Special Publication No. 14-12

Control Efforts for Invasive Northern Pike on the Kenai Peninsula, 2008

by

Rob Massengill

May 2014

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

In 2000, an invasive population of northern pike was discovered in Arc Lake near Soldotna, Alaska, causing the closure of Alaska Department of Fish and Game (ADF&G) fish stocking at this lake. ADF&G treated Arc Lake with a liquid rotenone formulation in October 2008 to eradicate the northern pike population. After rotenone treatment, gillnets were fished in Arc Lake between December 2008 and May 2009 to evaluate the treatment's success; no northern pike were captured. Water quality sampling in Arc Lake indicated similar water quality characteristics before and after treatment, except increased visibility the winter after treatment. Comparisons of zooplankton and macroinvertebrate presence between summer 2008 (before treatment) and 2009 (after treatment) indicated the invertebrate community remained similar, although some zooplankton species were far less common in posttreatment samples. In July and August of 2009, ADF&G restocked Arc Lake with coho salmon fingerlings.

Key words: Kenai Peninsula, Arc Lake, rotenone, northern pike, chemical treatment, restoration, invasive species, eradication, salmon stocking program.

INTRODUCTION

The Kenai Peninsula is one of the premier sport fishing areas in Alaska, receiving over 530,000 freshwater angler-days in 2008 (38% of the total freshwater sport fishing effort in Alaska) (McKinley 2013). Most angling effort on the peninsula is expended on the Kenai River, which is renowned worldwide for its large Chinook salmon (*Oncorhynchus tshawytscha*) and supports popular fisheries for coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), rainbow trout (*O. mykiss*), and Dolly Varden (*Salvelinus malma*).

A growing threat to sport fisheries on the Kenai Peninsula is the illegal introduction and spread of northern pike (*Esox lucius*) into area lakes and streams. Northern pike are indigenous north and west of the Alaska Range but not on the Kenai Peninsula. Northern pike are believed to have been illegally introduced sometime during the 1970s into the Soldotna Creek drainage (Figure 1) and were first confirmed by the Alaska Department of Fish and Game (ADF&G) in Derks Lake in 1976 (McKinley 2013; anonymous report[1]). Northern pike populations have been confirmed in a total of 18 lakes on the Kenai Peninsula, including Arc Lake and Soldotna Creek (Figure 1).

Soldotna Creek is a tributary of the Kenai River. A 2002 survey conducted by ADF&G and partially funded through a grant from the United States Fish and Wildlife Service (USFWS) Alaska Coastal Program found northern pike in 7 of 8 major lakes in the Soldotna Creek drainage (East Mackey, West Mackey, Denise, Derks, Union, Sevena, and Tree lakes) (McKinley 2013).

Not all 18 lakes where northern pike were detected still contain northern pike. Northern pike populations were removed from Scout Lake and Stormy Lake by ADF&G via chemical treatments (rotenone) in 2009 and 2012, respectively. ADF&G removed northern pike populations from 2 lakes through intensive gillnetting efforts (Hall Lake and Tiny Lake) in 2011, and Denise Lake lost its northern pike population by an unknown cause. The status of northern pike in Tree Lake is unclear, although it appears that population may have disappeared because of a severe drop in dissolved oxygen during the winter. Recent efforts to detect northern pike in Tree Lake have been unsuccessful.

[1] Report titled *Northern Pike (Esox lucius) in the Soldotna Creek System*, author anonymous, available at the Soldotna ADFG Office.

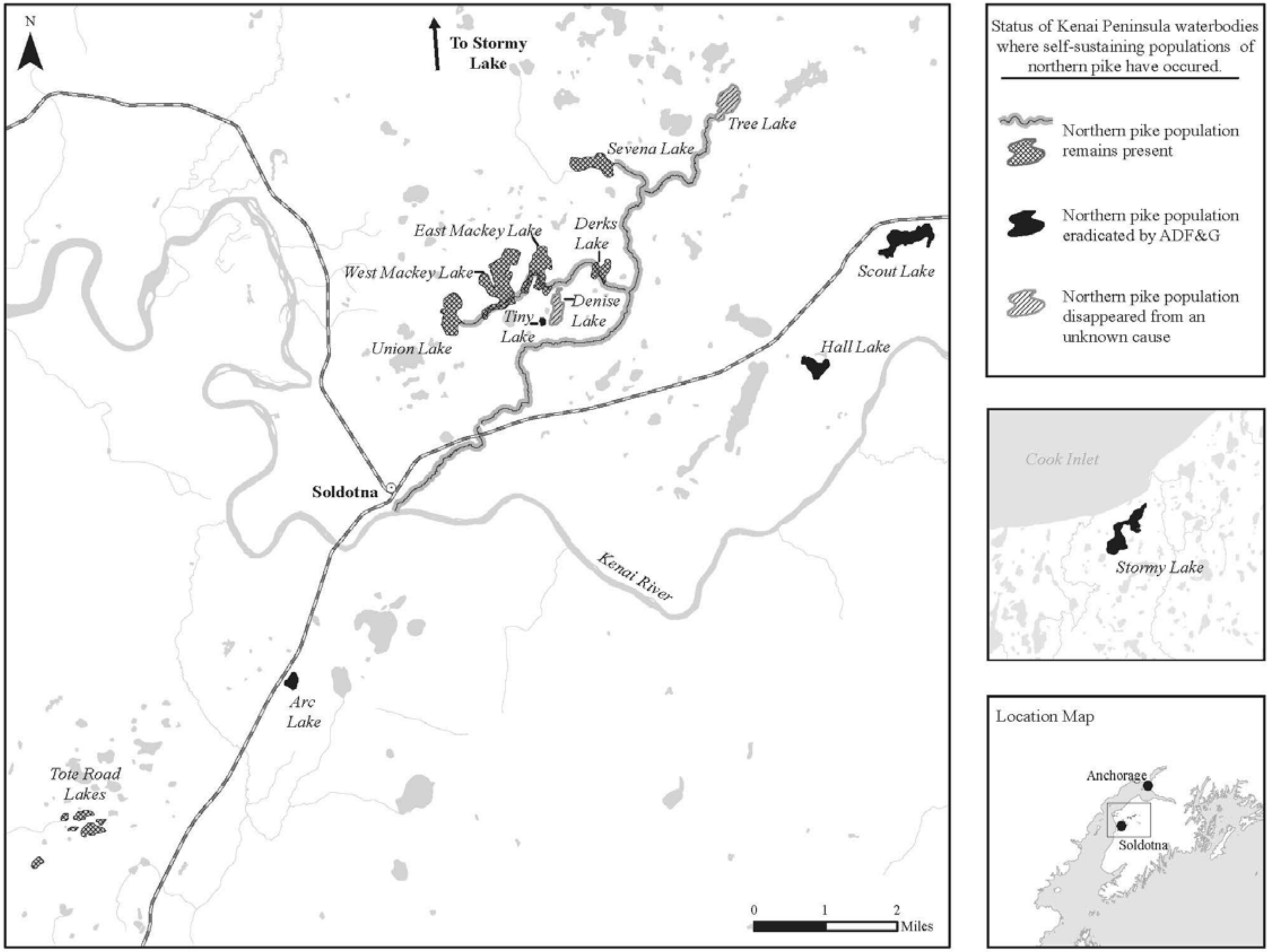

Figure 1.–Status of Kenai Peninsula water bodies that contain or have contained self-sustaining populations of northern pike.

Northern pike are currently present in the following 5 lakes in the Soldotna Creek drainage: Union Lake, East Mackey Lake, West Mackey Lake, Derks Lake, and Sevena Lake. Six lakes clustered in the Tote Road area (5 miles south of Soldotna) also contain northern pike. Fortunately, the Tote Road Lakes are essentially closed, although some are interconnected ephemerally, and discharge from the lake system diffuses into wetland that only has seasonal surface water.

There have been rare but substantiated reports of northern pike caught or observed in the Moose River drainage, a Kenai River tributary (Booth and Otis 1996; Tim McKinley, fisheries biologist, ADF&G, Soldotna, personal communication). Although the USFWS attempted to document the presence of northern pike in the Moose River in 1996, no northern pike were detected (Palmer and Tobin 1996). Occasionally, northern pike are caught by anglers fishing the Kenai River and reported in the ADF&G Statewide Harvest Survey (SWHS) (Howe et al. 2001a, 2001b, 2001c; McKinley 2013; Mills 1991, 1994). Outside the Soldotna Creek drainage, a reproducing northern pike population has not been detected in the Kenai River drainage.

Northern pike prefer slow-moving waters and vegetated habitat (Inskip 1982), and they rarely inhabit lake habitat away from the littoral zone. They are known to utilize habitat similar to that used by some juvenile salmonids and frequently prey on juvenile salmonids where they co-occur (Rutz 1996; Muhlfeld et al. 2008). Prior to the introduction of northern pike, some of the lakes in the Soldotna Creek drainage supported native rainbow trout, Dolly Varden, and Pacific salmon (primarily juvenile coho salmon). Now, most of these lakes are devoid of any native fish species (McKinley 2013). Northern pike threaten the area's substantial sport fisheries and the persistence and ecological relationships of other aquatic organisms.

Since 2003, various ADF&G northern pike control measures have been implemented on the Kenai Peninsula to remove or contain northern pike. Gillnetting has been the primary method used to control northern pike, although passage barriers and hoop nets have been used as well. Most of this effort has been directed at several major lakes within the Soldotna Creek drainage (Begich and McKinley 2005; Begich 2010; Massengill 2010, 2011).

ADF&G has evaluated different strategies for controlling or eradicating invasive northern pike. These strategies are listed in a document called the "Management Plan for Invasive Northern Pike in Alaska" available online at http://www.adfg.alaska.gov/static/species/nonnative/invasive/pike/pdfs/invasive_pike_management_plan.pdf.

Only 2 of the strategies listed in the management plan are deemed reliable for northern pike eradication: 1) dewatering (draining of the lake) and 2) chemical treatment. Of these alternatives, dewatering was deemed impractical due to the many water bodies containing northern pike and due to the lack of existing water control infrastructure. Therefore, ADF&G chose chemical treatment (rotenone) as the best method to initiate a northern pike eradication effort on the Kenai Peninsula.

Chemical treatment using rotenone, a natural plant-based piscicide, was a common ADF&G practice in the 1960s and 1970s in Southcentral Alaska to remove threespine sticklebacks (*Gasterosteus aculeatus*) from lakes before stocking with rainbow trout in order to reduce forage competition (Hammarstrom 1978; Chlupach 1977). Rotenone was also used successfully to eradicate illegally introduced yellow perch (*Perca flavescens*) from an unnamed lake in Nikiski in 2000 (Larry Marsh, retired fisheries biologist, ADF&G, Soldotna).

The selection process to determine the best location to initiate a northern pike eradication program using rotenone in 2008 was made using the following criteria:

1) Select a relatively small lake to facilitate development of technical application skills.
2) Select a closed-system water body that would simplify treatment and planning.
3) Select a water body where lost fishing opportunity could be restored.
4) Select a location where removing northern pike from that location would result in eliminating an easy source of northern pike that could be illegally transported alive to critically important salmonid habitat like the drainages of the Kenai and Swanson rivers.

Based on these criteria, Arc Lake was selected as the best candidate for ADF&G's initial northern pike eradication effort (Figure 2). The only known fish species native to Arc Lake is the threespine stickleback, first documented in the lake in 1965. Arc Lake was treated with rotenone to remove threespine sticklebacks prior to stocking with rainbow trout in 1966 (ADF&G Arc Lake file memo, Soldotna); threespine sticklebacks have not been present since. Rainbow trout, Chinook salmon, and coho salmon have all been stocked in the lake since then, although the most recent stocking (2000) consisted of only coho salmon fingerlings. All stocking of fish at Arc Lake was discontinued after northern pike were discovered because fishery managers were concerned that adding stocked fish to the lake could benefit the northern pike.

Arc Lake covers 18 surface acres, is 144 acre-feet in volume, and has a maximum depth of 14.5 feet. The land ownership surrounding the lake is all public (City of Soldotna, Kenai Peninsula Borough, and State of Alaska) (Figure 2).

OBJECTIVES AND TASKS

Objective

- Eradicate the invasive northern pike population from Arc Lake.

Goal

- Restore the recreational fishery in Arc Lake.

Tasks

1) Initiate scoping and information-sharing for the proposed restoration effort with the public, identified stakeholders, and appropriate government agencies.
2) Collect baseline physical, biological, environmental, and water quality data from Arc Lake prior to treatment.
3) Fulfill all permitting and interagency requirements necessary to conduct the piscicide treatment at Arc Lake.
4) Treat Arc Lake with a piscicide (rotenone).
5) Monitor Arc Lake after treatment to determine whether the treatment successfully eradicated northern pike, document the natural degradation of rotenone over time, and document when biological and water quality values become restored sufficiently for restocking.

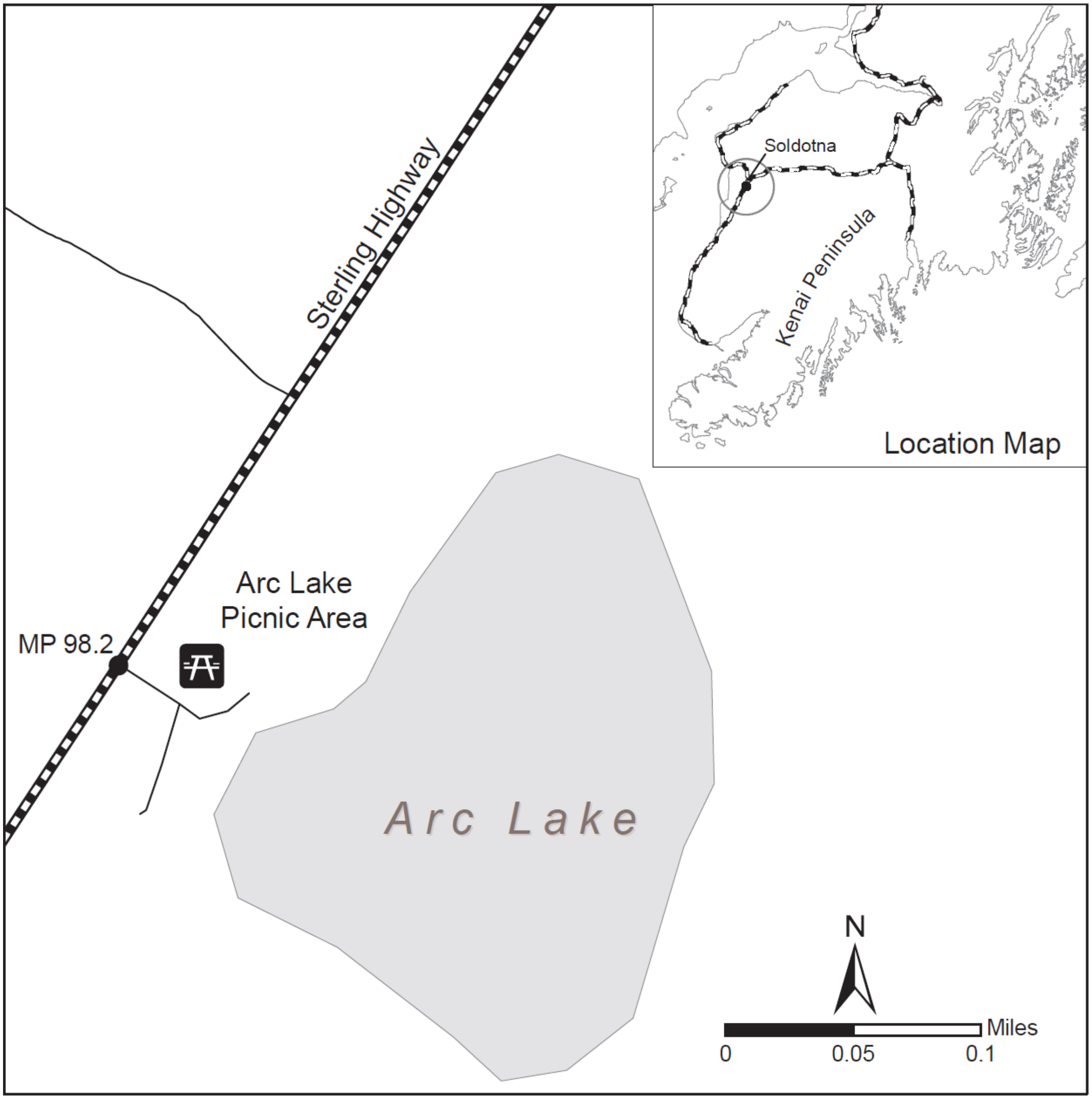

Figure 2.–Location of Arc Lake near Soldotna, Alaska.

METHODS

Clearances for Treatment

Multiple authorizations were required prior to conducting the rotenone treatment. ADF&G also solicited public and stakeholder involvement for this restoration effort. ADF&G obtained all required clearances for the Arc Lake restoration project, and these are summarized below.

National Environmental Policy Act (NEPA) Compliance

ADF&G submitted an environmental assessment to the USFWS for the Arc Lake restoration project on 20 August 2008, and a Finding of No Significant Impact (FONSI) was issued on 1

October 2008 (Appendix A1). The environmental assessment can be viewed online at http://www.adfg.alaska.gov/static/species/nonnative/invasive/rotenone/pdfs/arc_lake_ea.pdf.

Notifications

A list of the public scoping actions, notifications, and meetings provided by ADF&G in preparation for the Arc Lake restoration are provided below:

1) The local ADF&G advisory committees (Kenai-Soldotna, Cooper Landing, and Central Peninsula) and other identified stakeholders were notified and given a project synopsis of the Arc Lake restoration proposal on 25 April 2008. They were updated on the project's status during the period of late July through early August 2008 (Appendix A2).
2) A public presentation on invasive northern pike issues on the Kenai Peninsula, including the Arc Lake restoration proposal, was held on 1 May 2008 at the Kenai River Center in Soldotna, Alaska.
3) A presentation on the Arc Lake restoration proposal was given to the Soldotna City Council on 23 July 2008 at the Soldotna City Hall.
4) Public notices for the Arc Lake restoration pesticide use permit application were printed in the Peninsula Clarion on 23 July and 24 July 2008 as required by the Alaska Department of Environmental Conservation (DEC).
5) An ADF&G news release was issued on 30 July 2008 announcing that the Arc Lake public commenting period was open for the pesticide use application and environmental assessment (Appendix A3).
6) A presentation on the Arc Lake restoration proposal was given to the Kenai Peninsula Borough Assembly on 5 August 2008.
7) A synopsis describing the project was distributed to residents residing within one quarter mile of Arc Lake during early August of 2008.

State Level Approvals

The required state level authorizations obtained for the Arc Lake restoration project are listed below:

1) An Alaska Department of Environmental Conservation (DEC) pesticide use permit was issued on 28 August 2009 (Appendix A4).
2) An Alaska Coastal Management Program (ACMP) consistency review determination was made by DEC on 23 July 2008, stating that an ACMP review was not required (Appendix A5).
3) An Alaska Board of Fisheries approval of the Arc Lake restoration project (rotenone treatment) was issued on 20 August 2008 (Appendix A6).

WATER BODY PHYSICAL AND CHEMICAL CHARACTERIZATION

Lake Mapping

A bathymetric survey of Arc Lake was conducted to estimate its volume, which was used to determine the amount of rotenone needed and appropriate application rates. A shape file of the lake boundary was created using aerial images in a geographic information system (GIS), which was then loaded onto a Trimble GeoTX[2] 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, 100 depth measurements and associated waypoints were collected. The transducer for the FishFinder was secured to an adjustable mount that allowed 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 so they were 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. Efforts were made to ensure relatively even spacing between sample locations. At each sample location, the surveyors stopped the boat and allowed the Trimble to collect approximately 60 positions (one position per second for one 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 to verify the accuracy of the depth measured by the FishFinder. After the survey was completed, 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 for each sample location) has submeter accuracy.

Once postprocessed, 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 ortho-rectified and georeferenced. An ArcGIS tool called "Surface Volume" calculated the projected area, surface area, and volume of the 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

Water quality data are useful for planning a rotenone treatment (Finlayson et al. 2000). Rotenone degrades more quickly in water with increasing light, heat, or turbidity, and with shallow depths and low organics (Bradbury 1986; Dawson et al. 1991; Schnick 1974). Alkalinity can affect the degradation rate of rotenone and its effectiveness as a piscicide. In very high 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 of rotenone (Ott 2008) but can persist longer (Finlayson et al. 2001). Alkalinity has an inverse relationship with the potency of rotenone

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

(https://srac.tamu.edu/index.cfm/getFactSheet/whichfactsheet/219/, accessed 2 February 2014). Low pH can also prolong the active life of rotenone (Brian Finlayson, retired California Department of Fish and Game, personnel communication).

Our goal was to collect water quality data once per month for at least 1 year prior to and following the rotenone treatment. Water temperature, pH, dissolved oxygen, and specific conductivity data were collected from Arc Lake using a Quanta Hydrolab. Turbidity was measured with a Secchi disk. All data were collected in 1-meter increments from the lake surface to the bottom at a location at, or very near, the deepest part of Arc Lake. The sampling site was marked with a tethered buoy visible during open water and in winter was marked with a flagging stake anchored into the ice. Pretreatment monthly water quality sampling occurred from July 2006 through June 2007 and December 2007 through September 2008. Posttreatment monthly water quality sampling occurred from October 2008 through September 2009.

Two pretreatment alkalinity samples were collected at Arc Lake in summer 2008. The samples were collected by filling a single 500 ml glass jar with water from 60 cm below the lake surface from near the lake center. Total alkalinity was analyzed by ADF&G Limnology Lab personnel using the methods described in Koenings et al. (1987).

ADF&G had received public inquiries about potentially high fecal coliform bacteria levels in Arc Lake resulting from gulls, attracted to the nearby landfill and often congregating at Arc Lake, defecating in the water. The public was concerned that high fecal coliform levels could contaminate hatchery-stocked fish released into Arc Lake following the treatment and render them unsafe to eat. Water samples were collected by the Kenai Watershed Forum in fall 2008 and forwarded to the City of Soldotna wastewater treatment plant for fecal coliform testing.

Sampling for chemical contamination in Arc Lake is done annually to assess whether contamination is occurring in Arc Lake due to its close proximity to the Soldotna Landfill. The Kenai Peninsula Borough coordinates this annual contaminants testing at Arc Lake, which tests the water for an array of water quality Key Indicator Parameters (KIPs) including various metals and volatile organic compounds (VOCs).

BIOLOGICAL INVENTORY

Fish

Based on recent ADF&G efforts to sample fish from Arc Lake, it was believed northern pike were the only species of fish present in the lake (ADF&G unpublished[3]). To confirm this, baited minnow traps were fished in Arc Lake prior to rotenone treatment to determine and document whether threespine stickleback or other small fish were present.

Gillnets were also fished before the treatment to salvage northern pike for food donation and to further assess whether any species other than northern pike were present. Twenty-four sinking monofilament gillnets were used in summer 2008 to capture and remove northern pike. These nets, manufactured by Christiansen's Nets (http://www.christiansennets.com/), were each 120 ft long and 6 ft deep, with six 20 ft wide panels of variable mesh net (one each of sequentially attached half-inch, five-eighths-inch, three-quarter-inch, one-inch, 1½-inch, and 2-inch stretched

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[3] ADF&G stocked lakes survey data, unpublished lake file data archived in the Soldotna office.

mesh) with a half-inch lead line. The netting effort was based on staff time availability, and the goal was to fish all the nets at least 24 hours.

The 24 gillnets were set in littoral areas with a 2-person crew operating from an outboard motorboat. Nets were tethered near shore to a fencepost with an owl decoy placed on top to discourage bird activity near the net. After tethering, the net was stretched out from shore by feeding it out from the boat bow by one crew member while the other drove the boat away from shore in reverse. At the end of each net, a 2-pound lead fishing weight was attached to the lead line (to help anchor the unstaked net end), and a small buoy or cork was tethered to the hanging line to help the crew relocate the net end later.

Gillnets were used in spring 2009 to evaluate the treatment's success at removing northern pike from Arc Lake. Calculations of the amount of gillnetting effort needed to detect a small surviving population of northern pike and the corresponding probability of not detecting the population are found in Appendix B1. These calculations are derived from historical netting effort, catch, and abundance estimates for northern pike at Sevena Lake and account for differences in surface acreage between the lakes.

Posttreatment gillnetting was conducted with the same nets used during the pretreatment netting; however, gillnets deployed posttreatment were deployed under the ice and fished until ice-out the following spring. Gillnets were set under the ice by using a jigger board. A jigger board can be lowered through an ice hole and then propelled under the ice surface by a line-activated spring mechanism that moves the jigger board away from a person who is repeatedly jerking and releasing the line by hand. The jigger board is then relocated at a measured distance from the original ice hole and removed through a new hole made in the ice. The line carried by the jigger board is then used to pull a net into position under the ice.

Invertebrates

Macroinvertebrate and zooplankton sampling was conducted to determine if there was a posttreatment forage base for stocked coho salmon fingerlings and to assess the general effects of rotenone to the invertebrate community.

Macroinvertebrate and zooplankton sampling in Arc Lake was conducted at the same locations both before treatment during summer 2008 and after treatment in summer 2009 to identify taxa present. Locations were recorded with a handheld GPS before treatment so the same locations could be found by GPS and resampled after treatment; these locations are shown in Figure 3. At each sampling site, all invertebrates collected by a single gear type were combined into 1 glass specimen jar filled with 70% ethanol and labeled with the date, site location, and gear type.

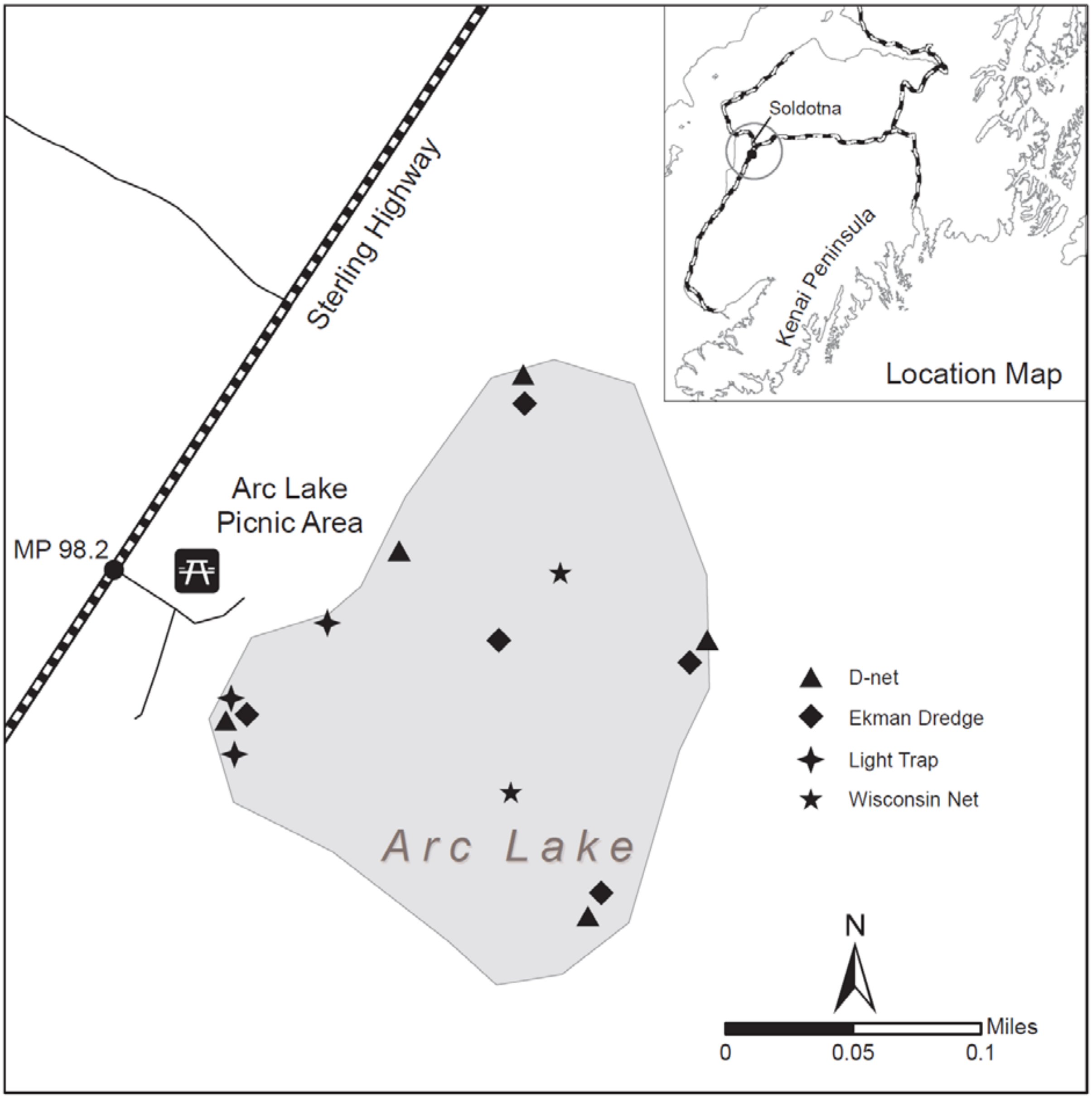

Figure 3.–Arc Lake invertebrate sampling locations and symbol codes.

Zooplankton collections were made at 2 sites by replicate vertical tows (from the bottom of the lake to the surface) in 2 midlake locations using a 0.5-meter diameter Wisconsin net with 153 µm mesh. The Wisconsin net was lowered to near the lake bottom (~5 m) with a hand line and then retrieved at a rate of 1 meter 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). To collect benthic macroinvertebrates, a 9-inch Ekman Bottom Grab Sampler was used to collect bottom sediment from 5 offshore sites. The Eckman sampler was deployed from an anchored outboard motorboat at each site in 1.5 to 3 m of water. Collected sediment was screened to filter out invertebrates, which were removed from the screen with tweezers. Hand-held 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. Floating Quatrefoil light traps were used and tethered to stakes set in 3 nearshore locations and fished during at least 1 hour of darkness. The Quatrefoil light traps used for sampling were designed and built by Southern Concepts (Birmingham, Alabama) and featured 6 mm entrance slots and light-emitting diodes (LED lights) powered by dry-cell batteries. A snorkel survey was conducted to search for freshwater mussels and snails opportunistically. All invertebrate sampling locations, except snorkeling, are shown in Figure 3.

BIOASSAYS

Bioassays using live fish were conducted at Arc Lake to determine a minimum effective dose (MED) of rotenone liquid formulation. The criterion for determining the MED is 5 times the rotenone concentration at which at least half of the bioassay fish are killed after 4 hours of exposure (Brian Finlayson, retired California Department of Fish and Game, personal communication). For example, if the bioassay concentration that kills at least half of the fish after 4 hours of exposure were 0.20 ppm, the MED would be 1.0 ppm (5×0.20 ppm = 1.00 ppm). To determine the MED for the rotenone formulation, the following bioassay concentrations were each tested with a single bioassay: 0.0 ppm (control), 0.05 ppm, 0.10 ppm, 0.20 ppm, 0.50 ppm, 1.00 ppm, and 1.50 ppm. Predetermined amounts of CFT Legumine needed for various bioassay container volumes and rotenone concentrations are provided in Table 1.

Juvenile coho salmon were collected from the Kenai River drainage for the bioassays. Coho salmon were used as a surrogate for northern pike because it is difficult to catch northern pike of appropriately small size for bioassay testing based on the practical limits of container size and the recommendation to not exceed loading the bioassays with more than 1 g of fish per liter of water (Brian Finlayson, retired California Department of Fish and Game, personal communication). Coho salmon have a higher tolerance to rotenone than northern pike (Marking and Bills 1976), so rotenone 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 rotenone formulation. There were 7 bioassays (see above). For each bioassay, 6 juvenile coho salmon with weights ranging from 2.0 g to 13.2 g were placed in 10 gallons of lake water within a 33-gallon (125-liter) gas-permeable "breathable" polyethylene bag. We weighed the fish to make sure that we did not exceed 1 g fish per liter of water as recommended in Finlayson et al. (2010). The bags were 91 cm by 122 cm low-density polyethylene (LLD) drum liners about 1.0 to 1.5 mm thickness purchased online at http://www.linersandcovers.com/polyethylene-plastic.php. These bags were selected for the bioassays because their polyethylene membranes exhibit permeability to oxygen (http://chemicalland21.com/plasticrawmaterial/pvc/LDPE%20FB3000.htm), allowing some oxygen to pass from surrounding water into the bags and therefore reducing the need for aeration (Horton 1997; Finlayson et al. 2000).

Each bioassay bag was filled with approximately 38 liters (10 gallons) of Arc Lake water treated with a preselected amount of rotenone formulation (CFT Legumine). Temperature in each bag was maintained close to that found in Arc Lake by keeping the bags suspended in the lake by means of spring clamps attached to an improvised post-and-beam rack set offshore in water about 70 cm deep. Each bioassay bag was mostly submerged in the lake with the bag opening about 30 cm above the water line.

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 liter	1 gallon (3.79 L)	1 liter
Target concentration in ppm[a]	Milliliters of premix[b]	Milliliters of premix[b]	Milliliters of premix[b]
0.10	0.011	0.00426	0.001
0.20	0.023	0.00852	0.002
0.50	0.056	0.02130	0.006
1.00	0.113	0.04259	0.011
1.50	0.169	0.06389	0.017
2.00	0.225	0.08518	0.023
3.00	0.338	0.12777	0.034
4.00	0.450	0.17036	0.045

[a] Target concentration refers to amount of total product (CFT Legumine), not active ingredient, in parts per million.
[b] Premix consists of 10 parts water to 1 part product.

Calculating Product Volume

The number of gallons of liquid CFT Legumine required to treat Arc Lake was calculated based on bioassay results (target concentration 1.0 ppm; see Results section) and the volume of Arc Lake, which was determined to be about 144 acre-feet (see Results section). The calculation to determine the number of gallons of liquid CFT Legumine product (G_p) required to treat 144 acre-feet of water at a target concentration of 1.0 ppm was deduced from the product label as follows:

$$G_p = 0.\overline{33} \times D_c \times V_e \quad (1)$$

where

$0.\overline{33}$ = Gallons of CFT Legumine product required to treat 1 acre-foot of water at 1.0 ppm (0.05 ppm active ingredient, per product label),

D_c = Desired target concentration (1.0 ppm) of CFT Legumine, and

V_e = Estimated volume (144 acre-feet) for Arc Lake.

Therefore it follows that for a desired target concentration of 1.0 ppm for 144 acre-feet,

$G_p = 0.\overline{33} \times 1.0 \times 144 = 48$ gallons of CFT Legumine.

TREATMENT APPLICATION

The Arc Lake rotenone treatment was planned for mid-October 2008, just before freeze-up. Near-freezing water temperature has been shown to slow the natural degradation of rotenone, sometimes prolonging rotenone persistence for months (Gilderhus et al. 1986; Finlayson et al. 2010). The treatment timing (mid-October) ensured northern pike would be exposed to a lethal concentration of rotenone for as long as possible, thus increasing the likelihood of project success.

The piscicide was applied from an 18-foot aluminum-hulled boat equipped with a 50-horsepower outboard motor. Because CFT Legumine requires premixing with water prior to application (Appendix C1), the rotenone formulation was premixed with lake water within a gas-powered pumping apparatus (Honda portable centrifugal pump, model WX10K1A) equipped with a discharge manifold loosely based on a design described in Finlayson et al. (2000). The pump drew lake water from an intake line and drew the rotenone formulation from a siphon line connected to the discharge line. The intake hose pumped lake water from below the waterline near the boat transom. Mixing of lake water and the rotenone formulation was accomplished by connecting an inline polypropylene venturi mixing siphon (Mazzei 885X injector) to the discharge hose of the pump. The mixing siphon creates a venturi vacuum as pressurized water (50 psi) is forced through the body of the device. A smaller diameter siphon line incorporated into the body of the mixing siphon draws liquid piscicide from a container (drum) and mixes it with lake water in a 1:10 ratio. Selection of the proper size mixing siphon to achieve a 1:10 pesticide-to-water premixture was critical and was accomplished by providing the specific application pump discharge rate and pressure to the mixing siphon manufacturer, who recommended an appropriate model mixing siphon. The pumping system was closed, meaning that all mixing was confined within the pumping system and no manual mixing occurred. The pumping apparatus was manually calibrated to achieve a discharge rate of about 4.4 gallons of premixture per minute. During the treatment, the rotenone and water premixture was pumped through a discharge hose that either dispersed the premixture below the lake surface near the boat's propeller wash or diverted the premixture to a handheld spray nozzle, based on applicator preference.

Because Arc Lake is relatively shallow (14.5-foot maximum depth), a near-surface application was believed adequate to thoroughly treat the lake (Grant Grisak; fisheries biologist; Montana Fish, Wildlife and Parks; personal communication). The specific gravity of CFT Legumine is 9% higher than water, allowing it to sink throughout the water column (Finlayson et al. 2000) and disperse into deeper areas.

The boat applicators (a 2-person team) began applying the premixture by traveling around the perimeter of the lake while using a handheld spray nozzle to apply the piscicide mixture along the lake perimeter. This process allowed the applicators to treat shallow vegetated shoreline areas that would otherwise be difficult to treat using the methods described next. After piscicide was applied along the lake perimeter, the premixture was applied to lake waters by pumping it below the water surface near the propeller wash of the boat while the boat traveled in increasingly smaller concentric circles toward the center of the lake. Application swath widths did not exceed 30 feet, as suggested by Randall (2006). Application swath spacing, boat speed, and water depth were continuously monitored by the boat operator using a Garmin GPSMAP 440s FishFinder. To assist the boat applicators, we estimated the appropriate boat speed and number of concentric application circuits needed to evenly apply the rotenone given the following: 1) the application swath was 30 feet wide, 2) the application would take 2 hours (not including breaks for refueling and cleaning rotenone containers), 3) the rate of premixture application was 4.4 gallons/minute, and 4) the average lake depth was about 9 feet (Table 2, Equations 2–4).

Table 2.–Parameters needed to estimate application rate, boat speed, and application circuits required to treat Arc Lake with CFT Legumine at 1 ppm in a 2 hour period.

Parameter for Arc Lake	Calculation	Estimate
Lake volume (acre-feet)	From lake mapping	144
Average lake radius in feet (approx. round surface morphology)	From lake mapping	500
Surface acres	From lake mapping	18
Square feet of lake surface	18 acres × 43,560 ft^2/acre	784,080
Miles of (30 ft width) application trail	784,080 ft^2/30 ft/5280 ft/mile	4.95
Gallons of CFT Legumine needed for 1 ppm concentration	Equation 1	48
Gallons of premixture (1:10 ratio) to apply	48 gal CFT Legumine + 480 gal water	528
Gallons of premixture to apply per surface acre	528 gal/18 acres	29.3
Application time in minutes	Given	120

The application rate was calculated as follows:

$$A = \frac{P}{m} = \frac{528\ \text{gal}}{120\ \text{min}} = 4.4\ \text{gal}/\text{min} \qquad (2)$$

where *A* is the application rate in gallons/minute, *P* is the amount of premixture applied, and *m* is the number of minutes available for application.

Boat speed was calculated as follows:

$$S = \frac{T}{h} = \frac{4.95\ \text{mi}}{2\ \text{h}} = 2.5\ \text{mi}/\text{h} \qquad (3)$$

where *S* is the required boat speed in miles/hour, *T* is the miles of application trail, and *h* is the number of hours available for application.

The number of application circuits required to treat Arc Lake (assuming a 30-foot application swath) was calculated as follows:

$$C = \frac{r}{w} = \frac{500\ \text{ft}}{30\ \text{ft}} = 17 \qquad (4)$$

where *C* is the approximate number of concentric boat circuits needed to complete the application, *r* is the radius of Arc Lake in feet, and *w* is the width of the application swath in feet.

Liquid rotenone formulations disperse rapidly in water both vertically and horizontally (Finlayson et al. 2000), but to further help enhance uniform mixing, boat speed was changed when the water depth varied by 50% or more from the mean lake depth of about 9 feet. For instance, if the depth was 4.5 feet or less (≤50% of the mean), boat speed was accelerated by 50% to 3.7 mph (2.5mph + .1.2 mph) (Table 3); likewise, boat speed was slowed by 50% in water at least 50% deeper than the mean depth.

Table 3.–Target boat speeds for the application boat over varying water depths.

Water depth (feet)	Boat speed (mph)
<4.5	3.7
4.5–13.5	2.5
>13.5	1.2

Caged juvenile coho salmon and adult northern pike were placed in the lake immediately prior to the lake treatment and served as sentinel fish to monitor the treatment's effectiveness in real time. These fish were suspended at 3 different lake depths as follows: 1) near surface (~1 ft; 0.3 m), 2) mid-water column (~7.5–10 ft; 2.3–3 m), and 3) near maximum depth (~14 ft; 4.3 m). From 3 to 5 fish were placed in each cage. The fish were frequently monitored to determine the time of visible distress and mortality.

After completing the application, all equipment and empty product containers were triple-rinsed with lake water and dried. The boat and pumps were completely drained into the lake before final cleanup with soap and clean water using a pressure washer offsite.

ROTENONE SAMPLING

Water and sediment samples were collected immediately before and shortly after the rotenone treatment to verify rotenone concentration. Sampling continued periodically posttreatment until the rotenone had degraded to a concentration no longer toxic to fish. The sampling schedule was dependent on the observed rate of rotenone degradation but was anticipated to be months between sampling events after the initial sampling on the treatment day.

Composite water samples, a single sample for each sampling event, were obtained by lowering a weighted, tethered container (1 gallon amber-colored glass jug) midway in the water column near the deepest area of the lake, remotely opening the container (with a pull string attached to a rubber stopper), and then slowly pulling the container back to the lake surface. With this method, the jug gradually filled with water as air was displaced through the small jug opening.

Composite sediment samples (100–150 ml each) were collected from 3 sites for each sampling event and were dug from the lake bottom along the western shoreline using a hand shovel. Sediments were combined into a single composite sample and placed in an amber-colored 500 ml glass jar. A composite sample was intended to be more representative of the overall rotenone concentration found in lake sediment and was a less costly approach than analyzing multiple grab samples. Both water and sediment samples were labeled with the sample date and location and then placed temporarily (< 24 hours) in cold storage. The samples were then sent to the Washington State Department of Agriculture (WSDA) Chemical and Hop Lab located in Yakima, Washington, for analysis. All samples were packaged with cold packs and express shipped with appropriate chain-of-custody paperwork.

RESULTS

Water Body Physical and Chemical Characterization

Lake Mapping

A bathymetric map and volume estimate for Arc Lake was completed in summer 2008. Arc Lake covers an estimated 18 surface acres and has a volume of 144 acre-feet, a maximum depth of 14.5 feet, and a mean depth of 8.6 feet (Figure 4).

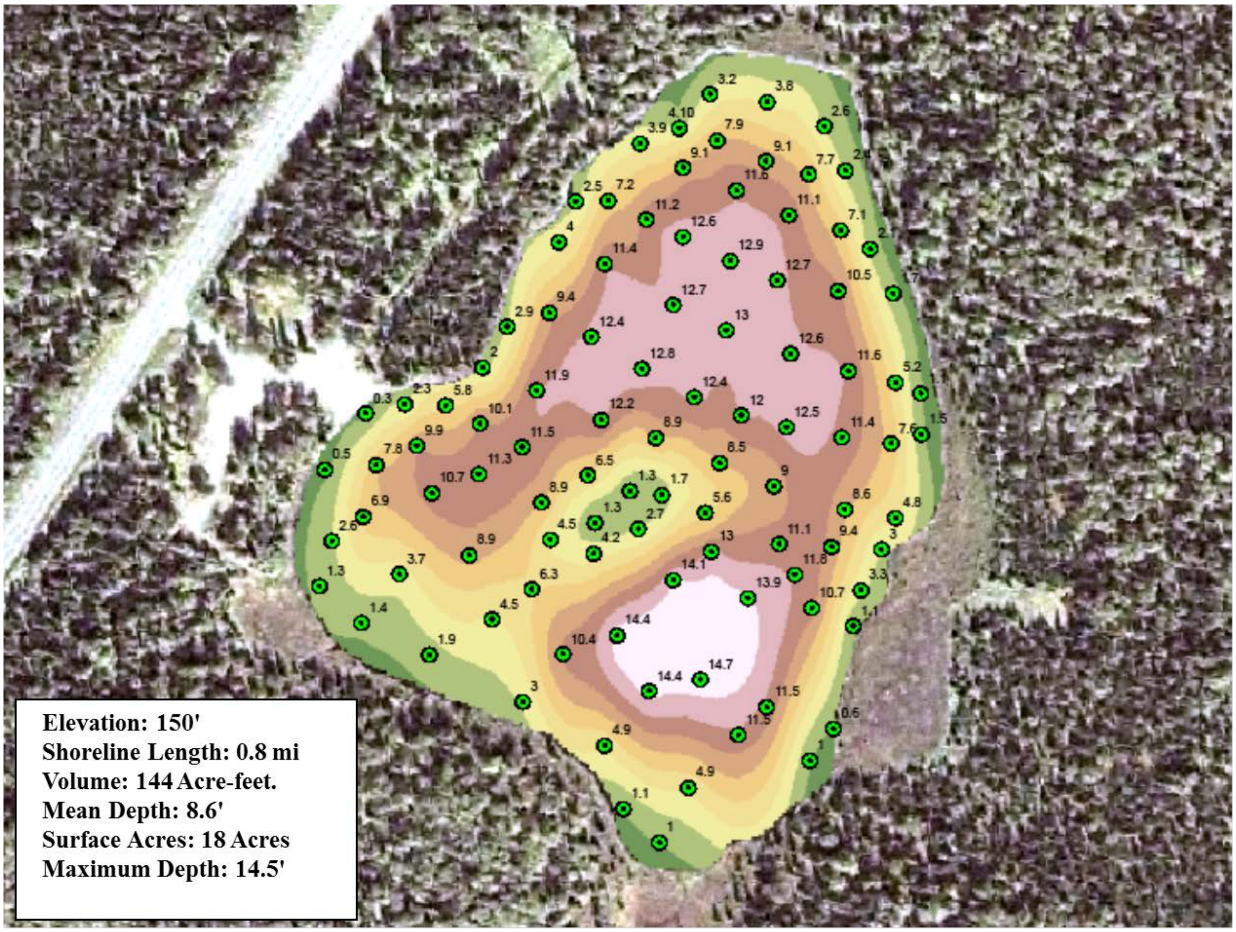

Figure 4.–Bathymetric map of Arc Lake with green dots depicting depth measurement sites.

Water Quality

Water quality sampling was conducted on a monthly to semi-monthly basis. The results show that water temperature, dissolved oxygen, specific conductivity, and pH remained similar between pretreatment and posttreatment periods (Figures 5–8, respectively). Visibility increased (0.7 meters) for a period after treatment (Figure 9).

Two pretreatment alkalinity samples were collected from about 0.6 m below the lake surface on 22 August 2008. Total alkalinity was found to be exceptionally low in both samples (1.5 mg/L and 1.9 mg/L $CaCO_3$).

The Kenai Peninsula Borough contaminants testing of Arc Lake for KIPs found no samples exceeding water quality standards before or after treatment (Appendix D1).

Fecal coliform sampling occurred courtesy of the Kenai Watershed Forum on 1 October 2008, and the samples were analyzed by the City of Soldotna Wastewater Treatment Plant. Four samples were collected and analyzed, and fecal coliform colony counts ranged from 0 to 4 colonies per 100 ml of water (Appendix D2); the counts were much lower than the minimum standard for recreational contact of 200 colonies per 100 ml, as reported online by the DEC at http://dec.alaska.gov/water/wqsar/wqs/pdfs/18%20AAC_70_WQS_Amended_July_1_2008.pdf.

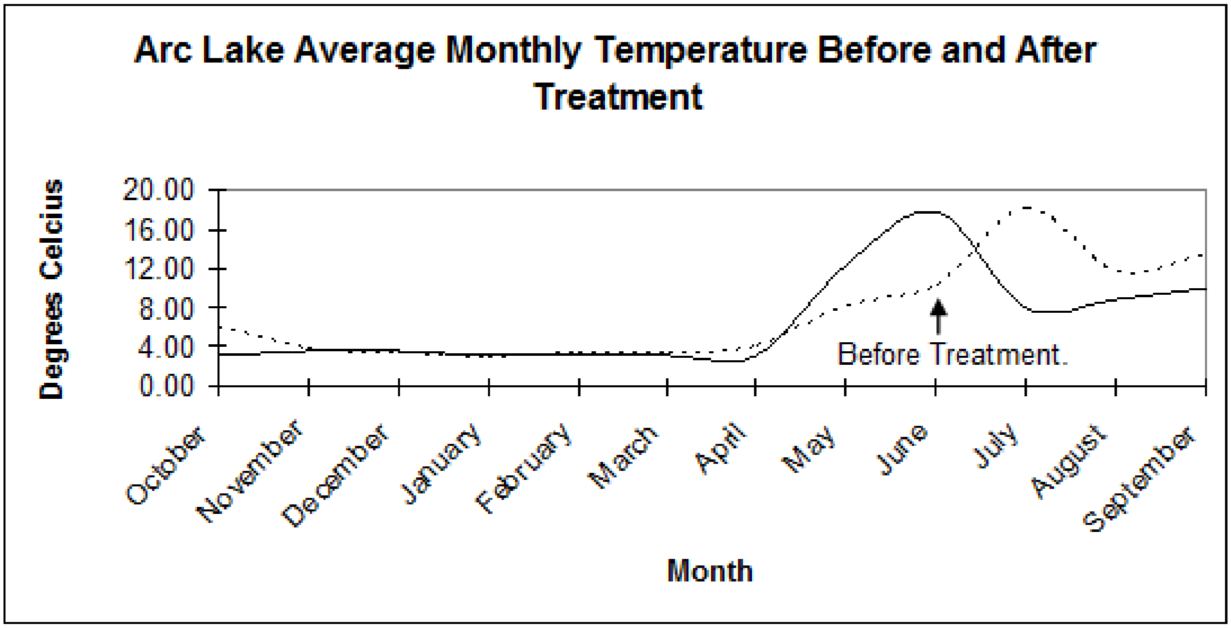

Figure 5.–Arc Lake average monthly temperature before treatment (dotted line; July 2006–June 2007, December 2007–September 2008) and after treatment (solid line; October 2008–September 2009).

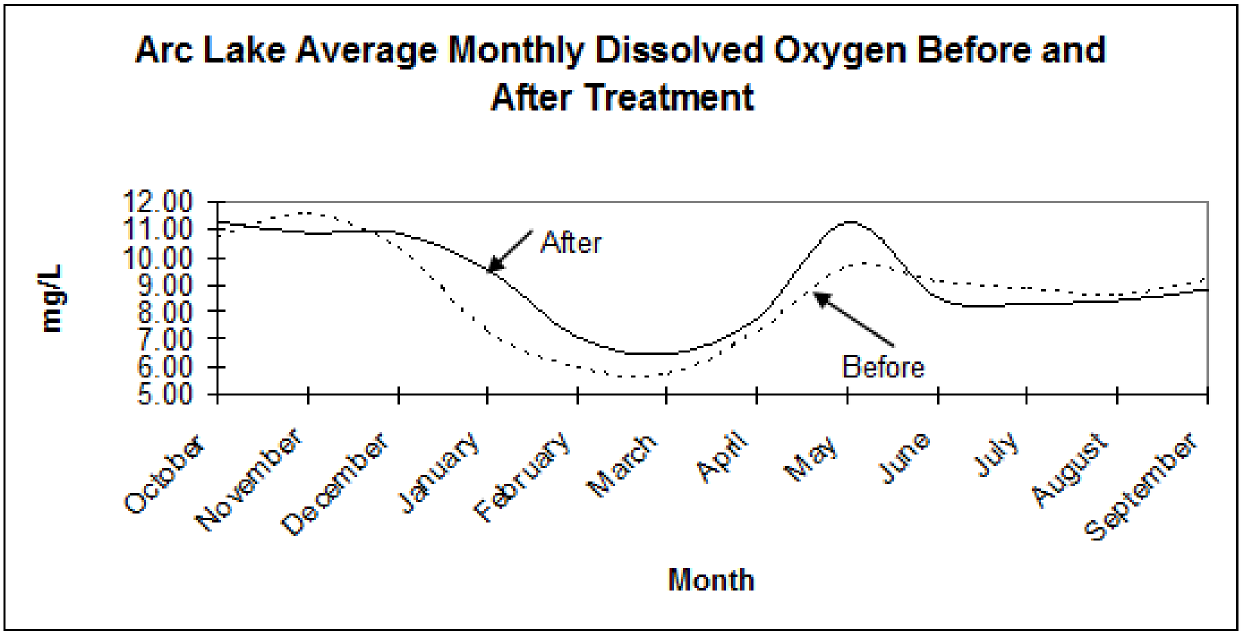

Figure 6.–Arc Lake average monthly dissolved oxygen before treatment (dotted line; July 2006–June 2007, December 2007–September 2008) and after treatment (solid line; October 2008–September 2009).

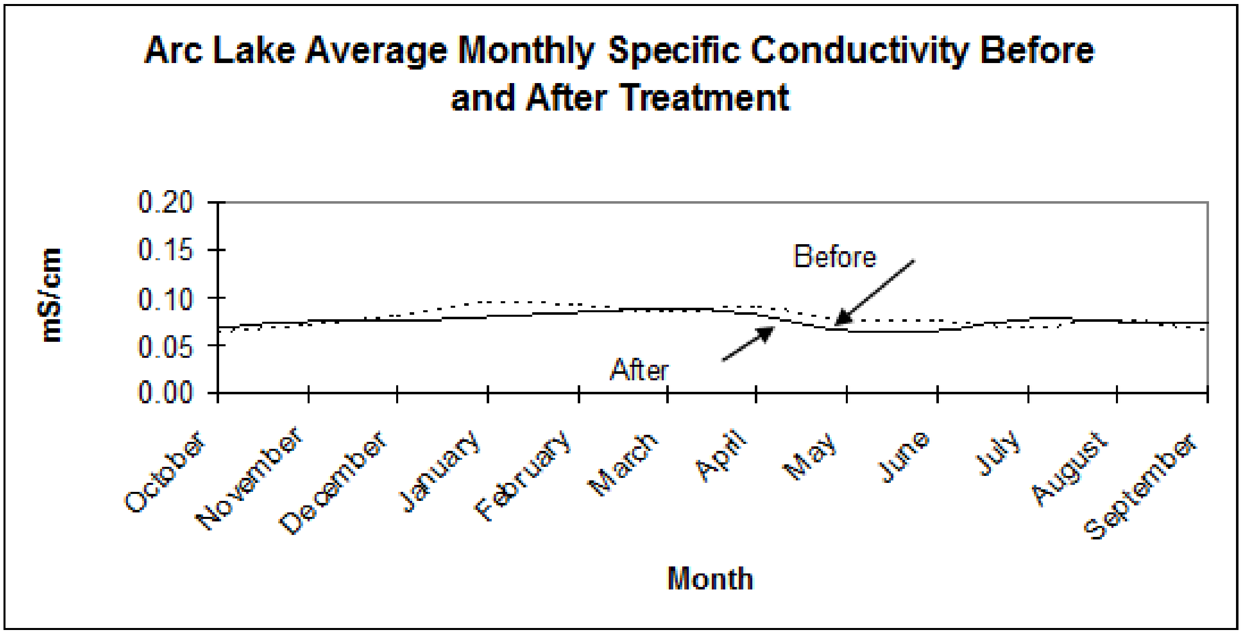

Figure 7.–Arc Lake average monthly specific conductivity before treatment (dotted line; July 2006–June 2007, December 2007–September 2008) and after treatment (solid line; October 2008–September 2009).

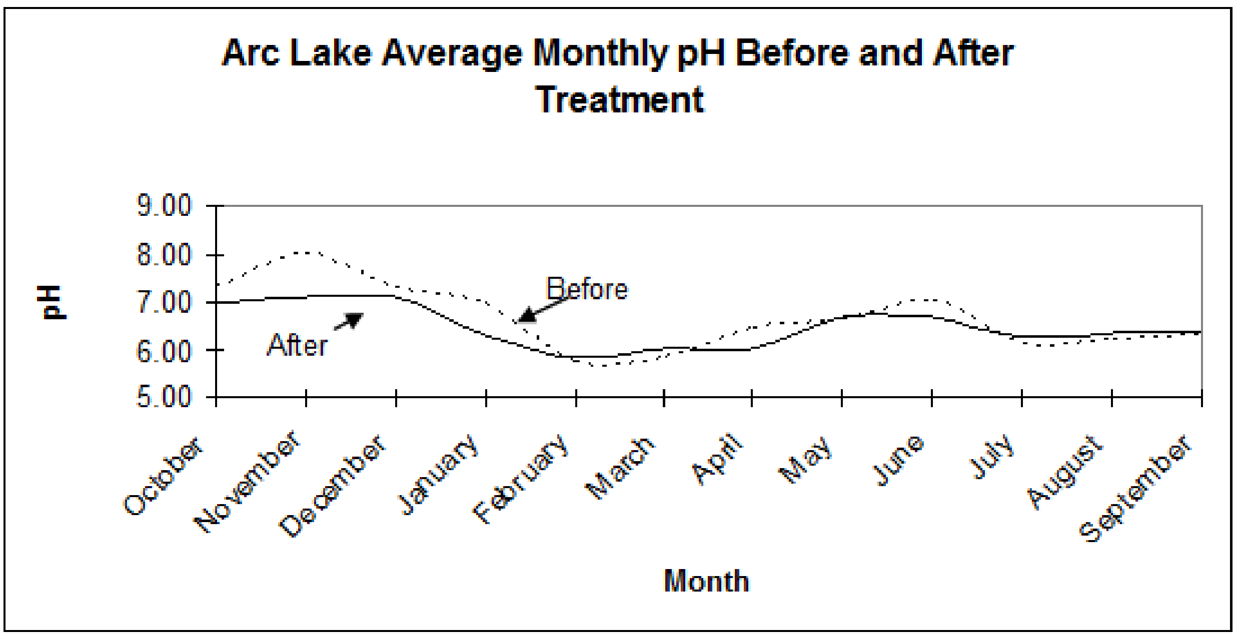

Figure 8.–Arc Lake average monthly pH before treatment (dotted line; July 2006–June 2007, December 2007–September 2008) and after treatment (solid line; October 2008–September 2009).

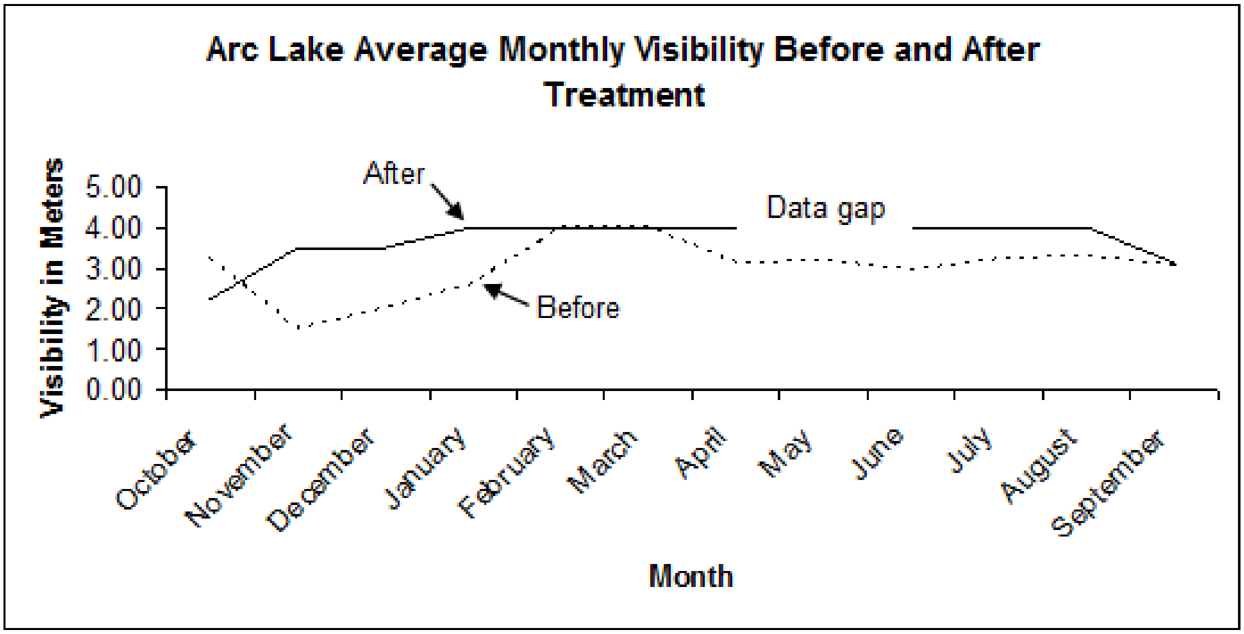

Figure 9.–Arc Lake average monthly visibility before treatment (dotted line; July 2006–June 2007, December 2007–September 2008) and after treatment (solid line; October 2008–September 2009).

BIOASSAYS

Bioassays using juvenile coho salmon were conducted in Arc Lake on 10 October 2008. The bioassay protocol deviated slightly from the original plan because of an error found in the calculations used to determine the amount of rotenone required for a desired concentration. The error was discovered while the bioassay tests were underway. This error resulted in higher-than-planned rotenone concentrations for the bioassays (except for the control, in which no rotenone was added). During the bioassays, we were able to determine the actual rotenone product (CFT Legumine) concentrations for 4 of the bioassays as follows: 0.0 ppm, 0.5 ppm, 1.0 ppm, and 1.5 ppm. Several bioassays of greater rotenone product concentrations were discarded because their concentration (> 1.5 ppm) was above what would be reasonable for our use. The bioassays with 0.5 ppm, 1.0 ppm, and 1.5 ppm rotenone product concentrations all resulted in all fish dying within 2 hours. No fish died in the control bioassay (Table 4).

Table 4.–Bioassay results for coho salmon subjected to different rotenone product (CFT Legumine) concentrations in Arc Lake.

Product concentration [a]	Start time	Finish time	Result [b]
0.0 control	13:50	14:39	all alive
0.5 ppm	13:52	14:40	all dead
1.0 ppm	13:54	14:41	all dead
1. 5 ppm	13:56	14:42	all dead

Note: Juvenile coho salmon were used as a surrogate for northern pike. Coho salmon weights ranged from 2.0 g to 13.2 g, and each bioassay container, containing 10 gallons of lake water, held 6 fish.

[a] Product concentration refers to the concentration in parts per million of CFT Legumine.

[b] Exact times of death were unknown, but all deaths occurred within 2 hours despite the plan for a 4 hour bioassay test.

Although lower concentrations of rotenone (< 0.5 ppm) were not tested as planned and would have been useful for evaluating 4-hour mortality and MED, the bioassays did confirm that the originally planned target concentration of 1.0 ppm rotenone formulation was more than adequate to kill northern pike in water conditions similar to Arc Lake. The rotenone formulation concentration of 1.0 ppm was selected as the target concentration for the treatment as a precaution against underestimating lake volume or other untested lake qualities that may have affected the potency of the rotenone.

ROTENONE TREATMENT

Arc Lake was treated with rotenone (CFT Legumine) on 14 October 2008. A total of 48 gallons of CFT Legumine was applied in an attempt to reach a target rotenone formulation concentration of 1 ppm (0.05 ppm active ingredient [rotenone]). The treatment began around noon and was completed by 6:30 PM. The actual application took much longer than the anticipated 2 hours because of frequent stops to clear fogging of eye protection and to resolve minor issues (clogging of the mixing valve, etc.) with the pump system.

After rotenone was applied to the lake, applicators continued to drive the application boat for another 40 minutes to create wakes and promote mixing of the piscicide. During the treatment, air temperatures ranged from −4.0°C to +1.5°C, skies were overcast, there was light snowfall during the morning, and ice was beginning to form along the shoreline. The water temperature averaged 3.5°C.

Just prior to initiating the treatment, 5 cages loaded with live sentinel fish (4 juvenile coho salmon per cage) were placed in predetermined locations in the lake, encompassing varying water depths and distances from the shore, to document the toxicity of the treatment. One of the cages also contained several adult northern pike (~400 mm) captured days earlier from Arc Lake. All sentinel fish had died by the completion of the treatment on 14 October 2009. Two dead northern pike were collected from Arc Lake the day following the treatment and disposed of at the Borough landfill. Most fish were expected to sink following this cold water treatment (Bradbury 1986).

The surface of Arc Lake completely froze early on the morning of 17 October 2008, about 2.5 days following the rotenone application.

ROTENONE SAMPLING

As expected, no rotenone was detected from water and sediment samples collected prior to the rotenone treatment on 13 October 2008. Results from samples taken immediately after the treatment on 14 October 2008 indicated both water and sediment samples contained 0.004 ppm rotenone, well below the target concentration of 0.05 ppm active ingredient.

Periodic posttreatment sampling revealed that the rotenone concentration in water and sediment samples initially increased over time (Figures 10–11). The peak rotenone concentration in the water samples occurred on 29 December 2008 (0.035 ppm rotenone), which was 70% of the target concentration goal of 0.05 ppm. Although not as high as desired, the concentration was still well within the suggested guidelines for normal use indicated on the CFT Legumine product label (Appendix C1). The peak rotenone concentration value detected in lake sediment samples occurred on 4 March 2009 (0.21 ppm). The rotenone concentration in both lake water and sediment samples slowly decreased after peak levels were attained and dropped to nontoxic levels after ice-out in late spring 2009 (Figures 10–11). The last water and sediment samples analyzed from Arc Lake were collected on 20 July 2009, and the rotenone concentrations were less than 0.0001 ppm and 0.005 ppm, respectively.

Caged juvenile coho salmon were regularly placed in Arc Lake at various depths during the spring and early summer of 2009 to help determine when the lake was no longer toxic to fish. It was not until 18 June 2009 that juvenile coho salmon began to consistently survive multiple days of exposure to Arc Lake water, indicating that detoxification had occurred.

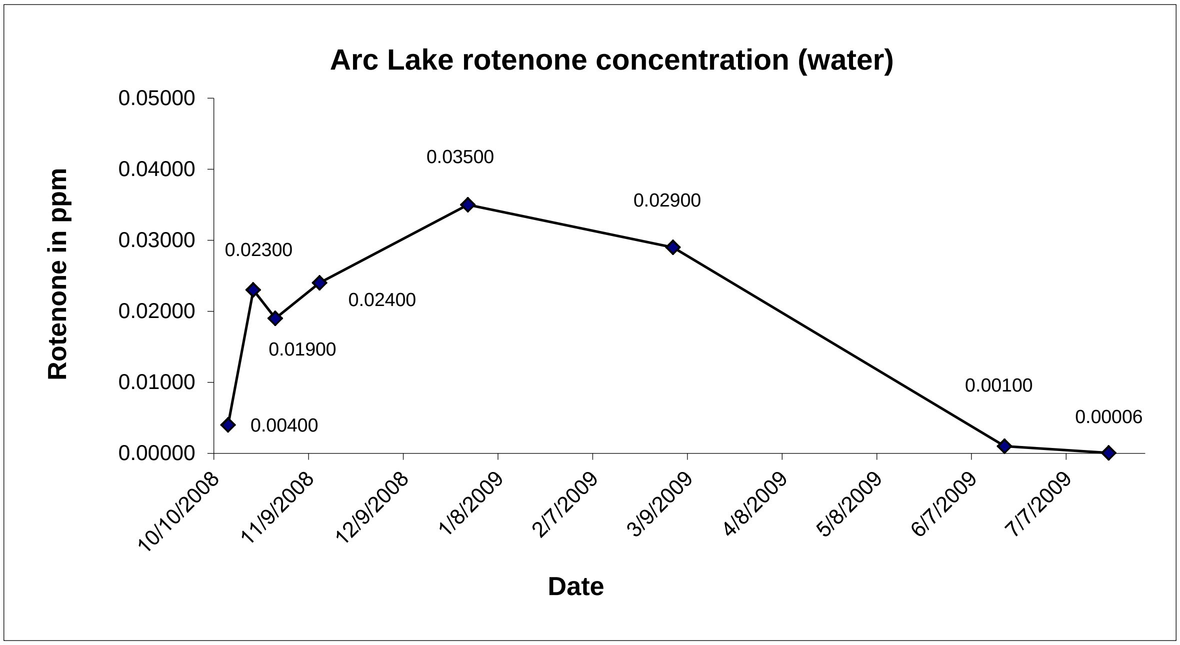

Figure 10.–Rotenone concentrations (ppm) in Arc Lake water samples over time.

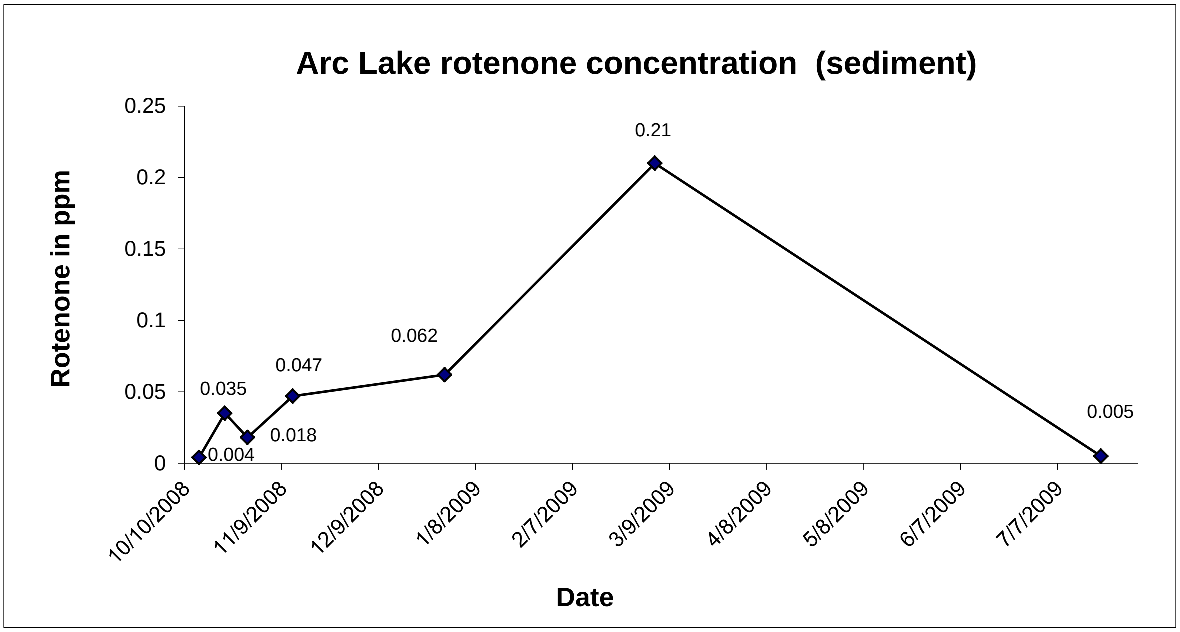

Figure 11.–Rotenone concentrations (ppm) in Arc Lake sediments over time.

BIOLOGICAL INVENTORY

Invertebrates

A total of 17 different taxa of aquatic invertebrates were identified during 3 pretreatment sampling events in 2008. Snorkeling was only conducted once during the pretreatment period and never posttreatment because no snails or mussels were found during the first snorkel survey. Thirteen different taxa were identified during the single posttreatment sampling event in 2009 (Table 5, Appendix E1). A total of 20 separate taxa were identified altogether between pre- and posttreatment sampling. Seven taxa were identified in pretreatment samples that were not found in posttreatment samples, and 3 taxa were identified in posttreatment samples that were not found in pretreatment samples.

Of special note is that copepods were not detected after the rotenone treatment but were detected in very high numbers prior to treatment (Appendix E1). This is consistent with findings elsewhere that copepod and cladoceran abundance can be temporarily but dramatically reduced following a rotenone treatment (Ling 2003; Finlayson et al. 2000; Chlupach 1977).

Primary food sources for juvenile coho salmon are dipterans (Nelson 1992) and cladocerans (Kyle 1990). These species remained present in Arc Lake in the summer of 2009 indicating forage was available should hatchery-reared coho salmon be restocked in 2009.

Table 5.–Invertebrates detected in Arc Lake before and after rotenone treatment, 2008–2009.

Phylum	Class	Order	Family	Before	After
Athropoda	Insecta	Coleoptera	Dysticidea (water beetles)	X	X
		Trichoptera (caddis flies)	Unknown	X	
		Diptera	Simulidae (black flies)	X	X
			Unknown	X	
			Tananidae (horse fly)	X	
			Chironomidae (midges)	X	X
			Ceratopogonidea (no-seeums)	X	
		Hemiptera	Corixidae (water boatmen)	X	X
			Gerridae (water striders)	X	X
			Acanthosomatidae (shield bugs)		X
		Odonata	Zygoptera (damselflies)	X	X
			Anispotera (dragonflies)	X	X
		Lepidoptera (moths)	Unknown		X
		Hymenoptera (wasp/ant)	Unknown	X	
	Branchiopoda	Cladocera (water fleas/daphnia)	Unknown	X	X
	Maxillopoda	Copepoda	Eucopepoda	X	
	Arachnida	Araneae (spiders)		X	X
		Acariformes (mites)			X
Annelida	Hirudinea			X	
Nematoda				X	

Note: Sampling was conducted June–September 2008 before rotenone treatment; after treatment, sampling was primarily conducted in June 2009. Sampling gear for both periods included light traps, kick nets, Wisconsin nets, and an Eckman bottom grab.

Fish

Seven minnow traps were fished for a combined total of 134.5 hours in Arc Lake on 18–19 June 2008 (Table 6), and no fish were caught. From 1 October through 2 October 2008, 24 variable-mesh gillnets were fished for a total of 692.3 hours of effort, and 21 northern pike were captured; no other fish species were caught (Table 7). Some of the northern pike were used as caged sentinel fish during the treatment, and the rest were donated to the local food bank.

Table 6.–Arc Lake pretreatment minnow trapping effort and catch, 18–19 June 2008.

Trap number	Date set	Time set	Date pulled	Time pulled	Fish catch	Hours fished
1	18 Jun 2008	13:25	19 Jun 2008	8:45	0	19.33
2	18 Jun 2008	13:32	19 Jun 2008	8:50	0	19.30
3	18 Jun 2008	13:38	19 Jun 2008	8:55	0	19.28
4	18 Jun 2008	13:42	19 Jun 2008	9:01	0	19.32
5	18 Jun 2008	13:48	19 Jun 2008	9:07	0	19.32
6	18 Jun 2008	14:14	19 Jun 2008	9:13	0	18.98
7	18 Jun 2008	14:19	19 Jun 2008	9:17	0	18.97
				Total	0	134.50

Table 7.–Arc Lake pretreatment gillnet effort and catch, 1–2 October 2008.

Net	Set date	Set time	Pull date	Pull time	NP catch[a]	Effort (h)
1	1 Oct 2008	10:00	2 Oct 2008	15:40	1	29.67
2	1 Oct 2008	10:05	2 Oct 2008	15:35	3	29.50
3	1 Oct 2008	10:10	2 Oct 2008	15:25		29.25
4	1 Oct 2008	10:15	2 Oct 2008	15:15	1	29.00
5	1 Oct 2008	10:20	2 Oct 2008	15:10	4	28.83
6	1 Oct 2008	10:25	2 Oct 2008	14:55		28.50
7	1 Oct 2008	10:30	2 Oct 2008	14:50	1	28.33
8	1 Oct 2008	10:35	2 Oct 2008	14:40		28.08
9	1 Oct 2008	10:40	2 Oct 2008	16:20		29.67
10	1 Oct 2008	10:45	2 Oct 2008	16:25	1	29.67
11	1 Oct 2008	10:50	2 Oct 2008	16:30	1	29.67
12	1 Oct 2008	10:55	2 Oct 2008	16:40		29.75
13	1 Oct 2008	11:05	2 Oct 2008	16:45	1	29.67
14	1 Oct 2008	11:10	2 Oct 2008	16:50	1	29.67
15	1 Oct 2008	11:15	2 Oct 2008	16:55	2	29.67
16	1 Oct 2008	11:20	2 Oct 2008	17:05	3	29.75
17	1 Oct 2008	11:25	2 Oct 2008	17:10	1	29.75
18	1 Oct 2008	11:30	2 Oct 2008	17:15		29.75
19	1 Oct 2008	11:40	2 Oct 2008	17:18		29.63
20	1 Oct 2008	11:42	2 Oct 2008	17:25		29.72
21	1 Oct 2008	11:48	2 Oct 2008	14:35		26.78
22	1 Oct 2008	12:00	2 Oct 2008	14:25		26.42
23	1 Oct 2008	12:05	2 Oct 2008	13:50		25.75
24	1 Oct 2008	12:10	2 Oct 2008	14:00	1	25.83
				Total	21	692.3

[a] NP = northern pike.

To evaluate the treatment's success, gillnets were fished in Arc Lake during 2 periods posttreatment. The first netting period occurred during 8 December through 12 December 2008 when 12 nets were fished. Of these nets, 5 became frozen into the lake after 2 days of fishing and could not be checked or removed until ice-out. Effort from the nets that froze into the lake was not used in the treatment success evaluation. However, no signs of fish were found in these nets upon their removal in the spring. No fish were caught from the 7 nets that could be checked during December.

Between 14 May and 22 May 2009, 24 gillnets were fished during daytime periods. A combined total of 1,323.2 hours of netting effort (1 net fished for 1 hour equals 1 hour of netting effort) was expended between the under-ice and open water posttreatment netting, and no fish were caught (Appendix F1).

Based on these results and the probability scenarios provided in Appendix B1, it is estimated there was less than an 8% probability that a small surviving northern pike population (4 catchable-sized fish) went undetected; therefore, we assumed that the rotenone treatment eradicated the northern pike population in Arc Lake.

RESTOCKING

Arc Lake was stocked with approximately 1,600 coho salmon fingerlings on 22 July 2009 and approximately 1,670 coho salmon fingerlings on 6 August 2009.

DISCUSSION

The Arc Lake restoration effort was ADF&G's first attempt to eradicate invasive northern pike anywhere in Alaska using rotenone. Useful information on rotenone concentration, persistence, and effects on invertebrates, as well as insight into the efficacy of the rotenone application equipment and personal protective equipment, was garnered by this project.

ROTENONE CONCENTRATION AND PERSISTENCE

Posttreatment water samples collected from Arc Lake and analyzed for rotenone concentration suggest that the target active ingredient (rotenone) concentration goal of 0.05 ppm was not attained. The highest concentration confirmed by lab analysis was 0.035 ppm (70% of our goal), detected 2.5 months after treatment. Possible reasons that the target concentration was not realized include the following:

1) errors occurred in estimating the amount of product needed or in estimating lake volume
2) product contained less active ingredient (rotenone) than stated by the manufacturer
3) errors occurred in water sampling or lab analysis
4) rotenone in the water samples degraded during shipping and handling

The amount of product needed was calculated from the product label (Appendix C1), and this calculation is an unlikely source for error. The first Arc Lake volume estimate was conducted by ADF&G in 1965 and the surveyors estimated lake volume at 137.4 acre-feet, surface acreage of 16 acres, and mean depth of 8.6 feet. The 2008 survey estimated lake volume at 144 acre-feet, surface acreage of 18 acres, and mean depth of 8.6 feet. The two lake-volume estimates are similar, but we opted to use the highest value (144 acre-feet) generated more recently in 2008. The 2008 estimate is believed most accurate because the survey coverage was more thorough than in 1965, when depth measurements were manually collected along north-to-south and east-to-west transects rather than a more complete coverage using GPS, depth finder, and GIS tools. Furthermore, the 2008 methods are the same ones that have been used by ADF&G to estimate volume in other area lakes. In 2013, ADF&G's efforts to create new volume estimates used different equipment and methods available through ciBioBase, a subscription-based lake mapping service provided by Contour Innovations. The 2013 method greatly increased the number of depth records collected compared to 2008 methods, which should increase the accuracy of volume estimates. We compared volume estimates for area lakes where both mapping methods were used and these showed little difference, suggesting our 2008 method was adequate to estimate volume. Finally, Stormy Lake in Nikiski was treated with rotenone in 2012, and its lake volume estimate was produced with the same methods and equipment used at Arc Lake in 2008. The Stormy Lake treatment attained a rotenone concentration very close to its target goal (Massengill *In prep*[4]), suggesting that the lake mapping methods used for Arc Lake in 2008 were sufficient. We believe any error in the 2008 Arc Lake volume estimate would not account for the 30% difference from our target concentration.

We did not confirm that the rotenone product (CFT Legumine) actually contained 5% rotenone as stated on the label; however, it was potent enough to kill fish quickly in all our bioassay tests. Product from the same manufacturer and shipment was used to treat another lake in Anchorage (Cheney Lake) the week following the Arc Lake treatment, and the peak product concentration detected (0.03 ppm) was similarly below the anticipated target goal of 0.05 ppm, raising concern that the product's rotenone concentration may have been lower than advertised.

Following the rotenone treatment, water samples were typically collected by a single midwater column "grab" from the same lake location and depth (approximately 6 feet below the lake surface near the deepest section of the lake). This sampling protocol may not have produced a representative water sample for the entire lake. All sentinel fish placed in different locations and depths in the lake quickly died following the treatment, including those in the deepest part of the lake, indicating mixing had readily occurred to a lethal degree. Whether incomplete mixing resulted in lower-than-expected rotenone values in our water samples is unknown. In the future, a composite water sample collected from various locations and throughout the water column may provide a more representative rotenone concentration.

We were unable to verify whether the lab results for rotenone concentration were inaccurate. In the future, it may be wise to submit a "reference" water sample containing a known rotenone concentration to verify lab accuracy.

One possible explanation for not attaining our target rotenone concentration is that the rotenone in the water samples might have degraded significantly during shipping prior to analysis. Rotenone is susceptible to natural detoxification through a variety of mechanisms such as water chemistry, water temperature, organic load, and exposure to oxygen and sunlight (Ware 2002; ODFW 2008; Loeb and Engstrom-Heg 1970; Engstrom-Heg 1972). The degradation rate of rotenone, which influences its effectiveness, is affected primarily by temperature and sunlight (Gilderhus et al. 1986). Care was taken to keep all samples refrigerated after collection, and samples were contained in amber colored glass containers to prevent photolysis. Shipment of the

[4] Massengill, R. L. *In prep*. Control efforts for invasive northern pike on the Kenai Peninsula, 2012. Alaska Department of Fish and Game, Anchorage.

samples to the lab typically took 2 days. Therefore, significant degradation during shipping appears to be an unlikely explanation for the observed low rotenone concentrations.

The discrepancy between the target rotenone concentration for Arc Lake (0.05 ppm) and that detected by lab analysis (0.035 ppm) underscores the importance of conducting bioassays prior to treatment to ascertain the product’s efficacy and the minimum product concentration needed to achieve desired results for the actual treatment. It also would have been appropriate to analyze samples of water from each bioassay test to confirm rotenone concentrations.

The peak rotenone concentration in Arc Lake water was detected 2.5 months posttreatment and not immediately after application. This suggests that rotenone took a long time to distribute throughout the water column, despite attempts at mixing the rotenone using propeller wash and boat wakes during the treatment. Liquid rotenone products are slightly heavier than water and sink in the water column over time (Finlayson et al. 2000). Arc Lake sediment analysis indicated the rotenone concentration rose until March 2009 (Figure 11), suggesting that rotenone slowly accumulated in the lake sediment. Rotenone adsorption to sediment organics is a potential mechanism that could have caused a lower-than-expected rotenone concentration in the lake.

The duration of Arc Lake toxicity (about 8 months) exceeded our expectations. Typical cold winter temperatures coupled with ice, snow cover, and reduced day length during the winter of 2008–2009 undoubtedly aided in the persistence of rotenone in Arc Lake. Studies of rotenone persistence in small ponds show that rotenone degrades 10 times faster at 21ºC than at 1ºC (Gilderhus et al. 1986, 1988). In one Minnesota study, rotenone from under-ice applications remained stable for several weeks when snow cover was present, only to quickly degrade after warm weather removed the snow cover (Bandow 1989). Rotenone persistence has exceeded 150 days in some Montana lakes (Grant Grisak; fisheries biologist; Montana Fish, Wildlife and Parks; personal communication, 2008).

Arc Lake has very low alkalinity (< 2.0 mg/l $CaCO_3$) and is acidic (pH ~6.5), which are conditions that promote the conversion of rotenone to rotenolone, a more durable metabolite of rotenone that is only about one-tenth as toxic (Brian Finlayson, retired California Department of Fish and Game, personal communication, 2008). Rotenolone may have been present in Arc Lake in spring 2009, contributing to the lengthy toxicity of the lake water; however, we were unable to locate a laboratory capable of testing for rotenolone to confirm this possibility.

A literature search for other rotenone lake treatments in Southcentral Alaska revealed that similar rotenone persistence was experienced following fall rotenone applications (Chlupach 1977, 1978; McHenry 1978). It seems likely that future closed-lake rotenone treatments applied near freeze-up will experience prolonged rotenone persistence, and detoxification should not be expected until ice-out or later.

INVERTEBRATE SAMPLING

Pretreatment and posttreatment invertebrate sampling were primarily intended to assess whether posttreatment food resources were adequate for restocking Arc Lake with fish and to help detect drastic posttreatment changes in invertebrate abundance and diversity. It appears some invertebrates in Arc Lake may have suffered severe reductions in abundance from the treatment, particularly zooplankton. Some invertebrate species were detected only before treatment, but this does not necessarily indicate that they were eradicated; in most cases, invertebrate species do not permanently disappear following a rotenone treatment (Bradbury 1986).

In Southcentral Alaska, the effect of rotenone on zooplankton abundance is typically temporary and requires 1–3 years for posttreatment levels of zooplankton to be restored to pretreatment levels (Chlupach 1977). This is longer than reported in many other areas of North America, where invertebrate recovery often takes a year or less (Kiser et al. 1963; Hamilton et al. 2009). Other studies show that zooplankton such as cladocerans and copepods have rotenone-resistant eggs capable of reseeding a lake after a rotenone treatment (Bradbury 1986; Melaas et al. 2001). Fall applications may help zooplankton communities recover because many species are in rotenone-resistant life stages, and there is time for population recovery before spring (Melaas et al. 2001).

In light of the relatively low long-term effect of rotenone on invertebrate populations, it may be reasonable to reduce or eliminate invertebrate sampling for future rotenone projects because it may be assumed that invertebrates will recover within several years.

APPLICATION AND SAFETY OBSERVATIONS

More than 6 hours were required to complete the rotenone treatment at Arc Lake, and this length of time was primarily controlled by the pesticide siphoning rate of the pumping system. Testing of the pumping system beforehand revealed the maximum pumping rate was approximately 30 gallons of pesticide per hour (when using water as a surrogate for a liquid pesticide). At that rate, the entire application could have been completed in 3 hours, including stops for refueling and opening and rinsing rotenone containers. The application took longer than this because the pesticide is more viscous than water and siphoned at a slower rate than expected, even clotting the siphon intake at times. Due to the viscosity of the pesticide and resultant slow siphoning, the pesticide premixture probably consisted of a higher water ratio than planned. Ad hoc boat-speed adjustments were made to disperse the pesticide evenly given that the pesticide pump rate was slower than expected. To speed up the application time in future treatments, a larger pumping system would be desired that could siphon liquid pesticide at a rate approaching 100 gallons per hour.

Fogging was a problem with the safety goggles used by the applicators. Cool air temperatures during the application coupled with the high activity levels of the applicators intensified the fogging problem and caused safety concerns. The author suggests that for future treatments, anti-fogging agents for safety eyewear, or full-face respirators, which have better ventilation, be used.

SUMMARY

This project did succeed in its primary goal of removing the invasive northern pike population and restoring the recreational fishery in Arc Lake. ADF&G gained much technical and practical rotenone application experience through this project, including experience with the permitting and public scoping processes required for rotenone treatments. The information and experiences that ADF&G acquired have directly benefited similar northern pike eradication projects in Southcentral Alaska during 2008–2012 (Scout Lake, Cheney Lake, Sand Lake, and Stormy Lake), which were all larger and more complex in scale. This project also brought much-needed awareness to the community about invasive northern pike issues and ADF&G's responsibility for addressing the problem. ADF&G demonstrated that rotenone can be used as a northern pike eradication tool with strong overall community support.

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Sincere gratitude is extended to the following people for their unselfish donation of time to help address technical concerns on this project: Grant Grisak (Montana Fish, Wildlife and Parks), Brian Finlayson (California Department of Fish and Game), John Hedges and Marcus Mueller (Kenai Peninsula Borough), Deric Marcorelle (DEC), Rick Woods (Soldotna Wastewater Treatment Facility) and Robert Ruffner (Kenai Watershed Forum).

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APPENDIX A: DOCUMENTS FOR TREATMENT CLEARANCE

Appendix A1.–*Finding of No Significant Impact* (FONSI) issued by the United States Fish and Wildlife Service for the Arc Lake restoration project environmental assessment.

U.S. Department of the Interior
Fish and Wildlife Service
Region 7, Alaska

FINDING OF NO SIGNIFICANT IMPACT

Proposed Removal of Invasive Northern Pike *Esox lucius* from Arc Lake
Arc Lake, Soldotna, Alaska

The Alaska Department of Fish and Game (ADF&G), Sport Fish Division, proposes the removal of an illegally introduced northern pike population using the piscicide rotenone in Arc Lake, Soldotna, Alaska. Planned activities include the complete eradication of northern pike from the lake and subsequent restocking with silver salmon or rainbow trout. It is anticipated the removal of northern pike from Arc Lake will lessen the risk that the population will expand through illegal introduction into nearby critically important systems like the Kenai River. The proposed actions will also restore a quality angling opportunity for the public in the area. The proposed project will be funded primarily by the U.S. Fish and Wildlife Service under the Aquatic Nuisance Species Program.

Alternatives Considered

Three alternatives were evaluated, including the use of gill nets and/or trap nets to selectively remove northern pike. However, the mechanical removal alternative was dismissed from further consideration as Arc Lake exceeds the surface area criteria necessary for success and due to the potential for exposing bald eagles, migratory birds, and aquatic mammals to the risk of net entanglement in the water. The "no action" alternative was also rejected since there would be continued risk that northern pike could be transported from Arc Lake to nearby wild fisheries.

Public Review

Three local ADF&G advisory committees on the Kenai Peninsula and other known stakeholders were notified in April 2008. A public meeting was held in Soldotna in April 2008. Presentations were given to the Soldotna City Council in July 2008 and to the Kenai Peninsula Borough Assembly in August 2008. Also in July, ADF&G issued a press release announcing 30 day public comment periods for 1) the Environmental Assessment prepared by ADF&G and 2) a proposed Alaska Department of Environmental Conservation (ADEC) Pesticide Use Permit for this project.

Public notices for the Arc Lake pesticide use permit application were printed in the Peninsula Clarion newspaper on two consecutive dates in July 2008 as part of the ADEC permitting process. A synopsis of the proposed project was also distributed to residents within ¼ mile of Arc Lake during early August 2008. The Environmental Assessment was posted on the ADF&G internet site and copies were mailed to individuals upon request.

-continued-

Issues raised by citizens included concern related to restocking of Arc Lake, since reports exist that the lake had high fecal coliform bacteria, a comment that this plan is an over-reaction since the lake is landlocked and poses little risk to other fisheries, and a comment that pike are a self-sustaining fishery that do not require restocking. The Kenai Peninsula Borough, Land Management Division, wrote a letter supporting this project. The Alaska Board of Fisheries also supported the use of rotenone to eradicate non-indigenous northern pike in Arc Lake. The ADF&G addressed each of these comments in the Environmental Assessment.

Conclusions

Study of the ecologic and socio-economic effects of the proposal has shown them not to represent a negative impact on the quality of the human environment. Further, no wetlands or other sensitive habitat will be affected by the work as proposed. Accordingly, I find that all reasonable alternatives were considered in the evaluation of this project. I also find that this project complies with the meaning of Executive Order 11990 and 11988. Therefore, based on a review and evaluation of the enclosed, environmental assessment, I have determined the proposed removal of invasive northern pike as described in the project entitled, "Arc Lake Restoration Project" is not a major federal action which would significantly affect the quality of the human environment within the meaning of Section 102 (2) (c) of the National Environmental Policy Act of 1969.

The environmental assessment, prepared by the Alaska Department of Fish and Game has been adopted by the U.S. Fish and Wildlife Service according to rules contained in 40 CFR 1506.3. Accordingly, preparation of an environmental impact statement on the proposed action is not required.

Thomas O. Melius
Thomas O. Melius
Regional Director

Oct. 1, 2008
Date

Appendix A2.–Synopsis of the Arc Lake restoration project.

Synopsis of Arc lake project proposal.

Arc Lake Restoration Project Synopsis

Alaska Department of Fish and Game

Sport Fish Division

Soldotna, Alaska

Contact: Robert Begich– Area Management Biologist (Sport Fish)

Ph (907) 262-9368

Northern pike *Esox lucius* do not naturally occur in Southcentral Alaska. Populations of invasive northern pike on the Kenai Peninsula resulted from illegal introductions in the Soldotna Creek drainage during the 1970's, and they have since spread to other Kenai Peninsula waters. Although native to much of Alaska, northern pike can severely alter aquatic ecosystems and fish assemblages that evolved in their absence. Currently, sixteen Kenai Peninsula lakes have been confirmed with northern pike and three of those lakes were formerly stocked by the Alaska Department of Fish and Game (ADF&G).

Typically, invasive northern pike in Southcentral Alaska dominate the fish community within a lake and reduce or eliminate the native fish species, particularly in shallow lakes where prey have difficulty avoiding predation. Of particular local concern are the vulnerable salmon and trout-rich Kenai and Swanson River drainages. Northern pike could establish reproducing populations in key fish rearing areas and impact these fisheries beyond the damage that has already occurred in the Soldotna Creek drainage. Expansion of invasive northern pike into new areas of the Kenai and Swanson River drainages, or other waters, would negatively impact valuable fisheries.

Netting and control barriers have been used by ADF&G to reduce pike populations on some Kenai Peninsula waters but these methods will not eliminate them. ADF&G is proposing to restore some lakes by eradicating northern pike. The preferred strategy is to treat the lake with a pisicide (rotenone), a naturally occurring plant derivative of the bean family that prevents a fish from using oxygen absorbed in the blood. Rotenone naturally degrades with light and temperature and does not enter the groundwater. No public health effects from rotenone uses as a piscicide have been reported.

Arc Lake is located two miles south of the Soldotna Bridge along the Sterling Highway. Northern pike were discovered there in 2000 by ADF&G stocked lakes personnel and stocking was discontinued. Because Arc Lake is relatively small in size (sixteen surface acres) and the surrounding lands are public (City of Soldotna, Kenai Peninsula Borough, State of Alaska), it lends itself as a strong candidate for an initial restoration effort. A successful restoration effort at Arc Lake will serve as a positive transition to the long-term goal of eradicating northern pike and restoring other Kenai Peninsula waters. Removing invasive pike from Arc Lake will restore a stocked lake fishing opportunity. Even more important, the removal of this species will lessen the possibility that the population expands through illegal introduction into nearby critically important systems like the Kenai River.

Appendix A3.–ADF&G news release for Arc Lake and Cheney Lake northern pike eradication projects.

ALASKA DEPARTMENT OF FISH AND GAME
Denby S. Lloyd, Commissioner

DIVISION OF SPORT FISH
Charles O. Swanton, Director

Contact:
Kristine Dunker
Fisheries Biologist
Phone: (907) 267-2889

July 30, 2008

RESTORATION OF TWO ANCHORAGE AND KENAI AREA LAKES

ADF&G Plans to Eradicate Invasive Northern Pike Populations

ADF&G is planning to use a naturally occurring pesticide to eradicate northern pike in two Southcentral lakes and is seeking public comment. ADF&G has prepared environmental assessment documents and applied for pesticide application permits through the Alaska Department of Environmental Conservation for both lakes. The public participation processes for these projects are now beginning. The environmental assessments can be viewed online at:

http://www.sf.adfg.state.ak.us/Statewide/InvasiveSpecies/PDFs/CheneyLakeEA.pdf

http://www.sf.adfg.state.ak.us/Statewide/InvasiveSpecies/PDFs/ArcLakeEA.pdf

Written public comments on these projects will be accepted through August 23, 2008.

Northern pike are native in most of Alaska, but were illegally stocked in Southcentral. Where northern pike are native, they are a valuable sport and subsistence fish. Outside of their native range, northern pike can cause tremendous ecological and economic damage. Pike deplete populations of salmon and trout in shallow, vegetated water bodies, and have severely affected local fisheries.

Cheney Lake in Anchorage and Arc Lake south of Soldotna are both small lakes that were once popular, accessible recreational fisheries. Northern pike introduced into these lakes have destroyed these popular fisheries. Currently, ADF&G cannot justify stocking these lakes with trout or salmon because the pike eat nearly all of them. More importantly, as long as invasive northern pike are in these lakes, there is increased potential for them to be introduced to nearby waters. Cheney Lake is located close to Chester Creek which supports wild salmon runs, rainbow trout, and Dolly Varden. Arc Lake is about two miles from the Kenai River which supports world renown salmon and trout fisheries.

During the last few years, ADF&G has addressed the pike issue by liberalizing bag limits for pike and setting gill nets to reduce pike populations in several Southcentral lakes. These efforts have not removed a significant number of pike. ADF&G is currently proposing to re-establish the fisheries in Cheney and Arc Lakes by eradicating all of the pike in those lakes. The most practical method to accomplish this involves using an organic chemical called rotenone. Rotenone is a naturally-occurring substance derived from the roots of tropical plants. Historically, it has been used by indigenous peoples in the tropics to catch fish for food and by fish managers in the U.S. to remove unwanted fish. Rotenone is also a common ingredient in agricultural and garden insecticides. Rotenone interrupts a biochemical process that allows fish to use oxygen in their blood, resulting in fish mortality. In the concentrations necessary to kill fish, rotenone is not dangerous for birds or mammals. No public health effects from the use of rotenone in fish management have been reported, although consuming fish following treatment is not recommended.

Cheney and Arc Lakes, because of their small size, lost recreational opportunities, and because of their close proximity to wild salmon and trout systems are strong candidates for initial lake restoration efforts. Successful restoration of these lakes will serve as a step toward restoring other Southcentral lakes where invasive northern pike threaten wild fish stocks or have damaged existing fisheries. The rotenone treatments are being planned for the fall of 2008. If the lakes are treated according to these plans, the lakes will be monitored throughout winter and spring to assure that pike have been eradicated. If all pike have been successfully removed, rainbow trout or land-locked coho salmon can be re-stocked in these lakes during the spring of 2009.

For more information on these projects, please contact ADF&G biologists Kristine Dunker (Anchorage) at 267-2889 or Robert Begich (Soldotna) at 262-9368 or see http://www.sf.adfg.state.ak.us/statewide/invasivespecies/index.cfm/FA/rotenone.home

Appendix A4.–The Alaska Department of Environmental Conservation pesticide use permit for Arc Lake.

STATE OF ALASKA
DEPARTMENT OF ENVIRONMENTAL CONSERVATION 555
CORDOVA STREET
ANCHORAGE, ALASKA 99501

PERMIT TO APPLY PESTICIDES

Permit No.: 08-0828-09-AQU-02
Date Issued: August 28, 2008
Date Effective: October 7, 2008 Date
Expires: December 31, 2009

The Alaska Department of Environmental Conservation (ADEC) , under authority of Alaska Statute 46.03.330 and Title 18, Chapter 90.525 of the Alaska Administrative Code (18 AAC 90.525), hereby grants a Permit to Apply Pesticides to:

Robert Massengill
Alaska Department of Fish and Game 43961
Kalifornsky Beach Road, Suite B Soldotna,
Alaska 99669

For the purpose of applying the pesticide **CFT Legumine Fish Toxicant,** EP A Registration Number **75338-2** to waters of the state to eradicate invasive Northern Pike in Arc Lake, near Soldotna, Alaska.

The permit holder shall manage and apply the pesticide in accordance with 18 AAC 90 and the permit application materials submitted July 16, 2008. In addition, the following permit conditions and stipulations are required:

1. Use pesticides only in the manner specified by the label instructions. Adhere to all the requirements specified by the pesticide product label.

2. Ensure that pesticides are applied only by a person properly certified by DEC to apply such pesticides, or a person under the direct supervision of a person so certified.

3. Apply pesticides using properly calibrated equipment, and in strict compliance with safety precautions.

4. Public notification signs must be posted prior to pesticide application at each point of access to the lake, as specified in 18 AAC 90.630(a). Signs shall remain posted at the treatment site until application is complete.

5. Maintain the following records for each pesticide used. Records must be available to DEC upon request:
    - Product name
    - EP A registration number
    - Target pest
    - Date and time of application
    - Method of application
    - Weather conditions during application

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- Amount of pesticide used
- Location and size of treatment area
- Names of applicators
- Purchase, storage, and disposal information

6. Dispose of empty pesticide containers in accordance with label directions and 18 AAC 90.615(a). Any burning of pesticide containers must be done in compliance with 18 AAC 50.

7. Immediately report any spill or accident, alleged accident, or complaint to the DEC Pesticide Program at 1-800-478-2577.

8. Ensure that decontamination, safety, and spill clean up supplies are available at the treatment site at all times during application.

9. Store all pesticide containers securely, as required by 18 AAC 90.615(d). Post a warning notice on the outside of each storage area in compliance with 18 AAC 90.615(e)-(h).

10. No later than **March 31, 2010,** submit a written Summary of Treatment Results in accordance with 18 AAC 90.535. This summary must include the following information for **each** pesticide used:
    - Product name
    - EP A registration number
    - Target pest
    - Dates and times of application
    - Method of application
    - Weather conditions during applications
    - Total amount of pesticide used
    - Location and size of treatment area
    - Names of applicators
    - Purchase, storage, and disposal information
    - Assessment of success or failure of the treatments
    - Any observed effect on human health, safety or welfare, animals, or the environment

In addition to the above stipulations, the ADEC Pesticide Program may monitor treatments to ensure compliance with 18 AAC 90 and the Permit Conditions and Stipulations.

This permit expires on **December 31, 2009,** or upon completion of the above described project, whichever comes first, and may be revoked in accordance with 18 AAC 90.540.

Kristin J. Ryan
Environmental Health Director

Appendix A5.–Alaska Coastal Management Program consistency review determination for the Arc Lake project.

STATE OF ALASKA / *SARAH PALIN, GOVERNOR*

DEPT. OF ENVIRONMENTAL CONSERVATION
DIVISION OF ENVIRONMENTAL HEALTH
PESTICIDES PROGRAM

1700 E. Bogard Rd. Bldg B. Ste 103
Wasilla, Alaska 99654
PHONE: (907) 376-1856
FAX: (907) 376-2382
htto://www.dec.state.ak.us/

July 23, 2008

Mr. Robert Massengill
Alaska Department of Fish and Game
43961 Kalifomsky Beach Road, Suite B
Soldotna, AK 99669

Dear Mr. Massengill

Subject: ARC LAKE PESTICIDE PERMIT

The Department of Environmental Conservation (DEC) has determined that an Alaska Coastal Management Program (ACMP) consistency review of your project is not required. This determination is based on the coastal district's response that this project does not include activities that are subject to a district enforceable policy.

The department will continue with review of your application for authorization under DEC authorities that are excluded from ACMP consistency review and determination.

If you have any questions about this review, please contact me at 907-376-1856 or e-mail Karin.Hendrickson@alaska.gov.

Sincerely,
Karin Hendrickson
Environmental Specialist

cc: Randy Bates, DNR, DC OM
Mr. Gary Williams, Kenai Peninsula Borough Coastal District Coordinator
Dan Easton, DEC, Deputy Commissioner

Appendix A6.–Alaska Board of Fisheries approval for the use of rotenone in Arc Lake.

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME
BOARD OF FISHERIES

SARAH PALIN, GOVERNOR

ADF&G
P.O . BOX 115526
JUNEAU, AK 998011-5526
PHONE: (907) 465-4110
FAX: (907) 465-6094

Charles Swanton
Director, Sport Fish Division
Alaska Department of Fish and Game
P.O. Box 115526
Juneau, AK 99811

August 20, 2008

Dear Mr. Swanton,

The Board of Fisheries received your August 12, 2008 letter asking for Board consent for the use rotenone to eradicate a non-indigenous Northern Pike populations from Cheney Lake in Anchorage and Arc Lake near Soldotna. The Board supports its use in this project. Board members were polled and there was no opposition.

Please contact Executive Director Jim Marcotté (465-6095) if you have any questions.

Regards,

Mel Morris
Chairman, Alaska Board of Fisheries

cc: Board of Fisheries members
Rob Bentz, ADF&G
Jim Hasbrouck, ADF&G
Robert Massengill, ADF&G

APPENDIX B: CALCULATING THE PROBABILITY OF DETECTING NORTHERN PIKE WITH POSTTREATMENT GILLNETTING EFFORTS

Appendix B1.–Calculations to determine the probability of detecting northern pike with posttreatment gillnetting efforts.

Estimates of northern pike catchability in Sevena Lake during 2005 and 2006 provide a basis for assessing the potential success for detecting northern pike in a lake using gillnets. Assuming that the capture or detection of northern pike can be modeled as a binomial random variable and that the product of catchability and fishing effort equate to the probability of capture, we have the following derivation:

$$q = \frac{C}{f\hat{N}} \Rightarrow qf = \frac{C}{\hat{N}} = \hat{p} \qquad \text{(B1)}$$

where

q	=	minimum catchability of northern pike in Sevena Lake during 2005 and 2006,
$\hat{N}$	=	the removal estimate of northern pike abundance in Sevena Lake (Massengill 2011),
C	=	the total catch of northern pike associated with the removal estimate,
f	=	the total fishing effort by number of gillnets associated with the removal estimate (a single unit of effort consists of fishing a 120 ft variable mesh gillnet for 24 hours), and
$\hat{p}$	=	the estimated probability of capturing or detecting a northern pike.

The catchability estimated for Sevena Lake northern pike was calculated using data from 4 unique netting efforts (and associated removal estimates) conducted during 2005 and 2006. The minimum catchability was estimated at 0.005 as depicted in the examples below:

Example: Sevena Lake spring 2005	**Example: Sevena Lake spring 2006**
Effort (f) = 192 Abundance estimate ($\hat{N}$) = 653 Total catch (C) = 643 so from equation B1, q = (653)/(192)(653) = 0.00521	Effort (f) = 144 Abundance estimate ($\hat{N}$) = 352 Total catch (C) = 344 so from equation B1, q = (344)/(144)(352) = 0.00679
Example: Sevena Lake fall 2005	**Example: Sevena Lake fall 2006**
Effort (f) = 168 Abundance estimate ($\hat{N}$) = 1,425 Total catch (C) = 1,403 so from equation B1, q = (1,403)/(168)(1,425) = 0.00586	Effort (f) = 48 Abundance estimate ($\hat{N}$) = 44 Total catch (C) = 38 so from equation B1, q = (38)/(48)(44) = 0.018

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The estimated probability of capturing or detecting a northern pike $\hat{p}$ given gillnetting effort f can be calculated from $q \times f$ (Equation B1). Values of $q \times f$ where minimum catchability of northern pike q = 0.005 for 4 different effort scenarios are as follows:

Amount of effort	$q \times f$
24 gillnets in one 24-hour period	0.12
12 gillnets in one 24-hour period	0.060
24 gillnets in one 96-hour period	0.49
12 gillnets in one 96-hour period	0.24

p^* is the estimated probability of not catching or failing to detect any northern pike in a particular lake given a population abundance N, an estimated probability of catching a fish p, and netting effort f:

$$p^* \approx (1 - \hat{p} \cdot f)^N \quad \text{(B2)}$$

p^* values for various population and gillnet effort scenarios in Sevena and Arc Lakes are provided in the following table. Arc Lake q^* values were calculated from Sevena Lake values and adjusted to account for differences in lake volume: the Sevena Lake value was multiplied by the ratio of Arc Lake volume to Sevena Lake volume (144 acre-feet/595 acre-feet = 0.242).

Nets per day	Number of individuals in lake	p^*equation	Probability of not detecting northern pike	
			Sevena Lake	Arc Lake
24 nets for 1 day	50	$p^* = (1-0.12)^{50}$	0.0017	0.00041
	20	$p^* = (1-0.12)^{20}$	0.078	0.019
	4	$p^* = (1-0.12)^{4}$	0.60	0.15
24 nets for 4 days	50	$p^* = (1-0.49)^{50}$	2.4E-15	5.8E-16
	20	$p^* = (1-0.49)^{20}$	1.4-06	3.4E-07
	4	$p^* = (1-0.49)^{4}$	0.068	0.016
12 nets for 1 day	50	$p^* = (1-0.060)^{50}$	0.045	0.011
	20	$p^* \ (1-0.060)^{20}$	0.15	0.037
	4	$p^* = (1-0.060)^{4}$	0.78	0.19
12 nets for 4 days	50	$p^* = (1-0.24)^{50}$	1.1E-06	2.7E-07
	20	$p^* = (1-0.24)^{20}$	0.0041	0.0010
	4	$p^* = (1-0.24)^{4}$	0.33	0.081

APPENDIX C: PRODUCT SPECIMEN LABEL

Appendix C1.–CFT Legumine specimen label.

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

CFT Legumine™

Fish Toxicant

For Control of Fish in Lakes, Ponds, Reservoirs, and Streams

ACTIVE INGREDIENTS:

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

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

KEEP OUT OF REACH OF CHILDREN
WARNING

FIRST AID	
Have product container or label with you when obtaining treatment advice.	
If swallowed	• Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice. • Do not give any liquid to the person. · Do not anything to an unconscious person • Do not induce vomiting unless told to do so by the poison control center or doctor.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.
If inhaled	• Move person to fresh air. • If person is not breathing, call an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. • Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.
Note to Physician: Contains Petroleum Distillates. Vomiting may cause aspiration pneumonia. For information on this pesticide product (including health concerns, medical emergencies, or pesticide incidents), call the National Pesticide Information Center at 1-800-858-7378.	

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

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PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS
WARNING

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

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

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

ENVIRONMENTAL HAZARDS

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

CHEMICAL AND PHYSICAL HAZARDS

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

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

STORAGE AND DISPOSAL

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

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

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

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

DIRECTIONS FOR USE

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

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

GENERAL INFORMATION

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

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Since such factors as pH, temperature, depth and turbidity will change effectiveness, use this product only at locations, rates, and times authorized and approved by appropriate State and Federal Fish and Wildlife Agencies. Rates must be within the range specified on the label.
Properly dispose of unused product. Do not use dead fish for food or feed.
Do not use water treated with rotenone to irrigate crops or release within ½ mile upstream of a potable water or irrigation water intake in a standing body of water such as a lake, pond or reservoir.
Re-entry Statement: Do not allow swimming in rotenone-treated water until the application has been completed and all pesticide has been thoroughly mixed into the water according to labeling instructions.

FOR USE IN PONDS, LAKES, AND RESERVOIRS

The actual application rates and concentrations of rotenone needed to control fish will vary widely, depending on the type of use (e.g., selective treatment, normal pond use, etc.) and the factors listed above. The table below is a general guide for the proper rates and concentrations.
This product disperses readily in water both laterally and vertically, and will penetrate below the thermocline in thermally stratified bodies of water.
Computation of Acre-Feet: An acre-foot is a unit of volume of a body of water having the area of one acre and the depth of one foot. To determine acre-feet in a given body of water, make a series of transects across the body of water taking depths with a measured pole or weighted line. Add the soundings and divide by the number made to determine the average depth. Multiply this average depth by the total surface area in order to determine the acre-feet to be treated. If number of surface acres is unknown, contact your local Soil Conservation Service, which can determine this from aerial photographs.
Amount of CFT Legumine Needed for Specific Uses: To determine the approximate number of gallons needed, find your "Type of Use" in the first column of the table below and then divide the corresponding numbers in the fourth column, "Number of Acre-Feet Covered by One Gallon" into the number of acre-feet in your body of water.

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

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

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

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

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

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

USE IN STREAMS IMMEDIATELY ABOVE LAKES, PONDS, AND RESERVOIRS

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

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

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

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

1. Concentration of Active Rotenone

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

2. Computation of Flow Rate for Stream

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

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

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

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3. Calculation of Application Rate

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

The application rate for the stream is calculated as follows:

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

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

4. Exposure Time

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

5. Amount of Product

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

$$A = R_s \times H$$

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

FOR USE IN STREAMS AND RIVERS

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

CFT LEGUMINE STREAM AND RIVER USE MONOGRAPH

USE IN STREAMS AND RIVERS

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

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

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

Application Rates and Concentration of Rotenone

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

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

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

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

Application of Undiluted Material

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

Calculation of Application Rate:

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

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

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

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

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

Application of Diluted Material

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

$$R = H \times 1.25$$

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

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

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

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

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

Detoxification

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

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

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

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

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

WARRANTY STATEMENT

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

APPENDIX D: ARC LAKE CONTAMINANTS AND FECAL COLIFORM TESTING

Appendix D1.–Arc Lake contaminants testing results, 2002–2009.

WATER QUALITY DATA - CENTRAL PENINSULA LANDFILL
for Arc Lake
Inorganics Chemical Contaminants Testing

PARAMETER	Water Quality Standard	7/16/02	7/14/03	7/14/04	7/26/05	7/26/06	7/18/07	7/30/08	7/23/09
Key Indicator Parameters									
Alkalinity - mg/L	-	4	6	10	<5	<5	1	<1	<4
Calcium - mg/L	-	<1.0	<1.0	<1.0	<1.0	0.7 J	0.9 J	0.7 J	0.7 J
Chemical Oxygen Demand - mg/L	-	17	5	8	11.0	9	9	8	11
Chloride - mg/L	-	2.6	9.6	11	15	19	18	17	17
Conductivity, lab - µmhos/cm	-	9	40	41	54	75	72	67	67
Conductivity, field - µmhos/cm	-	20	40	33	62	90	71	67	58
Iron - mg/L	-	0.04	0.08	-	0.05	0.01 J	0.04	0.06	0.06
Magnesium - mg/L	-	<1.0	<1.0	<1.0	<1.0	0.4 J	0.2 J	0.4 J	0.3 J
Manganese - mg/L	-	<0.01	0.01	-	0.01	0.03	0.03	0.03	0.03
Nitrate - mg/L	10	<0.05	<0.05	<0.05	<0.05	0.01 J	<0.05	<0.05	0.01 J
pH - standard units	-	6.93	6.10	5.85	6.08	6.90	5.7	5.5	5.7
Sodium - mg/L	-	1	6	6.2	8	11	12	9	11
Sulfate - mg/L	-	3	3.2	3.0	2.1	1.0	1.0	1	1
Phosphorus - mg/L	-	<0.01	0.01	<0.01	0.01	0.01	0.008 J	0.008 J	0.01
Total Suspended Solids - mg/L	-	<5	24	<5	9	2 J	<5	7	2 J
Total Metals									
Antimony - mg/L	0.006	<0.01	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic - mg/L	0.01	<0.01	0.01	-	<0.005	<0.005	<0.005	<0.005	<0.005
Barium - mg/L	2	<0.01	<0.01	-	<0.01	0.004 J	0.009 J	0.008 J	0.007 J
Beryllium - mg/L	0.004	<0.005	<0.004	-	<0.005	<0.005	<0.001	<0.001	<0.001
Cadmium - mg/L	0.005	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - mg/L	0.1	<0.01	<0.01	-	0.010	<0.01	<0.01	<0.01	<0.01
Cobalt - mg/L	0.04	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - mg/L	1.3	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Lead - mg/L	0.015	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel - mg/L	0.1	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - mg/L	0.05	<0.01	<0.01	-	<0.005	<0.005	<0.005	<0.005	<0.005
Silver - mg/L	0.1	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium - mg/L	0.002	<0.01	<0.002	-	<0.005	<0.005	<0.002	<0.002	<0.002
Vanadium - mg/L	0.26	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc - mg/L	5	<0.01	<0.01	-	<0.01	<0.01	0.002 J	0.002 J	0.003 J

µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
<0.05 = Below Detection Limit of 0.05 mg/L
J = Analyte was detected, but at a concentration less than the laboratory's reporting limit
- = Not Applicable
Shaded values exceed Water Quality Standard

CPL Arc Lake Inorganics

-continued-

WATER QUALITY DATA - CENTRAL PENINSULA LANDFILL
for Arc Lake
Volatile Organic Compounds Testing

PARAMETER	Water Quality Standard	7/16/02	7/14/03	7/14/04	7/26/05	7/26/06	7/18/07	7/30/08	7/23/09
1,1,1 Trichloroethane	200	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2 Trichloroethane	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	4.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1 Dichloroethane	7,300	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1 Dichloroethylene	7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloropropene	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2 Dichlorobenzene	600	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2 Dichloroethane	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2 Dichloropropane	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2,3-Trichloropropane	0.12	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2,4-Trimethylbenzene	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromo-3-Chloropropane	0.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	0.05	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,4 Dichlorobenzene	75	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2-Hexanone	-	<20	<20	<20	<20	<20	<20	<20	<20
Acetone	-	<20	<20	<20	<20	<20	<20	<20	<20
Acrylonitrile	-	<20	<20	<20	<20	<20	<20	<20	<20
Benzene	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromochloromethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromoform	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromomethane	48	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Disulfide	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbontetrachloride	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorobenzene	680	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
cis-1, 3-Dichloropropene	10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
cis-1,2-Dichloroethene	70	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochloromethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromomethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dichlorodifluoromethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	700	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Iodomethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methyl Ethyl Ketone	-	<20	<20	<20	<20	<20	<20	<20	<20
Methyl Isobutyl Ketone	-	<20	<20	<20	<20	<20	<20	<20	<20
Methylene Chloride	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	100	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	1,000	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,3-Dichloropropene	10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,2-Dichloroethene	100	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,4-Dichloro-2-Butene	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorfluoromethane	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Acetate	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Xylenes, total	10,000	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations in micrograms per liter (μg/L)

\- = Not Applicable

<1.0 = Below Detection Limit of 1.0 μg/L

J = Analyte was detected, but at a concentration less than the laboratory's reporting limit

CPL Arc Lake Organics

Appendix D2.–Fecal coliform analysis for Arc Lake, 1 October 2008.

FECAL COLIFORM ANALYSIS

DATE IN:	10/1/2004	DATE OUT:	10/2/2004
TIME:	See below	TIME:	9:15 AM
ANALYZER:	James Trissel	ANALYZER:	James Trissel
TEMP. IN	44.5	TEMP. OUT:	44.4
MF-C EXP. DATE:	6/25/2009	Lot# A8177	

Dish number	Sample location/RM	ml	Time sampled	Time in	Time out	Colony count	Actual colony count
1	Blank	100	9:15	1000	9:15	0	0/100mL
2	Arc 1	100	9:15	1000	9:15	3	3/100mL
3	Arc 2	100	9:15	1000	9:15	3	3/100mL
4	Arc 3	100	9:15	1000	9:15	0	0/100mL
5	Arc 4	100	9:15	1000	9:15	4	4/100mL
6	Blank	100	9:15	1000	9:15	0	0/100mL

APPENDIX E: ARC LAKE INVERTEBRATE SAMPLING SUMMARY

Appendix E1.–Arc Lake invertebrate sampling summary 2008–2009.

Treatment	Sampling event	Date	Invertebrate taxon[a]	Number of invertebrates caught by gear type: Ekman Bottom Grab[b]	Kick net (dip net)[c]	Light trap[d]	Wisconsin net[e]
Before rotenone	1	30 Jun 2008	Dysticidae (predacous diving beetle or whirligig)		1		
	1	30 Jun 2008	Diptera (unknown adult)		1		
	1	30 Jun 2008	Corixidae (water boatmen)		6		
	1	30 Jun 2008	Gerridae (water striders)		3		
	1	30 Jun 2008	Zygoptera (damselflies)		6		
	1	30 Jun 2008	Anispotera (dragonflies)		3		
	1	30 Jun 2008	Eucopepoda (copepods)		1		
	1	30 Jun 2008	Araneae (spiders)		2		
	1	30 Jun 2008	Hirudinea (leeches)		2		
	1	16 Jul 2008	Nematoda (worms)	1			
	1	16 Jul 2008	Chironomidae (midges)	1			
	1	16 Jul 2008	Cladocera (water fleas/daphnia)	3			1
	1	16 Jul 2008	Eucopepoda				3,700
	1	17 Jul 2008	Dysticidae (predacous diving beetle or whirligig)		11		
	1	17 Jul 2008	Corixidae (water boatmen)		10		
	1	17 Jul 2008	Gerridae (water striders)		31		
	1	17 Jul 2008	Zygoptera (damselflies)		6		
	1	17 Jul 2008	Cladocera (water fleas/daphnia)		1		
	1	17 Jul 2008	Eucopepoda (copepods)		4		
	1	17 Jul 2008	Araneae (spiders)		1		
	1	25 Jul 2008	Dysticidae (predacous diving beetle or whirligig)			4	
	1	25 Jul 2008	Corixidae (water boatmen)			27	
	1	25 Jul 2008	Gerridae (water striders)			1	
	1	25 Jul 2008	Zygoptera (damselflies)			1	
	1	25 Jul 2008	Eucopepoda (copepods)			12,000	

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Treatment	Sampling event	Date	Invertebrate taxon[a]	Number of invertebrates caught by gear type: Ekman Bottom Grab[b]	Kick net (dip net)[c]	Light trap[d]	Wisconsin net[e]
Before rotenone	2	19 Aug 2008	Nematoda (worms)	1			
	2	19 Aug 2008	Simulidae (black flies)		1		
	2	19 Aug 2008	Diptera - (unknown adult)		7		
	2	19 Aug 2008	Chironomidae		4		
	2	19 Aug 2008	Corixidae (water boatmen)		10		
	2	19 Aug 2008	Gerridae (water striders)		2		
	2	19 Aug 2008	Zygoptera (damselflies)	1	4		
	2	19 Aug 2008	Anispotera (dragonflies)	2			
	2	19 Aug 2008	Hymenoptera (wasp/ant)		2		
	2	19 Aug 2008	Cladocera (water fleas/daphnia)	2	27		
	2	19 Aug 2008	Eucopepoda (copepods)		46		
	2	19 Aug 2008	Araneae (spiders)		1		
	2	20 Aug 2008	Eucopepoda				2,100
	2	21 Aug 2008	Corixidae (water boatmen)			16	
	2	21 Aug 2008	Zygoptera (damselflies)			1	
	2	21 Aug 2008	Cladocera (water fleas/daphnia)			100	
	2	21 Aug 2008	Eucopepoda (copepods)			5,000	
	3	16 Sep 2008	Eucopepoda (copepods)				200
	3	22 Sep 2008	Dysticidae (predacous diving beetle or whirligig)		1		
	3	22 Sep 2008	Nematoda	1			
	3	22 Sep 2008	Trichoptera (caddis flies)		5		
	3	22 Sep 2008	Tananidae (horse fly)	1			
	3	22 Sep 2008	Chironomidae	5	1		
	3	22 Sep 2008	Ceratopogonidea (no-seeums)	2			
	3	22 Sep 2008	Corixidae (water boatmen)	1	4		
	3	22 Sep 2008	Zygoptera (damselflies)		4		
	3	22 Sep 2008	Anispotera (Dragonflies)		2		
	3	22 Sep 2008	Cladocera (water fleas/daphnia)	14	39		
	3	22 Sep 2008	Eucopepoda (copepods)		3		
	3	22 Sep 2008	Araneae (spiders)		2		
	3	22 Sep 2008	Hirudinea (leeches)	1			

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Appendix E1.–Page 3 of 3.

Treatment	Sampling event	Date	Invertebrate taxon[a]	Number of invertebrates caught by gear type: Ekman Bottom Grab[b]	Kick net (dip net)[c]	Light trap[d]	Wisconsin net[e]
Before rotenone	3	9/23/2008	Dysticidae (predacous diving beetle or whirligig)			4	
	3	9/23/2008	Corixidae (water boatmen)			63	
	3	9/23/2008	Zygoptera (damselflies)			5	
	3	9/23/2008	Cladocera (water fleas/daphnia)			165	
	3	9/23/2008	Eucopepoda (copepods)			300	
After rotenone	4	6/12/2009	Dysticidae (predacous diving beetle or whirligig)		5		
	4	6/12/2009	Simulidae (black flies)		1		
	4	6/12/2009	Chironomidae (midges)		17		
	4	6/12/2009	Corixidae (water boatmen)		1		
	4	6/12/2009	Gerridae (water striders)		4		
	4	6/12/2009	Acanthosomatidae (shield bugs)		1		
	4	6/12/2009	Zygoptera (damselflies)		9		
	4	6/12/2009	Anispotera (dragonflies)	1	16		
	4	6/12/2009	Cladocera (water fleas/daphnia)		1		
	4	6/12/2009	Araneae (spiders)		1		
	4	6/12/2009	Lepidoptera (moths)		1		
	4	8/12/2009	Dysticidae (predacous diving beetle or whirligig)			1	
	4	8/12/2009	Chironomidae (midges)			4	
	4	8/12/2009	Corixidae (water boatmen)			300	
	4	8/12/2009	Anispotera (dragonflies)			12	
	4	8/12/2009	Cladocera (water fleas/daphnia)			900	
	4	8/12/2009	Araneae (spiders)			1	
	4	8/12/2009	Acariformes (mites)			50	

[a] Identification of taxa was resolved to at least the order level and often the family level, except for Nematoda (phylum) and Hirudinea (class).

[b] The "Eckman Bottom Grab" opening was 9 × 9 inches. Five bottom sites were sampled in each pretreatment sampling event on the following dates: 16 July 2009, 19 August 2009, and 22 September 2009. Posttreatment samples (2) were collected on 12 June 2009.

[c] Five sites were sampled in each pretreatment sampling event by sweeping a kick net through vegetated nearshore areas on the following dates: 30 June 2009, 17 July 2009, 19 August 2009, and 22 September 2009. Posttreatment samples (5) were collected on 12 June 2009.

[d] Two sites were sampled in each pretreatment sampling event with a Wisconsin net on the following dates: 16 July 2009, 20 August 2009, and 16 September 2009. Posttreatment samples (2) were collected on 12 June 2009.

[e] Three sites were sampled with light traps during each pretreatment sampling event on the following dates: 25 July 2009, 21 August 2009, and 23 September 2009. Posttreatment samples (3) were collected on 12 August 2009.

APPENDIX F: EVALUATION OF ARC LAKE POSTTREATMENT SUCCESS USING GILLNETS TO DETECT SURVIVING NORTHERN PIKE

Appendix F1.–Evaluation of Arc Lake posttreatment success using gillnets to detect surviving northern pike.

Net #	Set date	Set time	Pull date	Pull time	Hours	Number of fish
1	8 Dec 2008	11:00	10 Dec 2008	10:20	47.3	0
2	8 Dec 2008	11:25	10 Dec 2008	10:35	47.2	0
3	8 Dec 2008	11:50	10 Dec 2008	10:50	47.0	0
4	8 Dec 2008	12:15	10 Dec 2008	11:05	46.8	0
5	8 Dec 2008	12:40	10 Dec 2008	11:20	46.7	0
6	8 Dec 2008	13:05	10 Dec 2008	11:35	46.5	0
7	8 Dec 2008	13:30	10 Dec 2008	11:50	46.3	0
8	8 Dec 2008	13:55	10 Dec 2008	12:05	46.2	0
9	8 Dec 2008	14:20	10 Dec 2008	12:20	46.0	0
10	8 Dec 2008	14:45	10 Dec 2008	12:35	45.8	0
11	8 Dec 2008	15:10	10 Dec 2008	12:50	45.7	0
12	8 Dec 2008	15:35	10 Dec 2008	13:05	45.5	0
1	10 Dec 2008	10:35	12 Dec 2008	10:30	47.9	0
2	10 Dec 2008	11:20	12 Dec 2008	11:15	47.9	0
3	10 Dec 2008	11:50	12 Dec 2008	12:00	48.2	0
4	10 Dec 2008	12:05	12 Dec 2008	12:25	48.3	0
5	10 Dec 2008	12:20	12 Dec 2008	12:50	48.5	0
6	10 Dec 2008	12:35	12 Dec 2008	13:15	48.7	0
7	10 Dec 2008	12:50	12 Dec 2008	14:00	49.2	0
1	14 May 2009	11:35	14 May 2009	15:05	3.5	0
2	14 May 2009	11:39	14 May 2009	15:10	3.5	0
3	14 May 2009	11:40	14 May 2009	15:13	3.6	0
4	14 May 2009	11:46	14 May 2009	15:18	3.5	0
5	14 May 2009	11:49	14 May 2009	15:21	3.5	0
6	14 May 2009	11:53	14 May 2009	15:25	3.5	0
7	14 May 2009	11:57	14 May 2009	15:29	3.5	0
8	14 May 2009	12:01	14 May 2009	15:38	3.6	0
9	14 May 2009	12:03	14 May 2009	15:42	3.7	0
10	14 May 2009	12:06	14 May 2009	15:45	3.7	0
11	14 May 2009	12:11	14 May 2009	15:49	3.6	0
12	14 May 2009	12:13	14 May 2009	15:53	3.7	0
13	14 May 2009	12:19	14 May 2009	15:56	3.6	0
14	14 May 2009	12:24	14 May 2009	16:00	3.6	0
15	14 May 2009	12:26	14 May 2009	16:04	3.6	0
16	14 May 2009	12:28	14 May 2009	16:08	3.7	0
17	14 May 2009	12:30	14 May 2009	16:12	3.7	0
18	14 May 2009	12:33	14 May 2009	16:15	3.7	0
19	14 May 2009	12:36	14 May 2009	16:20	3.7	0
20	14 May 2009	12:39	14 May 2009	16:23	3.7	0
21	14 May 2009	12:43	14 May 2009	16:29	3.8	0
22	14 May 2009	12:45	14 May 2009	16:33	3.8	0
23	14 May 2009	12:47	14 May 2009	16:36	3.8	0
24	14 May 2009	12:49	14 May 2009	16:40	3.8	0

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Net #	Set date	Set time	Pull date	Pull time	Hours	Number of fish
1	20 May 2009	10:55	20 May 2009	15:06	4.2	0
2	20 May 2009	10:58	20 May 2009	15:11	4.2	0
3	20 May 2009	11:00	20 May 2009	15:14	4.2	0
4	20 May 2009	11:03	20 May 2009	15:16	4.2	0
5	20 May 2009	11:05	20 May 2009	15:18	4.2	0
6	20 May 2009	11:07	20 May 2009	15:22	4.3	0
7	20 May 2009	11:12	20 May 2009	15:25	4.2	0
8	20 May 2009	11:14	20 May 2009	15:28	4.2	0
9	20 May 2009	11:16	20 May 2009	15:35	4.3	0
10	20 May 2009	11:18	20 May 2009	15:38	4.3	0
11	20 May 2009	11:21	20 May 2009	15:40	4.3	0
12	20 May 2009	11:23	20 May 2009	15:43	4.3	0
13	20 May 2009	11:26	20 May 2009	15:46	4.3	0
14	20 May 2009	11:28	20 May 2009	15:48	4.3	0
15	20 May 2009	11:30	20 May 2009	15:53	4.4	0
16	20 May 2009	11:32	20 May 2009	15:55	4.4	0
17	20 May 2009	11:34	20 May 2009	15:57	4.4	0
18	20 May 2009	11:37	20 May 2009	15:59	4.4	0
19	20 May 2009	11:43	20 May 2009	16:04	4.4	0
20	20 May 2009	11:45	20 May 2009	16:07	4.4	0
21	20 May 2009	11:47	20 May 2009	16:11	4.4	0
22	20 May 2009	11:49	20 May 2009	16:15	4.4	0
23	20 May 2009	11:53	20 May 2009	16:19	4.4	0
24	20 May 2009	11:55	20 May 2009	16:21	4.4	0
1	21 May 2009	10:14	21 May 2009	15:10	4.9	0
2	21 May 2009	10:19	21 May 2009	15:14	4.9	0
3	21 May 2009	10:22	21 May 2009	15:18	4.9	0
4	21 May 2009	10:25	21 May 2009	15:21	4.9	0
5	21 May 2009	10:27	21 May 2009	15:24	5.0	0
6	21 May 2009	10:30	21 May 2009	15:27	5.0	0
7	21 May 2009	10:33	21 May 2009	15:30	5.0	0
8	21 May 2009	10:35	21 May 2009	15:34	5.0	0
9	21 May 2009	10:38	21 May 2009	15:38	5.0	0
10	21 May 2009	10:40	21 May 2009	15:41	5.0	0
11	21 May 2009	10:43	21 May 2009	15:43	5.0	0
12	21 May 2009	10:47	21 May 2009	15:47	5.0	0
13	21 May 2009	10:51	21 May 2009	15:49	5.0	0
14	21 May 2009	10:53	21 May 2009	15:52	5.0	0
15	21 May 2009	10:55	21 May 2009	15:54	5.0	0
16	21 May 2009	10:57	21 May 2009	15:57	5.0	0
17	21 May 2009	10:58	21 May 2009	15:59	5.0	0
18	21 May 2009	11:00	21 May 2009	16:02	5.0	0
19	21 May 2009	11:02	21 May 2009	16:04	5.0	0

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Appendix F1.–Page 3 of 3.

Net #	Set date	Set time	Pull date	Pull time	Hours	Number of fish
20	21 May 2009	11:05	21 May 2009	16:09	5.1	0
21	21 May 2009	11:07	21 May 2009	16:12	5.1	0
22	21 May 2009	11:10	21 May 2009	16:15	5.1	0
23	21 May 2009	11:12	21 May 2009	16:17	5.1	0
24	21 May 2009	11:13	21 May 2009	16:20	5.1	0
1	22 May 2009	9:39	22 May 2009	14:16	4.6	0
2	22 May 2009	9:43	22 May 2009	14:21	4.6	0
3	22 May 2009	9:45	22 May 2009	14:25	4.7	0
4	22 May 2009	9:47	22 May 2009	14:31	4.7	0
5	22 May 2009	9:49	22 May 2009	14:36	4.8	0
6	22 May 2009	9:51	22 May 2009	14:42	4.9	0
7	22 May 2009	9:53	22 May 2009	14:48	4.9	0
8	22 May 2009	9:56	22 May 2009	14:54	5.0	0
9	22 May 2009	9:58	22 May 2009	15:01	5.1	0
10	22 May 2009	10:00	22 May 2009	15:06	5.1	0
11	22 May 2009	10:02	22 May 2009	15:10	5.1	0
12	22 May 2009	10:04	22 May 2009	15:13	5.2	0
13	22 May 2009	10:06	22 May 2009	15:17	5.2	0
14	22 May 2009	10:08	22 May 2009	15:19	5.2	0
15	22 May 2009	10:10	22 May 2009	15:22	5.2	0
16	22 May 2009	10:12	22 May 2009	15:26	5.2	0
17	22 May 2009	10:14	22 May 2009	15:28	5.2	0
18	22 May 2009	10:16	22 May 2009	15:31	5.3	0
19	22 May 2009	10:18	22 May 2009	15:34	5.3	0
20	22 May 2009	10:20	22 May 2009	15:36	5.3	0
21	22 May 2009	10:23	22 May 2009	15:40	5.3	0
22	22 May 2009	10:25	22 May 2009	15:44	5.3	0
23	22 May 2009	10:27	22 May 2009	15:46	5.3	0
				Total:	1,323.2	0.0