**Regional Operational Plan SF.2A.2018.11**

# Operational Plan: Threemile Lake Invasive Northern Pike Population Assessment

**by**

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**May 2018**

**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, $\chi^2$, 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 |

*REGIONAL OPERATIONAL PLAN SF.2A.2018.11*

# OPERATIONAL PLAN: THREEMILE LAKE INVASIVE NORTHERN PIKE POPULATION ASSESSMENT

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## SIGNATURE/TITLE PAGE

| | |
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**Approval**

| Title | Name | Signature | Date |
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# ABSTRACT

This project will estimate the population size of northern pike in the Threemile Lake Complex and survey Upper Lily Pad Lake to detect northern pike if they are there. These two activities will lay the foundation from which a long-term pike suppression program can be effectively designed and evaluated.

Key words: northern pike, *Esox lucius*, invasive species, Threemile Lake Complex, Southcentral Alaska, population estimate

# INTRODUCTION

## PURPOSE

The mission of the Alaska Department of Fish and Game (ADF&G), Division of Sport Fish (SF) is "to protect and improve the state's recreational fisheries resources," and an objective of the SF strategic plan is to "minimize impacts of invasive species on fish stocks, recreational fisheries, and fish habitat." Removing northern pike from vital salmon rearing habitat directly addresses this objective. ADF&G has an aquatic nuisance species management plan (Fay 2002) and an invasive northern pike management plan (ADF&G 2007). Goals and objectives in these plans address the need to remove invasive northern pike where possible and improve salmon populations that have been impacted by northern pike. The activities proposed in this project are aligned with several plans and initiatives, and ADF&G believes this project will provide the first step in a long-term initiative to effectively suppress the invasive northern pike population that has been documented in the Threemile Creek drainage near the Native Village of Tyonek.

## BACKGROUND

The northern pike (*Esox lucius*) is an invasive species in Southcentral Alaska that is impacting salmonid populations through predation of juvenile salmon in invaded waters (ADF&G 2007). The effects of this invasion are most severe in shallow, slow moving, vegetated lakes and streams where northern pike and rearing salmonids share habitat (Sepulveda et al. 2013, 2015). Northern pike are native throughout much of the state, but do not naturally occur south and east of the Alaska Range (Figure 1). Northern pike were first introduced by anglers to the Yentna River drainage in the late 1950s and subsequently spread throughout the Susitna River basin through flood events and further illegal stockings (Mills 1986). Currently, northern pike have been documented in over 120 lakes and rivers in Southcentral Alaska.

Smaller-scale "secondary" northern pike infestations (e.g., originating from the Susitna River infestation) have been reported recently throughout small stream systems draining to the western coast of Cook Inlet (herein referred to as West Cook Inlet). West Cook Inlet is not accessible by road, is sparsely populated, and contains hundreds of small, complex, salmon-producing stream systems. Many reports of northern pike presence have come from sport and subsistence anglers; however, most reports lack live or dead specimens, preventing conclusive knowledge of the extent of infestation.

One area where northern pike are well-established and have affected salmon populations is the Threemile Creek drainage on the western side of Cook Inlet between the communities of Beluga and the Native Village of Tyonek. The Tyonek Tribal Conservation District (TTCD) has identified the Threemile Creek drainage as the most significant watershed in the area where northern pike are adversely affecting salmon.

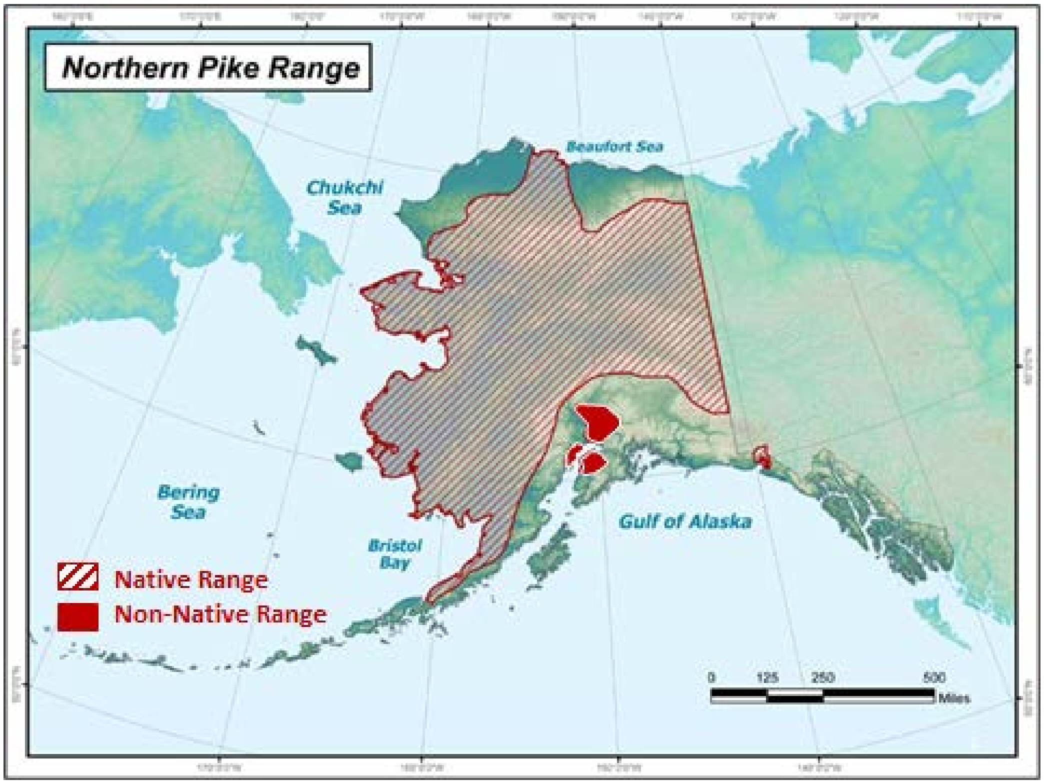


Figure 1.–Northern pike range in Alaska.

The Native Village of Tyonek (NVT) is a Dena'ina Athabascan village located 43 miles southwest of Anchorage in West Cook Inlet and is home to approximately 200 people. There are no roads to Tyonek, which necessitates access via boat or small aircraft. The remote setting and cultural heritage of NVT makes subsistence activities of paramount importance to the people in Tyonek, and many of these activities are focused on salmon. The total subsistence harvest for Tyonek in 2013 was 16,766 pounds of salmon or 118 pounds per capita (Jones et al. 2015). Threemile Creek is located about 3 miles north of Tyonek, and northern pike in that system are suspected of reducing salmon populations and therefore decreasing the number of salmon returning along the West Cook Inlet beaches where the people of Tyonek subsistence fish. If northern pike continue to thrive in the Threemile Creek drainage without management intervention to contain or control them, it is highly probable they will continue to spread into surrounding waterbodies in and around Tyonek and into vulnerable drainages along West Cook Inlet.

Initial assessments of the presence of northern pike in West Cook Inlet drainages between 2015 and 2017 (Swenson and Hagan *Unpublished* report) documented northern pike from several area waters (Threemile Lake, Chuit Lake, and Second Lake), though much uncertainty remains regarding overall pike distribution in the region. Survey data collected to date suggest the Threemile Creek drainage has been the most severely affected of the surveyed waters. This area yielded the greatest catch per unit effort (CPUE) of northern pike and no other species of fish were captured or observed during these investigations despite records for them in the ADF&G Anadromous Waters Catalog (AWC). This absence is often the case in waters where northern pike have had a significant ecological impact (Dunker et al. 2018). The area of the drainage where northern pike are thought to have the most impact is the Threemile Lake Complex, which consists of East and West Threemile lakes and Lower Lily Pad Lake. This lake complex is a strong candidate for annual invasive northern pike suppression, similar to ongoing efforts in Alexander Creek (Rutz et al. *In prep*). Initiating an effort like this could directly benefit salmon populations and both subsistence and sport fisheries in the Tyonek region. Most importantly, management of this invasive northern pike population might also hinder expansion of pike to other vulnerable drainages along West Cook Inlet.

The long-range goal of the partnership between TTCD, NVT, Cook Inlet Aquaculture Association (CIAA), and ADF&G is to reduce the impact of invasive northern pike on rearing salmonids by removing as many northern pike from the Threemile Lake Complex as possible. Complete eradication of northern pike in the Threemile Creek drainage is probably too costly and logistically prohibitive. However, relieving some of the predation pressure on salmon fry and smolt should increase their abundance by contributing to greater survival (Muhlfeld et al. 2008). Over time, greater survival of juvenile salmon may result in larger annual returns of adult salmon that support sport and subsistence fisheries in the TTCD. Increased salmon productivity in the Threemile Creek drainage coupled with reductions in the northern pike population could eventually allow salmonids to thrive. In other parts of Alaska where northern pike are native, and even in other drainages in Southcentral where they are not (e.g., the Deshka River), northern pike and salmonids can coexist; however, habitat complexity that allows salmonids opportunities to avoid predators is hypothesized to be a strong factor in mitigating predator-prey interactions within these fish communities (Sepulveda et al. 2013). In the Threemile Lake Complex, where the habitat is relatively homogenous and provides ideal conditions for northern pike, it is likely that salmonids are unable to avoid predation and therefore their populations can drastically decline (Dunker et al. 2018). In this case, annual suppression of the northern pike population in this area could be used to mitigate predator-prey interactions and eventually restore salmonid production to sustainable levels in the Threemile Creek drainage.

To effectively design and implement an annual northern pike suppression program in Threemile Lake, it is necessary to begin with a baseline estimate of the size of the northern pike population to facilitate future evaluation of the suppression program. With a baseline estimate, it is possible to assess the effectiveness of removal events (e.g., Baxter and Neufeld 2015), and direct comparisons can be made to later estimates of northern pike population levels following periods of suppression. Furthermore, the initial abundance estimate can be used to model annual removal targets to increase the effectiveness of the suppression program and determine, on an annual basis, if suppression activities are successfully meeting those targets.

Past investigations of northern pike in Upper Lily Pad Lake directly upstream of the Threemile Lake Complex did not catch any northern pike, although their presence was suspected and they are known to be present in the stream connection between Upper and Lower Lily Pad lakes (Swenson and Hagan *Unpublished*). Given the proximity of Upper Lily Pad Lake to other lakes in the complex, it is important to confirm the presence of northern pike in this lake. The inability to catch northern pike there previously means it is unlikely the population is prolific. However, if a well-established northern pike population is found and previously observed native fish species are in low abundance, expanding future northern pike suppression plans to include Upper Lily Pad Lake will be warranted.

Very little is currently known and documented about northern pike in the Threemile Lake Complex, other than the known association between pike presence and the decline of salmonid populations in the region (Swenson and Hagan *Unpublished*). In this pilot year, the partner agencies will conduct a mark–recapture study with the goal of estimating the population size of northern pike in the Threemile Lake Complex, collect biological data on sampled pike for future pike suppression modeling, and survey Upper Lily Pad Lake upstream of the Threemile Lake Complex to determine if northern pike are established there and to document the current fish assemblage.

# OBJECTIVES

This project will estimate the population size of northern pike in the Threemile Lake Complex and survey Upper Lily Pad Lake directly upstream to determine northern pike distribution. Results from this project will be used to design and evaluate a long-term northern pike suppression program. Objectives for the suppression program will be addressed in a separate operational plan for that effort. Specific objectives for this current project include the following:

## PRIMARY OBJECTIVE

1) Estimate the population size of northern pike ≥300 mm fork length (FL) in the Threemile Lake Complex such that the estimate is within 25% of the true population size 90% of the time.

## SECONDARY OBJECTIVES

1) Detect the presence of northern pike in Upper Lily Pad Lake such that the probability of detection is greater than 95% given the population is at least 4 northern pike.
2) Calculate the mean length (FL) and length range of northern pike in the Threemile Lake Complex.
3) Document stomach contents, sex, and age of northern pike in the Threemile Lake Complex.
4) Document CPUE of the native fish assemblage in Upper Lily Pad Lake and record any native fish that are captured during the northern pike population assessment in the Threemile Lake Complex.

# METHODS

## STUDY AREA

This project will take place in the Tyonek Tribal Conservation District (TTCD). The TTCD shares its boundaries with Alaska Game Management Unit 16B. The District’s eastern edge is the Susitna River, its northern and western boundaries are the divide of the Alaska Range, and its southern border is Cook Inlet. Population and infrastructure in the region is limited but is centered on the Tyonek–Beluga corridor. The Tyonek–Beluga corridor hosts a population of roughly 200 people, hosts over 80 miles of unimproved roads, and has 3 airstrips. Waterbodies in proximity to this small population corridor are classified as the Tyonek Area Watershed (Figure 2). The Watershed has 378 lakes and approximately 1,624 river miles of freshwater and is home to all 5 species of Pacific salmon. Juvenile salmonids are preferred prey for northern pike and the negative effects of pike infestations on salmonid populations in the region is well documented (Sepulveda et al. 2013).

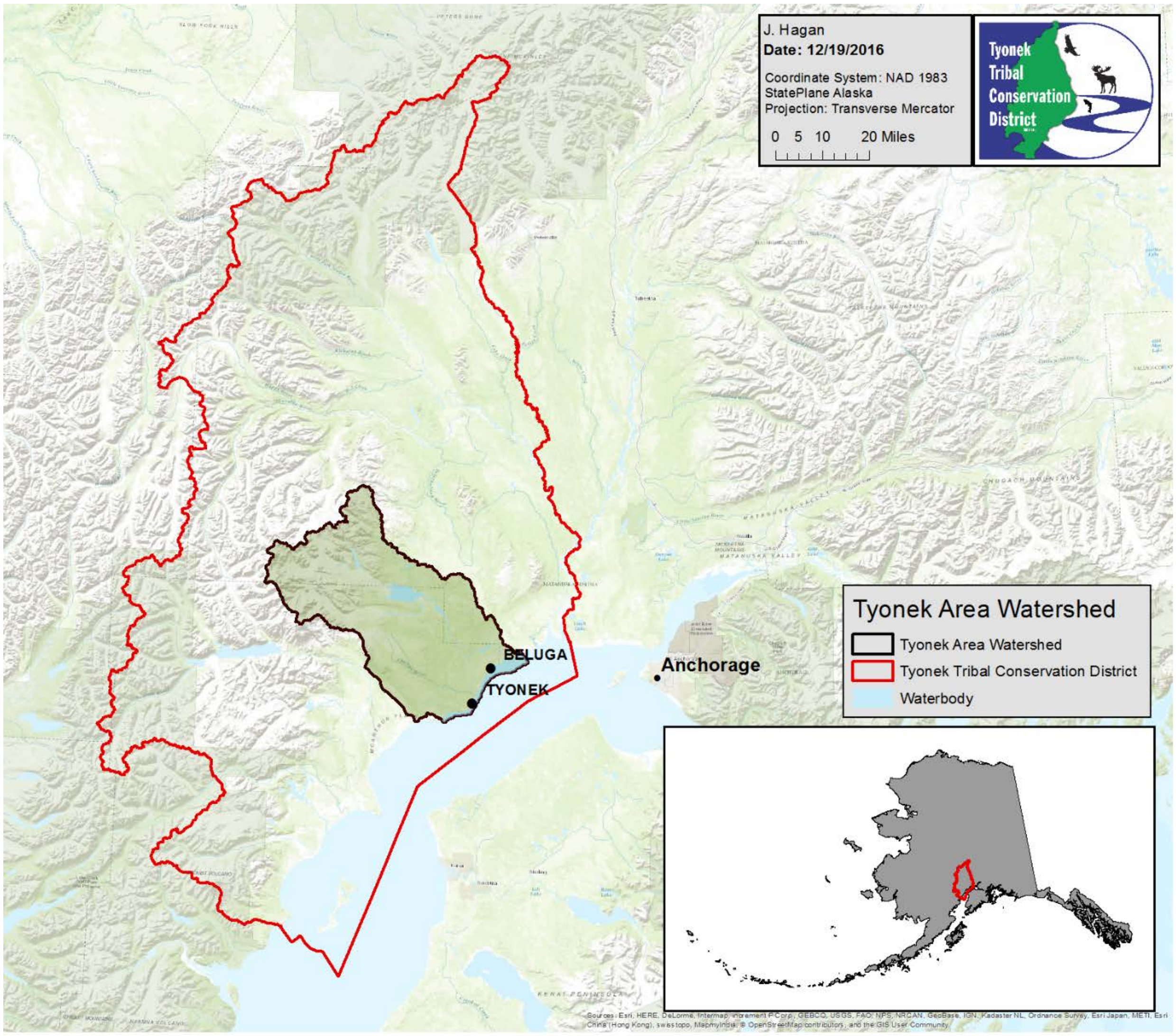


Figure 2.–Map of the Tyonek Area Watershed.

Waterbodies with direct access to the Tyonek–Beluga road system are the most heavily used for sport and subsistence fishing activities. The Threemile Lake Complex, defined in this plan as East and West Threemile lakes and Lower Lily Pad Lake, has several access points including a motorized watercraft launch accessible by all-terrain vehicle (ATV), and is the most heavily used area for sport fishing activities in the region. The Threemile Creek watershed is a complex stream system covering 20.4 square miles. There are more than 20 interconnected lakes and several more ephemeral lakes within the watershed. Due to the low-gradient landscape, flooding can connect lakes and connect off-channel habitat and oxbows for periods of time. The system is groundwater dominated. The mainstem of Threemile Creek runs between Threemile Lake and its mouth at Cook Inlet. Directly above Threemile Lake is Lower Lily Pad Lake and the confluence where West- and East Fork Threemile creeks converge. West Fork Threemile Creek is significantly larger than East Fork Threemile Creek. The West Fork itself has 2 main branches, known as West Branch West Fork Threemile Creek and East Branch West Fork Threemile Creek (Figure 3). All forks and branches have smaller tributaries, sloughs, and lakes.

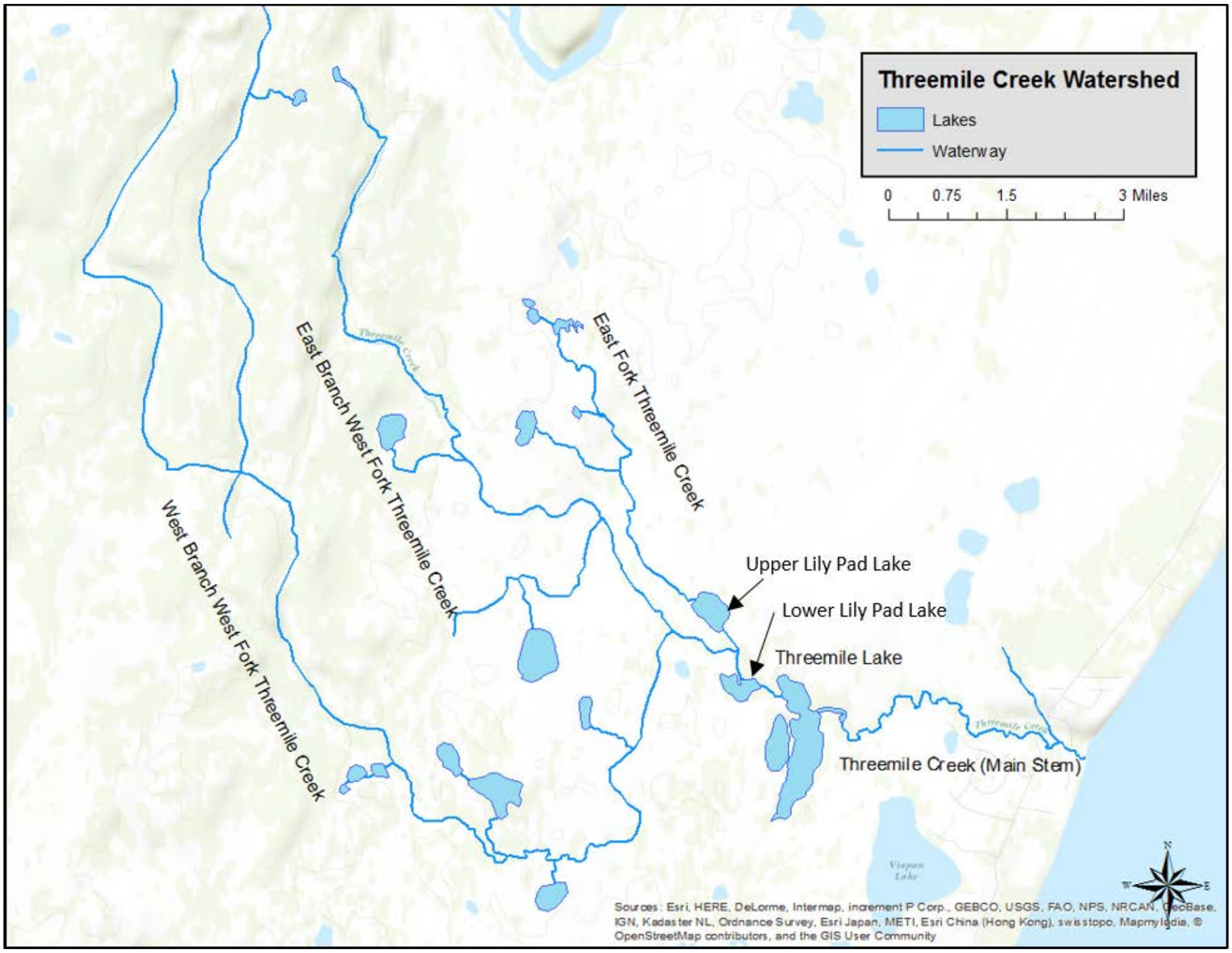


Figure 3.–Map of Threemile Creek Drainage.

## STUDY DESIGN

### Threemile Lake Northern Pike Population Estimate

This study is designed to estimate the abundance of northern pike within the Threemile Lake Complex (Figures 4 and 5) using a Petersen 2-event mark–recapture abundance estimator for a closed population (Seber 1982). Assumptions of the model are as follows:

1) the population is closed (northern pike do not enter the population via growth or immigration, or leave the population via death or emigration during the experiment)
2) all pike have a similar probability of capture during the first event or during the second event, or marked and unmarked fish will mix completely between events
3) marking of pike will not affect the probability of capture during the second event
4) marked pike will be identifiable during the second event
5) all marked pike will be reported when recovered in the second event

Failure to satisfy these assumptions may result in biased estimates; therefore, the study is designed to ensure these assumptions are reasonably valid.

Figure 4.–Photograph of the boat launch at Threemile Lake.

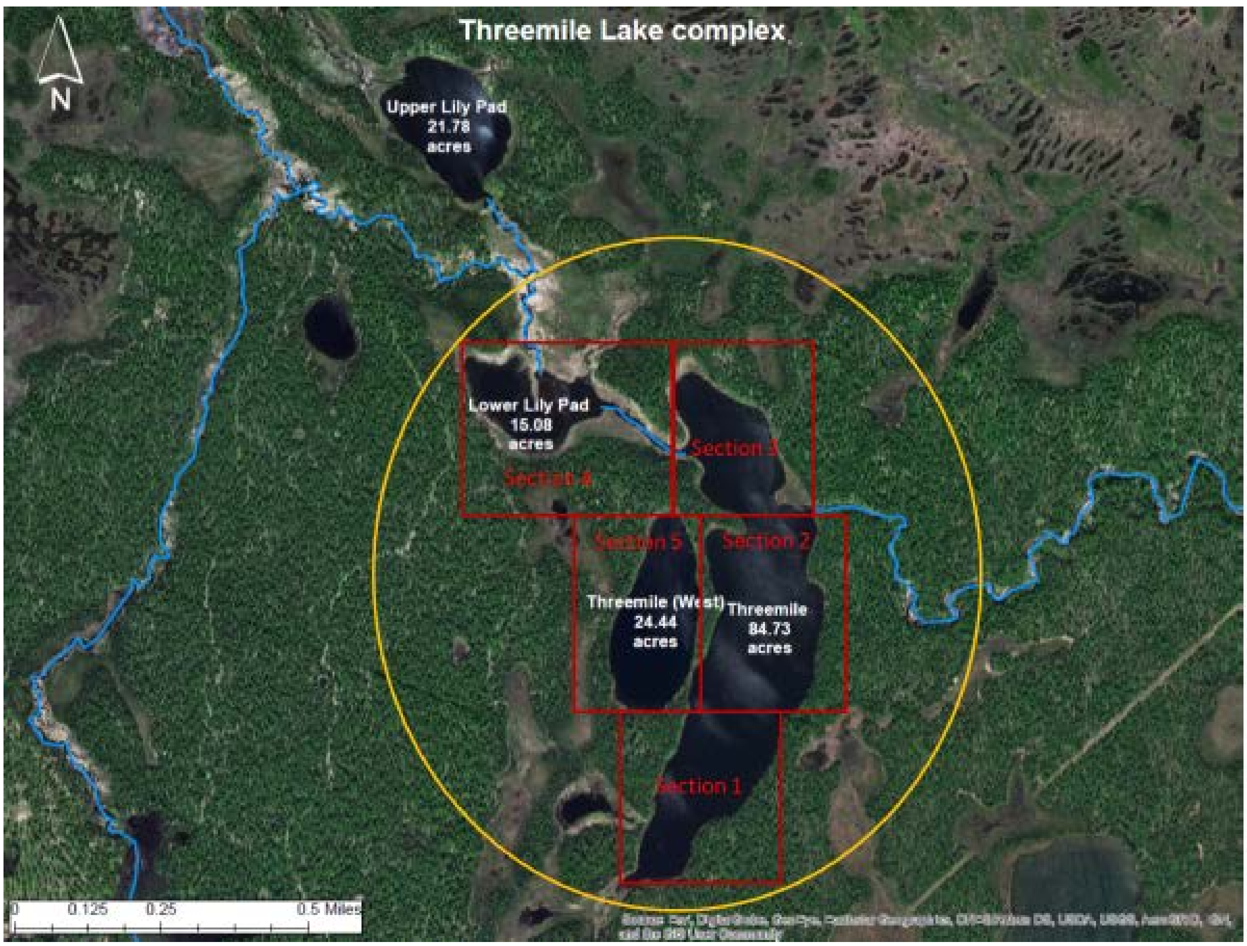


Figure 5.–The Threemile Lake Complex is delineated in yellow and the lake sections for the mark–recapture assessment are delineated in red.

### *Sampling*

Fyke nets or metal screening will be deployed in the inlets and outlets of the Threemile Lake Complex to prevent immigration and emigration of northern pike during the study and to ensure that Assumption 1 is not violated. The marking event will take place between 1 June and 10 June. At least 4 anglers will use hook-and-line gear and 2 crew members will deploy and monitor gillnets to sample northern pike for 8 hours each day over the course of 10 days during both the marking and recapture events. Fyke net locations will remain the same for both events and will be checked periodically each day to make sure they are effectively blocking access to the lake. To evaluate the assumptions and ensure sampling effort is uniformly distributed, the lake complex will be divided into 5 sections (Figure 4). During each event, the 4-person angling crew and the 2-person gillnetting crew will fish 1 section per day. Gillnetting and angling efforts will start on opposite ends of each lake section to ensure sampling efforts do not interfere with each other. Angling efforts will proceed systematically from one end of the complex to the other. After crews have fished the entire complex, they will return to the section they started to make a second pass of the entire complex so that each of the 5 sections is sampled twice during each of the two 10-day events.

A 2-person crew will set up to 10 gillnets in each section along the littoral zone at the beginning of the day's sampling period. Nets will be distributed uniformly in the littoral zone of each section, and locations will be recorded with GPS for repeatability. Throughout the sampling period, the crew will continuously boat along the nets and remove any northern pike that are captured. If it takes greater than 30 minutes between checking nets, or the fish in the nets appear impaired from time spent in the nets, some of the gillnets may be removed to reduce capture or handling mortality. For the marking event, the gillnets will be removed at the end of each day's sampling period to avoid overnight mortality.

Each day while the gillnetting effort is underway, 4 anglers will fish in the same lake section as the gillnetters for the 8-hour sampling period. Two anglers will fish from an inflatable boat, and 2 anglers will fish from shore. Anglers will work their way through each section in a systematic manner to ensure efforts are distributed uniformly across the lake. For instance, at the start of each day, anglers will begin at the southernmost part of each section and will position themselves relatively equidistant from each other (2 on opposite shorelines, and 2 in the middle of the section in inflatables). After a period of 15 minutes without catching a fish, anglers will be instructed to move northward about 20 meters to begin fishing a new fishing location. Otherwise, they will stay in the same location until catch rates slow to less than 1 northern pike per 15 minutes. Once anglers reach the opposite end of their lake section, they will continue repeating each transect until the fishing period ends for the day. A combination of pike lures with single hooks will be used, but the hooks will either be barbless or the barbs will be flattened to minimize injuries during capture.

For both anglers and gillnetters, location, time (start and stop times for nets, time spent fishing for anglers), and species will be recorded for each capture (Appendix A1). Captured northern pike will be measured for fork length (FL) in millimeters and all individuals ≥300 mm FL will be tagged with an individually numbered Floy[1] T-bar tag and released where they were caught. T-bar tags will be inserted through the proximal pterygiophore at the midlength of the dorsal fin. A

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

left pelvic fin clip will serve as a secondary mark to assess tag loss. A 10-day interval will separate the marking event from the recapture event. Mixing of tagged and untagged individuals should occur within this time period, but this assumption will be tested during data analysis.

The recapture event will take place between 21 June and 30 June. All captured northern pike will be killed during this event, providing the first opportunity to begin suppression of the northern pike population in the Threemile Lake Complex. Though the recapture event will allow for opportunistic suppression during this project, a formal suppression plan for future years will be developed after this current project concludes. All northern pike in the recapture event will be immediately dispatched, tagged with the capture location, and put in a cooler for later processing. Methods for capturing and recording fish during the recapture will be the same as those used during the marking event with the following exceptions: gillnets will be allowed to fish through the evening and will be moved the next morning to a new lake section, fyke nets will be fished concurrently with the gillnets, and all northern pike will be sacrificed. Up to 20 gillnets may be used during the recapture event. This increased fishing time is permitted during the recapture event because mortality of captured northern pike will no longer be a concern and because increased water temperatures and a cessation of spawning will probably mean less movement of northern pike and therefore increased sampling effort will be necessary. When the 8-hour fishing period ends each day, project staff will measure each captured northern pike for fork length and weight, remove the cleithrum for ageing, and dissect each fish to document stomach contents and sex; these data will be recorded (Appendix A2). If more than 6 people are available during the recapture event, additional staff will be allocated to processing these fish throughout each day.

### *Evaluation of Assumptions*

**Assumption 1 (the population is closed):** It is likely Assumption 1 will not be violated because inlets and outlets to the Threemile Lake Complex will be blocked off with fyke nets during this study. In addition, this study will be of short duration, and therefore growth, recruitment, and mortality will be insignificant. Also, if northern pike are mortally injured during the marking event (e.g., hook through the eye, bleeding gills, etc.) or seem unusually stressed, the fish will be sacrificed rather than marked.

**Assumption 2 (equal probability of capture during an event or mixing between events):** We do not know if northern pike will mix completely during the 10-day hiatus between events. However, Assumption 2 will be met if all fish are subject to the same probability of capture during each sampling event. Fishing effort for both anglers and gillnets will be distributed in proportion to the distribution of pike. Based on catch rates and visual observations, effort will be increased in areas where densities appear relatively high (e.g., shallow vegetated bays and outlet areas) and decreased where there appear to be few fish available (e.g., deep water zones). Sample sizes are expected to be large enough to provide sufficient power for tests of heterogenous capture probabilities. Differences in capture probability related to fish size, sex, and location will be tested for as described in Appendices B1 and B2. If significant differences are detected, stratified estimates of abundance and its variance will be used.

**Assumption 3 (marking does not affect probability of recapture):** The hiatus between marking and recapture events should allow marked fish to recover from the effects of handling and marking during the first event; therefore, Assumption 3 should be valid. However, it is unknown if fish captured in gillnets during the marking event will avoid this gear during the recapture event. The heavy use of hook and line sampling should mitigate such an effect if it exists.

**Assumption 4 (marked fish will be identifiable in the second event):** This assumption will be addressed by double-marking each northern pike captured during the first event. Tag loss will be noted when a fish is recovered during the second event with a first-event fin clip but without a Floy tag. In addition, tag placement will be standardized, which will enable the fish handler to verify tag loss by locating recent tag wounds.

**Assumption 5 (all marked fish will be reported in the second event):** All fish will be thoroughly examined for tags or recent fin clips. All markings (tag number, tag color, fin clip, and tag wound) for each fish will be recorded.

### *Sample Size*

As stated previously, the abundance estimate for northern pike in the Threemile Lake Complex established through this study will be used to model future pike suppression goals. This estimate will also serve as the baseline from which the pike suppression activities can be evaluated for their effectiveness. Since no previous estimates of abundance are available, a range of possible population sizes will be used to calculate the sample size required to meet the precision criteria. According to broad estimates, there are roughly 7,000 to 10,000 northern pike present in the Threemile Lake Complex (Andy Wizik, CIAA, personal communication). Since this is a rough guess, we will calculate necessary sample sizes for populations ranging from 5,000 to 15,000 fish. If there are 5,000 fish present, 437 fish will need to be sampled during each sampling event to meet the precision criteria of Objective 1 (Robson and Regier 1964). If there are 15,000 fish present, 785 fish will need to be sampled during each sampling event.

An educated guess of the sample size we can expect to obtain incorporates previous catch rates of northern pike in Threemile Lake, available man power, and allotted time for the project. In past investigations, it was possible to catch at least 1 northern pike per angler-hour in Threemile Lake, and CPUE with gillnets was approximately 1 northern pike per net-hour (Swenson and Hagan *Unpublished*). Assuming this experience remains the same for this study, 4 people fishing for 10 days each and catching northern pike at the rate of 1 fish per hour for 8 hours per day will yield approximately 320 fish. A gillnetting crew fishing 10 gillnets for 8-hour sets per day for 10 days at a rate of 1 northern pike per net-hour is likely to catch approximately 800 northern pike. Given these values, an anticipated sample size of up to 1,120 individuals per sampling event is possible.

## Upper Lily Pad Lake Northern Pike Survey

Gillnets are frequently used for the detection and suppression of invasive northern pike in Alaska (Sepulveda et al. 2013; Glick and Willette 2016; Rutz and Dunker *In prep*). Gillnets are most effective when fished in optimal habitat conditions for northern pike, which typically include sloughs and the shallow bays, embankments, and densely-vegetated littoral zones of lakes (Inskip 1982). Because these conditions are present at Upper Lily Pad Lake, gillnets will be used to survey for northern pike.

To quantify the netting effort necessary to detect if northern pike are established in Upper Lily Pad Lake (Figure 6), a method used for past projects was employed (Massengill *In prep*) that originated from pike removal estimates for lakes on the Kenai Peninsula (Appendix C1).

Figure 6.–Photograph of Upper Lily Pad Lake.

For this investigation, during the hiatus between the mark and recapture events in the Threemile Lake Complex, 11 gillnets will be deployed in Upper Lily Pad Lake. To obtain a probability of nondetection of about 2%, Upper Lilly Pad Lake will need to be sampled for 4 days, unless a northern pike is captured before then (Table 1).

Table 1.–Probabilities of not detecting a small northern pike population ($N$ = 4) in Upper Lily Pad Lake (about 22 acres surface area) with 0.5 nets per littoral surface area (11 nets) for up to 4 days of netting.

| Hours | Probability of nondetection |
|---|---|
| 24 | 0.39 |
| 48 | 0.15 |
| 72 | 0.06 |
| 96 | 0.02 |

Upper Lily Pad Lake will be sampled with one 2-person field crew. Gillnets will be deployed in the vegetated littoral zone and fished continuously until a northern pike is captured, or up to 4 days if not. The field crew will be present at the lake every day to check the nets, collect and record data, and free any bycatch. GPS coordinates will be collected at all net locations. If and when northern pike are captured, the netting strategy will be altered because the presence of northern pike will have been confirmed. If a northern pike is captured, the gillnets will remain in place for 48 hours following to calculate CPUE of northern pike and other fish as a way to characterize the fish assemblages in the lakes. Forty-eight hours after catching the first northern pike, the nets will be removed to avoid unnecessary bycatch. If no northern pike are captured during this netting assessment, it will be determined that the northern pike population in Upper Lily Pad Lake is not large enough to warrant future suppression activities. During the gillnetting assessment of Upper Lily Pad Lake, the netting crew will also deploy 2 gillnets in the stream connecting Upper and Lower Lily Pad lakes for a 24-hour period to measure CPUE. Minnow traps will also be deployed in the creek at this time to document the presence of juvenile salmonids.

## DATA COLLECTION

### Threemile Lake Northern Pike Population Estimate

All data and daily summaries will be recorded in waterproof notebooks following the formats in Appendices A1 and A2. For each fish caught, its fork length, tag number and tag color, and fin clip will be recorded in the notebook (see Appendix A1). All captured northern pike will be measured to the nearest millimeter. Any mark-event northern pike that die during handling and all recapture-event northern pike will be processed for fork lengths, weight, age (by counting annuli on cleithra bones), sex, and stomach contents and these data will be recorded on data sheets (Appendix A2). Also, any northern pike less than 300 mm FL will be dispatched and processed in the same manner. Each crew member will also keep a daily field journal in a waterproof notebook. To identify conditions that may have a substantial effect on the probability of capture during a sampling event, the following information will be recorded:

1) gear type that was most effective and at which times it was most effective
2) weather and water conditions (e.g., cloud cover, precipitation, temperature, water level, and clarity)
3) net set and pull times
4) hours worked each day by each crew member
5) number of fish captured and number of mortalities

### Northern Pike Population Characteristics

As previously stated, during the recapture event, additional data will also be collected for each of the captured northern pike. All northern pike removed during this event will be immediately dispatched and placed in a cooler for later processing of fork lengths, weight, age, sex, and stomach contents. All data will be recorded on data sheets (Appendix A2).

### Upper Lily Pad Lake Northern Pike Survey

All fish captured in gillnets will be counted and identified to species. Catch of all species other than northern pike will be recorded on data sheets (Appendix A1), and all fish other than northern pike will be released immediately. The fork lengths of all captured northern pike will be measured and recorded to the nearest millimeter. All captured pike will be dispatched on-site and their sex, maturity, and stomach contents will be recorded (Appendix A2).

## DATA REDUCTION

Data will be transferred from field notebooks and data sheets to Microsoft Excel worksheets for analysis. Column headings of the worksheet will include sample number, date of capture, event number, tag number, gear type, and field comments. Each fish will have a unique sample number, but to avoid duplication with other crew members in the field, crew will number their fish with their initials plus a number from 1….*n* (e.g., KD1, KD2,….KD*n*). During data entry, a column will be added to the file to provide a unique number from 1….*N* for each fish. In addition, a column will be created to document whether a fish captured during the second event was a recapture. For the recapture event, or fish captured during the marking event that were either injured or too small, additional data for length, sex, maturity, and stomach contents will also be entered into the Excel worksheet. Additional comments may be added for clarity and a glossary of all column headings will be provided as metadata with brief descriptions. Final copies of the Excel files will be provided with the completed report when it is submitted for review to be archived in the Division of Sport Fish Docushare repository. At that time, a file name and directory will be assigned, which will be included as an appendix in the final report.

## DATA ANALYSIS

### Threemile Lake Northern Pike Population Estimate

Abundance and its variance will be estimated with Chapman's (1951) modification of the Petersen estimator (Seber 1982):

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \qquad (1)$$

and

$$\hat{V}(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}, \qquad (2)$$

where

$n_1$ = the number of fish marked during the first sampling event,

$n_2$ = the number of fish examined during the second sampling event, and

$m_2$ = the number of fish captured during the second event with marks from the first event.

If tests indicate heterogenous capture probabilities related to size, length, or location, a stratified estimate of abundance and its variance will be used (Appendices B1 and B2). A histogram of northern pike captured by length category will also be generated for the Threemile Lake Complex.

### Upper Lily Pad Lake Northern Pike Survey

If northern pike are detected in multiple age classes or are numerous, their establishment in the lake will be confirmed. If northern pike are not detected within 4 days of gillnetting, it will be assumed that either no northern pike are in the lake or that there is a population of less than 4 northern pike in the lake (probability of nondetection error less than 0.02).

# SCHEDULE AND DELIVERABLES

| Dates | Activity |
|---|---|
| May 2018 | Purchase equipment and field camp gear |
| | Confirm field crews |
| | Transfer equipment |
| June 1–10 | Marking event |
| June 11–20 | Upper Lily Pad Lake assessment |
| June 21–30 | Recapture event; collect size, gender, maturity, and diet data |
| July 2018 | Data entry |
| August 2018 | Analyze data and write project report |
| | Model future northern pike suppression targets |

# RESPONSIBILITIES

*Kristine Dunker, Fishery Biologist III, ADF&G, Division of Sport Fish*
Duties: Provide oversight and make recommendations on study designs and project plans. Assist with data analysis and project reporting. Coordinate and assist with the completion of project deliverables.

*Parker Bradley, Fishery Biologist II, ADF&G, Division of Sport Fish*
Duties: Serve as the primary project biologist. Assist with planning and coordinating field logistics. Assist with project reporting and presentations to the public.

*Cody Jacobson, Fishery Biologist I, ADF&G, Division of Sport Fish.*
Duties: Assist with planning and coordinating field logistics and equipment procurement. Supervise field activities and technicians.

*Ben Buzzee, Biometrician IV, ADF&G, Division of Sport Fish.*
Duties: Provide guidance on study design. Assist with postseason data analysis. Review project operational plan and reports.

*Nicole Swenson, Biologist, Tyonek Tribal Conservation District*
Duties: Provide guidance on study design. Coordinate field logistics and equipment procurement.

*Justin Trenton, Environmental Director, Native Village of Tyonek*
Duties: Community outreach, field work, and equipment procurement.

*Andy Wizik, Biologist, Cook Inlet Aquaculture Association*
Duties: Provide guidance on study design; field assistance, and equipment procurement.

In addition, 4 Fish and Wildlife Technicians will be hired to assist with the field activities.

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# APPENDIX A: DATA SHEETS

Appendix A1.–First event (capture), second event (new captures and recaptures), and Upper Lily Pad Lake (capture) sampling form.

| **Threemile Northern Pike Capture Form 2018** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Samplers: | | Section # | | Start Date:<br>Stop Date: | | | |
| Net # | GPS | Start Time | Stop Time | Fish Spp. | Fork Length | Tag # | Comments |
| | | | | | | | |
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Appendix A2.–Recaptured or deceased northern pike sampling form.

| Threemile Northern Pike Stomach Sampling Form, 2018 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Date:** | | | | | | | | | **Samplers:** | **Page:** |
| Number | Tag # | Recap **(R or Blank)** | Section # | Net # | Fork Length (mm) | Weight (g) | Sex **( M, F, U )** | Stomach contents **( Yes/No )** | Stomach Content | Comments about fish or stomach content; deformatie |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
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# APPENDIX B: TESTS FOR SELECTIVE SAMPLING AND CONSISTENCY IN MARK–RECAPTURE EXPERIMENTS

Appendix B1.–Detection and mitigation of selective sampling during a 2-event mark–recapture experiment.

Size- and sex-selective sampling may cause bias in 2-event mark–recapture estimates of abundance and size and sex composition. Kolmogorov–Smirnov (KS) 2-sample tests are used to detect size-selective sampling, and contingency table analyses (chi-square tests of independence) are used to detect evidence of sex-selective sampling.

Results of the KS and chi-square tests will dictate whether the data need to be stratified to obtain an unbiased estimate of abundance. The nature of the detected selectivity will also determine whether the first, second, or both event samples are used for estimating size and sex compositions.

**Definitions**

M = lengths or sex of fish marked in the first event

C = lengths or sex of fish inspected for marks in the second event

R = lengths or sex of fish marked in the first event and recaptured in the second event

**Size-Selective Sampling: KS Tests**

Three KS tests are used to test for size-selective sampling:

KS Test 1 C vs. R Used to detect size selectivity during the 1st sampling event.
$H_o$: Length distributions of populations associated with C and R are equal

KS Test 2 M vs. R Used to detect size selectivity during the 2nd sampling event.
$H_o$: Length distributions of populations associated with M and R are equal

KS Test 3 M vs. C Used to corroborate the results of the first two tests.
$H_o$: Length distributions of populations associated with M and C are equal

**Sex-Selective Sampling: Chi-Square Tests**

Three contingency table analyses (chi-square tests on 2 × 2 tables) are used to test for sex-selective sampling (chi-square = $\chi^2$):

$X^2$ Test 1 C vs. R Used to detect sex selectivity during the 1st sampling event.
$H_o$: Sex is independent of the C–R classification

$\chi^2$ Test 2 M vs. R Used to detect sex selectivity during the 2nd sampling event.
$H_o$: Sex is independent of the M–R classification

$\chi^2$ Test 3 M vs. C Used to corroborate the results of the first two tests.
$H_o$: Sex is independent of the M–C classification

There are several possible results of selectivity testing, their interpretation, and prescribed actions (Table B1-1).

-continued-

Table A1-1.–Possible results of selectivity testing, interpretation, and action.

| Case | KS or $\chi^2$ Test: M vs. R (2nd event test) | KS or $\chi^2$ Test: C vs. R (1st event test) | KS or $\chi^2$ Test: M vs. C (1st vs. 2nd event) | Interpretation and Action | |
|---|---|---|---|---|---|
| I | Fail to reject $H_o$ | Fail to reject $H_o$ | Fail to reject $H_o$ | Interpretation: | No selectivity during either sampling event. |
| | | | | Action: | |
| | | | | Abundance: | Use a Petersen-type model without stratification. |
| | | | | Composition: | Use all data from both sampling events. |
| II | Reject $H_o$ | Fail to reject $H_o$ | Reject $H_o$ | Interpretation: | No selectivity during the 1st event but there is selectivity during the 2nd event. |
| | | | | Action: | |
| | | | | Abundance: | Use a Petersen-type model without stratification. |
| | | | | Composition: | Use data from the 1st sampling event without stratification. 2nd event data only used if stratification of the abundance estimate is performed, with weighting according to Equations B1–B3 below. |
| III | Fail to reject $H_o$ | Reject $H_o$ | Reject $H_o$ | Interpretation: | No selectivity during the 2nd event but there is selectivity during the 1st event. |
| | | | | Action: | |
| | | | | Abundance: | Use a Petersen-type model without stratification. |
| | | | | Composition: | Use data from the 2nd sampling event without stratification. 1st event data may be incorporated into composition estimation only after stratification of the abundance estimate and appropriate weighting according to Equations B1–B3 below. |
| IV | Reject $H_o$ | Reject $H_o$ | Either result | Interpretation: | Selectivity during the 1st and 2nd sampling event. |
| | | | | Action: | |
| | | | | Abundance: | Use a stratified Petersen-type model, with estimates calculated separately for each stratum. Sum stratum estimates for overall abundance. |
| | | | | Composition: | Combine stratum estimates according to Equations B1–B3 below. |
| V | Fail to reject $H_o$ | Fail to reject $H_o$ | Reject $H_o$ | Interpretation: | The results of the 3 tests are inconsistent. |
| | | | | Action: | Need to determine which of Cases I–IV best fits the data. Inconsistency can arise from high power of the M vs. C test or low power of the tests involving R. Examine sample sizes (generally M or C from <100 fish and R from <30 are considered small), magnitude of the test statistics ($D_{max}$), and the *P*-values of the three tests to determine which of Cases I–IV best fits the data. |

-continued-

**Composition estimation for stratified estimates**

An estimate of the proportion of the population in the *k*th size or sex category for stratified data with *I* strata is calculated as follows:

$$\hat{p}_k = \sum_{i=1}^{I} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \qquad \text{(B1)}$$

with variance estimated as

$$var[\hat{p}_k] \approx \frac{1}{\hat{N}^2} \sum_{i=1}^{I} \left( \hat{N}_i^2 var[\hat{p}_{ik}] + \left( \hat{p}_{ik} - \hat{p}_k \right)^2 var[\hat{N}_i] \right) \qquad \text{(B2)}$$

where

$\hat{p}_{ik}$ = estimated proportion of fish belonging to category *k* in stratum *i*,

$\hat{N}_i$ = estimated abundance in stratum *i*, and

$\hat{N}$ = estimated total abundance

where

$$\hat{N} = \sum_{i=1}^{I} \hat{N}_i \qquad \text{(B3)}$$

**Tests of Consistency for Petersen Estimator**

Three contingency table analyses are used to determine if the Petersen estimate can be used (Seber 1982). If any of the null hypotheses are not rejected, then a Petersen estimator may be used. If all three of the null hypotheses are rejected, a temporally or spatially-stratified estimator (Darroch 1961) should be used to estimate abundance.

Seber (1982) describes 4 conditions that lead to an unbiased Petersen estimate, some of which can be tested directly:

1) Marked fish mix completely with unmarked fish between events.
2) There is an equal probability of capture in event 1 and equal movement patterns of marked and unmarked fish.
3) There is an equal probability of capture in event 2.
4) The expected number of marked fish in a recapture stratum is proportional to the number of unmarked fish.

In the following tables, the terminology of Seber (1982) is followed, where $a$ represents fish marked in the first event, $n$ is the number of fish captured in second event, and $m$ is the number of marked fish recaptured; $m_{\bullet j}$ and $m_{i\bullet}$ represent summation over the $i$th and $j$th indices, respectively.

## I. Mixing Test

Tests the hypothesis (condition 1) that movement probabilities ($\theta_{ij}$), describing the probability that a fish moves from marking stratum $i$ to recapture stratum $j$, are independent of marking stratum: $H_0$: $\theta_{ij} = \theta_j$ for all $i$ and $j$.

| Area–time | Area–time recapture stratum ($j$) | | | | Not recaptured |
|---|---|---|---|---|---|
| marking stratum ($i$) | 1 | 2 | … | $t$ | $a_i - m_{i\bullet}$ |
| 1 | $m_{11}$ | $m_{12}$ | … | $m_{1t}$ | $a_1 - m_{1\bullet}$ |
| 2 | $m_{21}$ | $m_{22}$ | … | $m_{2t}$ | $a_2 - m_{2\bullet}$ |
| … | … | … | … | … | … |
| $s$ | $m_{s1}$ | $m_{s2}$ | … | $m_{st}$ | $a_s - m_{s\bullet}$ |

## II. Equal Proportions Test[2] (SPAS[3] terminology)

Tests the hypothesis (condition 4) that the marked to unmarked ratio among recapture strata is constant: $H_0$: $\Sigma_i a_i\theta_{ij}/U_j = k$, where $k$ is a constant, $U_j$ is unmarked fish in stratum $j$ at the time of 2$^{nd}$ event sampling, and $a_i$ is number of marked fish released in stratum $i$. Failure to reject $H_0$ means the Petersen estimator should be used only if the degree of closure among tagging strata is constant; i.e., $\Sigma_j\theta_{ij} = \lambda$ (Schwarz and Taylor 1998: p. 289). A special case of closure is when all recapture strata are sampled, such as in a fishwheel to fishwheel experiment, where $\Sigma_j\theta_{ij} = 1.0$, otherwise biological and experimental design information should be used to assess the degree of closure.

-continued-

[2]There is no 1:1 correspondence between Tests II and III and conditions 2–3 above. It is pointed out that equal probability of capture in event 1 will lead to (expected) non-significant Test II results, as will mixing, and that equal probability of capture in event 2 along with equal closure ($\Sigma j\theta ij = \lambda$) will also lead to (expected) nonsignificant Test III results.

[3] Stratified population analysis system (Arnason et al. 1996).

## II. Equal Proportions Test (continued)

| | Area–time recapture stratum ($j$) | | | |
|---|---|---|---|---|
| | 1 | 2 | … | $t$ |
| Recaptured ($m_{\cdot j}$) | $m_{\cdot 1}$ | $m_{\cdot 2}$ | … | $m_{\cdot t}$ |
| Unmarked ($n_j - m_{\cdot j}$) | $n_1 - m_{\cdot 1}$ | $n_2 - m_{\cdot 2}$ | … | $n_t - m_{\cdot t}$ |

## III. Complete Mixing Test (SPAS terminology)

Tests the hypothesis that the probability of resighting a released animal is independent of its stratum of origin: $H_0$: $\Sigma_j \theta_{ij} p_j = d$, where $p_j$ is the probability of capturing a fish in recapture stratum $j$ during the second event, and $d$ is a constant.

| | Area–time marking stratum ($i$) | | | |
|---|---|---|---|---|
| | 1 | 2 | … | s |
| Recaptured ($m_i$) | $m_{1\cdot}$ | $m_{2\cdot}$ | … | $m_{s\cdot}$ |
| Not recaptured ($a_i - m_{i\cdot}$) | $a_1 - m_{1\cdot}$ | $a_2 - m_{2\cdot}$ | … | $a_s - m_{s\cdot}$ |

# APPENDIX C: CALCULATING THE PROBABILITY OF DETECTING NORTHERN PIKE WITH GILLNETTING EFFORTS

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

$$CPUE_{ij} = K_j N_j - K_j C_{ij}^* \quad \text{(C1-1)}$$

where

$$CPUE_{ij} = {C_{ij}}/{E_{ij}} \quad \text{(C1-2)}$$

and

$$C_{ij}^* = \sum_{k=1}^{i-1} C_{kj} \; for \; (i \; in \; 2, \dots, s+1) \; with \; C_{1j}^* = 0 \quad \text{(C1-3)}$$

and

$N_j$ = the initial population size in experiment *j*, and

$K_j$ = average probability that a fish is captured with one unit of effort during experiment *j*.

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

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

Percentiles from the predictive distribution for the value of *K* in a new removal experiment are shown in Table C1-1 and the predictive distribution is shown in Figure C1-1.

Table C1-1. Percentiles from the predictive distribution of *K*.

| Percentile | Predicted *K* |
|---|---|
| 5% | 0.001 |
| 10% | 0.003 |
| median | 0.019 |
| 90% | 0.055 |
| 95% | 0.073 |

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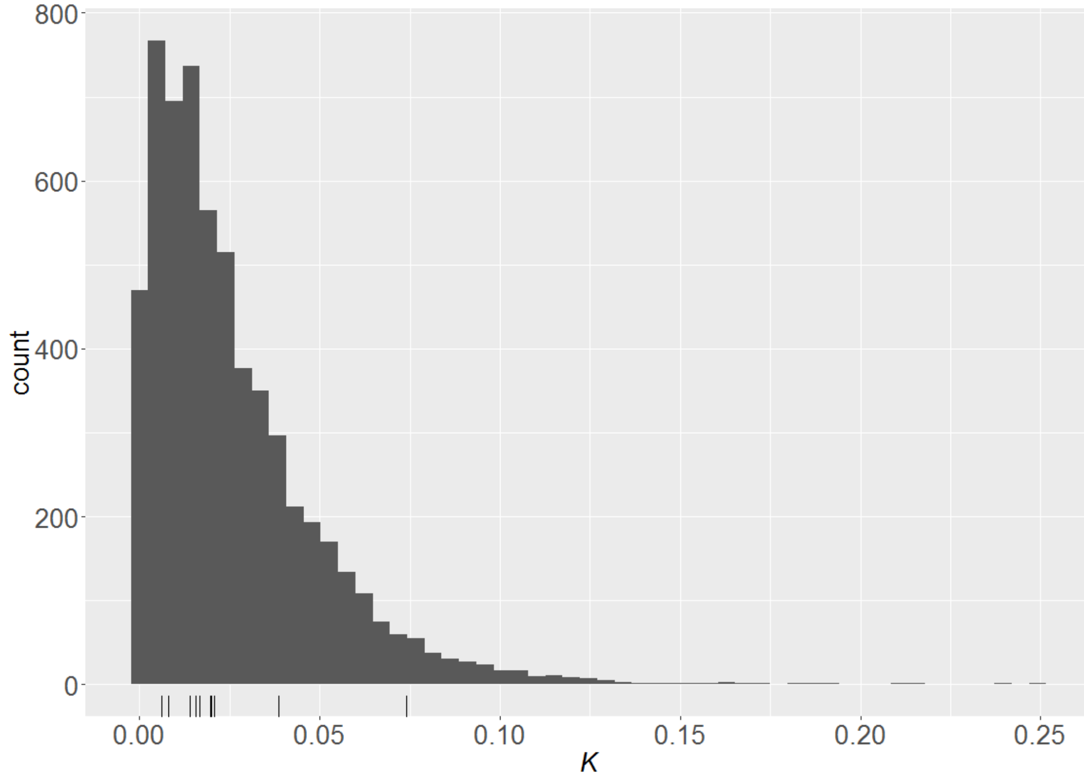


Figure C1-1.–Prediction distribution for *K*, the average probability a fish is captured in a new removal experiment with 1 unit of effort.

*Note*: Tick marks along the *x*-axis show the median values for *Kj*, the average probability a fish is captured with one unit of effort in each of the previous removal experiments.

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

$$D_p = \exp(-KE)^N. \quad \text{(C1-4)}$$

We will use the median value of *K* from Table C1-1 to calculate probabilities (Table C1-2). The value of effort will be chosen based on logistical considerations such as the number of nets and technicians available.

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Table C1-2.–Probability of failing to detect a population of 4 northern pike with various levels of netting effort.

| | Net densities | | | | | |
|---|---|---|---|---|---|---|
| Net soak time | 0.1 nets/sa | 0.25 nets/sa | 0.5 nets/sa | 0.75 nets/sa | 1 nets/sa | 2 nets/sa |
| 24 hours | 0.829 | 0.626 | 0.392 | 0.246 | 0.154 | 0.024 |
| 48 hours | 0.688 | 0.392 | 0.154 | 0.06 | 0.024 | 0.001 |
| 72 hours | 0.57 | 0.246 | 0.06 | 0.015 | 0.004 | 0 |
| 96 hours | 0.473 | 0.154 | 0.024 | 0.004 | 0.001 | 0 |

*Note*: Unit surface area is designated “sa.”