	20.5	264
			Lake total	83.3	718.6	100.0	86.4	1,113
			Other[b]	NA	NA	NA	25.6	6
			Grand total	83.3	718.6	100.0	112.0	1,119
	Loon Lake	8/24/2017	1	5.6	76.0	40.6	12.0	59
			2	7.3	56.0	29.9	9.0	43
			3	8.1	55.0	29.4	9.0	43
			Lake total	21.0	187.0	100.0	29.5	145
			Other[b]	NA	NA	NA	0.5	0
			Grand total	21.0	187.0	100.0	30.5	145
	Area 1 grand totals	2014-2017	Lake total	NA	NA	NA	427.6	5,193
			Other[b]	NA	NA	NA	62.6	24
			Grand total	NA	NA	NA	490.2	5,217
Area 2[c]	Sevena Lake[d]	6/26/2016	1	12.2	172.9	28.8	46.2	0
			2	15.5	118.5	19.7	31.6	0
			3	20.1	172.9	28.8	46.7	0
			4	25.2	135.7	22.6	36.1	0
			Lake total	73.0	600.0	100.0	160.6	0
			Other[b]	NA	NA	NA	32.0	5
			Grand total	73.0	600.0	100.0	192.6	5
	Soldotna Creek, Tree Creek, and their tributaries	6/26/16 to 6/30/16	Total	NA	NA	NA	50.6	25

-continued-

Table 2.–Page 3 of 3.

Treatment area	Waterbody	Application date	Lake section	Surface acres	Acre-feet	Percent (%) of lake volume	CFT Legumine applied (gal)	Prentox Fish Toxicant Powder applied (lb)
Area 2[c] (cont.)	Sevena Lake	6/15/2017	2	12.2	172.9	28.8	57.6	0
			3	15.5	118.5	19.7	39.5	0
			4	20.1	172.9	28.8	57.6	0
			5	25.2	135.7	22.6	45.2	0
			Lake total	73.0	600.0	100.0	200.0	0
			Other[b]	NA	NA	NA	2.8	5
			Grand total	73.0	600.0	100.0	202.8	5
	Area 2 Grand totals	2016	Lake total	NA	NA	NA	160.6	0
			Other[b]	NA	NA	NA	82.6	30
			Grand total	NA	NA	NA	243.2	30
		2016 and 2017	Lake total	NA	NA	NA	360.6	0
			Other[b]	NA	NA	NA	85.4	35
			Grand total	NA	NA	NA	445.9	35
All areas	All waterbodies	All years	Lake total	NA	NA	NA	788.1	5,193
			Other[b]	NA	NA	NA	148.0	59
			Grand total	NA	NA	NA	936.1	5,252

Note: “NA” means not applicable.

[a] Product amounts listed for the Derks Lake treatment include amounts used for Derks Pond.

[b] Total amounts applied to creeks wetlands and ponds outside of lake sections. Includes rotenone applied by handheld boat sprayer, canoe application, backpack sprayer, ATV sprayer, drip station or by helicopter.

[c] During the 2016 rotenone treatment in Sevena Lake and Soldotna Creek, a target concentration of 40 ppb rotenone was set. During the 2017 treatment (Sevena Lake only), we increased the target rotenone concentration to 50 ppb to compensate for the lower than desired rotenone concentration achieved during the 2016 treatment.

[d] The volume of Sevena Lake was intentionally reduced from about 677 acre-feet to 600 acre-feet by removing a beaver dam at the lake outlet and partially draining the lake. This also created lake storage capacity when the lake outlet was dammed with sandbags after treatment.

Water Quality

For most of the lakes destined for rotenone treatment, pretreatment monthly water quality sampling occurred from July 2006 through June 2007. No pretreatment water quality data were collected for Loon Lake or Derks Pond because of the short time between discovery of northern pike and subsequent rotenone treatment. Posttreatment water quality sampling occurred from July 2016 through June 2017, except for Loon Lake, which was sampled from August 2017 through July 2018, and Derks Pond, which was never sampled due to its relatively small size and because it shares similar water quality characteristics to Derks Lake, being its nearby wetland. Additional posttreatment sampling occurred at Sevena Lake from July 2017 through May 2018 because it was retreated with rotenone in 2017.

For each sampled lake, the average monthly water temperature, specific conductance, dissolved oxygen, pH, and turbidity results were recorded (Figures 15–20). In general, lake water quality parameters remained similar between pretreatment and posttreatment periods.

Stream Discharge

Pretreatment monthly stream discharge measurements were collected for Soldotna Creek and select tributaries between April 2006 and April 2007 as environmental conditions allowed (Table 3). This information aided in planning the rotenone treatments and estimating the amount of rotenone to purchase. Additional stream discharge measurements were collected just prior to and following the rotenone treatments to help estimate the amount of rotenone to apply and to calculate the dilution of rotenone when a treated stream mixed with an untreated stream (Table 4). We used lower mainstem Soldotna Creek (stream mile 0.7) discharge measurements as a general indicator of drainagewide discharge fluctuation. The pretreatment (2006–2007) discharge for Soldotna Creek at stream mile 0.7 ranged from a low of 5.9 ft^3/s in November 2007 to high of 44.1 ft^3/s in October 2006 and averaged 18.8 ft^3/s. During each rotenone treatment, Soldotna Creek discharge in its middle section (stream miles 5.0–7.5) ranged from 5.4 ft^3/s to 18.7 ft^3/s.

Among Soldotna Creek tributaries measured for discharge between 2014 and 2017, discharges ranged from 5.8 ft^3/s to 0.5 ft^3/s. The 2014 Area 1 pretreatment discharge at the Derks Lake outlet during 23 September through 12 October was unusually high because we intentionally breached an existing beaver dam near the lake outlet to draw down the lake volume. When Derks Lake was treated with rotenone, the outlet was temporarily plugged with sandbags to contain the rotenone. Stopping the discharge at Derks Lake temporarily reduced our need to use potassium permanganate to deactivate rotenone treated water that would have otherwise flowed downstream into Soldotna Creek and possibly affected native fish. A similar approach was used at Sevena Lake during the Area 2 treatments in 2016 and 2017 when an existing beaver dam at the lake outlet was breached prior to treatment to reduce the lake volume. After the lake drained to static height, the outlet was replugged with sandbags to help contain the rotenone treated lake water until the lake detoxified.

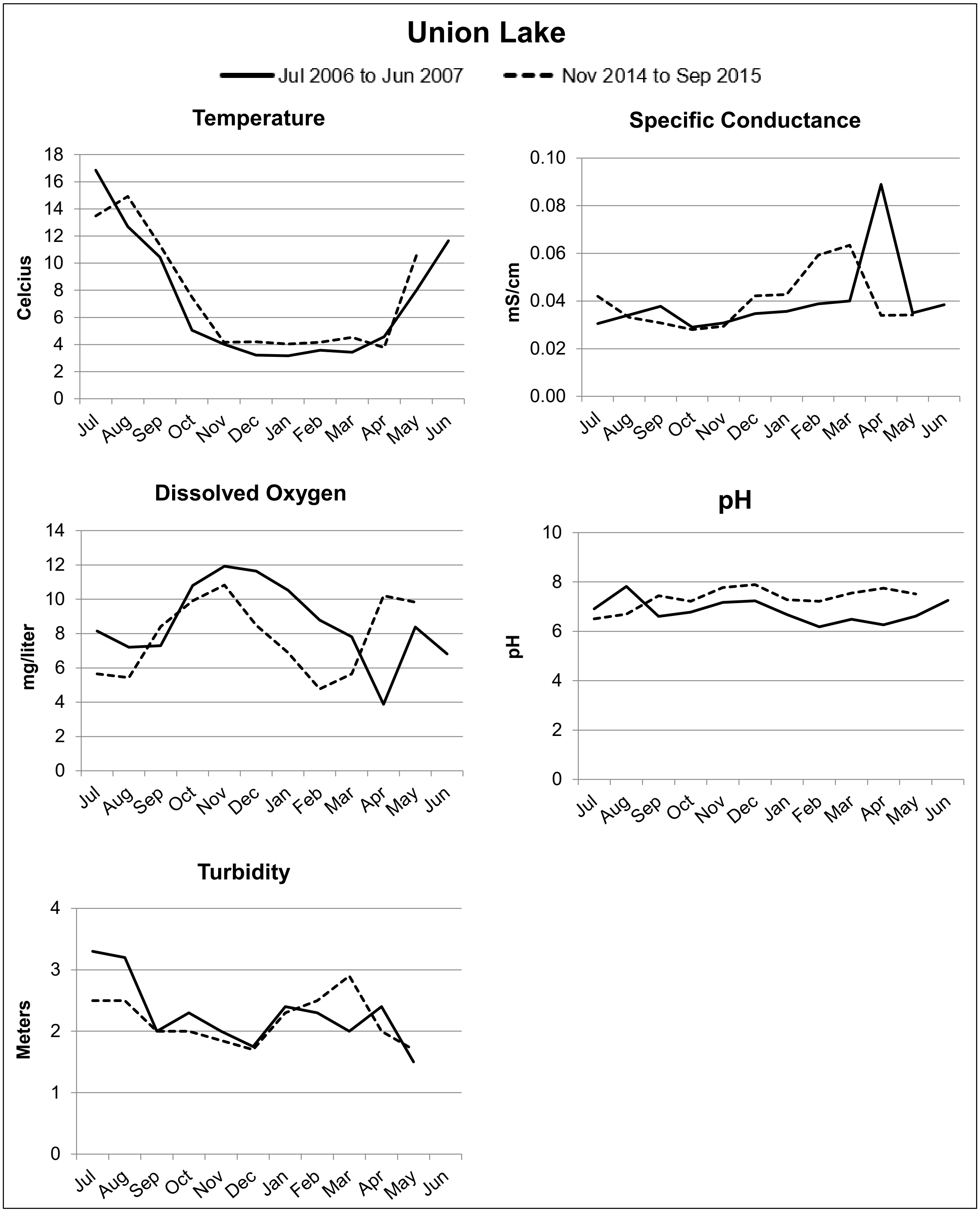

Figure 15.–Union Lake average monthly water quality data during 2006–2007 and 2014–2015.

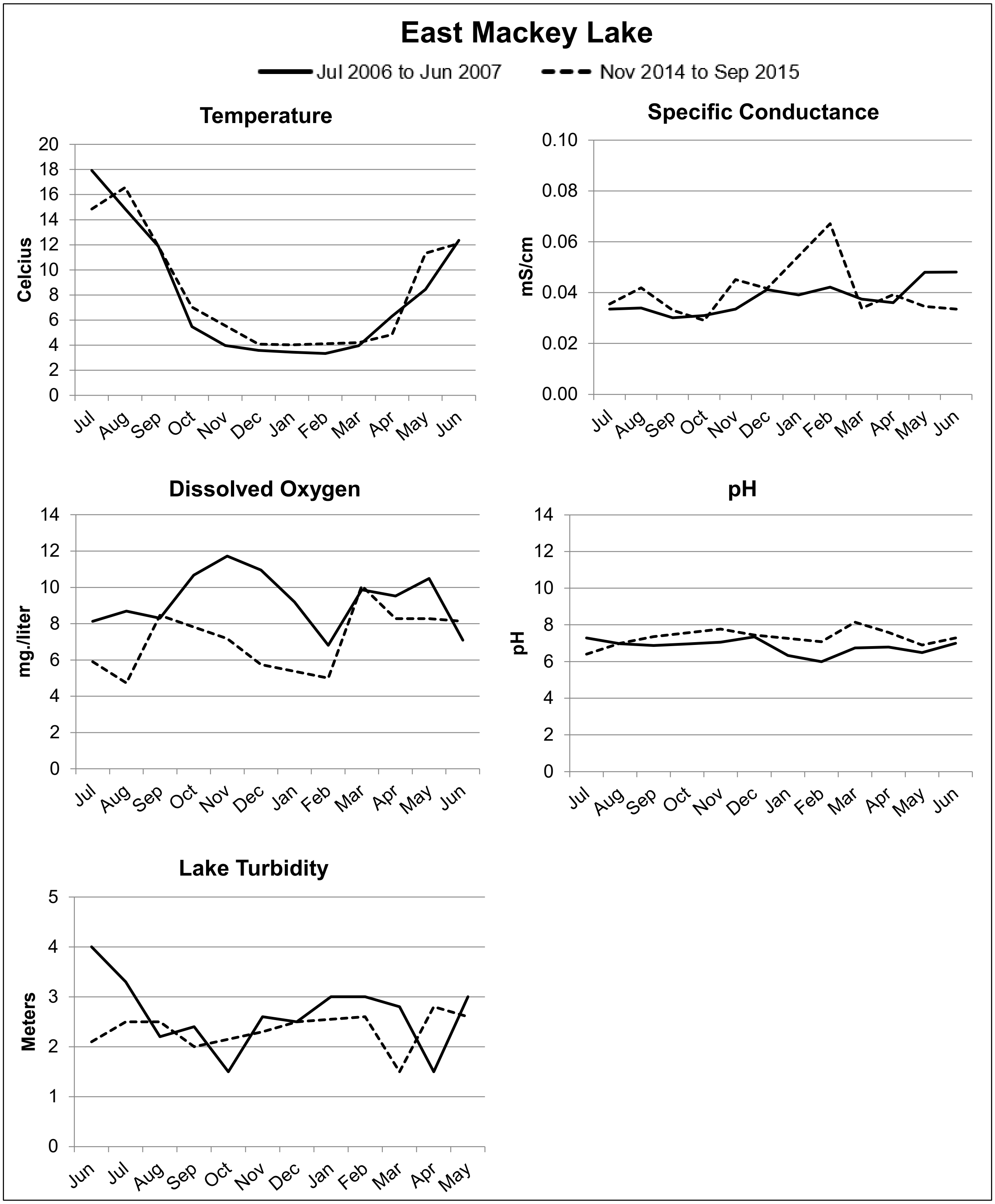

Figure 16.–East Mackey Lake average monthly water quality data during 2006–2007 and 2014–2015.

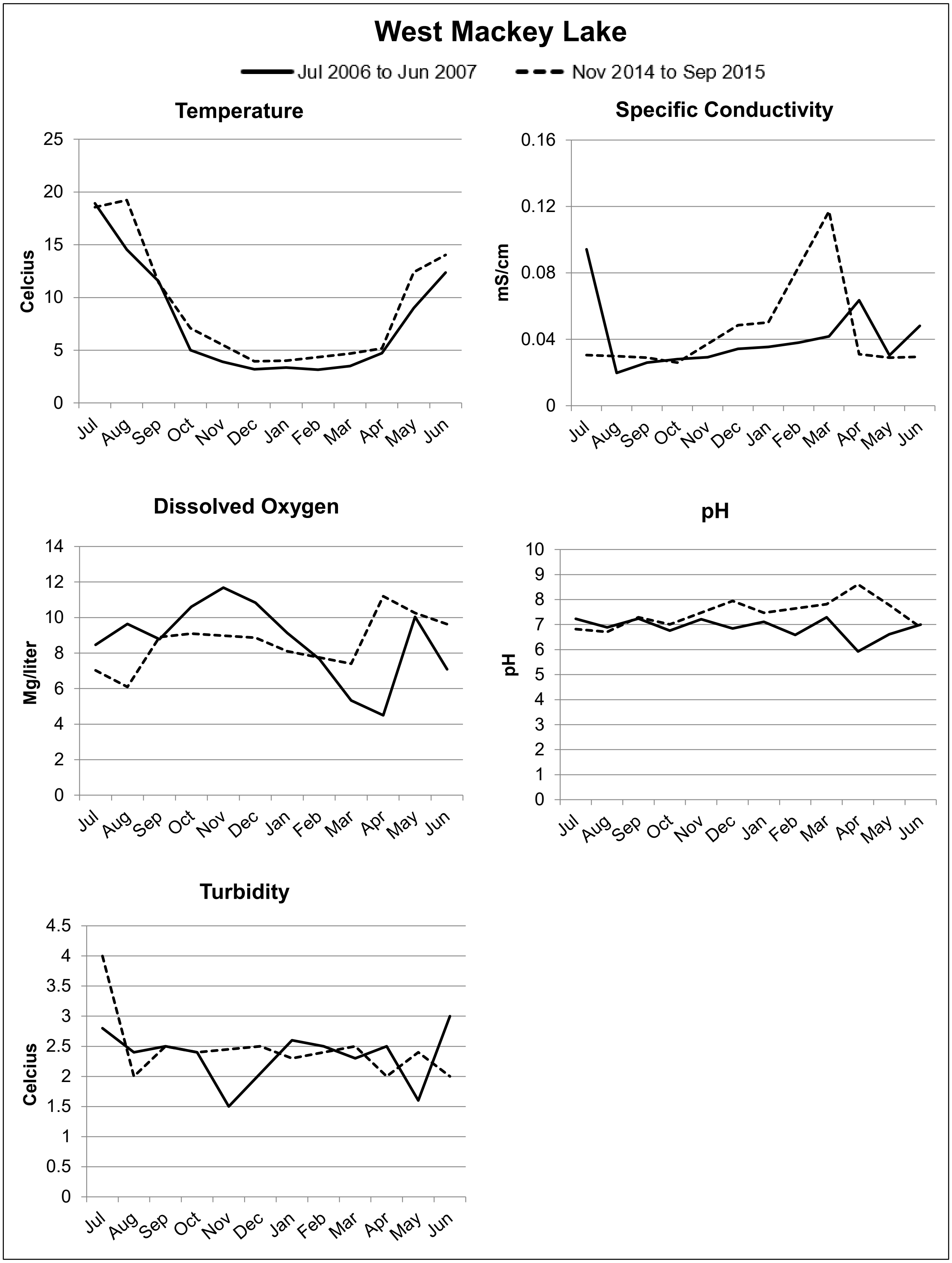

Figure 17.–West Mackey Lake average monthly water quality data during 2006–2007 and 2014–2015.

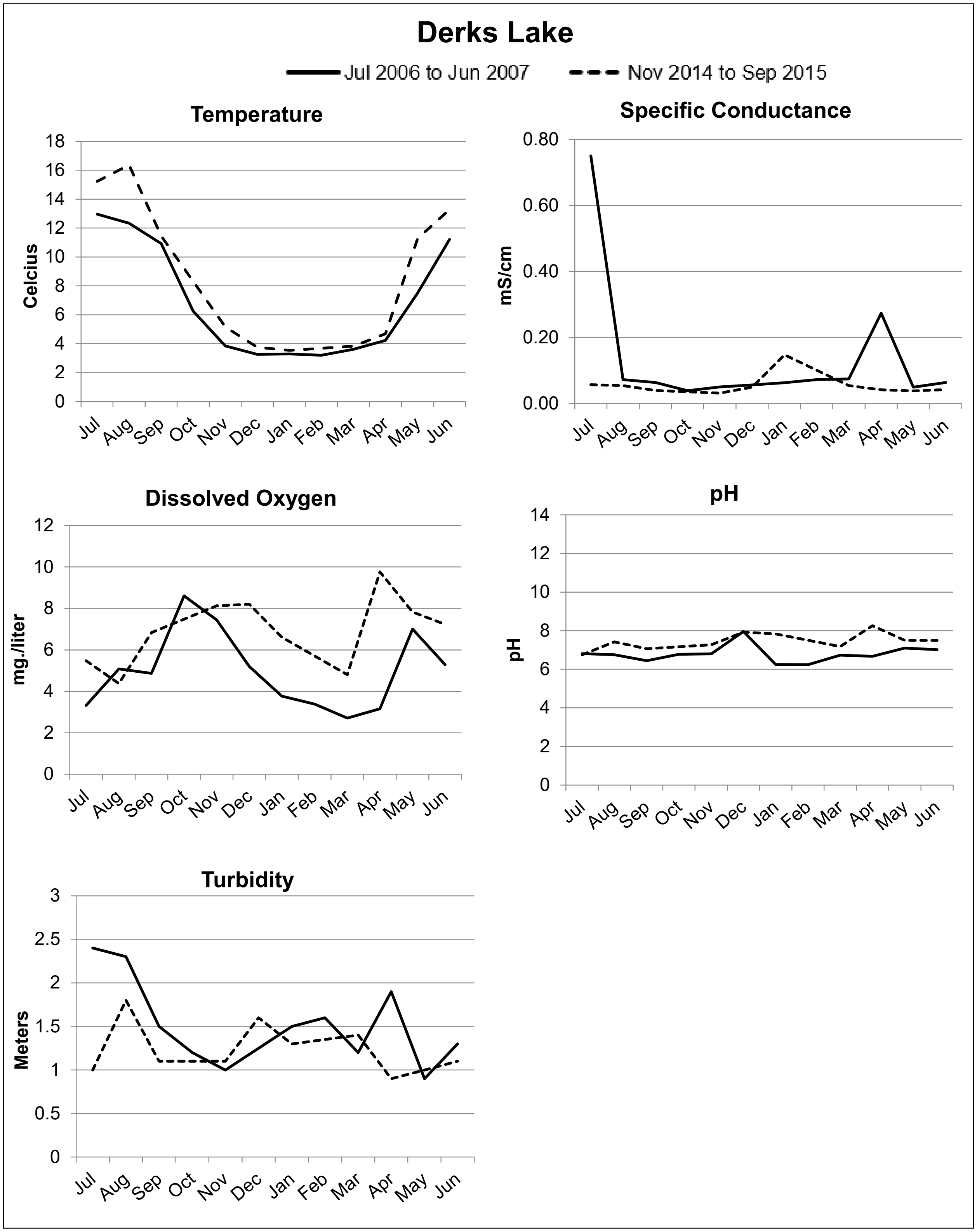

Figure 18.–Derks Lake average monthly water quality data during 2006–2007 and 2014–2015.

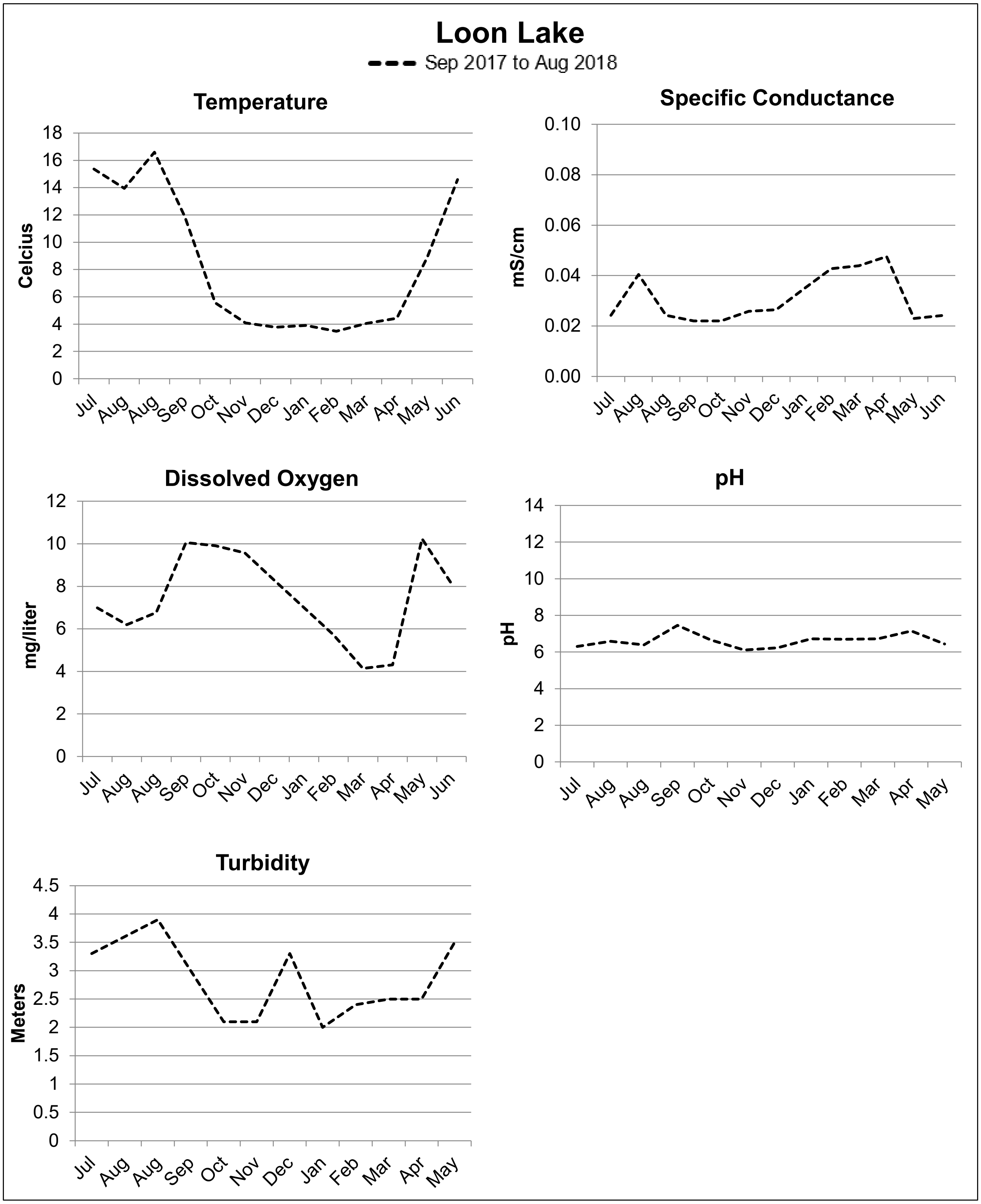

Figure 19.–Loon Lake average monthly water quality data, 2017–2018.

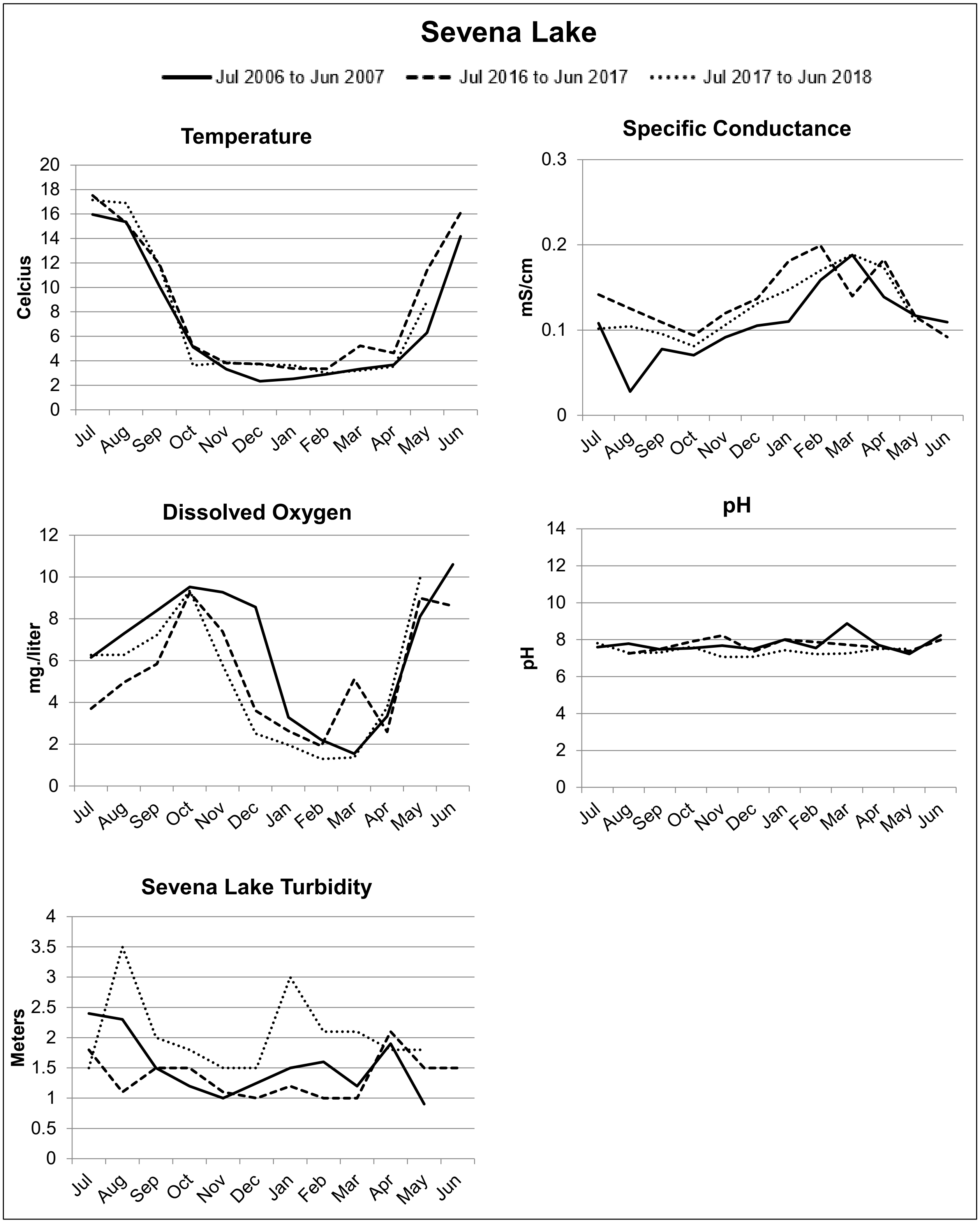

Figure 20.–Sevena Lake average monthly water quality data during periods 2006–2007, 2016–2017, and 2017–2018.

Table 3.–Monthly stream discharge for Soldotna Creek and select tributaries, April 2006–April 2007.

		Year															
	Sample site coordinates in	2006									2007						
Location[a]	Datum WGS84	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Max	Min	Avg
Derks Creek	N60-31-33.9; W150-57-45.8	2.7	–	–	0.1	0.1	–	–	1.9	0.9	0.4	–	–	0.6	2.7	0.1	1.0
East Mackey Creek	N60-31-39.7; W150-59-04.3	1.4	–	1.1	0.4	0.3	2.4	4.0	2.1	0.8	–	–	–	0.9	4.0	0.3	1.5
Sevena Creek	N60-33-00.0; W150-55-22.1	–	6.8	–	2.2	5.3	4.5	6.8	1.2	–	1.3	1.4	–	13.5	13.5	1.2	4.8
Soldotna Creek[b,c]	N60-29-05.5; W150-03-08.1	34.3	11.3	–	8.9	25.5	16.9	44.1	6.9	7.4	8.3	–	5.9	37.5	44.1	5.9	18.8
Tree Creek	N60-33-20.5; W150-55-21.4	–	2.0	1.1	0.5	1.3	1.5	1.0	0.6	1.0	1.7	1.5	0.3	2.4	2.4	0.3	1.2
Union Lake	N60-31-14.4; W150-010-33.6	0.1	–	0.0	0.0	0.0	0.4	0.6	0.1	–	–	–	–	0.4	0.6	0.0	0.2
West Mackey Lake	N60-31-31.0; W150-00-08.4	1.1	–	0.5	0.2	0.7	1.5	2.0	0.8	0.5	0.2	0.1	–	0.1	2.0	0.1	0.7

Note: An en dash indicates missing data primarily resulting from negligible and immeasurable stream flow or heavy surface ice preventing measurement.

[a] Location sample site names.

[b] Discharge measurements for Soldotna Creek for the months of December, January, and March were supplied courtesy of the Kenai Watershed Forum and collected at a location approximately ¼ mile upstream of the site used by ADF&G to measure discharge.

[c] ADF&G site location for measuring stream discharge was near stream mile 0.7.

Table 4.–Rotenone application and water discharge records for Soldotna Creek and select tributaries, 2014–2017.

Site	Area application period[a]	Date[b]	Discharge (ft^3/s)[c,d]
Derks Lake outlet	6–11 October 2014	09/23/2014	5.8
		09/30/2014	3.5
		10/12/2014	5.1[d]
		10/14/2014	0.5
		10/15/2014	0.8
		10/21/2014	2.2
Sevena Lake outlet	26–30 June 2016	06/24/2016	2.9
	15 June 2017	06/05/2017	4.0
		06/14/2017	2.8
East Mackey outlet	6–11 October 2014	10/11/2014	3.2
		10/12/2014	2.5
		10/13/2014	2.4
		10/14/2014	2.3
		10/15/2014	2.1
		10/16/2014	2.4
Soldotna Creek mile 6.9	26–30 June 2016	06/18/2016	8.2
		06/27/2016	5.4
	15 June 2017	06/05/2017	10.2
		06/13/2017	8.8
		06/14/2017	8.9
		06/16/2017	7.1
		06/21/2017	7.0
		06/22/2017	6.9
Soldotona Creek mile 7.5	6–11 October, 2014	10/11/2014	12.4
		10/12/2014	18.7
Soldotna Creek mile 5.0	26–30 June, 2016	06/24/2016	10.8
		06/28/2016	6.9
Tree Creek mile 2.0	26–30 June, 2016	06/22/2016	0.8
Tree Creek mile 1.2		06/22/2016	1.6

[a] Period when rotenone treatment was applied near the discharge measurement site.

[b] Date that the discharge measurement was taken.

[c] Cubic feet per second.

[d] The 2014 discharge at the Derks Lake outlet during 23 September through 12 October was unusually high because a beaver dam near the lake outlet was intentionally breached to draw down the lake volume.

BIOASSAYS

Bioassays to determine the rotenone minimum effective dose (MED) required to kill northern pike for this project were conducted at Derks Lake and Sevena Lake for the Area 1 and 2 treatments, respectively. The Area 1 bioassay occurred on 30 September 2014 at Derks Lake. The bioassays were duplicated for 3 product scenarios: Prentox Fish Toxicant Powder, CFT Legumine, and CFT Legumine with organic loading (1 cup of lake muck and vegetation was added to each bioassay container) to mimic conditions where lake organics are stirred up during an application. Both CFT

Legumine and Prentox Fish Toxicant Powder were planned to treat Area 1, so both were tested. CFT Legumine was deemed most appropriate for use in streams, nearshore areas, and deepwater applications due to its greater dispersal abilities, and Prentox fish Toxicant Powder was used in open offshore surface applications because it is less expensive.

The water temperature in the bioassay containers was 9.3°C, specific conductance was 0.33 millisiemens per cm (mS/cm), dissolved oxygen was 7.8 mg/L, and pH was 7.44. The rotenone concentrations tested for all bioassay scenarios were 0.0 ppb, 12.5 ppb, 25.0 ppb, 50.0 ppb, 100.0 ppb, and 200.0 ppb. For the CFT Legumine (without organic loading) scenario, 2 additional concentrations were tested (3.0 ppb and 6.0 ppb) to determine a MED for long (24 hour) exposure. Additionally, 40 ppb was also tested for Area 2.

All fish in all Area 1 bioassay trials with a rotenone concentration greater than or equal to 12.5 ppb died within 270 minutes or less. The CFT Legumine scenario (without organic loading) using rotenone concentrations of 6.0 ppb and 3.0 ppb failed to kill any fish after 24 hours of exposure. No fish died in the controls where the rotenone concentration was 0.0 ppb. At rotenone concentrations greater than or equal to 12.5 ppb, all scenarios yielded similar fish fates (death) although CFT Legumine generally killed fish faster than Prentox Fish Toxicant Powder, and organic loading with CFT Legumine delayed the onset of death only slightly (Table 5).

The Area 2 bioassay occurred on 24 June 2016 at Sevena Lake and only tested CFT Legumine without the addition of extra organic matter. At the time of the bioassay, water temperature in the bioassay containers was 19°C, specific conductance was 0.11 mS/cm, dissolved oxygen was 8.6 mg/L, and pH was 7.91.

All fish in all the Area 2 bioassays with CFT Legumine concentrations greater than or equal to 12.5 ppb died within 51 minutes or less (Table 5), with death occurring in less than 20 minutes when rotenone concentrations were greater than or equal to 50 ppb.

The warmer water temperatures present during the Area 2 bioassays may have caused the faster responses compared to the cooler water used in the Area 1 bioassays; the relative rate of rotenone toxicity is known to increase with temperature (Gerfsdorff 1943).

Standard operating procedures for fish eradication using rotenone suggests the minimum target concentration of rotenone should be double that which achieved 100% mortality in the bioassays after 8 hours (Finlayson et al. 2010); our bioassay results indicated that a rotenone concentration of 12.5 ppb would satisfy this minimum guideline.

Environmental factors that might significantly reduce the potency of rotenone include dense aquatic vegetation beds, dilution from wetland inputs, areas of deep organic substrate, and areas of deep water (>25 ft) where mixing might be poor (Finlayson et al. 2000). The observed potency of rotenone in the bioassays, even at low concentrations, assured us that the target rotenone concentrations (50 ppb for Area 1 and 40 ppb for Area 2) were probably sufficient to kill northern pike even when accounting for inhibiting environmental variables. The lower target rotenone concentration for Area 2 (≤40 ppb), compared to Area 1 (50 ppb), was intentional and enabled us to reduce the amount of potassium permanganate needed to deactivate rotenone in Soldotna Creek prior to entering the Kenai River.

Table 5.–Results of bioassays of rotenone exposure to fish for Area 1 and Area 2.

				Minutes until death at rotenone concentration (ppb)[a]								
Area	Date	Location	Rotenone product	0.0	3.0	6.0	12.5	25.0	40.0	50.0	100.0	200.0
Area 1	9/30/2014	Derks Lake	CFT Legumine	NE	NE	NE	270	240	NT	87	70	58
	9/30/2014	Derks Lake	CFT Legumine (with organic loading)[b]	NE	NT	NT	70	240	NT	135	79	67
	9/30/2014	Derks Lake	Prentox Fish Toxicant Powder	NE	NT	NT	270	255	NT	135	95	84
Area 2	6/24/2016	Sevena Lake	CFT Legumine	NE	NT	NT	51	28	29	20	15	14

Note: "NE" means no observed effect. "NT" means not tested.

[a] Bioassay containers were filled with 20 L of site water. Water temperature was 9°C in 2014 (Derks Lake) and about 19°C in 2016 (Sevena Lake). Five to 6 juvenile coho salmon were placed in each container and rotenone product was added to each container to produce the desired target rotenone concentration. Minutes until death is defined as the minutes elapsed until the last fish in the bioassay container died.

[b] Organic loading consisted of adding ½ cup of lake sediment and ⅔ cup of aquatic vegetation to each bioassay container.

PREPARATION AND TREATMENT DETAILS

Pretreatment Fish Surveys and Northern Pike Removal

To update our knowledge of northern pike distribution on the Kenai Peninsula gathered during the early 2000s (McKinley 2013), pretreatment gillnet surveys were conducted between 2010 and 2017. A gillnetting survey in 2010 first detected northern pike in Tiny Lake (5.5 surface acres) and subsequent intensive gillnetting successfully eradicated that small population (N = 26) as confirmed by follow-up eDNA sampling and gillnet surveys (Dunker et al. 2016). Multiple gillnetting surveys at Denise Lake in 2010 and 2012 failed to detect any northern pike despite their presence in years prior (McKinley 2013). The cause for their disappearance at Denise Lake is unknown, but residents report that this introduced northern pike population was very small and angler harvest alone may have been enough to remove them.

The gillnetting that occurred during 2013–2017 focused on expanding existing information about northern pike distribution and reducing its abundance within the Soldotna Creek drainage. Lakes netted during the 2013–2017 period included Cisca Lake, Derks Lake, Derks Pond, East Mackey Lake, Halfhorn Lake, Loon Lake, No Banjo Lake, Sevena Lake, Tree Lake, Union Lake, and West Mackey Lake (some lake names are unofficial; Figure 4). These lakes were selected because they either already had known northern pike populations or were suspected of having due to their proximity or potential surface water connection to known northern pike waters.

In total, 448,722 gillnet soak hours were expended during 2013–2017 in the Soldotna Creek drainage (Table 6). In addition, 2,018 gillnet soak hours were expended on Tiny Lake in 2010, and 2,620 gillnet soak hours were expended on Denise Lake between 2010 and 2012. The 2013–2017 total catch from all lakes was 3,089 northern pike, 303 rainbow trout, 458 Dolly Varden, 267 juvenile coho salmon, 1 adult coho salmon, and 317 unidentifiable fish (due to advanced decomposition of fish in overwintered nets). Most resident species were caught in Sevena Lake, where native fish populations rebounded dramatically following a suspected winterkill event in 2008 that nearly wiped out its northern pike population. Likewise, the catch of resident species at Derks Lake was significant and follows years of intensive northern pike removal efforts prior to 2013 (Begich 2010; Massengill 2010; Massengill 2011; McKinley 2013). Both Sevena Lake and Derks Lake have direct and open linkage to Soldotna Creek, which allows access for native fish recolonization.

Loon Lake is stocked annually with hatchery rainbow trout, so gillnet catches were expected to have rainbow trout despite the detection and presence of northern pike since 2017. In general, northern pike dominated the gillnet catches in all unstocked lakes except for Sevena Lake and Tree Lake. Like Sevena Lake, Tree Lake may have also experienced a winterkill event in 2019 that eliminated its northern pike population. Winterkill at both lakes appears possible because low average dissolved oxygen levels have been observed at both lakes in late winter (Massengill 2011), and there are anecdotal reports by residents of dead fish at spring ice-out. Lakes where no fish were caught by gillnet during 2013–2017 include Cisca Lake, Halfhorn Lake, and No Banjo Lake. Derks Pond, considered a wetland of Derks Lake, was gillnetted unsuccessfully for northern pike prior to 2013 (ADF&G, Soldotna, unpublished data) but when it was opportunistically gillnetting again in fall 2014, 1 northern pike was caught, so it was included in the 2014 Area 1 rotenone treatment.

Table 6.–Gillnet effort and catch in the Soldotna Creek drainage during 2010–2016.

Location	Net set date	Net pull date	Number of nets fished	Hours of netting effort[a]	Number of fish captured by species: Northern pike[b]	Rainbow trout	Dolly Varden	Coho salmon (adult)	Coho salmon (juv.)	Unknown species[c]
Cisca Lake	7/21/2016	7/22/2016	6	132	0	0	0	0	0	0
			Lake total	132	0	0	0	0	0	0
Denise Lake	02/15/2010	02/26/2010	6	803	0	0	0	0	0	0
	05/10/2010	05/14/2010	19	1,714	0	0	0	0	0	0
	05/09/2012	05/10/2012	4	103	0	0	0	0	0	0
			Lake total	2,620	0	0	0	0	0	0
Derks Lake	05/02/2013	05/03/2013	1	26	2	0	0	0	0	0
	10/07/2013	10/08/2013	21	756	58	0	0	0	0	0
	10/08/2013	10/09/2013	28	1,008	52	2	0	0	0	0
	10/09/2013	10/11/2013	33	1,980	47	0	4	1	3	0
	10/11/2013	10/14/2013	33	2,772	65	0	5	0	1	0
	10/14/2013	10/17/2013	29	2,436	95	0	3	0	3	0
	10/17/2013	10/21/2013	29	3,132	139	0	2	0	2	0
	10/21/2013	10/25/2013	29	3,132	95	0	14	0	19	0
	10/25/2013	10/31/2013	29	4,524	112	0	4	0	5	0
	11/01/2013	05/02/2014	29	126,672	650	0	0	0	0	0
			Lake total	146,438	1,315	2	32	1	33	0
Derks Pond	10/18/2014	10/19/2014	1	22	1	0	0	0	0	0
			Lake total	22	1	0	0	0	0	0
East Mackey Lake	05/02/2013	05/03/2013	1	26	0	0	0	0	0	0
	11/08/2013	05/01/2014	7	29,235	275	0	0	0	0	0
			Lake total	29,262	275	0	0	0	0	0
Halfhorn Lake	11/30/2015	11/2/2015	2	222	0	0	0	0	0	0
	11/20/2015	04/18/2016	3	3,599	0	0	0	0	0	0
			Lake total	3,821	0	0	0	0	0	0
Loon Lake	06/26/2017	06/26/2017	6	24	2	13	0	0	0	0
	06/28/2017	06/28/2017	13	52	0	19	0	0	0	0
	07/13/2017	07/14/2017	16	310	3	67	0	0	0	0
			Lake total	386	5	99	0	0	0	0

-continued-

Table 6.–Page 2 of 2.

Location	Net set date	Net pull date	Number of nets fished	Hours of netting effort[a]	Number of fish captured by species: Northern pike[b]	Rainbow trout	Dolly Varden	Coho salmon (adult)	Coho salmon (juv.)	Unknown species[c]
No Banjo Lake	10/26/2015	10/27/2015	3	84	0	0	0	0	0	0
			Lake total	84	0	0	0	0	0	0
Sevena Lake	10/16/2013	10/17/2013	6	144	23	16	3	0	2	0
	11/03/2015	04/14/2016	33	116,561	18	186	423	0	216	317
			Lake total	116,705	41	202	426	0	218	317
Tree Lake	10/26/2015	10/30/2015	6	576	0	0	0	0	16	0
			Lake total	576	0	0	0	0	16	0
Tiny Lake	09/06/2010	10/13/2010	16	2,018	26	0	0	0	0	0
			Lake total	2,018	26	0	0	0	0	0
Union Lake	05/24/2013	05/25/2013	7	172	0	0	0	0	0	0
	05/27/2013	05/28/2013	21	473	6	0	0	0	0	0
	05/28/2013	05/29/2013	21	437	107	0	0	0	0	0
	05/29/2013	05/30/2013	21	511	99	0	0	0	0	0
	11/08/2013	05/02/2014	9	37,768	300	0	0	0	0	0
			Lake total	39,361	512	0	0	0	0	0
West Mackey Lake	05/01/2013	05/02/2013	2	110	4	0	0	0	0	0
	10/09/2013	10/11/2013	19	1,140	53	0	0	0	0	0
	10/11/2013	10/14/2013	19	1,596	53	0	0	0	0	0
	10/14/2013	10/17/2013	19	1,596	30	0	0	0	0	0
	10/17/2013	10/21/2013	19	2,052	50	0	0	0	0	0
	10/21/2013	10/25/2013	19	2,052	64	0	0	0	0	0
	10/25/2013	11/01/2013	19	3,420	86	0	0	0	0	0
	11/01/2013	05/01/2014	23	99,969	600	0	0	0	0	0
			Lake total	111,935	940	0	0	0	0	0
Total										
2013–2017				448,722	3,089	303	458	1	267	317
2010–2017				453,360	3,115	303	458	1	267	317

[a] Gillnets with floating hanging lines and bottom lead lines were 120 ft long, 6 ft deep, and comprised 6 differently sized mesh panels of 0.75, 1.0, 1.25, 1.5, 1.75, and 2.0 inches.

[b] Northern pike catches were partially estimated for Sevena, Derks, West Mackey, and East Mackey Lakes and Derks Lake due advanced decomposition of some carcasses, making an accurate count difficult.

[c] Some fish were not identified to species due to advanced decomposition.

Application Overview

The treatment plan used a sequential approach by treating Area 1 with rotenone first in 2014 and Area 2 next in 2016. There was a partial retreatment of Area 2 in 2017. A new discovery of northern pike in Loon Lake in 2017 (a closed lake within Area 1) also resulted in an emergency treatment of that lake in the same year. To ensure each treatment was done as safely as possible, safety training was provided to all applicators and support staff prior to each treatment event. The safety trainings were held at the Soldotna ADF&G office and the training material identified the potential health and environmental risks associated with rotenone exposure, the proper use of personal protective equipment (PPE), and the proper piscicide handling and application procedures. Instructions were provided on first aid measures for various routes of rotenone exposure and the emergency contacts for specific incidents. Onsite training also focused on how to properly operate application equipment.

2014 Area 1 Treatment

Area 1 was treated with rotenone 6–11 October 2014. The treatment plan called for starting the treatment at Union Lake, then each day following, the next downstream lake was treated, finishing at Derks Lake, the terminus of Area 1. The 25-person application and support team consisted of staff from ADF&G Division of Sport Fish (SF), ADF&G Division of Commercial Fisheries (CF), The Kenai Watershed Forum (KWF), Cook Inlet Aquaculture Association (CIAA), the United States Fish and Wildlife Service (USFWS), and a contractor working for the Department of Defense (DOD). Immediately preceding the Area 1 treatment, fish passage barriers were installed below Derks Lake to ensure northern pike could not reenter Area 1 from Area 2.

On 6 October 2014, Union Lake was treated with rotenone, including the lake's tributaries and the wetland flowage connecting Union Lake and West Mackey Lake. Outboard boats applied rotenone to Union Lake and a combination of backpack, ATV, and airboat applicators treated the wetland downstream of Union Lake. Rotenone mixture balls treated the small creek seeps and tributaries draining into Union Lake.

On 7 October 2014, West Mackey Lake was treated with rotenone including a less than 1-acre human-made pond and channel connected to West Mackey Lake. Outboard boats were primarily used for application, and backpack applicators treated the stream linking West Mackey Lake to East Mackey Lake.

On 8 October 2014, East Mackey Lake was treated with rotenone with outboard boat and airboat applicators. ATV and backpack applicators treated the flowage connecting East Mackey Lake to Derks Lake.

On 9 October 2014, airboat and outboard boat applicators treated Derks Lake, and ATV and backpack applicators treated the outlet creek and wetlands associated with Derks Lake. Rotenone mixture balls treated the small seeps and tributaries draining into Derks Lake. The outlet of Derks Lake was barricaded with sandbags as a temporary measure to prevent outflow into Area 2, allowing some time for natural rotenone deactivation to occur before the lake height increased enough to spill over the barrier into Soldotna Creek (Area 2).

On 11 October 2014, an approximately 2-acre wetland pond associated with Derks Lake was treated by boat applicators (canoe) following the unexpected discovery of 1 northern pike in the pond on 10 October 2014.

Sentinel fish were used in all treated lakes, ponds, and streams to test the effectiveness of each stage of the treatment, and all perished less than 24 hours after the initiation of treatment. In total, 460 gallons of CFT Legumine and 5,072 pounds of Prentox Prenfish Fish Toxicant Powder were applied to Area 1 over a 5-day period (Table 2).

A deactivation station at the outlet of Derks Lake was installed prior to the Area 1 rotenone treatment as a precaution to protect native fish downstream in Area 2 (Soldotna Creek). The deactivation station could dispense $KMnO_4$ as needed based on the response of sentinel fish in Soldotna Creek.

By the spring of 2015, all the rotenone in Area 1 naturally detoxified and native fish restoration work ensued, involving the capture and relocation of thousands of native fish captured in Area 2 and released into Area 1. These native fish reintroductions continued during the open water season each year through 2018.

In the spring of 2017, northern pike were detected in Loon Lake within Area 1. On 24 August 2019, Loon Lake was treated with rotenone by outboard boat applicators, and backpack applicators treated adjacent inundated wetlands. A total of 30 gallons of CFT Legumine and 145 pounds of Prentox Fish Toxicant Powder were applied (Table 2).

2016 Area 2 Treatment

In 2016, a 24-person application and support team conducted the rotenone treatment of Area 2. The team included representatives from SF, CF, KWF, CIAA, USFWS, and an aerial piscicide applicator contracted by ADF&G. Dual deactivation stations were installed near the Soldotna Creek mouth to deactivate rotenone, if needed, as a precaution against impacts to fish residing in the Kenai River. About a week prior to the start of the rotenone treatment, Sevena Lake was lowered more than a foot by removing a beaver dam at the lake outlet, which aided in dewatering wetlands adjacent to Sevena Lake.

The treatment started near the drainage's headwaters, and each day thereafter we treated a successive downstream section of drainage referred to as "zones." The first zone "Zone 1" was treated on 26 June 2016 and included Sevena Lake and its tributaries. An airboat and outboard boats applied rotenone to the lake, backpack applicators treated some of the lake tributaries, and drip station applicators also treated some lake tributaries. A helicopter applicator treated a large adjacent wetland northwest Sevena Lake (Figure 21).

On 27 June 2016, we treated Zone 2, which included the entirety of Tree Creek and the upper section of Soldotna Creek between the outlet of Sevena Lake and the Derks Lake outlet stream. Drip stations were the primary method of application to the stream, but backpack sprayers also applied rotenone to stream-adjacent seeps and wetlands along the entire creek corridor of Zone 2. Rotenone mix balls were also used in seeps and in the lower section of Tree Creek in lieu of a drip station. A helicopter treated larger inundated adjacent wetlands (Figure 21).

On 28 June 2016, we treated Zone 3, which included Soldotna Creek and adjacent wetlands between the Derks Lake outlet stream and a powerline that crosses Soldotna Creek between stream miles 4 and 5. Drips stations continued to be the primary application method for flowing waters, backpack sprayers were used to spot treat seeps and wetlands along the creek corridor, and rotenone mix balls were used in seeps. The helicopter applicator spot treated large, inundated wetlands in Zone 3, and returned to Zone 2 to treat a wetland not treated previously (Figure 21).

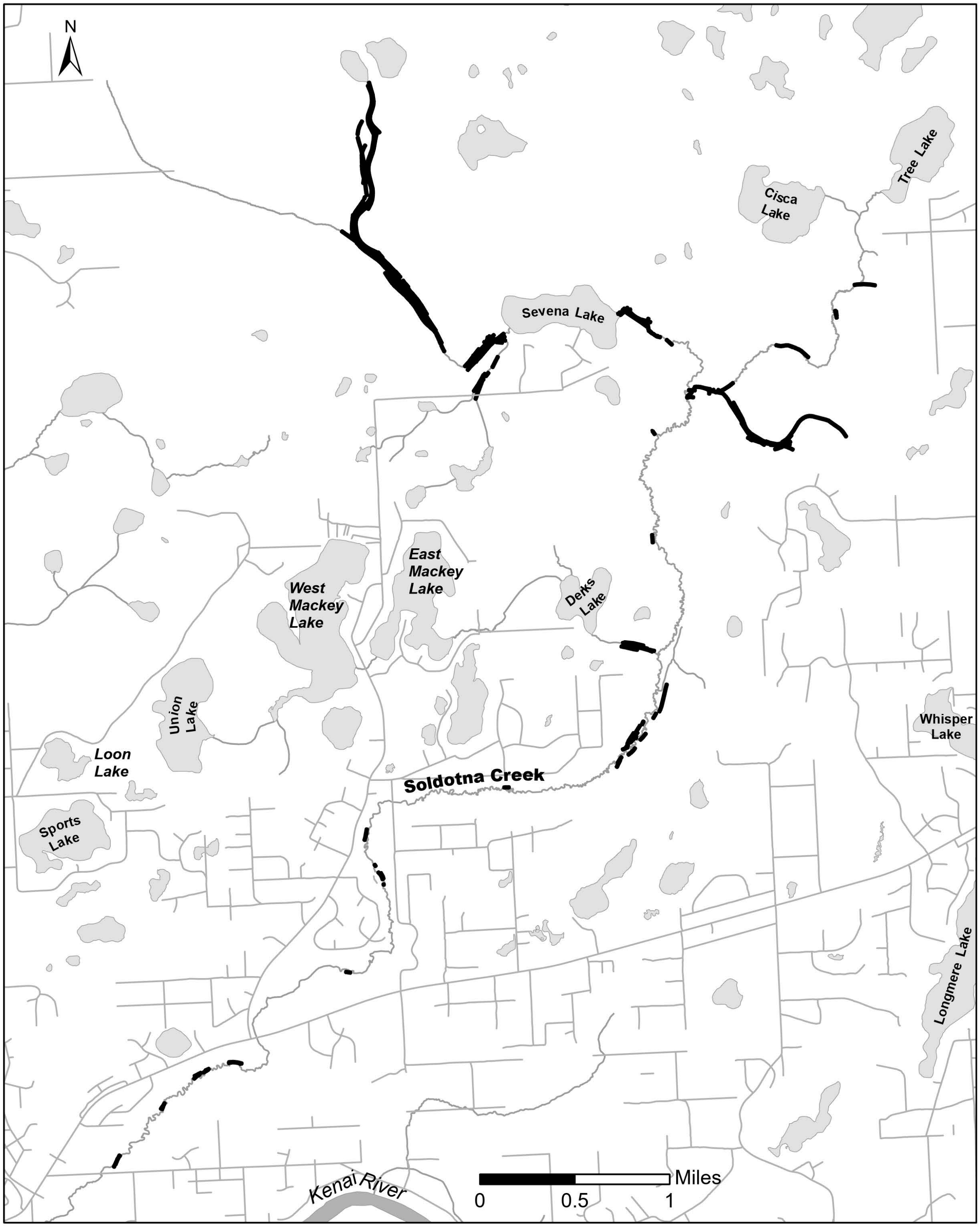

Figure 21.–Map of locations where rotenone was applied by helicopter in 2016.

Note: Areas of dark lines indicate locations where rotenone was applied by helicopter.

On 29 June 2016, drip stations applicators treated Zone 4, which included Soldotna Creek between the powerline at the Zone 3 terminus and the Sterling Highway. Backpack applicators were used to spot treat seeps and wetlands and used rotenone mixture balls as needed.

On 30 June 2016, 2 drips station operators applied rotenone to Zone 5, one in a tributary just south of the Sterling Highway and another at the Sterling Highway culvert. Three other planned drip stations downstream of the Sterling Highway were not utilized because sentinel fish were already observed dead and dying near the mouth of Soldotna Creek. Backpack sprayers were used to treat seeps, small tributaries, and wetlands along the creek corridor and applied rotenone mix balls at their discretion.

Throughout the 2016 Area 2 treatment, we relied on sentinel fish to demonstrate the effectiveness of the treatment in each zone, and as expected, all sentinel fish perished during or shortly after each zone's treatment. In total, 243 gallons of CFT Legumine and 30 pounds of Prentox Fish Toxicant Powder was applied to Area 2 between 26 and 30 June 2014 (Table 2).

As a precaution, the deactivation station was operated 26 June 2016 through 5 July 2016. During this period, no sentinel fish in the Kenai River downstream of the Soldotna Creek confluence exhibited signs of rotenone impairment.

2017 Area 2 Treatment

The 2017 treatment of Area 2 was modified significantly from the original plan of duplicating the entire treatment as done in 2016. The 2017 treatment only included Sevena Lake, its tributaries, and Loon Lake. The reason for not treating the remainder of Area 2 was because no northern pike were detected in Soldotna Creek or Tree Creek during the 2016 treatment despite multiple block nets that were placed throughout the Soldotna Creek corridor to collect rotenone killed fish. Furthermore, no backpack applicator observed any dead or impaired northern pike while walking the entire corridor of Tree Creek and Soldotna Creek during the 2016 treatment despite observing thousands of dead fish that were not northern pike. Sevena Lake and its tributaries were treated in 2017 over concerns that the 2016 treatment of Sevena Lake may have been ineffective based on laboratory results informing us that the peak rotenone concentration in the deepest part of the lake was far below our target. It was deemed appropriate to conduct a more limited 2017 rotenone treatment and avoid treating Soldotna Creek and Tree Creek to preserve native fish populations already reestablished. Loon Lake was added to the 2017 treatment area when northern pike were unexpectedly detected in this closed Area 1 lake in Spring 2017.

Just prior to the 2017 Sevena Lake treatment, the lake was again partially drained by removal of a beaver dam at the outlet. Sandbags were used to temporarily stop the discharge from Sevena Lake (allowing time for some natural rotenone deactivation after treatment) until the lake height rose and exceeded the barrier height. A pair of rotenone deactivation stations were installed on a privately owned bridge spanning Soldotna Creek about ⅓ mile downstream of the Derks Lake outlet creek confluence. This deactivation site was selected because it was the closest easily accessible site to Sevena Lake and would be capable of protecting native fish downstream in most of Soldotna Creek.

On 15 June 2017, Sevena Lake was treated with rotenone by outboard boat, airboat applicators, and backpack applicators, and drip station applicators treated the adjacent wetlands and tributaries. A total of 202.8 gallons of CFT Legumine was applied in 2017 (Table 2). Monitoring of the rotenone concentration in Sevena Lake indicated the peak concentration nearly attained the target in the deepest parts of the lake, and monitoring downstream in Soldotna Creek found no detectable rotenone. The rotenone deactivated quickly (<10 days) and before the lake height rose enough to breach the sandbag barrier at the lake outlet; therefore, an insignificant amount of rotenone traveled beyond Sevena Lake into Soldotna Creek thus negating the need to operate the deactivation station located downstream.

Drip Station and Deactivation Observations

Area 1 Drip and Deactivation Stations

Drip stations were not used in Area 1, but a rotenone deactivation station was utilized at the outlet of Derks Lake to prevent impacts to native fish downstream in Soldotna Creek. The deactivation station began operation on 12 October 2014 after rotenone treated water began to spill over the sandbag barrier at the Derks Lake outlet. The deactivation station was kept in nearly continuous operation until 14 November 2014, when it was stopped to test the survival of sentinel fish. Because sentinel fish survived in Soldotna Creek after more than 24 hours of exposure to creek water without deactivation, operation of the station was discontinued. During the period when the deactivation station was operational, discharge at the Derks Lake outlet ranged from less than 0.05 ft^3/s to 2.1 ft^3/s and averaged 1.0 ft^3/s. The deactivation station's application rate of $KMnO_4$ varied from 0.0 to 18.0 g/min and averaged 10.3 g/min. Periodic measurement of the residual $KMnO_4$ downstream of the deactivation station, representing 20–30 minutes of stream travel distance, varied between 0.0 ppm and 2.58 ppm, averaging 1.3 ppm, which aligned closely with the suggested target residual of 1.0 ppm (Finlayson et al. 2010; Appendix F1). After deactivation was first initiated, the deactivation station was attended by ADF&G staff nearly continuously through 27 October 2014. Afterwards, staff made periodic site visits to the deactivation station to ensure the equipment was operating properly. To help monitor the power to the deactivation station when staff were offsite, we used a satellite based alarm system to notify us by phone if power at the chemical feeder failed. Below freezing air temperatures made operation of the deactivation station challenging. Gear oil in the gearbox of the chemical feeder would thicken in the cold, often resulting in a power shutdown of the feeder. Our remedy was to wrap the gearbox with an electrical heating cord along with foil-lined insulation to keep the gear oil at an operating temperature (Figure 22).

Area 2 Drip and Deactivations Stations

In 2016, 21 drip station sites were used as the primary method to apply CFT Legumine to flowing waters throughout Area 2 (Figure 23). In 2017, just 3 drip stations were utilized to treat 2 Sevena Lake tributaries. In 2016, a total of 46.8 liters of rotenone were applied throughout Area 2 by drip stations; in 2017, only 1.5 liters of rotenone were applied by drip stations (Table 7). Drip station target application rates (drip rates) of CFT Legumine were based on the estimated stream discharge at each site and varied from 1.0 mL/min to 11.4 mL/min. The duration each drip station operated at each site ranged from a minimum of 240 minutes to 372 minutes (Table 7).

The Area 2 deactivation station operated only in 2016 and for 1 week (27 June through 4 July 2016) and was done only as an extreme precaution against rotenone in Soldotna Creek entering the Kenai River and potentially harming fish despite calculations suggesting dilution with the Kenai River would render any rotenone in the Kenai River harmless to fish (<2.0 ppb rotenone). All caged sentinel fish placed below the 2016 deactivation station in Soldotna Creek and in the Kenai River survived (Appendix F2). In 2017, we were prepared to prevent rotenone from impacting recolonizing native fish residing in the lower half of Soldotna Creek. However, the 2017 Area 2 deactivation station never operated due to the success of temporarily damming the Sevena Lake outlet, which impounded the lake long enough for natural deactivation of the rotenone to occur.

Figure 22.–Image of the deactivation station in the Derks Lake outlet creek located 300 yards from Soldotna Creek, operational from 12 October to 12 November 2014.

Note: The deactivation apparatus dispensed potassium permanganate crystals (KMnO4) to deactivate rotenone in the creek.

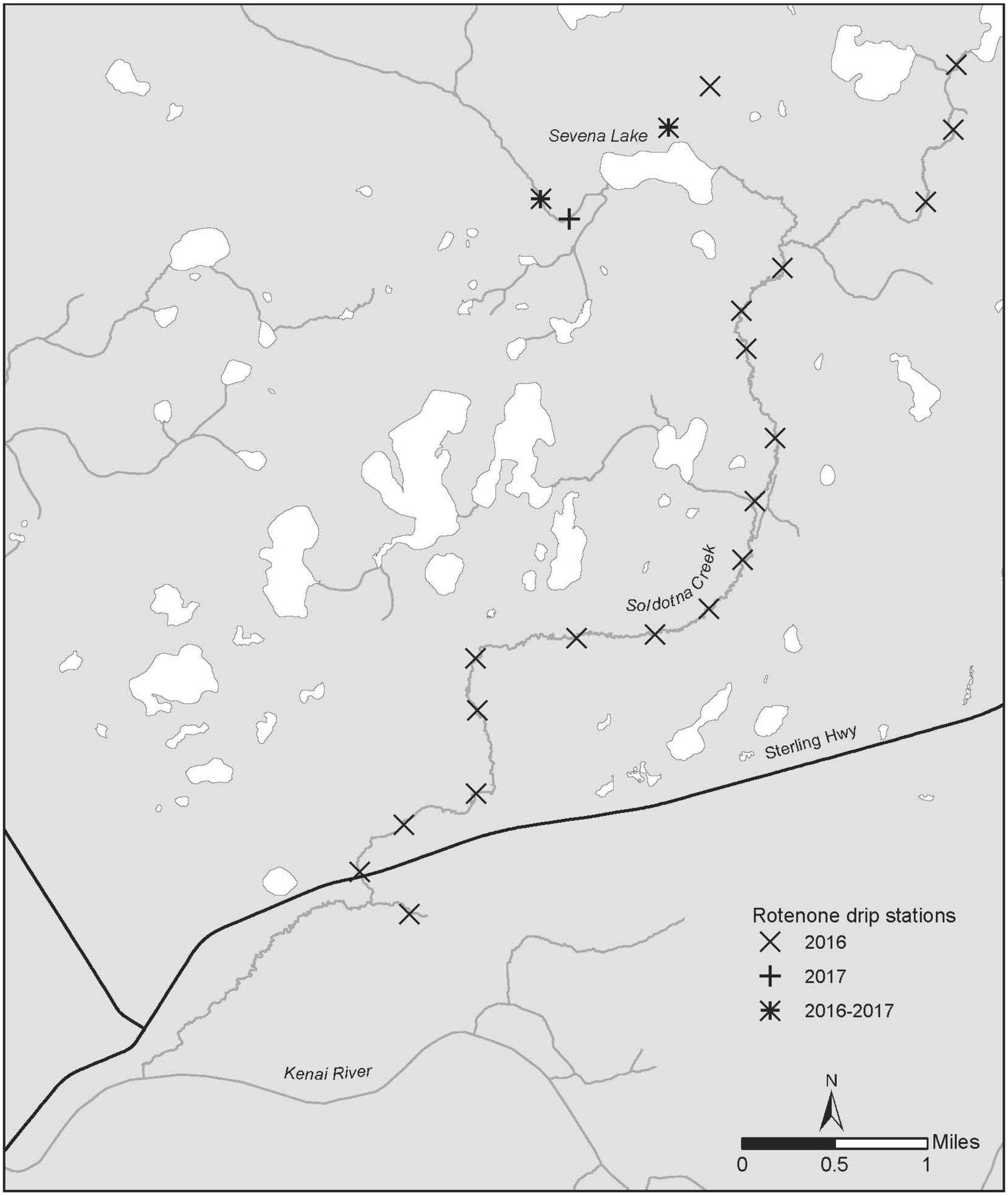

Figure 23.–Area 2 rotenone drip station locations during 2016 and 2017.

Table 7.–Area 2 rotenone drip station data, 2016 and 2017.

Date	Location	Start time	Stop time	Hours of operation	Minutes of operation	Estimated stream discharge (ft^3/s)[a]	Maximum target drip rate (mL/min)[b]	Total liters CFT Legumine applied
6/26/2016	Sevena Lake tributary (Clyde Creek long branch)	10:32	16:15	5.7	343	1	1	0.3
6/26/2016	Sevena Lake tributary (Northwest Creek 1/2 mile above lake)	10:30	16:15	5.8	345	2	2	0.7
6/26/2016	Sevena Lake tributary (Clyde Creek short branch)	10:14	16:15	6.0	361	1	2	0.7
6/27/2016	Mile 9.5 Soldotna Creek	09:20	15:20	6.0	360	8	11	4.0
6/27/2016	Mile 9.0 Soldotna Creek	10:20	15:30	5.2	310	8	11	3.4
6/27/2016	Mile 8.5 Soldotna Creek	10:00	15:45	5.8	345	8	11	3.8
6/27/2016	Mile 8.0 Soldotna Creek	10:09	16:15	6.1	366	8	11	4.0
6/27/2016	Mile 7.4 Soldotna Creek	10:45	16:20	5.6	335	8	11	3.7
6/27/2016	Mile 2.3 Tree Creek	11:00	16:30	5.5	330	2	2	0.7
6/27/2016	Mile 1.7 Tree Creek	10:27	16:30	6.1	363	2	2	0.7
6/27/2016	Mile 1.2 Tree Creek	11:45	16:30	4.8	285	2	2	0.6
6/28/2016	Mile 7.0 Soldotna Creek	09:08	15:20	6.2	372	9	8.5	3.2
6/28/2016	Mile 6.4 Soldotna Creek	10:05	15:20	5.3	315	9	8.5	2.7
6/28/2016	Mile 6.0 Soldotna Creek	08:28	14:30	6.0	362	12	12	4.3
6/28/2016	Mile 5.4 Soldotna Creek	08:25	14:30	6.1	365	12	11.5	4.2
6/29/2016	Mile 4.6 Soldotna Creek	08:25	13:45	5.3	320	12	4	1.3
6/29/2016	Mile 4.2 Soldotna Creek	08:45	14:20	5.6	335	12	4	1.3
6/29/2016	Mile 3.5 Soldotna Creek	09:15	15:15	6.0	360	12	6	2.2
6/29/2016	Mile 3.0 Soldotna Creek	09:05	15:05	6.0	360	13	6	2.2
6/30/2016	Mile 2.4 Soldotna Creek	09:00	13:00	4.0	240	13	11	2.6
6/30/2016	Mile 2.2 Soldotna Creek Tributary	09:00	13:00	4.0	240	1	1	0.2
6/15/2017	Sevena Lake tributary (Clyde Creek short branch)	10:32	16:15	5.7	343	1	1	0.3
6/15/2017	Sevena Lake tributary (Northwest Creek 1/2 mile above lake)	10:30	16:15	5.8	345	2	2	0.6
6/15/2017	Sevena Lake tributary (Northwest Creek 1/4 mile above lake)	10:14	16:15	6.0	361	2	2	0.6
2016 Total				116.9	7,012			46.8
2017 Total				17.5	1,049			1.5
Grand total				134.4	8,061			48.3

[a] At some locations, stream discharge was measured using a USGS Pygmy current meter; at others, discharge was approximated using the nearest measured discharge.

[b] At some locations, maximum rotenone drip rate was intentionally set below that required for a target rotenone concentration of 40 ppb because observations of sentinel fish in the creek suggested residual rotenone was still present from upstream treatments done the previous day. At other locations, the maximum drip rate might slightly exceed that required for 40 ppb; this was done to compensate for loss of rotenone expected from binding to stream organics (e.g., dense vegetation, muck substrate).

Fish Kill Cleanup and Observations

The cleanup of rotenone killed fish in Area 1 was minimal due to the pretreatment gillnetting that had already removed a large portion of the northern pike population. Roving boat crews searched for fish carcasses during treatment and after treatment in all lakes and less than 150 northern pike were recovered. No fish species other than northern pike were recovered from Area 1 except for Derks Lake where about 100 juvenile coho salmon were collected.

The cleanup of rotenone killed fish in Area 2 was more involved. To recover fish from Sevena Lake following the 2016 and 2017 treatments, a roving boat crew searched for carcasses and recovered 1 northern pike in 2016 and none in 2017. Thousands of dead sticklebacks were also recovered from Sevena Lake after both treatments along with a few rearing coho salmon.

Eight fyke nets, used as fish blocking and collection nets, were placed throughout Soldotna Creek in 2016 to restrict the movement of northern pike during treatment and to help recover rotenone killed fish (Table 8). Following the 2016 rotenone treatment of Area 2, thousands of native fish were collected from these block nets, but no northern pike were captured or observed, suggesting northern pike presence in Soldotna Creek was extremely rare. A random sample of 3,872 fish from the combined block net catch was identified to genus or species. Of these fish, 40.3% were juvenile coho salmon, 38.8% were stickleback, 29.4% were lamprey, 8.2% were sculpin, 7.3% were juvenile rainbow trout, and 1.7% were juvenile Dolly Varden (Table 9).

Table 8.–Fyke net locations.

Site name	Latitude	Longitude	Location description and comments
Sevena Lake main tributary	60°32′52.17″	150°59′07.92″	Approximately 600 yards upstream of Sevena Lake
Tree Creek confluence	60°32′39.98″	150°57′01.55″	In Soldotna Creek approximately 20 yards downstream of Tree Creek confluence
Bangerter Bridge	60°31′11.57″	150°57′33.45″	Below old bridge crossing Soldotna Creek on Bangerter property
Derks Gate area	60°30′56.12″	150°58′09.94″	Approximately 60 yards from huge glacial erratic boulder near stream
Dr. Spady Old Bridge site	60°30′55.30″	150°59′36.52″	Near site of an old bridge
Birch Street corner area	60°30′20.18″	151°00′00.37″	Approximately 125 yards from powerline parking area (downstream)
Davis Culvert area	60°30′04.36″	151°00′53.52″	Approximately 70 yards downstream
Sterling Highway area	60°29′48.88″	151°01′16.61″	Approximately 120 yards downstream
East Redoubt Avenue area	60°29′17.56″	151°02′46.01″	Approximately 80 yards upstream
KLT Footbridge area	60°29′04.76″	151°03′05.09″	Approximately 60 yards upstream
Lower Soldotna Creek	60°29′03.22″	151°03′17.43″	Near Kenai River Brewery approximately 225 yards upstream of Kenai River confluence

Note: KLT = Kachemak Land Trust

Table 9.–Fish counts from a random sampling of Soldotna Creek block net catches, 26–31 June 2016.

Species	Count[a]	Proportion (%) of sampled catch
Northern pike	0	0
Coho salmon	1,562	40.3
Rainbow trout	284	7.3
Dolly Varden	65	1.7
Sculpin	317	8.2
Stickleback	1,502	38.8
Lamprey	1,139	29.4
Total fish	3,872	100.0

Note: A total of 8 block nets were placed throughout the Soldotna Creek drainage (see Table 8) to prevent fish movement, collect dead fish to reduce nuisance issues, and provide a sample of the fish species present. The Lower Soldotna Creek block net was pulled before the treatment was completed due to debris plugging issues rendering it ineffective. Sampling of the fyke net catches was done by pooling the entire catch of fish then randomly selecting 3,872 fish for identification. The combined fyke net catch was also visually inspected to determine if any northern pike were present.

A subsample of the 2016 block net catch (N = 193) of juvenile salmonids and sculpin were measured for fork length (Table 10, Appendix G1).

In 2017, a single block net was placed in Soldotna Creek below the Derks Lake outlet confluence to collect any rotenone killed fish resulting from the treatment of Sevena Lake. No fish were recovered by the block net, which is consistent with the notion that fish downstream of Sevena Lake were not killed by the rotenone treatment because the temporary sandbag barrier at the lake outlet sufficiently retained the rotenone until it detoxified.

Table 10.–Number of individuals subsampled and average fork lengths (FL) by species from N = 193 fish collected by 8 fyke nets distributed throughout the Soldotna Creek during 27–30 June 2016.

	Individual fish lengths (mm)			
Statistic	Coho salmon	Dolly Varden	Rainbow trout	Sculpin
Total individuals	61	49	67	16
Average FL (mm)	81	121	117	66
SD FL (mm)	29.7	61.4	57.0	28.9
Maximum FL	194	280	280	85
Minimum FL	51	71	17	40

AREA TREATMENT EVALUATION

The effectiveness of the rotenone treatments at eradicating northern pike was assessed using multiple lines of evidence such as monitoring rotenone concentrations, posttreatment gillnet surveys, northern pike eDNA surveys, and the response of caged sentinel fish.

Sampling for Rotenone and Rotenolone

During 2014–2016, water and sediment samples were analyzed by the California Department of Fish and Game Water Pollution Control Lab in Rancho Cordova, California. In 2017, samples were analyzed by North Coast Laboratories LTD in Arcata, California. Sediment samples were collected less frequently than water samples partly because rotenone bound to sediment is not prone to leaching so sediment-bound rotenone is less of a concern. At Loon Lake in 2017, sentinel fish monitoring replaced water sampling after 1 month of posttreatment sampling as a cost saving measure. In 2016, for all treated lakes with waterfront residences, water from a representative private water well was sampled, and along Soldotna Creek, 2 different private wells were sampled.

Area 1 Rotenone and Rotenolone Sampling in 2014

Pretreatment water samples were collected from Area 1 lakes on 29 September 2014 and posttreatment sampling started 10 October 2014 and continued periodically until the rotenone was considered fully degraded (<2.0 ppb), which occurred by 1 June 2015 (Tables 11 and 12). Lake sediment pretreatment samples were collected on 29 September 2014 and the last posttreatment samples on 20 October 2014 (Table 13). For lakes, both a deepwater sample (midwater column or deeper from the deepest area of lake) and a shallow water sample (1 meter below lake surface) were collected during the first 2 posttreatment sampling events to better assess the mixing of rotenone shortly after application. Subsequent sampling was reduced to a single shallow water sample from each lake. Sediment sampling was halted after the second posttreatment sampling event because there was little ecological concern over sediment-bound rotenone.

To characterize the concentration and persistence of rotenone and rotenolone over time, concentrations were averaged whenever multiple water samples (both shallow and deep) were collected from a lake. When only 1 water sample per lake was collected during a sampling event, it was a shallow water sample. Average rotenone concentrations of water samples 1 day after treatment ranged from 25.8 ppb at East Mackey Lake to 21.3 ppb at Derks Lake (Tables 11 and 12, Figure 24). Lake water rotenone concentrations remained relatively stable in Union Lake, West Mackey Lake, and East Mackey Lake until midwinter when concentrations began falling faster. At Derks Lake, the rotenone concentration dropped more precipitously from the onset. At Union Lake and West Mackey Lake there was a slight increase in rotenone concentrations after the first posttreatment sample was collected. Although increasing rotenone concentrations after treatment may seem counterintuitive, this behavior has been documented elsewhere and is hypothesized to be driven by the initial binding of rotenone to phytoplankton that later release rotenone when decaying (Finlayson et al. 2014).

The concentration of rotenolone, a degradation product of rotenone, increased in all lake waters for about 2 months after treatment, peaking at 16–17 ppb in December 2014 (Figure 25). Residual rotenolone (<5.0 ppb) remained in West Mackey Lake and Union Lake waters when the sampling concluded on 1 June 2014, whereas it was no longer detectable at the other lakes.

Area 1 lake sediment samples were collected less frequently than the water samples. The sediment rotenone and rotenolone concentrations varied greatly between lakes with the rotenone ranging from 15.9 ppb to 407 ppb and rotenolone ranging from 15.2 ppb to 283 ppb on 8 October 2014 (Table 13). Rotenone and rotenolone concentrations on 20 October 2014 ranged between 0.0 ppb and 83.6 ppb and 0.0 ppb and 78.8 ppb, respectively (Table 13, Figures 26 and 27).

Table 11.–Area 1 lake water rotenone and rotenolone concentration (ppb) and related sampling data for Union, East Mackey, and West Mackey Lakes, 2014 treatment.

			Location and concentration in parts per billion (ppb)								
			Union Lake			East Mackey Lake			West Mackey Lake		
Chemical	Sample collection date(s)	Treatment status	Depth 1 m	Deep[a]	Well	Depth 1 m	Deep[a]	Well	Depth 1 m	Deep[a]	Well
Rotenone	9/29/2014	Before	0.0	NS	0.0	0.0	NS	0.0	0.0	NS	0.0
	10/8–10/10/2014	After	23.0	22.7	0.0	25.9	25.6	0.0	22.5	20.0	0.0
	10/20/2014		24.0	25.2	0.0	24.8	22.8	0.0	23.1	22.5	0.0
	11/17/2014		21.0	NS	0.0	23.4	NS	0.0	23.9	NS	0.0
	2/2/2015		20.5	NS	NS	20.1	NS	NS	22.0	NS	NS
	4/7/2015		8.0	NS	0.0	0.0	NS	0.0	4.2	NS	0.0
	4/21/2015		8.5	NS	NS	NS	NS	NS	3.3	NS	NS
	5/17/2015		3.8	NS	NS	NS	NS	NS	1.4	NS	NS
	6/1/2015		0.9	NS	NS	NS	NS	NS	0.0	NS	NS
Rotenolone	9/29/2014	Before	0.0	NS	0.0	0.0	NS	0.0	0.0	NS	0.0
	10/8–10/10/2014	After	6.8	7.0	0.0	5.2	7.2	0.0	7.0	6.1	0.0
	10/20/2014		7.9	7.9	0.0	7.6	7.6	0.0	7.5	8.6	0.0
	11/17/2014		16.0	NS	0.0	16.9	NS	0.0	16.7	NS	0.0
	2/2/2015		12.8	NS	NS	17.0	NS	NS	12.8	NS	NS
	4/7/2015		9.0	NS	0.0	0.0	NS	0.0	4.9	NS	0.0
	4/21/2015		10.7	NS	NS	NS	NS	NS	4.3	NS	NS
	5/17/2015		7.4	NS	NS	NS	NS	NS	2.9	NS	NS
	6/1/2015		4.8	NS	NS	NS	NS	NS	2.0	NS	NS

Note: "NS" means no sample was collected from that site; a zero value "0.0" indicates that the chemical of interest was not detected.

[a] Deep indicates a water sample collected at midwater column or deeper near the deepest part of the lake.

Table 12.–Area 1 lake water rotenone and rotenolone concentrations (ppb) and related sampling data for Derks and Loon Lakes, and Soldotna Creek, 2014–2017.

Treatment year	Chemical[a]	Sample collection date(s)	Treatment status	Derks Lake 1 m depth	Derks Lake deep[b]	Derks Creek	Soldotna Creek	Loon Lake		
								Depth 1 m	Deep[b]	Well
2014	Rotenone	9/29/2014	Before	0.0	NS	NS	NS	NS	NS	NS
		10/8–10/10/2014	After	23.5	22.2	NS	NS	NS	NS	NS
		10/20/2014		21.8	21.7	NS	NS	NS	NS	NS
		11/17/2014		18.7	NS	7.3	0.0	NS	NS	NS
		2/2/2015		9.5	NS	NS	0.0	NS	NS	NS
		4/7/2015		0.0	NS	NS	NS	NS	NS	NS
2017		8/24/2017	Before	NS	NS	NS	NS	0.0	NS	0.0
		8/25/2017	After	NS	NS	NS	NS	28.0	17.0	0.0
		9/5/2017		NS	NS	NS	NS	24.0	24.0	0.0
		9/25/2017		NS	NS	NS	NS	18.0	20.0	0.0
2014	Rotenolone	9/29/2014	Before	0.0	NS	NS	NS	NS	NS	NS
		10/8–10/10/2014	After	7.1	7.3	NS	NS	NS	NS	NS
		10/20/2014		7.1	7.4	NS	NS	NS	NS	NS
		11/17/2014		17.0	NS	9.4	1.1	NS	NS	NS
		2/2/2015		7.2	NS	NS	0.0	NS	NS	NS
		4/7/2015		0.0	NS	NS	NS	NS	NS	NS

Note: "NS" means no sample was collected from that site, a zero value "0.0" indicates that the chemical of interest was not detected.

[a] Lab analysis for rotenolone was unavailable in 2017.

[b] "Deep" indicates a water sample collected at midwater column or deeper near the deepest part of the lake.

Table 13.–Area 1 lake sediment rotenone and rotenolone sampling data, 2014.

Chemical	Sample collection date(s)	Treatment status	Union Lake nearshore	West Mackey Lake nearshore	East Mackey Lake nearshore	Derks Lake nearshore
Rotenone	9/29/2014	Before	0.0	0.0	0.0	0.0
	10/08–10/10/2014	After	15.9	28.0	407.0	22.4
	10/20/2014		26.7	0.0	35.8	83.6
Rotenolone	9/29/2014	Before	0.0	0.0	0.0	0.0
	10/8–10/10/2014		15.2	15.3	283.0	16.6
	10/20/2014		18.8	0.0	20.6	78.8

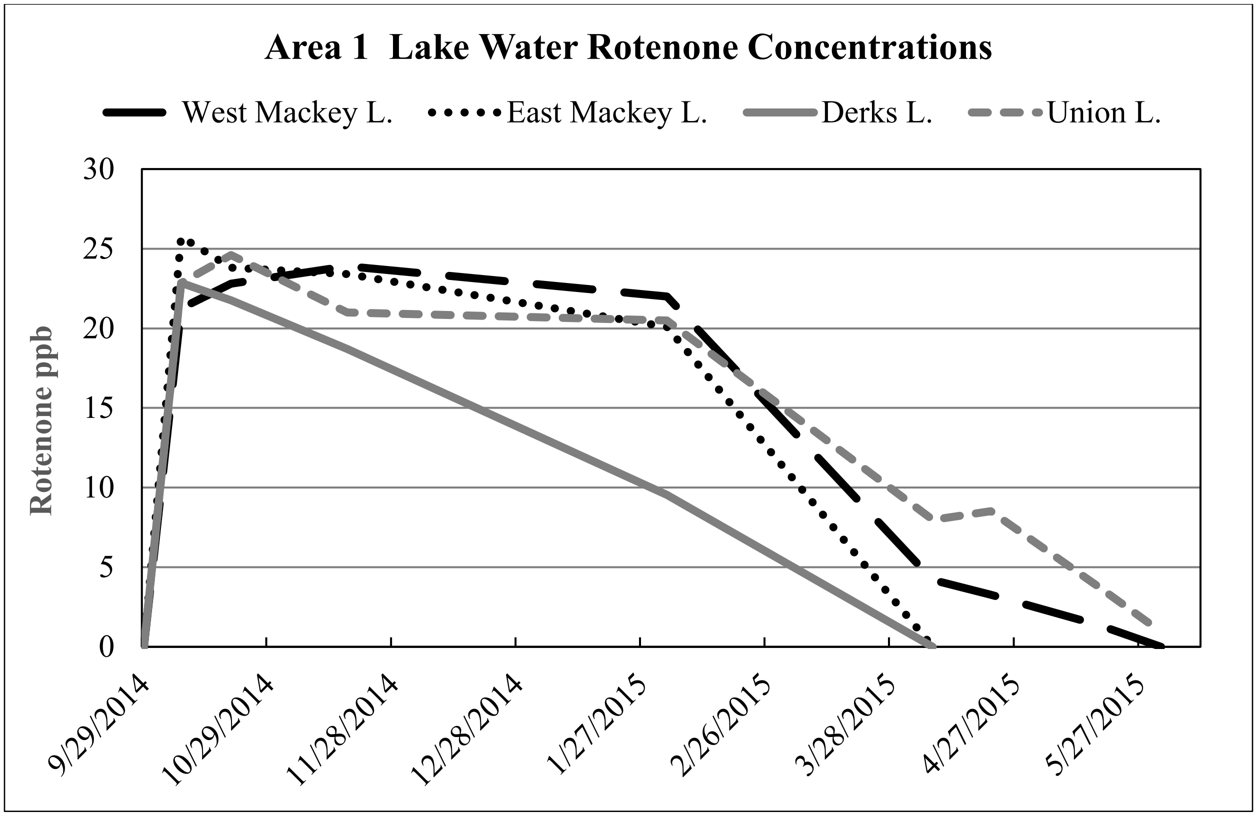

Figure 24.–Area 1 lake water rotenone concentrations, 2014–2015.

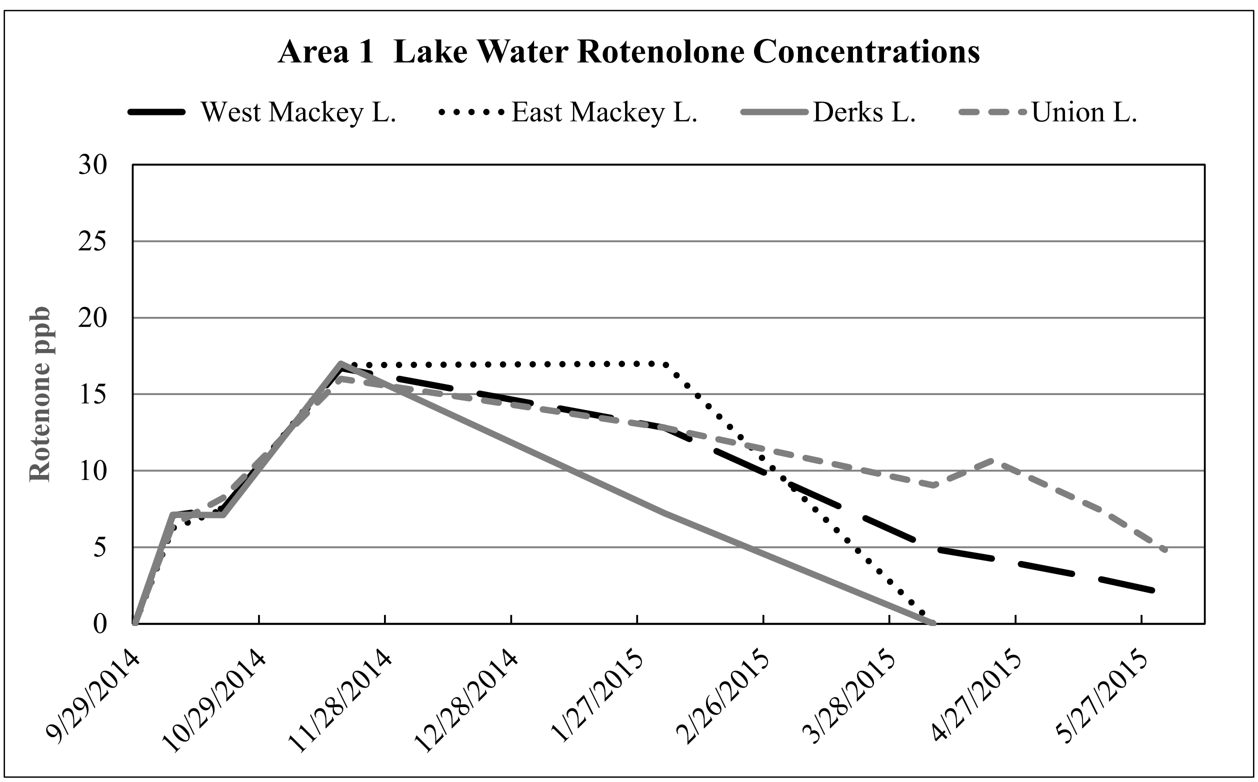

Figure 25.–Area 1 lake water rotenolone concentrations, 2014–2017.

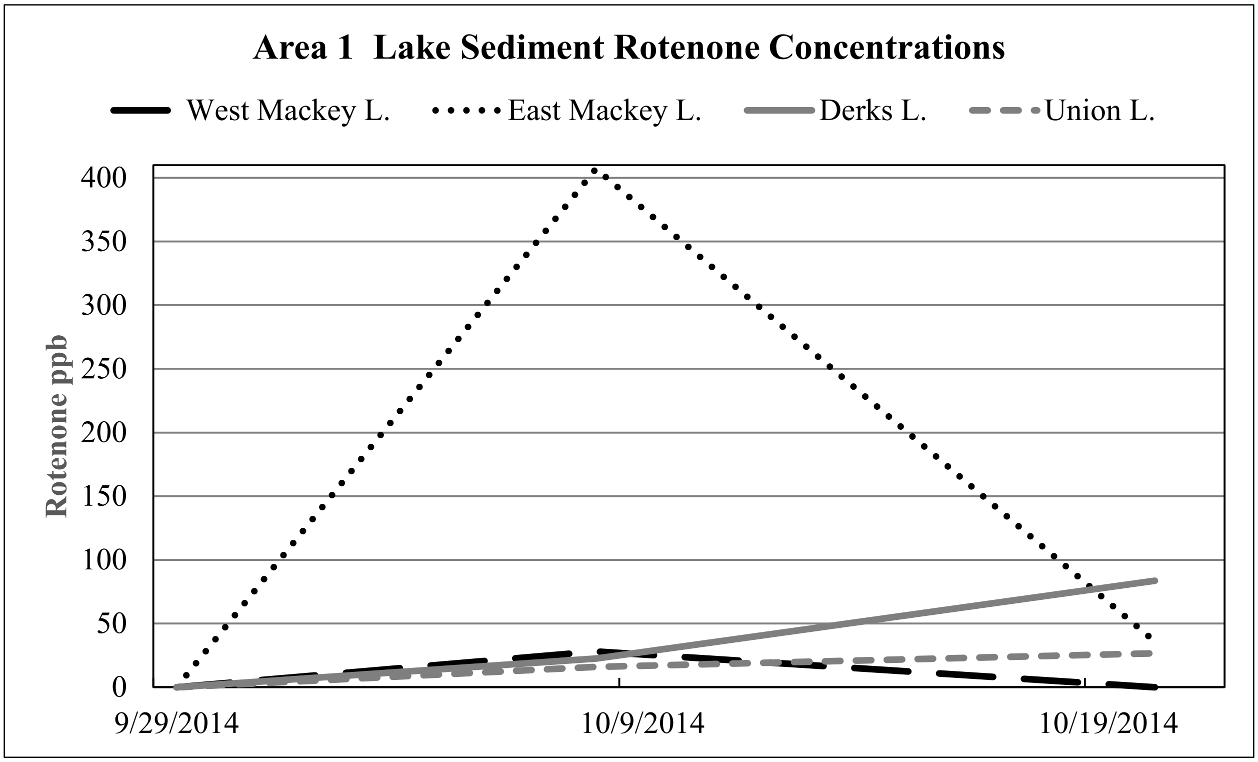

Figure 26.–Area 1 lake sediment rotenone concentrations, 2014–2017.

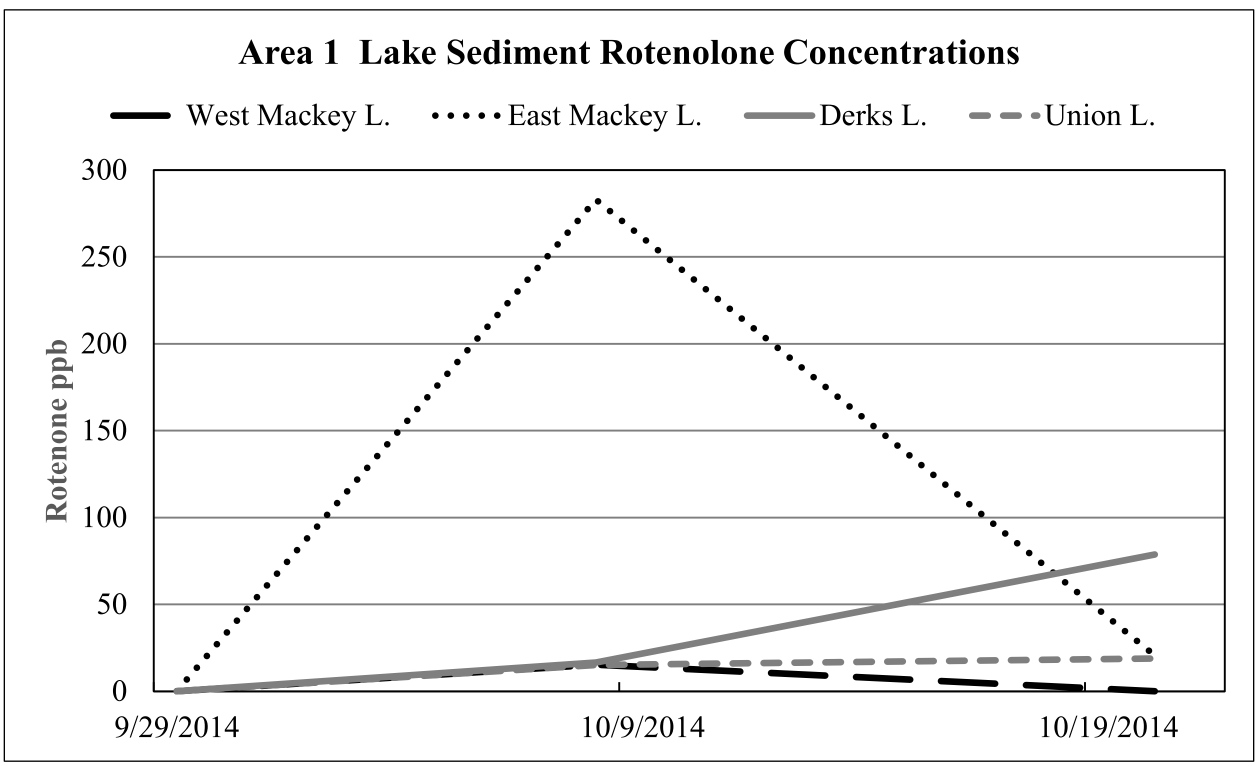

Figure 27.–Area 1 lake sediment rotenolone concentrations, 2014–2017.

The highest sediment concentrations of both compounds were detected at East Mackey Lake on 8 October 2014. Subsequent sediment sampling near the same site on 20 October 2014 showed concentrations of both compounds decreased by over an order of magnitude. Concentrations of both compounds in West Mackey Lake sediment were undetectable in the sample collected 20 October, whereas in the other lakes, the concentrations generally remained similar to concentrations detected in the previous sampling event. It is likely these compounds were not entirely absent in West Mackey Lake sediment on 20 October 2014 and their lack of detection may indicate unrepresentative sampling (e.g., sample obtained below rotenone's ability to penetrate soil). No rotenone or rotenolone was detected in any Area 1 pretreatment samples or from any posttreatment well water sample.

2016 Area 2 Rotenone and Rotenolone Sampling

Area 2 pretreatment water and sediment samples were collected on 21 June 2016 and included 1 water and sediment sample each from Sevena Lake and Soldotna Creek (stream mile 0.6), 1 Kenai River water sample from 400 meters downstream of the Soldotna Creek confluence, and 1 water sample each from 2 private water wells next to Soldotna Creek. No rotenone was detected in any pretreatment water sample (Table 14); however, 1 Soldotna Creek sediment sample (stream mile 5.0) detected a 2.1 ppb concentration of rotenolone in a Soldotna Creek pretreatment sediment sample (Table 15).

On 27 June 2016, 2 water samples were collected at Sevena Lake 1 day after treatment, and 1 was collected from Soldotna Creek (stream mile 6.9) immediately after treatment of the upper creek. The rotenone concentrations detected in Sevena Lake were 15.9 ppb for the shallow water sample and 2.9 ppb for the deepwater sample (Table 14), which might not have been a lethal concentration for northern pike. The rotenone concentration in Soldotna Creek at stream mile 6.9 was 36.1 ppb. Rotenolone concentrations at Sevena Lake were 14.8 ppb for the shallow water sample and 2.5 ppb for the deepwater sample and 41.3 ppb in the Soldotna Creek sample (stream mile 6.9). No sediment samples were collected on 27 June 2014.

The next sampling event occurred on 5 July 2016. A single composite water sample from Sevena Lake, representing a 50:50 mix of shallow and deep water, had a rotenone concentration of 1.7 ppb (Table 14), a concentration considered deactivated (Finlayson et al. 2010). The rotenolone concentration in this sample was 13.5 ppb. Water samples collected from Soldotna Creek at stream mile 5.0 had no rotenone or rotenolone present but a sediment sample did have a rotenone concentration of 13.3 ppb and a rotenolone concentration of 23.3 ppb (Table 15). Neither compound was detected in a Kenai River water sample collected 400 meters downstream of the Soldotna Creek confluence or in well water samples collected near Soldotna Creek at stream miles 0.6 and 5.0 (Table 14).

The final Area 2 sampling event was on 24 August 2016 and only sediment was sampled because previous water samples indicated the rotenone was already below 2.0 ppb. The Sevena Lake sediment sample had a rotenone concentration of 6.8 ppb and a rotenolone concentration of 0.0 ppb (Table 15). No rotenone or rotenolone were detected in the Soldotna Creek stream mile 5.0 sample.

Table 14.–Area 2 lake and stream rotenone and rotenolone water sampling data, 2016–2017.

				Location and concentration in parts per billion (ppb)									
				Sevena Lake				Soldotna Creek					Kenai River 400 m below Soldotna Creek confluence
Treatment year	Chemical[a]	Sample collection date	Treatment status	Depth 1 meter	Composite of 1 meter and deep[b,c]	Deep[b]	Well	Mile 0.7	Mile 5.0	Mile 6.9	Well at mile 0.6	Well near mile 5.0	
2016	Rotenone	6/21/2016	Before	0.0	NS	NS	NS	0.0	NS	NS	0.0	0.0	0.0
		6/27/2016	After	15.9	NS	2.9	NS	NS	NS	36.1	NS	NS	NS
		7/5/2016		NS	1.7	NS	NS	0.0	0.0	NS	0.0	0.0	0.0
	Rotenolon	6/21/2016	Before	0.0	NS	NS	NS	0.0	NS	NS	0.0	0.0	0.0
		6/27/2016	After	14.8	NS	2.5	NS	NS	NS	41.3	NS	NS	NS
		7/5/2016		NS	13.5	NS	NS	1.0	0.0	NS	0.0	0.0	0.0
2017	Rotenone	6/13/2017	Before	0.0	NS	0.0	0.0	NS	NS	0.0	NS	NS	NS
		6/16/2017	After	21.0	NS	32.0	NS	NS	NS	0.0	NS	NS	NS
		6/19/2017		36.0	NS	18.0	0.0	NS	NS	0.0	NS	NS	NS
		6/26/2017		0.0	NS	0.0	NS	NS	NS	0.0	NS	NS	NS

Note: "NS" means no sample was collected from that site, a zero value "0.0" indicates that the chemical of interest was not detected.

[a] Lab analysis for rotenolone was unavailable in 2017.

[b] "Deep" indicates a water sample collected at midwater column or deeper near the deepest part of the lake.

[c] Sevena Lake composite samples represented equal parts water collected from 2 sites, and at each site, half of the site sample was collected at 1 meter depth and half was collected from "deep".

Table 15.–Area 2 lake and stream rotenone and rotenolone sediment sampling data, 2016–2017.

Treatment year	Chemical[a]	Sample collection date	Treatment status	Sevena Lake	Soldotna Creek mile 4.8 nearshore	Soldotna Creek mile 6.9 nearshore
2016	Rotenone	6/21/2016	Before	0.0	0.0	NS
		7/5/2016	After	22.2	13.3	NS
		8/24/2016		6.8	0.0	NS
	Rotenolone	6/21/2016	Before	0.0	2.1	NS
		7/5/2016	After	22.4	23.3	NS
		8/24/2016		0.0	0.0	NS
2017	Rotenone	6/13/2017	Before	0.0	NS	0.0
		6/16/2017	After	0.3	NS	0.0
		6/19/2017		1.4	NS	0.0
		6/26/2017		0.1	NS	0.0

Note: "NS" means no sample was collected from that site, a zero value "0.0" indicates that the chemical of interest was not detected.

[a] Laboratory analysis for rotenolone was unavailable in 2017.

Rotenone and rotenolone results indicated the persistence of rotenone in both Sevena Lake and Soldotna Creek waters were similarly brief (Figure 28). At Sevena Lake, rotenolone degraded more slowly than it did in Soldotna Creek (Figure 28).

Concentrations of rotenone and rotenolone in Sevena Lake and Soldotna Creek sediment behaved similarly over time as those observed from water sampling, first increasing and then decreasing to low concentrations by mid-August 2016 (Figure 29).

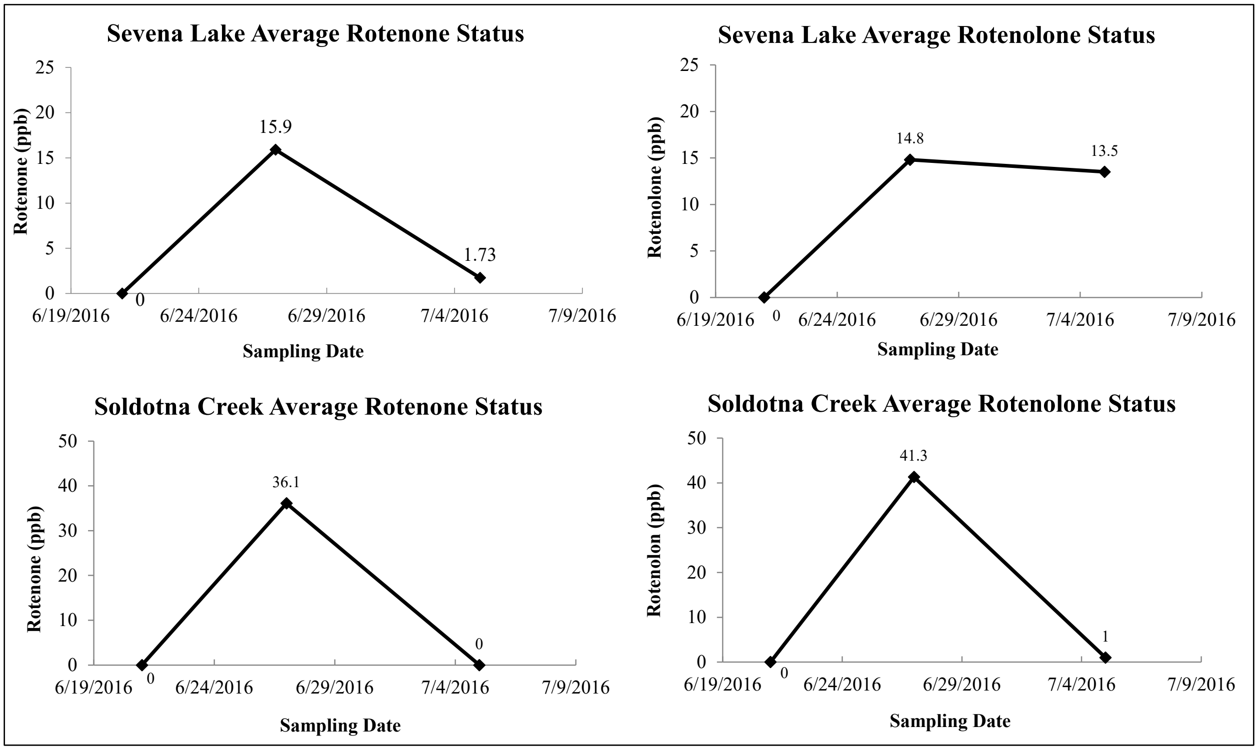

Figure 28.–Graph panel of Sevena Lake water (shallow or composite samples [Table 14]) and Soldotna Creek water (see Table 14 for sample locations) rotenone and rotenolone concentrations, June–July 2016.

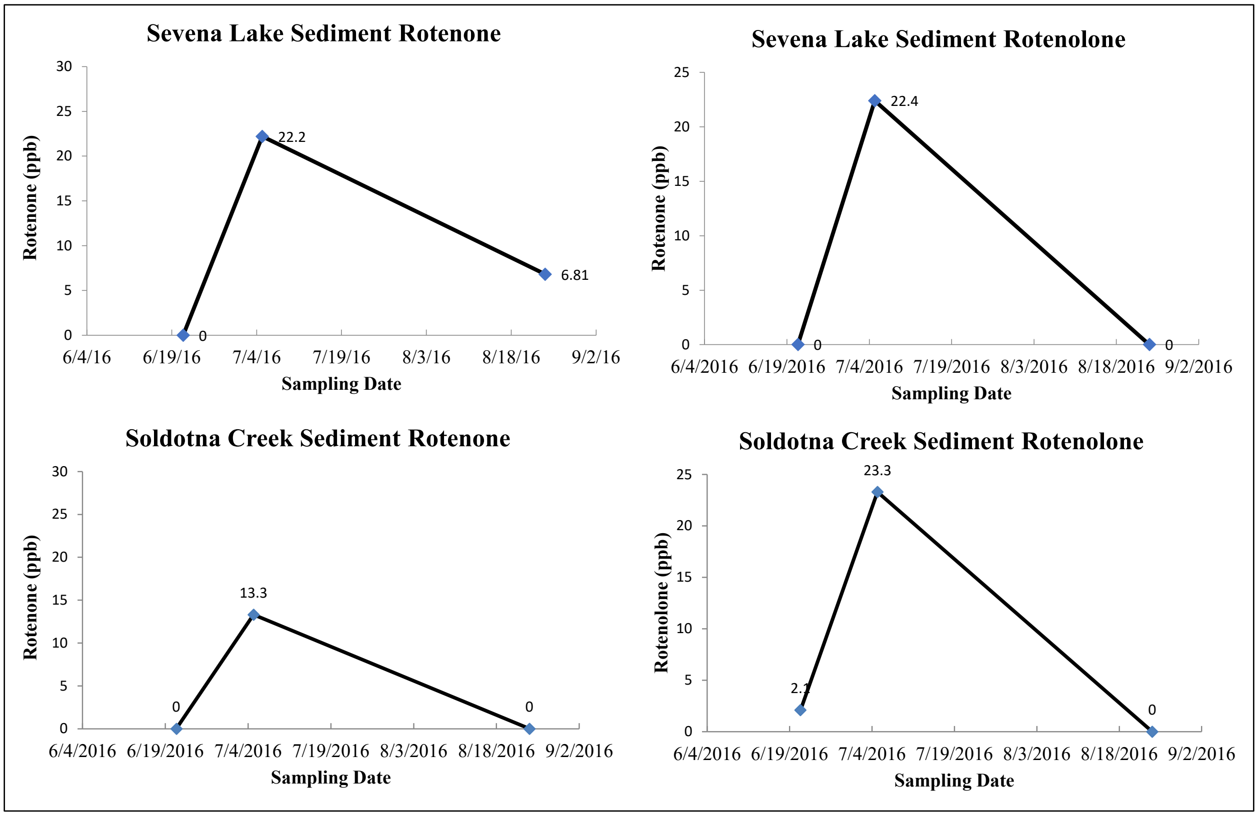

Figure 29.–Sevena Lake and Soldotna Creek mile 4.8 sediment rotenone and rotenolone concentrations, June–August 2016.

2017 Area 2 Sampling

Area 2 sampling was scaled back significantly in 2017 compared to 2016 to reflect the reduced size of the treatment area. We could no longer find a lab that could analyze samples for rotenolone in 2017 so samples were analyzed for rotenone content only. Pretreatment water samples collected on 13 June 2017 included 2 from Sevena Lake (1 shallow and 1 deepwater sample), 1 well water sample near Sevena Lake, and 1 sample from Soldotna Creek at stream mile 6.9 (Table 14). One sediment sample each was collected from Sevena Lake and Soldotna Creek (mile 6.9; Table 15). No rotenone was detected in any pretreatment water or sediment sample.

These same sites were resampled after treatment on 16 June 2017 except that no Sevena Lake well water sample was collected. Rotenone concentrations in Sevena Lake water were 21.0 ppb for the shallow sample and 32.0 ppb for the deep sample (Figure 29). No rotenone was detected from the Soldotna Creek stream mile 6.9 water sample. A sediment sample from Sevena Lake had a rotenone concentration of 0.3 ppb, and no rotenone was detected in the Soldotna Creek sediment sample (Figure 30).

On 19 June 2017, the same pretreatment samples sites were resampled after treatment and the rotenone concentration in Sevena Lake was 36.0 ppb (shallow) and 18.0 ppb (deep); no rotenone was ever detected in the Sevena Lake well sample or the Soldotna Creek sample (Table 15, Figure 30). The Sevena Lake sediment sample had a rotenone concentration of 1.4 ppb, and the Soldotna Creek sediment sample (stream mile 6.9) had no rotenone (Figure 31).

On 26 June 2017, the final sampling event occurred, and all sites sampled during the pretreatment sampling event were resampled except the Sevena Lake well. The only detection of rotenone was in the Sevena Lake sediment sample (0.01 ppb; Figure 30).

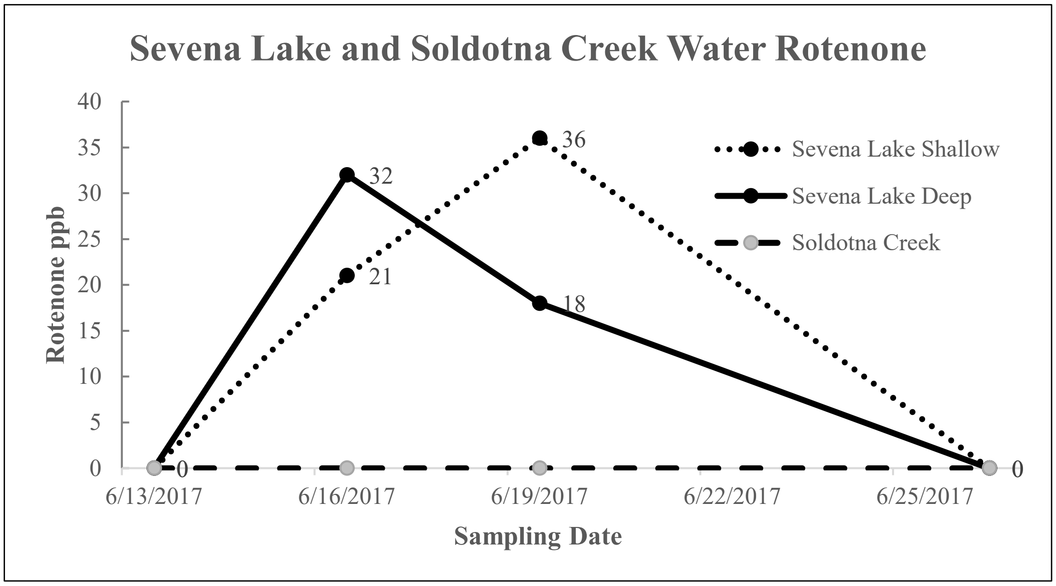

Figure 30.–Sevena Lake and Soldotna Creek water rotenone concentrations, June 2017.

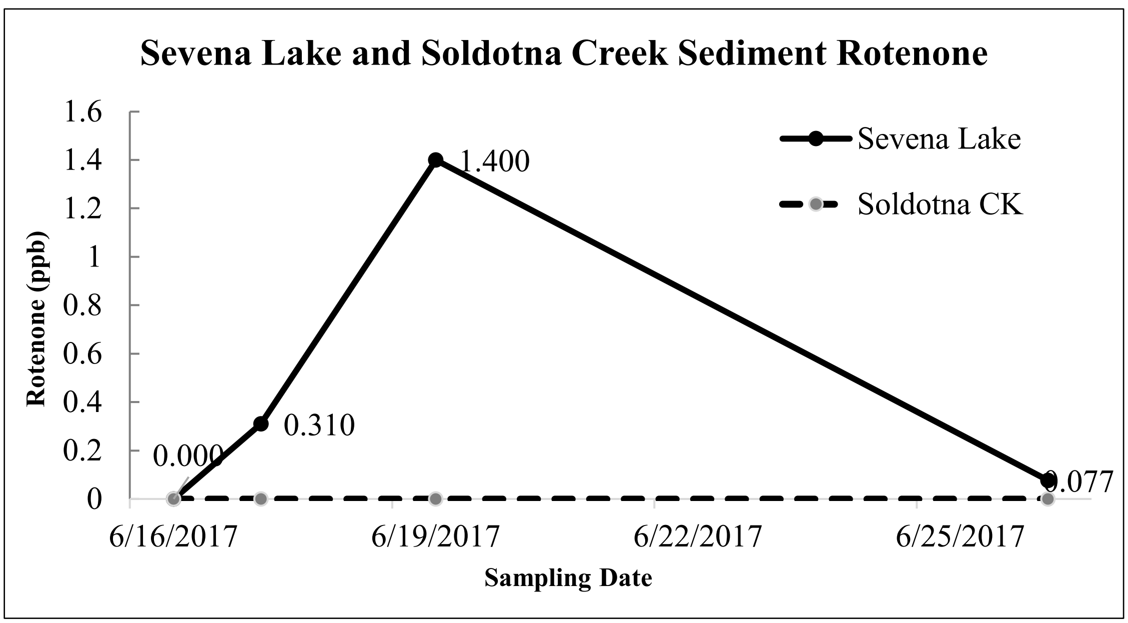

Figure 31.–Sevena Lake and Soldotna Creek sediment rotenone concentrations, 2017.

Posttreatment Gillnet Surveys

On 24 October 2014, which was immediately prior to the lakes freezing up, we set gillnets in Derks Lake ($N = 6$), West Mackey Lake ($N = 6$), and Union Lake ($N = 8$) to evaluate the success of the rotenone treatment at removing northern pike. The nets were fished continuously and unmonitored under the ice until removal at ice-out on 19 April 2015. At East Mackey Lake, we did not gillnet under the ice because of waterfowl bycatch risk; high waterfowl use has been observed there in the past immediately at ice-out. Instead, we fished 20 gillnets at East Mackey Lake after ice-out while continuously monitoring them during the period of 21–24 April 2015. At Derks Pond we also fished 3 gillnets after ice-out during 30 April 2015 through 1 May 2015. We set 3 gillnets in Loon Lake at freeze-up on 18 October 2017, and after a warming event caused the lake ice to melt, we removed the nets on 30 October 2017. In total we expended 85,171 hours of gillnet soak time in Area 1 to evaluate treatment success. Because netted fish decompose and become unidentifiable over time, this "raw" effort was converted to an estimated effort where identification of northern pike would still be possible. The estimated minimum duration a northern pike would remain identifiable in a gillnet fished under the ice is 48 days (Dunker et al. 2016). After adjusting the effort to 48 days for each gillnet fished, an estimated 24,409 netting hours was expended in Area 1. No northern pike were detected at any lakes (Table 16).

Posttreatment gillnetting at Sevena Lake (Area 2) commenced on 15 November 2016 and concluded 1 May 2017, totaling 23,961 hours of soak effort, which represents 6,912 hours of adjusted netting effort. No northern pike were caught but a variety of recolonizing resident fish species were caught (Table 16). Posttreatment gillnetting was not repeated after the 2017 Area 2 treatment because of a lack of northern pike detections after the 2016 treatment and over concerns of unnecessarily impacting native fish naturally recolonizing the lake.

In summary, the estimated probability of detecting a northern pike population of 4 fish based on the adjusted netting effort varied from a low of 29% at East Mackey Lake to a high of 99% at Derks Pond, Derks Lake, Union Lake, and Sevena Lake, and averaged 88% overall (Table 16).

Sentinel Fish

Cages with sentinel fish (2–3 juvenile coho salmon each) were placed in every lake, pond, and stream treated with rotenone to evaluate the effectiveness of the rotenone treatments. During the Area 1 treatment, 39 sentinel cages were deployed with 10 placed in West Mackey Lake, 8 in Union Lake, 7 each in East Mackey Lake and Derks Lake, 5 in Loon Lake, and 2 in Derks Pond. Some of the cages were placed in tributaries of these lakes. During the 2016 Area 2 treatment, 32 sentinel fish cages were deployed with 8 placed in Sevena Lake and its tributaries, 21 associated with drip stations operating in Soldotna Creek and Tree Creek, and 3 others associated with several small tributaries of Soldotna Creek. During the 2017 Area 2 treatment, we placed 8 sentinel fish cages in Sevena Lake and its tributaries and 2 in Soldotna Creek between Sevena Lake and the deactivation station located downstream near stream mile 6.9.

All sentinel fish died with 24 hours of exposure to all treated water except the fish in any cage placed between Sevena Lake and the deactivation station at Soldotna Creek mile 6.9 in 2017. This result was in alignment with our goal that the 2017 rotenone treatment be confined to Sevena Lake and its tributaries.

At our discretion, caged sentinel fish were also used to assess whether chemically deactivating rotenone was needed before leaving the treatment area and to determine if rotenone treated lakes had completely detoxified so native fish could be restored. Collectively, the sentinel fish results used for assessing the treatment success in Area 1 and Area 2 indicated the rotenone was well mixed and lethal to fish and supports our assumption that all northern pike were probably killed. Prior to restocking Area 1 lakes in 2015, caged sentinel fish were used to confirm when all treated lakes were detoxified enough to allow restocking of native fish. Restocking was indicated if all sentinel fish survived at least 24 hours of exposure to the lake water.

Table 16.–Area 1 and Area 2 posttreatment gillnet surveys to evaluate treatment success, October 2014–May 2017

						Fish species							
Treatment area	Location	Surface acres	Net set date	Net pull date	Number of nets fished	Northern pike	Rainbow trout	Dolly Varden	Coho salmon (juv.)	Hours of netting effort[a]	Adjusted hours of gillnetting effort[b]	Gillnetting hours for estimated 80% detection probability[c]	Detection probability[d] (%)
Area 1	Derks Lake	37.4	10/24/2014	4/19/2015	6	0	0	0	0	25,472	6,912	752	99
	Derks Pond	2.0	4/30/2015	5/1/2015	3	0	0	0	0	71	71	40	99
	Union Lake	84.0	10/24/2014	4/19/2015	8	0	0	0	0	33,329	9,216	1,690	99
	East Mackey Lake	100.3	4/21/2015	4/24/2015	20	0	0	0	0	432	432	2,018	29
	West Mackey Lake	183.7	10/24/2014	4/19/2015	6	0	0	0	0	25,001	6,912	3,696	95
	Loon Lake	22.0	10/18/2017	10/30/2017	3	0	0	0	0	866	866	443	96
Totals					46	0	0	0	0	85,171	24,409	8,639	
Area 2	Sevena Lake[e]	76.2	11/15/2016	5/1/2017	6	0	2	46	79	23,961	6,912	1,533	99
Combined area totals					52	0	2	46	79	109,132	31,321	10,172	NA
Average detection probability													88

Note: "NA" means not applicable.

[a] Gillnets were made with floating hanging lines and bottom lead lines and all were 120 ft in length, 6 feet deep, and composed of 6 different monofilament mesh panels in the following sizes: 0.75 in, 1.0 in, 1.25 in, 1.5 in, 1.75 in, and 2.0 in.

[b] Estimated hours of under-ice netting effort wherein it is unlikely a northern pike caught would decompose and be undetectable (Dunker et al. 2016).

[c] Estimated hours of netting effort required to detect a population of 4 surviving northern pike with a probability of 80% (Appendix D1).

[d] Estimated probability of detecting a population of 4 northern pike (>300 mm FL) using adjusted hours of gillnetting effort.

[e] Despite no northern pike being detected in Sevena Lake after rotenone treatment in 2016, the lake was retreated in June 2017 as a precaution.

Block Nets

In addition to the fish passage barriers installed in the outlet of Derks Lake to segregate Area 1 from Area 2, block nets were utilized throughout Area 2, and no northern pike were detected in any of the block nets that collected rotenone killed fish during the 2016 Area 2 treatment.

Because only Sevena Lake and its tributaries were targeted for rotenone treatment in 2017, just 1 block net was used in the 2017 treatment; it was located near stream mile 6.9 about ⅓ mile below the confluence of the Derks Lake outlet creek confluence and just above the deactivation station. No dead fish were collected by this block net, suggesting little impact occurred to native fish in Soldotna Creek from the rotenone treatment of Sevena Lake and its tributaries.

eDNA sampling

In Area 1, we tested eDNA detection methods to assess if northern pike eDNA sampling could be useful for evaluating the success of northern pike eradication attempts. Details and results of this evaluation method are reported in Dunker et al. (2016), but to summarize relevant results, 85 pretreatment water samples were collected from Area 1 lakes (Union Lake, West Mackey Lake, East Mackey Lake, and Derks Lake) in 2014, and of these, 70 resulted in positive northern pike eDNA detections, giving an overall positive detection rate of 82% (Table 17). Of 179 samples collected 230 days after treatment in the spring of 2015, 3 samples were positive for northern pike DNA for an overall positive DNA detection rate of 2%. The positive posttreatment eDNA samples represented single detections at Union Lake, East Mackey Lake, and Derks Lake. Relative DNA copy numbers of pretreatment water samples were large and had high variance at all lakes, but the posttreatment DNA copy numbers were near zero (Dunker et al. 2016).

Table 17.–Area 1 northern pike eDNA sampling summary, 2014–2017.

				Lake				
Treatment status	Description	Season	Year	Union Lake	West Mackey Lake	East Mackey Lake	Derks Lake	All
Before	Number of samples collected	Fall	2017	18	37	22	8	85
	Number of samples testing positive for northern pike DNA			15	32	19	4	70
	Positive detection rate			83%	86%	86%	50%	82%
After	Number of samples collected	Spring	2015	37	81	44	17	179
	Number of samples testing positive for northern pike DNA			1	0	1	1	3
	Positive detection rate			3%	0%	2%	6%	2%
	Number of samples collected	Summer	2017	22	46	26	10	104
	Number of samples testing positive for northern pike DNA			1	0	0	5	6
	Positive detection rate			5%	0%	0%	50%	50%

In July 2017, we resampled for northern pike eDNA in the 4 major Area 1 lakes that were treated in 2014. We collected 10 samples from Derks Lake, 26 samples from East Mackey Lake, 46 samples from West Mackey Lake, and 22 samples from Union Lake (Table 17). There were no northern pike eDNA detections in East or West Mackey Lakes samples. A single weak detection (low DNA copy number) from a Union Lake sample was detected, and half of 10 samples collected from Derks Lake were positive and included many samples with strong DNA copy numbers.

The 2017 Derks Lake eDNA results were unexpected and prompted more gillnet surveys to confirm the eDNA results. Despite additional gillnetting and D-net sampling of nearshore vegetated areas in the spring of 2018, no northern pike were ever captured in Derks Lake. Posttreatment gillnetting between 2015 and 2019 at all the treated lakes failed to detect any northern pike (Table 16).

NATIVE FISH RESTORATION

During 2015–2018, we actively promoted reestablishment of wild native fish populations in most Area 1 lakes by collecting fish from Area 2 and releasing them into Area 1 during 2015–2018. Species targeted for reestablishment in Area 1 lakes included rainbow trout, Dolly Varden, rearing coho salmon, stickleback, and sculpin, which are all considered native to lakes in Area 1 based on historical lake survey records (unpublished records, ADF&G, Soldotna office) and observations of species present at other lakes and tributaries within the drainage (R. Massengill, personal observation). Lamprey were not targeted for collection because of unsuccessful capture attempts using various gear types. Lakes receiving these fish included Union Lake, West Mackey Lake, East Mackey Lake, and Derks Lake. Derks Pond was not stocked with native fish due to its questionable suitability for overwintering salmonids and unimpeded connectivity to Derks Lake; this allowed for unaided stickleback recovery. Loon Lake, formerly an ADF&G stocked lake, resumed its annual stocking of hatchery-reared rainbow trout in 2018. In 2019, Loon Lake was also stocked with wild native threespine stickleback (*Gasterosteus aculeatus*) by a university based research team in collaboration with ADF&G.

There were 95,197 wild native fish released into Area 1 lakes during 2015–2018: 13,772 were released into Derks Lake; 27,005 were released into East Mackey Lake; 18,988 were released into Union Lake; 35,432 were released into West Mackey Lake; but none were released into Loon Lake (Table 18, Appendix H1). In each lake, the cumulative salmonid stocking density (salmonids/acre) was 246/acre at Derks Lake, 161/acre at East Mackey Lake, 134/acre at Union Lake, and 120/acre at West Mackey Lake. The total number of fish released into Area 1 included 4,545 rainbow trout, 4,837 Dolly Varden, 32,850 stickleback (largely *Gasterosteus aculeatus*), 3,694 sculpin, and 49,271 juvenile coho salmon (Table 18, Appendix H1).

Removal of all ADF&G-installed temporary fish barriers within the drainage by 2018 further promoted the natural dispersal and recolonization of native fish species. Despite the rotenone treatment of the entire Soldotna Creek mainstem in 2016, native fish quickly recolonized the creek, presumably from fish dispersing from the Kenai River, which allowed us to collect native fish there 1 year after treatment of the creek. Most of the stickleback were collected from Sevena Lake in 2016 because they were highly concentrated there. Nearly all other fish were collected in the lower third of Soldotna Creek where access was best and catch rates highest.

Table 18.–Summary of native fish releases into Area 1 lakes, 2015–2018.

Lake	Surface acreage	Release year	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species	Salmonids per acre
Derks Lake	37.4	2015	30	161	950	3	6,107	7,251	168
		2016	199	217	3,386	229	2,452	6,483	77
		2017	0	0	0	0	38	38	1
		Total	229	378	4,336	232	8,597	13,772	246
East Mackey	100.3	2015	355	366	5,362	960	1,396	8,439	21
		2016	696	484	4,103	439	6,564	12,286	77
		2017	176	436	0	0	2,506	3,118	31
		2018	220	436	0	0	2,506	3,162	32
		Total	1,447	1,722	9,465	1,399	12,972	27,005	161
Union	84	2015	195	173	3,532	183	2,173	6,256	30
		2016	277	407	3,563	419	7,259	11,925	95
		2017	38	130	0	0	604	772	9
		2018	35	0	0	0	0	35	0.4
		Total	545	710	7,095	602	10,036	18,988	134
West Mackey	183.7	2015	354	437	5,553	399	904	7,647	9
		2016	1,088	1,034	6,401	1,062	13,388	22,973	84
		2017	203	556	0	0	3,374	4,133	22
		2018	679	0	0	0	0	679	4
		Total	2,324	2,027	11,954	1,461	17,666	35,432	120
All lakes	405.4	2015–2018	4,545	4,837	32,850	3,694	49,271	95,197	145

BIOLOGICAL MONITORING

Assessment of Native Fish

Minnow Trap Surveys

We conducted pretreatment and posttreatment minnow trap surveys in Area 2 (Soldotna Creek drainage) flowing waters to assess whether major treatment associated changes in the native fish community were detectable in 2018. We conducted 4 pretreatment surveys (October 2010, May 2011, July 2011, and September 2011) and 2 posttreatment surveys (July–August 2018 and September 2018). The minnow trapping data provided information on seasonal fish distribution and CPUE; the latter was used as an index to compare pre- and posttreatment abundances (Statewide Aquatic Resources Coordination Unit 2016). Captured fish species included rainbow trout, Dolly Varden, coho salmon, Chinook salmon, stickleback, and sculpin (Table 19). No northern pike were captured.

On a drainagewide scale, no species detected before treatment went undetected after treatment. Based on the minnow trapping catch data, the distribution of species throughout the Soldotna Creek corridor remained similar between pretreatment and posttreatment surveys, except possibly for Chinook salmon, where the posttreatment catch shifted upstream (Appendix H2; see Figure 14 for distribution of traps). For each species and trapping site, we subtracted the pretreatment CPUE from the posttreatment CPUE taken during similar temporal periods (summer or fall) to determine posttreatment change in CPUE for species at each site. Summing the CPUE changes for all sites by species yielded a drainagewide change in CPUE, indicating change in abundance before and after treatment. The summer (July–August) drainagewide CPUE changes suggest that the posttreatment abundance increased relative to pretreatment abundance for all species (Table 19).

However, the fall (September) drainagewide CPUE change indicated a decrease in posttreatment abundance relative to pretreatment abundance for all species except sculpin, which showed a slight increase. Although anecdotal, during minnow trapping surveys, lamprey were observed in Soldotna Creek both before and after treatment.

Table 19.–Soldotna Creek drainagewide CPUE by species and trapping date.

	Trapping period and catch (CPUE)[a]						Change in CPUE as an index of relative abundance	
Species	Oct 2010	May 2011	Jul 2011	Sep 2011	Jul–Aug 2018	Sep 2018	Change in summer CPUE[b]	Change in fall CPUE[c]
Rainbow trout	67	16	14	37	33	22	19	-15
Dolly Varden	71	20	26	40	38	14	12	-26
Coho salmon	175	83	119	124	141	37	22	-87
Chinook salmon	2	0	0	12	7	0	7	-12
Stickleback (unspecified)	4	130	13	16	77	3	64	-13
Sculpin (unspecified)	0	0	0	4	9	6	9	2

[a] Effort was standardized to 30 minutes at each location (see Appendix H2 for detail).

[b] July 2018 CPUE minus July 2011 CPUE.

[c] September 2018 CPUE minus September 11 CPUE.

Taken collectively, the minnow trapping surveys indicated the presence of native fish species in Soldotna Creek recovered following the rotenone treatments. When comparing the peak drainagewide total CPUE of each species between pretreatment and posttreatment surveys, it suggests an increase in the abundance of each species the summer after treatment but a decrease during the fall (Table 19).

Minnow trapping surveys were conducted by McKinley (2013) in 2002 that included lakes later treated with rotenone (Sevena Lake in Area 2 and Derks Lake, East Mackey Lake, West Mackey Lake, and Union Lake, all in Area 1). No native fish species were detected in the Area 1 lakes; however, stickleback were caught at Sevena Lake in 2002 (Table 20). A minnow trapping survey conducted in August 2017 at Loon Lake (Area 1) just prior to treatment also found stickleback.

For comparison to the 2002 surveys (McKinley 2013), we also conducted posttreatment minnow trapping surveys at Sevena Lake in Area 2 and Derks Lake, East Mackey Lake, West Mackey Lake and Union Lake in Area 1 in July 2017. All lakes minnow trapped in 2017 found stickleback (Table 20). Coho salmon were also detected in all but Derks Lake, rainbow trout were detected in Derks and East Mackey Lakes, and 1 Dolly Varden was caught in East Mackey Lake. In total, 14 salmonids were captured in 2017 by minnow traps in treated lakes in Areas 1 and 2 compared to zero caught in 2002.

Table 20.–Soldotna Creek drainage pretreatment and posttreatment lake minnow trapping data.

Treatment status	Sampling period	Location	Area	Total trapping effort (hours)	Stickleback (Y/N)	Coho salmon	Rainbow trout	Dolly Varden
Before	May–Jun 2002	Cisca Lake	2	Not trapped	NA	NA	NA	NA
	May–Jun 2002	Derks Lake	1	126.0	N	0	0	0
	May–Jun 2002	Denise Lake	1	102.0	Y	0	0	0
	May–Jun 2002	East Mackey Lake	1	138.0	N	0	0	0
	May–Jun 2002	Sevena Lake	2	509.0	Y	0	0	0
	May–Jun 2002	Tree Lake	2	67.0	Y	0	0	0
	May–Jun 2002	Union Lake	1	133.5	N	0	0	0
	May–Jun 2002	West Mackey Lake	1	108.0	N	0	0	0
	Oct 2002	Cisca Lake [a]	2	132.0	Y	0	0	0
	Oct 2002	Derks Lake	1	137.5	N	0	0	0
	Oct 2002	Denise Lake	1	130.5	Y	0	0	0
	Oct 2002	East Mackey Lake	1	125.5	N	0	0	0
	Oct 2002	Sevena Lake	2	34.5	Y	0	0	0
	Oct 2002	Tree Lake	2	108.0	Y	1	0	0
	Oct 2002	Union Lake	1	123.0	N	0	0	0
	Oct 2002	West Mackey Lake	1	134.0	N	0	0	0
	Aug 2017	Loon Lake[b]	1	14.0	Y	0	0	0
Pretreatment total				2,122.5	No count	1	0	0
After	Not trapped	Cisca Lake	2	NA	NA	NA	NA	NA
	Jul 2017	Derks Lake	1	15.5	Y	0	2	0
	Not trapped	Denise Lake	1	NA	NA	NA	NA	NA
	Jul 2017	East Mackey Lake	1	10.0	Y	4	4	1
	Jun 2019	Sevena Lake	2	24.9	Y	2	0	0
	Not trapped	Tree Lake	2	NA	NA	NA	NA	NA
	Jul 2017	Union Lake	1	8.9	Y	2	0	0
	Jul 2017	West Mackey Lake	1	10.0	Y	6	0	0
	Not trapped	Loon Lake	1	NA	NA	NA	NA	NA
Posttreatment total				2,191.8	No count	14	6	1

Source: 2002 data from McKinley (2013).

[a] Cisca Lake was never treated with rotenone and no northern pike were ever detected there.

[b] Loon Lake was treated with rotenone in August 2017 and no minnow trapping was done after treatment; restocking of hatchery-reared rainbow trout resumed in 2018 and sticklebacks were released there in 2019.

Native Fish Posttreatment Gillnet surveys

Between 2017 and 2019, we periodically conducted gillnet surveys to monitor native fish recovery in Area 1 but we did not net Loon Lake, where a sport fishery for wild native fish has never existed and hatchery-reared rainbow trout provide the fishery. All Area 1 netting occurred during the open water season. In Area 2 at Sevena Lake, native fish survey data also included the posttreatment under-ice gillnetting in the winter of 2016–2017 because native fish quickly began recolonizing the lake after treatment (Table 21). Under-ice netting effort was adjusted and defined as the time preceding net removal when it is unlikely a captured northern pike would have decomposed and become undetectable, which was estimated at 48 days of effort per net (Dunker et al. 2016). The combined hours of netting effort expended in Area 1 and 2, when considering adjusted effort at Sevena Lake, was 8,615 net soak hours and the total catch was 920 salmonids. This catch was composed of 706 coho salmon, 153 rainbow trout, 54 Dolly Varden, and 7 salmonids too decomposed to identify. No fish were caught in Derks Pond.

Rainbow trout, Dolly Varden, and coho salmon were all detected in Derks Lake, Sevena Lake, Union Lake, and West Mackey Lake after treatment. At East Mackey Lake, only rainbow trout and coho salmon were detected. Among all sampling events in Area 1, excluding Derks Pond and Loon Lake (which had no catches nor netting, respectively), salmonid CPUE ranged from 1.3 to 0.1 salmonids/hour of effort. Average CPUE for individual lakes in Area 1 and Sevena Lake, excluding Derks Pond and Loon Lake, ranged from 0.6 (Derks Lake) to 0.3 salmonids/hour (East Mackey Lake). CPUE was variable between lakes and netting events but in general decreased over time in all lakes except Sevena Lake.

In 2016, native fish surveys with gillnetting were monitored continuously and most fish were captured alive; to reduce handling stress, fish were not measured. During 2017–2019, the nets were generally not monitored continuously, and we recorded fish lengths from all mortalities and some live fish. Length frequency charts are provided for rainbow trout, coho salmon, and Dolly Varden catch in Sevena Lake (Area 2) in 2019 and for combined catch for Area 1 lakes in 2017–2019 (Figures 32–33).

Table 21.–Soldotna Creek drainage posttreatment native fish gillnet surveys, 2016–2018.

Location	Net set date	Net pull date	Number of nets fished	Fish species: Northern pike	Rainbow trout	Dolly Varden	Coho salmon (juv.)	Unknown salmonid	Hours of netting effort[a]	Adjusted hours of netting effort[b]	Salmonid CPUE[c,d]
Derks Lake											
	7/17/2017	7/18/2017	8	0	17	0	79	0	88.4	88.4	1.1
	8/19/2017	8/20/2017	6	0	12	0	44	0	106.7	106.7	0.5
	10/18/2017	10/20/2017	3	0	8	1	105	0	139.2	139.2	0.8
	6/12/2018	6/13/2018	15	0	4	1	188	0	356.5	356.5	0.5
	10/16/2019	10/17/2019	2	0	5	0	4	0	42.5	42.5	0.2
			Subtotal	0	46	2	420	0	733	733	0.6
Derks Pond											
	07/17/2017	07/18/2017	3	0	0	0	0	0	67	67	0.0
East Mackey Lake											
	07/13/2017	07/13/2017	4	0	0	0	1	0	7	7	0.1
	07/14/2017	07/14/2017	5	0	3	0	1	0	9	9	0.4
	07/19/2017	07/19/2017	8	0	6	0	5	0	27	27	0.4
	10/22/2019	10/23/2019	1	0	0	0	6	0	22	22	0.3
			Subtotal	0	9	0	13	0	65	65	0.3
Sevena Lake											
	08/02/2016	08/02/2016	6	0	0	0	7	0	21	21	0.3
	11/15/2016	05/01/2017	6	0	2	46	79	7	23,961	7,056	0.02
	06/10/2019	06/10/2019	2	0	2	0	2	0	43	10	0.4
	10/16/2019	10/17/2019	3	0	19	0	10	0	0	43	0.7
			Subtotal	0	23	46	98	7	24,025	7,130	0.45
Union Lake											
	07/06/2017	07/07/2017	10	0	22	2	96	0	434	434	0.3
	06/15/2018	06/15/2018	10	0	7	1	71	0	102	102	0.8
	10/22/2019	10/23/2019	2	0	5	1	1	0	45	45	0.2
			Subtotal	0	34	4	168	0	582	582	0.4

-continued-

Table 21.–Page 2 of 2.

Location	Net set date	Net pull date	Number of nets fished	Fish species: Northern pike	Rainbow trout	Dolly Varden	Coho salmon (juv.)	Unknown salmonid	Hours of netting effort[a]	Adjusted hours of netting effort[b]	Salmonid CPUE[c,d]
West Mackey Lake											
	07/11/2017	07/11/2017	6	0	15	0	1	0	12	12	1.3
	07/12/2017	07/12/2017	9	0	8	1	0	0	31	31	0.3
	07/18/2017	07/18/2017	6	0	7	1	2	0	19	19	0.5
	10/22/2019	10/23/2019	2	0	11	0	4	0	44	44	0.3
			Subtotal	0	41	2	7	0	105	105	0.5
			Grand total	0	153	54	706	7	25,510	8,615	0.5

[a] Gillnets were made with floating hanging lines and bottom lead lines and all were 120 ft in length, 6 ft deep and composed of 6 different monofilament mesh panels in the following sizes: 0.75 in, 1.0 in, 1.25 in, 1.5 in, 1.75in and 2.0 in.

[b] Adjusted hours of under-ice netting effort where effort is defined as the time preceding net removal when it is unlikely a captured northern pike would have decomposed and become undetectable (Dunker et al. 2016).

[c] Salmonid CPUE is defined as the total catch of all salmonids divided by the adjusted netting hours.

[d] CPUE data for Sevena Lake catches from 11/15/2016 through 5/1/2017 were not included in CPUE subtotals or the grand total because the other lakes were not netted under the ice during that time so CPUE is not comparable.

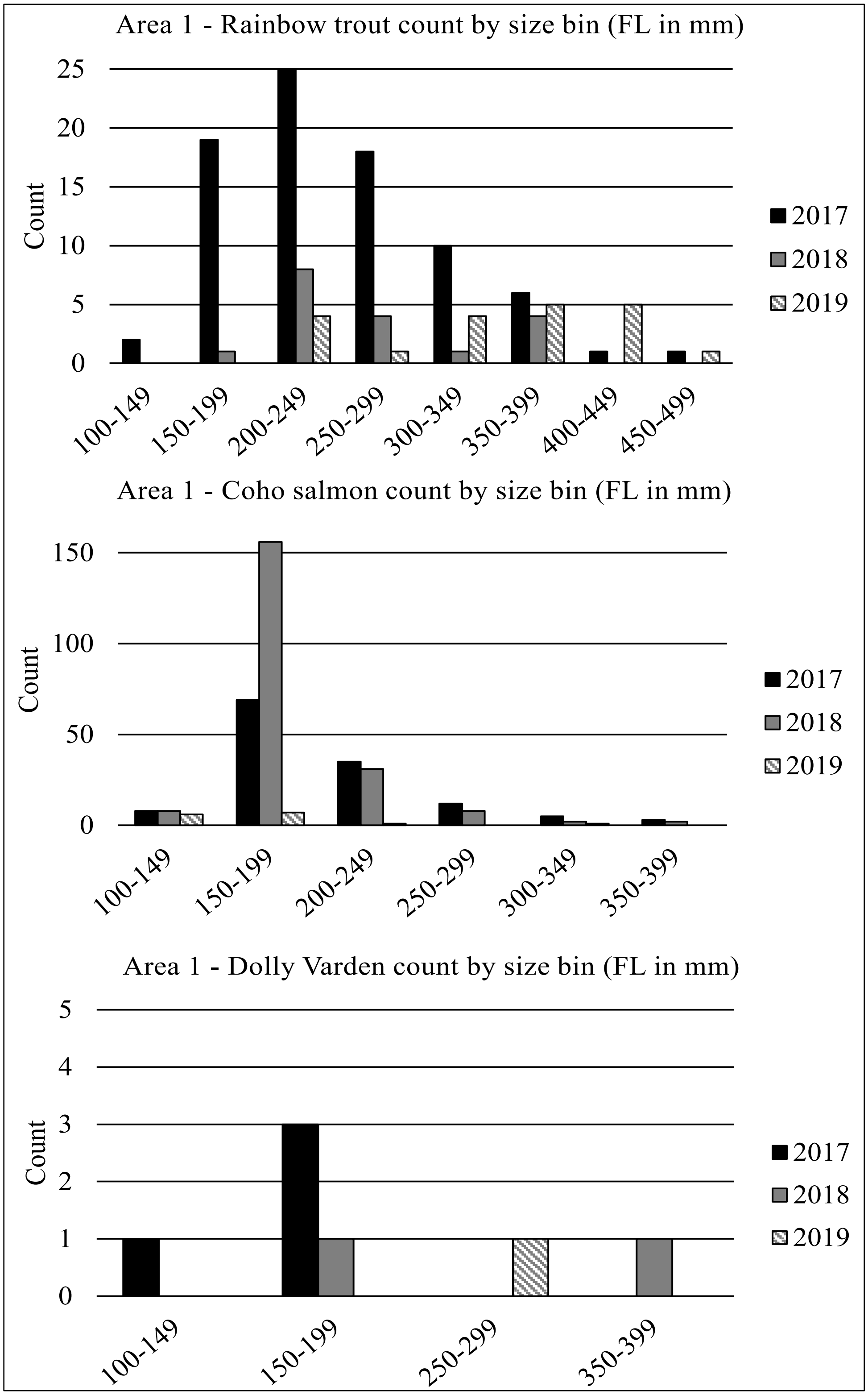

Figure 32.–Area 1 coho salmon, Dolly Varden, and rainbow trout length frequencies, 2017–2019.

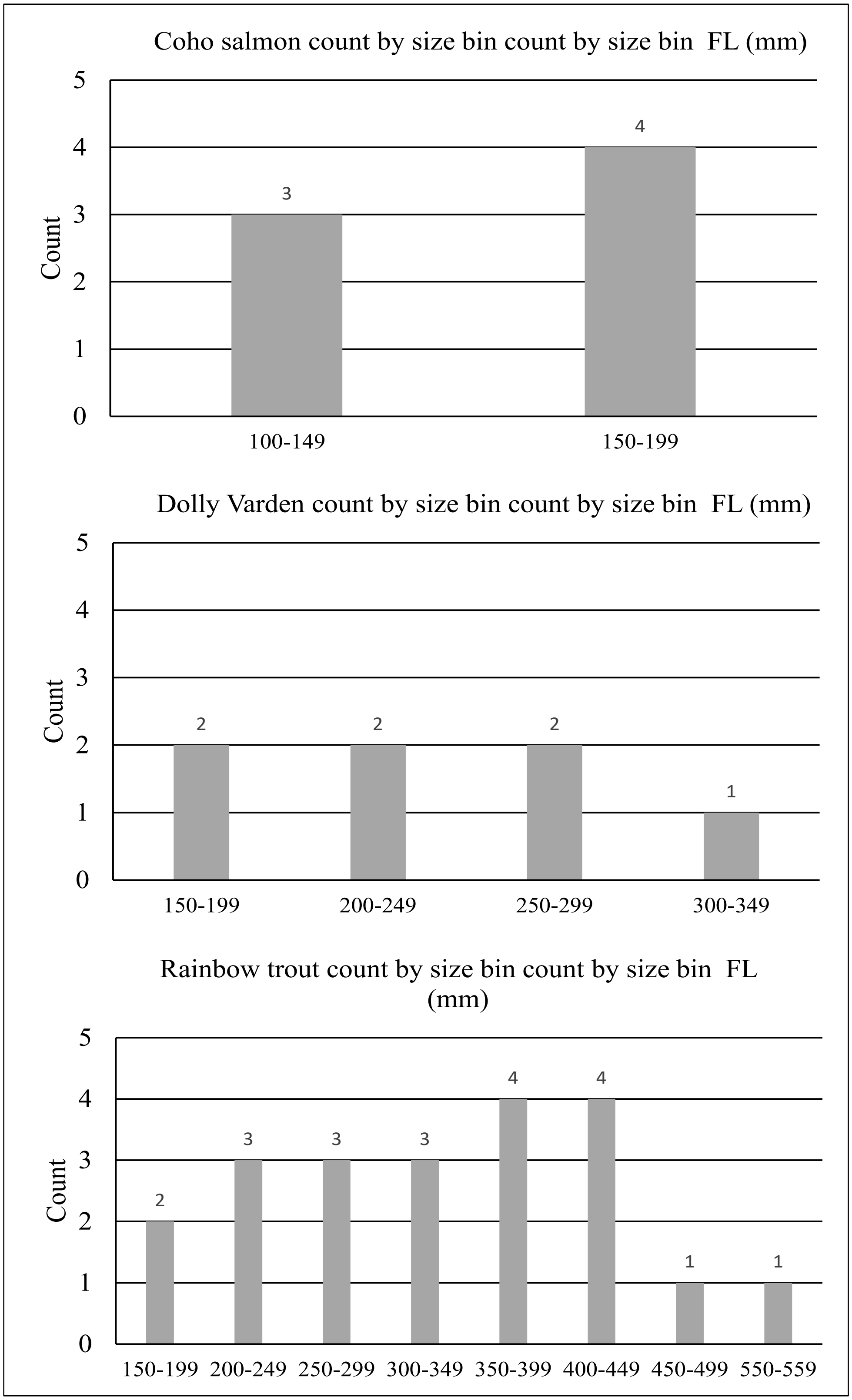

Figure 33.–Sevena Lake (Area 2) coho salmon, Dolly Varden, and rainbow trout length frequencies, 2019.

Invertebrate Surveys

A total of 25 invertebrate taxa were identified during the Area 1 and Area 2 pretreatment sampling that occurred between 2014 and 2015; 22 taxa were identified from these same areas during the posttreatment sampling that occurred between 2015 and 2018 (Table 22). Invertebrate sampling at Sevena Lake (Area 2) yielded 19 taxa before treatment and 13 taxa after treatment, a 32% decrease. Invertebrate sampling at West Mackey Lake (Area 1) yielded 21 taxa before treatment and 16 taxa after treatment, a 24% decrease. Invertebrate sampling at Soldotna Creek yielded 9 taxa before treatment and 11 taxa after treatment.

Table 22.–Invertebrate taxa detected in the Soldotna Creek Drainage before (pre) and after (post) rotenone treatment, 2014–2018.

	Combined areas[a]			Sevena Lake			West Mackey Lake			Soldotna Creek		
Taxon	Pre	Post	X[b]	Pre	Post	X[b]	Pre	Post	X[b]	Pre	Post	X[b]
Anispotera (dragonflies)	Y	Y		Y	Y		Y	Y		N	Y	
Annelida (segmented worms)	Y	N		Y	N		Y	N		N	N	
Araneae (spiders/mites)	Y	Y		Y	Y		Y	Y		Y	N	
Ceratopogonidae (no see-ums)	Y	N		–	–		Y	N		–	–	
Chaoboridae (phantom midges)	Y	Y		–	–		Y	Y		N	N	
Chironomidea (non-biting midges)	Y	Y		Y	Y		Y	Y		Y	Y	
Cladocera (water fleas)	Y	Y		Y	Y		Y	Y		–	–	
Coleoptera (beetles)	Y	Y		Y	Y		Y	Y		N	Y	
Copepoda (Clyclopoid)	Y	Y		Y	Y		Y	Y		–	–	
Corrixidae (water boatmen)	Y	Y		Y	N		Y	Y		Y	N	
Cuicidea (mosquitos)	N	Y		–	–		–	–		N	Y	
Dipteran spp. (flies)	Y	Y		Y	N		Y	N		Y	Y	
Ditiscidae (predaceous diving beetle, whirligig)	Y	Y		Y	Y		–	–		–	–	
Ephemeroptera (mayflies)	Y	Y		N	Y		Y	Y		Y	Y	
Gastropoda (snails)	Y	Y		Y	Y		Y	N		Y	Y	
Gerridae (water strider)	Y	Y		Y	Y		–	–		–	–	
Hirundea (leeches)	Y	Y		Y	N		Y	N		N	Y	
Hymenoptera (ants, wasps)	Y	Y		Y	N		N	Y		–	–	
Lepidoptera (butterflies, moths)	Y	Y		Y	N		N	Y		–	–	
Pelecypoda (molluscs)	Y	Y		Y	Y		Y	Y		Y	Y	
Plecoptera (stone files)	Y	Y		–	–		Y	Y		–	–	
Nematode (round worms)	Y	N		–	–		Y	N		–	–	
Nematomorpha (horsehair worms)	Y	N		–	–		Y	N		–	–	
Rotifera (Asplancha)	Y	Y		Y	N		Y	Y		–	–	
Trichopetera (caddis flies)	Y	Y		Y	Y		Y	Y		Y	Y	
Zygoptera (damselflies)	Y	Y		Y	Y		Y	Y		Y	Y	
Total taxa detected	25	22	−12%	19	13	−32%	21	16	−24%	9	11	22%

Note: Y = yes; en dash = not observed.

[a] Combined areas include Sevena lake, West Mackey Lake, and Soldotna Creek.

[b] Defined as the count of detected taxa after treatment minus the count before treatment divided by the count before treatment.

DISCUSSION

TREATMENT SUCCESS EVALUATION

We used multiple lines of evidence to evaluate the success of this northern pike removal project including eDNA sampling, gillnet surveys, caged sentinel fish observations, rotenone concentration monitoring, and visual observations. In particular, the absence of northern pike detected during gillnet surveys, despite extended durations and the high volume of nets, indicates a high likelihood that eradication efforts were successful. The only counter evidence was with single positive northern pike eDNA detections at Derks Lake, East Mackey Lake, and Union Lake in 2015. These detections were followed by periodic gillnet surveys during 2017–2019 that failed to find any northern pike. The Derks Lake eDNA results were particularly confounding when subsequent eDNA sampling of Area 1 lakes in 2017 indicated northern pike eDNA detection rates had increased since 2015.

Following the positive eDNA detections at Derks Lake in 2017, additional sampling was done using handheld dipnets. The dipnets were swept along weedy shallows to try and capture juvenile pike, all without success at finding any. We hypothesized the eDNA detections at Derks Lake must have come from a nonliving source such as eDNA preserved in the lake sediment, which can persist for years (Matsoo-Smith et al. 2008; Turner et al. 2015). Derks Lake was colonized by beavers (*Caster canadensis*) after treatment and their activities obviously stirred up lake sediment (e.g., using mud for building a lodge and dam). If sediment-preserved northern pike DNA was present, this could explain the unexpected temporal increase in positive eDNA detections. Because of the extreme sensitivity of eDNA detection methods, perhaps the most valuable information to be garnered by eDNA sampling, when used for evaluating eradication success, is when the sampling fails to detect any target eDNA. Although false positive eDNA detections can occur (e.g., via sample degradation, inadequate sampling, or processing inhibitors), a lack of positive detections is still informative, particularly when other lines of evidence support that result.

TREATMENT RELATED OBSERVATIONS

Several technical challenges and noteworthy observations were encountered during this project. During the 2016 rotenone treatment of Sevena Lake, the CFT Legumine applied to the lake repeatedly plugged the inline filter of the sprayer pump used on an airboat. Despite first warming and agitating the CFT Legumine well before premixing it with water and applying it, the product clogged the intake filter of the sprayer pump and required frequent disassembly and cleaning of the filter housing and screen to remove waxy buildup. We eventually removed the pump's filter screen, which allowed us to complete the application without further plugging problems. Likewise, backpack sprayers frequently had similar clogging issues with the in-tank filter and spray nozzle orifices. The consistency of CFT Legumine appeared to differ between product containers, with some having well homogenized product with low relative viscosity while others had a gelatinous or waxy deposit on the bottom of the drum that was difficult to dissolve and caused clogging problems during the application. We anticipated clogging might be an issue beforehand, and to mitigate this, we warmed the product containers in our warehouse to about 20°C prior to application to help homogenize the product but to little realized benefit. A paint mixer attachment with a handheld electric drill was used to mix the drum contents, but this also failed to cure the clogging problems. The best remedy was to remove filters from the pump sprayers or to use pump systems that had no filtering at all.

Another issue with the 2016 rotenone treatment at Sevena Lake was that we failed to reach a satisfactory rotenone concentration in the deeper parts of the lake. Our target was 40 ppb rotenone, but the maximum rotenone concentration detected from our water sample collected from deep in the water column shortly after the treatment was <3 ppb. It remains unclear what caused this shortfall, but plausible reasons include inadequate mixing of the rotenone, rotenone binding to organics in the lake, rapid environmental degradation of the rotenone prior to sampling, or inadequate or degraded rotenone content in some of the product. The decision to re-treat Sevena Lake with rotenone in 2017 was made, in part, by the low rotenone concentration realized in 2016, particularly in the deep areas of the lake. In 2017, we decided to increase the rotenone target concentration by 20% (to 50 ppb) and used a deepwater application apparatus to distribute rotenone deeper within the water column, something not done during the 2016 treatment. In 2017, the maximum rotenone concentration achieved in the deeper parts of Sevena Lake was 18 ppb, a 6-fold increase from 2016.

Following the 2014 treatment of Area 1, it was determined, based on the responses of sentinel fish in Soldotna Creek, that chemical deactivation of the rotenone in the outflow of Derks Lake was necessary to protect native fish residing downstream. We had prepared for this scenario yet still found that operation of a deactivation station in an area off the power grid required more maintenance and monitoring than expected, particularly with the additional challenges posed by the cold weather.

We discovered that heating the chemical feeder's gear box during cold spells decreased failure of the chemical feeder. A gas powered Honda generator that powered the chemical feeder also powered an electrical heat tape that we wrapped around the gear box to keep it warm and prevent the gear oil from congealing and stopping its operation. In hindsight, it would have been prudent to have budgeted more technician time to provide 24-hour monitoring of the deactivation station instead of using project leaders' time during the first 2 weeks of operation when there were other treatment related duties to complete.

Another unexpected observation associated with the 2016 rotenone treatment of Soldotna Creek involved the results of a single pretreatment sediment sample collected from the mainstem of Soldotna Creek. We collected pretreatment samples to document the absence of rotenone and rotenolone prior to treatment so we were surprised when a low concentration of rotenolone was detected (2.1 ppb). We speculate this was residual rotenolone that persisted following the 2014 treatment of Area 1 that resulted in low concentrations of rotenone entering Soldotna Creek from the Derks Lake outlet creek. Another possibility is there could have been contamination of the sample. Regardless, the detection of rotenolone was essentially a nonissue because such a low concentration poses no known concern to organisms or the environment.

Although we anticipated a complete fish kill in Soldotna Creek from the 2016 rotenone treatment, we were still surprised by the large number of lamprey killed. Lamprey do not recruit well to the mechanical capture methods we employed for fish rescue (i.e., minnow traps and fyke traps) so we had little sense of how prevalent lamprey might be in the drainage. We occasionally observed lamprey when conducting electrofishing in Soldotna Creek while attempting to collect juvenile salmonids. During the 2016 rotenone treatment of Soldotna Creek, most of the lamprey killed were juveniles that emerged from sediment, but there were also significant numbers of adult lamprey killed. In deep, slow-moving stream holes, dead lamprey accumulated in the tens and perhaps hundreds. Some lamprey were observed slithering out of the stream onto the stream bank before expiring. On the last day Soldotna Creek was treated in 2016, we received a call from a landowner who lived near Soldotna Creek. The landowner reported that gulls and other birds were feeding on dead fish in Soldotna Creek then roosting on their home and defecating. We investigated the report and found it to be true and spent several hours collecting hundreds of dead lamprey from Soldotna Creek all within several hundred yards of this residence, which immediately resolved the problem.

Because we inspected thousands of dead fish from the block net catches in 2016 and found no northern pike, it became clear that northern pike must rarely occupy the flowing waters of Soldotna Creek and prefer to occupy the lentic waters within the drainage. This assumption aligns with recent Soldotna Creek weir data from 2009 and 2010 wherein a total of just 3 northern pike passed the weir during the open water season of those years (Gates and Boersma 2011).

This project conducted the first warm-water (month of June) rotenone treatments for northern pike control in Alaska. Studies on rotenone persistence have documented that an increase in temperature and sunlight speeds the degradation of rotenone (Turner 2007; Couture 2022), yet we were still surprised at how quickly the rotenone fully detoxified following the 2016 and 2017 treatments. Sampling for rotenone after both treatments indicated it fully deactivated (<2.0 ppb) in 10 days or less. The half-life of rotenone, when water temperatures in shallow waters are relatively high and sunlight is nearly continuous, may be measured in a few days or perhaps even hours when conditions are ideal. This is an important consideration when attempting to detect peak rotenone concentrations achieved by the treatment. In warm water conditions (>15°C), we suggest future sampling for rotenone concentration be done as soon as the mechanical mixing of the rotenone is complete instead of waiting until the next day to sample, as has been our standard procedure. Sampling quickly after application could have some downsides because it would happen before the rotenone has an opportunity to mix via wind generated currents and diffusion. To mitigate poor mixing concerns prior to sampling, we advise applying the rotenone as evenly as possible and thoroughly mixing it in the lake using mechanical means (e.g., boat wakes, propeller wash), including use of deepwater application techniques as needed.

NATIVE FISH RESTORATION AND CONNECTIVITY CONCERNS

By 2016, it was common to observe stickleback in all Area 1 lakes, including young-of-year (YOY) fish, suggesting the stickleback reintroductions in 2015 led to self-sustaining populations. In Area 2, we observed that natural recolonization by native fish in Sevena Lake and Soldotna Creek occurred almost immediately following the 2016 rotenone treatment. Furthermore, gillnet catches found salmonids in Sevena Lake in the spring of 2017 (less than 1 year after both treatments), and minnow trap catches found salmonids and other native fish in Soldotna Creek in 2017 and beyond.

Area 1 once supported a viable self-sustaining wild rainbow trout fishery prior to the introduction of northern pike, and according to anecdotal landowner reports, rainbow trout were the primary sport fish species in the 1970s and earlier. Of concern now is whether rainbow trout will become self sustaining through either onsite reproduction or immigration into the Area 1 lakes not directly linked to Soldotna Creek (East Mackey Lake, West Mackey Lake, and Union Lake). This concern stems from the poor and often seasonal connectivity of these lakes to Soldotna Creek that may prevent fish movement, and the paucity of good spawning habitat in the outlets. Landowners report rainbow trout used to spawn at the inlet and outlet of East Mackey Lake in the 1970s near road culverts. It is unknown if this spawning successfully produced offspring or if these populations were sustained by fish dispersing upstream from Soldotna Creek. Sevena Lake and Derks Lake are both directly linked to Soldotna Creek, and based on recent observations and gillnet catches, receive inputs of native fish dispersing from Soldotna Creek, particularly during fall just prior to freeze-up in an apparent attempt by juvenile fish to overwinter in lakes.

Currently, little rainbow trout spawning habitat appears available anywhere in Area 1. The inlet and outlet of East Mackey Lake does harbor some potential spawning habitat (flowing water with gravel substrate), but these streams are ephemeral and can become stagnant or dry up by midsummer, possibly precluding full incubation of fertilized rainbow trout eggs which typically require about 550 accumulated thermal units (ACU) prior to emergence.[6] Rainbow trout typically require a minimum water temperature of 6–7°C to initiate spawning; this temperature is probably achieved by early to mid-May based on available temperature data from East Mackey Lake (Massengill 2010). In 2006, the late May surface water temperature in East Mackey Lake was 14.8°C and remained near that temperature until at least June 11. Assuming rainbow trout start spawning in East Mackey Lake tributaries in mid-May and water temperatures from mid-May until the end of June average 13°C, then eggs deposited in mid-May would require about 42 days before hatching of alevin occurs (Raleigh et al. 1984), with emergence as free swimming fry about 2 weeks later in late June or early July. Based on posttreatment staff observations, discharge in East Mackey Lake tributaries can be miniscule or nonexistent by mid to late July. It appears environmental conditions for successful rainbow trout spawning and egg incubation in the tributaries of East Mackey Lake are marginal, but perhaps feasible, during favorable years.

In spring 2018, during opportunistic visual foot surveys, we observed a few rainbow trout spawning inside a road culvert in the outlet creek of West Mackey Lake, and in spring 2020 again during opportunistic surveys, a few more spawners were observed spawning there and in the East Mackey Lake outlet. In 2018, a resident of West Mackey Lake reported seeing rainbow trout attempting to spawn along the shoreline located a couple hundred yards north of the lake's outlet. Several female rainbow trout captured in gillnets in West Mackey Lake in the fall of 2019 were carrying eggs showing development consistent with spawning in 2020. Informal minnow trapping on 8 August 2020 using 1 minnow trap in the West Mackey Lake outlet stream caught 4 rainbow trout YOY. On this same date, 2 minnow traps were fished in the East Mackey Lake outlet and 1 rainbow trout YOY was caught. Identical minnow trapping effort was expended again in both lake outlets on 28 August 2020 and 1 rainbow trout YOY was captured in the West Mackey Lake outlet and 2 caught in the East Mackey Lake outlet. Because the connectivity of these lakes to Soldotna Creek during the summer of 2020 was poor due to low stream flow and dense aquatic vegetation, these rainbow trout almost certainly represent the first documented naturally produced rainbow trout natal to these lake outlets, not migrants from Soldotna Creek, and gives hope that the rainbow trout population in these lakes may become self sustaining.

Loon Lake, an Area 1 closed-system lake treated in 2017, had been stocked annually by ADF&G with hatchery-reared rainbow trout. Stocking of hatchery fish resumed in 2018 after confirmation the northern pike population was successfully removed.

In fall 2019, during a routine gillnet monitoring survey under a different project (Massengill et al. 2020a), 6 juvenile coho salmon were captured in East Mackey Lake. Their fork lengths ranged from 126 mm to 155 mm FL. Based on historical length–age relationship data from the Kenai River drainage (unpublished data, ADF&G, Soldotna Office), these lengths represent freshwater ages of less than 4 years. The last year we released wild juvenile coho salmon into

[6]Information for the thermal unit requirements of incubating rainbow trout eggs is found in the draft document titled: "Incubation Procedures, Jack Hernandez Sport Fish Hatchery, Alaska Department of Fish and Game, Anchorage Alaska.

Area 1 lakes was in 2017; therefore, any coho salmon less than 140 mm captured during 2021 or later in Area 1 can reasonably be assumed to represent fish occurring there through natural means such as migration from Soldotna Creek.

Historical fish survey data suggests both East and West Mackey Lakes supported rearing coho salmon prior to the introduction of northern pike (unpublished lake files, ADF&G, Soldotna Office). Derks Lake and Sevena Lake also supported rearing coho salmon before the introduction of northern pike, and coho salmon have been sporadically detected in these lakes after the introduction of northern pike. It is likely that coho salmon production in the Soldotna Creek drainage will respond positively to the removal of northern pike; in particular, the restoration of Derks Lake and Sevena Lake, which are directly linked to the productive coho salmon rearing waters of Soldotna Creek. Especially poor stream connectivity to West Mackey Lake and Union Lake, caused in part by a perched culvert under Mackey Lake Road, make these most upstream lakes less likely to receive migrating juvenile salmonids seeking rearing areas.

Following rotenone treatment, juvenile coho salmon, Dolly Varden, rainbow trout, and all life stages of stickleback and sculpin appear to be very abundant in the Soldotna Creek mainstem based on minnow trapping catch data (Table 19). Adult coho salmon and sockeye salmon have also been observed in Soldotna Creek after treatment (R. Massengill, ADF&G fishery biologist, Soldotna Office, personal observation).

RECOMMENDATIONS AND LONG-TERM FISHERY MONITORING

To ensure the restoration of native fish in the Soldotna Creek drainage, particularly the rainbow trout fishery in Area 1, whose long-term viability may be tenuous due to poor stream connectivity, it will be essential to periodically survey Area 1 fisheries for species presence, CPUE, and to collect age and length data. Currently, the Soldotna ADF&G Sport Fish office has initiated a long-term project to survey for invasive fish on the Kenai Peninsula and to monitor native fisheries in all restored waters, including the Soldotna Creek drainage (Massengill et al. 2020b).

It is recommended that spring spawning surveys be conducted in the outlet creeks of West and East Mackey Lakes to document whether rainbow trout continue to spawn where they historically did, and to continue minnow trapping in these outlet streams during midsummer to determine if emergent rainbow trout YOY are being produced. If these surveys indicate rainbow trout are not successfully reproducing, it may require habitat improvements (e.g., West Mackey Lake outlet culvert replacement) to improve access for spawning and immigration. Fish passage between all Area 1 lakes is seasonal at best, and immigration of juvenile rainbow trout and coho salmon from Soldotna Creek might be the only feasible way for these species to naturally replenish during years with low stream flow. Germane to rainbow trout, if their spawning success in the lake outlet creeks is largely unsuccessful over the long term, immigration will be essential to naturally sustain their population. If evidence of naturally occurring rainbow trout production is absent in future surveys, ADF&G should consider relocating more juvenile rainbow trout from Soldotna Creek to Area 1 lakes to encourage development of a self-sustaining population.

Since 2015, an ADF&G emergency order has been issued each year that prohibits the retention of all fish species in East and West Mackey Lakes, Sevena Lake, Derks Lake, and Union Lake. Continuation of this emergency order appears warranted until ADF&G can demonstrate that enough natural rainbow trout recruitment is occurring to sustain harvest. Sampling the age–length composition of Area 1 rainbow trout, along with gillnet CPUE, will provide the information needed for making comparative population assessments to other Kenai Peninsula waters supporting stable wild rainbow trout fisheries.

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APPENDIX A: CONTRIBUTED MEMOS AND DATA

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MEMORANDUM

TO: James Hasbrouck

FROM: Rob Massengill
Sam Ivey
Chuck Brazil
Tammy Davis
Kristine Dunker
Jack Erickson

DATE: 2/12/10

SUBJECT: Region II Invasive Northern Pike Priorities

Invasive northern pike have been a fisheries management concern in waters of Southcentral and Yakutat for several decades. To date, several actions have been implemented to reduce northern pike populations and prevent further spread. These include developing an invasive northern pike management plan, reducing pike populations with control netting efforts, and applying rotenone to eradicate northern pike from four lakes in Southcentral and a series of ponds in Yakutat. With the accomplishment of these initial efforts, Sport Fish Division staff are looking ahead to plan future projects and implement control and eradication efforts in large, open systems where wild fisheries are threatened. To succeed with these larger-scale endeavors, there is a need to further define the region's invasive northern pike program and develop a comprehensive, regional approach to prioritizing, funding, and implementing future northern pike projects.

In December 2009, a regional northern pike subcommittee was formed to address this need. The subcommittee is made up of local research and management biologists who work on pike projects in Soldotna (Rob Massengill), Palmer (Sam Ivey), and Anchorage (Chuck Brazil) as well as the state-wide invasive species program project lead (Tammy Davis), the region II invasive species coordinator (Kristine Dunker), and the region II research coordinator (Jack Erickson). The subcommittee's tasks were to 1) review and define the invasive northern pike

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program's goals, 2) create a reference catalog of all known pike waters in the region, 3) develop a planning tool to objectively prioritize future northern pike projects, 4) score project concepts submitted by the Soldotna, Palmer and Anchorage area offices, and 5) prepare scopes of work for the highest ranking projects.

The subcommittee met via teleconference on four occasions in January and early February. The subcommittee's work will be ongoing, but they have made significant progress on all of their assigned tasks as detailed below.

Region II Invasive Northern Pike Program Goals

The subcommittee defined the following as the goals for Region II's invasive northern pike program:

1) Prevent introductions of northern pike.
2) Reduce or eliminate pike populations where possible in Region II.
3) Increase public awareness about invasive northern pike.
4) Document where northern pike occur in Region II.
5) Improve understanding of pike movement and biology in Region II.
6) Improve understanding of control and eradication techniques for northern pike.

1) Pike Waters Catalog

Northern pike currently have an extensive distribution in region II. To date, they are either documented or suspected in at least 165 water bodies in the region. The subcommittee is currently documenting known information for these waters in a regional "pike waters catalog". Information documented in this catalog will include: geographic location, stocking category, past management actions, stocking status, size of the water body, availability of spawning habitat, relevance to preventing spread, potential for control or eradication, occurrence of other fish species, and known size (i.e. mean length) of pike. Not all of this information is available for all of the region's pike waters. This catalog will identify where information gaps are and will also function as a central storage location for the region's pike records. Rob Massengill, Sam Ivey, and Chuck Brazil will be compiling this information for waters in their respective areas by May 15, 2010.

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The catalog can be viewed on Docushare through the following pathway:

Home > Sport Fish – Collaborative Project Area > Southcentral Region > Region II – Pike > Strategic Planning for Region II Pike (2009) > **Pike Waters**

1) *Project Scoring Matrix*

During January 2010, the subcommittee created a scoring matrix to objectively prioritize invasive northern pike projects for the region. This matrix was designed to ask "yes" or "no" questions pertaining to a proposed project concept or proposal. The subcommittee worked together to assign priority levels and weighted scores for each question in the matrix. Low, medium, high, and very high priority-level questions were weighted with 1, 5, 10, and 30 points, respectively. Therefore, when answering the matrix questions for a proposed project, all yes answers receive the point values assigned by the subcommittee for those questions. All "no" answers receive zero points. After all questions in the matrix are answered for a proposed project, the sum of the point values provides an overall project score.

The matrix includes 62 questions. Individually, no one question can completely alter the outcome of a project's score. However, together, the criteria can help illustrate the importance of a particular project request. The highest score any project can receive is 394 points. Obviously, a project with a high score should be given consideration before a project that scores lower. However, there are other factors such as implementation cost, public processes, permitting timelines, and stipulations within requests for proposals that may cause the region to implement a lower ranking project before a higher ranking one. It is anticipated that project scores will be reviewed on an annual or bi-annual basis. New projects can be added to the priority list when needed. Further, it is possible that continued experience using the matrix may result in future adjustments to clarify the wording of some matrix questions.

The questions included in the scoring matrix are all relevant to the Sport Fish Division Strategic Plan and represent the following topics: recreational fisheries, regulatory effects, pike impacts, education and outreach, habitat significance, watershed characterization, cultural significance, economic impacts, research, feasibility, permitting and inter-agency cooperation, and ADF&G significance. The following is a brief description of each category and the rational as to why it was included.

Recreational Fisheries. Questions pertaining to this category address details about historic fisheries in the proposed project area and intent of the project to increase angler effort.
Regulatory Effect. These questions address concerns about wild, regulated sport fisheries and whether or not pike presence has altered fishing regulations.
Pike Impacts. This series of questions address pike abundance and impacts on wild fish populations, potential for loss of fisheries, and association with escapement goal concerns.
Education and Outreach. These questions pertain to educational opportunities the project may provide, stakeholder involvement, and opportunities to demonstrate new pike control or eradication techniques.

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Habitat Significance. Questions in this category address details about open and anadromous systems, the ability of a project to prevent the spread of pike, and potential effects on other species.
Watershed Characterization. This section prioritizes habitat types that are most vulnerable to pike establishment.
Cultural Significance. These questions relate to cultural, subsistence, or user group concerns from northern pike in the proposed project area.
Economic Impacts. These questions specifically address economic concerns with pike in the proposed project area.
Research. Questions in this category address what can be learned from implementing the proposed project.
Feasibility. These questions address project feasibility through location and access, ability to permanently remove or contain the pike, and ability to achieve project results relative to funding availability.
Permitting and Inter-Agency Cooperation. These questions address permitting needs, potential for collaboration, and relation to existing watershed plans.
ADF&G Significance. This section validates that the proposed project is consistent with ADF&G's mission and the Sport Fish Division strategic plan.

The complete scoring matrix can be viewed on Docushare through the following pathway:

Home > Sport Fish – Collaborative Project Area > Southcentral Region > Region II – Pike > Strategic Planning for Region II Pike (2009) > **Pike Priorities Scoring Matrix**

1) *Northern Pike Project Priority List*

Rob Massengill, Sam Ivey, and Chuck Brazil worked with their staffs to identify pike project ideas for their respective areas. The five preferred project ideas from each of their lists were submitted to the subcommittee for scoring. Projects were initially scored by the area subcommittee members and then submitted to the entire subcommittee for review. The subcommittee met on February 3, 2010, to review and finalize the scoring of these projects.

The following is the list of region II's invasive northern pike project priorities:

Note: Denise Lake on the Kenai Peninsula will be treated with rotenone in the fall of 2010 to eradicate the northern pike population. This project is not included in the priority list because funding for the project is already secured.

1. Control net Alexander Lake and Alexander Creek annually to reduce the northern pike population in the system. The lake will be netted during spring and fall of each year, and the creek will be netted during the spring. This project will benefit Chinook salmon runs in the Alexander system (Score = 292).

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2. Control net mainstem side-channel sloughs of Alexander Creek annually to reduce pike abundance. This is a less intensive version of project #1, although benefits to Chinook salmon are still expected (Score = 282).

3. Eradicate northern pike from the Soldotna Creek drainage. This is the first project of this type in Alaska. This project will involve a multi-phase approach. During phase 1, a management plan will be developed. Phase 2 will involve hiring an engineer to design temporary barriers to partition the system, and Phase 3 will involve barrier construction and systematic rotenone applications to remove northern pike from the entire drainage (Score = 261).

4. Eradicate northern pike from Stormy Lake. This project will involve the construction of a temporary barrier to facilitate rotenone treatment of the lake. This will be the largest rotenone treatment attempted in Alaska to date. If successful, this project will prevent northern pike from escaping into the Swanson River drainage (Score = 257).

5. Radio telemetry study in the Alexander Creek system. This project will assist the control netting efforts by better defining the location and intensity of netting required to meet project objectives (Score = 232).

6. Control net Otter Lake on Fort Richardson to reduce the pike population (Score = 188).

7. Control net Lower Fire Lake to reduce the pike population and measure CPUE in that system (Score = 187).

8. Eradicate northern pike from Union Lake on the Kenai Peninsula using rotenone (Score = 178).

9. Control net Nancy Lake annually during the spring to reduce the number of northern pike spawners in the system. This project will benefit rearing sockeye salmon (Score = 178).

10. Develop a northern Kenai Peninsula "Area" pike plan. This plan will detail how pike will be removed from all Kenai Peninsula waters (Score = 178).

11. Radio telemetry study in the Campbell Creek system. Pike have been documented in Campbell Lake, but the extent of their distribution is currently unknown within Campbell Creek. This information is vital to planning future pike eradication efforts in Campbell Lake (Score = 162).

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12. Eradicate northern pike from Jewel Lake with rotenone. Jewel Lake is within a half-mile of Sand Lake where northern pike were eradicated last year. This is a recent pike record, and ADF&G still has to confirm the presence of pike in this water body. However, if present, the pike are a risk to the long-term success of the Sand Lake eradication effort (Score = 153).

13. Survey the Cottonwood Creek drainage for pike. If not already present, ADF&G may be able to prevent pike from spreading into this system by eradicating them from Anderson Lake via a rotenone treatment (Score = 138).

14. Survey the Moose River drainage for the presence of northern pike (Score = 124).

15. Survey the APU Lake/ Chester Creek drainage for the presence of northern pike (Score = 123).

2) Scopes of Work for High Priority Projects

Scopes of work (SOW) have been developed for the two highest scoring project ideas in each area (Palmer, Anchorage and Soldotna). The project scopes of work include estimated budgets and are attached below. SOWs for the remaining projects will be written by March 31st. These SOWs will be stored on Docushare and used as a basis for preparing detailed project proposals when responding to future funding opportunities. That is the next step in this process. The subcommittee will compile a list and schedule of potential grant opportunities and will begin actively seeking funding for these projects. The subcommittee will meet at least annually or biannually to add new projects to the priority list and review and update this process and scoring system.

Soldotna Creek Flow Project

Conducted by the Kenai Watershed Forum

Purpose

The purpose of this study was to use salt tracer techniques to determine flow rates along Soldotna Creek.

Dates of Fieldwork

September 6, 2011
September 15, 2011

Methods

1) Calibrated Hydrolabs in the laboratory using a HYDROLAB Conductivity Standard Solution of potassium chloride at varying concentrations, programmed the instruments with run times
2) Deployed HydroLabs along Soldotna Creek
3) Dissolved 25 lbs salt in ~ 55 gallons of creek water and dumped into the creek as a single slug of salt solution
4) Retrieved Hydrolabs after slug moved through
5) Downloaded conductivity data and removed any outlying data points
6) Recorded time of slug passage at the beginning of the spike, middle and end of spike
7) Calculated travel time from slug injection to each HydroLab location
8) Calculated travel distances from the injection point to each Hydrolab with measurements derived from imagery in Google earth® and LiDAR
9) Divided the length of creek traveled by the time it took the salt slug to reach that point to get flow rates (Flow =distance/time) for each of the reaches

Due to a beaver dam located approximately halfway down the creek and the dispersion that would occur from the upper injection point to the mouth of Soldotna Creek, the creek was divided into two sections. One was above the dam and the other was immediately below it.

Results

September 6, 2011

Salt slug was dumped on 09/06/11 at 13:31. The flow gauge read 1.15. The following summarizes the time it took for the slug to first show up in the data, for the peak concentration to pass and the travel times for the slug to get to each Hydrolab.

-continued-

Hydrolab name	Time at start of peak (hh:mm)	Time at top of peak (hh:mm)	Time at end of peak (hh:mm)	Travel time from injection point to the top of the peak (hh:mm)	Width of peak (hh:mm)
Hydrolab 1-090611	9/6/2011 14:52	9/6/2011 15:17	9/6/2011 16:42	01:47	01:50
Hydrolab 2 -090611	9/6/2011 17:12	9/6/2011 03:00	9/6/2011 19:49	13:30	02:37
Hydrolab 3-090611	9/6/2011 22:25	9/7/2011 00:03	9/7/2011 03:40	10:33	05:15
Hydrolab 4-090611	9/7/2011 03:02	9/7/2011 04:46	9/7/2011 08:55	15:16	05:53
Hydrolab 5-090611	9/7/2011 03:35	9/7/2011 05:35	9/7/2011 09:51	16:05	06:16

The following is a summary of flow rates in each reach where length is the distance between points. Travel times are the amount of time it took the peak of the slug to pass through each point.

Reach name	Travel time (seconds)	Length (ft)	Flow = length/time (ft/s)
Injection Point 1 to Hydrolab 1-090611	6,420	1,586	0.25
Hydrolab 1-090611 to Hydrolab 2-090611	9,960	1,924	0.19
Hydrolab 2-090611 to Hydrolab 3-090611	21,600	7,714	0.36
Hydrolab 3-090611 to Hydrolab 4-090611	16,980	7,639	0.45
Hydrolab 4-090611 to Hydrolab 5-090611	2,940	892	0.30

September 15, 2011

Salt slug was dumped on 09/15/11 at 15:30. The flow gauge read 0.90. The following summarizes the time it took for the slug to first show up in the data, for the peak concentration to pass and the travel times for the slug to get to each Hydrolab.

Hydrolab name	Time at start of peak (hh:mm)	Time at top of peak (hh:mm)	Time at end of peak (hh:mm)	Travel time from injection point to the top of the peak (hh:mm)	Width of peak (hh:mm)
Hydrolab 1-0901511	------------------------------------FAILED TO TAKE DATA------------------------------------				
Hydrolab 2 -091511	9/15/2011 23:07	9/16/2011 00:36	9/16/2011 03:06	09:06	03:59
Hydrolab 3-091511	9/16/2011 05:32	9/16/2011 07:19	9/16/2011 11:02	15:49	05:30
Hydrolab 4-091511	9/16/2011 10:22	9/16/2011 12:20	N/A	20:50	N/A
Hydrolab 5-091511	9/16/2011 11:51	9/16/2011	N/A	21:44	N/A

Note, for Hydrolabs 4 and 5 the peaks were partial because the instruments were pulled before the slug had finished moving through. On both graphs the top of the peak is visible but the right slope is incomplete.

The following is a summary of flow rates in each reach where length is the distance between points. Travel times are the amount of time it took the peak of the slug to pass through each point.

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Reach name	Travel time (seconds)	Length (ft)	Flow = length/time (ft/s)
Injection Point 2 to Hydrolab 1-091511	N/A	10,684	N/A
Injection Point 2 to Hydrolab 2-091511	32760	14,424 (10,684 + HL1 to HL2)	0.44
Hydrolab 2-091511 to Hydrolab 3-091511	24180	10084	0.42
Hydrolab 3-091511 to Hydrolab 4-091511	18060	10148	0.56
Hydrolab 4-091511 to Hydrolab 5-091511	3240	1846	0.57

Discussion

For the upper reach flow rates ranged from 0.19 to 0.45 ft/s. For the lower reach flow rates ranged from 0.42 to 0.57 ft/s. Based on elevation changes as seen in Google Earth, the lower reach has substantially greater loss in elevation which, consequently, should result in the higher flow rates. A decrease in cross-sectional area of the creek channel would also contribute to an increase in the flow rate.

Overall, these data serve as a good estimate of flow. They do not reflect channel length in oxbows and slough channels. When the upper portion of the creek was floated several of these side features were noted. Furthermore, lengths were based on imagery in Google Earth and LiDAR and do not represent exact measurements. These values should serve as a guide to understanding how flow behaves in Soldotna Creek and not to be used as exact figures.

APPENDIX B: ROTENONE PRODUCT LABELS

RESTRICTED USE PESTICIDE
Due to aquatic toxicity
For retail sale to, and use only by, Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification.

CFT Legumine™
Fish Toxicant
For Control of Fish in Lakes, Ponds, Reservoirs, and Streams

ACTIVE INGREDIENTS:

Rotenone	5.0%	w/w
Other Associated Resins	5.0%	
OTHER INGREDIENTS[1]	90.0%	
Total	100.0%	

[1] Contains Petroleum Distillates
CFT Legumine is a trademark of CWE Properties Ltd., LLC

KEEP OUT OF REACH OF CHILDREN
WARNING

FIRST AID
Have product container or label with you when obtaining treatment advice.

If swallowed	• Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice. • Do not give any liquid to the person. · Do not anything to an unconscious person • Do not induce vomiting unless told to do so by the poison control center or doctor.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.
If inhaled	• Move person to fresh air. • If person is not breathing, call an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. • Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.

Note to Physician: Contains Petroleum Distillates. Vomiting may cause aspiration pneumonia. For information on this pesticide product (including health concerns, medical emergencies, or pesticide incidents), call the National Pesticide Information Center at 1-800-858-7378.

EPA Reg. No. 75338-2 EPA Est. No. 655-GA-1
Manufactured for CWE Properties Ltd., LLC, P.O. Box 336277, Greeley CO 80633

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PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS
WARNING

May be fatal if inhaled or swallowed. Causes moderate eye irritation. Harmful if absorbed through skin. Do not breathe spray mist. Do not get in eyes, on skin, or on clothing. Wear goggles or safety glasses.

When handling undiluted product, wear either a respirator with an organic-vapor-removing cartridge with a prefilter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C), or a canister approved for pesticides (MSHA/NIOSH approval number prefix 14G), or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any R, P, or HE prefilter.

Wash thoroughly with soap and water after handling and before eating, drinking, or using tobacco. Remove contaminated clothing and wash before reuse. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals.

ENVIRONMENTAL HAZARDS

This pesticide is extremely toxic to fish. Fish kills are expected at recommended rates. Consult your State Fish and Game Agency before applying this product to public waters to determine if a permit is needed for such an application. Do not contaminate untreated water when disposing of equipment washwaters.

CHEMICAL AND PHYSICAL HAZARDS

FLAMMABLE: KEEP AWAY FROM HEAT AND OPEN FLAME. FLASH POINT MINIMUM 45°F (7°C).

For information on this pesticide product (including health concerns, medical emergencies, or pesticide incidents), call the National Pesticide Information Center at 1-800-858-7378.

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.

STORAGE: Store only in original containers, in a dry place inaccessible to children and pets. This product will not solidify nor show any separation at temperatures down to 40°F and is stable for a minimum of one year when stored in sealed drums at 70°F.

PESTICIDE DISPOSAL: Pesticide wastes are acutely hazardous. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal law. If these wastes cannot be disposed of by use according to label instructions, contact your state pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

CONTAINER DISPOSAL: Triple rinse or equivalent. Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or by other procedures approved by state and local authorities.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

CFT Legumine is registered for use by or under permit from, and after consultation with State and Federal Fish and Wildlife Agencies.

GENERAL INFORMATION

This product is a specially formulated product containing rotenone to be used in fisheries management for the eradication of fish from lakes, ponds, reservoirs and streams.

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Since such factors as pH, temperature, depth and turbidity will change effectiveness, use this product only at locations, rates, and times authorized and approved by appropriate State and Federal Fish and Wildlife Agencies. Rates must be within the range specified on the label.
Properly dispose of unused product. Do not use dead fish for food or feed.
Do not use water treated with rotenone to irrigate crops or release within ½ mile upstream of a potable water or irrigation water intake in a standing body of water such as a lake, pond or reservoir.

Re-entry Statement: Do not allow swimming in rotenone-treated water until the application has been completed and all pesticide has been thoroughly mixed into the water according to labeling instructions.

FOR USE IN PONDS, LAKES, AND RESERVOIRS

The actual application rates and concentrations of rotenone needed to control fish will vary widely, depending on the type of use (e.g., selective treatment, normal pond use, etc.) and the factors listed above. The table below is a general guide for the proper rates and concentrations.
This product disperses readily in water both laterally and vertically, and will penetrate below the thermocline in thermally stratified bodies of water.

Computation of Acre-Feet: An acre-foot is a unit of volume of a body of water having the area of one acre and the depth of one foot. To determine acre-feet in a given body of water, make a series of transects across the body of water taking depths with a measured pole or weighted line. Add the soundings and divide by the number made to determine the average depth. Multiply this average depth by the total surface area in order to determine the acre-feet to be treated. If number of surface acres is unknown, contact your local Soil Conservation Service, which can determine this from aerial photographs.

Amount of CFT Legumine Needed for Specific Uses: To determine the approximate number of gallons needed, find your "Type of Use" in the first column of the table below and then divide the corresponding numbers in the fourth column, "Number of Acre-Feet Covered by One Gallon" into the number of acre-feet in your body of water.

Type of Use	Parts per Million		Number of Acre-Feet Covered by One Gallon
	CFT Legumine	Active Rotenone	
Selective Treatment	0.10 to 0.13	0.005 to 0.007	30 to 24
Normal Pond Use	0.5 to 1.0	0.025 to 0.050	6.0 to 3.0
Remove Bullheads or Carp	1.0 to 2.0	0.050 to 0.100	3.0 to 1.5
Remove Bullheads or Carp in Rich Organic Ponds	2.0 to 4.0	0.100	1.5 to 0.75
Preimpoundment Treatment Above Dam	3.0 to 5.0	0.150 to 0.250	1.0 to 0.60

*Adapted from Kinney, Edward. 1965. Rotenone in Fish Pond Management. USDI Washington, DC Leaflet FL-576

Pre-Mixing and Method of Application: Pre-mix with water at a rate of one gallon of CFT Legumine to 10 gallons of water. Uniformly apply over water surface or bubble through underwater lines.

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Detoxification: Water treated with this product will detoxify under natural conditions within one week to one month depending upon temperatures, alkalinity, etc. Rapid detoxification can be accomplished by adding chlorine or potassium permanganate to the water at the same rate as CFT Legumine in parts per million, plus enough additional to meet the chlorine demand of the untreated water.

Removal of Taste and Odor: Waters treated with this product do not retain a detectable taste or odor for more than a few days to a maximum of one month. Taste and odor can be removed immediately by treatment with activated charcoal at a rate of 30 ppm for each 1 ppm of CFT Legumine remaining. (Note: As this product detoxifies, less charcoal is required.)

Restocking After Treatment: Wait 2 to 4 weeks after treatment. Place a sample of fish to be stocked in wire cages in the coolest part of the treated waters. If the fish are not killed within 24 hours, the water may be restocked.

USE IN STREAMS IMMEDIATELY ABOVE LAKES, PONDS, AND RESERVOIRS

The purpose of treating streams immediately above lakes, ponds and reservoirs is to improve the effectiveness of lake, pond and reservoir treatments by preventing target fish from moving into the stream corridors, and not to control fish in streams per se. The term "immediately" means the first available site above the lake, pond or reservoir where treatment is practical, while still creating a sufficient barrier to prevent migration of target fish into the stream corridor.

In order to completely clear a fresh water aquatic habitat of target fish, the entire system above or between fish barriers must be treated. See the use directions for streams and rivers on this label for proper application instructions.

In order to treat a stream immediately above a lake, pond or reservoir you must: (a) Select the concentration of active rotenone, (b) Compute the flow rate of the stream, (c) Calculate the application rate, (d) Select an exposure time, (e) Estimate the amount of product needed, (f) Follow the method of application.

To prevent movement of fish from the pond, lake, or reservoir, the stream treatment should begin before and continue throughout treatment of the pond, lake or reservoir until mixing has occurred.

1. Concentration of Active Rotenone

Select the concentration of active rotenone based on the type of use from those listed on the table. Example: If you select "normal pond use" you could select a concentration of 0.025 parts per million.

2. Computation of Flow Rate for Stream

Select a cross section of the stream where the banks and bottom are relatively smooth and free of obstacles. Divide the surface width into 3 equal sections and determine the water depth and surface velocity at the center of each section. In slowly moving streams, determine the velocity by dropping a float attached to 5 feet of loose monofilament fishing line. Measure the time required for the float to move 5 feet. For fast-moving streams, use a longer distance. Take at least three readings at each point. To calculate the flow rate from the information obtained above, use the following formula:

$$F = \frac{Ws \times D \times L \times C}{T}$$

Where F = flow rate (cubic feet/second), Ws = surface width (feet), D = mean depth (feet), L = mean distance traveled by float (feet), C = constant (0.8 for rough bottoms and 0.9 for smooth bottoms), T = mean time for float (sec.).

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3. Calculation of Application Rate

In order to calculate the application rate (expressed as gallons/second), convert the rate in the table (expressed as gallons/acre-feet) to gallons per cubic feet and multiply by the flow rate (expressed as cubic feet/second). Depending on the size of the stream and the type of equipment, the rate could be expressed in other units, such as ounces/hour, or cc/minute.

The application rate for the stream is calculated as follows:

$$R_s = R_p \times C \times F$$

Where R_s = application rate for stream (gallons/second), R_p = application rate for pond (gallons/acre-feet), C = 1 acre-foot/43560 cubic feet and F = flow rate of the stream (cubic feet/second).

4. Exposure Time

The exposure time would be the period of time (expressed in hours or minutes) during which CFT Legumine is applied to the stream in order to prevent target fish from escaping from the pond into the stream corridor.

5. Amount of Product

Calculate the amount of product for a stream by multiplying the application rate for streams by the exposure time.

$$A = R_s \times H$$

Where A = the amount of product for the stream application, R_s = application rate for stream (gallons/second) and H = the exposure time expressed in seconds.

FOR USE IN STREAMS AND RIVERS

Only state or Federal Fish and Wildlife personnel or professional fisheries biologists under the authorization of state or Federal Fish and Wildlife agencies are permitted to make applications of CFT Legumine for control of fish in streams and rivers. Informal consultation with Fish and Wildlife personnel regarding the potential occurrence of endangered species in areas to be treated should take place. Applicators must reference the Stream and River use Monograph before making any application to streams or rivers.

CFT LEGUMINE STREAM AND RIVER USE MONOGRAPH

USE IN STREAMS AND RIVERS

The following use directions are to provide guidance on how to make applications of CFT Legumine to streams and rivers. The unique nature of every application site could require minor adjustments to the method and rate of application. Should these unique conditions require major deviation from the use directions, a Special Local Need 24(c) registration should be obtained from the state.

Before applications of CFT Legumine can be made to streams and rivers, authorization must be obtained from state or federal Fish and Wildlife agencies. Since local environmental conditions will vary, consult with the state Fish and Wildlife agency to ensure the method and rate of application are appropriate for that site.

Contact the local water department to determine if any water intakes are within one mile downstream of the section of stream, river, or canal to be treated. If so, coordinate the application with the water department to make sure the intakes are closed during treatment and detoxification.

Application Rates and Concentration of Rotenone

Slow Moving Rivers: In slow moving rivers and streams with little or no water exchange, use instructions for ponds, lakes and reservoirs.

Flowing Streams and Rivers: Apply rotenone as a drip for 4 to 8 hours to the flowing portion of the stream. Multiple application sites are used along the length of the treated stream, spaced

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approximately ½ to 2 miles apart depending on the water flow travel time between sites. Multiple sites are used because rotenone is diluted and detoxified with distance. Application sites are spaced at no more than 2 hours or at no less than 1-hour travel time intervals. This assures that the treated stream remains lethal to fish for a minimum of 2 hours. A non-toxic dye such as Rhodamine-WTR or fluorescein can be used to determine travel times. Cages containing live fish placed immediately upstream of the downstream application sites can be used as sentinels to assure that lethal conditions exist between sites.

Apply rotenone at each application site at a concentration of 0.25 to 1.0 part per million of CFT Legumine. The amount of CFT Legumine needed at each site is dependent on stream flow (see Computation of Flow Rate for Stream).

Application of Undiluted Material

CFT Legumine can drain directly into the center of the stream at a rate 0.85 to 3.4 cc per minute for each cubic foot per second of stream flow. Flow of undiluted CFT Legumine into the stream should be checked at least hourly. This is equivalent to from 0.5 to 2.0 ppm of this product, or from 0.025 to 0.100 ppm rotenone. Backwater, stagnant, and spring areas of streams should be sprayed by hand with a 10% v/v solution of CFT Legumine in water to assure a complete coverage.

Calculation of Application Rate:

$$X = F\,(1.699\,B)$$

X = cc per minute of CFT Legumine applied to the stream, F = the flow rate (cu.ft/sec.) see Computation of Flow Rate for Stream section of the label, B = parts per million desired concentration of CFT Legumine

Total Amount of Product Needed for Treatment: Streams should be treated for 4 to 8 hours in order to clear the treated section of stream of fish. To determine the total amount of CFT Legumine required, use the following equation:

$$Y = X\,(0.0158\,C)$$

Y = gallons of CFT Legumine required for the stream treatment, X = cc per minute of CFT Legumine applied to the stream, C = time in hours of the stream treatment.

Application of Diluted Material

Alternatively, for stream flows up to 25 cubic feet per second, continuous drip of diluted CFT Legumine at 80 cc per minute can be used. Flow of diluted CFT Legumine into the stream should be checked at least hourly. Use a 5 gallon reservoir over a 4 hour period, a 7.5 gallon reservoir over a 6 hour period, or a 10 gallon reservoir over an 8 hour period. The volume of the reservoir can be determined from the equation:

$$R = H \times 1.25$$

Where R = the volume of the reservoir in gallons, H = the duration of the application in hours.

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The volume of CFT Legumine diluted with water in the reservoir is determined from the equation:

$$X = Y(102\ F)H$$

Where X = the cc of CFT Legumine diluted in the reservoir, Y = parts per million desired concentration of CFT Legumine, F = the flow rate (cubic feet/second), H = the duration of the application (hours).

For flows over 25 cubic feet per second, additional reservoirs can be used concurrently. Back-water, stagnant and spring areas of streams should be sprayed by hand with a 10% v/v solution of CFT Legumine in water to assure a complete coverage.

Detoxification

To limit effects downstream, detoxification with potassium permanganate can be used at the downstream limit of the tre ated area. Within ½ to 2 miles of the furthest downstream CFT Legumine application site, the rotenone can be detoxified with a potassium permanganate solution at a resultant stream concentration of 2 to 4 parts per million, depending on rotenone concentration and permanganate demand of the water. A 2.5% (10 pounds potassium permanganate to 50 gallons of water) permanganate solution is dripped in at a continuous rate using the equation:

$$X = Y(70\ F)$$

Where X = cc of 2.5% permanganate solution per minute, Y = ppm of desired permanganate concentration, F = cubic feet per second of stream flow.

Flow of permanganate should be checked at least hourly. Live fish in cages placed immediately above the permanganate application site will show signs of stress signaling the need for beginning detoxification. Detoxification can be terminated when replenished fish survive and show no signs of stress for at least four hours.

Detoxification of rotenone by permanganate requires between 15 to 30 minutes contact time (travel time). Cages containing live fish can be placed at these downstream intervals to judge the effectiveness of detoxification. At water temperatures less than 50°F detoxification may be retarded, requiring a longer contact time.

WARRANTY STATEMENT

Our recommendations for the use of this product are based upon tests believed to be reliable. The use of this product being beyond the control of the manufacturer, no guarantee, expressed or implied, is made as to the effects of such or the results to be obtained if not used in accordance with directions or established safe practice. To the extent consistent with applicable law, the buyer must assume all responsibility, including injury or damage, resulting from its misuse as such, or in combination with other materials.

RESTRICTED USE PESTICIDE
DUE TO AQUATIC, ACUTE ORAL AND INHALATION TOXICITY
For retail sale to, and use by, Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification.

ROTENONE FISH TOXICANT POWDER

SPECIMEN

ACTIVE INGREDIENTS:

Rotenone- Minimum Guaranteed	7.4% w/w
Other Associated Resins	11.1%
OTHER INGREDIENTS:	81.5%
TOTAL:	100.0% w/w

ROTENONE ASSAY ____________________% ROTENONE

PRENTOX® - Registered Trademark of Prentiss Incorporated

KEEP OUT OF REACH OF CHILDREN

DANGER
POISON

FIRST AID

Have the product container or label with you when calling a poison control center or physician, or going for treatment.

If swallowed	• Call a Poison Control Center, physician, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice. • Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by the Poison Control Center or physician. • Do not give anything by mouth to an unconscious or convulsing person.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a Poison Control Center, physician, or the National Pesticide Information Center at 1-800-858-7378 for treatment advice.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a Poison Control Center, physician, or the National Pesticide Information Center at 1-800-858-7378 for treatment advice.
If inhaled	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. • Call a Poison Control Center, physician, or the National Pesticide Information Center at 1-800-858-7378 for treatment advice.

For information on this pesticide product (including health concerns, medical emergencies, or pesticide incidents), call the National Pesticide Information Center at 1-800-858-7378.

SEE INSIDE LEAFLET FOR ADDITIONAL PRECAUTIONARY STATEMENTS AND DIRECTIONS FOR USE

Manufactured by: 5/02 **E.P.A. REG. NO. 655-691**
E.P.A. EST. NO. 655-GA-1

PRENTISS INCORPORATED
Plant: Kaolin Road, Sandersville, GA 31082
Office: C.B. 2000, Floral Park, NY 11002-2000

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS
DANGER

Fatal if inhaled or swallowed. Harmful if absorbed through the skin. Causes moderate eye irritation. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals. Do not breathe dust. Use a dust/mist filtering respirator (MSHA/NIOSH approval number prefix TC-21C), or a NIOSH approved respirator with any N, R, P or HE filter. Avoid contact with skin, eyes or clothing. Wash thoroughly with soap and water after handling and before eating, drinking or using tobacco. Remove contaminated clothing and wash clothing before reuse.

ENVIRONMENTAL HAZARDS

This pesticide is extremely toxic to fish. Fish kills are expected at recommended rates. Consult your State Fish and Game Agency before applying this product to public waters to determine if a permit is needed for such an application. Do not contaminate untreated water when disposing of equipment washwaters.

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STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.

STORAGE: Store only in original container, in a dry place inaccessible to children and pets. If spilled, sweep up and dispose of as below.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

CONTAINER DISPOSAL: Completely empty bag into application equipment. Then dispose of bag in a sanitary landfill or by incineration, or if allowed by State and local authorities by burning. If burned, stay out of smoke.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

USE RESTRICTIONS:

Use against fish in lakes, ponds, and streams (immediately above lakes and ponds).

Since such factors as pH, temperature, depth, and turbidity will change effectiveness, use this product only at locations, rates, and times authorized and approved by appropriate state and Federal fish and wildlife agencies. Rates must be within the range specified in the labeling.

Properly dispose of dead fish and unused product. Do not use dead fish as food or feed.

Do not use water treated with rotenone to irrigate crops or release within ½mile upstream of a potable water or irrigation water intake in a standing body of water such as a lake, pond or reservoir.

Note to User: Adjust pounds of Rotenone according to the actual Rotenone Assay as noted under the Ingredient Statement on this label. For example, if the required amount of 5% rotenone is 21 pounds, and the Rotenone Assay is 7%, use 5/7 of 21 pounds or 15 pounds of this product to yield the proper amount of active rotenone.

APPLICATION DIRECTIONS:

Treatment of Lakes and Ponds

1. **Application Rates and Concentrations of Rotenone**

The actual application rates and concentrations of rotenone needed to control fish will vary widely, depending on the type of use (e.g. selective treatment, normal pond treatment, etc.) and the factors listed above. The table below is a general guide for the proper rates and concentrations.

2. **Total Amount of Product Needed for Treatment**

To determine the total number of pounds needed for treatment, divide the number of acre-feet covered by one pound for a specific type of use (e.g., selective treatment, etc.), as indicated in the table below, into the number of acre-feet in the body of water.

General Guide to the Application Rates and Concentrations of Rotenone Needed to Control Fish in Lakes and Ponds[1]

Type of Use	No. of Acre-Feet Covered by One Pound	Parts Per Million	
		Active Rotenone	5% Product
Selective Treatment	3.7 to 2.8	0.005 - 0.007	0.10 - 1.3
Normal Pond Use	0.74 to 0.37	0.025 - 0.050	0.5 - 1.0
Remove Bullheads or Carp	0.37 to 0.185	0.050 - 0.100	1.02 - 2.0
Remove Bullheads or Carp in Rich Organic Ponds	0.185 to 0.093	0.100 - 0.200	2.0 - 4.0
Pre-impoundment Treatment above Dam	0.123 to 0.074	0.150 - 0.250	3.0 - 5.0

5. **Restocking**

Waters treated with this product detoxify within 2 to 4 weeks after treatment, depending on pH, temperature, water hardness, and depth. To determine if detoxification has occurred, place live boxes containing samples of fish to be stocked in treated waters. More rapid detoxification can be accomplished by adding Potassium Permanganate or chlorine at a 1:1 ratio with the concentration of rotenone applied, plus sufficient additional compound to satisfy the chemical oxidation demand caused by organic matter that may be present in the treated water.

Treatment of Streams Immediately Above Lakes and Ponds

The purpose of treating streams immediately above lakes and ponds is to improve the effectiveness of lake and pond treatments and not to control fish in streams per se. The term "immediately" means the first available site above the lake or pond where treatment is practical.

In order to treat a stream immediately above a lake or pond, you must select a concentration of active rotenone, compute the flow rate of a stream, calculate the application rate, select an exposure time, estimate the amount of product needed, and follow the method of application.

1. **Concentration of Active Rotenone**

Select the "Concentration of Active Rotenone" based on the type of use from those on the table. For example, if you select "Normal Pond Use" you could select a concentration of "0.025 Parts per Million".

2. **Computation of Flow Rate for Stream**

Select a cross section of the stream where the banks and bottom are relatively smooth and free of obstacles. Divide the surface width into 3 equal sections and determine the water depth and surface velocity at the center of each section. In slowly moving streams, determine the velocity by dropping a float attached to 5 feet of loose, monofilament fishing line. Measure the time required for the float to move 5 feet. For fast-moving streams, use a longer distance. Take at least three readings at each point. To calculate the flow rate from the information obtained above, use the following formula:

$$F = \frac{Ws \times D \times L \times C}{T}$$

where F = flow rate (cu. ft./sec.), Ws = surface width (ft.), D = mean depth (ft.), L = mean distance traveled by float (ft.), C = constant (0.8 for rough bottoms and 0.9 for smooth bottoms), and T = mean time for float (sec.).

For example, after using the above formula, you might have computed the stream's flow rate to be "10 cu. ft. per sec."

3. **Calculation of Application Rate**

In order to calculate the application rate (expressed as "pound per sec"), you convert the rate in the table (expressed as "pound per acre-feet"), to "pound per cu. feet" and multiply by the flow rate (expressed as "cu. ft. per sec."). Depending on the size of the stream and the type of equipment, the rate could be expressed in other units, such as "ounces per hr."

The application rate for the stream above is calculated as follows:

$$R_s = R_p \times C \times F$$

where R_s = Application Rate for Stream (lb/sec), R_p = Application Rate for Pond (lb/acre feet), C = 1 acre foot/43560 cu. ft., and F = Flow Rate (cu. ft/sec).

In the example, the Application Rate for Stream would be:

R_s = 1 lb/0.74 acre-foot x 1 acre-foot/43560 cu. ft. x 10 cu. ft./sec.

R_s = .00031 lb/sec or 17.9 oz./hr.

4. **Exposure Time**

The "Exposure Time" would be the period of time (expressed in hours or seconds) during which target fish should **not** enter the lake or pond under treatment. In the example, this period of time could be 4 hours.

5. **Amount of Product**

Calculate the "Amount of Product" for a stream by multiplying the "Application Rate for Stream" by the "Exposure Time". In the example, the "Amount of Product" would be 71.6 oz. (17.9 oz./hr. x 4 hr.) or 4.5 lb.

RE-ENTRY STATEMENT

Do not allow swimming in rotenone-treated water until the application has been completed and all pesticide has been thoroughly mixed into the water according to labeling instructions.

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-continued-

[1]Adapted from Kinney, Edward, 1965 Rotenone in Fish Pond Management. USDI Washington, D.C. Leaflet FL-576.

Computation of acre-feet for lake or pond: An acre-foot is a unit of water volume having a surface area of one acre and a depth of one foot. Make a series of transects across the surface, taking depths with a measured pole or weighted line. Add the measurements and divide by the number made to determine the average depth. To compute **total acre-feet**, multiply this average depth by the number of surface acres, which can be determined from an aerial photograph or plat drawn to scale.

3. **Pre-Mixing Method of Application**

Pre-mix one pound of Rotenone with 3 to 10 gallons of water. Uniformly apply over water surface or bubble through underwater lines.

Alternately place undiluted powder in burlap sack and trail behind boat. When treating deep water (20 to 25 feet) weight bag and tow at desired depth.

4. **Removal of Taste and Odor**

Rotenone treated waters do not retain a detectable taste or odor for more than a few days to a maximum of one month. Taste and odor can be removed immediately by treatment with activated charcoal at a rate of 30 ppm. for each 1 ppm. Rotenone remaining (Note: As Rotenone detoxifies, less charcoal is required).

APPENDIX C: TREATMENT RELATED DIFFERENCES

Appendix C1.–Target boat speeds (miles per hour [mph]) for applying CFT Legumine at select lake depths to attain about 40 ppb rotenone concentration.

Water depth (ft)	Water volume[a]	Gallons of product[b]	Boat speed (mph)[c]
1	0.07	0.0	46.4
2	0.14	0.0	23.2
3	0.21	0.1	15.5
4	0.28	0.1	11.6
5	0.34	0.1	9.3
6	0.41	0.1	7.7
7	0.48	0.1	6.6
8	0.55	0.1	5.8
9	0.62	0.2	5.2
10	0.69	0.2	4.6
11	0.76	0.2	4.2
12	0.83	0.2	3.9
13	0.90	0.2	3.6
14	0.96	0.3	3.3
15	1.03	0.3	3.1
16	1.10	0.3	2.9
17	1.17	0.3	2.7
18	1.24	0.3	2.6
19	1.31	0.3	2.4
20	1.38	0.4	2.3
21	1.45	0.4	2.2
22	1.52	0.4	2.1
23	1.58	0.4	2.0
24	1.65	0.4	1.9
25	1.72	0.5	1.9
26	1.79	0.5	1.8
27	1.86	0.5	1.7
28	1.93	0.5	1.7
29	2.00	0.5	1.6
30	2.07	0.6	1.5

Note: Target treatment concentration was 0.80 ppm of rotenone product (40 ppb rotenone). It was assumed that the boat could apply 0.75 gallons of liquid formulation per minute.

[a] Water volume (acre-feet) in every 100 linear foot stretch of a 30 ft wide application swath.

[b] Gallons of product needed per 100 linear feet of boat travel to apply product at a rotenone concentration of 40 ppb.

[c] Boat speed is in miles per hour., At water depths less than 5 ft, target boat speed is impractically fast. In this case, applicators reduced product pumping rate so that boat speed could be reduced to a practical speed.

AERIAL APPLICATION METHODS FOR PATHFINDER AVIATION

Aircraft:
The aircraft used to aerially apply the piscicide to wetlands was a Bell 206 series helicopter with an enclosed cockpit.

Release Height:
Piscicide spray was released at the lowest height consistent with pest control and flight safety.

Boom Length:
The application spray boom length did not exceed 35 feet representing 90% of rotor Bell 206 rotor blade diameter (39 feet). The boom spray nozzles were orientated backward with minimal downward angle into the slip stream.

Swath Adjustment:
For applications made with a cross wind, the swath was displaced downwind. The applicator compensated for this displacement at the downwind edge of the application area by adjusting the path of the aircraft upwind. The applicator left at least 1 swath unsprayed at the downwind edge of the treated area.

Droplet Size:
The applicator used low drift nozzles designed to produce larger spray droplets with fewer driftable fines. Piscicide was applied as a medium or coarse spray (ASAE standard 572).

Wind Speed:
All aerial applications were done with less than 10 knots of wind.

Application Tracking:
A TracMap agricultural GPS system provided aerial guidance to aid in targeting and tracking of the aerial application swaths.

Pilot Safety:
The pilot used a cockpit that had a nonporous barrier totally surrounding the cockpit occupants preventing contact with piscicides outside the enclosed area. Pilots in enclosed cockpits may wear a long-sleeved shirt, long pants, shoes, and socks instead of personal protective equipment.

Appendix C3.–Target boat speeds (miles per hour [mph]) for applying Prentox Fish Toxicant Powder for known lake depths and application rates to attain about 40 ppb rotenone concentration.

Water depth (ft)	Water volume[a]	Boat speed (mph)[b]
1	0.1	38.2
2	0.1	19.1
3	0.2	12.7
4	0.3	9.5
5	0.3	7.6
6	0.4	6.4
7	0.5	5.5
8	0.6	4.8
9	0.6	4.2
10	0.7	3.8
11	0.8	3.5
12	0.8	3.2
13	0.9	2.9
14	1.0	2.7
15	1.0	2.5
16	1.1	2.4
17	1.2	2.2
18	1.2	2.1
19	1.3	2.0
20	1.4	1.9
21	1.4	1.8
22	1.5	1.7
23	1.6	1.7
24	1.7	1.6
25	1.7	1.5

Note: Target treatment concentration was 0.80 ppm of rotenone product (40 ppb rotenone). It was assumed that the boat could apply 5.0 gallons of powdered formulation per minute.

[a] Water volume (acre-feet) in every 100 linear foot stretch of a 30 ft wide application swath.

[b] Boat speed is in miles per hour., At water depths less than 5 ft, target boat speed is impractically fast. In this case, applicators reduced product pumping rate so that boat speed could be reduced to a practical speed.

APPENDIX D: CALCULATING THE PROBABILITY OF FAILING TO DETECT NORTHERN PIKE WITH GILLNETTING EFFORTS

To quantify the netting effort necessary to detect a remnant surviving northern pike population of at least 4 fish with an estimated probability of detection of 80%, we utilized data from past northern pike removal experiments.

Between 2005 and 2010, ADF&G conducted 12 removal experiments with northern pike populations on the Kenai Peninsula using similar gillnetting methods. Data collected from these experiments included catch C_{ij} and effort E_{ij} (in units of net-hours per surface acre) for sample i where $i = 1,\ldots,s$ and experiment j where $j = 1,\ldots,12$. Populations were assumed to be closed except for captured fish, and fishing was assumed to represent a Poisson process with a constant probability of capture for all individuals. Data were analyzed using a hierarchical version of Leslie's regression method (Seber 1982):

$$CPUE_{ij} = K_j N_j - K_j C_{ij}^{*} \tag{D1}$$

where

$$CPUE_{ij} = {C_{ij}}/{E_{ij}} \tag{D2}$$

$$C_{ij}^{*} = \sum_{k=1}^{i\text{-}1} C_{kj} \text{ for } (i \text{ in } 2, \ldots, s+1) \text{ with } C_{1j}^{*} = 0 \tag{D3}$$

and

N_j = the initial population size in experiment j

K_j = average probability that a northern pike of any size is captured with 1 unit of effort during experiment j.

The probabilities of capture for each experiment are assumed to come from a common distribution: $K_j \sim \text{beta}(a, b)$.

The analysis was conducted using the RJAGS package (Plummer 2013) within R (R Development Core Team 2016). Noninformative priors were used for all parameters. Although Leslie's method is typically used to estimate the initial population size, our interest was in the posterior and predictive distributions of K for the purpose of estimating the probability of detecting small northern pike populations in future (new) removal experiments.

Percentiles from the predictive distribution for the value of K in a new removal experiment are listed as follows:

Percentile	Predicted K
5%	0.001
10%	0.003
50%	0.019
90%	0.055
95%	0.073

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The predictive distribution for a new removal experiment is shown in Figure D1.

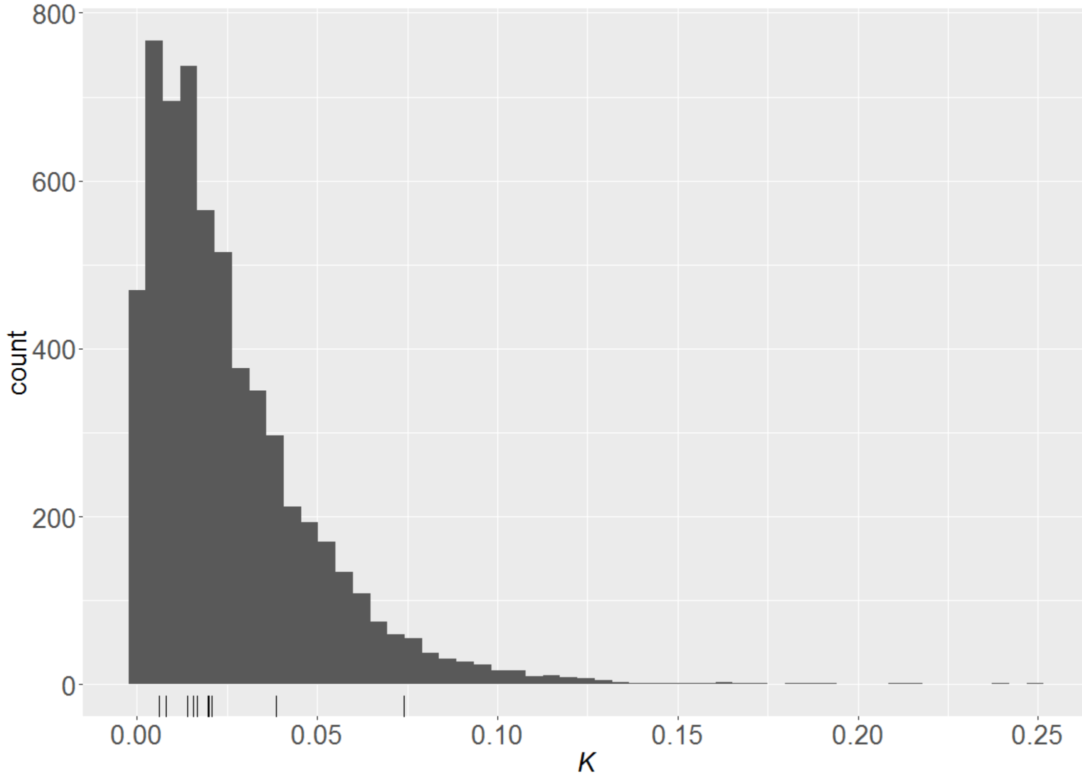

Figure D1.–Prediction distribution for K, the average probability a fish is captured in a new removal experiment with 1 unit of effort. Tick marks along the *x*-axis show the median values for *Kj*, the average probability a fish is captured with 1 unit of effort in each of the previous removal experiments.

Under the assumption that fishing represents a Poisson counting process, the probability of failing to detect a population of pike of size *N* as a function of net-hours per acre (*E*) is

$$D_p = \exp(-KE)^N$$

We used the median value of *K* (0.019 from the 50th percentile listed above) to calculate the probabilities listed in Table D1. The netting effort and associated probabilities found in Table D1 were used to satisfy precision criteria.

Table D1.–Probability of failing to detect a population of 4 northern pike with various levels of net density (nets per surface acre [sa]) and net hours.

	Net densities					
Netting hours	0.1 nets/sa	0.25 nets/sa	0.5 nets/sa	0.75 nets/sa	1 nets/sa	2 nets/sa
24 hours	0.829	0.626	0.392	0.246	0.154	0.024
48 hours	0.688	0.392	0.154	0.060	0.024	0.001
72 hours	0.570	0.246	0.060	0.015	0.004	0
96 hours	0.473	0.154	0.024	0.004	0.001	0

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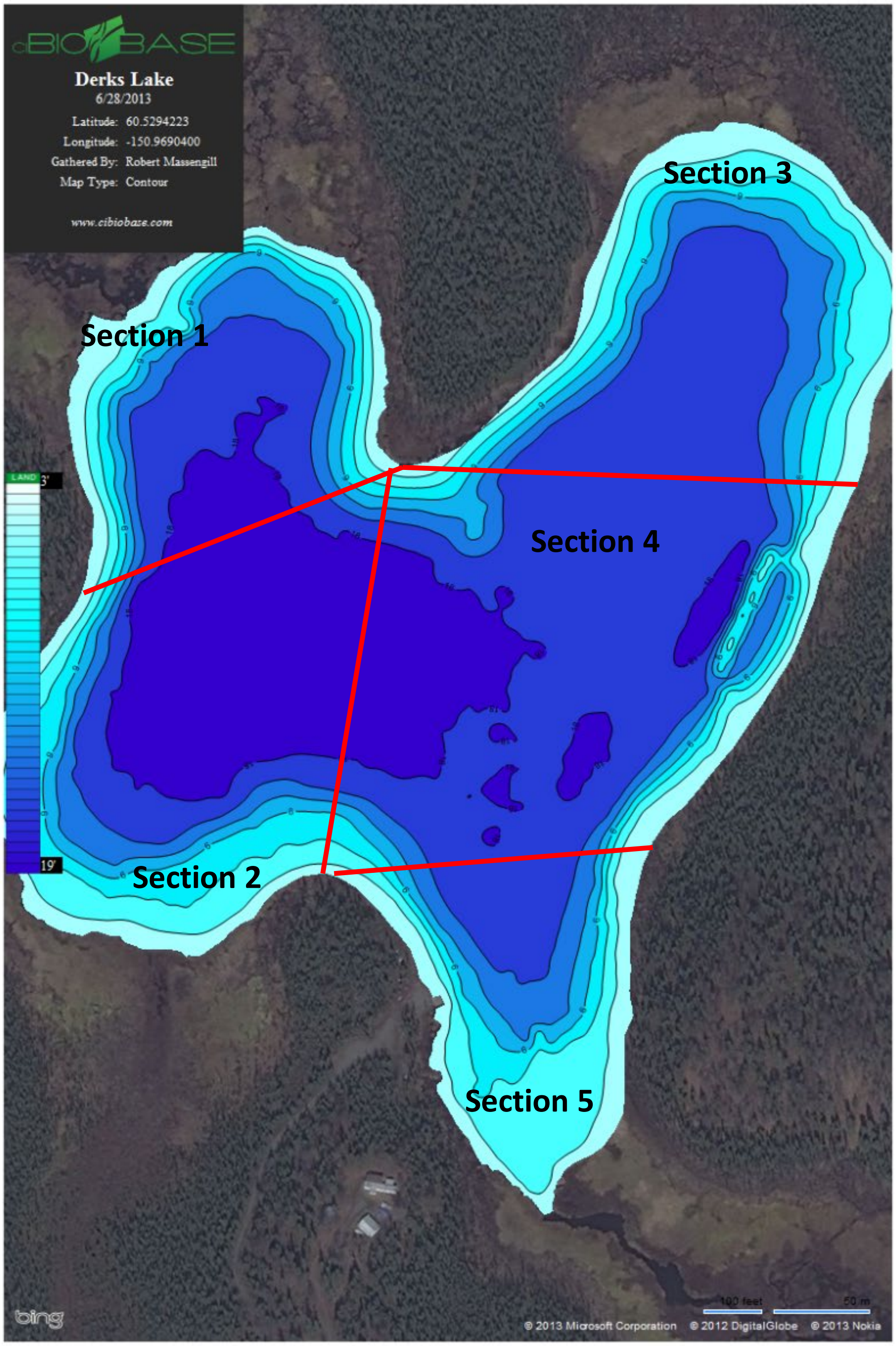
Gillnets used for northern pike surveys were identical to those used in the 12 removal experiments mentioned previously and the pretreatment northern pike removal activities. The gillnets were manufactured by Duluth Nets and made of single-strand monofilament mesh hung from a polypropylene floating line with the net bottom attached to 30 lb lead line. Each net was 120 ft long, 6 ft deep, with six 20 ft wide panels of size mesh (1 each of sequentially attached 0.5-inch, 0.625-inch, 0.75-inch, 1.0-inch, 1.5-inch, and 2.0-inch stretched mesh) all tied with #9 twine. Gillnets were deployed in vegetated littoral areas and fished continuously as practical.

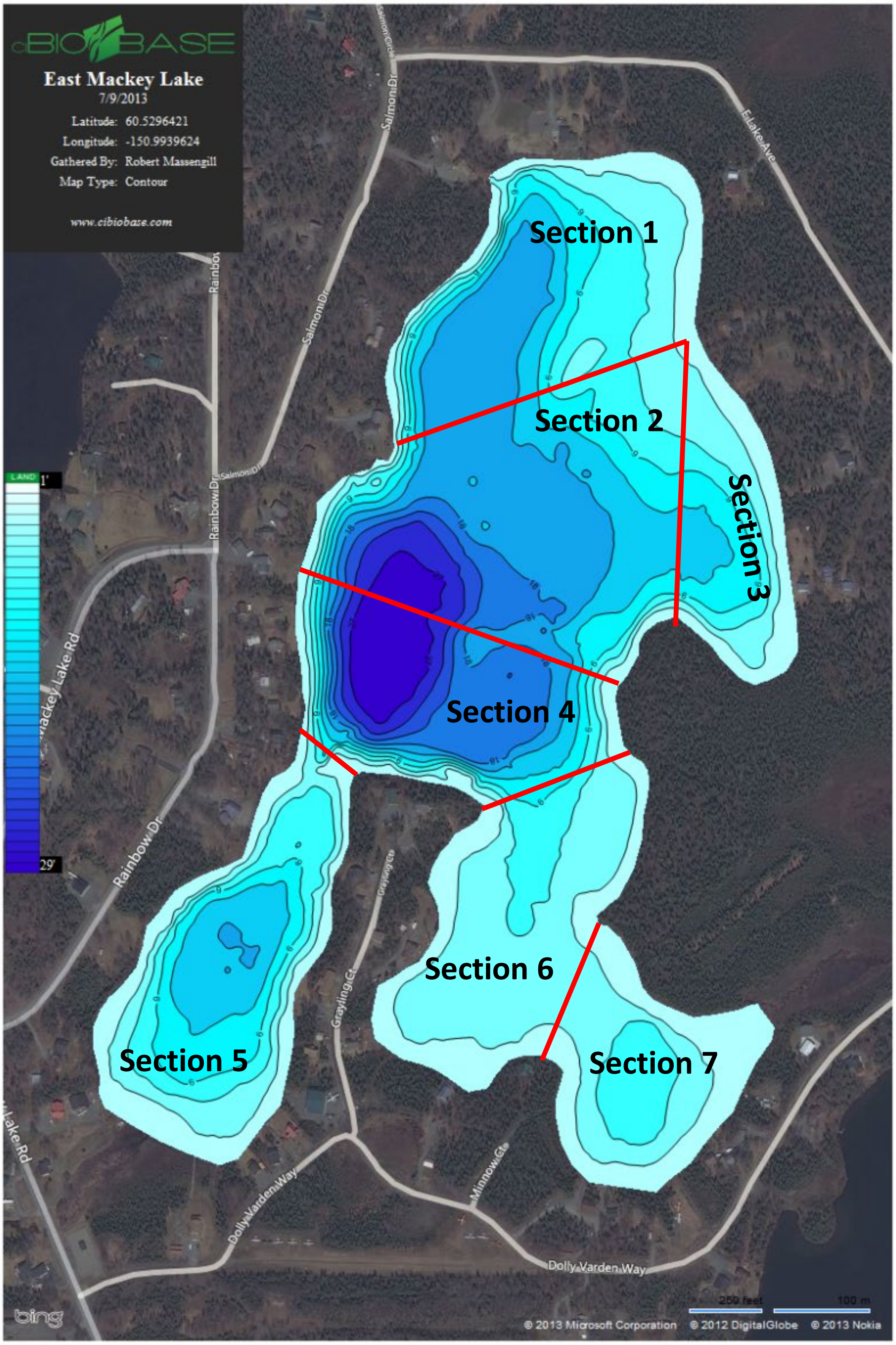
APPENDIX E: BATHYMETRIC LAKE MAPS

Appendix E1.–Bathymetric map of Derks Lake.



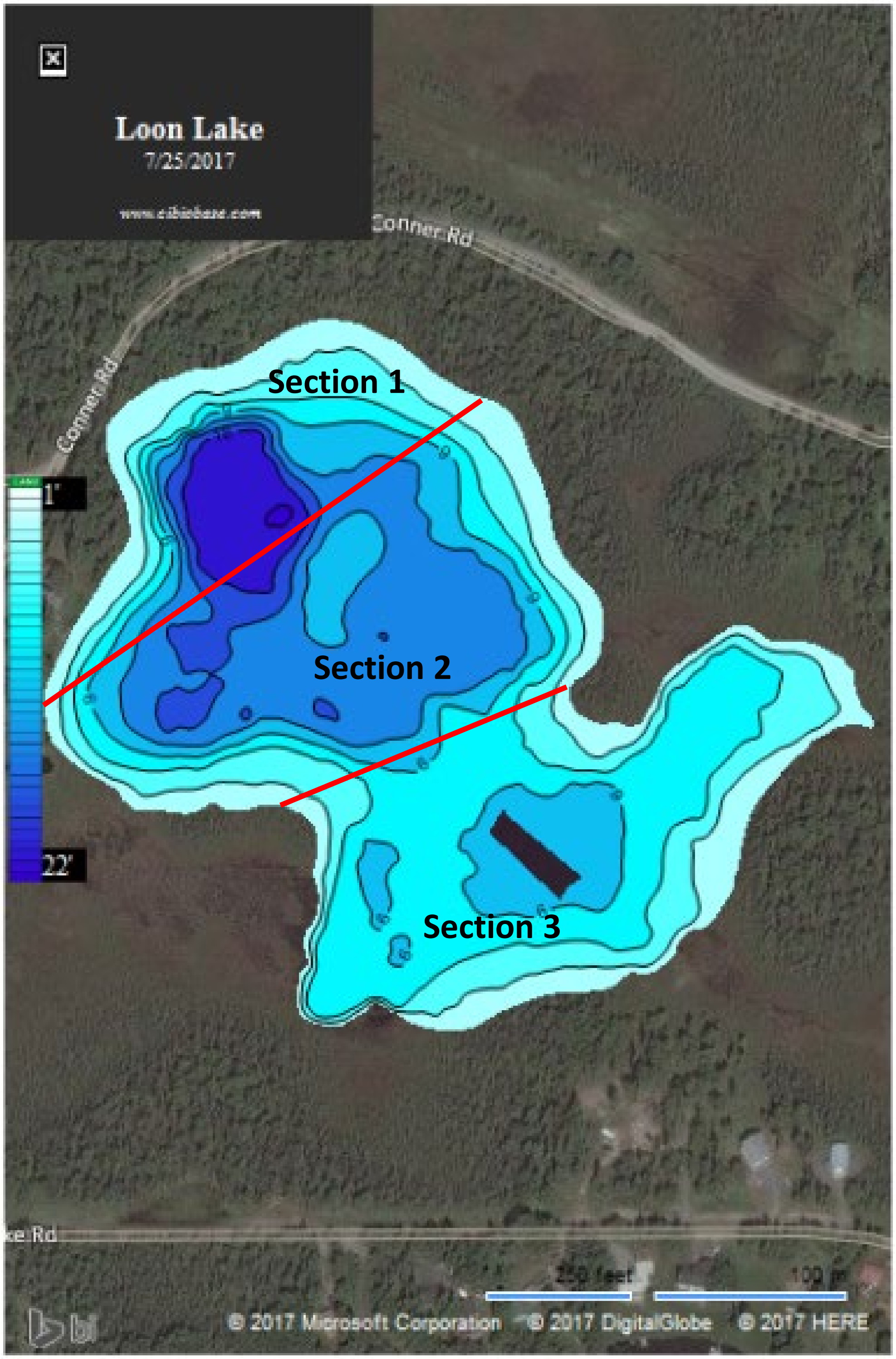
Note: Red lines delineate sections.

Appendix E2.–Bathymetric map of East Mackey Lake.



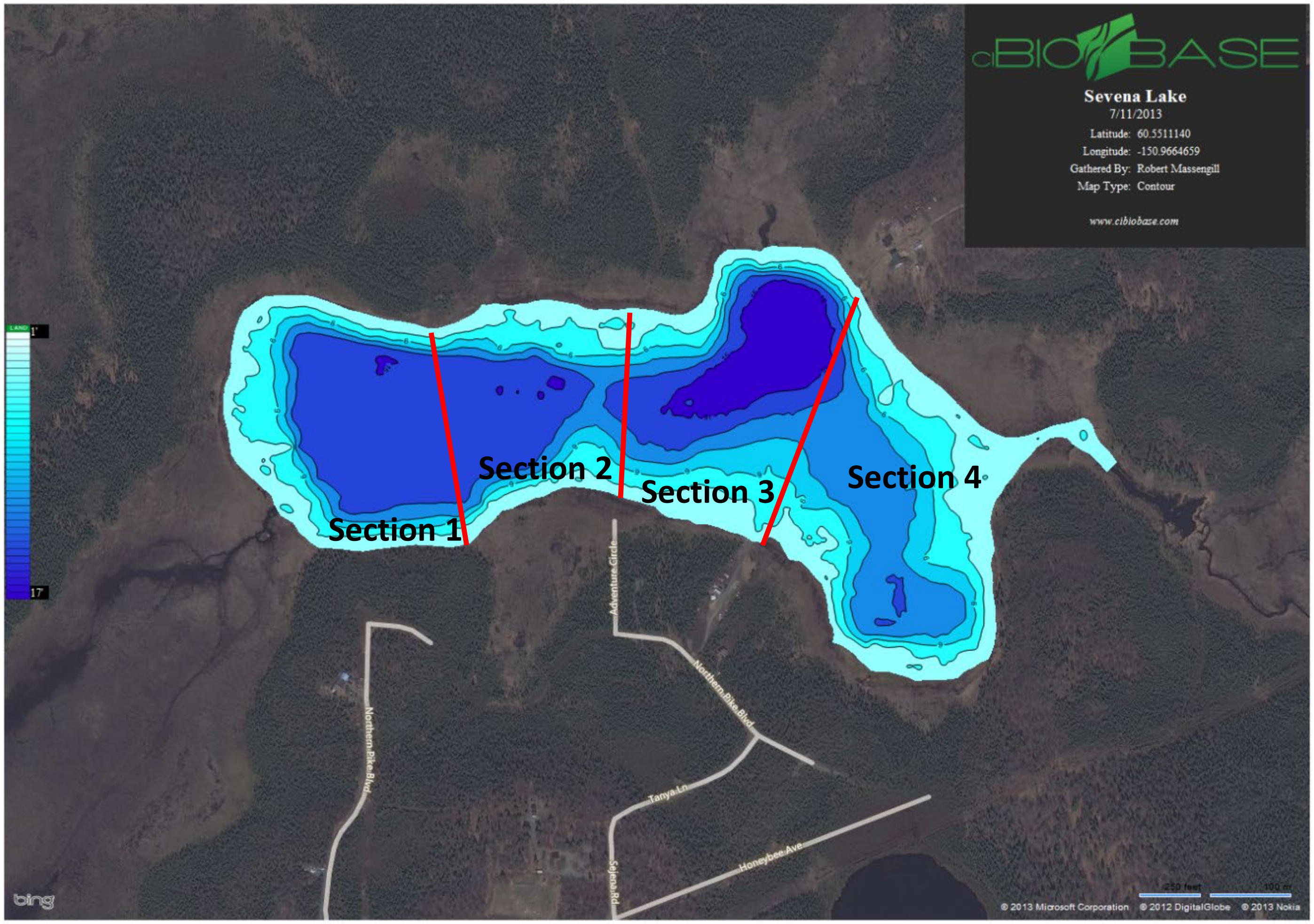
Note: Red lines delineate sections.

Appendix E3.–Bathymetric map of Loon Lake.



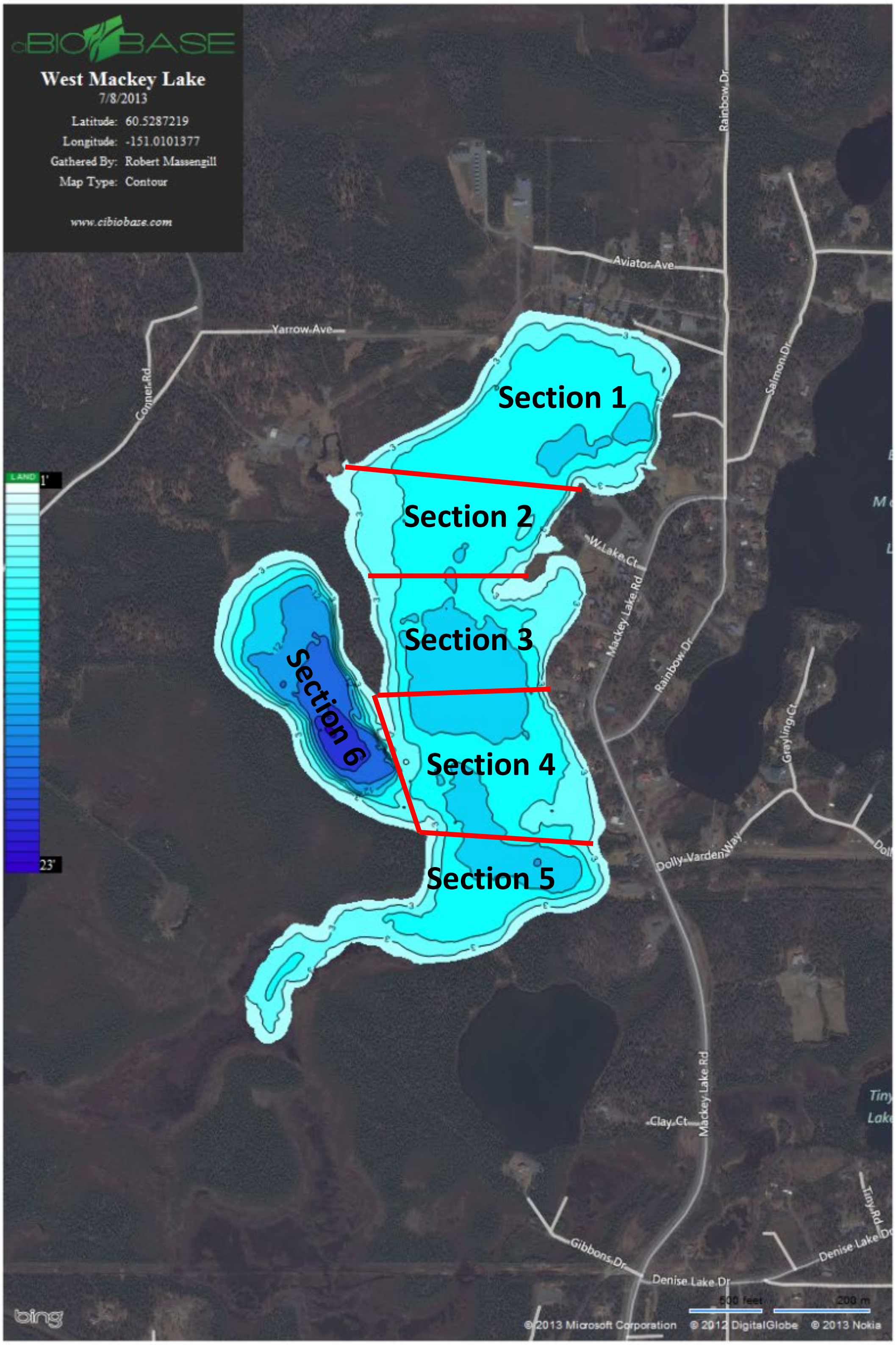
Note: Red lines delineate sections.

Appendix E4.–Bathymetric map of Sevena Lake.



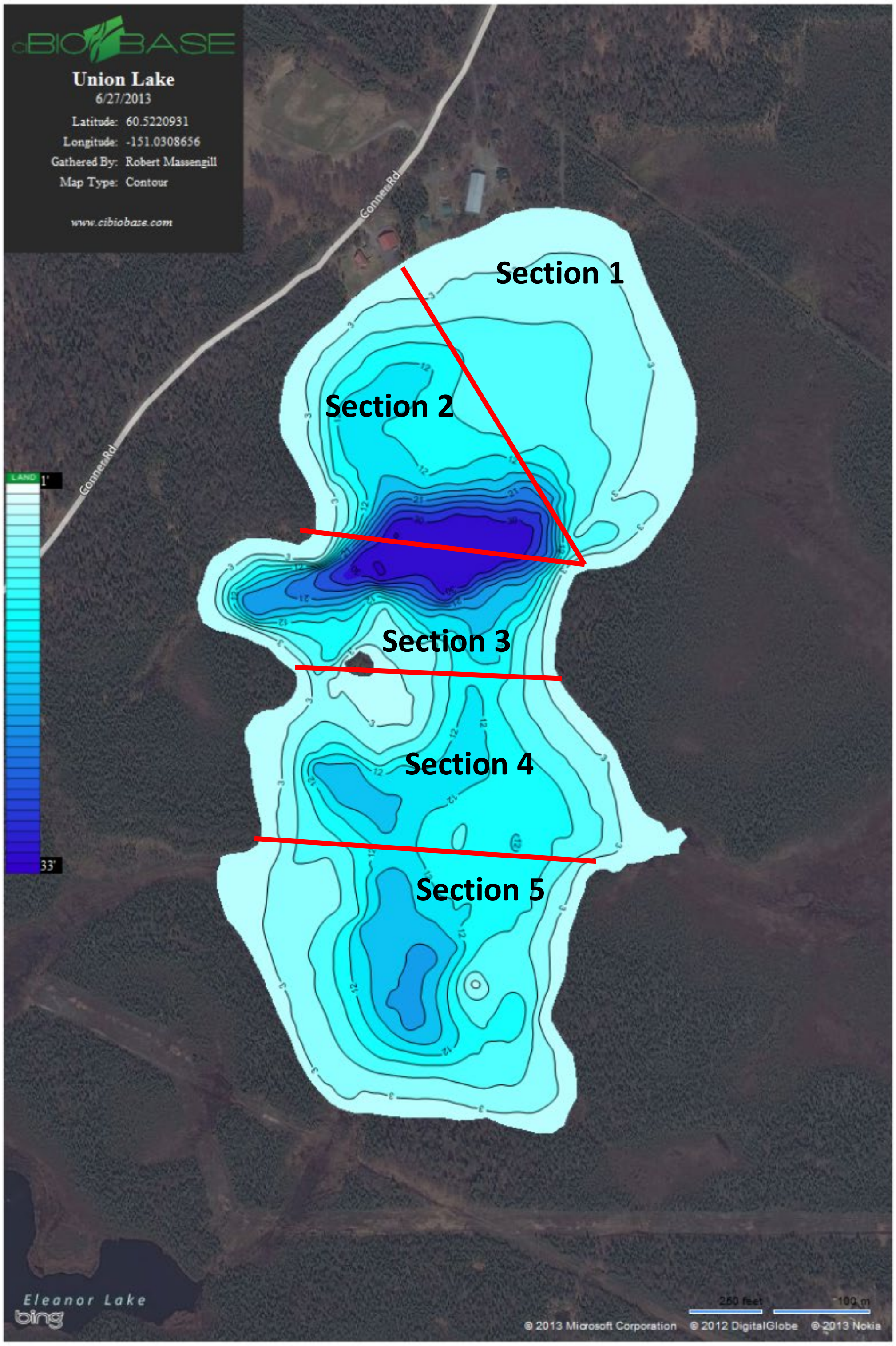
Note: Red lines delineate sections.

Appendix E5.–Bathymetric map of West Mackey Lake.



Note: Red lines delineate sections.

Appendix E6.–Bathymetric map of Union Lake.



Note: Red lines delineate sections.

APPENDIX F: DEACTIVATION STATION DATA

Appendix F1.–Derks Lake outlet creek deactivation data and sentinel fish status, October 2014–March 2015.

Date	Time	Derks Lake outlet creek temperature (°C)	Derks Lake outlet creek discharge (ft^3/s)	$KMNO_4$ feed rate (g/min)	$KMnO_4$ concentration (ppm)[a]	SFC[b] at mouth of Derks[c]	SFC[b] in upper Soldotna Creek[d]	SFC[b] in lower Soldotna Creek[e]	Comments
10/12/2014	12:00	4.5	0.05	18.0	NR	NR	NR	NR	Tested deactivation station
10/12/2014	18:00	6.0	.	0.0	.	2-G	2-G	None	
10/14/2014	17:30	.	.	0.0	.	2-G	2-G	None	Tested deactivation
10/15/2014	09:15	.	.	0.0	.	2-G	2-G	None	
10/15/2014	13:00	.	0.80	0.0	.	2-G	2-G	None	Edge ice forming on lakes
10/15/2014	16:00	.	.	0.0	.	1-I, 1-G	2-G	None	
Deactivation begins									
10/15/2014	19:00	4.0	.	14.0	.	2-I	2-I	None	Sentinel fish impaired, started deactivation at 19:30; replaced sentinel fish
10/15/2014	21:00	.	.	14.0	.	2-I	2-G	None	
10/16/2014	02:00	.	.	14.0	.	2-G	2-G	None	
10/16/2014	08:00	.	1.89	14.0	0.80	2-G	2-G	None	
10/17/2014	15:30	.	.	14.0	.	2-G	2-G	None	
10/17/2014	17:00	.	.	14.0	.	2-G	2-G	None	
10/18/2014	08:00	.	.	0.0	0.00	2-G	2-G	None	Stopped deactivation for a short period
10/18/2014	10:15	.	.	0.0	.	2-G	2-G	3-G	
10/18/2014	13:10	.	.	0.0	.	1-D, 1-I	2-G	3-G	
10/18/2014	15:15	5.5	.	0.0	.	2-G	2-G	3-G	
10/18/2014	18:00	.	.	0.0	.	2-I	2-I	3-G	
10/18/2014	19:00	.	.	14.0	.	2-G	2-G	3-G	Replaced sentinel fish
10/19/2014	08:00	.	.	14.0	0.40	2-G	2-G	NC	
10/20/2014	08:00	.	.	14.0	.	2-G	2-G	2-G	
10/21/2014	NR	.	2.10	14.0	.	2-G	2-G	2-G	
10/23/2014	NR	.	.	14.5	.	2-G	2-G	2-G	Lakes froze
10/24/2014	8:00	.	.	0.0	.	2-G	2-G	2-G	Deactivation found not running; length of outage unknown

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Date	Time	Derks Lake outlet creek temperature (°C)	Derks Lake outlet creek discharge (ft^3/s)	$KMNO_4$ feed rate (g/min)	$KMnO_4$ concentration (ppm)[a]	SFC[b] at mouth of Derks[c]	SFC[b] in upper Soldotna Creek[d]	SFC[b] in lower Soldotna Creek[e]	Comments
10/25/2014	08:20	.	.	0.0	.	1-D, 1-G	2-I	2-G	Deactivation found not running; length of outage unknown
10/25/2014	18:30	3.5	.	0.0	.	2-I	2-I	NC	Deactivation station intentionally shut down for a period
10/25/2014	21:30	.	.	0.0	.	2-I	2-I	2-G	Deactivation station intentionally shut down for a period
10/26/2014	03:45	.	.	14.5	.	NC	2-I	2-G	Deactivation station intentionally shut down for a period
10/26/2014	08:30	.	.	14.5	.	2-I	2-I	2-I	Started up deactivation station
10/26/2014	12:40	3.5	.	14.5	.	2-I	2-D	2-I	Replaced dead sentinel fish
10/27/2014	07:45	.	.	14.2	.	2-I	2-D	1-D, 1-G	Deactivation found not running; length of outage unknown, replaced sentinel fish
10/28/2014	20:00	3.0	0.95	18.0	1.07	2-G	2-G	3-G	
10/29/2014	NR	.	0.94	17.0	.	2-G	2-G	3-G	
10/30/2014	NR	.	.	17.0	.	2-G	2-G	3-G	
10/31/2014	16:00	.	0.93	17.0	.	2-I	2-I	3-G	Replaced only impaired fish
10/31/2014	15:34	3.0	.	16.7	1.42	NC	NC	NC	
11/01/2014	07:00	.	.	16.7	.	NC	NC	NC	
11/01/2014	17:30	3.0	0.94	17.2	1.87	NC	2-G	NC	
11/02/2014	08:30	3.0	0.93	16.6	.	2-G	2-G	1-D,2-G	Replaced sentinel fish
11/02/2014	15:40	3.5	.	.	2.58	NC	NC	NC	
11/03/2014	08:35	3.0	0.93	15.5	.	2-G	NC	NC	
11/03/2014	14:00	.	.	15.0	.	NC	2-G	NC	
11/03/2014	15:50	3.5	.	.	3.03	NC	NC	2-G	
11/04/2014	08:43	3.0	0.91	15.4	.	2-G	2-G	NC	Replaced sentinel fish
11/04/2014	15:35	3.5	.	15.2	1.89	NC	NC	2-G	

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Appendix F1.–Page 3 of 5.

Date	Time	Derks Lake outlet creek temperature (°C)	Derks Lake outlet creek discharge (ft^3/s)	$KMNO_4$ feed rate (g/min)	$KMnO_4$ concentration (ppm)[a]	SFC[b] at mouth of Derks[c]	SFC[b] in upper Soldotna Creek[d]	SFC[b] in lower Soldotna Creek[e]	Comments
11/05/2014	08:32	3.0	0.90	14.9	.	2-G	2-G	NC	
11/05/2014	13:00	.	.	.	.	.	.	.	
11/05/2014	15:15	3.5	.	.	1.01	NC	NC	NC	
11/06/2014	08:40	3.0	0.90	15.3	.	2-G	2-G	2-G	Replaced sentinel fish
11/06/2014	15:10	3.0	.	.	1.60	NC	NC	NC	
11/07/2014	08:35	.	.	.	.	NC	NC	NC	
11/07/2014	14:00	3.0	0.90	14.0	1.80	2-G	2-G	NC	
11/08/2014	08:00	.	.	.	.	NC	NC	NC	Replaced sentinel fish
11/08/2014	16:00	3.0	0.90	14.0	2.05	3-G, 1-I	2-G	2-G	
11/09/2014	08:17	3.5	0.92	14.2	.	4-G	2-G	2-G	
11/09/2014	15:35	3.5	.	7.0	1.62	NC	NC	NC	
11/10/2014	08:20	2.5	0.94	7.0	0.89	4-G	2-G	2-G	
11/10/2014	15:20	.	.	.	1.40	NC	NC	NC	
11/11/2014	08:30	3.0	0.94	6.0	.	2-G	2-G	2-G	Replaced sentinel fish
11/12/2014	15:15	3.0	.	.	0.89	NC	NC	NC	
11/12/2014	08:48	3.0	0.97	6.7	1.10	3-G	2-G	2-G	
11/12/2014	10:40	.	.	.	.	.	.	NC	
11/12/2014	15:45	.	.	.	.	3-G	2-G	NC	Deactivation stopped to test sentinel fish response
11/13/2014	06:25	.	.	.	.	3-G	2-G	NC	
11/13/2014	08:45	3.0	0.98	.	0.20	3-G	2-G	2-G	
11/13/2014	15:25	3.0	.	.	0.20	3-G	2-G	NC	
11/14/2014	08:00	.	0.93	.	.	3-G	2-G	NC	
Deactivation stops permanently									
11/16/2014	10:30	.	0.93	0.0	NR	3-G	2-G	NC	
11/17/2014	10:30	3.0	0.93	.	.	3-G	1-G, 1-D	2-G	Replaced fish, sandbag spillway blocked at Derks lake outlet
11/19/2014	09:38	3.0	0.92	.	.	3-G	2-G	2-G	Replaced sentinel fish
11/21/2014	09:30	3.0	0.92	.	.	3-G	2-G	2-G	Replaced sentinel fish

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Date	Time	Derks Lake outlet creek temperature (°C)	Derks Lake outlet creek discharge (ft^3/s)	$KMNO_4$ feed rate (g/min)	$KMnO_4$ concentration (ppm)[a]	SFC[b] at mouth of Derks[c]	SFC[b] in upper Soldotna Creek[d]	SFC[b] in lower Soldotna Creek[e]	Comments
11/24/2014	09:50	3.0	0.98	.	.	3-G	2-G	2-G	Replaced sentinel fish
11/26/2014	09:30	2.5	0.96	.	.	3-G	2-G	2-G	Only replaced sentinel fish at site 150 yards downstream of Derks outlet creek confluence
11/28/2014	09:46	2.5	0.92	.	.	3-G	2-G	2-G	Only replaced sentinel fish at site 150 yards downstream of Derks outlet creek confluence
12/02/2014	12:00	.	.	.	.	3-G	2-G	2-D	Dead fish apparently killed by sediment buildup. Pulled all sentinel cages except two cages at site 150 yards downstream of Derks creek confluence
12/05/2014	14:30	.	.	.	.	Removed cage	2-G, 1-I	Removed cage	One impaired fish, other two OK; 2 of 3 fish held for one week, impairment may be due to confinement.
12/09/2014	10:15	.	1.00	.	.		I-D, 1-G	.	Replaced sentinel fish
12/15/2014	12:00	.	0.90	.	.		I-G	.	Replaced sentinel fish
12/26/2014	13:00	.	0.82	.	.		3-G	.	
01/05/2015	11:30	.	.	.	.		1-D, 2-G	.	Stream discharge impossible due to ice conditions
01/14/2015	02:00	.	.	.	.		1 G	.	
01/15/2015	10:40	.	.	.	.		1-D	.	Replaced sentinel fish
01/20/2015	11:20	.	.	.	.		2-G	.	
01/28/2015	11:00	.	.	.	.		2-G	.	Replaced sentinel fish
02/02/2015	10:30	.	.	.	.		2-G; Removed cage	.	
04/03/2015	NR	.	.	.	.	.	.	.	Removed deactivation station from the field
Average rates during deactivation operation			1.0	11.3	1.3			.	

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Note: "NR" means not recorded. A period (.) also indicates data were not recorded but also assumes previous value in the column.

[a] Estimated stream $KMnO_4$ concentration (ppm) in Derks outlet creek below deactivation station.

[b] Sentinel fish condition (SFC) codes are provided in a number-letter format (e.g., 2-G, 1-I). Numbers reflect the number of fish, and letters reflect the condition of those fish where "G" is good, "I" is imparted, and "D" is dead. "None" indicates no fish were present. "NC" means fish not checked.

[c] Location at mouth of Derks outlet creek.

[d] Location in Soldotna Creek 100 yards downstream of the Derks outlet creek confluence.

[e] Location in Soldotna Creek 1.5 miles downstream of the Derks outlet creek confluence.

Appendix F2.–Soldotna Creek deactivation data and sentinel fish status, 26 June–4 July 2016.

Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
06/26/2016	22:02	10.6	NR	NR	NR	G	NR	NR
06/26/2016	23:37	11.2	.	.	.	G	.	.
06/27/2016	00:43	10.2	.	.	.	G	.	.
06/27/2016	02:01	9.8	.	.	.	G	.	.
06/27/2016	03:24	14.9	.	.	10.8	G	.	.
06/27/2016	04:36	10.7	1.07	.	10.8	G	.	.
06/27/2016	05:33	13.1	.	2.75	13.2	G	.	.
06/27/2016	06:10	13.5	.	2.75	11.8	G	.	.
06/27/2016	07:20	12.0	.	2.75	11.8	G	.	.
06/27/2016	08:30	12.3	.	2.75	11.8	G	.	.
06/27/2016	09:30	11.2	0.53	2.75	11.8	G	.	.
06/27/2016	10:45	14.8	.	2.63	12.2	G	.	.
06/27/2016	11:45	12.2	.	2.63	12.8	G	.	.
06/27/2016	12:45	12.6	.	2.63	13.0	G	.	.
06/27/2016	13:45	8.3	.	2.63	13.2	G	.	.
06/27/2016	14:45	12.1	.	2.51	14.0	G	.	.
06/27/2016	15:45	10.2	.	2.75	14.8	G	.	.
06/27/2016	16:45	12.4	0.35	2.63	15.0	G	.	.
06/27/2016	17:38	12.8	.	2.63	15.0	G	.	.
06/27/2016	18:45	13.3	.	2.62	15.0	G	.	.
06/27/2016	19:45	11.2	0.49	2.64	15.0	G	.	.
06/27/2016	20:45	10.9	0.62	2.58	14.8	G	.	.
06/27/2016	21:45	11.8	.	2.65	14.8	G	.	.
06/27/2016	23:01	11.6	.	.	14.0	G	.	.
06/28/2016	00:11	12.5	.	.	13.6	G	.	.
06/28/2016	01:30	9.6	.	.	13.0	G	.	.
06/28/2016	02:43	10.2	.	.	12.7	G	.	.
06/28/2016	04:40	17.4	5.34	.	12.5	SI	.	.
06/28/2016	05:48	11.5	.	.	12.8	SI	.	.
06/28/2016	07:00	10.4	.	2.50	12.0	G	.	.

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Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
06/28/2016	07:58	7.4	.	2.50	12.2	G	.	.
06/28/2016	10:50	11.0	.	.	13.0	G	.	.
06/28/2016	11:55	11.2	.	2.50	13.2	G	.	.
06/28/2016	13:45	6.4	0.53	2.50	14.8	G	G	G
06/28/2016	14:40	11.7	.	2.50	15.0	G	.	.
06/28/2016	15:40	9.7	.	2.55	15.0	SI	.	.
06/28/2016	16:20	41.5	.	2.50	15.0	I	.	.
06/28/2016	17:00	41.4	.	2.60	15.0	I	.	.
06/28/2016	18:30	43.2	.	2.62	15.0	D	.	.
06/28/2016	19:35	44.5	0.89	2.70	14.8	.	.	.
06/28/2016	20:22	50.9	.	2.75	15.0	D	G	G
06/28/2016	21:07	52.7	1.06	2.64	14.5	D	G	G
06/28/2016	22:03	52.1	1.60	2.56	14.0	.	G	.
06/28/2016	23:07	59.8	.	2.75	13.7	.	.	.
06/28/2016	00:00	52.7	.	2.75	13.6	.	G	.
06/29/2016	01:03	52.2	.	2.80	13.2	.	.	.
06/29/2016	02:05	53.6	.	2.40	12.8	.	.	.
06/29/2016	03:02	49.3	.	2.70	12.8	.	.	.
06/29/2016	04:01	48.7	.	2.60	12.6	.	.	.
06/29/2016	05:01	48.7	0.58	2.50	12.8	.	.	.
06/29/2016	05:49	52.1	.	2.60	12.8	.	.	.
06/29/2016	07:25	48.7	1.42	2.50	12.0	D	G	.
06/29/2016	07:35	46.4	.	.	.	.	.	.
06/29/2016	08:30	39.4	.	.	12.0	.	.	.
06/29/2016	09:30	49.5	1.33	.	12.2	.	.	.
06/29/2016	10:40	45.8	.	.	12.8	D	G	G
06/29/2016	12:30	39.5	1.60	2.50	13.0	D	G	G
06/29/2016	13:30	39.2	.	2.60	14.2	D	.	.
06/29/2016	14:30	42.0	0.98	2.58	14.1	D	.	.

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Appendix F2.–Page 3 of 7.

Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
06/29/2016	15:40	38.7	.	2.58	15.0	D	G	G
06/29/2016	16:40	42.6	.	2.60	15.0	D	.	.
06/29/2016	17:38	41.8	0.84	2.60	15.0	D	G	G
06/29/2016	18:30	41.7	.	2.50	15.5	D	G	G
06/29/2016	19:20	37.7	.	2.55	15.0	D	.	.
06/29/2016	20:45	39.4	.	2.50	15.0	D	.	.
06/29/2016	21:45	33.4	0.80	2.55	14.8	D	SI	G
06/29/2016	22:37	35.9	0.93	2.50	13.8	D	SI	G
06/30/2016	00:03	35.1	.	2.50	12.5	.	.	.
06/30/2016	01:07	34.2	.	2.50	13.2	.	.	.
06/30/2016	02:03	35.0	0.87	2.50	12.8	.	SI	G
06/30/2016	03:00	44.3	0.98	2.50	12.8	.	.	.
06/30/2016	04:30	38.7	.	2.50	12.5	.	.	.
06/30/2016	05:45	36.8	0.98	2.55	12.6	.	.	.
06/30/2016	06:50	41.2	.	2.50	12.2	.	.	.
06/30/2016	07:30	.	0.13	.	.	D	G	G
06/30/2016	08:30	38.5	.	.	12.6	.	.	.
06/30/2016	09:40	44.7	.	.	13.0	.	.	.
06/30/2016	11:45	46.7	1.15	2.50	13.8	.	G	G
06/30/2016	12:45	41.1	.	2.48	14.6	.	G	G
06/30/2016	13:40	40.9	.	2.50	14.6	.	G	G
06/30/2016	14:40	43.2	1.06	2.50	15.0	D	G	.
06/30/2016	15:30	43.2	.	2.48	16.0	D	G	.
06/30/2016	16:30	46.3	.	2.51	16.0	D	.	.
06/30/2016	17:25	48.6	0.98	2.50	16.0	D	.	.
06/30/2016	18:30	44.4	.	.	15.8	D	.	.
06/30/2016	19:30	40.8	.	.	15.5	D	.	.
06/30/2016	20:45	41.2	1.07	.	15.0	D	G	G
06/30/2016	21:20	47.6	.	.	14.8	.	.	.

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Appendix F2.–Page 4 of 7.

Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
06/30/2016	23:02	44.0	.	.	14.0	.	G	G
07/01/2016	00:03	41.1	.	.	13.8	.	.	.
07/01/2016	01:07	44.2	.	.	13.5	.	.	.
07/01/2016	02:05	39.5	.	.	13.3	.	.	.
07/01/2016	03:45	44.7	0.91	2.50	13.0	.	G	G
07/01/2016	05:15	38.5	.	.	12.8	.	.	.
07/01/2016	06:30	33.7	.	.	12.8	.	.	.
07/01/2016	07:40	38.8	.	.	12.6	.	.	.
07/01/2016	08:30	35.9	.	.	12.6	.	.	.
07/01/2016	09:00	.	1.33	.	.	.	G	.
07/01/2016	09:50	39.1	.	.	12.6	.	.	.
07/01/2016	09:50	32.8	.	.	12.8	.	.	.
07/01/2016	11:15	41.1	1.25	2.75	13.0	.	.	.
07/01/2016	13:00	39.4	.	2.75	13.0	.	G	G
07/01/2016	14:40	40.0	.	2.81	13.0	.	G	G
07/01/2016	15:40	39.6	1.06	2.75	13.0	.	G	G
07/01/2016	16:40	40.9	.	2.75	13.0	.	G	G
07/01/2016	18:40	48.5	.	3.80	13.0	.	.	.
07/01/2016	19:40	42.9	1.15	3.80	13.0	.	G	G
07/01/2016	20:40	38.0	.	3.80	13.0	.	G	G
07/01/2016	21:30	44.6	.	3.75	13.1	.	G	G
07/01/2016	21:54	39.1	1.10	.	12.8	.	G	G
07/01/2016	23:07	36.0	.	.	12.5	.	.	.
07/02/2016	00:02	37.2	.	.	12.3	.	.	.
07/02/2016	01:06	39.1	.	.	11.8	.	.	.
07/02/2016	02:14	37.3	.	.	11.8	.	.	.
07/02/2016	03:04	39.4	.	.	11.6	.	.	.
07/02/2016	04:07	36.1	1.02	.	11.8	.	G	G
07/02/2016	05:15	33.6	.	.	11.5	.	.	.

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Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
07/02/2016	06:30	33.7	.	.	11.8	.	.	.
07/02/2016	07:30	33.2	.	.	11.3	.	.	.
07/02/2016	09:00	.	1.25	2.8	.	.	G	G
07/02/2016	09:40	37.2	.	.	11.8	.	.	.
07/02/2016	10:45	37.4	.	.	12.0	.	G	G
07/02/2016	11:45	31.0	.	2.8	12.2	.	.	.
07/02/2016	12:40	38.8	1.06	2.8	12.8	.	G	G
07/02/2016	13:45	33.5	.	2.8	13.0	.	G	G
07/02/2016	14:40	40.7	.	2.8	13.0	.	G	G
07/02/2016	15:30	38.8	.	2.8	13.0	.	G	G
07/02/2016	16:45	40.6	1.06	2.8	13.0	.	G	G
07/02/2016	17:40	39.9	.	2.8	13.0	.	G	G
07/02/2016	18:40	41.4	.	2.8	13.0	.	.	.
07/02/2016	19:40	44.8	.	2.8	13.0	.	.	.
07/02/2016	21:00	40.6	0.97	2.8	12.5	.	G	G
07/02/2016	23:00	40.3	.	.	12.4	.	.	.
07/03/2016	00:37	39.7	1.23	.	12.0	.	G	G
07/03/2016	02:03	39.0	.	.	12.0	.	.	.
07/03/2016	03:02	42.7	.	.	11.7	.	G	G
07/03/2016	04:03	37.1	1.25	2.3	12.0	.	.	.
07/03/2016	05:00	36.7	.	.	.	.	.	.
07/03/2016	06:30	39.2	.	.	11.8	.	G	G
07/03/2016	07:30	42.2	.	3.00	11.8	.	.	.
07/03/2016	09:30	.	1.34	3.00	.	.	.	.
07/03/2016	09:55	31.9	.	.	11.8	.	.	.
07/03/2016	10:45	35.3	.	2.78	12.0	.	.	.
07/03/2016	11:45	39.2	.	.	12.4	.	G	G
07/03/2016	13:00	.	.	.	.	.	.	.
07/03/2016	13:15	34.4	.	.	12.8	.	G	G

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Appendix F2.–Page 6 of 7.

Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
07/03/2016	14:40	38.8	.	2.80	13.0	.	.	.
07/03/2016	15:40	38.8	1.06	2.80	13.3	.	.	.
07/03/2016	16:45	37.5	.	2.80	14.0	.	.	.
07/03/2016	17:40	35.4	.	2.80	14.0	.	G	G
07/03/2016	18:40	30.6	.	2.80	13.5	.	.	.
07/03/2016	19:40	36.1	0.89	2.80	13.5	.	.	.
07/03/2016	21:00	0.5	.	2.75	13.5	.	G	G
07/03/2016	23:00	32.2	.	.	13.0	.	.	.
07/04/2016	00:24	34.2	1.20	.	12.6	.	.	.
07/04/2016	02:12	27.3	.	.	12.8	.	.	G
07/04/2016	03:00	31.9	.	.	12.4	.	.	.
07/04/2016	04:21	32.5	.	.	12.2	.	.	.
07/04/2016	05:23	37.6	.	.	12.5	.	.	.
07/04/2016	06:45	28.2	1.25	.	12.0	.	.	.
07/04/2016	07:45	27.6	.	2.75	12.0	.	.	.
07/04/2016	08:35	28.9	.	.	12.0	G	G	G
07/04/2016	10:08	30.1	.	.	12.2	G	.	.
07/04/2016	11:15	22.0	.	.	12.2	G	.	.
07/04/2016	12:15	31.0	.	2.76	12.4	G	.	.
07/04/2016	12:30		1.10	.	.	G	G	G
07/04/2016	14:40	26.8	.	2.76	12.5	SI	G	G
07/04/2016	15:40	29.6	.	2.75	12.5	SI	.	.
07/04/2016	16:40	33.1	1.06	2.75	12.5	SI	.	.
07/04/2016	17:40	30.0	.	2.75	.	SI	.	.
07/04/2016	18:30	27.4	.	2.75	12.0	SI	.	.
07/04/2016	19:30	2.4	0.89	2.75	12.0	SI	.	.
07/04/2016	00:00		.	.	.	SI	.	.
07/04/2016	00:00		0.01	.	.	SI	G	G
07/04/2016	23:02		.	.	.	SI	G	G

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Date	Time	$KMNO_4$ feed rate (g/min)	$KMNO_4$ concentration in Soldotna Creek[a]	Stream gauge height (in)	Stream temperature (°C)	SFC in Soldotna Creek just above deactivation station[b]	SFC in Soldotna Creek mouth[b]	SFC in Kenai River downstream of Soldotna Creek mouth[b]
07/05/2016	00:33	.	0.01	.	.	SI	G	G
07/05/2016	01:05	.	.	.	.	SI	G	G
07/05/2016	02:01	.	0.00	.	.	SI	G	G
07/05/2016	03:21	.	.	.	.	SI	G	G
07/05/2016	05:01	.	0.00	.	.	G	G	G

Note: "NR" means not recorded. A period (.) also indicates data were not recorded but also assumes previous value in the column.

[a] Estimated $KMNO_4$ concentration in Soldotna Creek 400 yards below deactivation station (30 min stream travel distance).

[b] Sentinel fish condition (SFC) codes are provided in a number-letter format (e.g., 2-G, 1-I). Numbers reflect the number of fish, and letters reflect the condition of those fish where G is good, I is impaired, SI is severely impaired (barely moving or rolled), and D is dead.

APPENDIX G: FORK LENGTH MEASUREMENTS FROM A SAMPLE OF FISH COLLECTED FROM SOLDOTNA CREEK FOLLOWING ROTENONE APPLICATION

Appendix G1.–Fork lengths (FL) in millimeters by species from a random subsample of $N = 193$ fish collected by 8 fyke nets distributed throughout the Soldotna Creek during 27–30 June 2016.

	Individual fish lengths (mm)			
Individual or statistic	Coho salmon	Dolly Varden	Rainbow trout	Sculpin
Individual 1	51	71	17	40
Individual 2	55	72	63	50
Individual 3	60	85	70	55
Individual 4	60	86	73	55
Individual 5	65	87	74	60
Individual 6	65	89	74	65
Individual 7	65	89	76	65
Individual 8	65	90	80	65
Individual 9	65	91	80	70
Individual 10	68	92	80	70
Individual 11	69	93	81	70
Individual 12	70	98	81	70
Individual 13	70	100	82	75
Individual 14	70	100	82	75
Individual 15	70	102	82	85
Individual 16	70	102	83	85
Individual 17	71	103	83	NA
Individual 18	73	111	84	NA
Individual 19	73	112	85	NA
Individual 20	74	113	85	NA
Individual 21	74	113	85	NA
Individual 22	74	114	85	NA
Individual 23	75	116	85	NA
Individual 24	75	117	86	NA
Individual 25	75	118	86	NA
Individual 26	75	120	87	NA
Individual 27	75	120	88	NA
Individual 28	77	120	88	NA
Individual 29	78	120	88	NA
Individual 30	79	121	88	NA
Individual 31	80	126	89	NA
Individual 32	80	127	90	NA
Individual 33	80	130	90	NA
Individual 34	80	130	93	NA
Individual 35	80	130	94	NA
Individual 36	80	130	95	NA
Individual 37	82	136	97	NA
Individual 38	82	139	97	NA
Individual 39	83	140	97	NA
Individual 40	83	142	98	NA
Individual 41	84	142	98	NA
Individual 42	84	143	102	NA
Individual 43	85	148	102	NA
Individual 44	85	150	105	NA

-continued-

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	Individual fish lengths (mm)			
Individual or statistic	Coho salmon	Dolly Varden	Rainbow trout	Sculpin
Individual 45	85	155	106	NA
Individual 46	86	160	110	NA
Individual 47	86	178	120	NA
Individual 48	87	180	121	NA
Individual 49	88	280	125	NA
Individual 50	90	NA	135	NA
Individual 51	91	NA	137	NA
Individual 52	92	NA	139	NA
Individual 53	92	NA	141	NA
Individual 54	92	NA	142	NA
Individual 55	93	NA	152	NA
Individual 56	94	NA	160	NA
Individual 57	96	NA	164	NA
Individual 58	98	NA	186	NA
Individual 59	100	NA	188	NA
Individual 60	132	NA	217	NA
Individual 61	194	NA	222	NA
Individual 62	NA	NA	225	NA
Individual 63	NA	NA	255	NA
Individual 64	NA	NA	260	NA
Individual 65	NA	NA	265	NA
Individual 66	NA	NA	265	NA
Individual 67	NA	NA	280	NA
Total individuals	61	49	67	16
Average FL (mm)	81	121	117	66
SD FL (mm)	29.7	61.4	57.0	28.9
Maximum FL	194	280	280	85
Minimum FL	51	71	17	40

Note: "NA" means not applicable. Sculpin were not identified to species.

APPENDIX H: NATIVE FISH STOCKING AND ASSESSMENT DATA

Appendix H1.–Native fish released into Area 1, 2015–2018.

Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
Derks	8/14/2015	0	0	165	0	200	365
	9/2/2015	0	0	0	0	275	275
	9/3/2015	0	0	0	0	332	332
	9/4/2015	0	0	0	0	305	305
	9/8/2015	1	2	1	0	268	272
	9/9/2015	1	5	13	0	516	535
	9/10/2015	1	5	11	0	603	620
	9/11/2015	0	8	16	3	574	601
	9/15/2015	0	0	0	0	205	205
	9/22/2015	3	4	5	0	602	614
	9/25/2015	1	22	3	0	159	185
	9/30/2015	2	8	3	0	158	171
	10/3/2015	0	3	12	0	145	160
	10/20/2015	5	53	352	0	827	1,237
	10/23/2015	0	5	135	0	193	333
	10/29/2015	13	44	186	0	532	775
	11/2/2015	3	2	48	0	156	209
	11/24/2015	0	0	0	0	34	34
	11/25/2015	0	0	0	0	23	23
	2015 Subtotal	30	161	950	3	6,107	7,251
	4/14/2016	6	6	30	6	0	48
	5/3/2016	1	0	0	0	2	3
	5/20/2016	1	0	2,330	6	33	2,370
	6/24/2016	95	125	99	141	1,402	1,862
	6/25/2016	95	68	33	76	700	972
	9/13/2016	0	6	510	0	68	584
	9/19/2016	0	3	205	0	57	265
	9/26/2016	0	1	23	0	65	89
	9/29/2016	0	1	150	0	75	226
	10/5/2016	1	4	6	0	26	37
	10/7/2016	0	2	0	0	10	12
	10/10/2016	0	0	0	0	9	9
	10/19/2016	0	1	0	0	5	6
	2016 Subtotal	199	217	3,386	229	2,452	6,483
	9/15/2017	0	0	0	0	12	12
	10/12/2017	0	0	0	0	8	8
	10/30/2017	0	0	0	0	18	18
	2017 Subtotal	0	0	0	0	38	38
	2015–2017 Total	229	378	4,336	232	8,597	13,772

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Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
East Mackey	6/9/2015	0	0	130	0	0	130
	6/11/2015	0	0	150	0	0	150
	6/12/2015	0	0	130	0	0	130
	6/15/2015	0	0	200	0	0	200
	6/16/2015	0	0	1,120	2	0	1,122
	6/19/2015	0	0	750	0	0	750
	7/2/2015	1	0	450	0	0	451
	7/7/2015	0	0	600	0	0	600
	7/13/2015	11	0	600	0	0	611
	7/21/2015	37	28	3	89	168	325
	7/22/2015	8	10	0	20	80	118
	7/24/2015	3	4	551	25	0	583
	7/26/2015	0	0	650	0	0	650
	7/27/2015	9	21	2	1	47	80
	7/28/2015	18	21	13	45	73	170
	7/29/2015	33	17	0	61	76	187
	7/30/2015	18	44	1	37	110	210
	7/31/2015	17	48	2	72	198	337
	8/5/2015	68	18	0	180	119	385
	8/6/2015	12	2	0	46	110	170
	8/7/2015	17	3	0	59	119	198
	8/13/2015	10	2	0	31	65	108
	8/18/2015	20	30	0	46	51	147
	8/19/2015	7	19	2	13	31	72
	8/20/2015	10	1	0	130	72	213
	8/21/2015	9	25	6	21	60	121
	8/24/2015	3	10	0	10	11	34
	8/25/2015	13	20	1	30		64
	8/26/2015	7	21	0	21	6	55
	8/27/2015	24	22	1	21		68
	2015 Subtotal	355	366	5,362	960	1,396	8,439
	4/22/2016	2	1	0	2	0	5
	4/26/2016	5	1	1,410	0	0	1,416
	4/27/2016	6	0	1,400	2	0	1,408
	5/16/2016	3	13	0	8	40	64
	5/18/2016	1	0	1,010	2	60	1,073
	5/19/2016	9	16	2	19	70	116
	5/26/2016	5	2	0	5	50	62
	6/6/2016	72	83	7	11	1,405	1,578
	6/7/2016	76	70	41	44	664	895
	6/8/2016	154	101	65	71	1,511	1,902
	6/9/2016	191	121	90	85	1,398	1,885
	6/10/2016	172	76	78	190	1,366	1,882
	2016 Subtotal	696	484	4,103	439	6,564	12,286

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Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
East Mackey	(continued)						
	5/24/2017	0	0	0	0	29	29
	5/26/2017	2	49	0	0	81	132
	5/31/2017	16	105	0	0	134	255
	6/7/2017	5	14	0	0	76	95
	6/8/2017	0	10	0	0	202	212
	6/9/2017	0	40	0	0	139	179
	6/21/2017	14	26	0	0	208	248
	6/22/2017	18	16	0	0	115	149
	6/26/2017	1	92	0	0	105	198
	6/28/2017	0	8	0	0	19	27
	7/27/2017	12	6	0	0	302	320
	7/28/2017	6	12	0	0	181	199
	7/31/2017	11	14	0	0	135	160
	8/22/2017	5	18	0	0	360	383
	8/24/2017	8	26	0	0	420	454
	6/29/2018	78	0	0	0	0	78
	2017 Subtotal	176	436	0	0	2,506	3,118
	7/6/2018	26	0	0	0	0	26
	7/17/2018	18	0	0	0	0	18
	2018 Subtotal	220	436	0	0	2,506	3,162
	2015–2018 Total	1,447	1,722	9,465	1,399	12,972	27,005
Union	6/3/2015	5	5	29	2	0	41
	6/4/2015	7	1	36	2	0	46
	6/5/2015	0	7	62	2	0	71
	6/9/2015	1	12	9	2	0	24
	6/10/2015	18	1	8	3	0	30
	6/11/2015	8	2	5	6	0	21
	6/12/2015	11	12	5	21	0	49
	6/17/2015	19	24	18	6	0	67
	6/18/2015	6	8	8	16	0	38
	6/19/2015	30	26	2	20	0	78
	7/9/2015	0	0	600	0	0	600
	7/10/2015	16	16	350	28	42	452
	7/15/2015	31	29	0	65	52	177
	7/20/2015	0	0	750	0	0	750
	7/22/2015	0	0	550	0	0	550
	7/29/2015	0	0	550	0	0	550
	7/31/2015	0	0	550	0	0	550
	8/19/2015	0	1	0	0	125	126
	8/20/2015	0	0	0	0	130	130
	8/21/2015	0	0	0	0	100	100

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Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
Union	continued						
	8/25/2015	0	0	0	0	475	475
	8/26/2015	0	0	0	0	612	612
	8/27/2015	0	0	0	0	450	450
	10/14/2015	13	6	0	4	123	146
	10/15/2015	13	11	0	6	64	94
	10/16/2015	17	12	0	0	0	29
	2015 Subtotal	195	173	3,532	183	2,173	6,256
	5/23/2016	0	0	1,850	2	4	1,856
	5/25/2016	0	0	1,650	4	1	1,655
	5/27/2016	20	44	27	113	1,489	1,693
	5/31/2016	17	19	3	22	354	415
	6/1/2016	18	17	3	18	371	427
	6/2/2016	95	76	5	68	915	1,159
	6/3/2016	107	95	25	155	1,822	2,204
	9/14/2016	8	28	0	13	545	594
	9/15/2016	7	15	0	16	914	952
	9/16/2016	5	46	0	8	765	824
	9/22/2016	0	67	0	0	79	146
	2016 Subtotal	277	407	3,563	419	7,259	11,925
	8/1/2017	4	0	0	0	38	42
	8/2/2017	13	2	0	0	84	99
	8/3/2017	13	118	0	0	131	262
	8/7/2017	7	7	0	0	196	210
	8/10/2017	1	3	0	0	155	159
	2017 Subtotal	38	130	0	0	604	772
	10/2/2018	35	0	0	0	0	35
	2018 Subtotal	35	0	0	0	0	35
	2015–2018 Total	545	710	7,095	602	10,036	18,988
West Mackey	6/22/2015	5	2	850	1	0	858
	6/23/2015	26	27	31	4	0	88
	6/24/2015	13	8	601	26	0	648
	6/25/2015	41	31	15	15	8	110
	6/26/2015	14	18	802	36	11	881
	6/30/2015	20	5	750	5	41	821
	7/1/2015	4	5	0	8	0	17
	7/2/2015	45	29	2	65	85	226
	7/6/2015	13	18	0	15	26	72

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Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
West Mackey	continued						
	7/7/2015	16	10	0	42	76	144
	7/8/2015	17	20	0	35	152	224
	7/9/2015	11	16	0	24	0	51
	7/14/2015	2	0	0	18	12	32
	7/17/2015	0	0	1,100	1	0	1,101
	8/3/2015	0	0	600	0	0	600
	8/6/2015	0	0	400	0	0	400
	8/7/2015	0	0	400	0	0	400
	8/28/2015	11	18	1	0	0	30
	9/1/2015	13	13	0	8	130	164
	9/2/2015	13	15	0	24	10	62
	9/3/2015	13	32	0	17	45	107
	9/4/2015	23	24	0	17	69	133
	9/9/2015	3	43	0	8		54
	9/10/2015	10	30	0	3	16	59
	9/11/2015	9	23	1	11	10	54
	9/15/2015	10	22	0	5	10	47
	9/16/2015	1	21	0	2	82	106
	10/24/2015	16	7	0	9	121	153
	11/25/2015	5	0	0	0	0	5
	2015 Subtotal	354	437	5,553	399	904	7,647
	4/20/2016	1	0	710	0	0	711
	4/21/2016	1	0	630	2	0	633
	5/12/2016	1	0	1,220	0	130	1,351
	5/13/2016	0	0	870	0	2	872
	5/19/2016	9	5	1,950	5	51	2,020
	5/25/2016	7	16	42	6	99	170
	5/27/2016	23	39	1	19	141	223
	6/13/2016	64	15	70	18	362	529
	6/14/2016	173	64	65	109	1,066	1,477
	6/15/2016	148	94	242	143	1,144	1,771
	6/16/2016	110	71	219	210	958	1,568
	6/17/2016	148	62	90	212	853	1,365
	6/20/2016	39	18	8	3	227	295
	6/21/2016	69	51	51	39	494	704
	6/22/2016	77	109	114	88	800	1,188
	6/23/2016	122	108	112	158	1,175	1,675
	9/27/2016	0	6	5	0	90	101
	9/29/2016	6	60	0	0	108	174
	10/4/2016	27	68	0	21	838	954

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Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
West Mackey	continued						
	10/5/2016	16	37	0	9	561	623
	10/6/2016	2	25	0	14	547	588
	10/7/2016	2	23	2	6	544	577
	10/11/2016	14	17	0	0	274	305
	10/12/2016	12	31	0	0	482	525
	10/13/2016	6	39	0	0	461	506
	10/14/2016	5	14	0	0	534	553
	10/18/2016	3	23	0	0	685	711
	10/19/2016	3	32	0	0	501	536
	10/21/2016	0	7	0	0	261	268
	2016 Subtotal	1,088	1,034	6,401	1,062	13,388	22,973
	5/9/2017	0	1	0	0	65	66
	5/12/2017	0	1	0	0	25	26
	5/16/2017	0	0	0	0	85	85
	5/17/2017	0	0	0	0	24	24
	6/29/2017	6	14	0	0	107	127
	6/30/2017	9	4	0	0	182	195
	7/5/2017	5	46	0	0	253	304
	7/6/2017	11	31	0	0	91	133
	7/7/2017	9	14	0	0	110	133
	7/10/2017	9	37	0	0	119	165
	7/18/2017	13	10	0	0	86	109
	7/19/2017	5	3	0	0	146	154
	7/26/2017	21	33	0	0	263	317
	9/5/2017	0	0	0	0	80	80
	9/6/2017	1	15	0	0	85	101
	9/7/2017	30	8	0	0	109	147
	9/13/2017	6	15	0	0	125	146
	9/20/2017	23	56	0	0	425	504
	9/27/2017	24	92	0	0	298	414
	9/28/2017	6	28	0	0	178	212
	9/29/2017	15	147	0	0	459	621
	11/2/2017	10	1	0	0	59	70
	2017 Subtotal	203	556	0	0	3,374	4,133
	6/26/2018	136	0	0	0	0	136
	6/27/2018	101	0	0	0	0	101
	6/28/2018	99	0	0	0	0	99
	6/29/2018	62	0	0	0	0	62
	7/18/2018	71	0	0	0	0	71

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Lake	Collection date[a]	Rainbow trout	Dolly Varden	Stickleback	Sculpin	Coho salmon	All species
West Mackey	(continued)						
	8/2/2018	8	0	0	0	0	8
	8/3/2018	38	0	0	0	0	38
	8/6/2018	87	0	0	0	0	87
	8/7/2018	27	0	0	0	0	27
	8/13/2018	4	0	0	0	0	4
	8/14/2018	24	0	0	0	0	24
	9/13/2018	22	0	0	0	0	22
	2018 Subtotal	679	0	0	0	0	679
	2015–2018 Total	2,324	2,027	11,954	1,461	17,666	35,432
All lakes	2015–2018 Total	4,545	4,837	32,850	3,694	49,271	95,197

Note: Juvenile salmonids were collected primarily from the mainstem of Soldotna Creek and stickleback were collected mostly from Sevena Lake. The majority of fish were collected by minnow trapping but other collection gear used included backpack electrofishing and fyke net traps. Stickleback and sculpin were not identified to species.

[a] The collection date indicates date of capture; date of release into Area 1 varied from immediately after capture to 1 week later.

Appendix H2.–Soldotna Creek drainage minnow trapping survey data, 2011–2018.

Species	Trapping site	Trapping period and catch (CPUE)[a]						Change in CPUE as an index of relative abundance	
		Oct 2010	May 2011	Jul 2011	Sep 2011	Jul–Aug 2018	Sep 2018	Change in summer CPUE[b]	Change in fall CPUE[c]
Rainbow trout									
	Soldotna Creek#1 DN	17	0	0	6	3	1	3	-5
	Soldotna Creek#1 UP	8	1	3	0	1	4	-2	4
	Soldotna Creek#2 DN	8	5	0	0	13	3	13	3
	Soldotna Creek#2 UP	6	3	6	14	1	8	-5	-6
	Soldotna Creek#3 DN	3	2	1	7	7	2	6	-5
	Soldotna Creek#3 UP	5	2	0	0	5	4	5	4
	Soldotna Creek#4 DN	8	2	2	6	1	0	-1	-6
	Soldotna Creek#4 UP	0	1	2	3	1	0	-1	-3
	Soldotna Creek#5 DN	1	0	0	1	0	0	0	-1
	Soldotna Creek#5 UP	3	0	0	0	0	0	0	0
	Soldotna Creek#6 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#6 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#7 DN	0	0	0	0	1	0	1	0
	Soldotna Creek#7 UP	8	0	0	0	0	0	0	0
	Soldotna Creek#8 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#8 UP	0	0	0	0	0	0	0	0
	Drainagewide total	67	16	14	37	33	22	19	-15
Dolly Varden									
	Soldotna Creek#1 DN	11	6	0	1	1	2	1	1
	Soldotna Creek#1 UP	4	0	4	9	8	2	4	-7
	Soldotna Creek#2 DN	5	0	1	3	3	0	2	-3
	Soldotna Creek#2 UP	1	8	0	0	0	5	0	5
	Soldotna Creek#3 DN	2	1	3	9	22	4	19	-5
	Soldotna Creek#3 UP	28	4	1	3	1	1	0	-2
	Soldotna Creek#4 DN	0	0	6	9	1	0	-5	-9
	Soldotna Creek#4 UP	1	0	7	2	2	0	-5	-2
	Soldotna Creek#5 DN	4	0	3	3	0	0	-3	-3
	Soldotna Creek#5 UP	3	0	1	1	0	0	-1	-1
	Soldotna Creek#6 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#6 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#7 DN	0	1	0	0	0	0	0	0
	Soldotna Creek#7 UP	12	0	0	0	0	0	0	0
	Soldotna Creek#8 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#8 UP	0	0	0	0	0	0	0	0
	Drainagewide total	71	20	26	40	38	14	12	-26

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Species	Trapping site	Trapping period and catch (CPUE)[a]						Change in CPUE as an index of relative abundance	
		Oct 2010	May 2011	Jul 2011	Sep 2011	Jul–Aug 2018	Sep 2018	Change in summer CPUE[b]	Change in fall CPUE[c]
Coho salmon									
	Soldotna Creek#1 DN	0	0	12	0	9	2	-3	2
	Soldotna Creek#1 UP	4	0	36	6	36	24	0	18
	Soldotna Creek#2 DN	10	1	4	1	30	4	26	3
	Soldotna Creek#2 UP	0	0	14	9	3	5	-11	-4
	Soldotna Creek#3 DN	2	0	2	2	8	1	6	-1
	Soldotna Creek#3 UP	0	0	0	3	3	1	3	-2
	Soldotna Creek#4 DN	8	12	8	17	8	0	0	-17
	Soldotna Creek#4 UP	14	8	10	14	6	0	-4	-14
	Soldotna Creek#5 DN	22	7	5	14	9	0	4	-14
	Soldotna Creek#5 UP	21	9	6	24	16	0	10	-24
	Soldotna Creek#6 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#6 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#7 DN	32	16	7	14	5	0	-2	-14
	Soldotna Creek#7 UP	62	26	13	17	0	0	-13	-17
	Soldotna Creek#8 DN	0	0	2	2	0	0	-2	-2
	Soldotna Creek#8 UP	0	4	0	1	8	0	8	-1
	Drainagewide total	175	83	119	124	141	37	22	-87
Chinook salmon									
	Soldotna Creek#1 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#1 UP	0	0	0	3	0	0	0	-3
	Soldotna Creek#2 DN	1	0	0	0	0	0	0	0
	Soldotna Creek#2 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#3 DN	0	0	0	7	0	0	0	-7
	Soldotna Creek#3 UP	0	0	0	1	0	0	0	-1
	Soldotna Creek#4 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#4 UP	1	0	0	1	0	0	0	-1
	Soldotna Creek#5 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#5 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#6 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#6 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#7 DN	0	0	0	0	7	0	7	0
	Soldotna Creek#7 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#8 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#8 UP	0	0	0	0	0	0	0	0
	Drainagewide total	2	0	0	12	7	0	7	-12

-continued-

Appendix H2.–Page 3 of 3.

Species	Trapping site	Trapping period and catch (CPUE)[a]						Change in CPUE as an index of relative abundance	
		Oct 2010	May 2011	Jul 2011	Sep 2011	Jul–Aug 2018	Sep 2018	Change in summer CPUE[b]	Change in fall CPUE[c]
Stickleback (unspecified)									
	Soldotna Creek#1 DN	0	0	0	0	0	1	0	1
	Soldotna Creek#1 UP	0	0	0	0	3	1	3	1
	Soldotna Creek#2 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#2 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#3 DN	0	0	0	0	0	1	0	1
	Soldotna Creek#3 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#4 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#4 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#5 DN	0	0	0	2	1	0	1	-2
	Soldotna Creek#5 UP	0	0	0	1	0	0	0	-1
	Soldotna Creek#6 DN	1	0	0	7	1	0	1	-7
	Soldotna Creek#6 UP	0	0	1	2	0	0	-1	-2
	Soldotna Creek#7 DN	1	27	6	0	52	0	46	0
	Soldotna Creek#7 UP	2	102	3	4	0	0	-3	-4
	Soldotna Creek#8 DN	0	1	0	0	3	0	3	0
	Soldotna Creek#8 UP	0	0	3	0	17	0	14	0
	Drainagewide total	4	130	13	16	77	3	64	-13
Sculpin (unspecified)									
	Soldotna Creek#1 DN	0	0	0	0	0	3	0	3
	Soldotna Creek#1 UP	0	0	0	1	0	0	0	-1
	Soldotna Creek#2 DN	0	0	0	0	1	2	1	2
	Soldotna Creek#2 UP	0	0	0	3	6	1	6	-2
	Soldotna Creek#3 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#3 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#4 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#4 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#5 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#5 UP	0	0	0	0	1	0	1	0
	Soldotna Creek#6 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#6 UP	0	0	0	0	1	0	1	0
	Soldotna Creek#7 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#7 UP	0	0	0	0	0	0	0	0
	Soldotna Creek#8 DN	0	0	0	0	0	0	0	0
	Soldotna Creek#8 UP	0	0	0	0	0	0	0	0
	Drainagewide total	0	0	0	4	9	6	9	2

Note: Refer to Figure 14 for numbered trap locations. “DN” and “UP” indicate the downward and upward triangles, respectively.

[a] All minnow traps were fished for (30 minutes) at each location. Because effort was standardized, the values for catch and CPUE are equal. For example, if the coho salmon catch at a site was 7, then CPUE = 7 because 1 unit of time = 30 minutes.

[b] July 2018 CPUE minus July 2011 CPUE.

[c] September 2018 CPUE minus September 2011 CPUE.