Special Publication No. 17-18

Stormy Lake Restoration: Invasive Northern Pike Eradication, 2012

by

Rob Massengill

December 2017

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. 17-18

STORMY LAKE RESTORATION: INVASIVE NORTHERN PIKE ERADICATION, 2012

by
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ABSTRACT

In 2001, the Alaska Department of Fish and Game (ADF&G) verified a population of invasive northern pike in Stormy Lake, a tributary of the Swanson River drainage near Nikiski. ADF&G treated Stormy Lake and its outlet creek with rotenone in September 2012 to eradicate the northern pike population. Prior to treatment, representative native fish were collected from Stormy Lake and held in net pens at Wik Lake for restocking purposes. Arctic char brood stock from Stormy Lake and Dolly Varden Lake provided gametes to produce Arctic char fingerlings used for restocking Stormy Lake. To assess the treatment's effectiveness, ADF&G monitored the fates of 13 free-roaming radiotagged northern pike in Stormy Lake, observed the fates of caged sentinel fish during the treatment, conducted gillnet surveys, and monitored the concentration and persistence of rotenone in Stormy Lake. Collectively, the results of the assessments suggest the treatment was successful at removing the northern pike population. The rotenone in Stormy Lake fully degraded by 21 January 2013, about 4 months after being applied. Native fish held in offsite net pens were reintroduced to Stormy Lake on 1 March 2013, and 6,836 hatchery-reared Arctic char fingerlings were stocked in Stormy Lake on 17 June 2013. Water quality sampling in Stormy Lake indicated similar water quality characteristics before and after treatment. Invertebrate diversity in Stormy Lake remained similar between pre- and posttreatment surveys. A netting survey in May of 2014 revealed native salmonid populations were recovering.

Key words: Kenai Peninsula, Stormy Lake, rotenone, northern pike, Arctic char, chemical treatment, restoration, invasive species, eradication, Swanson River

INTRODUCTION

The northern pike (*Esox lucius*) is native to Alaska north and west of the Alaska Range and near Yakutat to the southeast. Northern pike do not naturally occur in Southcentral Alaska (Figure 1) and were first recorded there from an illegal introduction into Bulchitna Lake in the Yentna River drainage in the 1950s (ADF&G 2007). Northern pike on the Kenai Peninsula are believed to have originated from an illegal introduction to the Soldotna Creek drainage (a Kenai River Tributary) during the 1970s and quickly spread by natural dispersion and additional introductions (McKinley 2013; anonymous report[1]).

Northern pike are considered an aquatic nuisance species in southcentral Alaska because they are nonnative to the region and their introduction can cause economic and environmental harm (Fay 2002). Northern pike have been implicated in the decline of localized salmonid abundance in southcentral Alaska (McKinley 2013; Rutz 1999) and may prefer soft-finned juvenile salmonids over other available prey species (Rutz 1996, 1999). Consumption of native juvenile salmonids by introduced northern pike has also been observed elsewhere in the northwestern United States (McMahon and Bennett 1996; Muhlfeld et al. 2008; Rich 1992; Schmetterling 2001). In southcentral Alaska, northern pike prey may be particularly vulnerable to predation because they evolved in the absence of these predators. In interior Alaska, northern pike share an evolutionary history with their prey, which have evolved adaptations for predator avoidance (Oswood et al. 2000).

The Kenai Peninsula is one of the premier sport fishing areas in Alaska, receiving over 479,000 freshwater angler-days in 2012 and representing 44% of the total freshwater sport fishing effort in Alaska[2].

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

2 Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited September 19, 2019). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

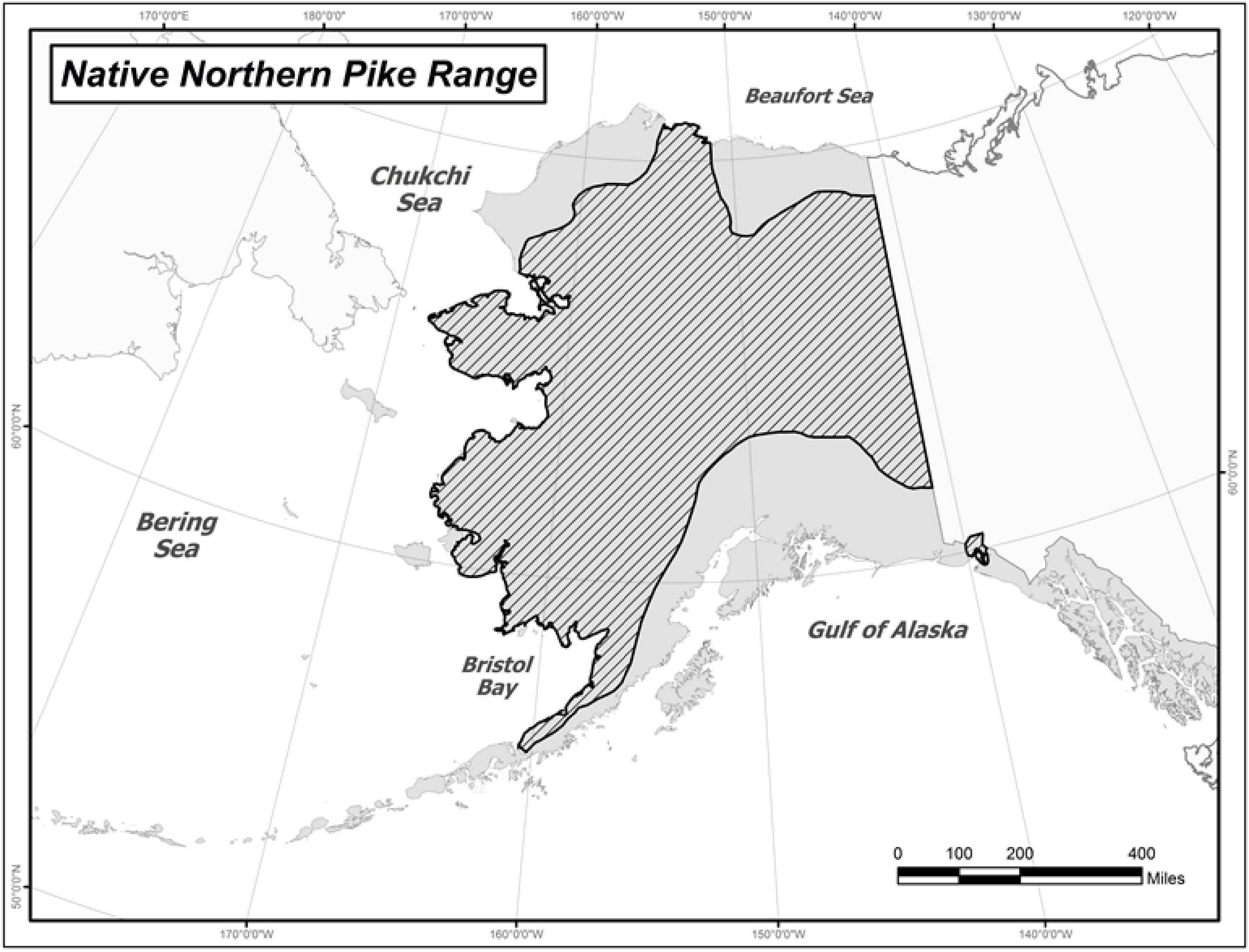

Figure 1.–Native range of northern pike (*Esox lucius*) in Alaska.

Since the 1970s, a total of 24 waterbodies on the Kenai Peninsula have had confirmed northern pike populations (Figure 2). Excluding Stormy Lake, northern pike were eradicated from all of these waterbodies except 8 in the Tote Road area. The first two eradication projects were at Arc Lake and Scout Lake using rotenone in 2008 and 2009 respectively (Massengill 2014a, 2014b). All waters in the Soldotna Creek drainage with northern pike, including the creek itself, were restored between 2011 and 2017 by either removing northern pike with rotenone (8 waterbodies) or gillnets (1 waterbody) with the exception that 2 waterbodies (Denise and Tree lakes) had northern pike populations that disappeared by unknown means prior to 2011 (Unpublished data, ADF&G Soldotna Office). Northern pike were also removed via intensive gillnetting from Hall Lake (2011) and Warfle Lake in 2017 (unpublished data, ADF&G Soldotna Office). Stormy Lake is located near Nikiski and northern pike were first confirmed there in 2001 (Begich and McKinley 2005). The presence of northern pike at Stormy Lake could pose a serious threat to the wild fisheries of the Swanson River drainage should they disperse from the lake. Stormy Lake drains into the Swanson River via a 1,200 m outlet steam (Figure 3). A net barrier at the outlet of Stormy Lake was maintained by ADF&G since 2001 to reduce the chance that northern pike leave the lake.

The Swanson River drainage is considered highly vulnerable to northern pike infestation because suitable northern pike habitat is prevalent and prey resources are available. The Swanson River drains a large portion of the Kenai National Wildlife Refuge and is well known for its popular wild coho salmon (*Oncorhynchus kisutch*) and rainbow trout (*O. mykiss*) fisheries. Annual coho salmon escapement to the Swanson River can exceed 20,000 fish (Jones et al. 1993). The 2011 ADF&G Statewide Harvest Survey[2] (SWHS) estimated that 3,922 angler-days were expended in the Swanson River resulting in a catch of 650 rainbow trout and 1,348 coho salmon (Jennings et al. 2015). Both species often rear in shallow, slow-moving waters that also serve as preferred habitat for northern pike (Mecklenburg et al. 2002). This habitat type is characteristic of the Swanson River drainage. Both salmon and rainbow trout fisheries have severely declined in similar habitats heavily impacted by northern pike such as Alexander Creek in the Matanuska–Susitna Valley (Oslund et al. 2013).

Invasive northern pike appear to have severely reduced some populations of native fish inhabiting Stormy Lake including rainbow trout, Arctic char (*Salvelinus alpinus*), and coho salmon. Other species that exist in Stormy Lake include longnose sucker (*Catostomus catostomus*), Slimy sculpin (*Cottus cognatus*), threespine stickleback (*Gasterosteus aculeatus*) and lamprey (Petromyzontidae). Additional native fish species found elsewhere in the Swanson River drainage include sockeye salmon (*O. nerka*), Chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), eulachon (*Thaleichthys pacificus*), and Dolly Varden (*S. malma*) (Jones et al. 1993).

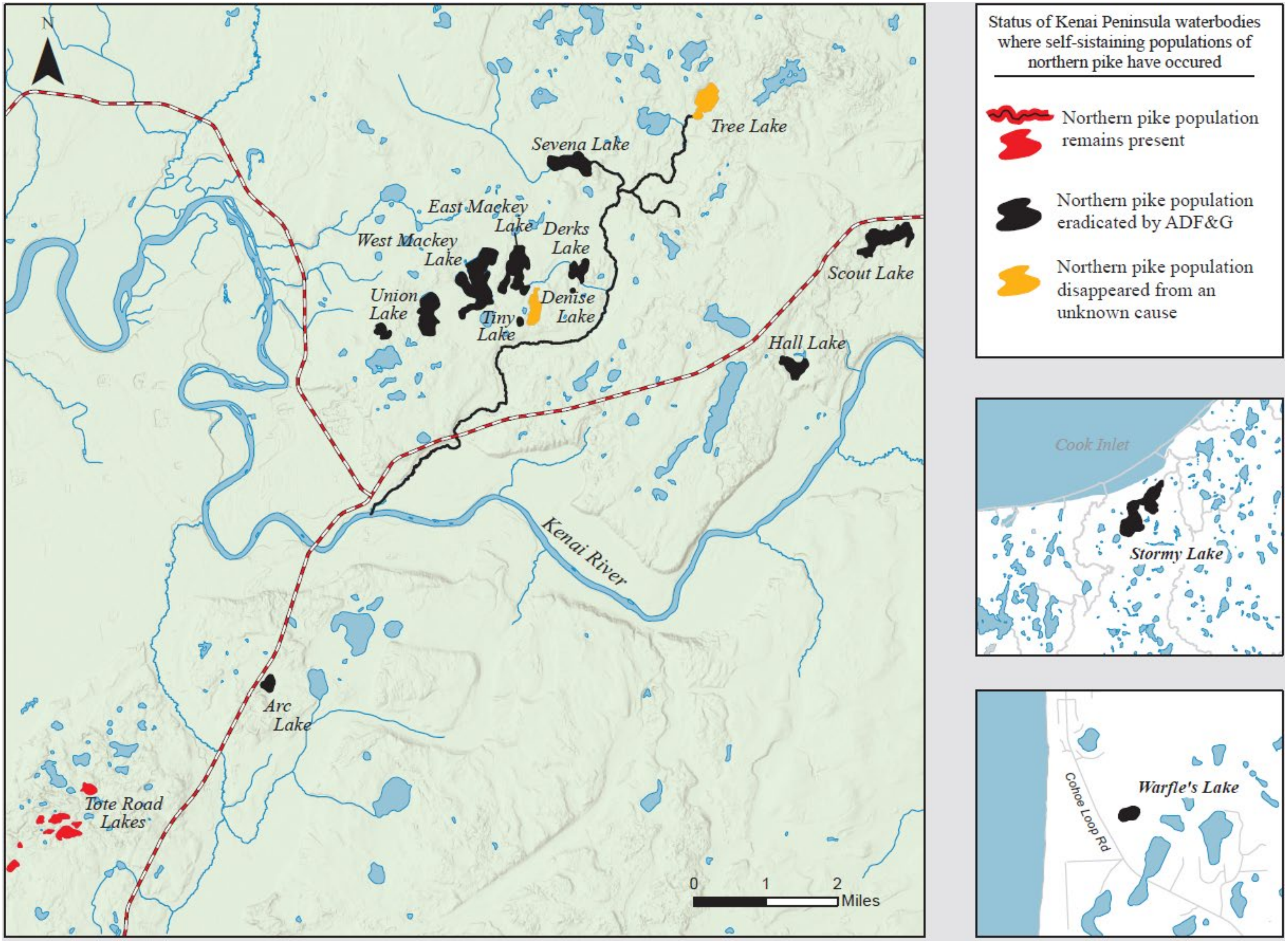

Figure 2.–Status of Kenai Peninsula waterbodies that contain or have contained self-sustaining populations of northern pike.

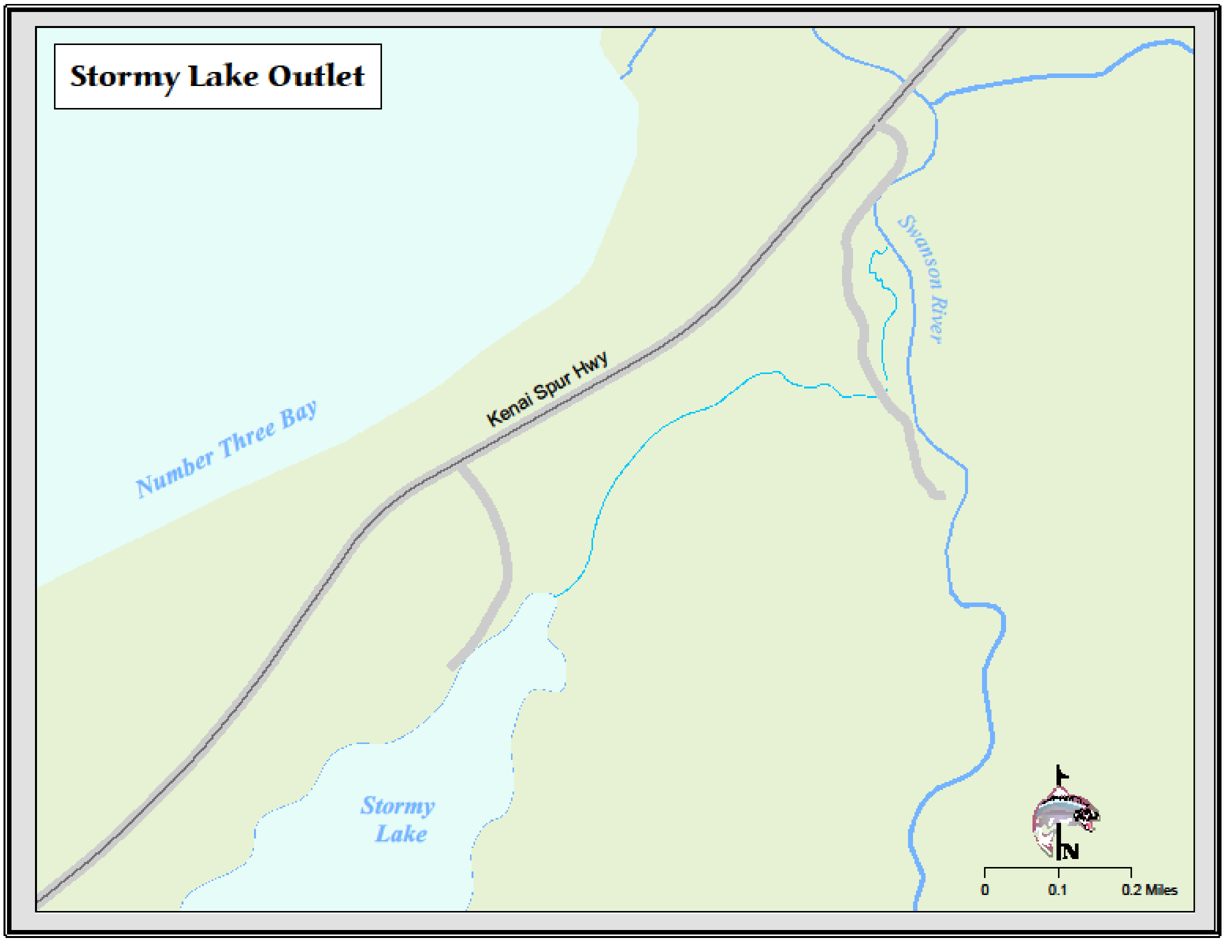

Figure 3.–Stormy Lake and its outlet creek.

Historically, anecdotal angler reports describe Stormy Lake as a consistent producer of large rainbow trout and Arctic char prior to the introduction of northern pike. Recent ADF&G gillnetting efforts in 2009 and 2010 captured relatively few native fish species in Stormy Lake (Massengill 2017). During approximately 2,000 hours of gillnetting efforts during this period, ADF&G only caught 150 longnose suckers, 3 rainbow trout, and 2 Arctic char. ADF&G SWHS estimated only 31 rainbow trout and no Arctic char were caught by sport anglers in 2008 (Jennings et al. 2010). In comparison, the 1994 estimated catch of these species from Stormy Lake was 567 rainbow trout and 835 Arctic char (Howe et al. 1995).

Since 2008, ADF&G has maintained signage at public accesses along the Swanson River drainage. The signage solicits anglers to retain and report any northern pike captured. To date, no northern pike have been reported, although some anglers have mistaken threespine sticklebacks for juvenile northern pike. In 2007, ADF&G conducted fish surveys in the Crane Lake and Gruskka Lake drainages (Swanson River tributaries with habitat believed highly vulnerable to northern pike) and no northern pike were detected (Figure 4). Because northern pike were not known to exist in the Swanson River drainage outside of Stormy Lake, ADF&G believed there remained a window of opportunity to remove them from Stormy Lake before they spread elsewhere in the drainage and cause irrevocable damage.

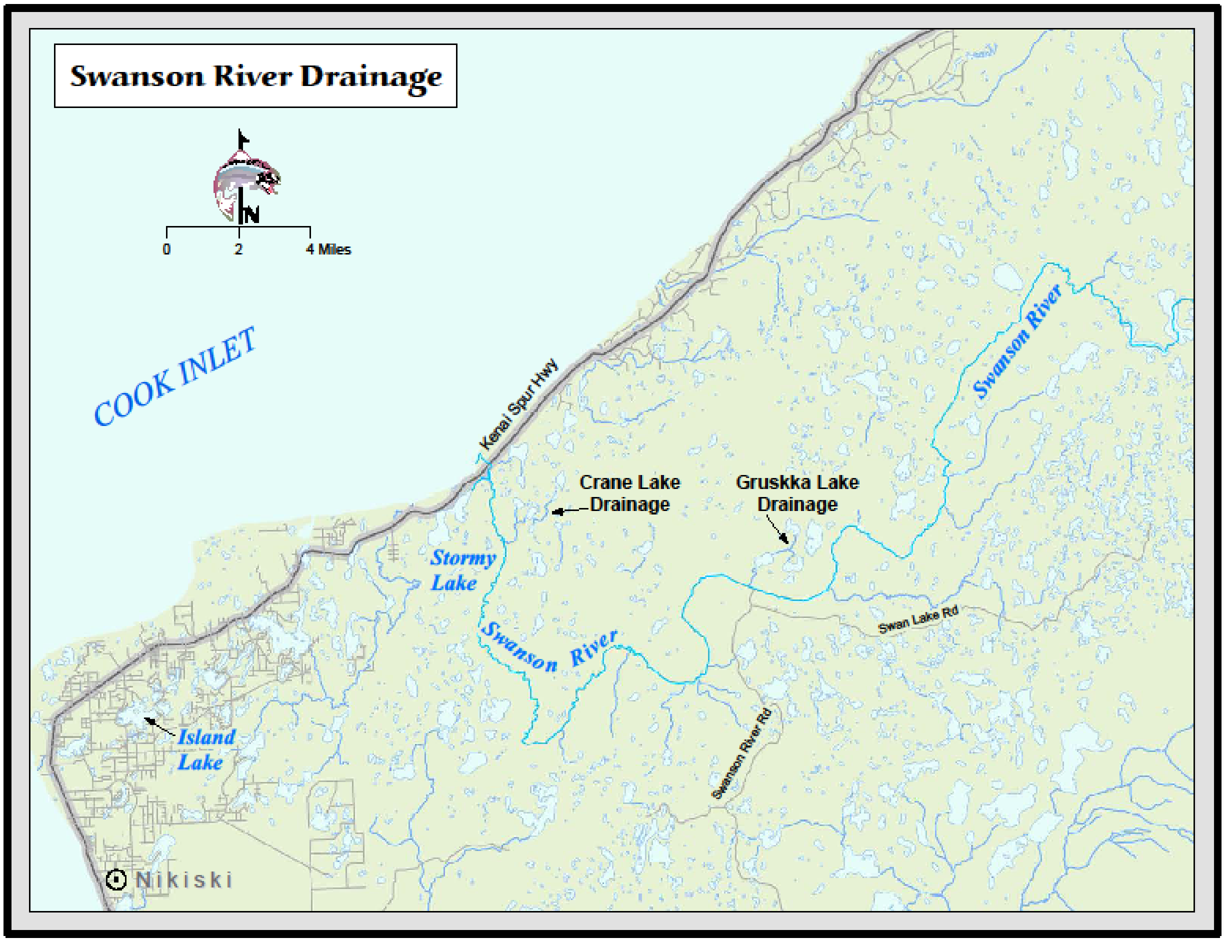

Figure 4.–Location of the Crane Lake and Gruskka Lake drainages.

Northern pike on the Kenai Peninsula have already reduced or eliminated wild fish populations from some Kenai Peninsula lakes (McKinley 2013) and caused the cessation of ADF&G fish stocking in 3 lakes. ADF&G is mandated by law to "Manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state…" (Alaska Administrative Code 5AAC Section 16.05.020). Removing northern pike from Stormy Lake would serve to restore wild salmonid fisheries and habitat, reduce the likelihood northern pike expand to new locations in the Swanson River drainage, and support ADF&G's long-term goal of eradicating northern pike from the entire Kenai Peninsula. ADF&G has evaluated different strategies for controlling or eradicating invasive northern pike; these strategies are listed in the plan titled "Management Plan for Invasive Northern Pike in Alaska," publicly available online (ADF&G 2007).

Netting and passage barriers have been used by ADF&G to control northern pike populations in some Kenai Peninsula waters, but these methods do not eliminate the threat of northern pike predation on native fisheries (Begich and McKinley 2005; Massengill 2010, 2011). During public scoping meetings, ADF&G provided several alternatives for removing or controlling northern pike at Stormy Lake (fish passage barrier, lake drain, chemical treatment, and no action); ADF&G ultimately decided that the most cost-effective alternative was chemical treatment using rotenone.

Rotenone is a naturally occurring plant derivative of the bean family (Fabaceae). Rotenone acts by inhibiting oxygen transfer needed for cellular respiration. It is effective at killing fish in water at low concentrations because it is readily absorbed into the bloodstream through the thin cell layer of the gills. Mammals and other nongill-breathing animals do not have this rapid absorption route into the bloodstream and can tolerate exposure to higher concentrations than those used to kill fish. Typically, nongilled, nontarget organisms are not negatively affected at the concentrations necessary to kill fish (Finlayson et al. 2000; Ling 2003; USEPA 2007[3]).

Of particular concern was preserving the native Arctic char population of Stormy Lake because this population is believed to produce the largest Arctic char found on the Kenai Peninsula. It is unknown whether their potentially large size (sometimes exceeding 3.5 kg) is a genetic trait unique among Kenai Peninsula Arctic char populations or whether it is a result of unique environmental conditions in Stormy Lake. Regardless, the population was clearly threatened by northern pike predation. However, it was unclear if a sufficient number of individuals could even be collected to propagate the Arctic char population posttreatment. Furthermore, unlike all other native fish species found in Stormy Lake, Arctic char could not migrate or disperse from the Swanson River to naturally recolonize Stormy Lake posttreatment because they are not known to inhabit the Swanson River. To overcome these obstacles to preserving the Stormy Lake Arctic char population, we planned to collect Stormy Lake Arctic char broodstock prior to the rotenone treatment and rear their offspring in a hatchery for the purpose of restocking Stormy Lake posttreatment.

We planned to preserve other species of native fish by rescuing individuals both before and during the rotenone treatment and then temporarily holding them offsite in net pens at another lake until Stormy Lake detoxified, allowing their return.

This report documents ADF&G's restoration of Stormy Lake through the eradication of its northern pike population and provides details on the rotenone application, efforts to preserve the lake's native fish populations, evaluations to assess the success of the eradication effort, and treatment associated monitoring of water quality and aquatic organisms.

OBJECTIVES

The goal of this project was to restore the fish habitat of Stormy Lake.

Primary Objective

1) Eradicate the invasive northern pike population in Stormy Lake.

Secondary Objectives

1) Conduct public scoping of eradication or control options for Stormy Lake northern pike.
2) Collect pretreatment physical, biological, and water quality data from Stormy Lake and its outlet creek.
3) Fulfill all permitting obligations required for the eradication or control effort.
4) Collect Stormy Lake native fish species for reestablishment in Stormy Lake posttreatment, including Arctic char broodstock collection.

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[3] USEPA (United States Environmental Protection Agency). 2007. Reregistration eligibility decision for rotenone. Available at: https://archive.epa.gov/pesticides/reregistration/web/pdf/rotenone_red.pdf (accessed October 1, 2019)

5) Release and monitor 13 radiotagged northern pike in Stormy Lake to evaluate their fate during the rotenone treatment.
6) Treat Stormy Lake and its outlet creek with rotenone.
7) Deactivate rotenone in the outlet creek, as needed, prior to treated waters entering the Swanson River.
8) Monitor Stormy Lake posttreatment to assess the success of the treatment and to track the concentration and persistence of rotenone.
9) Collect pre- and posttreatment biological and water quality data from Stormy Lake and its outlet creek.
10) Restock Stormy Lake with native fish.

METHODS

CLEARANCES FOR TREATMENT

Many approvals and permits were required for this project. ADF&G also solicited public and stakeholder involvement for this restoration effort. ADF&G obtained all clearances for the Stormy Lake restoration project as required; these are available for inspection in the ADF&G Soldotna office and are summarized below.

Federal Level Approvals

1) An environmental assessment for the Stormy Lake Restoration was submitted to the United States Fish and Wildlife Service (USFWS) on 27 June 2012. A Finding of No Significant Impact (FONSI) was issued on 7 July 2012. The environmental assessment can be viewed online at: http://www.adfg.alaska.gov/static/species/nonnative/invasive/rotenone/pdfs/stormy_lake_ea.pdf
2) ADF&G submitted an electronic Notice of Intent (eNOI) to the Environmental Protection Agency (EPA) for the Stormy Lake Restoration Project on 13 January 2012. The eNOI permit number is #AK87A024 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, which is archived in the ADF&G Soldotna Office.
3) A USFWS Pesticide Use Permit (PUP) application was completed and submitted by USFWS staff from the Kenai Fish and Wildlife Field Office. A PUP is a requirement prior to discharging pesticide on USFWS property. The PUP was issued (#R7-12-73110-001) on 26 July 2012.

State Level Approvals

The required State authorizations for the Stormy Lake restoration project are listed below:

1) An Alaska Department of Environmental Conservation (DEC) Pesticide Use Permit was issued on 7 May 2012.
2) An ADF&G Fish Resource Permit (P-11-006) for collecting and spawning Stormy Lake Arctic char and Fish Transport Permit (11A-0082) for transporting Dolly Varden Lake

Arctic char milt were received on 3 August 2011 and 3 November 2011, respectively. Fish Transport Permits (13A-0062, 12A-0084, and 11-0075) allowed for the transport of Stormy Lake Arctic char or their eggs, and these were received on 11 June 2013, 31 May 2012, and 3 August 2011, respectively.

3) ADF&G Fish Transport Permits (12-0080, 12-0083, 12-0085, 12-0086, and 12-0087) were issued for collecting and holding an assortment of native fish species from Stormy Lake; these permits were issued on 2 May 2012.
4) An ADF&G Fish Habitat Permit (FH 11-V-0112) was issued on 23 August 2011 which permitted the installation and maintenance of 2 temporary fish barriers in the Stormy Lake outlet creek.
5) The Alaska Department of Natural Resources (DNR) Division of Parks and Recreation issued a Park Use Permit (11-KA-1069) on 9 September 2011 permitting the use of the Stormy Lake boat launch area for staging treatment-related activities.
6) The approval of the ADF&G Division of Sport Fish Director to use rotenone for the Stormy Lake restoration project, per AS 16.35.200, was received via email on 6 May 2012.
7) The approval of the Alaska Board of Fisheries to allow the use of rotenone for the Stormy Lake restoration project, per AS 16.35.200, was received via e-mail on 19 June 2012.

Public Scoping and Notices

A list of the ADF&G public scoping meetings and notifications for the Stormy Lake restoration project are provided below:

1) Public meetings to solicit input on Stormy Lake restoration alternatives were held on 4 occasions in May 2011. An ADF&G news release announcing the meetings was issued on 10 May 2011.
2) ADF&G issued a press release announcing the public commenting periods for the Stormy Lake environmental assessment and DEC pesticide use permit application on 20 January 2012.
3) Public notices for the Stormy Lake restoration DNR pesticide use permit application were printed in the Peninsula Clarion on 2 consecutive days (22–23 January 2012) as required by DEC.
4) Public notices for the Stormy Lake restoration environmental assessment were printed in the Peninsula Clarion on 2 consecutive days (22–23 January 2012).
5) The Peninsula Clarion newspaper published an article about the Stormy Lake invasive pike issue and restoration alternatives on 27 May 2011 (cited 2/22/2018): http://peninsulaclarion.com/stories/052711/new_835881397.shtml
6) The Redoubt Reporter newspaper published an article about the Stormy Lake invasive pike issue and restoration alternatives on 1 June 2011: https://redoubtreporter.wordpress.com/2011/06/01/stormy-sees-pike-plans-%E2%80%94%C2%A0fish-and-game-seeks-input-ideas-to-combat-invasive-species/

WATER BODY PHYSICAL AND CHEMICAL CHARACTERIZATION

Lake Mapping

A bathymetric survey of Stormy Lake was conducted to estimate its volume. A shape file of the lake boundary was created from aerial images using a geographic information system (GIS); this lake boundary shape file was then loaded onto a Trimble GeoTX[4] global positioning system (GPS) unit. Using the Trimble to collect GPS coordinates and a Garmin GPSMAP 440s FishFinder mounted on an outboard motorboat to collect water depth data, 1,265 depth measurements and associated waypoints were collected. The transducer for the FishFinder was secured to an adjustable mount allowing the transducer depth to be set at just below the lake surface. The surveyors collected data by first traveling around the entire perimeter of the lake and then continuing along a pattern of increasingly smaller concentric loops until the entire lake was covered. An attempt was made to place sample locations relatively equidistant apart. Sample locations were chosen by visual navigation using the lake image and a cursor indicating the boat's location relative to sample waypoints that were visible on the Trimble screen, thus allowing the surveyors to judge where the next depth measurement and waypoint would be collected. At each sample location, the surveyors stopped the boat and allowed the Trimble to collect approximately 60 positions (1 position per second for 1 minute). Before moving to the next sample location, the depth measurement was manually entered into the Trimble to create a waypoint, which was marked on the shape file and used for navigation.

Throughout the survey, the surveyors manually verified the sonar depth reading using a weighted meter tape. This was done approximately every 20 samples, and this verified that the FishFinder was accurately measuring depth. After the survey was complete, waypoint and depth data from the Trimble were offloaded into PathFinder Office 4.0 and postprocessed using the GPS base station at the Kenai Municipal Airport. Postprocessing corrects the GPS data so that the final estimate of location (using the multiple positions collected at each location) is at submeter accuracy.

Following postprocessing, the depth, location, and lake outline data were input into ArcGIS wherein a digital elevation model (DEM) of the lake bottom surface was made. ArcGIS provides a single command to create the DEM from point bathymetry data. The command is called "TOPO to Raster" and it interpolates a hydrologically correct raster surface from point, line, or polygon data. 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. By adjusting the elevation of the reference plane in the Surface Volume tool, estimates for specific depth strata were generated using basic grid algebra techniques and simple subtraction.

Water Quality

Our goal was to collect water quality data once per month for at least 1 year before and 1 year after the rotenone treatment. Water temperature, pH, dissolved oxygen, and specific conductivity (in millisiemens per centimeter, mS/cm), data were collected from Stormy Lake using a Quanta Hydrolab. Water turbidity data were measured with a Secchi disc. Pretreatment monthly water

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[4] Product names used in this publication are included for completeness but do not constitute product endorsement

quality sampling occurred from September 2007 through September 2008. Posttreatment monthly water quality sampling occurred from September 2012 through September 2013. Water quality data were collected from the lake surface to the bottom in 1-meter increments at a single site located near the deepest part of the lake. Turbidity data were measured at the same location. The sampling site was marked with a tethered buoy visible during open water and was marked in winter with a flagging stake anchored into the ice.

Two alkalinity samples were collected before treatment to help assess the potential persistence posttreatment of both rotenone and a degradation product (rotenolone). In highly alkaline water (>170 ppm $CaCO_3$), rotenone deactivation can be delayed (Skorupski 2011), and at very low alkalinity (<15 ppm $CaCO_3$) rotenolone can be a significant degradation byproduct that has about one-tenth the toxicity as rotenone (Ott 2008) but can persist longer (Finlayson et al. 2001). The alkalinity samples were collected at Stormy Lake by filling a 500 ml glass jar with water from 60 cm below the lake surface near the lake center. Total alkalinity was analyzed by ADF&G Limnology Lab personnel using the methods described in Koenings et al. (1987).

Stream Discharge

Periodic stream discharge measurements were collected from the Stormy Lake outlet creek from June 2006 through September 2012. The measurements were collected near the outlet of Stormy Lake. Discharge was measured twice in the Swanson River during this same period and was measured near the confluence of the Stormy Lake outlet creek. 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. Stream discharge was collected in accordance with principals provided by ADF&G Division of Sport Fish – Research and Technical Services and the Statewide Aquatic Resources Coordination Unit[5].

Stream discharge was also measured in both the upper and lower reach of the Stormy Lake outlet creek and the Swanson River just prior to the 2012 rotenone treatment to assist in calculating the rotenone drip station and deactivation station application rates. As a courtesy to ADF&G, the Kenai Watershed Forum (KWF) provided these discharge measurements and used an acoustic Doppler-based meter to measure the discharge.

BIOASSAYS

Bioassays using live fish were conducted at Stormy Lake to determine the minimum effective dose (MED) of rotenone. The criterion for the MED is the concentration that achieves 100% mortality after 8 hours of exposure (Finlayson et al. 2010), and it is recommended that the target rotenone concentration for a treatment be at least double the MED to account for environmental and biotic factors that can impeded rotenone's effectiveness (Finlayson et al. 2010). For example, if the MED were 50 parts per billion (ppb), a target treatment concentration should be at least 100 ppb (2 × 50 ppb = 100 ppb). An applicator must also consider the effects of pH, turbidity, temperature, sunlight intensity, and water depth when selecting a rotenone target concentration while also ensuring the target concentration is within allowable limits (Finlayson et al. 2010).

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5 Tom Cappiello, "How to Measure Stream Discharge" (course, ADF&G, Anchorage, AK, April 26, 2006)

Juvenile coho salmon were collected from the Swanson River 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.

Each bioassay was a single test to determine the response of fish over time to a specific concentration of a rotenone. For each bioassay, 4 fish were placed in a plastic bucket filled with 20 liters of lake water. Added to each bucket was a preselected amount of a liquid rotenone formulation (CFT Legumine) according to directions provided in Finlayson et al. (2010). The bioassays tested the following concentrations of active ingredient (rotenone): 0.0 (control), 12.5 ppb, 25 ppb, 50 ppb, 100 ppb, and 200 ppb. A reference chart listing the amount of rotenone premixture (liquid rotenone formulation diluted with water) needed to attain various rotenone concentrations for the bioassays is found in Table 1.

Table 1.–Reference table for the amount of CFT Legumine premix added to various bioassay container volumes to achieve desired concentrations.

		Bioassay container volume	
		10 L	20 L
Target concentration in ppm [a]	Target concentration in ppb [b]	mL of premix [c]	mL of premix [c]
0.0125	12.5	2.5	5
0.0250	25	5	10
0.0500	50	10	20
0.1000	100	20	40
0.2000	200	40	80

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

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

[c] Premix consists of 1 mL of CFT Legumine to 1L of water.

CALCULATING PRODUCT REQUIRED

A combination of rotenone formulations (liquid and powdered) was used to treat Stormy Lake. Liquid formulations were used to target weedy shallow areas and deep water (>30 feet) where the powdered formulation may not distribute as well. Powdered formulations were primarily used for open offshore surface applications. The number of gallons of liquid CFT Legumine and the number of pounds of Prentox Prenfish Rotenone Fish Toxicant Powder required to treat Stormy Lake was calculated based on bioassay results (see Results section) and the volume of Stormy Lake. Examples of the methods used to calculate the amounts of product needed to treat Stormy Lake are provided below with an assumed target concentration of 1.0 ppm of product (0.05 ppm active rotenone).

Stormy Lake is about 6,958 acre-feet in volume; we planned that 39.2% of the lake volume (about 2,728 acre-feet) would be treated with liquid formulation and 60.8% of the volume (about 4,230 acre-feet) with powdered formulation. In the examples below, we used this assumption to attain an overall rotenone product target concentration of 1.0 ppm. We originally planned to treat only one-third of the Stormy Lake volume (33%) with liquid formulation but it was increased to 39.2% due to limited availability of the powdered rotenone product.

Stormy Lake

CFT Legumine Liquid Toxicant Example

The number of gallons of liquid CFT Legumine product (G_p) required to treat 2,728 acre-feet of water at a target concentration of 1.0 ppm was calculated from the product label in this manner:

$$G_p = 0.\overline{33} \times D_c \times V_e \tag{1}$$

where

$0.\overline{33}$	=	gallons of CFT Legumine product required to treat 1 acre-foot of water at 1.0 ppm (per product label; Appendix A1),
D_c	=	desired target concentration (1.0 ppm) of CFT Legumine, and
V_e	=	estimated volume (2,728 acre-feet) for one-half of Stormy Lake.

Therefore, it follows that for a desired target concentration of 1.0 ppm for 2,728 acre-feet,

$G_p = 0.\overline{33} \times 1.0 \times 2{,}728 = 908.3$ gallons of CFT Legumine are needed.

Prentox Prenfish Rotenone Fish Toxicant Powder Example

The number of pounds of Prentox Prenfish Rotenone Fish Toxicant Powder (P_p) required to treat 60.8% of Stormy Lake (4,230 acre-feet) at a target concentration of 1.0 ppm was calculated from the product label 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 A2),
D_c	=	desired target concentration (1.0 ppm) of Prentox Fish Toxicant Powder, and
V_e	=	estimated volume (4,230 acre-feet) of Stormy Lake.

It therefore follows that for a desired target concentration of 1.0 ppm for 4,230 acre-feet,

$P_p = 2.7027 \times 1.0 \times 4{,}230 = 11{,}451$ pounds of Prentox Fish Toxicant Powder are needed.

However, to compensate for the difference between the actual assayed rotenone concentration listed on the containers of Prentox Prenfish Rotenone Fish Toxicant Powder (7.4%) and that found on the label directions (5%), an adjustment to the calculation was required. That is, the pounds of Prentox Fish Toxicant Powder required to treat 4,230 acre-feet at 1.0 ppm of product was multiplied by a coefficient derived by dividing the actual assayed rotenone concentration on the container label (7.4%) by the rotenone concentration percentage used in product label directions (5%) as follows: $5 \div 7.4 = 0.676$.

Therefore, it follows that for a target concentration of 1.0 ppm for 4,230 acre-feet,

$P_p = 11{,}451.6 \times 0.676 = 7{,}741$ pounds of Prentox Prenfish Rotenone Fish Toxicant Powder (at 7.4% assayed rotenone concentration) are needed.

The availability of Prentox Fish Toxicant Powder offered by the supplier was limited to 70 drums, each containing 110.2 pounds of product, so there were only 7,714 pounds of powdered product available and the shortage (0.3%) was not addressed because it was deemed insignificant to the treatment's efficacy.

Stormy Lake Outlet Creek

CFT Legumine Liquid Toxicant Example

Only liquid rotenone formulations can be used when treating flowing waters (Finlayson et al. 2010). As a general rule, stream applications typically utilize 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). Actual drip station placement and application rates are based on stream discharge and stream travel rates observed throughout a stream.

The liquid rotenone release rates of a single drip station and the total amount of liquid rotenone released by multiple drip stations were calculated in the following manner. The amount of undiluted liquid CFT Legumine formulation required to treat the Stormy Lake outlet creek (with a flow of 2 ft^3/s) at 1.0 ppm of liquid product per minute was calculated as follows:

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

where,

1.692 = formula constant (Finlayson et al. 2010),

F = flow of the stream in cubic feet per second, and

C = desired rotenone concentration in parts per million (ppm).

It follows that for a flow rate of 2 ft^3/s and a desired rotenone concentration of 1.0 ppm, $X = 2(1.692 \times 1.0) = 3.4$ ml of undiluted rotenone per minute or 34 ml of diluted rotenone (dilution ratio: 9 parts water to 1 part product) are needed.

To calculate the amount of CFT Legumine required for 480 minutes (8 h) of treatment using 3 drip stations along the stream,

$$X^t = X \times M \times D \tag{4}$$

where

M = number of minutes of treatment and

D = number of drip stations.

Therefore, it follows that to treat for 8 hours at 3 drip stations,

$X^t = 3.4 \times 480 \times 3 = 4{,}896$ milliliters (4.9 liters or 1.3 gallons of CFT Legumine) are needed.

TREATMENT STRATEGIES

Treatment Timing

The Stormy Lake treatment was planned for early September 2012. This timing was chosen because it allowed us to take advantage of a changing lake thermocline (fall turnover), which could aid in mixing the rotenone. A late summer or early fall treatment was expected to speed the deactivation of rotenone compared to other recently applied rotenone treatments applied later in the fall, in which the rotenone persisted until after ice-out (Massengill 2014a, 2014b). This persistence probably happened because cold water (<5°C) can delay the natural deactivation of rotenone for many months (Finlayson et al. 2010; Gilderhus et al. 1986).

A September treatment appeared to offer a balance between keeping the rotenone active longer than a just a few days or weeks and reducing the likelihood any northern pike could survive in marginally treated areas versus having the rotenone persist late into the winter or following spring and delaying restocking plans. Treating Stormy Lake in September would also lessen impacts to water recreationists as opposed to an earlier summer treatment when temperatures are more conducive to swimming and boating.

Treatment Partitioning

Water volumes were calculated for 6 discrete sections of Stormy Lake (Figure 5) including volumes for each 10-foot depth stratum within each section (Table 2). To keep the overall rotenone product concentration at 1.0 ppm in each lake section, the certified applicator used individual discretion to determine the amount of each product formulation (liquid or powder) to apply to each section. Lake sections with greater amounts of deep water (>30 feet) or large beds of aquatic vegetation received more liquid formulation because of its better dispersal properties. The amount of each rotenone formulation planned for each lake section is detailed in Table 3. Tethered buoys were used to visibly define each lake section during the treatment to assist the boat applicators.

Liquid Rotenone Boat Application

CFT Legumine (Appendix A1) is a liquid rotenone product containing additives that improve its emulsion and dispersal in water, and we planned to use it to treat areas where mixing could be impeded (e.g., weedy shoreline areas, deep water >30 feet). To a far lesser degree, CFT Legumine would be applied to open lake surfaces.

We applied CFT Legumine primarily with 2 outboard powered boats and 1 airboat. All liquid rotenone application boats required 2 applicators, one to operate the boat and another to operate the pumping apparatus. All application boats were equipped with gas-powered semi-closed pumping apparatuses. All CFT Legumine pumping apparatuses consisted of a Honda trash pump with intake and discharge hoses. CFT Legumine must be premixed with water prior to application. Premixing occurred within the pump apparatuses by way of forked intake lines wherein a large diameter (2-inch) intake line could draw lake water from near the boat transom while a smaller intake line (one-quarter to three-quarter-inch diameter) drew pesticide from a container. Both the pesticide and water were drawn, mixed, and discharged by the pumping apparatus. A valve on the pesticide intake line was used to control the rate of pesticide withdrawal from the container.

One of the CFT Legumine application outboard boats had a discharge hose that ran to a spray nozzle mounted on a 3.5-foot tall swiveling turret in the bow of the boat (Figure 6). The sprayer was used to spray the rotenone premixture up to 25 feet into shallow and weedy areas. Another application boat had a discharge hose that fed to a pair of 20-foot long, 1.5-inch diameter well pipes (Figure 7). The pipes could be lowered below the surface for deep water applications. The well pipes were secured on each side of the boat near the boat's aft with hinged mounts. Near the open discharge end, the pipes were secured together with a spacer pipe that held the pipes apart a distance slightly wider than the boat's width.

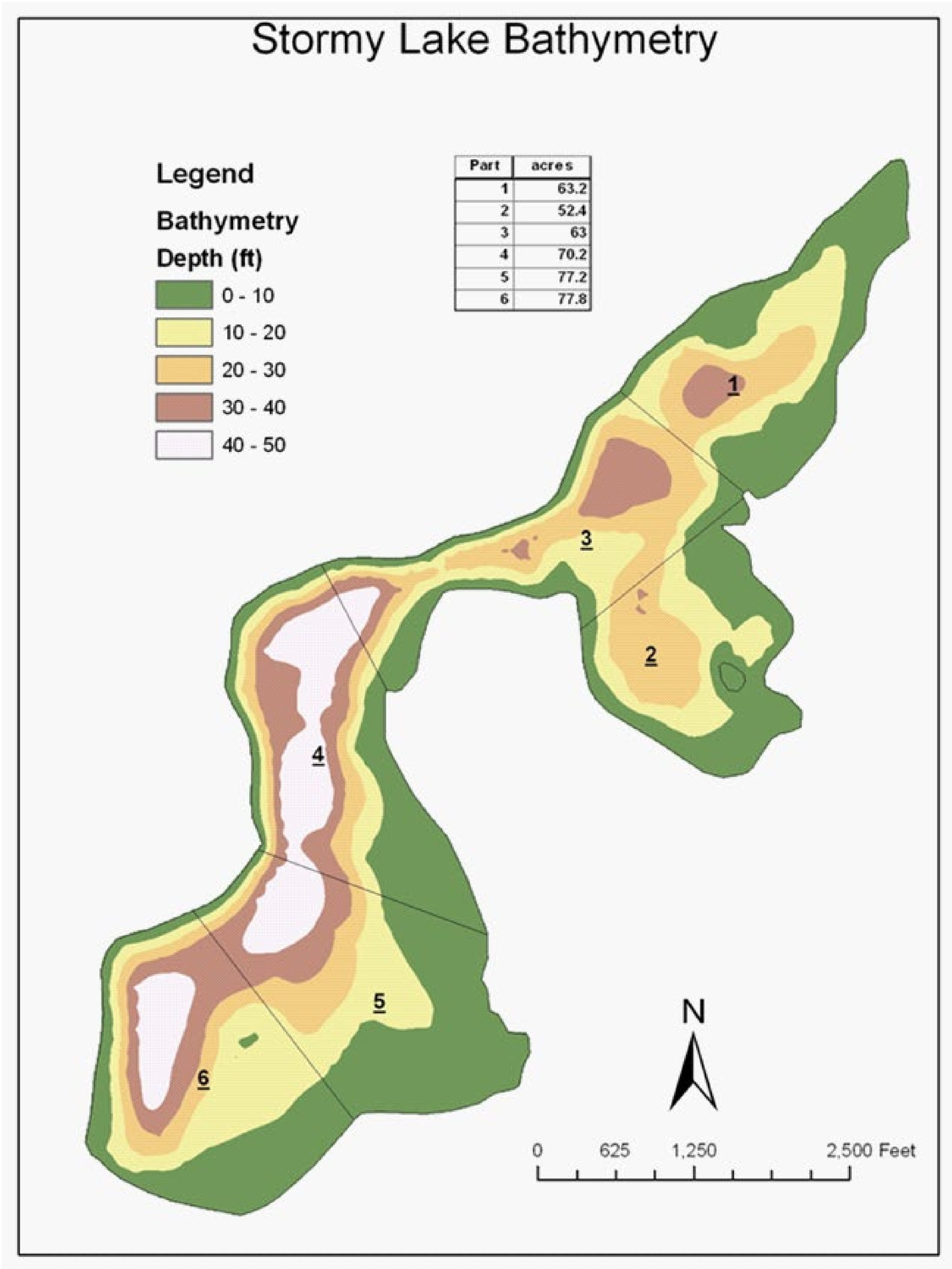

Figure 5.–Stormy Lake bathymetric map with treatment sections (1–6) and associated acre-feet of water in each section.

Table 2.–Lake section and 10-foot depth stratum volumes for Stormy Lake.

Lake section	Volume of entire section (acre-feet)	Volume by depth stratum 0–10 feet	10–20 feet	20–30 feet	30–40 feet	40–50 feet
Area 1	736	430	223	73	9	0
Area 2	624	381	182	61	0	0
Area 3	1,218	540	410	204	58	5
Area 4	1,659	559	431	349	248	71
Area 5	1,266	582	322	218	126	20
Area 6	1,455	646	381	251	149	29
Total	6,958	3,137	1,949	1,156	591	124

Table 3.–Amounts of CFT Legumine and Prentox Fish Toxicant Powder applied to Stormy Lake by lake section.

	Liquid CFT Legumine				Powdered Prentox Fish Toxicant Powder
Lake section	Applied to the lake surface <50 yd offshore or in large aquatic weedbeds (gal)	Applied to deep water (>30 ft) and >50 yd offshore (gal)	Applied to the lake surface >50 yd offshore (gal)	Total applied to each lake section (gal)	Applied to the lake surface >50 yd offshore (lb)
1	57	2	15	75	1,670
2	51	0	12	63	1,709
3	72	19	24	115	1,488
4	149	101	33	282	590
5	155	45	25	225	1,067
6	64	55	29	148	1,190
Total	548	223	137	908	7,714

A hand crank winch mounted near the boat's bow, and with its cable connected to the spacer pipe, allowed the well pipes to be raised up or down in tandem to a desired angle and depth. In this manner, the pipes could be lowered in tandem beneath the waterline at a desired depth below the lake surface to a maximum depth of about 6 meters.

An electronic depth finder (Garmin GPSMAP 440s FishFinder) was used by the boat applicators for applying both liquid and powdered rotenone formulations. Generally, in any given area, applicators would apply first to the outermost perimeter of the area and work their way inward by making increasing smaller concentric loops while maintaining approximately 30-foot distances between application swaths. Applicators could adjust their boat speed and application rate throughout the treatment according to water depth readings. The depth finder display screen provided instant depth, boat speed, and path tracking, allowing the boat operator to detect gaps in rotenone coverage. A printed reference chart (Appendix B1) allowed boat operators to adjust boat speed in relation to observed water depths and known rotenone discharge rates to promote even distribution of the liquid rotenone product.

An airboat applied CFT Legumine to several acres of inundated wetlands adjacent to Stormy Lake that were unnavigable by outboard boat and too large an area for backpack applicators to cover. The airboat was equipped with a similar pump designed to allow the applicators to spray using a handheld hose and nozzle.

Figure 6.–Surface-drive outboard applying rotenone with turret-style spray nozzle.

Figure 7.–Rotenone application boat with custom-made deep-water delivery system for applying rotenone.

Powdered Rotenone Boat Application

Prentox Fish Toxicant Powder was applied to the surface of Stormy Lake typically 50 yards or more offshore. The powdered rotenone must be premixed with water prior to application (Appendix A2), and it was applied with 2 outboard powered boats equipped with pumping apparatuses that utilized 13 horsepower high-pressure Gorman-Rupp water pumps. The pumps have a 2-inch water intake line and a 1.5-inch discharge line. The discharge line of each pump was fitted with an inline 1.5-inch interior diameter cast iron chemical eductor by Scot Pump. The eductor utilizes the Venturi effect of water flowing through a restriction to vacuum pesticide into the body of the eductor through a siphon line that connects to the eductor body. The mixing ratio of water and powdered formulation was controlled by a breather valve fitted in the siphon line, which decreased the siphon's vacuum when opened.

The powder application boats required at least 3 applicators per boat to efficiently apply the product. One applicator operated the boat, another applicator probed the siphon line and tube into the drum of powder, and a third applicator broke up clumped rotenone by pounding on the side of the drum with a bat because agitating and breaking apart clumped rotenone powder improved its ability to be siphoned, particularly after the product has been in long-term storage. A printed reference chart (Appendix B2) allowed boat operators to adjust boat speed in relation to observed water depths and known rotenone discharge rates to promote even distribution of powdered rotenone product.

Sand-Gelatin-Rotenone Mixture Ball Application

Sand-gelatin-rotenone mixture balls were used to treat wetland seepages feeding into the lake. The mixture balls consisted of a ratio of 1.0 pound of sand to 1.0 pound of rotenone to 2 oz of unflavored gelatin. The ingredients are mixed and moistened with water then wrapped into balls covered with cheesecloth. 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 to 3-foot long wooden survey stakes. The stakes were pushed by hand into wetland seepages so that the mixture balls would be submerged below the waterline but not rest on the bottom where they could be covered in sediment.

Backpack Application

Backpack applicators spot-treated shallow marshy nearshore areas of the lake and sections of the outlet creek water where mixing was likely to be poor (e.g., seeps, off channel pools, etc.). Backpack applicators premixed liquid rotenone formulation with lake water within their backpack tanks in a 2:100 volume to volume ratio of CFT Legumine to water (Finlayson et al. 2010). A few tablespoons of rhodamine dye were often added to the backpack's tank to distinguish treated areas from untreated areas.

Drip Station Application

Drip stations treated the Stormy Lake outlet creek. The most upstream station was within 10 meters of the lake outlet; spacing between drip stations was about one-third of a mile, which approximated the estimated average stream travel rate of 2 hours over that distance. Stream travel rate was estimated by averaging stream velocity measurements collected every 0.5 feet across the width of the stream at 2 sites using a USGS Pygmy Current Meter and Aqua Pulse Counter–Timer attached to a wading rod.

The drip stations each consisted of a 12-volt battery-powered variable speed peristaltic pump made by Control Company (Figure 8). Each drip station pumped undiluted liquid rotenone formulation into the creek through a silicon tube that was suspended directly over the creek. Drip rates were calibrated by measuring discharge over a 1-minute period and then making appropriate adjustments using either the variable speed controller of the pump or by the selection of a different diameter tube or both. Drip rates were checked at least hourly and the treatment was planned to last a minimum of 4 hours.

Caged juvenile coho salmon served as sentinel fish in the creek to monitor how effective the stream treatment was in real time. These fish were placed just upstream of each drip station and also below the lowest drip station near the creek's confluence with the Swanson River.

Figure 8.–Drip station used to treat the Stormy Lake outlet creek with rotenone.

Rotenone Deactivation

Generally, rotenone must be deactivated before it leaves a treatment area to prevent exposure to nontarget organisms. Deactivation of rotenone can occur through several mechanisms. Exposure to warm temperatures and sunlight are 2 factors that most influence the rate of natural degradation (Engstrom-Heg 1972; Gilderhus et al. 1986; Loeb and Engstrom-Heg 1970; ODFW 2008; Ware 2002). Rotenone released into relatively warm water (about 15°C) is expected to fully detoxify within 2–4 weeks (Dawson et al. 1991).

Dilution can also decrease rotenone concentrations to nondetectable levels (defined as <2.0 ppb of rotenone). Finlayson et al. (2010) showed how to estimate the rotenone concentration after 2 streams mix when 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:

$$C = D \times R \tag{5}$$

where

D = dilution fraction = T_S/U_S,

R = rotenone concentration of the treated stream in parts per billion (ppb),

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 Swanson River from rotenone introduced by the Stormy Lake outlet creek treated at 50 ppb of rotenone. This model assumed that the Stormy Lake outlet creek discharge rate was at a historical average while the Swanson River discharge rate was at a historical low, giving a conservative concentration because the concentration under average discharge would be far less (Table 4). This model shows that without any rotenone deactivation occurring prior to mixing, the concentration in the Swanson River would be below 2.0 ppb.

Table 4.–Estimated highest concentration of rotenone in the Swanson River after mixing with Stormy Lake outlet creek discharge treated with rotenone.

Minimum Swanson River discharge observed in August or September [a]	Average Stormy Lake outlet creek discharge observed in August or September [b]	Estimated rotenone concentration in the Swanson River after mixing with creek discharge treated with rotenone (50 ppb rotenone)
46 ft^3/s	1.32 ft^3/s	1.43 ppb [c]

[a] Source: Inghram and Ireland (1990).

[b] Massengill, R. Unpublished stream flow data collected in 2007 through 2009. Alaska Department of Fish and Game, Division of Sport Fish, Soldotna Office.

[c] ppb means parts per billion.

In situations where it is desirable to deactivate rotenone quickly, potassium permanganate ($KMnO_4$) can be applied. Chemical deactivation of rotenone using $KMnO_4$ is typically accomplished after about 30 minutes of mixing between the two compounds between ratios of 1.0:1.5 to 1.0:2.0 of rotenone to $KMnO_4$ (Finlayson et al. 2010).

As a precautionary measure, we planned to chemically deactivate the rotenone in the lower section of the Stormy Lake outlet creek with crystalline $KMnO_4$ when the rotenone concentration was anticipated to be highest. Deactivation occurred during and for a short period following the application of rotenone to the outlet creek. To apply the $KMnO_4$, a rotenone deactivation station was installed 500 yards upstream from the creek's confluence with the Swanson River. The deactivation station consisted of an Acrison model 105-C/2 volumetric feeder with a 2 cubic foot supply hopper (Figure 9). The feeder was powered by a portable gas-powered Honda 2000 generator. The $KMnO_4$ feed rate was adjusted by a motor controller and also by the size of the feeder auger selected. The feeder was capable of metering the discharge of $KMnO_4$ crystals between 0.032 to 0.25 cubic feet per hour. The entire deactivation station was suspended about 18 inches over the outlet creek by a temporary wooden platform and surrounded with an electric fence to reduce the likelihood of bear damage.

To confirm that chemical deactivation was not needed, we planned to temporarily halt operation of the deactivation station every 1–2 days for a 4-hour period and monitor the response of downstream sentinel fish. Chemical deactivation would resume unless the sentinel fish displayed no rotenone stress symptoms (i.e., mortality, rolling, imbalance, or gasping) following 4 hours of exposure to undeactivated water (Finlayson et al. 2010).

Figure 9.–Rotenone deactivation station that utilized a gas-powered volumetric feeder to dispense $KMnO_4$ crystals into the Stormy Lake outlet creek.

Once the rotenone drip stations stopped applying rotenone to the creek, we expected the creek would flush its peak rotenone concentration within 6–8 hours based on stream travel estimates. After discontinuing the application of rotenone to the creek, the only rotenone input would be from Stormy Lake. The rotenone entering the creek from the lake would be expected to dilute from untreated water inputs (ground seepage, springs, etc.). There would also be natural rotenone degradation occurring over the course of the creek through streambed oxidative processes and the effects of temperature and sunlight. Therefore, chemical deactivation of rotenone in the Stormy Lake outlet creek, once initiated, was anticipated to be relatively brief (<1 week). However, ADF&G was prepared to operate the deactivation station for much longer if necessary based on observations of caged sentinel fish held downstream of the treatment area. If the sentinel fish showed signs of rotenone toxicity (i.e., swimming imbalance, lethargy, gasping or immobility), deactivation would resume.

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. For example, in distilled water and 30 minutes of contact time, the ratio of $KMnO_4$ to rotenone should be about 2:1, whereas the ratio at 60 minutes should be about 1:1.

$KMnO_4$ deactivation is a dynamic operation that requires applicators to use judgment in selecting the initial $KMnO_4$ concentration and to monitor its effectiveness by 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 $KMnO_4$ was left 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 converted to a potassium permanganate value by multiplying the chlorine value by a coefficient of 0.89 (Finlayson et al. 2010). Measuring the $KMnO_4$ concentration in the outlet creek was planned to occur 3 or more times daily while the $KMnO_4$ was being applied. Below are example calculations used to determine the application rate of $KMnO_4$ to the Stormy Lake outlet creek to neutralize rotenone at a 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 the Stormy Lake outlet creek, the following equation is utilized:

$$Y = A + B + C \quad (6)$$

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 = 2, B = 2, and C = 1 (determined by stream characteristic investigations), then Y = 2 + 2+ 1, or 5 ppm of $KMnO_4$.

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

$$SF = Y \times 1.7 \times Q \quad (7)$$

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 = 0.89 ft^3/s, then SF = 5 ppm × 1.7 × 0.89 ft^3/s = 7.6 g/min $KMnO_4$.

To convert the desired $KMnO_4$ application rate of 7.6 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:

7.6 g/min $KMnO_4$ ÷ 1.43 g/ml = 5.3 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 would decrease accordingly.

TREATMENT SUCCESS EVALUATION

Rotenone Sampling

Stormy Lake water and sediment samples were collected immediately before and periodically after the rotenone treatment to verify rotenone and rotenolone concentrations. Sampling continued until the lake was no longer toxic to fish based on laboratory analysis of the rotenone concentration of lake water and caged sentinel fish responses. Typically, at each of 3 regular sampling locations (sites 2a, 2b; 3a, 3b; and 5a, 5b) (Figure 10), 2 discrete samples were collected from 1 m below the lake surface and another from 1.5 m from the lake bottom. One-gallon water samples were obtained by lowering a weighted vertically oriented 2.2 L Kemmerer sampling tube to the desired lake depth and activating the capture mechanism of the Kemmerer sampling tube. The water samples were transferred from the Kemmerer sampling tube to 1 gal amber-colored glass jugs. Sediment samples were collected from 2 nearshore sites along the eastern edge of the lake and were extracted from the lake bed using a shovel or hand trowel. Each sediment sample (about 500 ml) was placed into an amber-colored glass jar. All samples were immediately labeled, placed into cold storage, and express shipped with chain-of-custody paperwork to the California Department of Fish and Game Water Pollution Control Lab in Rancho, California, for analysis of rotenone and rotenolone concentration.

Radio Telemetry

To evaluate the success of the rotenone treatment, 12 adult Stormy Lake northern pike were surgically implanted with radio transmitters before being released back into the lake 1 week before the rotenone treatment. The radio transmitters were repurposed transmitters recovered from a recent northern pike movement study conducted at Stormy Lake during 2009–2011 (Massengill 2017). There was also 1 live radiotagged northern pike remaining in Stormy Lake from the movement study that was included in this evaluation, bringing the total number of live radiotagged northern pike in Stormy Lake to 13. All transmitters were programmed to emit a mortality signal after 4 hours of no movement. The Model 1845 radio transmitters were made by Advanced Telemetry Systems and operated at either 152.043, 152.073, or152.133 MHz.

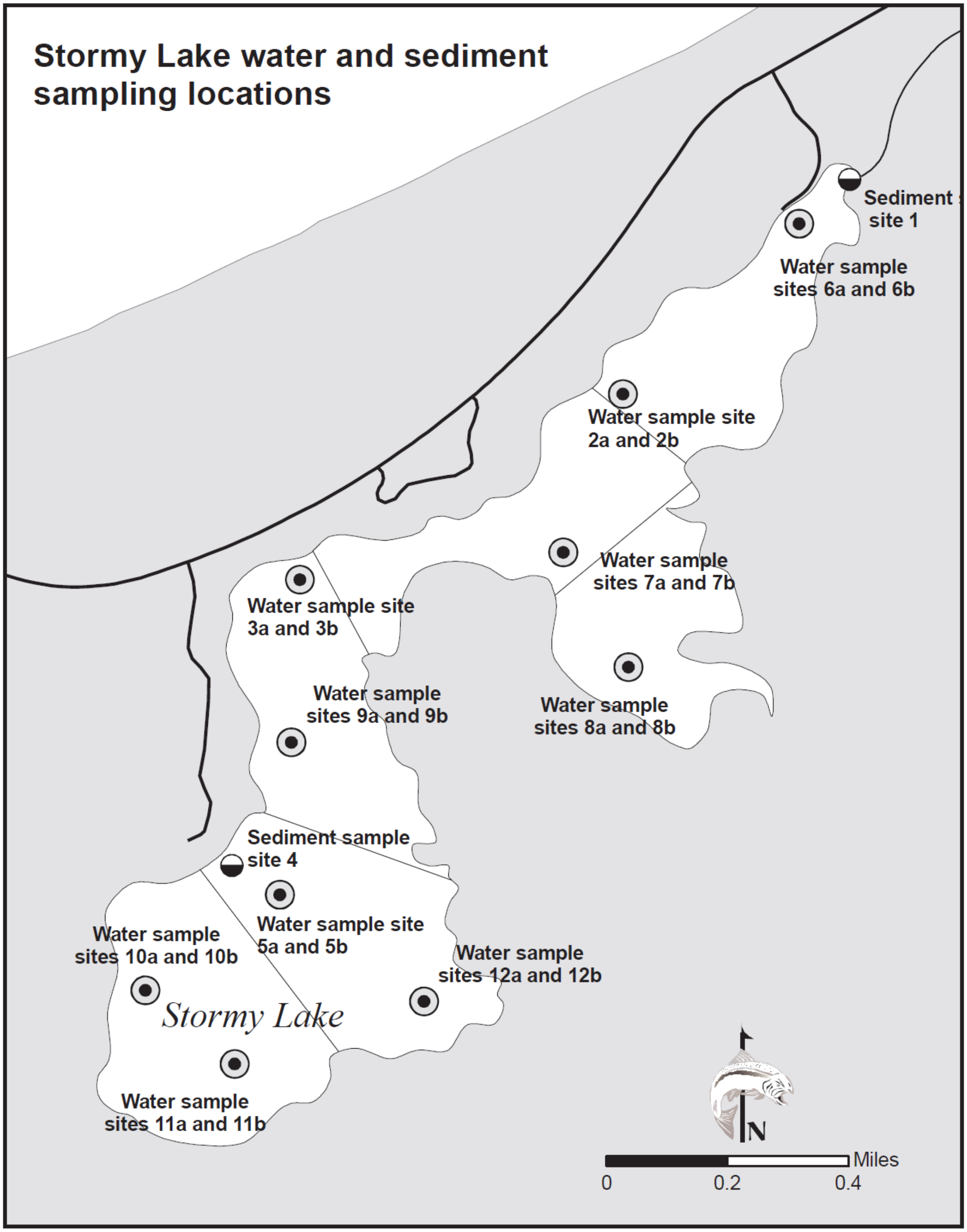

Figure 10.–Stormy Lake water and sediment sampling sites.

Northern pike used in this evaluation were collected with gillnets and selected for radiotagging if they were 400 mm in length or greater and without observable significant injury from capture. The northern pike were anesthetized with food grade clove oil following the solution and dosage guidelines recommended by Peake (1998). A custom-made fish cradle was used to hold fish horizontally for surgery with the ventral side facing up. While in the cradle, the head of the fish was positioned so the gills extended beyond one end of the cradle allowing the head to be supported by the hand of a surgery assistant. A turkey baster was used by the assistant to aerate the fish during surgery by transferring lake water from a bucket to the gill filaments of the fish. The surgical incision was 2–3 cm long along the *linea alba*, anterior to the pelvic girdle (Hart and Summerfelt 1975). The transmitter's antenna was inserted into an open end of a hollow five-sixty-fourth-inch diameter stainless steel rod about 20 cm in length. One tip of the rod was solid and smoothly rounded with a 50 degree angle bend occurring at the last 2 cm. After the initial incision, the solid end of the rod was inserted into the incision and gently pushed posteriorly. Light pressure was maintained on the rod in such a way that the angled tip created a slight bulge visible on the outside of the fish's abdomen. Once the rod tip moved past the pelvic girdle, a scalpel was used to poke through the abdominal wall exposing the rod tip. Once exposed, the rod was pushed completely out of the abdomen leaving the antenna trailing outside the fish body. The radio transmitter was then worked into the abdominal cavity through the initial incision and seated in the gut cavity by pulling on the trailing antenna cable. No antibiotics were used. Three to 5 sutures (3-0, FS-1) and Vetbond or similar surgical glue was used to close the initial incision; the small antenna incision was not big enough to require stitching. All radiotagged fish were placed in a net pen until they recovered swimming ability then released immediately back into the lake.

Tracking of radiotagged fish was accomplished by boat surveys using an ATS R4500C tracking receiver connected to a handheld H antenna. Tracking surveys were planned to be done opportunistically at least once immediately before, during, and following the rotenone treatment.

Creek Electrofishing

During operational planning, backpack electrofishing was deemed a potential method for evaluating the success of the Stormy Lake outlet creek treatment. A trial electrofishing survey conducted prior to the rotenone treatment clearly indicated that electrofishing in the outlet creek would be extremely difficult due to dense streamside vegetation limiting both visibility and mobility. Electrofishing was therefore rejected as a useful survey method for this project.

Gillnetting and Minnow Trapping

Gillnets were the primary method selected to assess the treatment's success. Our hope was that Stormy Lake would detoxify before freeze-up in 2012 and, in theory, surviving fish could move freely throughout the lake and be subject to capture. If no northern pike were detected, restocking could occur before freeze-up thus avoiding the expense of extended hatchery rearing of Arctic char offspring and prolonged maintenance of rescued native fish at the Wik Lake net pens.

Based on the surface acreage of Stormy Lake and the amount of netting effort (net density and days of fishing), the probability of not detecting a small surviving northern pike population (4 individuals) using gillnets can be estimated (Appendices C1–C3).

To ensure compliance with the Migratory Bird Treaty Act, gillnets were monitored frequently to minimize the potential for the unauthorized "take" of loons and other birds that might become entangled. Owl decoys were positioned onshore near gillnets to discourage birds from utilizing the area.

In addition to gillnetting, 5 minnow traps baited with salmon eggs were fished continuously for 24 hours each in Stormy Lake on 2 separate occasions posttreatment in an attempt to detect the presence of small or juvenile fish. Minnow traps were fished in shallow water (<2 ft) and near shoreline weed beds.

Sentinel Fish

Caged juvenile coho salmon served as sentinel fish to monitor how effective the treatment was in real time. These fish were suspended at various depths in 8 locations dispersed throughout the lake (Figure 11). At least 3 fish were placed in each cage. The fish were monitored periodically throughout the treatment to verify the lethality of the treatment.

BIOLOGICAL COLLECTIONS

Invertebrate Surveys

Macroinvertebrate and zooplankton collections to identify taxa from Stormy Lake were conducted during summers both before and after the rotenone treatment. A minimum of 2 pretreatment and 2 posttreatment sampling surveys were planned to increase the likelihood more species would be detected. Sampling was conducted at the same locations both before and after the rotenone treatment. Sampling locations were recorded with a handheld GPS to aid in resampling the same sites (Figure 12). At each sampling site, all collected invertebrates were combined into a single glass specimen jar filled with a 70% ethanol solution and labeled with the date, site location, and gear type.

During each sampling survey, zooplankton collections were made with replicate vertical tows (from bottom of the lake to surface) at 2 different sites in locations near maximum lake depth using a 0.5 m diameter Wisconsin net with 153 µm mesh. 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).

Multiple gear types were used to sample macroinvertebrates. Collected macroinvertebrates were identified to the order, suborder, or family level when feasible, using keys provided by Pennak (1989) and Voshell (2002). During each sampling survey, benthic macroinvertebrates were collected using a 9-inch Ekman Bottom Grab Sampler to collect bottom sediment from 5 offshore sites. The Ekman sampler was deployed from an anchored outboard motorboat at each site 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 invertebrates along vegetated nearshore areas (<0.6 m in depth) in 5 locations. 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.

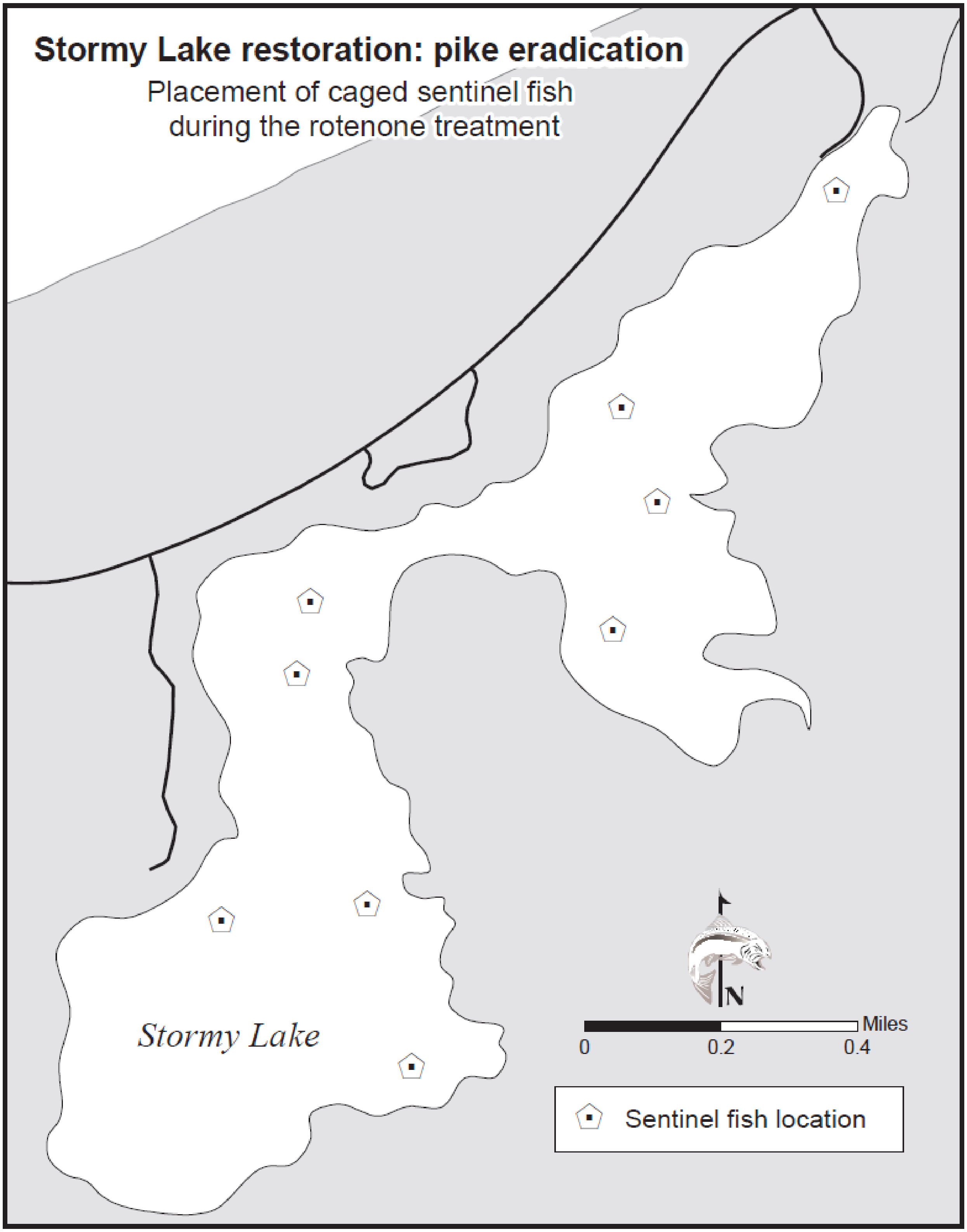

Figure 11.–Stormy Lake caged sentinel fish location during 7–9 September 2012.

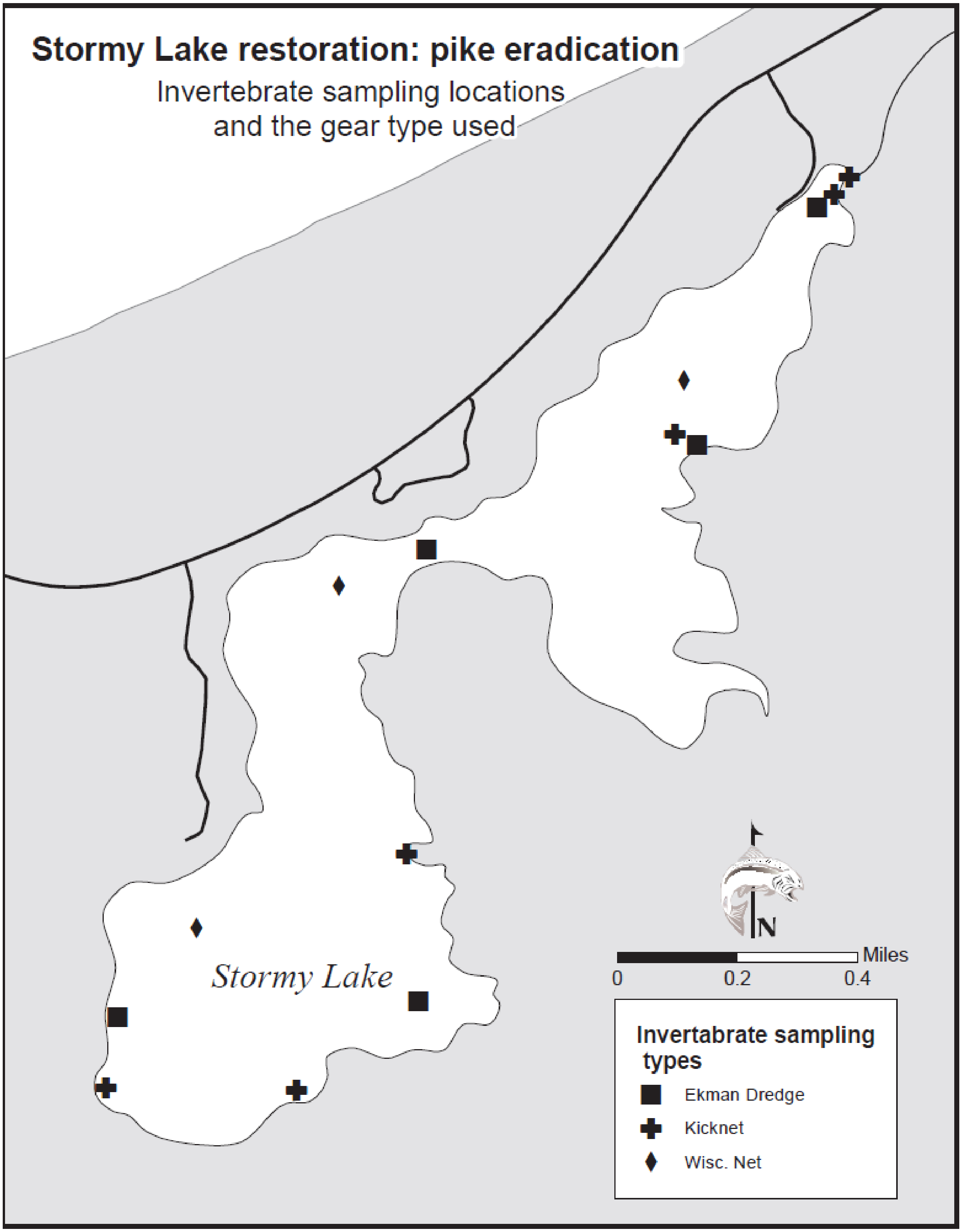

Figure 12.–Stormy Lake invertebrate sampling sites by gear type.

Native Fish and Arctic Char Broodstock Collections

Pretreatment fish collections were conducted to salvage northern pike for educational use, to collect live northern pike for radiotagging purposes, to collect Arctic char broodstock, and to collect native fish for return posttreatment.

Arctic Char Broodstock Collection

Collection of Arctic char for broodstock occurred during the late summer and fall of 2011 and utilized a variety of fishing gear that included gillnets, entanglement nets, hoop nets, funnel traps, trotlines, and a commercial purse seiner.

The gillnets, manufactured by Christiansen Net Company, were made of single strand monofilament mesh with floating polypropylene hanging line and half-inch lead line. Each net was 120 ft long, 6 ft deep, with six 20 ft wide panels of variable mesh net (1 each of sequentially attached ½-inch, ⅝-inch, ¾-inch, 1-inch, 1½-inch, and 2-inch stretched mesh). Gillnets were set with a 2-person crew operating an outboard motorboat. Nets set offshore were typically tethered to buoys to aid in recovery. At nearshore sites, the small mesh end of each net was tethered to fence stakes along the shoreline and an owl decoy was placed on top of each fencepost to discourage bird activity near the net. After tethering the net, the net was stretched out away from shore by 1 crew member feeding the net from the boat bow while the boat operator drove the boat away from shore in reverse. A small buoy or cork was tethered to the offshore end of the hanging line to help locate and identify the net.

Entanglement nets were meant to capture Arctic char with minimal injury. Typically, these nets capture fish by the snout or mouth reducing the chance a fish penetrates the net deep enough to entangle its gills. Entanglement nets, made by Christiansen Net Company of either monofilament or multifilament mesh, were set in a variety of lake depths in mostly offshore areas. Monofilament nets were constructed with either ⅝-inch or three-quarter-inch square mesh with 0.2 mm–0.15 mm diameter monofilament. Multifilament nets were constructed with one-half-inch mesh made with 201/2 twine. The entanglement nets varied between 6 and 15 feet in depth and each utilized floating polypropylene hanging line and one-half-inch lead line.

The hoop nets were 5 ft in diameter and about 15 ft in length with approximately 1-inch mesh covering the framework. Each net had a 20 ft lead on each side of its entrance. The fyke nets were of similar design as the hoop nets but with a 4 ft square opening and covered in one-eighth-inch fabric mesh. The fyke nets also had 20 ft leads attached to each side of the entrance. Both hoop and fyke nets were fished in shallow lake areas (2 to 5 feet deep) with the net body orientated parallel to the shoreline with one lead attached to shore perpendicular to the fyke or hoop body and the other lead running offshore to deeper water. Both nets types were commonly deployed so that the net leads would span natural openings in emergent weed beds that provided natural fish movement corridors.

Funnel traps were constructed by hand and were 5 ft in length and about 18 inches in diameter with convex funnel entrances at both ends of the cylinder. The entire trap was composed of one-half-inch Vexar mesh. Funnel traps were baited with salmon roe or shrimp and were suspended with buoys at different depths throughout the lake in open water.

Trotlines were made by hand and consisted of a 150 ft braided mainline (about 150-pound test) with 20 lb test monofilament snoods connected every 10 ft along the mainline. Terminal gear consisted of one-half-inch gapped J-hooks baited with salmon roe, leeches, or commercial trout bait. Colored floating beads or “corkies” were threaded into the snoods so that they would slide and serve as both an attractor and help suspend the bait. The trotlines were fished by staking one end of the mainline near shore and anchoring the other end in deeper water (10–25 ft depth).

A commercial jitney seiner and crew were contracted to spend 8 hours fishing in Stormy Lake in waters ranging between 10 and 40 feet in depth in an effort to capture Arctic char.

Native Fish and Northern Pike Collection

Prior to rotenone treatment in Stormy Lake, many of the same capture methods (gillnets, entanglement nets, hoop nets) used for collecting Arctic char broodstock were also utilized to collect native fish species and northern pike. We also fished galvanized 18-inch long minnow traps in nearshore weedy locations to target stickleback and sculpins. The goal of this native fish collection effort was to collect as many representative fish species as possible and hold them in net pens at Wik Lake (Figure 13) until Stormy Lake detoxified and they could be returned. This collection effort also allowed us to obtain northern pike for the radiotelemetry component of this project. These native fish and northern pike collections were planned for August and early September of 2012.

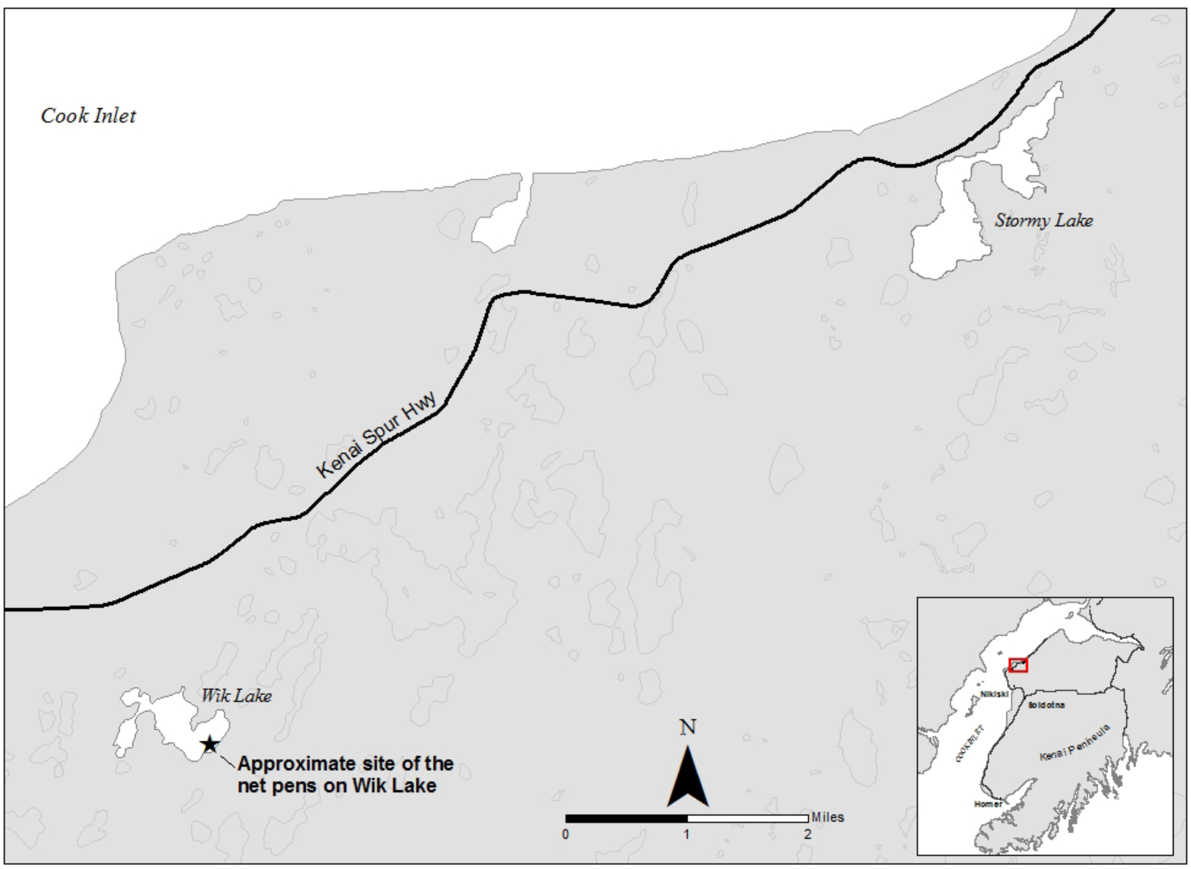

Figure 13.–Location of Wik Lake and the net pens used to hold native fish collected from Stormy Lake.

We also collected northern pike with gillnets in the spring of 2011 to obtain specimens for educational use, recover radiotagged northern pike that had been released for a separate project study that had concluded (Massengill 2017), and assess spawning condition of northern pike.

A fyke net, which had been maintained in the Stormy Lake outlet creek for over a decade to prevent northern pike dispersal into the Swanson River, also served to collect juvenile native fish. Many of the fish of suitable size that did not survive capture were utilized for educational purposes, genetic sampling, or were donated as food. To promote the natural recolonization of Stormy Lake posttreatment via dispersal from wild fish populations in the Swanson River, this fyke net was planned to be removed during 2013 if the northern pike population in Stormy Lake was eradicated.

RESULTS

WATER BODY PHYSICAL AND CHEMICAL CHARACTERIZATION

Lake Mapping

Bathymetric data were collected at Stormy Lake on 10 May 2010. Processing of the data revealed that Stormy Lake covers 403 surface acres, has a volume of 6,958 acre-feet, and a maximum depth of 50 feet. A bathymetric map depicting the lake was divided into 6 treatment sections, with corresponding volume estimates for each, and is shown in Figure 5.

Water Quality

The overall monthly water temperature, specific conductance (mS/cm), dissolved oxygen, pH, and turbidity results were recorded and graphed (Figures 14–18, respectively). Dissolved oxygen and turbidity decreased slightly posttreatment and temperature, specific conductance, and pH increased slightly posttreatment (although pH did decrease notably by the summer of 2013).

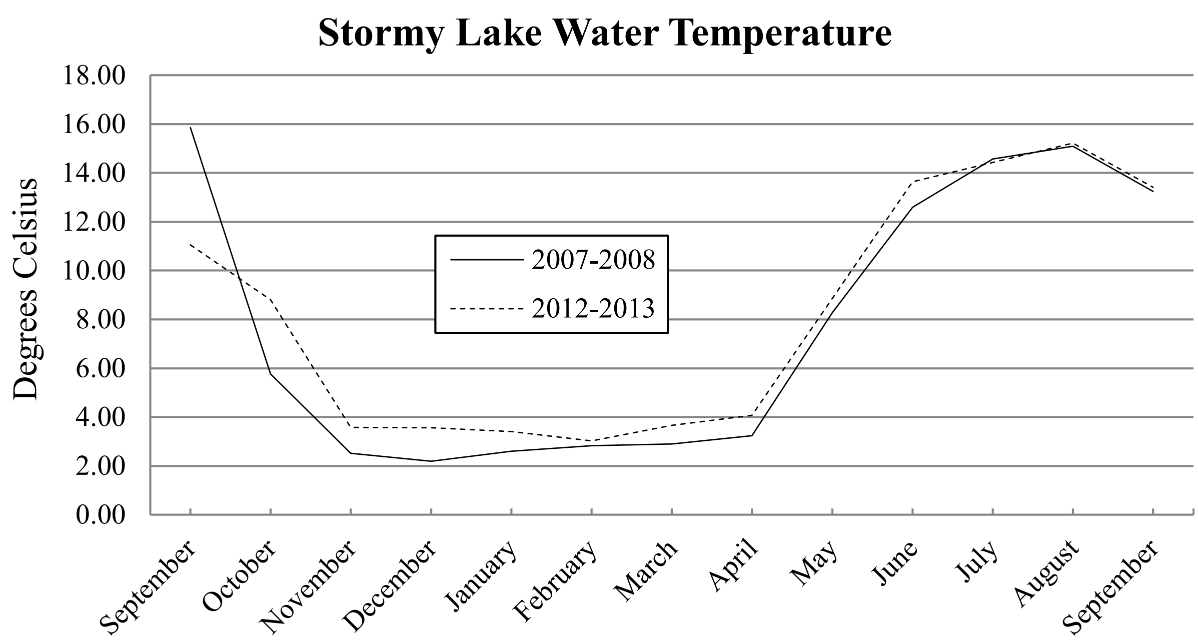

Figure 14.–Average midmonth water temperature (Celsius) for Stormy Lake before rotenone treatment (September 2007–June 2008; solid line) and after (September 2012–September 2013; dotted line).

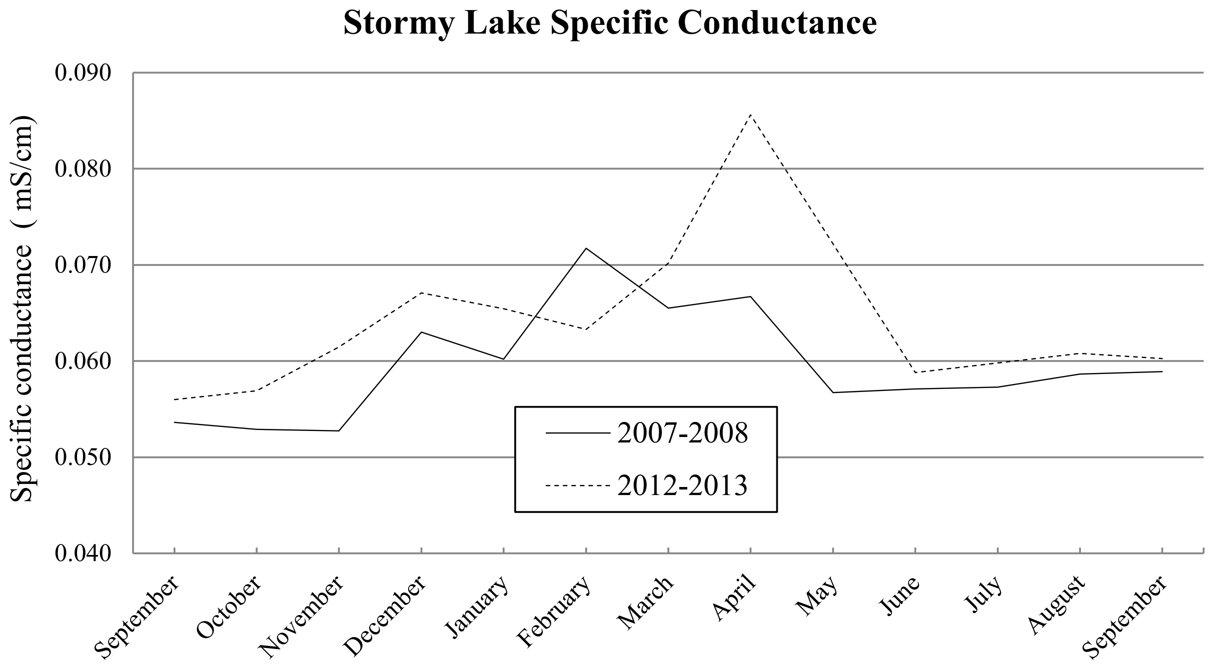

Figure 15.–Average midmonth water specific conductance (mS/cm) for Stormy Lake before rotenone treatment (September 2007–June 2008; solid line) and after (September 2012–September 2013; dotted line).

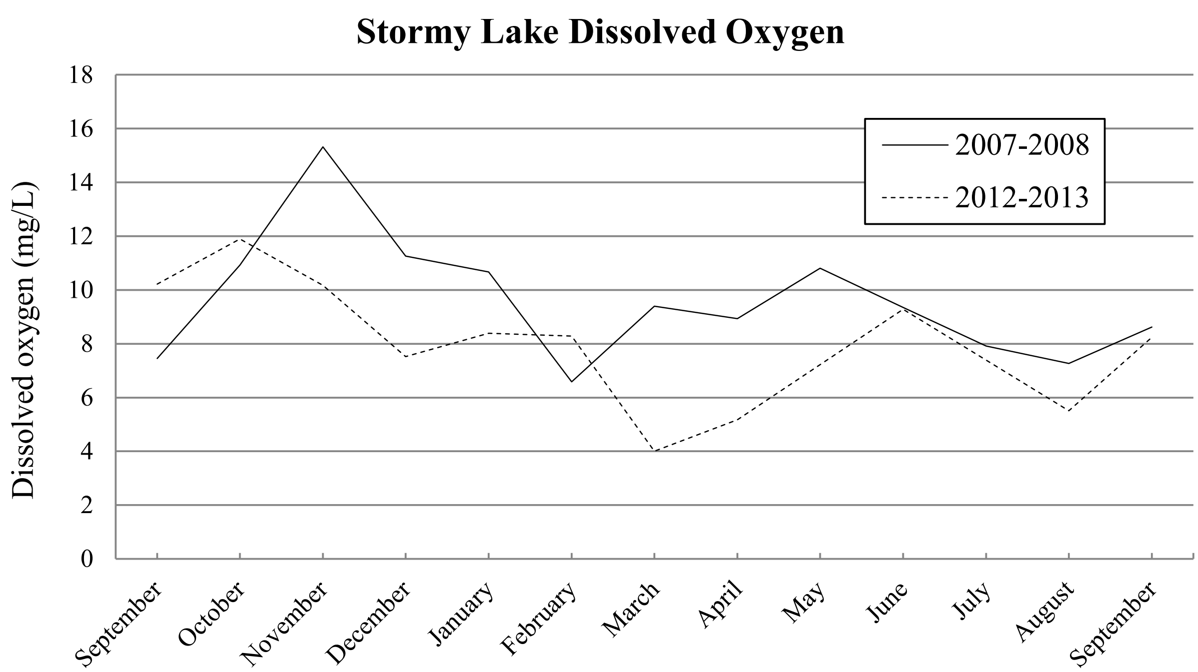

Figure 16.–Average midmonth water dissolved oxygen concentration (mg/L) for Stormy Lake before rotenone treatment (September 2007–June 2008; solid line) and after (September 2012–September 2013; dotted line).

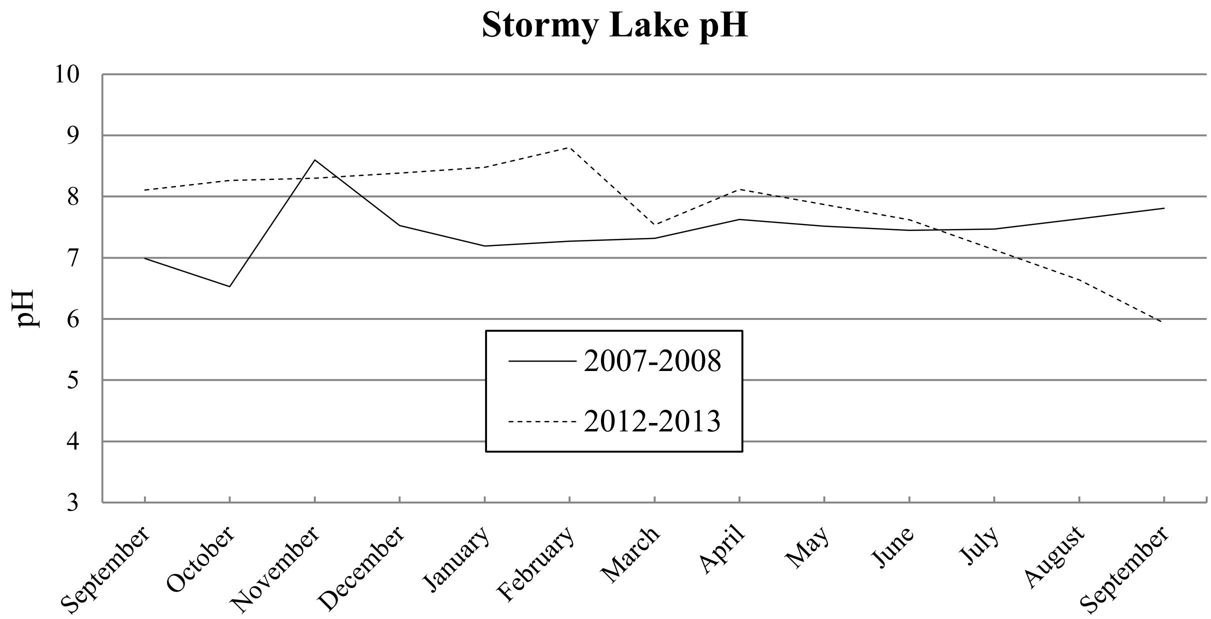

Figure 17.–Average midmonth water pH for Stormy Lake before rotenone treatment (September 2007–June 2008; solid line) and after (September 2012–September 2013; dotted line).

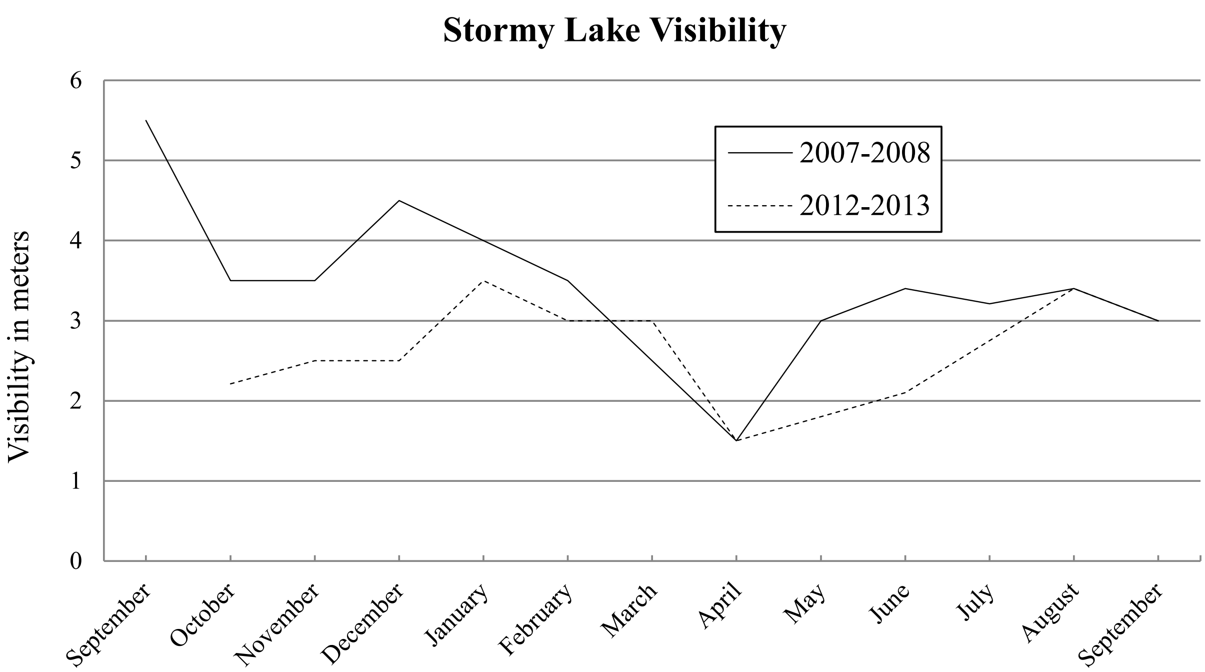

Figure 18.–Average midmonth visibility (turbidity) for Stormy Lake before rotenone treatment (September 2007–June 2008; solid line) and after (September 2012–September 2013; dotted line).

Stream Discharge

Discharge measurements were collected periodically for the upper reach of the Stormy Lake outlet creek between June 2006 and September 2012 (Table 5). Two discharge measurements were also collected from the Swanson River near its confluence with the Stormy Lake outlet creek during that period. During the years 2008 and 2009, when the most consistent monthly discharge measurements were collected, the maximum recorded discharge in the upper reach of the Stormy Lake outlet creek was 1.74 ft^3/s, the minimum discharge was 0.05 ft^3/s and average discharge across both years was 0.78 ft^3/s. Immediately prior to the rotenone treatment in 2012, the discharge measurement for the upper reach of the Stormy Lake outlet creek was 0.53 ft^3/s. The discharge measurement for the lower reach (near its confluence with the Swanson River) was 0.89 ft^3/s. The discharge measurement for the Swanson River near the Stormy Lake outlet creek confluence was 96.1 ft^3/s.

Table 5.–Stream discharge measurements periodically collected from the Stormy Lake outlet creek and Swanson River, June 2006–September 2012.

	Stream discharge (ft^3/s)								
	2006	2007		2008	2009	2011	2012		
Month	Upper Stormy Lake Outlet Creek	Upper Stormy Lake Outlet Creek	Swanson River	Upper Stormy Lake Outlet Creek	Upper Stormy Lake Outlet Creek	Upper Stormy Lake Outlet Creek	Upper Stormy Lake Outlet Creek	Lower Stormy Lake Outlet Creek	Swanson River
Jan				0.94	1.51				
Feb				0.95	0.98				
Mar				0.8	0.99				
Apr				0.76	0.93				
May				1.39	1.08				
Jun	0.73			0.51	0.49	0.11			
Jul				0.18	0.10				
Aug				0.18	0.05				
Sep			93.4	0.66			0.53	0.89	96.1
Oct				1.74					
Nov	2.04	0.67							
Dec		0.77		0.82					
Avg.	1.39	0.67		0.80	0.77				
Max.	2.04	0.67		1.74	1.51				
Min.	0.73	0.67		0.18	0.05				

[a] Global Positioning System (GPS) coordinates are recorded using Datum WGS84; Upper Stormy Lake Outlet Creek: 60°47′23.89″N.

[b] Discharge measurements in 2012 were supplied courtesy of the Kenai Watershed Forum.

BIOASSAYS

Bioassays to determine the minimum effective dose of rotenone were conducted near the Stormy Lake boat launch on 4 September 2012 starting at 6:00 PM. Four juvenile coho salmon (each about 110 mm fork length) were added to each of 6 plastic buckets filled with 20 liters of Stormy Lake water. At the time of the bioassays, the water temperature in the bioassay containers was 14°C, specific conductance was 0.056 mS/cm, dissolved oxygen was 8.5 mg/L, and pH was 7.25.

Fish in the bioassays with the lowest rotenone concentrations (12.5 ppb) were severely impaired within 40 minutes and were dead in 1 hour (Table 6). Fish in the of 25 ppb rotenone bioassay were dead within 50 minutes. Fish in the remaining bioassays (50, 100, and 200 ppb) all died within 30 minutes.

Table 6.–Results of rotenone bioassays on fish, 4 September 2012.

	Rotenone concentrations (ppb) used in bioassays				
	12.5	25	50	100	200
Time until death (min) [a]	60	50	30	30	30

[a] Bioassay containers were filled with 20 liters of Stormy Lake water (water temperature was about 14°C) and 4 juvenile coho salmon were placed in each container and a CFT Legumine solution was added to each container to produce the desired target rotenone concentration.

To take into account the effects that pH, turbidity, temperature, sunlight intensity, and depth could have on rotenone toxicity, the minimum target concentration of rotenone needed to be at least double the MED that achieved 100% mortality after 8 hours of exposure (Finlayson et al. 2010). The bioassay results indicate that all tested rotenone concentrations would be extremely effective at killing northern pike. This observed potency of CFT Legumine, even at relatively low concentrations, assured us that our proposed target rotenone concentration (50 ppb) was more than adequate to kill northern pike in Stormy Lake.

Despite the bioassays results indicating a rotenone concentration well below 50 ppb would be effective, we selected 50 ppb as the target rotenone concentration for the treatment. That decision was based on recent experience with other rotenone treatments wherein the target rotenone concentration fell 30–50% below target, possibly because of strong rotenone-binding effects by organics in the lake (Massengill 2014a, 2014b). Environmental factors that might significantly reduce the potency of rotenone in Stormy Lake include the presence of dense submerged aquatic vegetation beds, dilution from wetland inputs, areas of deep organic substrate, and areas of deep water (>30 feet).

TREATMENT DETAILS

Application Overview

The Stormy Lake rotenone treatment team consisted of 30 people representing ADF&G Division of Sport Fish and Division of Commercial Fisheries, the USFWS Kenai Field Office, the Kenai National Wildlife Refuge, the Alaska Department of Natural Resources Division of Parks and Recreation, the Kenai Watershed Forum, and an observer from the USFWS Gene Conservation Lab in Anchorage.

A safety meeting for the entire treatment team was held on 4 September 2012. The safety meeting occurred at the Stormy Lake day-use picnic area and lasted about 90 minutes. The safety meeting identified the potential health risks associated with rotenone exposure and the proper use of personal protective equipment (PPE) including common pesticide handling procedures that protect against exposure. Instructions were provided on first aid measures for various routes of rotenone exposure and the emergency contacts for specific incidents.

After the safety meeting, the treatment team relocated to the Stormy Lake boat launch where the treatment team became familiar with the application equipment and were shown the rotenone loading area and where supplies were stored. Next, the treatment team was shown how to operate the various rotenone pump systems in the different application boats. The treatment team was then divided into groups and these groups practiced operating the boats and application equipment for a couple hours.

On 5 September 2012, the rotenone treatment began at 9:00 AM with the outboard boat applicators. Shortly thereafter, backpack applicators began to treat wetlands adjacent to Stormy Lake. The treatments continued until 4:00 PM. Following application, all application equipment was cleaned before applicators adjourned for the day.

On 6 September 2012, rotenone treatment was resumed at 8:30 AM with the outboard boat applicators. High winds (>30 mph) developed by noon, creating challenging boat application conditions. By late morning, the drip station applicators and backpack applicators began treatment of the Stormy Lake outlet creek. Operation of the rotenone chemical deactivation station began and continued to operate until the following day. The rotenone treatment of the Stormy Lake outlet creek lasted over 4 hours.

Applicators with an airboat treated about 3 acres of wetlands adjacent to Stormy Lake. Applicators also used rotenone mixture balls (rotenone and sand wrapped in cheesecloth) to treat seeps along the lake perimeter. Treatment activities continued until 4:00 PM and by then the entire lake and outlet creek had been completely treated. The deactivation station in the Stormy Lake outlet creek operated throughout the day and through the night.

On 7 September 2012, most of the treatment team was either relieved of their duties or were transporting equipment back to the Soldotna ADF&G office. A 5-person application team treated a small 1-acre pond connected to Stormy Lake and also spot treated a few weed beds in Stormy Lake where mixing may have been poor. By early afternoon, all treatment activities were complete. The deactivation station was stopped for 4 hours at midday and no impairment effects were observed with the caged sentinel fish held in the Swanson River (location was just below the Stormy Lake outlet creek confluence) so the deactivation station remained off. In total, 910 gallons of CFT Legumine and 7,716 pounds of Prentox Prenfish Fish Toxicant Powder were applied to the treatment area over a 3-day period.

Drip Station and Deactivation Observations

Three rotenone drip stations began operating the morning of 6 September 2012 to treat the Stormy Lake outlet creek (Table 7). Operation of the deactivation station near the Swanson River began on 6 September 2012 at 1:30 PM and concluded on 7 September 2012 at 12:00 PM. The stream discharge in the lower section of the creek at the time of treatment was approximately 0.89 ft^3/s. The target range for the rate of $KMnO_4$ application by the deactivation station rate was 8.3–8.5 g/min (calculated to deactivate 1.3 ppm of rotenone formulation with a contact time of 30 minutes, a background stream $KMnO_4$ demand of 2.0 ppm, and a desired $KMnO_4$ residual concentration of 1.0 ppm), and this target was achieved (Table 8). Estimated stream concentrations of $KMnO_4$ varied between 0.0 and 1.1 ppm. It was assumed that the concentration of rotenone found in the outlet creek above the deactivation station would be higher than our target concentration (1.0 ppm) because rotenone entering the creek from the Stormy Lake treatment was in addition to that applied by the drip stations.

Rotenone-impaired salmonids and sticklebacks were observed floating downstream in the creek about 50 minutes after the drip stations began applying rotenone. Caged sentinel fish placed above each drip station were all dead in less than 2 hours (Table 7). Caged fish held downstream of the deactivation station in the Swanson River (20 yards below the outlet creek's confluence) never died or showed signs of rotenone impairment (Table 8).

By noon on September 7, operation of the deactivation station was halted to observe the effect on caged sentinel fish held in the Swanson River. After 7 hours without deactivation, the sentinel fish appeared healthy and robust. Because the sentinel fish in the Swanson River were not impaired and because the concentration of rotenone in the Swanson River was calculated to be below 2.0 ppb, chemical deactivation was permanently discontinued. Hach Total Chlorine tests were done 4 times near the confluence as a surrogate test for $KMnO_4$ residual. $KMnO_4$ concentrations ranged from 0.7 to 1.1 ppm and approximated the 1.0 ppm $KMnO_4$ residual target goal (Finlayson et al. 2010).

Table 7.–Stormy Lake outlet creek rotenone drip station treatment data and sentinel fish response.

Stream section [a]	Stream discharge (ft^3/s)	Time [b]	Drip rate of undiluted CFT Legumne (mL/min)	Sentinel fish response [c]
Upper	0.53	**9:30**	2.0	Sentinel fish exposed, 3 of 3 alive
Upper	0.53	10:00	2.0	1 of 3 alive
Upper	0.53	10:30	2.0	0 of 3 alive
Upper	0.53	11:30	2.0	
Upper	0.53	12:30	2.0	
Upper	0.53	13:30	2.0	
Upper	0.53	14:30	2.0	
Upper	0.53	15:00	Stopped	
Middle	0.7	**10:05**	2.6	Sentinel fish exposed, 7 of 7 alive
Middle	0.7	11:01	2.2	4 of 7 alive
Middle	0.7	12:00	2.6	0 of 7 alive
Middle	0.7	13:07	2.5	
Middle	0.7	14:03	2.7	
Middle	0.7	15:00	2.6	
Middle	0.7	16:06	Stopped	
Lower	0.86	**10:30**	3.3	
Lower	0.86	11:05	3.3	
Lower	0.86	11:30	3.3	Sentinel fish exposed, 3 of 3 alive
Lower	0.86	11:46	2.7	0 of 3 alive
Lower	0.86	12:16	2.5	
Lower	0.86	12:37	3.1	
Lower	0.86	13:11	3.2	
Lower	0.86	14:00	3.1	
Lower	0.86	14:43	3	
Lower	0.86	15:16	3.2	
Lower	0.86	15:45	3.2	
Lower	0.86	15:55	Stopped	

Note: Rotenone was delivered to the Stormy Lake outlet stream using drip stations consisting of portable battery-powered peristaltic pumps that pumped rotenone through a drip line suspended just above the surface of the creek.

[a] Drip station locations were as follows: "upper" was located at the lake outlet, "middle" was located at about the midpoint between the lake outlet and a culvert in the lower section of the stream, and "lower" was located approximately 700 yards upstream from the Swanson River.

[b] Drip station start times are shown in bold print.

[c] Sentinel fish were juvenile coho salmon caged just upstream of each drip station.

Table 8.–Stormy Lake outlet creek rotenone deactivation station data including $KMnO_4$ feed rate, estimated stream $KMnO_4$ concentration, and sentinel fish response.

Date	Time	$KMNO_4$ feed rate (g/min)	Total chlorine test location	Total chlorine test value [a]	Estimated stream $KMNO_4$ concentration (ppm)	Swanson River sentinel fish response [b]
6 Sep 2012	13:30	8.3	NA		Not estimated	Alive - no response
6 Sep 2012	14:20	8.3	Stream mouth	0	0.0	Alive - no response
6 Sep 2012	14:40	8.4	Stream mouth	0	0.0	Alive - no response
6 Sep 2012	14:50	8.5	150 yards above stream mouth	1.2	1.1	Alive - no response
6 Sep 2012	15:05		NA			Alive - no response
6 Sep 2012	15:30	8.5	Stream mouth	0.8	0.7	Alive - no response
6 Sep 2012	15:45	8.5	150 yards above stream mouth	1.2	1.1	Alive - no response
6 Sep 2012	16:00	8.5	NA			Alive - no response
6 Sep 2012	18:00	8.5	Stream mouth	1	0.9	Alive - no response
7 Sep 2012	11:00	8.5	Stream mouth		0.0	Alive - no response
7 Sep 2012	12:00	Stopped	NA		Not estimated	Alive - no response
7 Sep 2012	18:00					Alive - fish removed

Note: The deactivation station was located about 500 yards upstream from the creek mouth and consisted of a chemical feeder powered by a gas generator suspended over the creek on a walkway platform. The deactivation apparatus dispensed potassium permanganate crystals ($KMnO_4$) to deactivate rotenone.

[a] The total chlorine test acts as a surrogate test for $KMnO_4$ and was done using a Hach total chlorine test kit using a "DPD method"; that is, a colorwheel was used to estimate the surrogate chlorine concentration in parts per million which was then multiplied by a coefficient of 0.89 to estimate the $KMnO_4$ concentration in parts per million.

[b] Five caged juvenile coho salmon were used as sentinel fish and placed in the Swanson River about 50 yards downstream of the Stormy Lake outlet creek mouth along the same bank that the creek enters.

Fish Cleanup

Most of the fish carcasses resulting from the lake treatment sank, as expected when water temperatures are cool (Bradbury 1986). An attempt to collect floating dead fish and those submerged in shallow water (<3 feet) was made with roving boat crews equipped with dip nets and fish spears. Although an exact count of dead fish did not occur, an estimated 150–200 longnose suckers, 40 northern pike, and several rainbow trout and Arctic char were collected between 5 and 7 September 2012. Hundreds of dead sticklebacks that washed ashore near the Stormy Lake boat launch were collected with rakes. All fish carcasses were disposed of at the Soldotna landfill.

Treatment Evaluation

The effectiveness of the Stormy Lake rotenone treatment at eradicating the northern pike population was assessed in the following ways: analysis of rotenone concentration in the treatment area, gillnet surveys, fates of caged sentinel fish, and the fates of radiotagged northern pike exposed to the treatment.

Rotenone Sampling

Water and sediment samples were collected from Stormy Lake just prior to the rotenone treatment and periodically afterwards until the rotenone fully degraded in the lake water. All samples were analyzed for both rotenone and rotenolone concentrations (rotenolone is a less toxic degradation product of rotenone), which allowed us to track the natural degradation of these chemicals. The samples also allowed us to assess whether the rotenone was well mixed within the treatment area and at a concentration lethal to northern pike.

One pretreatment sediment sample and 2 pretreatment water samples were collected on 4 September 2012 which confirmed that rotenone and rotenolone were not present in the treatment area prior to treatment. After the rotenone treatment, multiple water and sediment samples were collected periodically from sites 1–6 (Figure 10). Not all sample locations were sampled during each sampling event, and the sampling frequency varied at the discretion of the project leader based on the observed rate of rotenone degradation determined by previous sampling results.

Results show that the peak average rotenone concentration in Stormy Lake water (47.6 ppb) occurred on 7 September 2012 (Figure 19). On that date, individual water samples ranged from 80.0 ppb to 33.1 ppb rotenone, and average rotenolone concentration was 13.5 ppb (Table 9). Following this date, the concentration of rotenone at all lake water sampling sites decreased steadily over time and was no longer detectable by 21 January 2013 (Figure 20). The average concentration of rotenolone, a rotenone degradation byproduct, peaked on 17 September 2012. The rotenolone degradation trend was similar to rotenone and it was no longer detectable in lake water by 21 January 2013 (Figure 21).

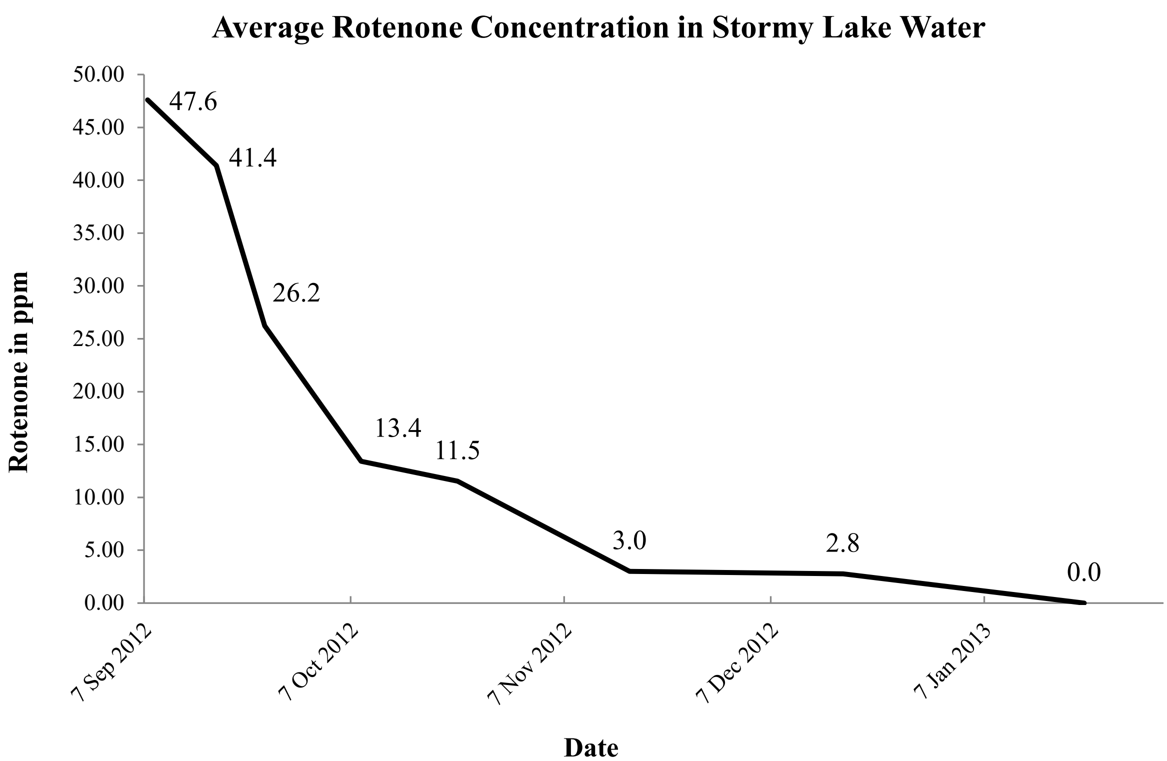

Figure 19.–Average rotenone concentration in Stormy Lake water.

Table 9.–Summary of Stormy Lake and Stormy Creek water and sediment sampling to determine concentration of rotenone and rotenolone.

Chemical	Sample date	Treatment status	Concentration of rotenone and rotenolone (ppm) [a] Site 1 sediment	Site 2a water	Site 2b water	Site 3a water	Site 3b water	Site 4 sediment	Site 5a water	Site 5b water	Upper Creek [b]	Lower Creek [b]	Avg. of water sites	Percent change from first post-treatment sampling event	Percent change from previous post-treatment sampling event
Rotenone															
	9/4/12	Pre	0.0	0.0	0.0										
	9/7/12	Post	22.0	66.8	80.0	36.4	36.2	18.3	33.1	33.1			47.6		
	9/17/12	Post	0	48.0	53.6	41.6	36.5	5.0	33.2	35.4			41.4	0.13	0.13
	9/24/12	Post	309.0	28.1	29.8	25.8	24.1	0.0	24.3	25.2			26.2	0.45	0.37
	10/8/12	Post	55.7	14.5	10.8	14.1	12.5		12.2	16.4			13.4	0.72	0.49
	10/22/12	Post		15.1	10.6				11.1	10.3	10.5	0.0	11.5	0.76	0.14
	11/16/12	Post		3.0	3.0								3.0	0.94	0.74
	12/17/12	Post	17.9	5.6	1.5	4.9	0.0		3.91	0.0			2.8	0.94	0.08
	1/21/13	Post	0.0	0.0	0.0	0.0	0.0		0.0	0.0			0.0	1.00	1.00
Rotenolone															
	9/4/12	Pre	0.0	0.0	0.0										
	9/7/12	Post	14.4	19.0	22.2	10.3	11.6	15.1	9.16	8.7			13.5		
	9/17/12	Post	0.0	18.0	21.8	17.4	14.8	0.0	12.8	13.3			16.4	0.66	−0.21
	9/24/12	Post	157.0	14.0	13.7	12.7	12.3	0.0	10.7	10.0			12.2	0.74	0.25
	10/8/12	Post	256.0	12.1	12.8	11.7	12.5		12.0	12.2			12.2	0.74	0.00
	10/22/12	Post		13.3	12.9				11.8	11.2	11.7	0.0	12.3	0.74	−0.01
	11/16/12	Post		12.7	9.5								11.1	0.77	0.10
	12/17/12	Post	24.0	9.3	1.0	7.4	0.0		6.88	0.0			4.1	0.91	0.63
	1/21/13	Post	0.0	0.0	0.0	0.0	0.0		0.0	0.0			0.0	1.00	1.00

[a] Blank values indicate no sample was collected from that site; a zero value indicates that the chemical of interest was not detected.

[b] Sample was collected in the Stormy Lake outlet creek.

Stormy Lake Water Samples: Rotenone Concentration

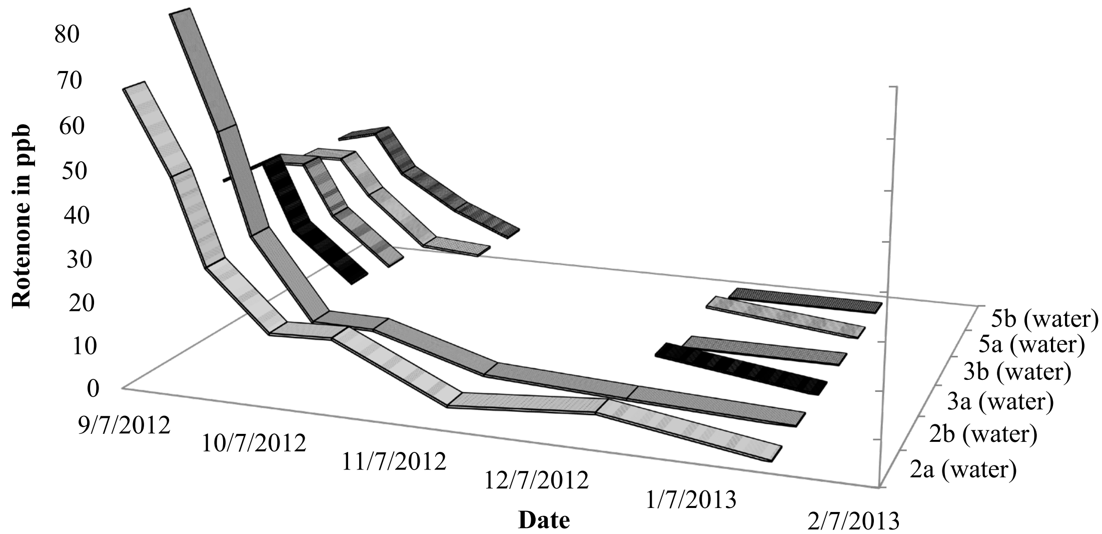

Figure 20.–Rotenone concentrations at 6 Stormy Lake sampling locations from 7 September 2012 through 7 February 2013.

Stormy Lake Water Samples: Rotenolone Concentration

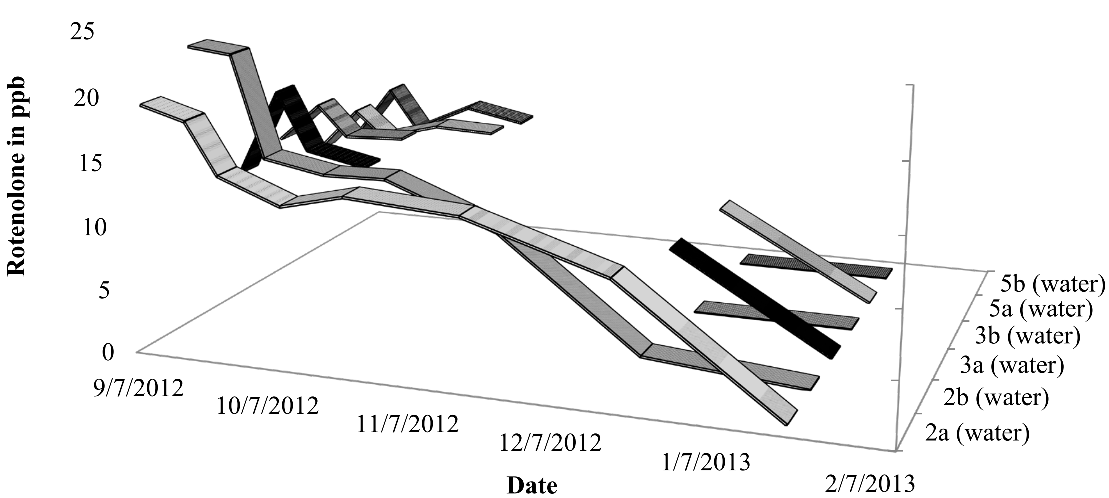

Figure 21.–Rotenolone concentrations at 6 Stormy Lake sampling locations from 7 September 2012 through 7 February 2013.

Two water samples were collected from the Stormy Lake outlet creek on 22 October 2012. One sample was collected just below the lake outlet and the other was collected about 500 yards above the creek's confluence with the Swanson River. These samples were collected to assess rotenone degradation from stream-related effects over a three-quarter-mile length of stream. The rotenone and rotenolone concentrations of the upper stream sample were 10.5 ppb and 11.7 ppb, respectively; the lower stream sample had no detectable rotenone or rotenolone.

The average rotenolone concentration in lake water increased (from 13.5 ppb to 16.4 ppb) by the second posttreatment sampling event, and then fell to about 12 ppb where it plateaued for several months before falling sharply to 4.1 ppb by 17 December 2012 (Table 9).

Sediment samples were not collected as often as water samples because of difficulties sampling sediment though ice. The peak rotenone concentration detected in a sediment sample (309 ppb) was collected on 24 September 2012 but at this same sampling site, it was undetectable by 21 January 2013. Rotenone tends to bind strongly with organics in sediment (Turner et al. 2007); elevated rotenone levels in sediment were not unexpected.

To assess whether rotenone persisted outside the regular sampling sites, we collected samples from 16 new water sites and 1 new sediment site on 11 February 2012 (Figure 10 and Table 10). Results of those samples confirmed that no rotenone or rotenolone was present in Stormy Lake water. The new sediment sample taken near the outlet creek had a rotenone concentration of 8.5 ppb and a rotenolone concentration of 9.9 ppb.

The peak average rotenone concentration measured in the lake water (47.6 ppb) indicates the target concentration of 50 ppb was nearly attained. The lowest average peak rotenone concentration detected from sites 1–6 was 33.2 ppb, suggesting the rotenone concentration was lethal to northern pike even where rotenone concentration was lowest. By September 24, the overall rotenone concentration in the lake had degraded significantly but its concentration was more homogenous across sample sites and ranged from 24.1 ppb to 29.8 ppb.

Table 10.–Summary of Stormy Lake water and sediment sampling to determine concentration of rotenone and rotenolone from sites 1 and 6–13.

	Concentration of chemical in ppm	
Sampling site	Posttreatment rotenone sample (11 Feb 2012)	Posttreatment rotenolone sample (12 Feb 2012)
Site 1 (sediment) [a]	8.5	9.9
Site 6a (water)	0	0
Site 6b (water)	0	0
Site 7a (water)	0	0
Site 7b (water)	0	0
Site 8a (water)	0	0
Site 8b (water)	0	0
Site 9a (water)	0	0
Site 9b (water)	0	0
Site 10a (water)	0	0
Site 10b (water)	0	0
Site 11a (water)	0	0
Site 11b (water)	0	0
Site 12a (water)	0	0
Site 12b (water)	0	0
Site 13a (water)	0	0
Site 13b (water)	0	0

[a] Sample was collected in the upper reach of the Stormy Lake outlet creek near the lake.

Radio Telemetry

Thirteen live free-roaming radiotagged northern pike were present in Stormy Lake at the onset of the rotenone treatment. These fish were tagged on 29 August 2012, with the exception of 1 fish that was already present in the lake from an unrelated northern pike movement study completed in 2011.

By completion of the rotenone treatment, all the radiotagged northern pike were dead (Appendix D1). The first of 4 tracking surveys was conducted on 5 September 2012 just prior to the onset of the rotenone application. This survey revealed that none of the radiotagged northern pike were emitting mortality signals. The lack of a mortality signal does not necessarily mean a radiotagged fish is alive, particularly if wind generated currents move a carcass and prevent activation of the mortality signal. However, the tracking survey conducted on 5 September was done under calm conditions, so we presumed the lack of any mortality signals accurately reflected the lack of mortality in radiotagged fish.

Three additional surveys were conducted during or after the rotenone treatment. After the final survey, 9 of the fish were confirmed dead by either carcass recovery or by detection of a mortality signal from their radio transmitter. There were 4 radiotagged fish that did not emit mortality signals and were not recovered as carcasses. It is possible that wind-generated waves prevented activation of the radiotag mortality signal. In these 4 cases, each death was verified by either visual observation or by the inability of the tracking crew to solicit a movement response after repeatedly driving the tracking boat over the area where the strongest radio signal was detected. Such boating activity reliably caused movement of radiotagged fish during tracking surveys at Stormy Lake for an unrelated northern pike movement study during 2009–2011 (Massengill 2017).

Sentinel Fish

Cages with sentinel fish (2–3 juvenile coho salmon each) were placed in Stormy Lake on the morning of 5 September 2012 at 9 locations (Figure 11). The cages were placed at various depths between 1 and 25 feet. By 4:00 PM on 5 September, the only sentinel fish still alive were in 2 cages suspended in the middle of the water column in the southernmost basin of Stormy Lake. By midmorning on 6 September 2012, all sentinel fish were confirmed dead; this occurred before the entire lake treatment had been completed.

After treatment, sentinel fish trials were used to assess the lake toxicity and determine when fish restocking could occur (Table 11). By 11 February 2013, fish were surviving in the lake after 72 hours of exposure, indicating the lake was safe for restocking.

Table 11.–Responses of sentinel fish after treatment of Stormy Lake.

Date	Location description	Cage depth (ft)	Number of fish in cage	Initial exposure period (h)	Number of live fish after initial exposure	Second exposure period (h)	Number of live fish after second exposure
12/4/2012	Lake outlet	1	10	24	2	48	1
12/4/2012	100 yards ESE from boat launch	10	3	24	3	48	2
12/4/2012	100 yards ESE from boat launch	6	3	24	0	48	
2/11/2013	100 yards ESE from boat launch	6	1	72	1		
2/11/2013	Border of Areas 2 and 3	12	1	72	1		
2/11/2013	East end of Area 2	5	1	72	1		
2/11/2013	East end of Area 3	15	1	72	1		
2/11/2013	Area 4 near narrows	10	1	72	Cage stolen		
2/11/2013	Area 4 near narrows	25	1	72	Cage stolen		
2/11/2013	Area 5 outside of reed bed	5	1	72	Cage stolen		
2/11/2013	Area 6 SE part of lake	6	1	72	Cage stolen		
2/11/2013	Border of Areas 5 and 6 offshore of swim beach	5	1	72	1		
2/11/2013	Border of Areas 4 and 5 N of point north of beach	8	1	72	Cage stolen		

Gillnetting and Minnow Trapping

We greatly reduced the amount of posttreatment gillnetting effort planned for assessing the treatment's success because the lake froze before the rotenone had degraded enough to allow surviving fish to disperse from their sanctuaries. On 22 October 2012, when it became apparent the lake would freeze before complete rotenone deactivation could occur, we fished 14 gillnets for a combined 194 hours of netting effort (Table 12). We pulled the nets on 23 October 2012 and had to break ice to remove them. No fish of any species were caught.

Stormy Lake detoxified by mid-January of 2013, and on 19 March 2013, native fish held in net pens in Wik Lake were released into Stormy Lake. Because of this, it was not possible to conduct a full-scale gillnet survey. We did conduct a second abbreviated gillnet survey of Stormy Lake on 19 May 2014 to assess fish species presence and to collect biological data. This effort consisted of 4 gillnets fished for a combined total of 75 hours and no northern pike were caught; native fish catches were plentiful (Table 12).

Minnow traps were fished posttreatment in an effort to capture juvenile northern pike despite that method having extremely low success during pretreatment efforts. Five minnow traps were each fished for 24 hours on 24 July 2014 and again on 30 July 2014; no northern pike were captured although 13 juvenile coho salmon, 9 juvenile rainbow trout, and 1 juvenile longnose sucker were caught in one trap fished in the Stormy Lake outlet creek about 10 meters downstream from the lake (Table 13).

It is noteworthy that staff did observe numerous small juvenile sticklebacks swimming in Stormy Lake while tending the minnow traps despite not catching any in the minnow traps.

BIOLOGICAL COLLECTIONS

Invertebrate Surveys

A total of 25 different invertebrate taxa were identified during the pretreatment sampling that occurred in 2010, 2011, and 2012. Nineteen different taxa were identified during the posttreatment sampling that occurred in 2013 and 2014 (Table 14 and Appendix E1). A total of 27 separate taxa were identified altogether. Seven taxa were identified in pretreatment samples that were not found in posttreatment samples and 2 taxa were identified in posttreatment samples that were not found in pretreatment samples.

Although zooplankton were not enumerated like other invertebrates, it is noteworthy that rotifers that were common in July pretreatment Wisconsin net samples were absent in July posttreatment Wisconsin net samples. Temporary but strong decreases in zooplankton abundance posttreatment were expected (Chlupach 1977; Finlayson et al. 2000; Ling 2003).

ADF&G staff working from a boat at Stormy Lake in the spring of 2013 observed a large biomass of scuds (freshwater shrimp) distributed throughout shallow areas of Stormy Lake and observed numerous live freshwater mussels throughout the lake.

Table 12.–Netting surveys on Stormy Lake between August 2012 and May 2014.

Treatment status	Net type	Net check date	Number of nets fished	Fish species: Northern pike	Rainbow trout	Arctic char	Longnose sucker	Coho salmon (juv.)	Hours of netting effort
Pretreatment									
	Gill net [a]								
		08/09/12	2						7.2
		08/10/12	4				2		15.9
		08/13/12	4				2		13.5
		08/15/12	7	11			31		144.2
		08/16/12	7	11			34		177.3
		08/17/12	7	6	1		22		166.7
		08/21/12	10	15			58		201.9
		08/22/12	10				20		273.6
		08/23/12	8	3			4		87.1
		08/24/12	8				10		33.9
		08/27/12	12	2			2		59.2
		08/29/12	12	23			17		253.8
		10/23/12	14						346.9
		Subtotal		71	1	0	202	0	1,781.0
	Entanglement net [b]								
		08/09/12	3						11.2
		08/10/12	3						13.9
		08/13/12	3						10.8
		08/15/12	3						70.0
		08/16/12	3			1			74.5
		08/17/12	4						106.4
		08/20/12	6	1			3		23.5
		08/21/12	4						71.5
		08/24/12	4			4			197.0
		Subtotal		1	0	5	3	0	578.8
	Grand total			72	1	5	205		2,359.8

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Table 12.–Page 2 of 2.

Treatment status	Net type	Net check date	Number of nets fished	Fish species					Hours of netting effort
				Northern pike	Rainbow trout	Arctic char	Longnose sucker	Coho salmon (juv)	
Posttreatment									
	Gill net [a]								
		10/22/12	14	0	0	0	0	0	194.0
		05/19/14	4	0	32	72	2	36	75.0
	Grand total			0	32	72	2	36	269.0

[a] Made with floating hanging lines and bottom lead lines, all gillnets 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, 1.75 in and 2.0 in.

[b] Entanglement nets were a combination of 2 styles as follows: monofilament nets 150 ft in length and 16 ft deep that were constructed with five-eighths in or three-quarter in square mesh made with 0.2–0.15 mm monofilament, and multifilament nets 150 ft in length and 6 ft deep constructed with one-half in mesh made with 201/2 twine. These nets were set primarily to target Arctic char for rescue purposes.

Table 13.–Posttreatment minnow trapping in Stormy Lake.

Date	Trap no.	Catch				
		Northern pike	Stickleback	Rainbow trout	Coho salmon	Longnose sucker
7/24/2014	1	0	0	0	0	0
7/24/2014	2	0	0	0	0	0
7/24/2014	3	0	0	0	0	0
7/24/2014	4	0	0	0	0	0
7/24/2014	5	0	0	0	0	0
7/30/2014	1	0	0	0	0	0
7/30/2014	2 [a]	0	0	9	13	1
7/30/2014	3	0	0	0	0	0
7/30/2014	4	0	0	0	0	0
7/30/2014	5	0	0	0	0	0
	Total	0	0	9	13	1

[a] This minnow trap was fished in the Stormy Lake outlet creek, not the lake.

Table 14.–Invertebrate taxa detected in Stormy Lake before and after rotenone treatment.

Taxa	Detected before treatment	Detected after treatment
Amphipoda (scud)	X	X
Anispotera (dragonflies)	X	X
Araneae (spiders) [b]	X	
Asplanchna (rotifers)	X	X
Chironomidae (nonbiting midges)	X	X
Chrysomelidae (leaf beetles) [b]	X	
Cladocera (water fleas, daphnia)	X	X
Coleoptera (unknown beetles)	X	X
Copepod (Clyclops, Diaptomus)	X	X
Corixidae (water boatmen)		X
Cuicidea (mosquito)	X	
Diptera (unknown adult)	X	X
Dysticidae (predacious diving beetle or whirligig)	X	X
Ephemeroptera (mayfly)	X	X
Gastropoda (snails)	X	X
Gerridae (water striders)	X	X
Hirudinea (leeches)	X	X
Hydrophilidae (water scavenging beetle) [b]	X	
Hymenoptera (wasp, ant)	X	X
Kellicotta (rotifer)	X	
Nematoda	X	
Oligochaeta (earthworms)		X
Pelecypoda (molluscs)	X	X
Plecoptera (stone flies) [b]	X	
Syrphidae (aphid eating fly) [b]	X	
Trichoptera (caddis flies)	X	X
Zygoptera (damselflies)	X	X
Total taxa detected	25	19

Note: Taxa identification was resolved to at least the order level, often the family level, with the following exceptions: Nematoda (phylum), and Oligochaeta, Hirudinea, Pelecypoda, and Gastropoda (class).

Native Fish Collections and Restocking

Efforts to preserve the Stormy Lake native fish populations occurred during several phases of this project. The first phase occurred in 2011 when wild Arctic char in Stormy Lake and Dolly Varden Lake (both lakes are in the Swanson River drainage) were captured for broodstock (Table 15). Because no male Arctic char survived capture at Stormy Lake, we collected males from Dolly Varden Lake as surrogates. All Arctic char broodstock were held after capture in net pens in their lake of origin and monitored regularly for spawning ripeness. On 11 November 2011, eggs were collected from 10 Stormy Lake females and milt was collected from 14 Dolly Varden Lake males. All fish were released back into their lake of origin after their gametes were collected. Eggs were fertilized and offspring reared to fingerling size at the ADF&G Fort Richardson hatchery in Anchorage.

A second fish preservation phase occurred in the summer of 2012 when Stormy Lake native fish were collected using nets and traps and fish were relocated to net pens in Wik Lake and held until Stormy Lake detoxified 5 months posttreament. Table 12 summarizes the 2012 pretreatment netting effort and catch, and Table 16 summarizes the 2012 trapping effort and catch using fyke net traps, hoop traps, minnow traps and dipnetting. Most of the native fish captured by trapping and netting were successfully relocated to the Wik Lake net pens with the exception of sticklebacks. Several hundred sticklebacks were relocated to the net pens, but it became quickly apparent the mesh size of the pen netting was too large to contain sticklebacks so further stickleback relocation was discontinued. There were 113 freshwater mussels collected by dip net from Stormy Lake in 2012 and placed within a 10 ft × 5 ft wire-screen fence enclosure installed at Wik Lake.

A third fish preservation phase occurred during the first 2 days of rotenone treatment at Stormy Lake (5–6 September 2012) when rotenone-impaired native fish were collected by roving boat crews using dip nets. Collected fish were transported to aerated live wells containing untreated lake water near the Stormy Lake boat launch. Any fish that revived was then relocated to the net pens at Wik Lake.

To reduce handling-related mortality throughout all fish preservation efforts, rescued fish were not individually counted. We estimated the total number of each species relocated to the net pens by estimating how many were present in each dip net load while transferring them. A summary of the estimated number of fish relocated to the Wik Lake net pens is found in Table 17. Fish that survived the 5 months of net-pen confinement in Wik Lake were returned to Stormy Lake (after the lake detoxified) and on 1 March 2013 and included 51 adult longnose suckers, 55 juvenile rainbow trout, 38 juvenile coho salmon, and 35 adult freshwater mussels. There were 6,836 hatchery-reared Arctic char of mixed Stormy Lake and Dolly Varden Lake parentage also released into Stormy Lake on 17 June 2013.

Fish collected and relocated to net pens at Wik Lake experienced a high mortality rate, presumably from the stress of capture and long-term confinement (Table 17). Most mortality occurred during transport or shortly thereafter and when water temperatures exceeded 13°C.

A fish passage barrier (fyke net) that had been maintained in the Stormy Lake outlet creek since northern pike were discovered in 2001 was breached in the summer of 2013 to allow movement of native fish between the lake and the Swanson River and to facilitate the natural recolonization of fish into Stormy Lake by migrants from the Swanson River.

In the summer of 2014, we conducted a netting survey at Stormy Lake to detect species presence and to collect biological data. During 5–6 May 2014, four gillnets were fished for a total of 75 hours netting effort. The catch consisted of 72 Arctic char, 32 rainbow trout, 36 juvenile coho salmon, and 2 longnose suckers (Table 12). No northern pike were detected. All live fish were immediately released back into the lake and all dead fish were measured for length (FL) and assigned a length range (Figure 22).

It is noteworthy that staff did observe numerous small juvenile sticklebacks swimming in Stormy Lake while tending the minnow traps despite not catching any in the minnow traps.

Table 15.–Stormy Lake Arctic char collection effort and catch during September and October of 2011.

	Fish species					
Gear type and gear ID number [a-g]	Longnose sucker	Rainbow trout	Arctic char	Northern pike	Threespine stickleback	Gear effort (days) [h]
Entanglement net (mono) #1	1			3		25.5
Entanglement net (mono) #2	10		2	2		25.5
Entanglement net (mono) #3	6		3	3		25.5
Entanglement net (mono) #4	8		4			25.5
Entanglement net (mono) #5	4		9	3		25.4
Entanglement net (mono) #6	13		4	1		25.4
Entanglement net (mono) #7						2.0
Entanglement net (mono) #8						1.9
Entanglement net (mono) #9	2					1.9
Entanglement net (mono)						1.9
Entanglement net (mono)	1					1.9
Entanglement net (mono)						1.9
Entanglement net (mono)	2					1.9
Entanglement net (mono)						1.9
Entanglement net (multi) #1	1			1		16.0
Entanglement net (multi) #2	2		3			16.0
Funnel trap #1					Present [i]	6.6
Funnel trap #2					Present [i]	6.6
Funnel trap #3					Present [i]	6.6
Funnel trap #4					Present [i]	6.6
Funnel trap #5					Present [i]	6.6
Funnel trap #6					Present [i]	6.6
Herring net				1		1.1
Hoop net #1	12					16.0
Hoop net #2		1		1		16.0
Hoop net #3				2		14.0
Variable mesh gillnet #1	3			4		5.0
Variable mesh gillnet #2	6			7		5.0
Variable mesh gillnet #3	3			8		3.1
Variable mesh gillnet #4	3					1.0
Variable mesh gillnet #5						1.0
Variable mesh gillnet #6	1					1.0
Variable mesh gillnet #7						1.0
Variable mesh gillnet #8						1.0

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Table 15.–Page 2 of 2.

Gear type and gear ID number [a-g]	Fish species					Gear effort (days) [h]
	Longnose sucker	Rainbow trout	Arctic char	Northern pike	Threespine stickleback	
Purse seine	12			1		0.2
Trotline #1						1.6
Trotline #2						1.6
Total	90	1	25	37		308.5

[a] Monofilament entanglement nets were 150 ft long and 16 ft deep and constructed with five-eighth inch or three-quarter inch square mesh made with 0.2 mm–0.15 mm monofilament. Multifilament nets were 150 ft long and 6 ft deep and constructed with one-half inch mesh made with 201/2 twine.

[b] Funnel traps were 18 in long cylindrical minnow traps made of one-eighth inch mesh metal screen and baited with salmon roe.

[c] The herring net was approximately 150 ft in length, 20 ft deep, and made of 2-inch monofilament mesh suspended from a polypropylene hanging line with a cork every 3 feet and a lead line on the bottom of the net.

[d] Hoop nets were 5 ft in diameter with 50 ft leads.

[e] Variable mesh gillnets were 120 ft long, 6 ft deep, with 6 different sized mesh panels from three-quarter inch to 2 inch with floating poly hanging lines and lead lines.

[f] The purse seine was a contracted 28-foot commercial fishing vessel (Jitney seiner)

[g] Trotlines used a 200-foot mainline with baited gangions at 10-foot intervals.

[h] One day of gear effort equals 24 hours of fishing for a single piece of fishing gear.

[i] Species was captured but not enumerated.

Table 16.–Stormy Lake and outlet creek trapping and dipnetting effort and fish catch during August 2012.

Date	Trap type	Number of traps fished	Threespine stickleback	Coho salmon	Rainbow trout (juv.)	Dolly Varden	Longnose sucker [a]	Lamprey	Northern pike	Slimy sculpin	Fresh-water mussel	Total hours fished
08/24/12	Fyke trap	1	Present									48.0
08/26/12	Fyke trap	1	Present									24.0
08/27/12	Fyke trap	1	Present									24.0
08/28/12	Fyke trap	1	Present									23.6
08/29/12	Fyke trap	1	Present									24.0
Cumulative fish catch			[b]									143.6
08/22/12	Hoop trap	1					4					95.0
08/26/12	Hoop trap	1					1					24.0
08/27/12	Hoop trap	1					2					24.0
08/28/12	Hoop trap	1					3					23.4
08/29/12	Hoop trap	1										24.0
Cumulative fish catch			[b]				10					190.4
08/20/12	Minnow trap	7	Present	8	3					1		138.4
08/21/12	Minnow trap	7	Present	6	7	1		1		1		189.5
08/23/12	Minnow trap	16	Present	9	25			1		5		174.2
08/24/12	Minnow trap	16	Present	7	21				1	3		67.8
08/25/12	Minnow trap	6	Present	5	12			1		1		25.0
Cumulative fish catch			[b]	35	68	1		3	1	11		565.8
8/16/12–8/20/12	Hand dip net										113	8.0
Grand total			[b]	35	68	1	10	3	1	11	113	928.9

Note: Hoop and fyke traps were fished in Stormy Lake; minnow traps were fished in the lake and the outlet creek and all salmonids were caught in the outlet creek.

[a] Estimated catch; some were lost to river otter predation.

[b] Sticklebacks were not enumerated but hundreds were caught in fyke nets and a lesser amount in minnow traps.

Table 17.–Estimated number of Stormy Lake fish transferred to Wik Lake net pens in 2012 and the number released back into Stormy Lake in March 2013.

Fish fate	Longnose sucker	Dolly Varden	Rainbow trout	Coho salmon	Threespine stickleback	Slimy sculpin	Mussel [a]
Delivered alive to Wik Lake net pens in 2012	253	1	80	72	314	11	113
Returned alive to Stormy Lake in 2013	51	0	55	38	0	0	35
Estimated loss during net pen confinement	80%	100%	31%	47%	100%	100%	N/A

Note: Fish were captured at Stormy Lake in August and September 2012 by netting, trapping, and by collecting rotenone-impaired fish with dip nets.

[a] Freshwater mussels were collected with a dip net; mussel mortality was not estimated because many mussels escaped.

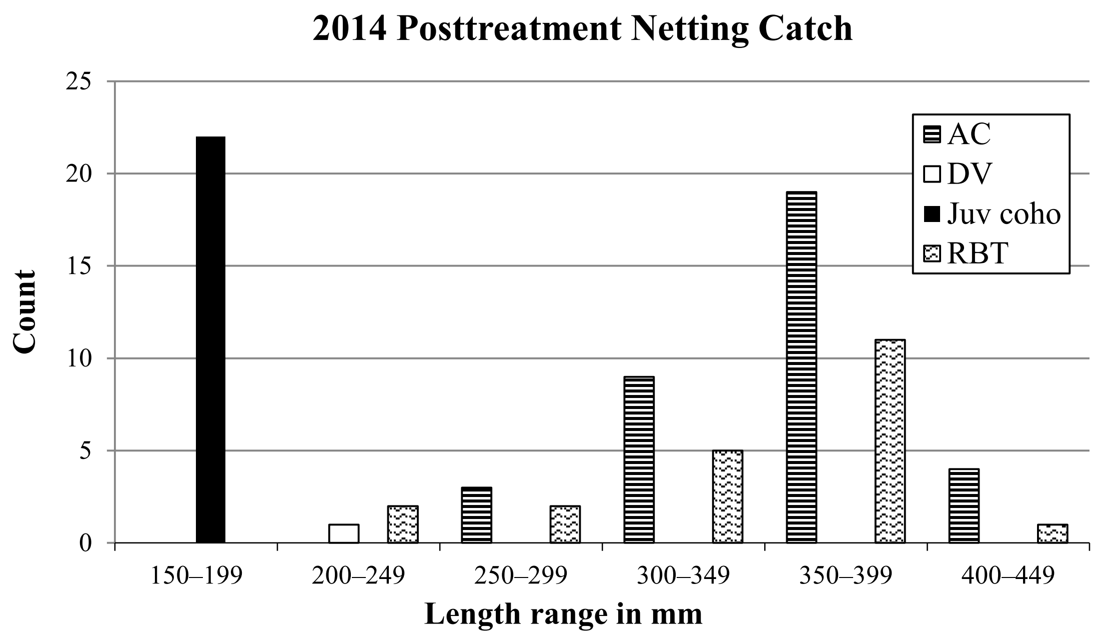

Figure 22.–Length range frequency of Stormy Lake native fish sampled during May 2014.

Note: "AC" means Arctic char, "DV" means Dolly Varden, "Juv coho" are juvenile coho salmon, and "RBT" means rainbow trout.

DISCUSSION

The Stormy Lake restoration project was ADF&G's largest northern pike eradication effort to date. This project provided an opportunity to demonstrate the feasibility of conducting a large-scale invasive northern pike eradication project in conjunction with a large-scale native fish restoration effort. It was also the first time ADF&G applied rotenone to an open system with the presence of anadromous fish on the Kenai Peninsula.

There is no means to determine with certainty whether the project eradicated the entire invasive northern pike population at Stormy Lake. However, several indicators, which include the fates of caged sentinel fish, fates of radiotagged northern pike, results of gillnet and minnow trap surveys, and the monitoring of rotenone concentration and persistence, provide supporting evidence that the treatment was successful.

Efforts to preserve the native fish assemblage of Stormy Lake were unprecedented and include the following:

1) Arctic char broodstock collections and hatchery rearing of their offspring
2) netting and trapping efforts to relocate fish temporarily to net pens at Wik Lake
3) collecting, reviving, and relocation of rotenone-impaired fish during the treatment
4) removal of the Stormy Lake outlet barrier to promote natural recolonization by fish from the Swanson River

The 2014 Stormy Lake netting survey captured more salmonids following 75 hours of netting effort than were captured during the combined pretreatment netting efforts (7,604 hours) expended in 2011 and 2012. Nonsport fish species such as sculpin, lamprey, and stickleback were not captured posttreatment although small sticklebacks were visually observed in great abundance. Two adult longnose suckers and 1 juvenile were captured in 2014, indicating at least some had persisted. We recommend annual net and minnow trap surveys be conducted at Stormy Lake for the next 5 years to determine species presence and collect biological data. Evidence of a sexually mature Arctic char population is desired prior to reopening their sport fishery to previous regulations[6]. Conducting the net surveys in the fall would allow assessment of the reproductive and maturity status of the population.

The 1-year growth of the Arctic char released as fingerlings in the spring of 2013 and captured in the spring of 2014 was impressive with some fish exceeding 400 mm. In Alaska, Arctic char typically become sexually mature in 6 to 9 years (Craig and Poulin 1975). It is possible that earlier-than-average maturation may occur at Stormy Lake because in 1 year posttreatment, stocked Arctic char nearly reached the size of their broodstock parents (collected in 2011; these ranged from 475 mm to 657 mm FL), and this also suggests that forage resources in Stormy Lake are more than adequate.

As expected, the Stormy Lake rotenone treatment did not negatively impact fish in the Swanson River as evidenced by sentinel fish held in the Swanson River showing no impairment during and immediately after the treatment. A chemical deactivation station that dispensed $KMnO_4$ to neutralize the rotenone before it entered the Swanson River was operated for about 1 day but this was probably not needed and was operated only as a precautionary measure. Dilution alone appeared sufficient to render the rotenone harmless to fish when it entered the Swanson River.

Native fish relocated to the Wik Lake net pens experienced a very high mortality rate. Much of the mortality appeared within the first couple weeks of relocation. Many relocated fish had been captured by gillnets in relatively warm water (13–15°C) and many of the longnose suckers had external netting injuries and developed skin infections. Although anecdotal, it appeared rotenone-impaired longnose suckers fared better than those collected by gillnetting efforts. It is possible the rotenone-impaired longnose suckers benefited from cooler water temperatures and avoiding the stress of net capture and handling. Mortality of all fish species in the net pens decreased with decreasing water temperature and very little mortality occurred once water temperatures decreased to 10°C. By ice-up in November, when the water temperature was well

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[6] The retention of Stormy Lake Arctic char after the 2013 stocking was prohibited for the 2013–2014 and 2014–2015 ice fishing seasons by ADF&G emergency order (EO). To date, the EO's effective dates have been 21 November 2013 to 30 April 2014 and 14 November 2014 to 30 April 2015. The coincidental DNR Division of Parks and Recreation access and watercraft closure of the Stormy Lake boat launch over concerns that invasive *Elodea* might be transported by watercraft, effectively closed fishing during the open water season at Stormy Lake.

below 10°C, visible skin infections were gone or healing on most surviving fish. Fish in the net pens were fed at least once per week with BioClark's Fry 1.2 mm feed. Within 2 weeks of feeding, penned fish would respond to feed hitting the water and swarm near the surface to feed, particularly juvenile coho salmon and rainbow trout. To facilitate feeding and improve water circulation in the net pens, we decided to keep the net pens ice free and installed an electric deicer that circulated the water with a submerged propeller. We used a 120 V one-half horsepower Kasco Marine model 2400D deicer, which worked very well at keeping the net pens ice free throughout the winter (Figure 23). A 300-foot extension cord brought power to the deicer from a lakeshore residence.

Figure 23.–Wik Lake floating net pens holding rescued Stormy Lake fish; a submerged electric deicer kept the water surface ice free.

Since 2008 when rotenone was first used to remove invasive northern pike from Kenai Peninsula waters, we've sampled for invertebrate presence before and after the treatments to assess treatment-related changes to the invertebrate assemblage and whether food resources would be available for restocked fish. Stormy Lake is the third Kenai Peninsula lake that has been successfully restocked with fish less than 1 year after being treated with rotenone, and no known forage concerns have arisen. In general, invertebrate diversity in these lakes has remained similar before and after rotenone treatments. Although changes in invertebrate taxa were observed in all years, failure to detect some taxa could be the result of inadequate sampling effort. An ADF&G study evaluating rotenone effects on zooplankton in southcentral Alaska detected strong posttreatment declines in zooplankton abundance, but full recovery occurred within 1–3 years with no species loss occurring (Chlupach 1977). It appears reasonable that invertebrate surveys may not be a critical monitoring task associated with rotenone treatments given the observed rearing success of restocked fish at Stormy Lake in 2014, the research indicating zooplankton populations fully recover within 1–3 years, and that invertebrate monitoring of several Kenai Peninsula lakes since 2008 indicates invertebrate taxon diversity remains similar both before and 1 year after rotenone treatment.

A key factor in successfully removing target fish populations with rotenone is to ensure the rotenone is well mixed and at a concentration lethal to the fish. Recent rotenone treatments on the Kenai Peninsula have expended considerable effort to ensure the rotenone products were applied uniformly and when thermoclines were weak or absent. Rotenone application rates were primarily controlled by boat speed; deep water required slower boat speeds than shallow water. To accomplish this, the boat operator needed to simultaneously track boat speed and water depth with an electronic chart plotter while continuously varying the boat speed appropriate to the water depth. The greatest variation in rotenone concentration between sampling sites (46.9 ppb on 7 September 2012) representing an amount equal to 99% of the average concentration. By 24 September 2012, the maximum variation in rotenone concentration was reduced to 5.7 ppm (an amount equal to 22% of the average rotenone concentration). It is likely that wind generated wave action aided the mixing of rotenone between sampling events. Nearly two-thirds of the rotenone applied in Stormy Lake was Prentox Fish Toxicant Powder, which is pure ground plant material with no additives to aid in dispersion, as opposed to CFT Legumine, which is a liquid. Therefore, the powdered product requires some physical means to evenly distribute the rotenone. Although we followed the advice of a rotenone treatment expert (Brian Finlayson, retired California Department of Fish and Game biologist, personal communication) to attain equal rotenone concentrations throughout the lake by injecting the rotenone into deep areas with pipes or weighted hoses and stringently controlling application boat speed, these kinds of effort may be unnecessary if strong winds generate waves for mixing. The wind action we encountered at Stormy Lake was sufficient to homogenize rotenone concentrations and was more effective than our efforts to homogenize concentrations by both adjusting application boat speed to water depth and through selective use of a deepwater rotenone delivery system. Less stringent boat application protocols might be considered in the future. Boat application strategies that appeared useful at Stormy Lake were as follows:

1) Distribute the rotenone thoroughly over the lake surface using electronic navigation aids to track application paths and identify areas of poor coverage.

2) When feasible, apply the rotenone when lake thermoclines are absent or very weak.

3) Avoid rotenone treatments that occur immediately before freeze-up so wind action has time to mix the rotenone.

4) Apply rotenone when average water temperatures are cool (<12°C) to increase rotenone persistence.

5) Encourage the use of CFT Legumine over powdered rotenone products because it has better dispersal properties.

ACKNOWLEDGEMENTS

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Multiple agencies contributed their time and expertise with field work, planning, or both and include the USFWS Kenai Field Office (in particular Area Fisheries Research Supervisor Doug Palmer), Robert Ruffner (Executive Director of the Kenai Watershed Forum), and the DNR Division of Parks and Recreation Area Supervisor Jack Blackwell.

ADF&G staff members that were instrumental to this project's success include Tim McKinley (Soldotna Office Sport Fish Area Research Supervisor) who had the vision to initiate the first invasive northern pike control program on the Kenai Peninsula over a decade ago and who first confirmed the presence of northern pike in Stormy Lake. Tim also provided supervision to the project leader, participated in the public scoping process, assisted with all project planning, and helped with the rotenone application and fish restocking components. Kristine Dunker (ADF&G Regional Invasive Species Coordinator) gave selflessly of her time and energy and helped in all phases of this project including operational planning, grant writing, public scoping, bathymetric mapping planning, and helped with the rotenone application. Kristine also discovered an aquatic invasive plant at Stormy Lake (*Elodea* sp.), which had never before been detected on the Kenai Peninsula and which eventually led to a multi-agency *Elodea* control program. A thank you is also warranted for Robert Begich (ADF&G Soldotna Office Sport Fish Area Manager) and Jason Pawluk (Sport Fish Assistant Area Manager) for their help with public scoping, media interactions, and their help with native fish preservation efforts.

Other ADF&G staff that worked tirelessly in the field to ensure this project's success included Fish and Wildlife technicians Jerry Strait and Amanda Alaniz. Jerry seemed to work endless hours to support all field aspects of this project, and his familiarity with the project area helped immensely. ADF&G staff that generously volunteered their time to assist in the rotenone application included Tony Eskelin, Jeff Perschbacher, Adam Reimer, Jenny Cope, Bill Glick, Jack Erickson, Patti Berkhahn, Tim Vangelderen, Mark Hatfield, and Skip Repetto. Special thanks go to both Cody Jacobson and Chuck Pratt of ADF&G. Chuck provided his time and expertise to ensure the Arctic char gamete collections and hatchery rearing were successful. He also volunteered to oversee the native fish rescue effort during the rotenone treatment. Cody Jacobson skillfully operated an airboat during the treatment and helped to troubleshoot various equipment issues.

Volunteers from other agencies that helped with the application include Jeff Anderson, Cheryl Anderson, Jim Boersma, Ken Gates (all from the USFWS Kenai Field Office). Todd Eskelin, Toby Burke, Matt Bowser, Mark Laker (USFWS Kenai National Wildlife Refuge) also provided help in the field during the rotenone treatment and Refuge Manager Andy Loranger participated in public scoping meetings.

We appreciated the expertise of Brian Finlayson (California Department of Fish and Game, retired biologist) who was hired as a consultant to assess the project's feasibility, review planning documents, and provide technical assistance. Skip and Lynn Smith provided access and electricity for the net pens at Wik Lake and were more than patient tolerating our frequent presence. We also were granted boat launch access to Wik Lake by Sid Morris, which was extremely useful and for which we are very thankful.

Last but not least, we wish to thank those in the public that attended scoping meetings, provided comments during the permitting process, or voiced their support, concerns, and suggestions because it was vital to the integrity of this project that stakeholders and the local community be involved in the project planning.

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APPENDIX A: POWDERED AND LIQUID ROTENONE PRODUCT LABELS

Appendix A1.–CFT Legumine specimen label (liquid toxicant).

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%
[1] Contains Petroleum Distillates Total 100.0%
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:

$$R_s = R_p \text{ x } C \text{ x } F$$

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.

$$A = R_s \text{ x } H$$

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.

Appendix A2.–Prentox Prenfish Rotenone Fish Toxicant specimen label (powdered toxicant).

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

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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[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 B: RECOMMENDED BOAT SPEEDS FOR APPLICATION

Appendix B1.–Recommended boat speeds for applying CFT Legumine at select lake depths and rotenone pumping rates.

Water depth (ft)	Water volume (ft^3) [a]	Water volume (acre-ft)	Recommended boat speed [b] Application rate of 0.5 gal/min [c]	Application rate of 1.0 gal/min [c]	Application rate of 3.0 gal/min [c]	Application rate of 6.0 gal/min [c]
1	3,000	0.069	25	50	149	297
2	6,000	0.138	12	25	74	149
3	9,000	0.207	8	17	50	99
4	12,000	0.275	6	12	37	74
5	15,000	0.344	5	10	30	59
6	18,000	0.413	4	8	25	50
7	21,000	0.482	4	7	21	42
8	24,000	0.551	3	6	19	37
9	27,000	0.620	3	6	17	33
10	30,000	0.689	2	5	15	30
11	33,000	0.758	2	5	14	27
12	36,000	0.826	2	4	12	25
13	39,000	0.895	2	4	11	23
14	42,000	0.964	2	4	11	21
15	45,000	1.033	2	3	10	20
16	48,000	1.102	2	3	9	19
17	51,000	1.171	1	3	9	17
18	54,000	1.240	1	3	8	17
19	57,000	1.308	1	3	8	16
20	60,000	1.377	1	2	7	15
21	63,000	1.446	1	2	7	14
22	66,000	1.515	1	2	7	14
23	69,000	1.584	1	2	6	13
24	72,000	1.653	1	2	6	12
25	75,000	1.722	1	2	6	12
26	78,000	1.790	1	2	6	11
27	81,000	1.859	1	2	6	11
28	84,000	1.928	1	2	5	11
29	87,000	1.997	1	2	5	10
30	90,000	2.066	1	2	5	10

Note: Target treatment concentration was 1.0 ppm of rotenone product. It was assumed that the boat could apply 0.05–6.00 gallons of liquid formulation per minute.

[a] Water volume (ft^3) in every linear foot stretch of a 30 ft wide application swath.

[b] Boat speed is in miles per hour.

[c] Gallons of product needed per 100 linear feet of boat travel to apply product at a concentration of 1.0 ppm.

Appendix B2.–Recommended boat speeds for applying Prentox Fish Toxicant Powder for known lake depths and application rates.

			Recommended boat speed [b]			
Water depth (ft)	Water volume (ft^3) [a]	Water volume (acre-ft)	Application rate of 3.0 lbs/min [c]	Application rate of 4.0 lbs/min [c]	Application rate of 5.0 lbs/min [c]	Application rate of 6.0 lbs/min [c]
1	3,000	0.069	18	24	31	37
2	6,000	0.138	9	12	15	18
3	9,000	0.207	6	8	10	12
4	12,000	0.275	5	6	8	9
5	15,000	0.344	4	5	6	7
6	18,000	0.413	3	4	5	6
7	21,000	0.482	3	3	4	5
8	24,000	0.551	2	3	4	5
9	27,000	0.620	2	3	3	4
10	30,000	0.689	2	2	3	4
11	33,000	0.758	2	2	3	3
12	36,000	0.826	2	2	3	3
13	39,000	0.895	1	2	2	3
14	42,000	0.964	1	2	2	3
15	45,000	1.033	1	2	2	2
16	48,000	1.102	1	2	2	2
17	51,000	1.171	1	1	2	2
18	54,000	1.240	1	1	2	2
19	57,000	1.308	1	1	2	2
20	60,000	1.377	1	1	2	2
21	63,000	1.446	1	1	1	2
22	66,000	1.515	1	1	1	2
23	69,000	1.584	1	1	1	2
24	72,000	1.653	1	1	1	2
25	75,000	1.722	1	1	1	1

Note: Target treatment concentration was 1.0 ppm of rotenone product. It was assumed that the boat could apply 3.0–6.0 pounds of powdered formulation per minute.

[a] Water volume (ft^3) in every linear foot stretch of a 30 ft wide application swath.

[b] Boat speed is in miles per hour.

[c] Pounds of product needed per 100 linear feet of boat travel to apply product at a concentration of 1.0 ppm.

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

Estimating the probability (D_p) of failing to detect a small abundance of northern pike (p) in a target lake of known surface acreage with a selected amount of gillnetting effort (net density and days of fishing) can be achieved as follows:

$$D_p = \hat{P}_f^{(T \times R)}, \qquad \text{(E1)}$$

where

$\hat{P}_f$ = the estimated probability that none of p remaining fish are captured on the final day of netting at the reference lake with gillnet density f nets per surface acre,

T = number of days of gillnetting effort (24-hour day) at the target lake, and

R = relative net density at the target lake.

where

$$R = \frac{N/A}{f}, \qquad \text{(E2)}$$

and

N = desired number of nets set in the target lake,

A = surface acreage of the target lake, and

f = nets per acre used at the reference lake on final day of netting for that lake.

In order to calculate D_p for Stormy Lake with p = 4 northern pike, we used an estimated catch rate for the final 24-hour day of a netting period intended to remove northern pike from Derks Lake. Northern pike were intensively removed from Derks and Sevena lakes (Figure 2) using gillnets during 2005–2007 (Appendix C2). Although the catch rate on the last day of netting at Derks Lake during fall 2007 was the lowest estimated, it was not used to estimate D_p because emigration of northern pike during the removal period was suspected. The second lowest estimated capture rate was for Derks Lake in fall 2005. Emigration was not observed during the removal period so the capture rate of 0.12 was used in estimating the probability of not detecting northern pike in Stormy Lake (Appendices C2 and C3). In addition, this capture rate serves as a conservative surrogate to be used when estimating northern pike detection probabilities in other lakes with small abundances. The surrogate capture rate can be adjusted by the surface acreage of a particular lake and the number of gillnets and days fished when assuming the catchability of northern pike is proportional to the density of nets in the lake as well as the duration the nets are soaked.

The 0.12 capture rate can be viewed as the probability of capture per individual fish in a single 24-hour day of gillnetting effort where gillnet density (f) of the reference lake is equal to 0.364 nets per acre (Appendix C2). Therefore, the probability of an individual fish not being captured in the reference lake under those conditions is equal to 1 – 0.12 = 0.88. The probability of not capturing any of 4 fish remaining in the target lake is $\hat{P}_f$ = $(0.88)^4$ = 0.605. Probabilities of failing to detect northern pike in Stormy Lake with 50 gillnets and with a remaining abundance of 4 fish under different levels of netting effort (days) are presented in Appendix C3.

Appendix C2.–Historical net effort and catch-and-removal population estimates for Derks and Sevena lakes during the years 2005–2007.

	2005				2006				2007			
	Sevena Lake		Derks Lake		Sevena Lake		Derks Lake		Sevena Lake		Derks Lake	
Attributes	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall [a]	Spring	Fall
Nets fished per day	12	12	12	12	12	12	12	12	24	–	24	24
Net density (nets/surface acres)	0.166	0.166	0.364	0.364	0.166	0.166	0.364	0.364	0.332	–	0.729	0.729
Catch on last day	5	27	6	15	7	3	1	12	2	–	10	32
Total seasonal catch	643	1,403	143	312	344	38	74	276	10	–	80	469
Population estimate	653	1,425	149	424	352	44	74	352	10	–	86	978
Estimated population size at start of last day	15	49	12	127	15	9	1	88	2	–	16	541
Capture rate on last day	0.333	0.551	0.500	0.118	0.467	0.333	1.000	0.136	1.000	–	0.625	0.059
Percent of available population caught per net on last day	0.028	0.046	0.042	0.010	0.039	0.028	0.083	0.011	0.042	–	0.026	0.002

Note: Sevena Lake is 72.23 surface acres. Derks Lake is 32.94 surface acres.

[a] No netting was done in Fall 2007.

Appendix C3.–Probabilities of not detecting 4 northern pike in Stormy Lake using 50 gillnets and a value of 0.605 are listed for selected days of effort.

	T (days of effort)									
	1	2	3	4	5	6	7	8	9	10
Probability (D_p)	0.8426	0.7101	0.5983	0.5042	0.4248	0.3580	0.3017	0.2542	0.2142	0.1805

Note: Stormy Lake is 403 surface acres. Probability is calculated using the following parameters: surface acres = 403, density of nets = 50 nets/acre = 0.2353, *R* (relative net density) = 0.3406.

APPENDIX D: STORMY LAKE RADIOTAGGED NORTHERN PIKE TRACKING DATA AND FATES

Appendix D1.–Tracking data and fates of radiotagged northern pike in Stormy Lake, September 2012.

Radio tag frequency	Radio tag pulse code	Tracking date	Time	Lake area	Estimated distance from shore (meters)	Radio tag mortality signal detected (Y or N)	Fate	Comments
152.043	19	5 Sep	11:00	1	35	N		
		5 Sep	13:00	1	40	N		
		6 Sep	08:30	1	30	N [a]		
		6 Sep	13:00	1	60	N [a]		
		10 Sep	14:20	1	5	N [a]	Died	Carcass recovered
152.043	22	5 Sep	11:00	5	20	N		
		5 Sep	13:00	5	50	N		
		6 Sep	09:30	5	100	Y		
		10 Sep	15:26	5	not estimated	Y	Died	
152.043	23	5 Sep	11:00	5	40	N		
		5 Sep	13:00	5	80	N		
		10 Sep	15:33	5	not estimated	Y	Died	
152.073	16	5 Sep	11:00	6	20	N		
		6 Sep	09:24	5	60	Y		
		10 Sep	15:19	5	50	Y	Died	
152.073	17	5 Sep	11:00	5	30	N		
		5 Sep	13:00	5	80	N		
		6 Sep	09:24	5	70	Y		
		10 Sep	15:12	5	not estimated	Y	Died	
152.073	19	5 Sep	11:00	5	30	Y		
		5 Sep	13:00	5	80	N		
		6 Sep	09:25	5	70	Y		
		10 Sep	15:05	5	not estimated	Y	Died	
152.073	20	5 Sep	11:00	2	50	N		
		5 Sep	13:00	2	40	N		
		6 Sep	10:00	2	50	Y		
		10 Sep	15:40	2	5	Y	Died	
152.073	21	5 Sep	11:00	5	25	N		
		5 Sep	13:00	5	60	N		
		6 Sep	09:25	5	80	Y		
		10 Sep	14:58	5	not estimated	Y	Died	
152.073	22	5 Sep	11:00	1	20	N		
		5 Sep	13:00	1	20	N		
		6 Sep	13:40	1	80	Y		
		10 Sep	14:51	1	80	Y	Died	

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Radio tag frequency	Radio tag pulse code	Tracking date	Time	Lake area	Estimated distance from shore (meters)	Radio tag mortality signal detected (Y or N)	Fate	Comments
152.073	23	5 Sep	11:00	1	15	N		
		5 Sep	13:00	1	50	N		
		6 Sep	08:30	1	40	N [a]		
		6 Sep	09:35	5	70	Y		
		6 Sep	09:30	5	100	Y		
		6 Sep	13:20	1	20	N [a]		
		10 Sep	14:37	1	not estimated	Y	Died	
152.073	26	5 Sep	11:00	2	40	N		
		5 Sep	13:00	2	25	N		
		5 Sep	13:00	5	50	N		
		6 Sep	13:15	1	30	N [a]		
		10 Sep	14:44	1	not estimated	N [a]	Died	
152.133	23	5 Sep	11:00	5	25	N		
		5 Sep	13:00	5	80	N		
		10 Sep	14:30	1	20	N [a]	Died	Carcass recovered
152.133	26	6 Sep	08:48	1	50	N [a]	Died	

Note: All northern pike were captured from Stormy Lake and surgically implanted with a radio transmitter and released back into Stormy Lake on August 29, 2012.

[a] Despite the lack of a mortality signal from 4 radiotagged northern pike, these fish were determined to be dead by either direct visual observation of a carcass that could not be retrieved or the inability to elicit movement from the radiotagged fish despite prolonged, repeated, and intentional disturbance by an outboard motorboat of the immediate area of the transmitter signal source. In all cases, the 4 radiotagged fish that never emitted a mortality signal must have been dead because many other nontagged fish were dead in the immediate vicinity and no discernable fish movement response was observed despite efforts to scare the fish. Wind or boat generated wave action is suspected of shifting the radiotagged fish carcasses enough to prevent activation of the radio transmitter mortality signal that is triggered if the fish does not move for 4 hours.

APPENDIX E: INVERTEBRATE SAMPLING COUNTS

Appendix E1.–Pretreatment and posttreatment invertebrate sampling counts for Stormy Lake by date and gear type.

Status	Date	Taxon	D-Net	Eckman	Wisconsin net
Pretreatment	7/14/2010	Amphipoda (scud)	15	1	
	7/14/2010	Anispotera (dragonflies)	2		
	7/14/2010	Araneae (spiders)	2		
	7/14/2010	Chironomidae (Nonbiting midges)	2		
	7/14/2010	Coleoptera (unknown beetle)	3		
	7/14/2010	Cyclopoida (copepod)			Present
	7/14/2010	*Daphnia* (cladoceran)			Present
	7/14/2010	Diptera (unknown adult fly)	6		
	7/14/2010	Dysticidae (predacious diving beetle or whirligig)	2		
	7/14/2010	Ephemeroptera (mayflies)	1		
	7/14/2010	Gastropoda (snails)	53	9	
	7/14/2010	Gerridae (water striders)	13		
	7/14/2010	Hirudinea (leeches)	4		
	7/14/2010	Hydrophilidae (water scavenging beetle)	1		
	7/14/2010	Hymenoptera (wasps, ants)	1		
	7/14/2010	Nematoda (round worms)		1	
	7/14/2010	Bivalvia (molluscs)	3	1	
	7/14/2010	Plecoptera (stone flies)	1		
	7/14/2010	Syrphidae (hoverflies)		1	
	7/14/2010	Trichoptera (caddis)	4		
	7/14/2010	Zygoptera (damselflies)	5		
	6/22/2011	*Asplanchna* (rotifer)			Present
	6/23/2011	Amphipoda (scud)	6	3	
	6/23/2011	Anispotera (dragonflies)	13		
	6/23/2011	*Bosmina* (cladoceran)			Present
	6/23/2011	Chironomidae (nonbiting midges)	3	2	
	6/23/2011	Chrysomelidae (leaf beetles)	3		
	6/23/2011	*Daphnia* (cladoceran)			Present
	6/23/2011	*Diaptomus* (copepod)			Present
	6/23/2011	Dysticidae (predacous diving beetle or whirligig)	2		
	6/23/2011	Ephemeroptera (mayflies)	7		
	6/23/2011	Gastropoda (snails)	35	4	
	6/23/2011	*Kellicottia* (rotifer)			Present
	6/23/2011	Nematoda (round worms)		3	
	6/23/2011	Bivalvia (molluscs)	4	12	
	6/23/2011	Trichoptera (caddis)	1	1	
	9/7/2011	Amphipoda (scud)		6	
	9/7/2011	Anispotera (dragonflies)	1		
	9/7/2011	Araneae (spiders)	2		
	9/7/2011	*Asplanchna* (rotifer)			Present
	9/7/2011	*Bosmina* (cladoceran)			Present
	9/7/2011	Chironomidae (nonbiting midges)	1	2	
	9/7/2011	Cyclopoid (copepod)			Present
	9/7/2011	*Daphnia* (cladoceran)			Present

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Status	Date	Taxon	D-Net	Eckman	Wisconsin net
Pretreatment					
	9/7/2011	Gastropoda (snails)	153	3	
	9/7/2011	Gerridae (water striders)	7		
	9/7/2011	Nematoda (round worms)		1	
	9/7/2011	Pelecypoda (molluscs)	75	4	
	9/7/2011	Trichoptera (caddis)	2	1	
	9/7/2011	Zygoptera (damselflies)	4		
	8/6/2012	Amphipoda (scud)	2	1	3
	8/6/2012	*Asplanchna* (rotifer)			Present
	8/6/2012	*Bosmina* (cladoceran)			Present
	8/6/2012	Chironomidae (nonbiting midges)	2	3	
	8/6/2012	Culicidea (mosquitos)	2		
	8/6/2012	*Daphnia* (cladoceran)			Present
	8/6/2012	*Diaptomus* (copepod)			Present
	8/6/2012	Diptera (unknown adult fly)	7		
	8/6/2012	Gastropoda (snails)	53	3	
	8/6/2012	Nematoda (round worms)		3	
	8/6/2012	Bivalvia (molluscs)	14	14	12
	8/6/2012	Trichoptera (caddis)			5
	8/6/2012	Zygoptera (damselflies)	7		3
Posttreatment	6/24/2013	Amphipoda (scud)	28	25	
	6/24/2013	Anispotera (dragonflies)	1	1	
	6/24/2013	*Asplanchna* (rotifer)			Present
	6/24/2013	*Bosmina* (cladoceran)			Present
	6/24/2013	Chironomidae (nonbiting midges)	1	5	
	6/24/2013	Corixidae (water boatmen)	3		
	6/24/2013	Cyclopoid (copepod)			Present
	6/24/2013	Diptera (unknown adult fly)	2		
	6/24/2013	Dysticidae (predacous diving beetle or whirligig)	1		
	6/24/2013	Ephemeroptera (mayflies)		1	
	6/24/2013	Gastropoda (snails)	2	12	
	6/24/2013	Gerridae (water striders)	2		
	6/24/2013	Isopoda (sow bug)			2
	6/24/2013	Bivavlia (molluscs)	2		
	6/24/2013	Zygoptera (damselflies)	1		
	7/24/2014	Amphipoda (scud)	2	12	
	7/24/2014	Anispotera (dragonflies)	1		
	7/24/2014	*Bosmina* (cladoceran)			Present
	7/24/2014	Chironomidae (nonbiting midges)		6	
	7/24/2014	Coleoptera (unknown beetle)	1	1	
	7/24/2014	Corixidae (water boatmen)	34		
	7/24/2014	*Daphnia* (cladoceran)			Present
	7/24/2014	Diptera (unknown adult fly)	1		
	7/24/2014	Gastropoda (snails)	17	6	1
	7/24/2014	Gerridae (water striders)	2		

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Status	Date	Taxon	D-Net	Eckman	Wisconsin net
Posttreatment					
	7/24/2014	Hirudinea (leeches)		1	
	7/24/2014	Hymenoptera (wasps, ants)	2		
	7/24/2014	Oligochaeta (aquatic earthworms)		4	
	7/24/2014	Bivalvia (molluscs)		1	
	7/24/2014	Trichoptera (caddis)		6	6
	7/24/2014	Unknown copepod			Present
	7/24/2014	Zygoptera (damselflies)	15		

Note: Taxa identification was resolved to at least the order level, often the Family level, except for the following: Oligochaeta, Hirudinea, Bivalvia and Gastropoda (class), and Nematoda (phylum). Invertebrate catch data reflect the actual enumeration of each taxon observed by gear and date except for rotifers (*Asplanchna*), eucopepods (Copepods), and *Daphnia* (Cladocera), which were not enumerated but listed if present.