Technical Guidance and Management Plan for Invasive Northern Pike in Southcentral Alaska: 2022 – 2030

ALASKA INVASIVE SPECIES PARTNERSHIP

Invasive Northern Pike Committee

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Executive Summary

Northern Pike (*Esox lucius*) are an invasive species in Southcentral Alaska. Northern Pike are native north and west of the Alaska Range but do not naturally occur in Southcentral Alaska. The proliferation of Northern Pike within Southcentral is a tremendous fisheries management and ecological concern. Northern Pike are apex predators that preferentially prey on juvenile salmonids. Outside their native range, Northern Pike can interfere with ecosystem function and devastate economically important fisheries. Due to illegal introductions and subsequent spread away from introduction sites, Northern Pike have been found in over 150 lakes and rivers in Southcentral Alaska. Over the last decade, significant resources from multiple organizations have been allocated toward invasive Northern Pike eradication, suppression, and monitoring. In addition, invasive Northern Pike research in the region has helped guide management programs, though much remains unknown. In this next decade, the Alaska Department of Fish and Game, in partnership with federal agencies, non-governmental organizations, and universities aims to galvanize efforts to further advance invasive Northern Pike management success in Southcentral Alaska. This document is a summary of a shared vision of collaborative interdisciplinary and interagency partnership.

The specific objectives of this management plan are to:

1. Minimize future intentional invasive Northern Pike introductions and reintroductions as well as spread to new waters.
2. Increase public awareness of the invasive Northern Pike issue and support for management efforts.
3. Implement scientifically sound management tools to detect, eradicate, contain, or suppress invasive Northern Pike populations.
4. Restore fish populations that have been impacted by invasive Northern Pike introductions.
5. Conduct research to fill knowledge gaps that currently impede management of invasive Northern Pike.

This plan, guided by the known stages of the invasion process (also known as the invasion curve), identifies actions for accomplishing these objectives. Specifically, this plan provides protocols, decision matrices and standard operating procedures to: guide efforts to prevent new Northern Pike introductions, respond to new Northern Pike introductions, eradicate Northern Pike populations where feasible, restore native fish populations from waters where Northern Pike have been eradicated, contain Northern Pike populations to prevent their spread, suppress and/or monitor Northern Pike populations that cannot be eradicated, and continue research to better inform invasive Northern Pike management efforts.

While significant progress has been made in recent years, most of the work on invasive Northern Pike management in Alaska is in its infancy. Under this plan, several partner organizations are joining forces to increase capacity for invasive Northern Pike control. With this alliance there is need to coordinate and organize response activities. This plan is the first step in accomplishing this and is a significant milestone in continuing Southcentral Alaska's fight against one of its most notorious and tenacious aquatic invasive species.

Plan Development and Review Process

This Technical Guidance and Management Plan for Invasive Northern Pike in Southcentral Alaska is a guiding document developed by the Invasive Northern Pike Committee of the Alaska Invasive Species Partnership (AKISP). This committee currently includes representation by the:

- Alaska Department of Fish and Game (ADFG)
- United States Fish and Wildlife Service (USFWS)
- United States Geological Survey (USGS)
- Joint Base Elmendorf-Richardson 673 Civil Engineer Squadron (JBER-CES)
- Tyonek Tribal Conservation District (TTCD)
- University of Alaska Fairbanks (UAF)
- University of Alaska Anchorage (UAA)
- Cook Inlet Aquaculture Association (CIAA)
- Kenai Watershed Forum (KWF)

This plan includes multiple tools such as Standardized Operating Procedures (SOPs) to guide invasive Northern Pike management activities. This document is intended to foster consistency across all efforts to maximize benefits to Alaska's ecosystems and fisheries and to increase efficiencies across partner organizations. The plan was developed and written between winter 2020 and spring 2022 by a subcommittee of volunteer authors from the AKISP Invasive Northern Pike Committee. Upon completion of the plan in June 2022, it was made available for public and stakeholder review and comment. Public comments will be accepted continuously. All written public comments received will be cataloged for consideration in future revisions to the document.

This plan will be implemented between 2022-2030 and is non-binding. To keep pace with the ever-changing conditions on the ground, the plan is considered a living document and will be reassessed, revised, and updated every two years to ensure the most current information is incorporated and available to plan partners, especially in SOPs involving emerging technologies.

Biennial reviews of this plan will be conducted in 2024, 2026, and 2028. The AKISP Invasive Northern Pike Committee meets at least twice each year and provides an outlet for work sessions and discussions regarding the plan. One of these meetings in each of the review years will be dedicated to identifying needed plan updates, and the committee chair will coordinate the revision process. In 2030, a new edition of the plan will be drafted for the new decade. A similar process for plan development and public review will take place at that time.

This management plan is available online at:
Invasive Northern Pike - Removal Options, Alaska Department of Fish and Game.
About the Partnership - Alaska Invasive Species Partnership

For questions or comments, please contact the AKISP Invasive Northern Pike Committee Chair at: Kristine.dunker@alaska.gov or akispboard@gmail.com.

Mission

The mission of the AKISP Invasive Northern Pike Committee is to protect and restore the ecological and economic interests of Alaska from invasive Northern Pike.

Purpose

The purpose of this management plan is to assist plan partners in approaching Northern Pike management efficiently, consistently, and collaboratively through the standardization of methods and the sharing of expertise and resources.

Goals

1. Coordinate and collaborate with all organizations conducting invasive Northern Pike management and research in Southcentral Alaska.
2. Align methods, strategies, and protocols across all organizations working on similar response activities.
3. Identify priorities for the period, 2022-2030.
4. Strive to remain in the early detection/ rapid response phases of the invasion curve for invasive Northern Pike populations as much as possible during this plan period.

Objectives

1. Minimize future intentional Northern Pike introductions and reintroductions as well as natural spread to new waters.
2. Increase public awareness of the invasive Northern Pike issue and support for management efforts.
3. Implement scientifically sound management to detect, eradicate, contain, or suppress invasive Northern Pike populations.
4. Restore fish populations that have been impacted by invasive Northern Pike introductions.
5. Conduct research to fill knowledge gaps that guide management of invasive Northern Pike.

Problem Statement

The introduction and proliferation of Northern Pike outside their native range in Alaska has caused the loss of native fish populations, which threaten culturally and economically important fisheries and natural ecosystem function. The AKISP Invasive Northern Pike Committee will identify, prioritize, and implement outreach, management and research actions that address invasive Northern Pike concerns in manners that are scientifically sound and feasible.

Interagency Coordination and Partners

The AKISP Invasive Northern Pike Committee includes participation by multiple government, non-profit, and university groups all working toward common goals and objectives to protect Alaska's ecosystems and fisheries from the impacts caused by non-native Northern Pike introductions. The following list identifies each partner and describes their mission, jurisdiction, and roles pertaining to invasive Northern Pike management in Alaska.

Alaska Department of Fish and Game (ADF&G)

Mission Statement: The mission of ADF&G is to protect, maintain, and improve the fish, game, and aquatic plant resources of the state, and manage their use and development in the best interest of the economy and the well-being of the people of the state, consistent with the sustained yield principle.

Sport Fish Division Mission Statement: Protect and improve the state's sport fishery resources.

Commercial Fisheries Division Mission Statement: manage subsistence, commercial, and personal use fisheries in the interest of the economy and general well-being of the citizens of the state, consistent with the sustained yield principle, and subject to allocations through public regulatory processes.

Jurisdiction: ADF&G has invasive Northern Pike management jurisdiction in all waters owned by the state of Alaska.

Roles:

- Coordinates the AKISP Invasive Northern Pike Committee
- Lead agency on Northern Pike eradication projects in state waters
- Lead agency on Northern Pike suppression projects in state waters
- Lead agency for Northern Pike monitoring activities in state waters
- Partner agency on Northern Pike eradication in non-state waters
- Partner agency on Northern Pike suppression in non-state waters
- Partner agency on research efforts pertaining to invasive Northern Pike management
- Partner agency on outreach efforts pertaining to invasive Northern Pike management

United States Fish and Wildlife Service (USFWS)

Mission Statement: The mission of USFWS is to work with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people.

Jurisdiction: The USFWS implements invasive species management efforts in coordination with partners under multiple Federal Acts, Executive Orders (e.g., 13122 and 13751), and national program policies. These mandates provide the USFWS opportunities to work with others within and outside of National Wildlife Refuges (NWR) to conserve USFWS Trust species and their habitats. UFSWS has invasive Northern Pike management jurisdiction in waters owned by the Federal government.

Roles:

- Member of the AKISP Invasive Northern Pike Committee
- Lead agency in ensuring management activities comply with federal regulations (e.g., National Environmental Policy Act, Wilderness Act, Endangered Species Act) when actions occur on USFWS lands or partners are using USFWS funds
- Lead agency in rapid response for waters under USFWS ownership, and partner agency outside of those waters
- Partner agency in early detection
- Partner agency on outreach and education for invasive Northern Pike
- Partner agency on invasive Northern Pike research
- Partner agency in securing resources (e.g., data, funding, etc.) necessary to develop conservation and recovery strategies for native species

Note: Ownership of waters within Federal lands is not always clear and may require legal consultation to determine pre-statehood ownership clauses. This clarification will be sought in cases of Northern Pike introductions to National Wildlife Refuges, National Parks, Forest Service, or Forest Service lands. Otherwise, all waters in Alaska fall under state management authority.

United States Geological Survey (USGS)

Mission Statement: The mission of the USGS is to monitor, analyze, and predict current and evolving dynamics of complex human and natural Earth-system interactions and to deliver actionable intelligence at scales and timeframes relevant to decision makers.

Jurisdiction: The USGS does not have fisheries management jurisdiction.

Roles:

- Member of the AKISP Invasive Northern Pike Committee
- Partner agency on research efforts pertaining to invasive Northern Pike management.

Joint Base Elmendorf-Richardson (JBER)
673 Civil Engineer Squadron

Mission Statement: The mission of the JBER 673 Civil Engineer Squadron (CES) is to support the military mission and enhance readiness by sustaining natural environments on JBER for training, minimizing conflicts between mission requirements and land and the natural resources it supports, and to serve as stewards of the land by maintaining natural landscape features and ecosystem integrity at a broad landscape scale.

The primary objectives of fisheries management on JBER is to sustain, maintain and enhance the aquatic ecological integrity for ensuring sustainable use and environments required for realistic military training and recreational use. Streams and Lakes on JBER are managed for a variety of purposes including military training, recreational fishing, and protection of ecosystem health, sustainability, and productivity.

Jurisdiction: The Integrated Natural Resources Management Plan (INRMP) is the principal tool for managing natural resources on a military installation. JBER 673 CES Conservation office is responsible for managing natural resources on JBER, through implementation of the JBER INRMP.

Roles:
- Member of the AKISP Invasive Northern Pike Committee
- Lead agency for Northern Pike monitoring activities in JBER waters
- Partner agency on Northern Pike suppression projects in JBER waters
- Partner agency on Northern Pike eradication projects in JBER waters
- Partner agency on research efforts pertaining to invasive Northern Pike management efforts

Kenai Watershed Forum (KWF)

Mission Statement: The mission of the KWF is to work together for healthy watersheds on the Kenai Peninsula.

Jurisdiction: The Kenai Watershed Forum works throughout the Kenai Peninsula but does not have fisheries management jurisdiction.

Roles:
- Member of the AKISP Invasive Northern Pike Committee
- Partner organization on Northern Pike eradication in Kenai Peninsula waters
- Partner organization on outreach pertaining to invasive Northern Pike management
- Partner organization for early detection of invasive Northern Pike in Kenai Peninsula waters

Tyonek Tribal Conservation District (TTCD)

Mission Statement: The TTCD is a non-regulatory, nonprofit 501c3 organization that addresses local issues through community-driven conservation. Their mission is to conserve, enhance, and encourage the wise use of their natural resources. The District shares its boundaries with Game Management Unit 16B, and includes Tyonek, Beluga, Shirleyville, Alexander Creek, and Skwentna. The role of the TTCD is to provide technical and financial assistance to landowners and stakeholders within the District to help them achieve their conservation goals.

Jurisdiction: TTCD coordinates invasive species monitoring and control efforts within the District and participates in invasive species efforts in the immediately surrounding regions but holds no fisheries management jurisdiction.

Roles:

- Member of the AKISP Invasive Northern Pike Committee
- Partner agency for Northern Pike monitoring activities in waters within the TTCD
- Partner agency on Northern Pike control in waters within the TTCD
- Partner agency on research efforts pertaining to invasive Northern Pike management
- Partner agency on outreach efforts pertaining to invasive Northern Pike management
- Partner agency on juvenile salmonid monitoring

University of Alaska Fairbanks

Mission Statement: UAF is a Land, Sea, and Space Grant university and an international center for research, education, and the arts, emphasizing the circumpolar North and its diverse peoples. UAF integrates teaching, research, and public service as it educates students for active citizenship and prepares them for lifelong learning and careers.

Jurisdiction: The University of Alaska does not have fisheries management jurisdiction.

Roles:

- Member of the AKISP Invasive Northern Pike Committee
- **Educate:** Undergraduate and graduate students and lifelong learners
- **Research:** Create and disseminate new knowledge, insight, technology, artistic and scholarly works
- **Prepare:** Alaska's career, technical, and professional workforce
- **Connect:** Alaska Native, rural, and urban communities by sharing knowledge and ways of knowing
- **Engage:** Alaskans through outreach for continuing education and community and economic development
- In these capacities, UAF is a lead partner on research efforts pertaining to invasive Northern Pike ecology, evolution, and management.

University of Alaska Anchorage

Mission Statement: UAA transforms lives through teaching, research, community engagement and creative expression in a diverse and inclusive environment. Serving students, the state, and the communities of Southcentral Alaska, UAA is a comprehensive, open access, public university.

Jurisdiction: The university of Alaska does not have fisheries management jurisdiction.

Roles:

- Member of the AKISP Invasive Northern Pike Committee
- UAA is a lead partner on research pertaining to rotenone persistence and degradation.

Cook Inlet Aquaculture (CIAA)

Mission Statement: Cook Inlet Aquaculture Association is a nonprofit regional association which exists to:

- Protect self-sustaining salmon stocks and the habitat upon which they depend,
- Rehabilitate self-sustaining salmon stocks,
- Rehabilitate salmon habitat,
- Maximize the value of the Cook Inlet common property salmon resource by applying science and enhancement technology where appropriate.

Jurisdiction: Cook Inlet Aquaculture Association operations are focused on salmon fisheries enhancement and habitat projects in the Cook Inlet and Resurrection Bay watersheds but holds no jurisdiction over fisheries management decisions.

Roles:

- Member of the AKISP Invasive Northern Pike Committee
- Monitor salmon smolt and adult populations,
- Conduct habitat assessment and improvement projects,
- Assist governmental and other organizations to benefit salmon and their habitats,
- Provide community outreach and education on issues affecting the region's salmon populations and invasive species concerns,
- Serve on several regional and statewide boards and committees concerned with salmon issues,
- Operate hatcheries, which supplement natural salmon production and provide stability in the year-to-year harvest of salmon by all users–personal, sport, subsistence, and commercial.

Partner Contacts

Table 1. Primary points of contact for each partner organization

Organization	Role	Region	Name	Contact Info
ADF&G	Region II Invasive Species Coordinator **(AKISP Invasive Northern Pike Committee Chair)**	Southcentral AK	Kristine Dunker	kristine.dunker@alaska.gov (907) 267-2889
USFWS	Regional Invasive Species Program Coordinator	All of Alaska	Aaron Martin	Aaron_E_Martin@fws.gov (907) 376-0568
USGS	Research Ecologist	Western States	Dr. Adam Sepulveda	asepulveda@usgs.gov (406) 994-7975
JBER (CES)	Fisheries Biologist	Joint Base Elmendorf-Richardson	Colette Brandt	Colette.brandt@us.af.mil (907) 384-3380
KWF	Environmental Scientist	Kenai Peninsula	Maura Schumacher	maura@kenaiwatershed.org (907) 260-5449 x1208
TTCD	Conservation Director	ADF&G Game Management Unit 16B	Jillian Jablonski	jjablonski@tyonek.com (907) 646-3110
UAF	Associate Professor College of Fisheries and Ocean Sciences	All of Alaska	Dr. Peter Westley	pwestley@alaska.edu (907) 474-7458
UAA	Associate Professor and ASET Lab Coordinator	All of Alaska	Dr. Patrick Tomco	pltomco@alaska.edu (907) 786-1260
CIAA	Biologist	Cook Inlet Watershed	Andy Wizik	awizik@ciaanet.org (907) 283-5761

Note: Updated through July 2022.

How to Get Involved

In addition to the plan partners listed above, other organizations are encouraged and welcomed to become involved with invasive Northern Pike response. Potential additional stakeholders include, but are not limited to, tribal organizations and governments, sport and commercial fishing organizations, sport fish guide businesses, borough and municipal governments, conservation non-profits, and law enforcement entities. For stakeholders desiring formal participation in this plan and the Alaska Invasive Species Partnership (AKISP) Invasive Northern Pike Committee, organization representatives should contact the committee chair (currently ADF&G Southcentral Invasive Species Coordinator) at: kristine.dunker@alaska.gov or the AKISP Board of Directors at: akispboard@gmail.com to be put in contact with the current committee chair.

Partner Coordination and Agreements

For projects that cross jurisdictions or involve multiple plan partners, efforts should be made to establish clear guidance on the roles and responsibilities of each organization during the initial planning phase of projects. In most cases, the management agency partner organization with jurisdiction of the affected waterbody should be the project lead. For all new projects initiated under this plan, partner organizations will strive to identify goals, timeframes, permit requirements, staff and equipment needs, and cost estimates during initial planning of each project. Primary points of contact (POCs) will be identified for each contributing partner organization. POCs will facilitate project discussions within their respective organizations and serve as liaisons for communications between partners. Under the best practices suggested by this plan, these tasks should be completed before funding acquisition begins.

It is anticipated that most projects conducted under this plan will require funding support through grants (Appendices 1,2). The agency partner with jurisdiction should lead the grant application process. However, whenever possible, participating partners should all review grant applications before submittal. It will be the POCs' responsibilities to acquire any needed approvals within their organizations during this review process. Once funding is acquired, partner organizations should immediately develop a Cooperative Agreement (CA) detailing the project timeline, resource contributions, and the tasks each partner is responsible for (Appendix 3). The lead organization should draft the initial agreement, but all partners must be involved in its development. In certain cases, a multi-phase CA may be required. This would be appropriate for projects requiring compliance with the National Environmental Policy Act (NEPA) or other permits that may result in final project plans differing from those agreed upon during initial planning. In these cases, the first CA may establish responsibilities through the permitting processes, and the second CA would then outline the technical details after a management action is selected and permitting concludes.

The steps and considerations outlined above will facilitate communication and organization of complex efforts. These may not be required for small-scale actions, but they are encouraged for all projects that are multi-jurisdictional, involve emerging technologies, or where collaboration would be beneficial. However, as discussed throughout this plan, invasive Northern Pike management success is often contingent on early detection and rapid response of new populations. All efforts to establish project partnerships should be mindful of this and as expedient as possible, especially in cases necessitating rapid coordinated response.

Background: Invasive Northern Pike in Alaska

Distribution

Northern Pike (*Exox lucius)*, hereafter Northern Pike, have a native Holarctic circumpolar distribution including northern Europe, Asia, and North America generally above 40° latitude. Illegal anthropogenic introductions of Northern Pike have expanded their range in several countries in Europe and Africa, southwestern British Columbia, and throughout the American west including Southcentral Alaska (Figure 1). Northern Pike are native in northern and western Alaska, but not native south or east of the Alaska Mountain range, except for a small, isolated remnant population near Yakutat that was recently confirmed to have ancient origins genetically aligned with populations outside Alaska (Jalbert 2018; Mecklenburg et al. 2002; Morrow 1980; Figure 2). The natural distribution of Northern Pike in Alaska is largely the result of geologic barriers during the Late Pleistocene when the majority of southern Alaska was glaciated (Oswood et al. 2000, Seeb et al. 1987; Figure 2 Insert). For approximately 11,000 years, freshwater fish assemblages in drainages in Southcentral Alaska, defined as the region south of the Alaska Mountain Range, developed in the absence of this aquatic apex piscivore (Haught and von Hippel 2011, Patankar et al. 2006). Stories from residents converge on an account that in the late 1950s, Northern Pike were first transported by an angler from the Minto Flats in the Interior to Bulchitna Lake in the Yentna River drainage in the Susitna River basin. Subsequent flooding (Lamke 1972), continued illegal introductions, and Northern Pike movements through open waters resulted in their eventual establishment in over 150 lakes and rivers in the Susitna drainage, Knik Arm drainage, Anchorage Municipality, northern Kenai Peninsula and west Cook Inlet drainages (Figure 3).

Biology and Life History

Northern Pike are commonly found in shallow vegetated lakes, flooded wetlands, low-gradient rivers, and backwater sloughs. They are opportunistic apex predators that are primarily piscivorous but will also prey on small mammals, waterfowl, amphibians, and invertebrates. Where Northern Pike are not native, they can both directly and indirectly alter freshwater fish communities especially in waters providing optimal spawning and rearing conditions (i.e. Cathcart 2019, Sepulveda et al. 2013, Bystrom et al. 2007). They occupy a top predator niche in all waters they occur in (Persson et al. 2018). In their native range, Northern Pike naturally play a pivotal top-down role in shaping freshwater fish assemblages in shallow low-flow habitats with abundant aquatic vegetation (Spens and Ball 2008). Examples of natural Northern Pike-dominated systems in Alaska include the Minto Flats near Fairbanks, the Dall River tributary of the Yukon River, and the Innoko River in western Alaska. In Southcentral Alaska, there is a plethora of similar lowland habitat that naturally functions as vital rearing habitat for Chinook Salmon (*Oncorhynchus tshawytscha)*, Coho Salmon (*O. kisutch)*, and Rainbow Trout (*O. mykiss)*, among other species. In these waters, Northern Pike predation on juvenile salmon and trout is prevalent (Dunker et al. 2018a).

Northern Pike spawn in the spring, generally beginning under ice cover in April and continuing through the end of May, though this is site-specific. They become mature at 2-3 years of age

(Craig 2008). Fecundity varies by size, but large females can produce up to 300,000 tiny eggs during annual spawning events (Frost and Kipling 1967). Northern Pike are broadcast spawners; therefore, abundant aquatic or emergent vegetation is essential habitat criteria for egg adhesion (Inskip 1982). After fertilization, eggs generally hatch within 30 days, and Northern Pike fry are free-swimming by two weeks depending on water temperature (Raat 1988). By the time they reach 50 mm in length, they can be piscivorous (Casselman 1996). Northern Pike have broad physiochemical tolerances and can withstand a wide range of water quality conditions, including saline conditions up to 10-15 ppt (Jacobsen and Engstrom-Ost 2018). Under optimal habitat, prey, and temperature conditions, Northern Pike can achieve high population densities (Haugen and Vollestad 2018). Their movement patterns are variable with some populations exhibiting limited movement while other populations move significant distances, especially if migrating to overwintering habitats (Albert 2016). Within populations, individual movement patterns also vary with some individuals remaining mostly sedentary while others are highly mobile (Rutz et al. 2020). In Southcentral Alaska, commercial salmon set netters occasionally report catching Northern Pike in Cook Inlet [ADFG Unpublished]. Recently, otolith microchemistry has established that Northern Pike can use Cook Inlet to disperse presumably from the Susitna River to colonize new drainages (See Research Section: Figure 28). Life history factors such as these all contribute to the invasion success of Northern Pike in Southcentral Alaska (Dunker et al. 2018).

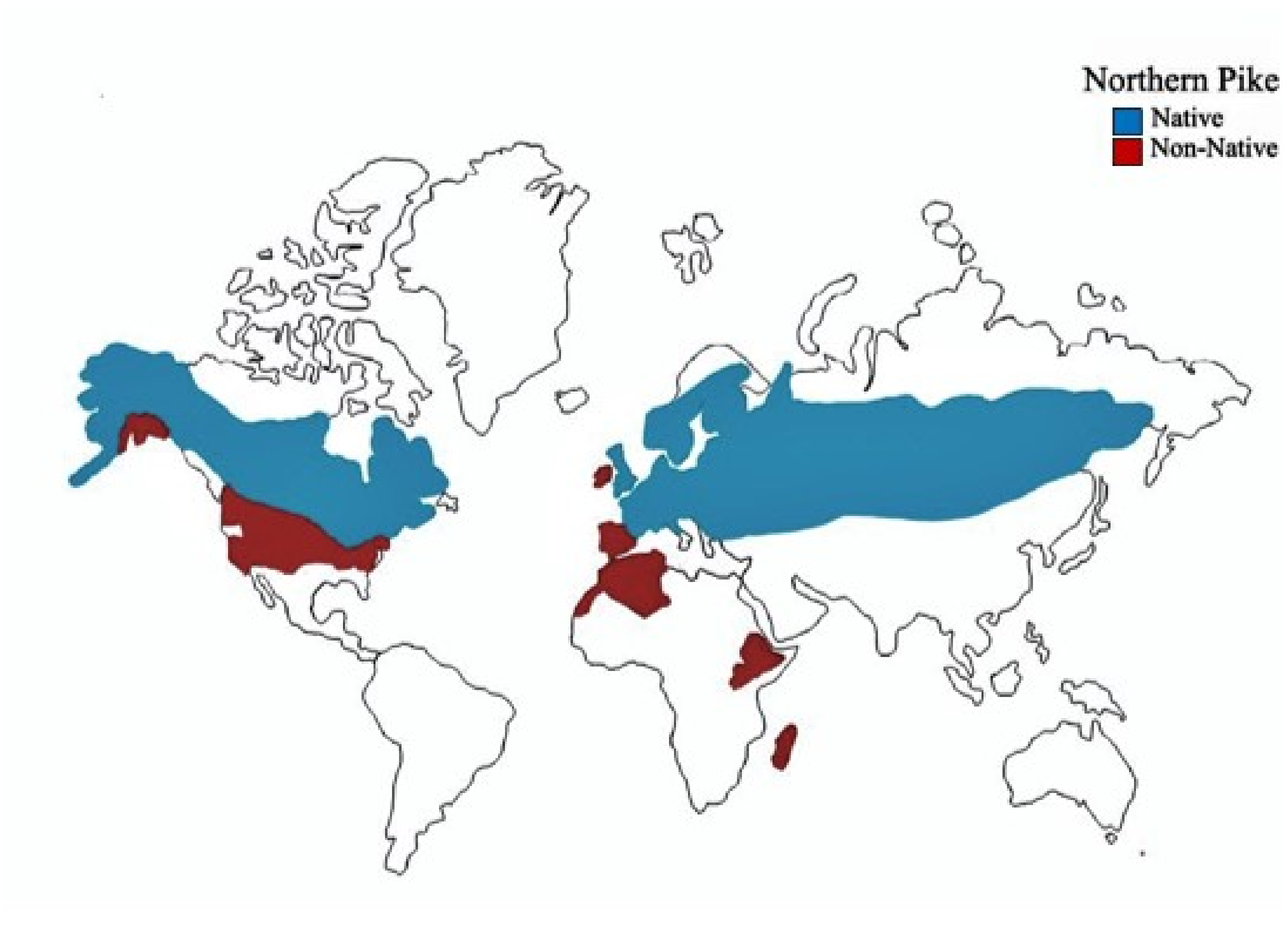
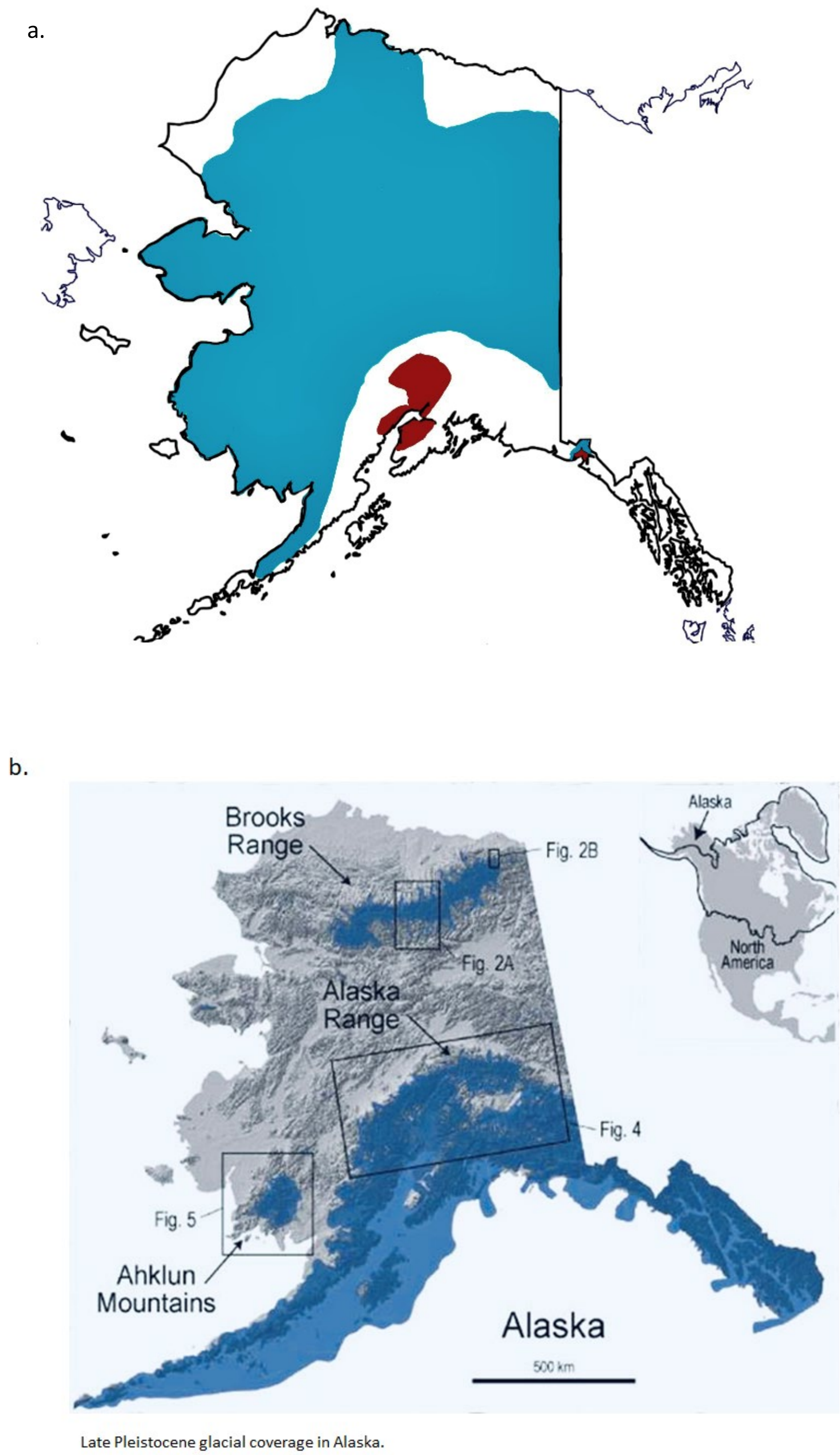
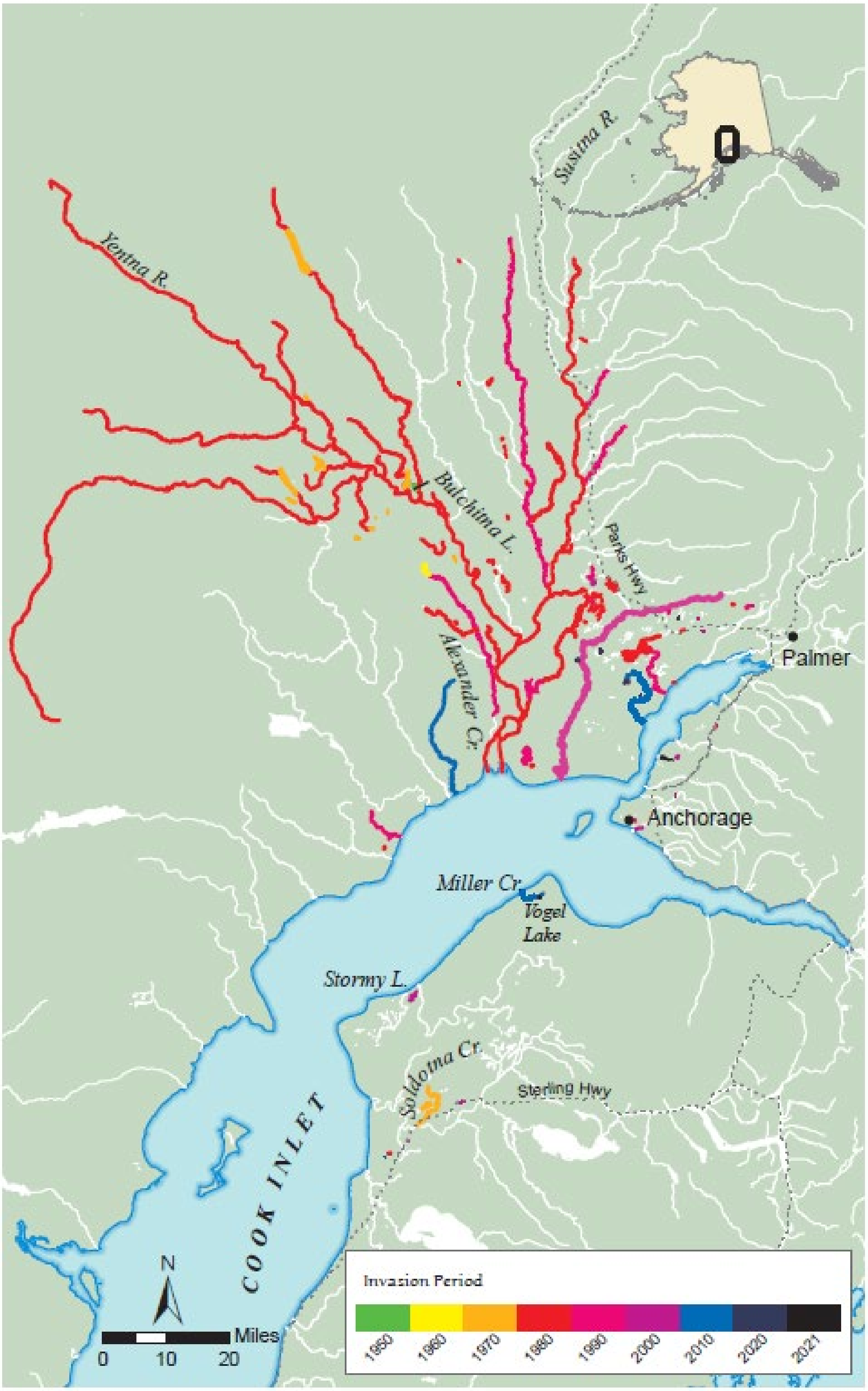


Figure 1. Global distribution of native and non-native Northern Pike



Note: a. Northern Pike range in Alaska Invasive range aligns with late Pleistocene glacial coverage as shown in panel b.

Figure 2. Distribution of native and non-native Northern Pike in Alaska.



Note: Modified with permission from Dunker et al. 2018a.

Figure 3. Time series of Northern Pike introductions to Southcentral Alaska.

Ecological and Economic Impacts

The impacts of Northern Pike in Southcentral Alaska span a spectrum from little observable changes to fish communities to complete extirpation of all fish except stunted Northern Pike. The degree of habitat complexity and connectivity across invaded waters is thought to be the primary reason explaining this variability (Dunker et al. 2018a, Sepulveda et al. 2013, Spens and Ball 2008). Where Northern Pike are native in western Alaska, they co-occur with the world's largest sockeye salmon (*O. nerka)* stocks in Bristol Bay. However, large sockeye drainages like the Wood-Tikchick, for example, are enormous systems with deep expansive lakes, high velocity streams, and marshy lowlands (Chihuly 1979). Northern Pike are abundant in littoral regions, marshy lake outlets, and flooded wetlands, but are rare in pelagic waters of deep lakes and turbid glacial rivers. In drainages with this high degree of habitat heterogeneity, salmon can be spatially or temporarily vulnerable to Northern Pike predation during parts of their life cycle, but largely avoid predation otherwise; therefore, the population-level implications for salmon populations are more negligible (Glick and Willette 2016, Sepulveda et al. 2013). In drainages where Northern Pike are native and have more homogenous habitat with favorable conditions for them, they naturally make up a large proportion of the fish in those waters (Baker 2018, Stuby 2018, Schwanke 2012, Russell 1980). Northern Pike in the nearshore shallows likely limit Coho and Chinook Salmon abundance in Bristol Bay.

Where Northern Pike are not naturally occurring in Southcentral Alaska, there is similar diversity in habitat with areas that are both highly suitable and unsuitable for Northern Pike. The Susitna Basin is approximately 1.6 million acres, and much of the watershed includes high-velocity clear or turbid glacial rivers, particularly in the eastside Susitna River tributaries. In these waters, Northern Pike may be less likely to establish abundant populations or have significant population-level impacts on salmonid populations because of habitat segregation that mitigates their predation risk (Jalbert et al. 2021). In contrast, the westside Susitna streams tend to be lower-gradient, and the surrounding landscape is an extensive interconnected mosaic of lakes, ponds, creeks, marshes and floating bog. Habitat conditions for Northern Pike in several westside tributaries are much more favorable, and consequently, Northern Pike abundances in these drainages are higher. However, in some cases, westside tributaries with more variable habitat (i.e. Deshka River) have high localized Northern Pike predation on salmonids, but salmon populations persist because there are areas of the river where salmonids can avoid predation (Sepulveda et al. 2013). In contrast, in systems that lack predation refugia and have complete habitat overlap between salmon and Northern Pike (i.e. Alexander Creek), predation impacts are greater (Sepulveda et al. 2013). This same effect was observed in over 20 shallow lakes on the Kenai Peninsula where Northern Pike became the only species present not long after Northern Pike were introduced. In waters where habitat conditions favor Northern Pike, multiple native fish populations from salmonids to sticklebacks (*Gasterosteus aculeatus)* have been lost (Haught and von Hippel 2011, Patankar et al. 2006). Northern Pike diet investigations have illustrated a general trend where Northern Pike prey on soft-rayed fishes before species such as sticklebacks and sculpin (*Cottus congnatus*), waterfowl, mammals, or other Northern Pike are depredated (Sepulveda et al. 2013). However, Northern Pike exhibit plasticity in their diets and shift to other taxa, most typically aquatic insects, once preferred prey are depleted (Cathcart 2019).

Changing climate patterns have potential to exacerbate the ecological impacts of invasive species (Havel 2015), including Northern Pike (Ohlund et al. 2015, Spens and Ball 2008). Specific to

Northern Pike, warming water temperatures have the potential to make them even more efficient predators (Hein et al. 2014). Modelling studies from Scandinavia predict that Northern Pike will spread to waters they are not naturally found and eventually displace populations of native Brown Trout (*Salmo trutta)* (Hein et al. 2014, Hein et al. 2011). Their prediction, using established climate models, is that Northern Pike will colonize over 9,000 currently Northern Pike-free lakes as temperatures and habitats change. Within a century, these models predict that coexistence of Northern Pike and trout will only remain possible in 15 of these lakes (Hein et al. 2011). While these predictions relate specifically to range expansion within Northern Pike's native range in Europe, the implications are daunting in the context of invasive Northern Pike in waters historically dominated by salmonids in Alaska, especially considering rapidly warming water temperatures throughout Southcentral Alaska (Mauger et al. 2017).

In addition to the ecological consequences of invasive Northern Pike introductions, the economic and recreational impacts can be substantial and the cultural impacts priceless. In Southcentral Alaska, where salmonid populations often decline following Northern Pike introductions, so do the fisheries that depend upon them. An economic analysis found that recreational fisheries contribute approximately $1.4 billion to Alaska's economy with about 75% of that value occurring where Northern Pike are invasive (Southwick Associates Inc. et al. 2008). Commercial salmon fisheries contribute $5.6 billion annually to Alaska's economy (McDowell Group 2020), and multimillion-dollar commercial fishing operations rely on harvesting salmon that now originate in invasive Northern Pike waters (Glick and Willette 2016). When salmon harvest is reduced because of Northern Pike predation, there can be profound economic effects. Further, lodges and guide services that accommodate anglers operate in areas where Northern Pike have been introduced. Though not easily measurable, economic losses caused by Northern Pike predation can be significant, and this does not consider management costs which in Southcentral Alaska, has exceeded $8 million to date. Consequences such as these classify Northern Pike as an invasive species outside its native range (Dunker et al. 2018). Presently, Northern Pike remain restricted to only a fraction of their available habitat in Southcentral Alaska, but many drainages and salmon populations remain vulnerable to Northern Pike invasion (Jalbert et al. 2021). Northern Pike management in Southcentral has shifted greatly in recent years to mitigate this.

History of Northern Pike Regulations in Southcentral Alaska

Given that Northern Pike are a popular sport fish, their management in Southcentral as an invasive species has been an evolving and sometimes contentious process. Northern Pike are desired by many anglers and managing them both as a sport fish and an invasive species is often complicated, contradictory, and confusing for the public. ADF&G is tasked with providing recreational fishing opportunity, but the practice of enhancing fisheries by stocking hatchery-produced fish also makes public messaging about invasive Northern Pike management challenging. The Alaska Board of Fisheries (BOF) is the governing body that sets fisheries regulations in the state. Prior to 1989, Northern Pike as a newcomer to the region were not managed in Southcentral in any capacity. The list in Table 2 describes the regulatory actions that the Alaska BOF has enacted for Northern Pike in Southcentral Alaska since then. Today, there is no limit for non-native Northern Pike, and all angler-caught Northern Pike in Southcentral cannot be released alive, signaling a change in management focus from maintaining larger trophy fisheries for Northern Pike, to reducing their impacts on native species.

History of Invasive Northern Pike Management in Southcentral Alaska (2000-2020)

Table 2. History of Board of Fisheries regulatory decisions for Northern Pike in Northern Cook Inlet.

Year	Sport Fishing Regulations for Northern Pike
1989	Northern Pike bag limit was established at 10 per day 10 in possession in the Susitna-West Cook Inlet Area.
1997	Sport fishing for Northern Pike using five lines was allowed in specified lakes of the Susitna-West Cook Inlet Area including: Alexander Lake, Sucker Lake, Trapper Lake, Flathorn Lake, Whiskey Lake, Hewitt Lake, Donkey Lake, Three Mile Lake (Beluga area), Neil Lake, Kroto Lake, and lakes of the Nancy Lake Recreation Area excluding Nancy and Big No Luck Lake. No other fish caught on those lines could be retained. Lines were required to be attended, and hooks could not exceed 3/4" between point and shank.
	The 10 fish bag and possession limits on Northern Pike in the Susitna-West Cook Inlet Area were repealed.
1998	A slot limit was established for Northern Pike in Alexander and Trapper lakes. No bag and possession limits were in effect for Northern Pike less than 22 inches in length. Northern Pike between 22 inches and 30 inches were illegal to retain. The bag and possession limits for Northern Pike 30 inches in length or greater were 1 per day and 1 in possession. Additionally, the action taken for Alexander and Trapper lakes reduced the number of lines allowed when fishing through the ice for Northern Pike from 5 to 2 lines and prohibited the use of spears and bow and arrows in these lakes.
	This action resulted in allowing the use of bow and arrow for taking Northern Pike in other NCI waters and resulted in eliminating the ¾-inch single-hook size restriction when fishing through the ice on select northern Cook Inlet lakes where 5 lines were allowed.
2002	The use of five lines while ice fishing for Northern Pike expanded to seven additional lakes in Northern Cook Inlet: Trapper Lake, Big No Luck Lake, Figure Eight Lake, Cabin Lake, Lower Vern Lake, Upper Vern Lake and Lockwood Lake.
	On Trapper Lake, the slot limit for Northern Pike was removed.
	Bait, multiple hooks, spears, and bow and arrow gear were allowed on all lakes. For the purposes of sport fishing, legal bow and arrow gear was specified to include crossbows. When ice-fishing, anglers were allowed two hooks on a single line, provided that both hooks were attached to one piece of bait.
2009	The BOF met out-of-cycle in 2009. The slot limit regulation on Alexander Lake was replaced with a size limit regulation. Under the new regulation, all Northern Pike less than 27" could be harvested without a bag or possession limit, while only 1 Northern Pike larger than 27" could be retained per day and in possession.
2011	The size limit for Northern Pike on Alexander Lake was repealed; no bag, possession, or size limit exists year-round. Bow-and-arrow and spears for take of Northern Pike were allowed as in other areas of NCI.
	Anglers could fish for Northern Pike through the ice on Big and Nancy Lakes under specific guidelines: five lines from November 1 – March 15, fishing only allowed 8:00 a.m. - 5:00 p.m., hook gap at least ¾ - inch from point to shank, two single hooks allowed per line so long as both hooks were attached to the same bait, only whole legally recognized bait fish such as a herring or smelt used, bait suspended above the bottom of the lake, all lines closely attended, all fish except Northern Pike immediately released unharmed.
	In the Susitna River drainage, including all West-side tributaries and waters of the eastside Susitna River north of Willow Creek, and in all West Cook Inlet area waters, it became illegal to release Northern Pike back into the water alive. Anglers could choose to either discard dead Northern Pike in a responsible manner or harvest their catch.
2020	It became illegal to release Northern Pike back into ANY Southcentral waters alive. Anglers could continue choosing to either discard dead Northern Pike in a responsible manner or harvest their catch.
	The lakes where anglers are allowed to use five lines while fishing for Northern Pike through the ice expanded to Stephan Lake (Knik Arm Lake), Parker Lake, Whitsol Lake, Ladyslipper Lake, and Amber lakes (lower Susitna River), Shirley Lake (Willow Creek drainage lake), and Threemile Creek drainage (West Cook Inlet).
	The Threemile Lake outlet was opened to fishing for Northern Pike so long as salmon were not targeted.

Note: Color gradient indicates shift in regulations from Northern Pike fisheries to removal

Given the impacts to native fish populations that have already been incurred in Southcentral Alaska and the potential for further impacts, management efforts have been underway to mitigate the damages through invasive Northern Pike eradication, suppression, and research efforts (Figure 4).

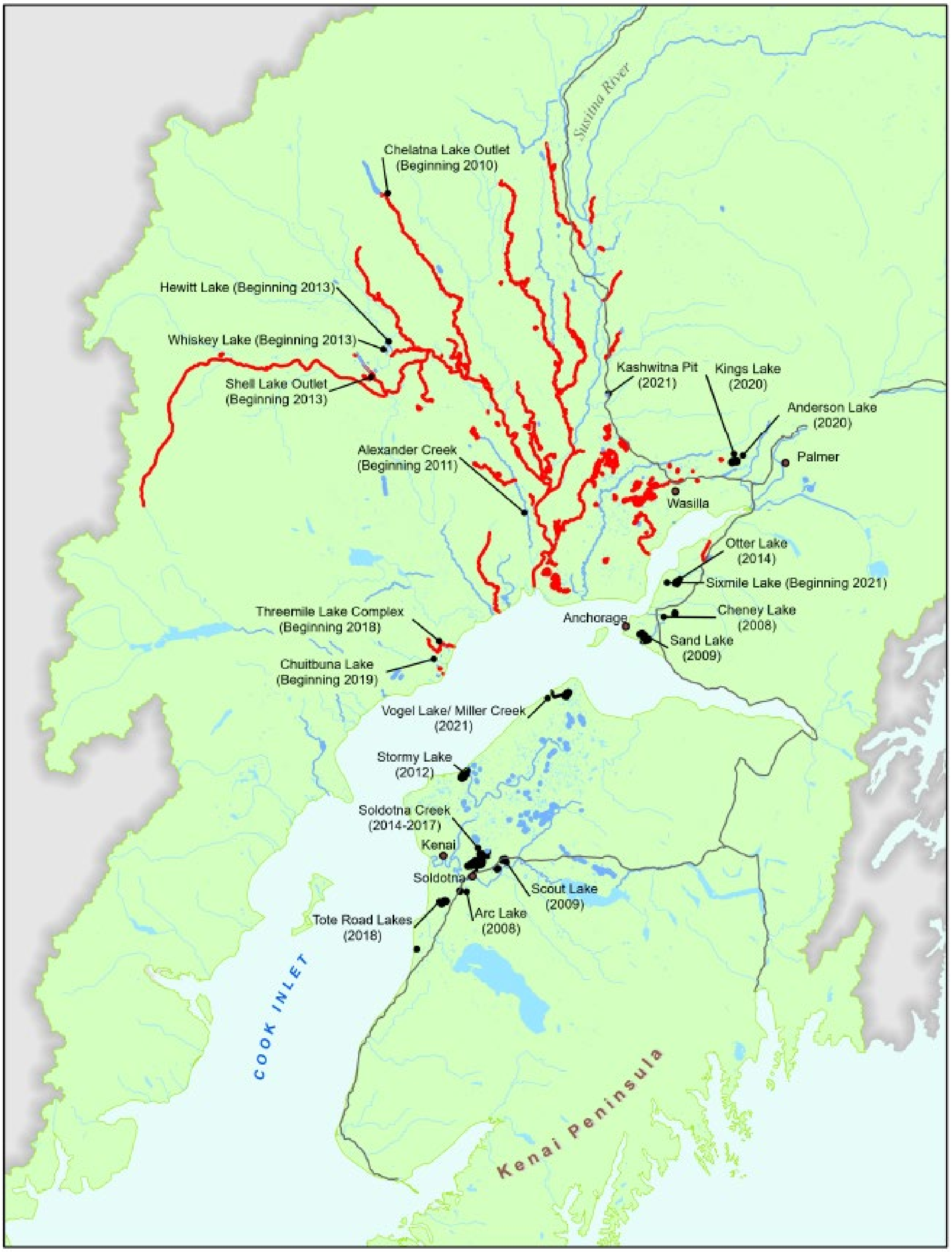


Figure 4. Drainages with Northern Pike populations (red) and with management efforts (black)

Eradication. The preferred option, whenever possible, is to eradicate Northern Pike populations because this allows for direct restoration of native fish assemblages. At present, there are few management tools that can eradicate fish populations. In rare cases, fish populations from very small lakes have been eradicated with gillnets. This was successful in three lakes on the Kenai Peninsula with intensive under-ice gillnetting, but each lake was less than 50 acres, contained low-density Northern Pike populations (~less than 30 fish), and recruitment was low (Massengill 2022). The most common method used to eradicate fish is through chemical treatments using piscicides, particularly liquid and powdered formulations of rotenone (Finlayson 2018).

ADF&G has completed over 25 rotenone treatments for Northern Pike eradication since 2008. Eradication of invasive Northern Pike in Southcentral began with small treatments of isolated lakes and later expanded to more complex systems (Table 3). Projects involving rotenone have taken one to four years to complete. These involved planning the treatments, conducting water quality and biological assessments, lake mapping, public scoping, and acquiring permits. The volume and habitat conditions of each waterbody determined the application methods (Massengill 2022, Massengill 2017b, Massengill 2014a; Table 2). Rotenone treatment success was confirmed through gillnetting, caged sentinel fish observations, analytic determination of rotenone concentration achieved, and eDNA (Sepulveda et al. 2018, Dunker et al. 2016) Post-treatment, lakes were monitored to ensure Northern Pike were not reintroduced (Massengill et al. 2020). Once rotenone treatments were complete and post-treatment assessments confirmed successful Northern Pike eradication, fisheries were restored to the treated lakes (Table 2).

Since 2008, rotenone treatments for Northern Pike eradications predominantly took place in Anchorage and the Kenai Peninsula. It is feasible to eradicate invasive Northern Pike populations entirely from these areas if they do not spread. This contrasts with the highly interconnected and expansive range of Northern Pike in the Susitna Basin. Over the last decade, the primary focus of Northern Pike eradication efforts in Southcentral Alaska has been working toward this goal.

Population Suppression. Population suppression is a common strategy employed for invasive fish management when eradication of an entire population is not feasible (Carim et al. 2022, Zelasko et al. 2016, Syslo 2013, Syslo 2011, Britton 2011). There are several Northern Pike suppression programs in westside Susitna River waters where management is necessary to mitigate impacts to native fisheries, but the spatial extent and reinvasion potential makes successful eradications unlikely. Current suppression programs in the Susitna basin take place in Alexander Creek, Chelatna, Whiskey, Hewitt, and Shell lakes and the Threemile Lake complex and Chuitbuna Lake on the west side of Cook Inlet (Dunker et al. 2020; Figure 4, Table 3).

Population Monitoring and Research. Research and monitoring of invasive Northern Pike has been on-going over the last decade and has included investigations into diets and impacts (Cathcart 2019, Sepulveda 2014, Sepulveda et al. 2013), movement patterns (Rutz et al. 2020b, Massengill 2017b), population genetics (Jalbert 2018), predicting invasion risk (Jalbert et al. 2021), comparing phenotypic and physiological differences between native and invasive Northern Pike populations (Berghaus et al. 2019, Cubbage et al. *in prep*), developing eDNA tools (Sepulveda et al. 2018, Dunker et al. 2016, Olsen et al. 2015), understanding the benefits gained by suppression in alleviating salmon consumption (Courtney et al. 2018) and better understanding the degradation process of rotenone (Redman et al. 2020, Couture et al. 2022). These investigations are highly collaborative among the organizations represented in this plan.

Table 3. History of Northern Pike eradication projects in Southcentral AK 2008-2020

Year	Water Body	Location	Volume (Ac-Ft)	Quantity[a]	Rotenone Concentration Target /Actual	Detoxification Time	Application Method	Species Re-Stocked[b]
2008	Arc Lake	Soldotna	144 AF	48 gal. CFT	50 ppb/ 35.ppb	8 months	Boat	SS, **ST**
2008	Cheney Lake	Anchorage	175 AF	58 gal. CFT	50 ppb/ 30 ppb	5 months	Boat, Backpack Spray	RT, GR, SS, **ST**
2009	Scout Lake	Sterling	835 AF	185 gal. CFT +1,100 lbs. Powder	70 ppb/ 30 ppb	8 months	Boat, Backpack Spray	RT, GR, SS, **ST**
2009	Sand Lake	Anchorage	1,138 AF	380 gal. CFT	50 ppb/ 30 ppb	7 months	Boat	RT, GR, SS, AC
2012	Stormy Lake	Nikiski	6,958AF	910 gal. CFT +7,716 Powder	50 ppb/ 48 ppb	4 months	Boat (Weighted Hose), Airboat, Backpack Spray, Deactivation	**RT, AC, SS, LS**
2014	Union Lake	Soldotna	719 AF	86.4 gal. CFT +1,113 lbs. Powder	50 ppb/ 24 ppb	8 months	Boat, Backpack Spray	**RT, SS, DV, SC, ST**
2014	East Mackey Lake	Soldotna	937 AF	112 gal of CFT + 1,445 lbs. Powder	50 ppb/ 26 ppb	6 months	Boat, Backpack Spray	**RT, SS, DV, SC, ST**
2014	West Mackey Lake	Soldotna	1,220 AF	149 gal. CFT +1,990 lbs. Powder	50 ppb/ 24 ppb	8 months	Boat, Backpack Spray	**RT, SS, DV, SC, ST**
2014	Derks Lake	Soldotna	457 AF	54.5 gal. CFT +500 lbs. Powder	50 ppb/ 24 ppb	6 months	Boat, Airboat, Backpack Spray, Deactivation	**RT, SS, DV, SC, ST**
2015	Otter Lake	JBER	839 AF	370 gal. CFT +50 lbs. Powder	50 ppb/ 24 ppb	4 months	Boat, Airboat, Backpack Spray, Drip Stations	RT
2016/ 17	Sevena Lake	Soldotna	600 AF	160 gal. CFT	40 ppb/ 36 ppb	10 days	Boat, Airboat, Backpack Spray	**RT, SS, DV, SC, ST**
2016	Soldotna Creek	Soldotna	-	50.6 gal. CFT	40 ppb/ 36 ppb	5 days	Helicopter, Drip Stations, Backpack Sprayers, ATV, Deactivation	**Natural Recolonization**
2016	Loon Lake	Soldotna	198 AF	29.5 gal. CFT + 145 lbs. of powder	40 ppb/ 28 ppb	8 months	Boat	RT
2018	Hope Lake	Soldotna	411 AF		40 ppb/ 18 ppb	3 months	Boat, Backpack Spray	**RT, SS, ST**
2018	G Lake	Soldotna	282 AF	75.2 gal. CFT	40 ppb/ 28 ppb	3 months	Boat	**RT, SS, ST**
2018	Crystal Lake	Soldotna	277 AF	73.9 gal. CFT	40 ppb/ 40 ppb	3 months	Boat	**RT, SS, ST**
2018	Leisure Lake	Soldotna	123 AF	32.8 gal. CFT	40 ppb/ 40 ppb	3 months	Boat	**RT, SS, ST**
2018	Leisure Pond	Soldotna	11 AF	3.6 gal. CFT	40 ppb/ 24 ppb	3 months	Boat, Backpack Spray	**RT, SS, ST**
2018	Fred's Lake	Soldotna	15.2 AF	15.2 gal. CFT	40 ppb/ 11 ppb	3 months	Boat, Backpack Spray	**RT, SS, ST**
2018	Ranchero Lake	Soldotna	41.6 AF	11.1 gal. CFT	40 ppb/ 24 ppb	3 months	Boat, Backpack Spray	**RT, SS, ST**

Table 2. Continued.

Year	Water Body	Location	Volume (Ac-Ft)	Quantity[a]	Rotenone Concentration Target /Actual	Detoxification Time	Application Method	Species Re-Stocked[b]
2018	CC Lake	Soldotna	267 AF	7.1 gal. CFT	40 ppb/ 26 ppb	3 months	Boat	**RT, SS, ST**
2020	Anderson Lake	Wasilla	960 AF	240 gal. CFT	40 ppb/ 39 ppb	6 months	Boat, Backpack Spray	RT, **LS, ST**
2020	King's Lake	Wasilla	872 AF	230 gal. CFT	40 ppb/ 26 ppb	6 months	Boat, Airboat, Backpack Spray	RT, **LS, ST**
2021	Kashwitna Pit	Willow	25 AF	6 gal. CFT	40 ppb/ 20.5 ppb	3 weeks	Boat	-
2021	Miller Creek (wetlands and tribs)	Kenai NWR	136 AF	36.4 gal. CFT + 10 lbs. of powder	40 ppb/ 23 ppb		Helicopter, Drip Stations, Backpack Sprayers, Mixture Balls	
2021	Vogel Lake	Kenai NWR	2,546 AF	424 gal. CFT +1,860 lbs. of powder	40 ppb/ 22.1 ppb		Boats	
2021	North Vogel Lake	Kenai NWR	727 AF	199.6 gal. CFT	40 ppb/ 20.3 ppb		Boats	

[a]CFT – CFT Legumine Liquid Rotenone, Powder – Prentox Prenfish Rotenone Fish Toxicant Powder;

[b]SS– Coho salmon, RT– Rainbow trout, GR– Grayling, AC– Arctic char, DV– Dolly Varden, LS– Longnose suckers, SC– Sculpin Sp., ST– Threespine stickleback;

Wild fish in **Bold**, otherwise hatchery stock.

Table 4. History of invasive Northern Pike suppression projects, 2011-2021.

Project Years	Water Body	Location	Total Northern Pike Removed	Project Season	Organizations	Gear
2011 – Present	Alexander Creek	Mat-Su	23,791	May	ADFG	Variable Mesh Gillnets
2011 – Present*	Deshka River	Mat-Su	920	June	ADFG	Variable Mesh Gillnets
2012 – Present	Shell Lake	Mat-Su	7,084	May-September	CIAA	1"-Bar (50'*5') Gillnets, Angling, Fyke nets
2014, 2016–Present	Whiskey Lake	Mat-Su	6,175	May-September	CIAA, ADFG	1"-Bar (50'*5') Gillnets, Angling
2014, 2016–Present	Hewitt Lake	Mat-Su	4,224	May-September	CIAA, ADFG	1"-Bar (50'*5') Gillnets, Angling
2012-2016 2017-2019	Chelatna Lake	Mat-Su	4,128	May-September	CIAA ADFG	Variable Mesh Gillnets 1"-Bar (50'*5') Gillnets, Angling, Fyke nets
2018 - Present	Threemile Lake	WCI	2,696	June	TTCD, ADFG	Variable Mesh Gillnets, Fyke Nets, Angling
2019 - Present	Chuitbuna Lake	WCI	215	June	TTCD, ADFG	Variable Mesh Gillnets, Angling
2021	Sixmile Lake	JBER	40	Winter (Under Ice)	JBER, ADFG	Variable Mesh Gillnets

Note: WCI = West Cook Inlet, JBER = Joint Base Elmendorf- Richardson (Anchorage)

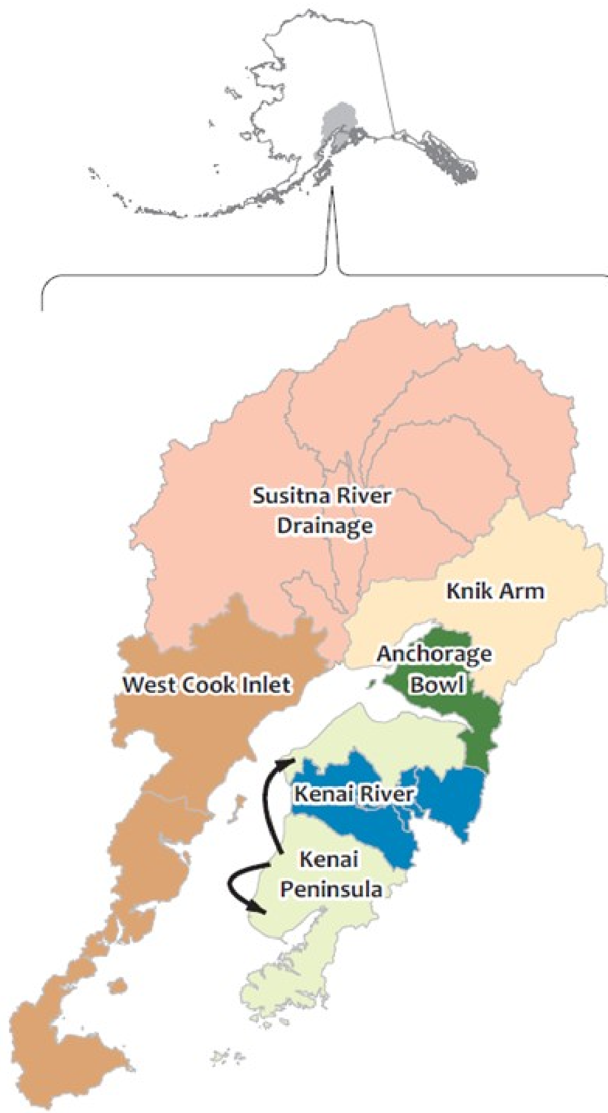
Variable mesh gillnets used were: 6 panels (3/4", 1", 1.25", 1.5", 1.75", and 2") or 4 panels (1.25", 1.5", 1.75" and 2")

*Whiskey and Hewitt Lakes were netted for less time during funding restrictions in 2016-2017, and Chelatna Lake in 2015-2016

Known Northern Pike Waters

A regularly updated GIS map of all confirmed and unconfirmed invasive Northern Pike populations in Southcentral Alaska can be found at: [Invasive Northern Pike in Southcentral Alaska (arcgis.com)](https://www.arcgis.com).

Status of Known Northern Pike Waters (2021)



Note: Borders of maps below correspond to the matching area color in this figure.

Figure 5. Southcentral Alaska management areas affected by invasive Northern Pike

Upper Kenai Peninsula

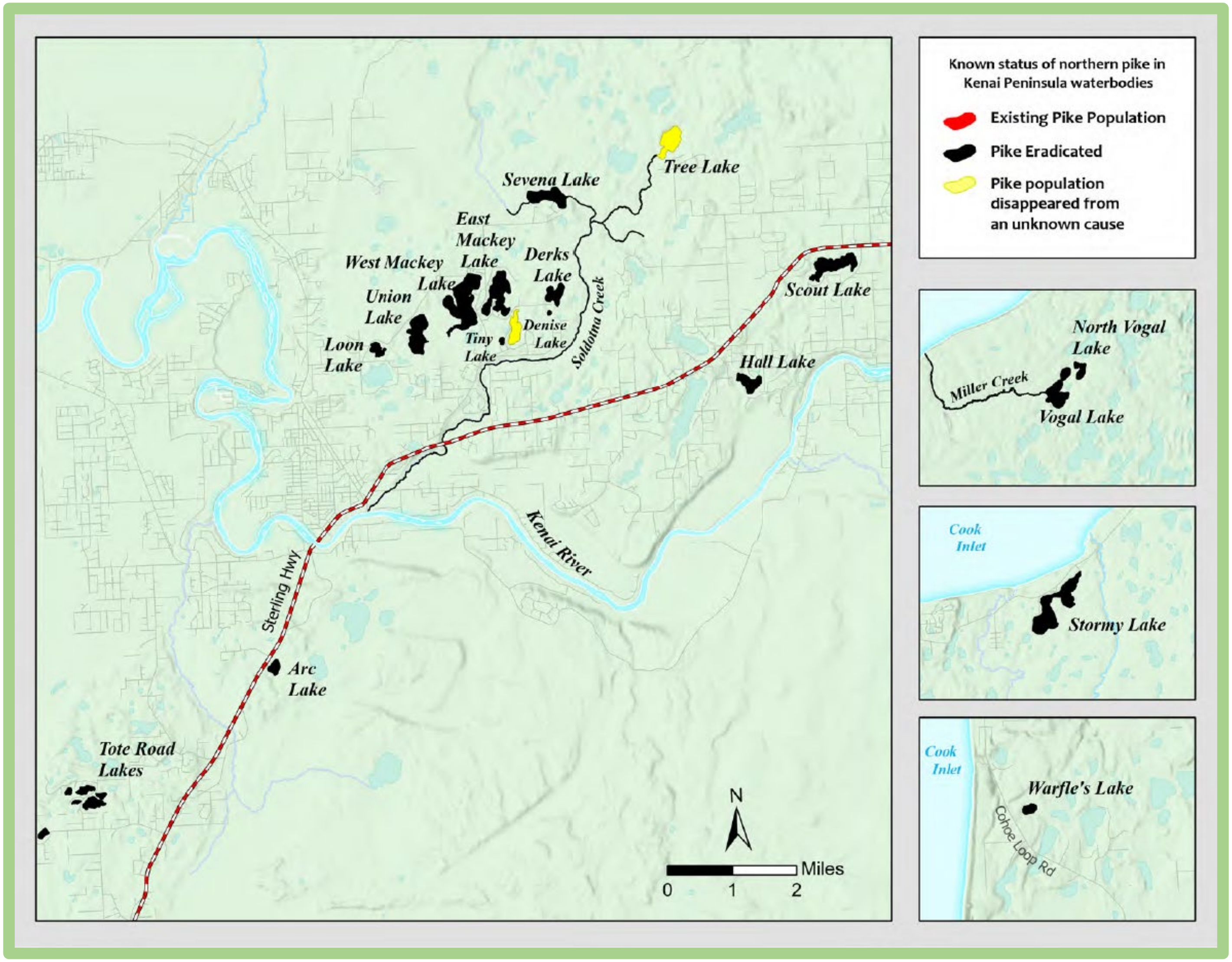


Figure 6. Status of Northern Pike waters on the Kenai Peninsula (2021)

West Cook Inlet

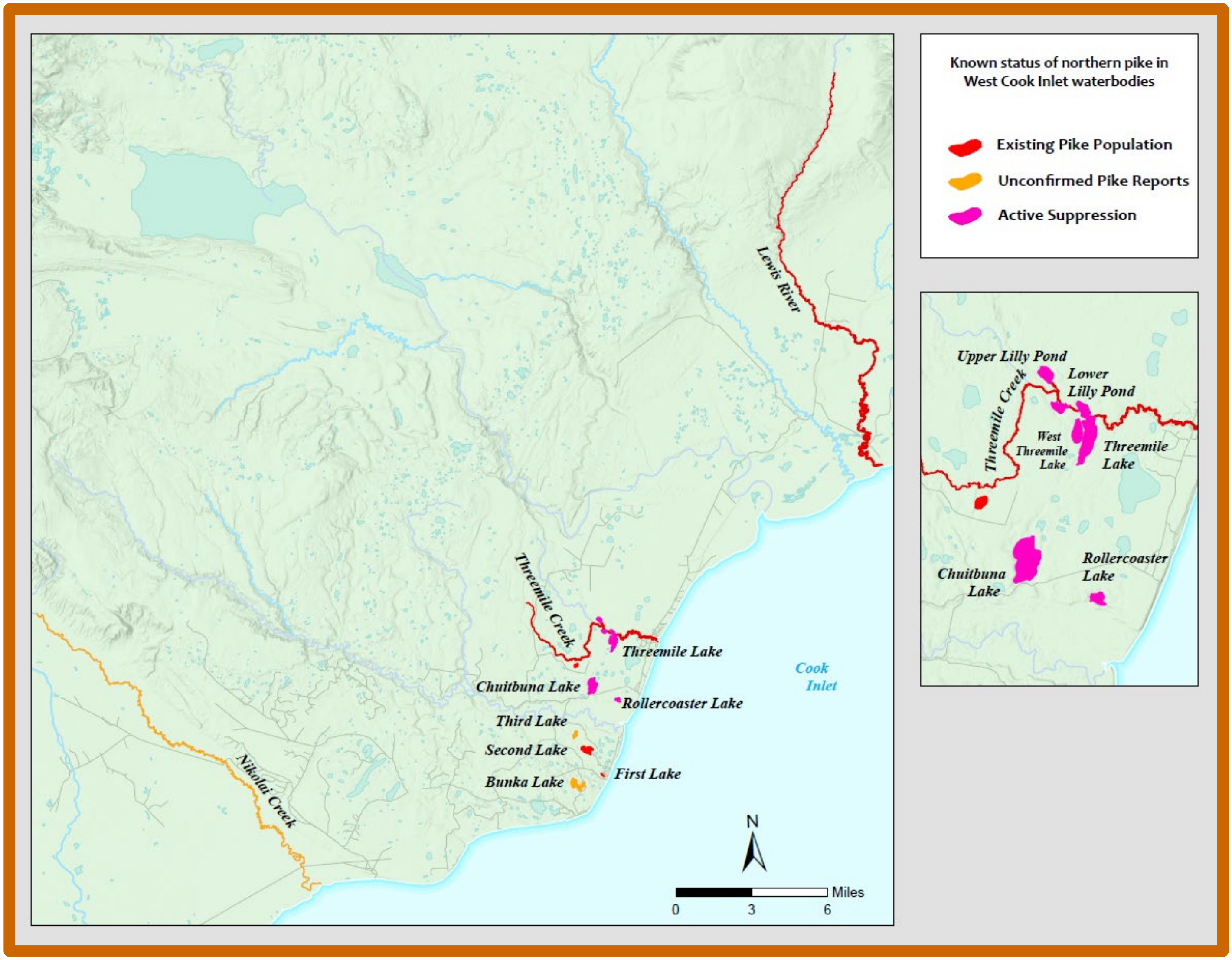


Figure 7. Status of Northern Pike waters on the westside of Cook Inlet (2021)

Anchorage

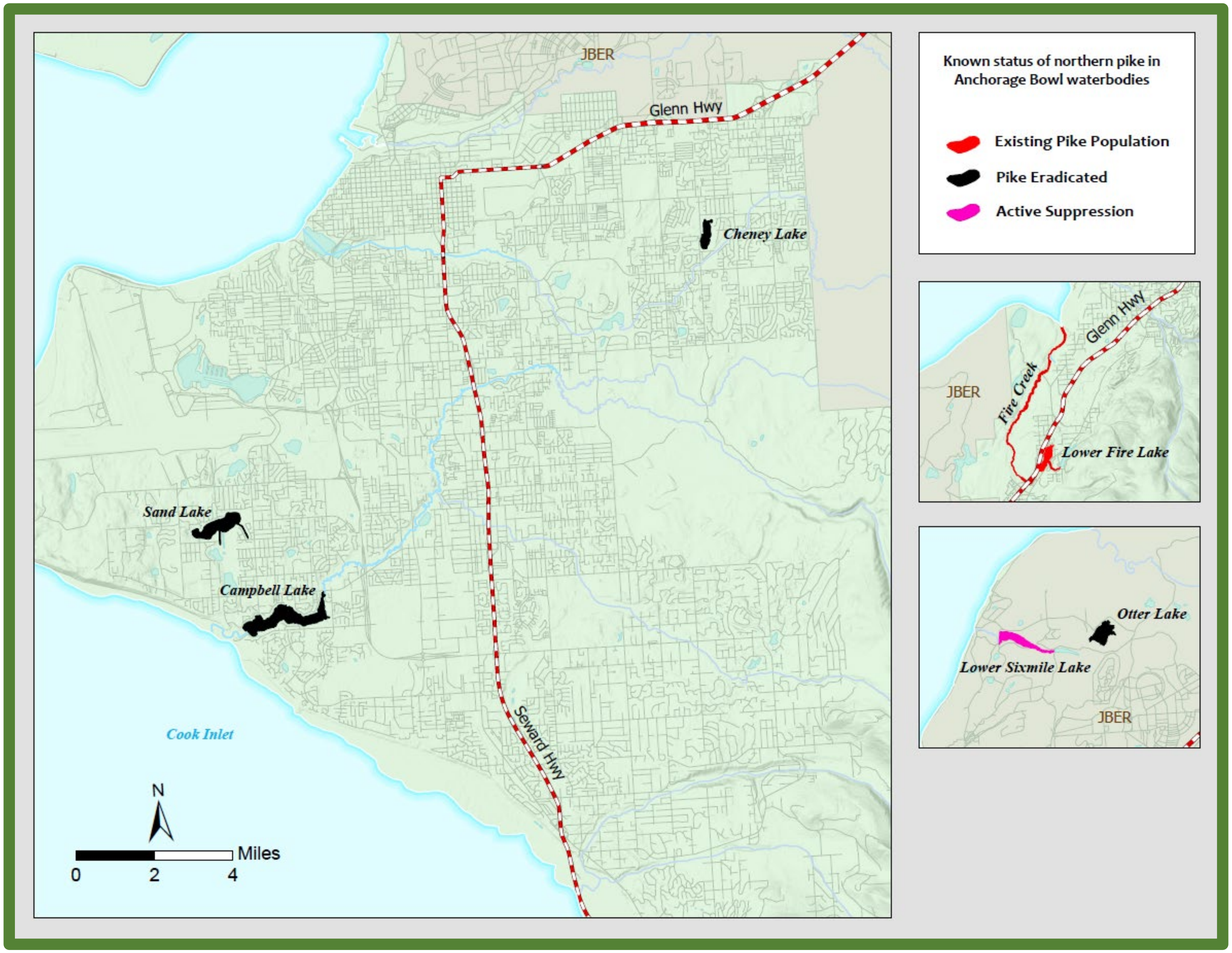


Figure 8. Status of Northern Pike waters in the Municipality of Anchorage (2021)

Matanuska - Susitna Valley - Knik Arm Drainage

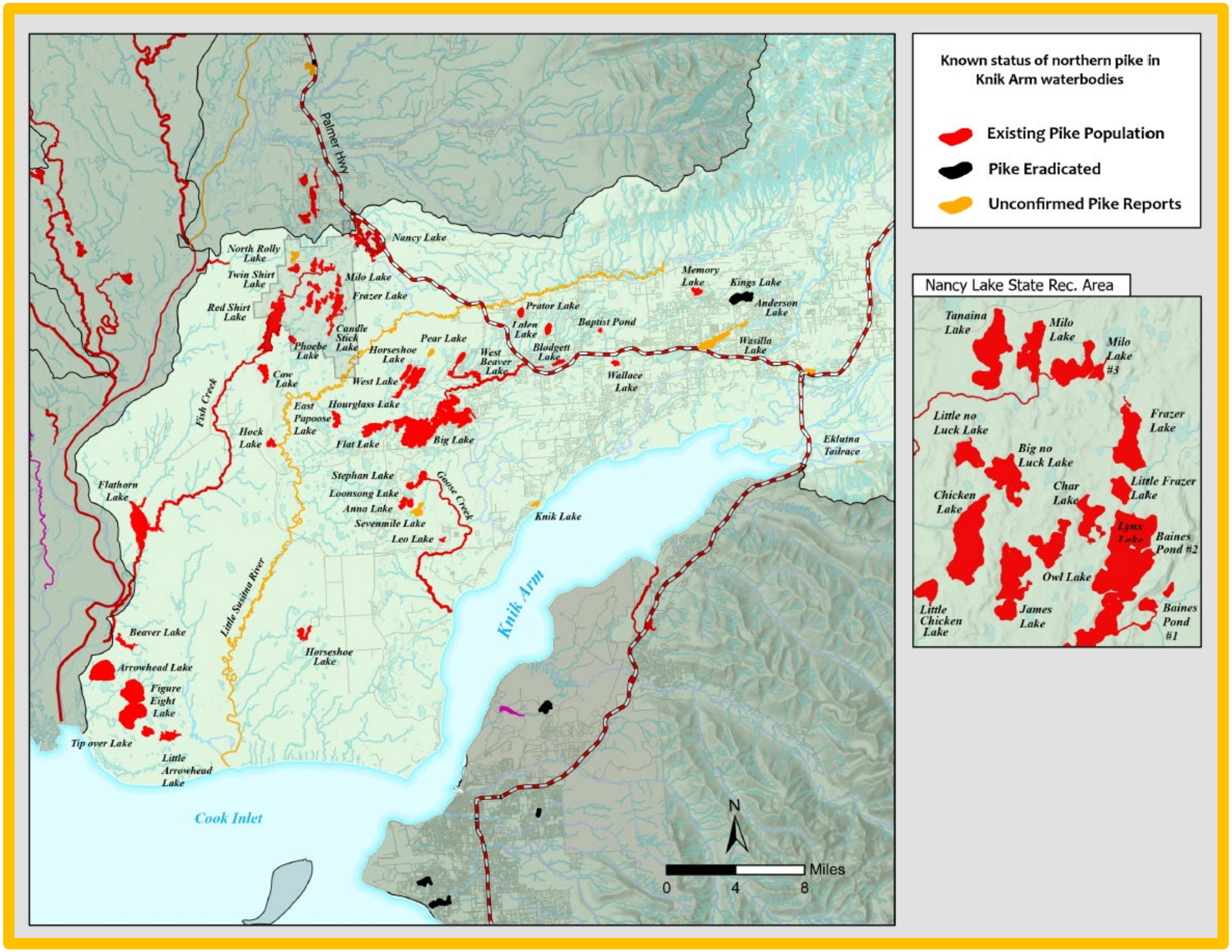


Figure 9. Status of Northern Pike waters in the Knik Arm Drainage (2021)

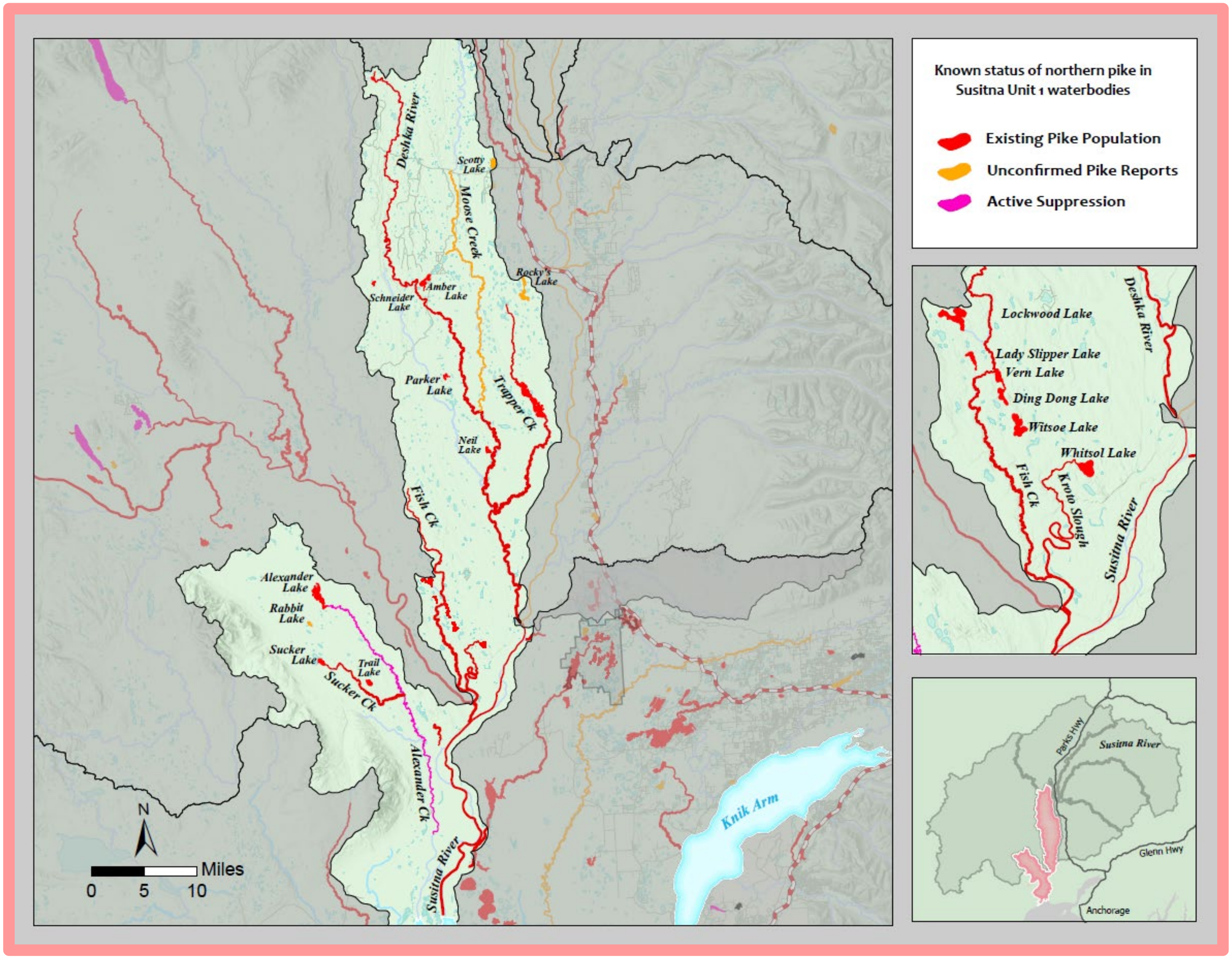


Figure 10. Status of Northern Pike waters in Susitna River Drainage Unit 1 (2021)

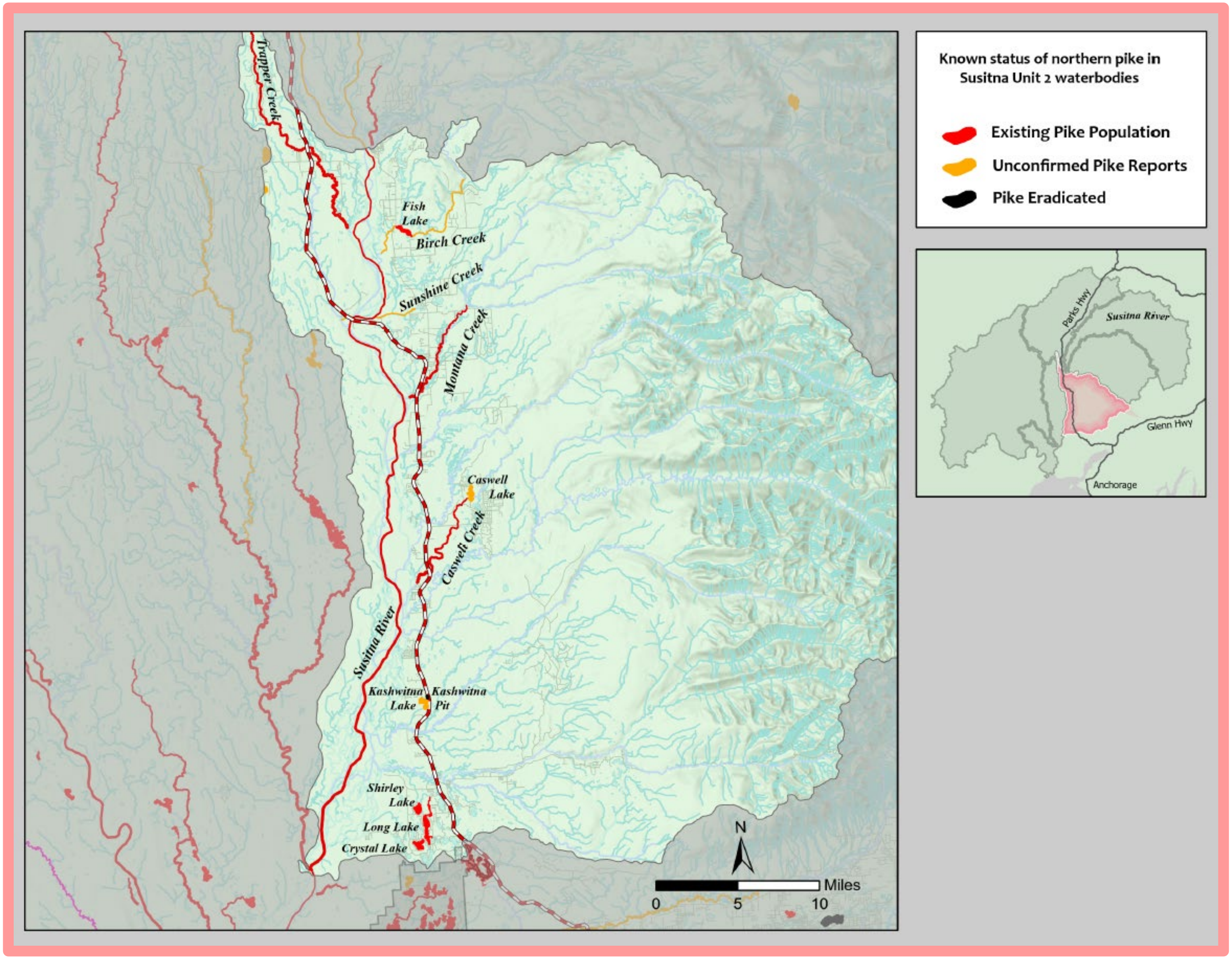


Figure 11. Status of Northern Pike waters in Susitna River Drainage Unit 2 (2021)

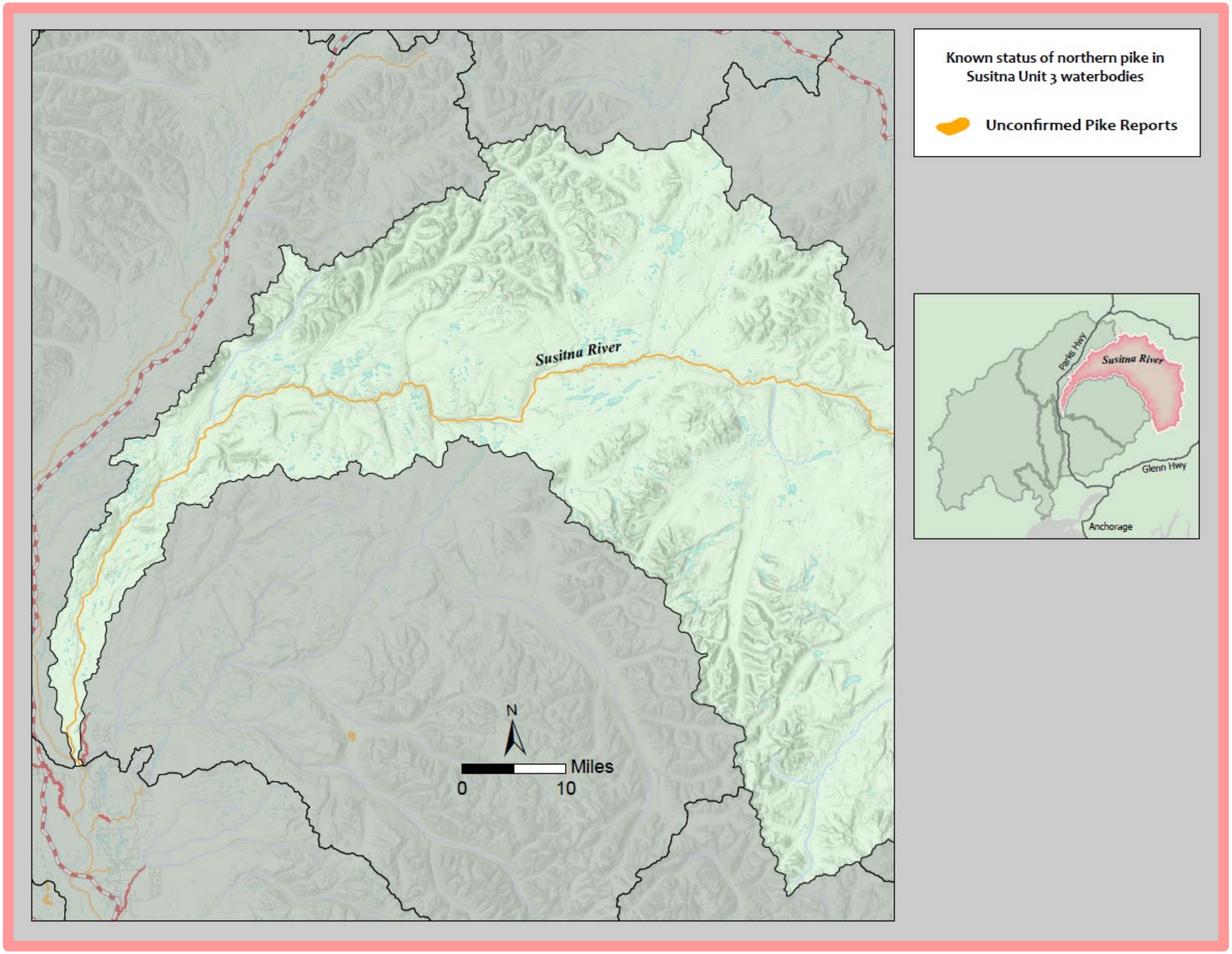


Figure 12. Status of Northern Pike waters in Susitna River Drainage Unit 3 (2021)

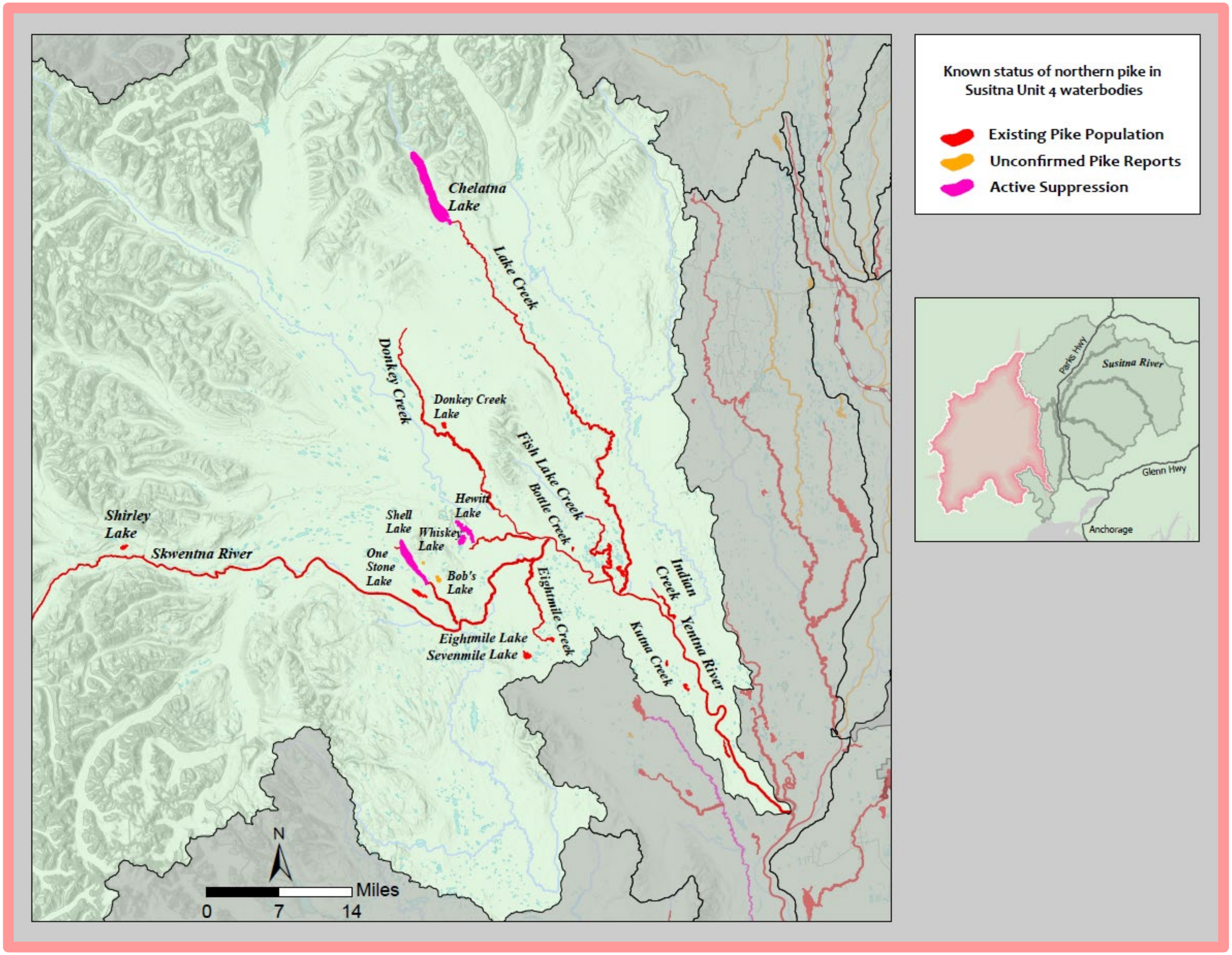


Figure 13. Status of Northern Pike waters in Susitna River Drainage Unit 4 (2021)

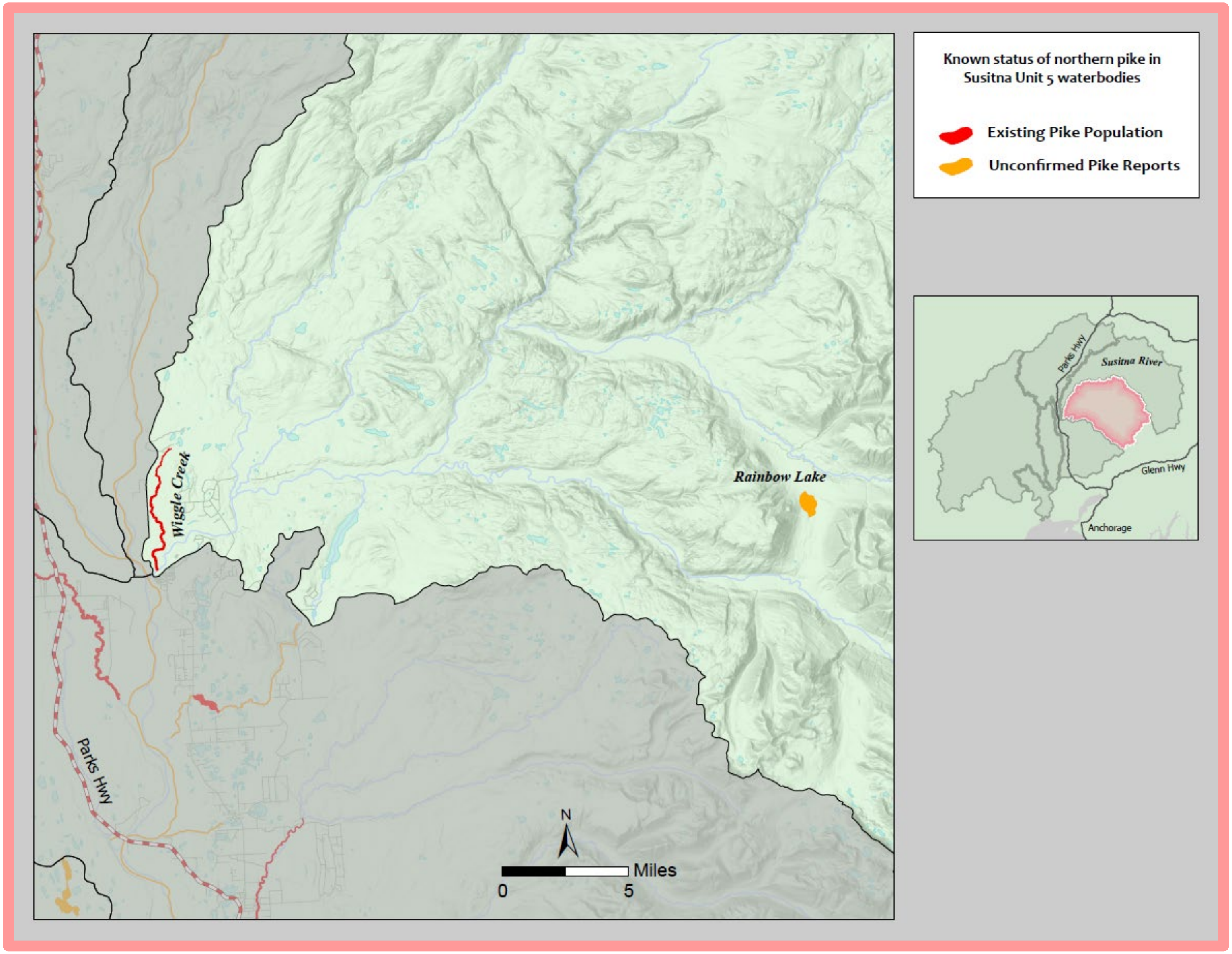


Figure 14. Status of Northern Pike waters in the Susitna River Drainage Unit 5 (2021)

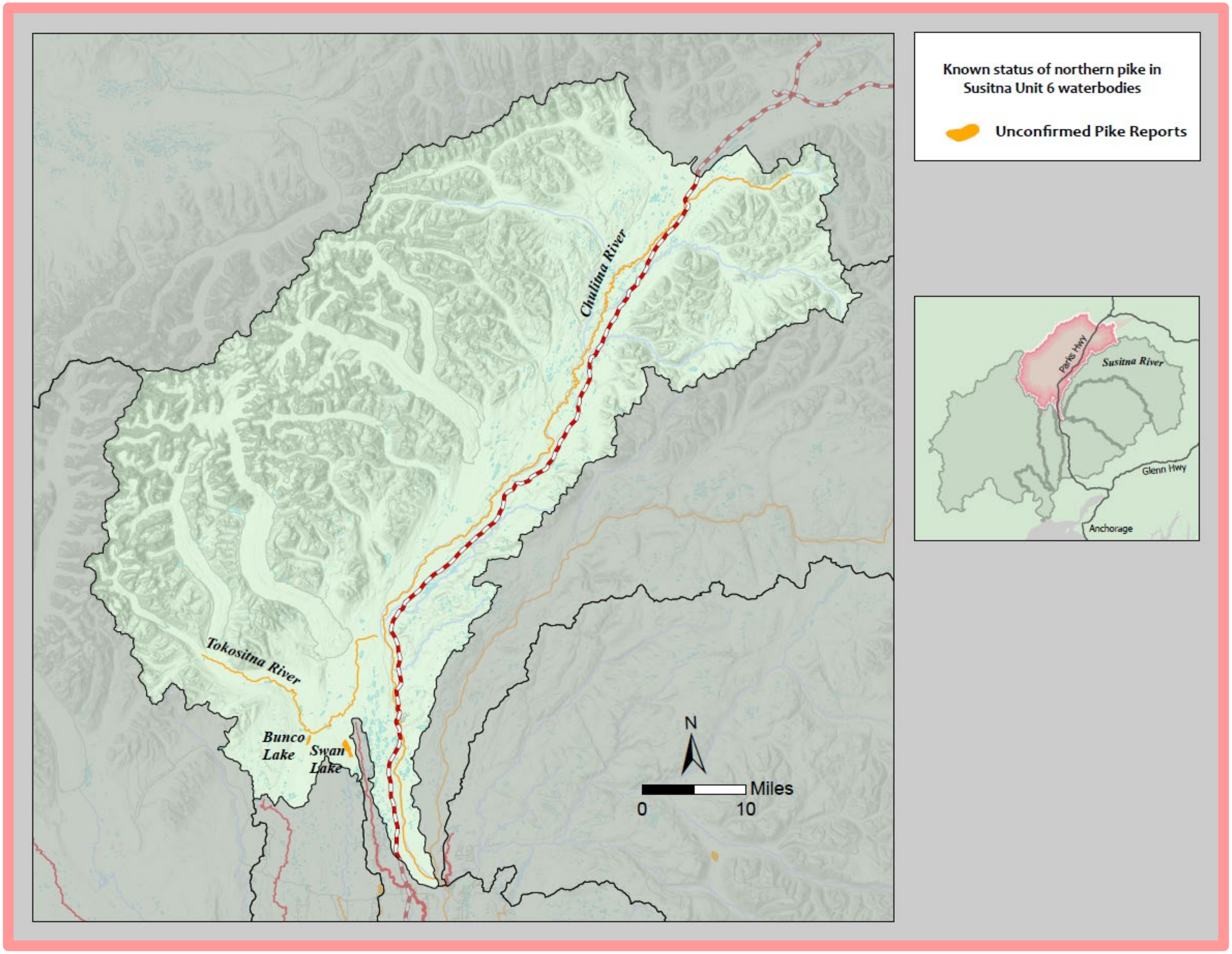


Figure 15. Status of Northern Pike waters in Susitna River Drainage Unit 6 (2021)

Northern Pike Management Strategy

The AKISP's Invasive Northern Pike Management Plan Strategy is based on the tenants of the invasive species curve in the field of invasion biology (Figure 16).

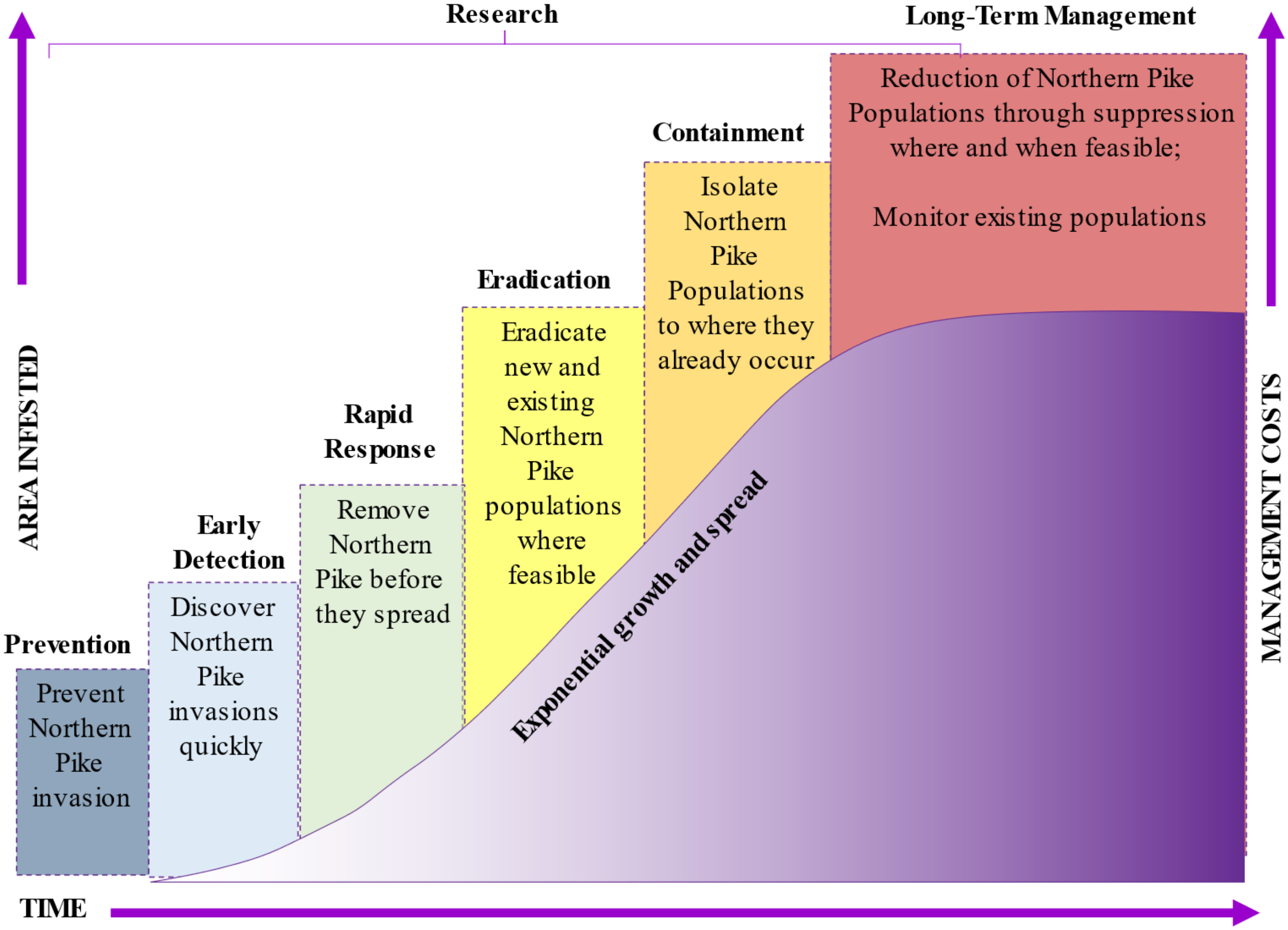
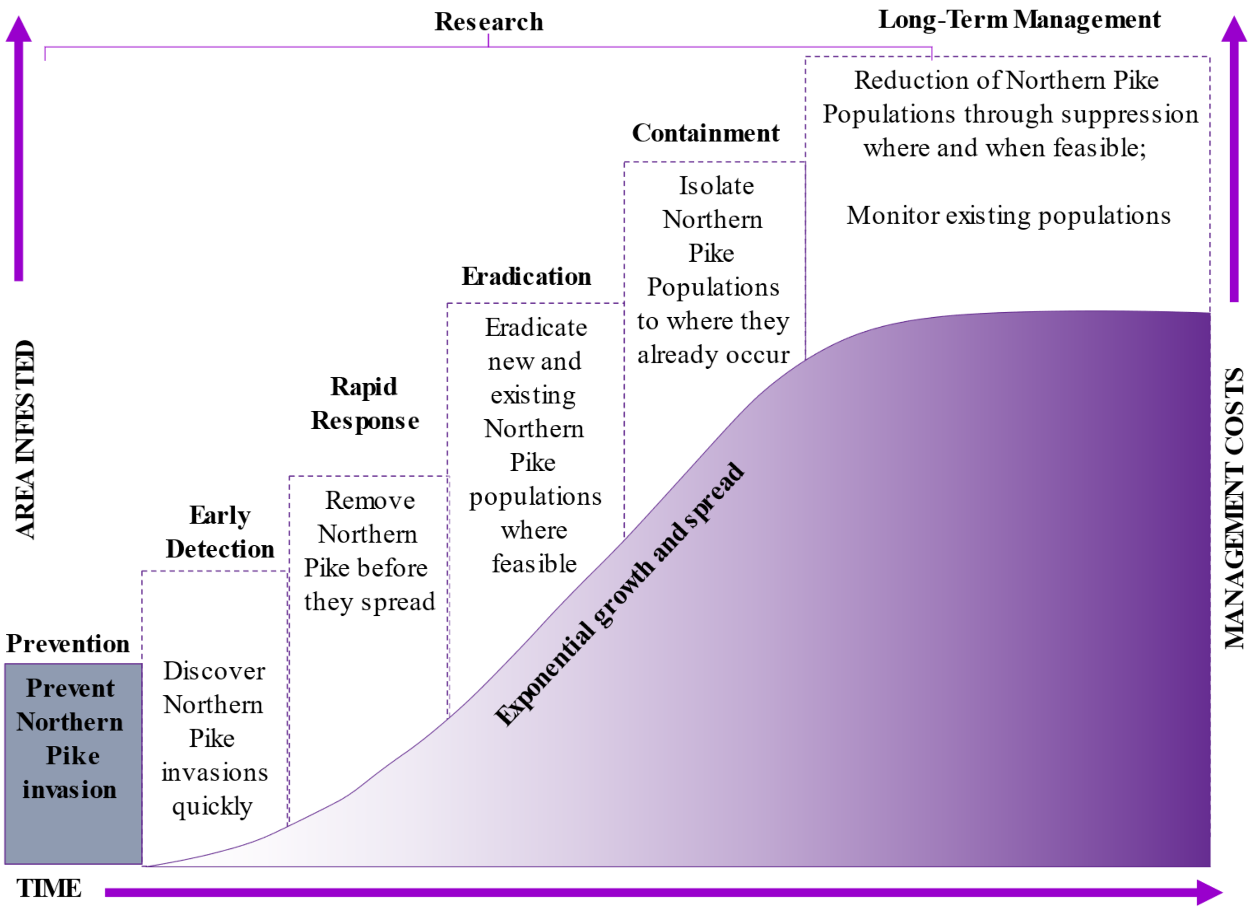


Figure 16. Invasion curve for Invasive species management

STEP 1: Prevention

Preventing introductions of invasive species is the most efficient and cost-effective management strategy when feasible (Lodge et al. 2006). With Northern Pike in Southcentral Alaska, many waters are beyond the prevention stage, but despite their widespread establishment, they still occupy only a portion of their available habitat within the region (Jalbert et al. 2021). Therefore, to the extent possible, Northern Pike management activities should be prioritized to prevent new populations from establishing. To illustrate how Northern Pike are introduced and spreading within Southcentral Alaska, and to prioritize activities that can minimize pathways of greatest concern, a Pathways Analysis is included as the first step toward improving prevention of new Northern Pike introductions. Other preventative measures discussed include the use of effective outreach and law enforcement to minimize incidences of new anthropogenic introductions. Other means of prevention, particularly those to impede the natural spread of Northern Pike from infested waters, will be discussed in the containment section of this plan.

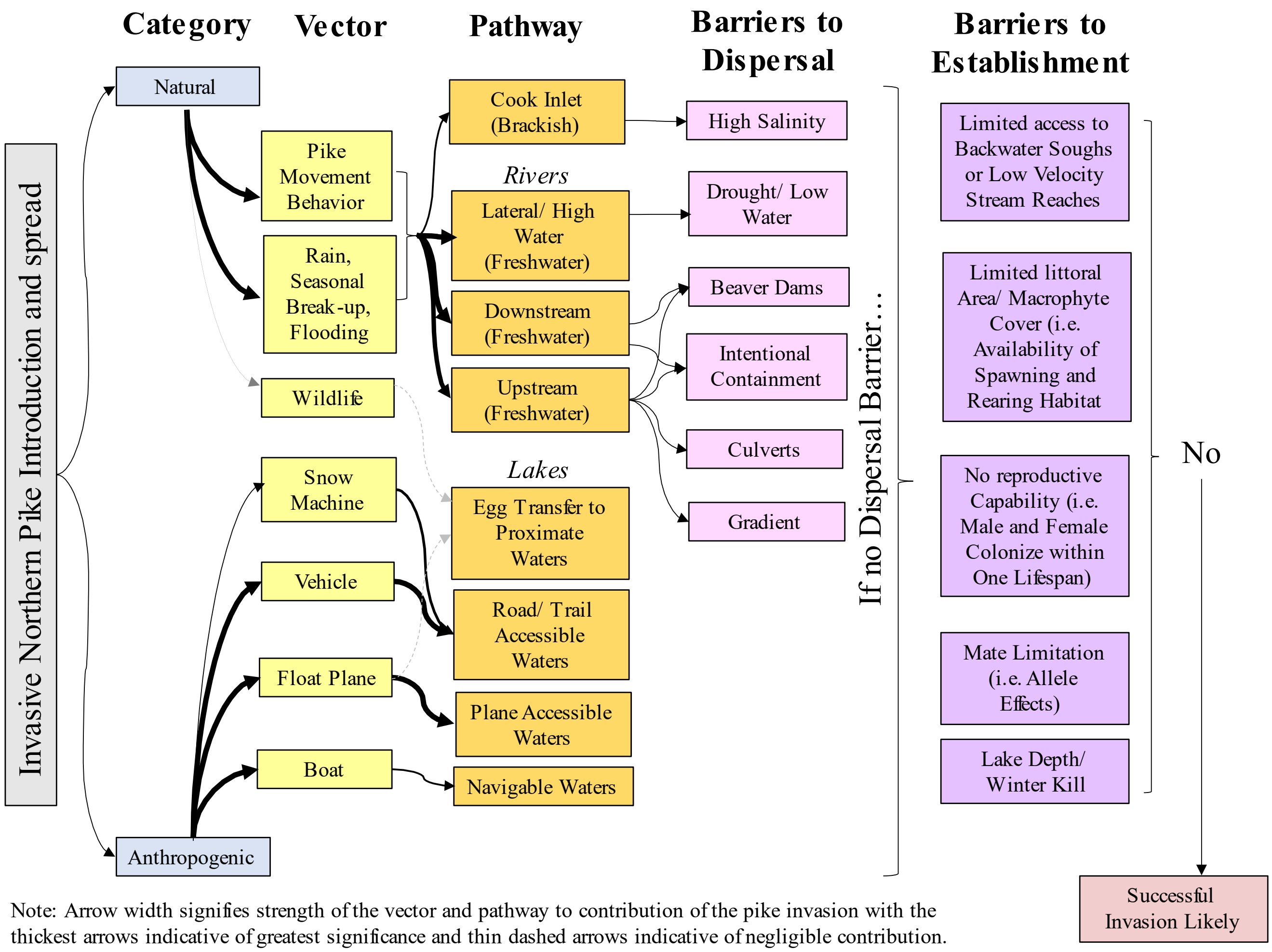


1.1 Pathway Analysis

Role of Pathways Analyses in Invasive Species Management. Determining the vectors and pathways that contribute most to invasive Northern Pike introductions and dispersal can help plan partners focus limited resources on Northern Pike prevention where these resources are most needed or can be most effective. Preventing introductions and subsequent spread is considered the most effective strategy for aquatic invasive species management (Lodge et al. 2006). To be successful, understanding the different pathways of spread is paramount (Ricciardi and Rasmussen 1998, Kolar and Lodge 2002, Kolar 2004). Failure to identify and restrict significant pathways could negate other investments in invasive species management. Therefore, as a starting point in this management plan, a risk assessment of possible vectors, pathways, potential for establishment, and knowledge gaps for introduction and spread of invasive Northern Pike are considered. This analysis will serve as the cornerstone of this management plan to prioritize activities and efforts that can best contain the invasive Northern Pike problem in Southcentral Alaska and prevent it from becoming more widespread.

Description of Pathways and Vectors. In the field of invasion biology, the term "pathway" refers to the ways by which invasive species, in this case Northern Pike, are introduced to new environments. Vectors are the mechanisms by which an invasive species enters a pathway. Vectors are either natural (i.e., those not aided by humans) or anthropogenic (human-caused). In some cases, the natural vs. anthropogenic nature of a vector can be unclear. For example, within the native European range for Northern Pike, there are accounts of 'natural' range expansions stemming from Northern Pike movements; however, the underlying cause is attributed to habitat changes resulting from human-induced climate change (Hein et al. 2014, Hein et al. 2011), making it difficult to clearly discern the natural vs. anthropogenic basis of the expansion. In contrast, in Alaska, the original introduction event of Northern Pike into the Southcentral region is clearly of anthropogenic origin. There is no physical way in which Northern Pike could traverse the geologic barrier of the Alaska Mountain Range naturally; thus, all populations originally result from an anthropogenic source (i.e., illegal introductions beginning in the late 1950s). However, once introduced to the Southcentral AK region, Northern Pike spread from that point of introduction can either occur naturally or anthropogenically, though at this point in the invasion, natural movements through open systems are likely more prevalent than illegal introductions. The following discussion analyzes these differences under this basic understanding that all Northern Pike in Southcentral are the result of initial human introductions.

Pathways Analysis Process. To develop this Pathways Analysis, a subcommittee of plan partners formed to identify possible vectors and pathways of Northern Pike spreadin Southcentral Alaska and the potential for new populations to result (Figure 17). Inferences were drawn from the scientific literature and expert opinion from a survey of invasive Northern Pike biologists and researchers in Alaska that sought to determine which vectors and pathways were of greatest concern and how well understood these pathways are based on field observations and available research. The survey was administered to plan partners, and the results were scored (means of weighted survey response values, scale: 0-3) and presented in Table 5. Pathways in the table are listed from the greatest to least contribution to Northern Pike invasion within natural and anthropogenic categories. In addition, survey respondents were asked to indicate whether more research into each pathway is needed and score its importance (scale: 0-1).



Note: Arrow width signifies strength of the vector and pathway to contribution of the pike invasion with the thickest arrows indicative of greatest significance and thin dashed arrows indicative of negligible contribution.

Figure 17. Pathways Analysis for invasive Northern Pike in Southcentral Alaska

Table 5. Results of the expert opinion survey on i pathways for Northern Pike in Southcentral AK

	Vector	Pathway	Contribution	Survey Score	Research Needed
Natural	Northern Pike Movement	Freshwater Dispersal (Downstream)	High	2.6	0.4
	Northern Pike Movement	Freshwater Dispersal (Lateral)	High	2.2	0.9
	Northern Pike Movement	Freshwater Dispersal (Upstream)	Moderate	1.9	0.6
	Northern Pike Movement	Brackish Dispersal (Cook Inlet)	Moderate	1.4	0.9
	Other Wildlife	Egg adhesion	Low	0.3	0.4
Anthropogenic	Road Vehicle	Road System lakes and streams	High	2.5	0.1
	Boat	Navigable Waters	High	2.2	0.4
	Float Plane	Waters where planes can land	High	2	0.1
	Snow Machine	Any freshwater	Low	0.9	0.4
	Float Plane	Accidental egg transfer	Low	0.5	0.6

Note: Survey Scores – (Scale 0-3) 2-2.9 = High, 1-1.9 = Moderate, 0-0.9 = Low; Research Scale (0-1)

Pathways Analysis Natural vectors include Northern Pike movements within and between river systems through seasonal migrations (Albert 2016) or individual movements between waters. There is great variability in the degree to which Northern Pike move (Rutz et al. 2020b). Northern Pike can move to spawning and overwintering grounds, to seek prey or embark on long-range migrations for unknown reasons. Seasonal conditions such as rain events, spring break-up, or flooding from other causes are thought to be significant vectors. Northern Pike movement behavior and conditions that increase accessibility of habitat to Northern Pike can lead to dispersal pathways in freshwater upstream and downstream, as well as laterally. For example, during flood events, Northern Pike may gain access to sloughs, wetlands, or other waters that are only ephemerally connected. Such lateral dispersal can allow Northern Pike to spread to proximate waters. Upstream dispersal is thought to be constrained in some areas by gradient and flow, as Northern Pike are not commonly found in high-velocity waters (Spens et al. 2007). Downstream movement of Northern Pike was considered the most common pathway of dispersal, but the question of how flow affects dispersal is not fully understood. Expert opinion from the survey agreed that more data are needed to fully understand freshwater dispersal patterns in Southcentral Alaska. Another pathway of concern is Northern Pike dispersal through the brackish waters of Cook Inlet. Both occasional catches of Northern Pike in commercial set-nets and stable isotope analysis of Northern Pike otoliths has confirmed the potential for Northern Pike transit through parts of Cook Inlet to colonize new drainages [Mat Wooller, UAF, unpublished], but little is currently known about how common this is nor how much this pathway contributes to the overall invasion potential for Northern Pike in Southcentral. Given the complexity of managing this pathway, however, there was consensus that this question remains a priority for research.

The final vector considered for ‘natural’ dispersal of Northern Pike within Southcentral was other wildlife, but there is no evidence that this an actual contributor to the Northern Pike invasion. Northern Pike have adhesive eggs, and as such, there is public perception that eggs might be carried on the feathers of waterfowl or fur of mammals between waters. While the possibility cannot be excluded entirely for very short-range movements between adjacent or proximate waters, there is no evidence waterfowl are a significant pathway for any fish species to new waters (Hirsch et al. 2018). With respect to Northern Pike, spawning often occurs under the ice making eggs inaccessible to wildlife, and Northern Pike eggs are unable to survive out of the water for durations needed for transfer between distant waters. Even small sudden changes in temperature that eggs would be exposed to while being taken in and out of the water would result in mortality (Hassler 1970). Because waters that are in proximity are already subject to flooding connectivity and lateral dispersal, wildlife as a vector, and adhesive egg transfer as a pathway, is likely negligible. Group consensus in the analysis is that egg transfer by wildlife is a negligible to non-existent pathway of invasion for Northern Pike within Southcentral.

Several anthropogenic vectors were considered in this analysis. These include human transfer via road vehicle, snow machine, float plane, and boat. There is a strong pattern in Southcentral Alaska where most known Northern Pike waters are either road or floatplane accessible (Jalbert 2018). Illegal introductions of fish by people is a ubiquitous problem for fisheries management (i.e., Rahel 2007, Rahel 2004, Moyle and Light 1996). In Anchorage and on the Kenai Peninsula, >90% of Northern Pike waters were accessible by road. In the Matanuska-Susitna Valley, most of the known Northern Pike lakes are also either on or connected to waters on the road system or can accommodate float plane landings, making direct human introductions or dispersal from them responsible. Despite the significant problem Northern Pike pose in Southcentral, they still occupy only a small portion of their available habitat (Jalbert et al. 2021). The association of Northern Pike waters with road and float plane accessibility is strong evidence that anthropogenic vectors of road vehicles and float planes are significant pathways for illegal introductions to occur. Within the analysis, an additional possibility was considered in which float planes may unintentionally pick up eggs either directly or through water that seeps into their floats. This unintentional movement of Northern Pike eggs was not considered a viable pathway for Northern Pike. Any eggs attached to floats would rapidly desiccate and detach from water and wind shear when the plane takes off. Shore ice during spawning would further inhibit a plane from picking up eggs. Lake water containing Northern Pike eggs is also unlikely to seep into rivetted float seams as these are too narrow for eggs to move through, and again, ice conditions would typically prevent contact between plane floats and Northern Pike eggs. However, there are many anecdotal accounts of float plane pilots adding water to their floats to keep adult Northern Pike alive in while flying between waters. This is believed to have been the method by which Northern Pike were first introduced to Bulchitna Lake decades ago. Intentional movement of Northern Pike using float planes to create Northern Pike fisheries in remote lakes is considered a significant vector and pathway of introduction. Snow machines were also considered as a possible vector as they have winter access to almost any freshwater pending snow, ice, and overflow conditions. However, there are no known accounts or data available on snow machines as a vector for Northern Pike introductions. The difficulty of moving live Northern Pike and water during cold temperatures in the winter likely limits this pathway, but the committee consensus is that too little is known to rule this pathway out completely from the analysis. Finally, transfer of Northern Pike via boat from one navigable water to another was the final anthropogenic vector considered. As with snow machines, there is limited anecdotal information available to help identify how common or uncommon illegal Northern Pike introductions via boat are. However, despite its high contribution score in the survey (Table 5), this pathway is diminished in importance as any navigable water that can accommodate boat traffic would already provide opportunity for Northern Pike to move on their own.

Based on results of the expert panel survey and further analysis, the pathways of highest concern include natural Northern Pike movements, especially during flooding events, and intentional anthropogenic illegal introductions via road vehicle and float planes. The highest priorities for future pathways-related research is to further investigate movement patterns of Northern Pike within open systems, where seasonal flooding can allow lateral dispersal, and to increase knowledge of the role of Cook Inlet in Northern Pike dispersal.

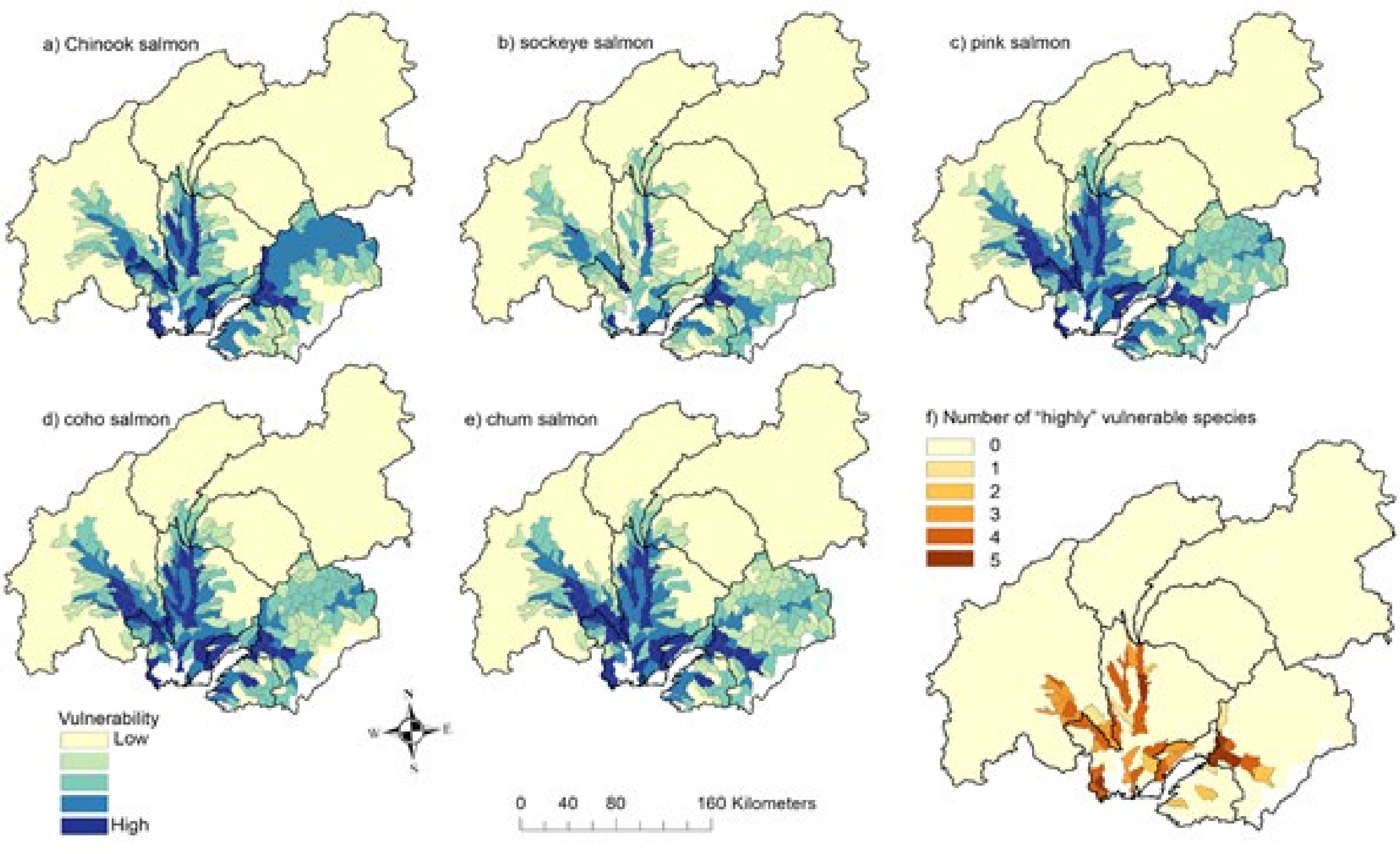
Barriers to Spread and Establishment. Once pathways for Northern Pike are accessed, there are further considerations that help determine how likely it is for a new Northern Pike population to result. These are barriers to spread and barriers to establishment. For this pathway analysis, it is assumed that once Northern Pike enter lakes through anthropogenic vectors and pathways, the introduction is complete, and a population is anticipated to result if there are no barriers to establishment (Figure 17). In river systems, however, pathways can be impeded by physical or physiological barriers that restrict Northern Pike movements. Separately, for the Cook Inlet pathway, Northern Pike are not as tolerant of oceanaic marine conditions (~35ppt), so salinity can function as a barrier to dispersal, even though Northern Pike are capable of surviving and moving through brackish conditions (Jacobsen and Engstrom-Ost 2018). Time of year and current patterns that affect salinity levels in Cook Inlet are factors that influence when or if salinity is a prohibitive barrier to Northern Pike dispersal through this pathway. These conditions could change, and salinities could lower with added freshwater inputs from melting glaciers. Within rivers and streams, barriers to dispersal include natural variables such as gradient, stream velocity, waterfalls, and presence of impassible beaver dams. Anthropogenic barriers such as impassible culverts or intentionally engineered containment mechanisms for Northern Pike are further barriers to spread that could prevent Northern Pike from moving throughout all areas of an open system.

If no such dispersal barriers prevent Northern Pike from moving through a pathway, the final line of defense rests with potential ecological barriers to establishment. For example, Northern Pike require habitats with aquatic vegetation cover for spawning, rearing, and feeding. In rivers without access to low velocity stream reaches or consistent access to backwater sloughs, introduced Northern Pike are unlikely to spawn and establish a population. The same is true in lakes. If there is not sufficient littoral area with abundant vegetation cover within a lake or its outlet, the population may not successfully establish, and if it does, it may not achieve high population densities nor be found throughout the entire lake. While shallow vegetated lakes tend to be very suitable for Northern Pike, if the lake is so shallow that it freezes entirely or frequently winterkills due to low dissolved oxygen that can kill pike (<1 mg/l), this too could be a barrier to long-term establishment. Finally, biological factors such as reproductive capability and mate limitation can impede successful establishment. Northern Pike are broadcast spawners where gametes are released simultaneously into the water column and as such small founding populations have the potential to restrict successful establishment resulting from positive density-dependence, also called Allele Effects (Sakai et al. 2001). However, given the prolific invasion of Northern Pike in Southcentral thus far, small numbers of founders have not likely been a significant hindrance either demographically or genetically. Taken together, it currently appears that the barriers to establishment are generally insufficient to preclude establishment if Northern Pike enter a pathway.

Systems of Greatest Concern. Prioritizing locations with the greatest potential impact to invasion is a vital management tool. As such, the vulnerability of Pacific salmon to invasive Northern Pike based on intrinsic potential habitat modelling has helped prioritize locations for monitoring (Jalbert et al. 2021). A key insight is that there remains greater than 1,000 stream-km of currently unoccupied suitable Northern Pike habitat in the Matanuska-Susitna Valley alone where significant impacts to salmon would be expected if Northern Pike invade (Figure 18). This is based on anadromous waters that share ideal habitat conditions for Northern Pike. This work corroborates, for example, that the Jim Creek drainage in the Knik River watershed is a high priority for Northern Pike prevention in the Mat-Su; this area has long been a concern of ADF&G's. On the Kenai Peninsula, highest priorities would include preventing Northern Pike introductions in the Moose River drainage, the Swanson River drainage, and the previously infested Miller Creek drainage (ADF&G, Unpublished). In the West Cook Inlet region, there is concern about Northern Pike spreading to the Robert's Creek drainage near Tyonek where other invasive Northern Pike populations are currently present (TTCD, Unpublished).

Lake Prioritization Tool. To assist in determining invasion risk to a waterbody, an invasive species mapping tool, incorporating known Northern Pike distribution data (Invasive Northern Pike in Southcentral Alaska (arcgis.com)), municipal and DOT (Dept. of Transportation) records for road access, floatplane pattern data (Schwoerer et al. 2022), and the intrinsic potential modeling (Jalbert et al. 2021) will be available in summer 2023. This lake prioritization tool was developed in collaboration with the University of Alaska, Anchorage, and will assist plan partners with prioritizing water bodies for monitoring at the USGS HUC12 (Hydrological Unit) level (See: [Nonindigenous Aquatic Species (usgs.gov)]() for a description of HUCs). The website for this tool will be made available to plan parterns when complete.

With insights generated through this pathways analysis and upcoming prioritization tools, this management plan will now focus on informing procedures for response to new invasions that can result in effective rapid response.



Note: Figure used with permission from Jalbert et. al. 2021; Species-specific estimates shown in panels a – e and a composite "highly-vulnerable" estimate shown in panel f. Black lines represent sub-basins. Darker colors represent higher vulnerability with species-specific vulnerability shown in blues and the number of species identified as "high" vulnerability shown in oranges.

Figure 18. Vulnerability of Pacific salmon to invasion by Northern Pike for the Mat-Su basin

1.2 Outreach

Outreach and education can be effective tools in the prevention of illegal introductions of non-native species (Novoa et al. 2017). If there is public awareness and, more specifically, personal connection with the consequences of illegal releases of fish or other animals, people are less likely to release them. A well-informed public is also more capable of assisting with early detection of new introductions, thus allowing for greater opportunity for rapid response (i.e. Niemiec et al. 2017). Since beginning Northern Pike management in Alaska, partners have worked to communicate the importance of these efforts to the public, but there remains strong opposition to some invasive Northern Pike management approaches and a desire among some anglers to manage sport fisheries for Northern Pike rather than controlling them. Continued efforts to educate the public to the inherent trade-offs associated with Northern Pike introductions are suggested. Simply put, anglers cannot have flourishing salmon and trout fisheries. Effective outreach campaigns will be the first line of defense to prevent further illegal introductions and to solicit reports from the public to find new introductions quickly. This plan, therefore, provides guidance for streamlining invasive Northern Pike outreach efforts. Outreach developed for invasive Northern Pike prevention will focus on the following key messages, audiences, and tools:

Key Messages:

1) **Keep *Southcentra*l Alaska wild and free of invasive Northern Pike. (Help reduce the spread of Northern Pike in Southcentral Alaska.)**

*(Keep Alaska Wild and Free of invasive species is a statewide slogan used by the AKISP)***.**
Within this message, it is important to acknowledge that invasive Northern Pike control activities in Southcentral benefit native fish populations and fisheries. While some anglers might appreciate the fishing diversity that has resulted from both authorized and illegal non-native fish introductions in other states, these ultimately have caused detrimental impacts to native fish communities in those areas. Alaska's physical distance and youth as a state provide the unique opportunity to learn from past missteps elsewhere and to prevent similar non-native fish impacts here. The overall impetus is to 'Keep Alaska, Alaska' and protect the state's world-class salmon and trout fisheries, and intact ecosystems.

2) **Healthy sustainable aquatic ecosystems and fisheries benefit Alaskans ('You can't have your pike and salmon too').**

Salmon fisheries in Alaska contribute $7 billion annually to the state's economy, with much of this value generated from areas of the state where Northern Pike are not native (McDowell 2020). Controlling invasive Northern Pike protects this important component of the Alaskan economy. Where Northern Pike are native in Alaska, they are managed as an important subsistence and sport resource. Where they are not native in Southcentral, they are controlled as an invasive species. It is, therefore, important for anglers to recognize that fishing regulations in these areas differ significantly for this reason. While Northern Pike are recreationally valued by anglers throughout the state, this does not change their invasive status in Southcentral. If left uncontrolled, Northern Pike dispersal and subsequent predation can lead to losses of economically significant fisheries and native fish populations.

3) Invasive Northern Pike and native fish management depends on everyone's engagement.

Everybody can help prevent Northern Pike from spreading by not illegally moving them between waters, dispatching all Northern Pike caught in Southcentral, reporting catches of Northern Pike from new waters to ADF&G, and engaging in public processes for proposed Northern Pike management activities. Invasive Northern Pike management is a collaborative effort among many partner organizations and Alaskan residents.

4) Adaptive management leads to greatest success in protecting Southcentral Alaska's waters from invasive Northern Pike.

There is no single management approach that is optimal for all invasive Northern Pike populations. Feasible strategies are condition-dependent, and integrated pest management strategies incorporating multiple tools for control are often needed to ensure successful outcomes. Fisheries impacted by Northern Pike have been restored in Southcentral in several places such as Arc and Scout Lakes (Kenai Peninsula), Stormy Lake (Nikiski), the Soldotna Creek drainage (Soldotna), Tote Road area lakes (Soldotna), Miller Creek Drainage (Kenai National Wildlife Refuge), Cheney, Sand, and Otter lakes in Anchorage, and Anderson and Kings lakes in Wasilla. Many other Northern Pike populations in the Matanuska-Susitna Valley and the west side of Cook Inlet have active invasive Northern Pike suppression programs on them. Similar work occurs elsewhere in the western United States where Northern Pike are non-native and problematic (i.e. Columbia River basin; i.e., Harvey and Bean 2019). Certainly, invasive Northern Pike are not the only factor negatively affecting salmon and native fish in Southcentral AK. Climate change, habitat degradation, marine conditions, and harvest all play a role, but controlling invasive Northern Pike relieves some of the overall pressure on salmonid populations.

Key Audiences: The primary audience for these key messages includes all AKISP invasive Northern Pike partner organizations to ensure all outreach messaging for invasive Northern Pike in Southcentral Alaska is unified and consistent. Secondary audiences who may also receive these messages through outreach efforts by individual partner organizations include local and tribal governments, tribal organizations, the Alaska Board of Fisheries, Alaska Legislature, conservation NGOs, national fish habitat partnerships, recreational anglers, subsistence anglers, Northern Pike enthusiasts, university researchers and students, and law enforcement officers.

Outreach Tools: The appropriate outreach tools to relay key messages to secondary audiences will be tailored to fit the specific audience and the appropriate context. The options can include:

- Radio (PSA's, guest interviews)
- Television and web advertisements
- Educational videos created and posted on platforms (YouTube, Vimeo, Instagram)
- Social Media (i.e., Recurring topic on the AKISP and partner Facebook pages)
- Public events (i.e., Great Alaska Sportsman Shows)
- Professional conference presentations
- Public meetings and presentations
- Invasive species volunteer events
- Participation in the Alaska and National Invasive Species Awareness Weeks
- Print (newspapers and magazines, brochures, factsheets)

- Signage (posters, flyers, announcement boards, signs at invaded waterbodies)
- Features on partner websites, AKISP website, and the AKISP Facebook group page
- Online story maps

Groups and resources that will assist with funding, development, and dissemination of these products include all AKISP invasive Northern Pike committee partner organizations, ADF&G's Sport Fish Division Communications and Outreach Committee, and the AKISP Outreach and Education Committee.

Outreach Images: The following are example images available for any AKISP Invasive Northern Pike Committee outreach needs. Open access stock images for invasive Northern Pike outreach are available to all plan partners in the supplemental materials with this plan (Appendix 5) and can also be solicited from the AKISP Invasive Northern Pike Committee Chair. Photo credits can be given as "AKSIP Invasive Northern Pike Committee".

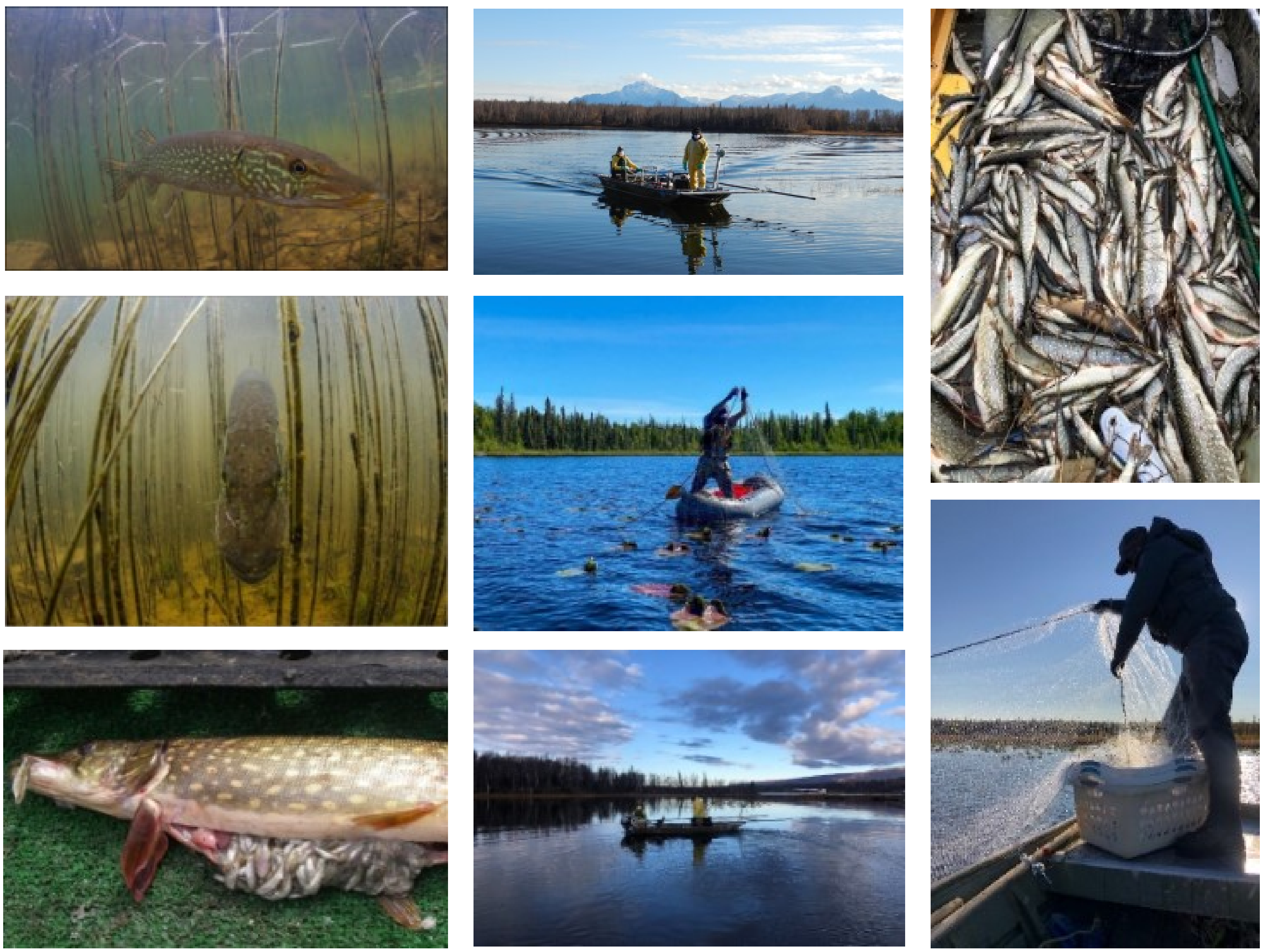


Figure 19. Open access invasive Northern Pike and project images

1.3 Law Enforcement

The Alaska state laws pertaining to transport and release of aquatic organisms are as follows:

Table 6. Alaska laws regarding fish releases

Alaska Statues
Sec. 16.05.020. Functions of commissioner. The commissioner shall … (2) manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state;
Sec.16.05.251. Regulations of the Board of Fisheries. (a)The Board of Fisheries may adopt regulations it considers advisable in accordance with AS 44.62 (Administrative Procedure Act) for … (9) prohibiting the live capture, possession, transport, or release of native or **exotic** fish or eggs;
Sec. 16.05.920. Prohibited conduct generally. (a) Unless permitted by AS 16.05 – AS 16.40 or by regulation adopted under AS 16.05 – AS 16.40, a person may not take, possess, transport, sell, offer to sell, purchase, or offer to purchase fish, game, or marine aquatic plants, or any part of fish, game, or aquatic plants, or a nest or egg of fish or game.
Sec. 16.05.940. Definitions. In AS 16.05 – AS 16.40, … (12) "fish" means any species of aquatic finfish, invertebrate, or amphibian, in any stage of its life cycle, found in or **introduced** into the state, and includes any part of such aquatic finfish, invertebrate, or amphibian; …
Sec. 16.35.210. Nonindigenous fish. (a) A person may not knowingly release, or transport, possess, import, or export for the purpose of release, into the water of the state live **nonindigenous** fish or live fertilized eggs of nonindigenous fish, unless permitted by AS 16.05 – AS 16.40 or by a regulation adopted under AS 16.05 – AS 16.40. This subsection does not apply to… (2) generally accepted conduct in relation to permitted saltwater commercial or sport fishing. … (d) In addition to the penalty imposed under (c) of this section, a person who is convicted of violating this section may be ordered by the court to pay restitution to the state to cover the costs of damages to fishery resources of the state and of removing the **introduced** fish species from the water of the state. … (e) In this section, … (2) "**nonindigenous** fish" means a species of fish that is not native to the body of water in which the fish is released or is intended to be released; (3) "**ornamental fish**" means an aquatic finfish, commonly referred to as tropical fish, aquarium fish, or goldfish, an aquatic invertebrate, or an amphibian that is imported, cultured, or sold in the state customarily for viewing in an aquarium or for raising in an artificial containment system and that is not customarily used for sport fishing in the state or used for human consumption;
Alaska Administrative Code
5 AAC 01.010. Methods, means, and general provisions. … (n) The use of live **nonindigenous** fish as bait is prohibited.
5 AAC 41.005. Permit Required. (a) Except as otherwise provided, a person may not collect, transport, possess, propagate, export from the state, or release into the waters of the state, any aquatic organism, unless the person holds a fish transport or aquatic resource permit issued by the commissioner, and the person is in compliance with all conditions of the permit and the provisions of this chapter. A fish transport or aquatic resource permit will be issued for a fixed term subject to the provisions of this section.
5 AAC 41.070. Prohibitions on importation and release of live fish. (a) Except as provided in (b) – (d) of this section, no person may import any live fish into the state for stocking or rearing in the waters of the state. … (c) **Ornamental** fish not raised for human consumption or sport fishing purposes may be imported into the state but may not be reared in or released into the waters of the state. Fish wastes and wastewater from ornamental fish may not be released directly into the waters of the state. … (e) A person may not import, own, possess, breed, transport, distribute, release, purchase or sell within this state any species listed under 50 C.F. R. 16.13, as revised as of October 1, 2002, as an injurious live, or dead fish, mollusk, crustacean, or their eggs.
5 AAC 92.990. Definitions. (a) In addition to the definitions in AS 16.05.940, in 5 AAC 84 – 5 AAC 92, unless the context requires otherwise, … (42) "**invasive species**" (A) means a nonnative species whose introduction does or is likely to cause economic or environmental harm or harm to human health; this (B) includes deleterious exotic wildlife.

Maximum penalties for violations of these laws are severe and include citations with fines up to $25,000 and restitution to the state for costs of removing the introduced species. The penalties also include revocation of fishing licenses and potential incarceration for up to one year. These maximum penalties are significant given the potential gravity of the ecological and economic ramifications that can result from illegal introductions. They can also serve as a deterrent for the public to avoid breaking these laws.

One of the greatest challenges in utilizing law enforcement as a preventative deterrent in illegal introductions of Northern Pike is that is it can be difficult to build a case if evidence is lacking. To facilitate this and increase investigative potential for illegal Northern Pike introductions, ADF&G and partner organizations will communicate regularly with enforcement officers to encourage timely investigations of suspected violations. As part of this, ADF&G area management biologists will identify non-native fish introductions, including Northern Pike, as a priority for law enforcement during annual pre-season meetings between state fishery managers and the Department of Public Safety. When new Public Safety officers are hired, local ADF&G invasive species biologists will meet with them to discuss the issue of illegal Northern Pike introductions, the potential gravity of these violations, and the need to maintain regular communication on these matters. Instances of public admissions to Northern Pike introductions in Southcentral, including those made on social media and observed by plan partners, will be communicated to the ADF&G Southcentral Invasive Species Coordinator and passed along to the appropriate local law enforcement contacts. Every effort will be made to pass any evidence of illegal Northern Pike introductions to law enforcement as soon as possible and before any public notification or media involvement to ensure investigative needs are prioritized. Once law enforcement has had the opportunity to investigate and provides consent, outreach efforts can commence to bring public awareness to the investigation. In specific cases where reintroductions occur following previous Northern Pike eradications, ADF&G may partner with the Department of Public Safety to post joint statements and send notices to residences surrounding the waterbody that explains the problem, the penalties, and provides a Department of Public Safety tip line for anyone who has information on the illegal introduction. Public communication, specifically highlighting these legal investigations can, alone, serve as a powerful deterrent to prevent future illegal Northern Pike introductions.

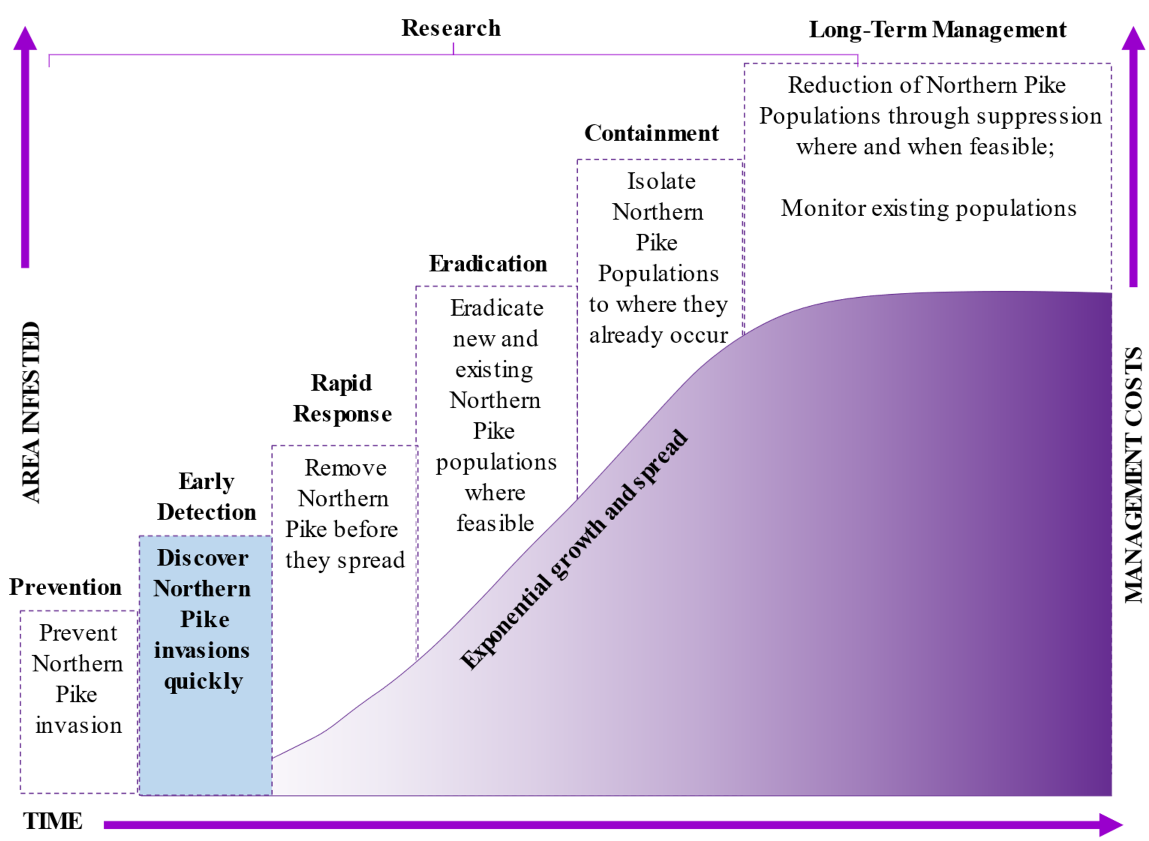
STEP 2: Early Detection

Even with strong prevention protocols in place, invasive Northern Pike populations are likely to continue spreading in Southcentral Alaska. Early detection leading to rapid response is a critical secondary defense against the establishment of invasive species populations (Reaser et al. 2020). Early detection increases the likelihood that new populations can be eradicated or contained before spreading and becoming more widely established, ultimately increasing management efficiency by reducing the scale and cost of response efforts (Kaiser and Burnett 2010).

This plan section provides guidance to partners for increasing capacity for early detection of new Northern Pike populations. Specifically, this section identifies the protocol for reporting new Northern Pike populations and includes a decision matrix for selecting the best tools for responding to public Northern Pike reports given unique characteristics of waterbodies. Those tools (data collection, gillnets, eDNA, Hook and Line, and Visual surveys) are briefly described here and then detailed in a collection of Standard Operating Procedures (SOPs) that establish guidance for partners so that early detection surveys are conducted consistently and comparably. These can be found in the Standard Operating Procedures section of this document.

STEP 2: EARLY DETECTION SOPs

SOP 1: Northern Pike Survey and Monitoring Data Collection
SOP 2: Gillnet Use for Early Detection Surveys
SOP 3: eDNA Use for Early Detection Surveys
SOP 4: Hook and Line Surveys for Early Detection
SOP 5: Visual Surveys for Early Detection



2.1 Reporting Protocol for New Northern Pike Populations

As discussed in the Pathway Analysis, Northern Pike have significant potential to expand their range in Southcentral Alaska. **Preventing the additional spread of Northern Pike, to the greatest extent possible, is a primary objective of this management plan.** Illegal anthropogenic introductions and Northern Pike spread through open systems and estuarine waters are primary vectors of new Northern Pike introductions. However, as monitoring efforts across partner organizations increase, identification of existing but previously unknown Northern Pike populations is also anticipated. Responses to new Northern Pike populations will differ depending on these circumstances.

Definitions. For this plan, a new Northern Pike **introduction** is defined as the presence of one or more Northern Pike individuals physically confirmed by a plan partner organization in a waterbody from which Northern Pike were not previously known to occur. A new **confirmed population**, in contrast, is defined as a new waterbody from which there is evidence of natural reproduction of Northern Pike through direct observations by plan partners of fish in spawning condition and/ or the presence of multiple age classes. Northern Pike are suspected but **unconfirmed** from a new location if there is genetic evidence of their presence (i.e., eDNA) or a credible Northern Pike report from an angler or member of the public where photographic or other evidence is provided to a plan partner.

Reporting. In all cases where Northern Pike are reported from a previously unknown location, the report will be entered by the plan partner receiving the report into the Alaska Department of Fish and Game's Invasive Species Reporter: Invasive Species Reporter, Alaska Department of Fish and Game. Optimal reports to this database will include identification photos of the fish as well as the area from which the fish was observed. High quality location photos include distinguishing landmarks, signs, or other features that can help identify where the photo was taken. The number of Northern Pike observed, their life stages, date of observation, location specifics (including GPS coordinates if available), and contact information of the observer are also important to include with each report. Reports are received by the ADF&G Statewide Invasive Species Coordinator. The information will be distributed as shown in Figure 20.

Northern Pike reports received directly by local fishery biologists should also be entered into the online invasive species reporter within 48 hours for consistent distribution of information so that decisions on appropriate response can be made. It is critical for all local fisheries staff (appropriate plan partners, ADF&G invasive species biologists, ADF&G management biologists for the area of the report, and local law enforcement if necessary) to be informed before the report is made public. Ideally, public communication may begin, as appropriate, after the introduction or population has been confirmed.

ADF&G maintains an online GIS map of confirmed, unconfirmed, and managed (i.e. eradication or on-going suppression) Northern Pike populations. ADF&G will update this map quarterly (March, July, September, and December). At this time, ADF&G will also share confirmations of new populations with the USGS Non-indigenous Aquatic Species Database: Nonindigenous Aquatic Species (usgs.gov), which houses national records of non-native aquatic species introductions. Note that the ADF&G's online map will be the most frequently updated source.

Law Enforcement. In all cases where a new introduction or population is confirmed and there is evidence that it resulted from an illegal anthropogenic introduction, ADF&G will alert the Alaska Wildlife Troopers for cases occurring in state jurisdiction. A single point of contact, the ADF&G Region II (Southcentral) Invasive Species Coordinator (or their designee), will initiate these communications. For cases in National Wildlife Refuges, the USFWS Region 7 Invasive Species Program Coordinator will be the lead point of contact with federal enforcement officers (Figure 20). Illegal Northern Pike introductions are typically suspected if they occur in closed waters from where no natural pathway exists or in open waters that are accessible by road, floatplane, boat, or snow machine. In cases of the latter, evidence such as witness testimony, photographs or video of the introduction, admittance (either directly or through social media) and/ or forensic information such as genetics or otolith microchemistry is typically needed to distinguish the introduction as anthropogenic rather than Northern Pike movement through open systems. To date, there have been several investigations by Alaska State Troopers, but only one successful prosecution for an illegal introduction of out-of-state rainbow trout. Tangible evidence is critical to successful prosecution and, hence, use of law enforcement as a deterrent to illegal Northern Pike introductions. Evidence collection should therefore be a priority where illegal introductions of Northern Pike are suspected.

Law Enforcement Contacts:

For State of Alaska Jurisdiction

ADF&G Southcentral Invasive Species Coordinator (907-267-2889) →

Alaska State Wildlife Troopers:

Table 7. Contact numbers for the Alaska State Wildlife Troopers

Northern Detachment	Captain	Post	Phone Number
	907-334-2505	Palmer (HQ)	907-745-4247
		Anchorage	907-352-5401
		Girdwood	907-352-5401
		Glenallen	907-822-3263
		Mat-Su West	907-373-8305
	Lieutenant	Soldotna	907-262-4573
	907-260-6806	Anchor Point	907-235-8239
		Cordova	907-424-3184
		Seward	907-224-3935
		Valdez	907-835-4307

Source: Contact - AWT - Alaska Department of Public Safety

For Federal Jurisdiction

ADF&G Southcentral Invasive Species Coordinator (907-267-2889) →
USFWS Region 7 Invasive Species Program Coordinator (907-786-3510) →
Alaska Region 7 Office of Law Enforcement (907-786-3311)
(If in a National Park), National Park Service (Anna O'Brien anna_obrien@nps.gov)
(if in a National Forest), National Forest Service (Adam Cross adam.cross@usda.gov)

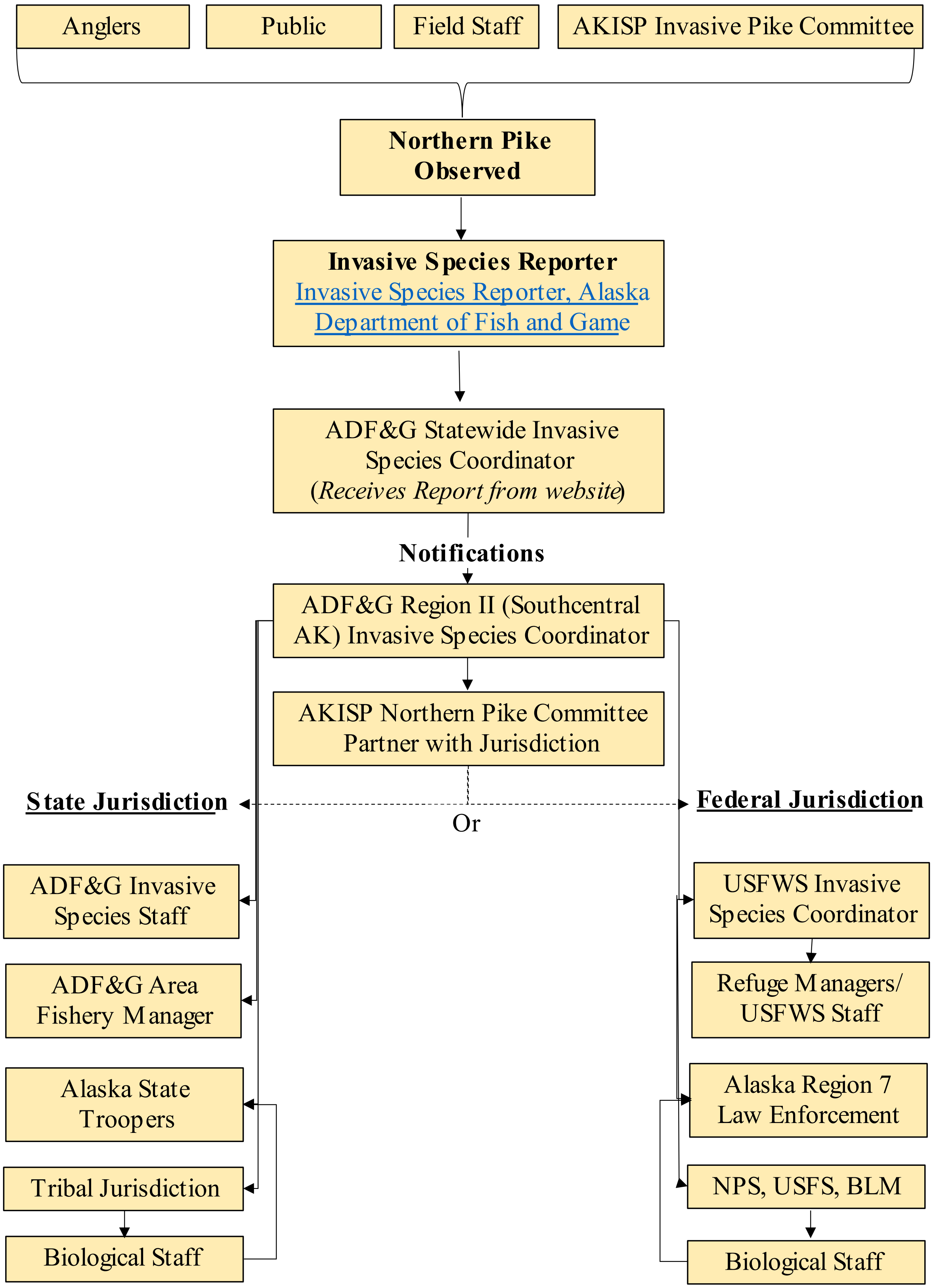
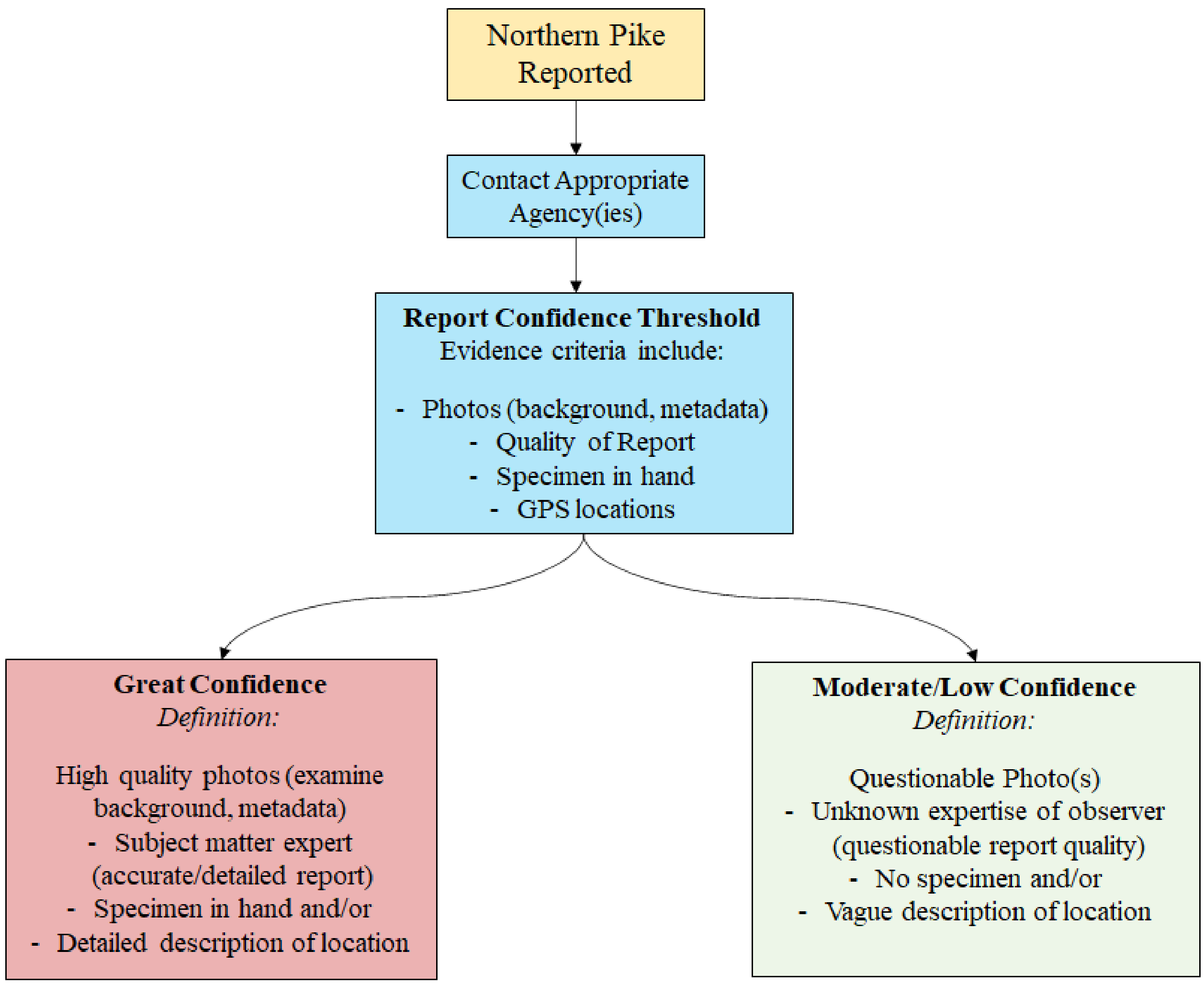


Figure 20. Flow of information from a new Northern Pike Report to Law Enforcement

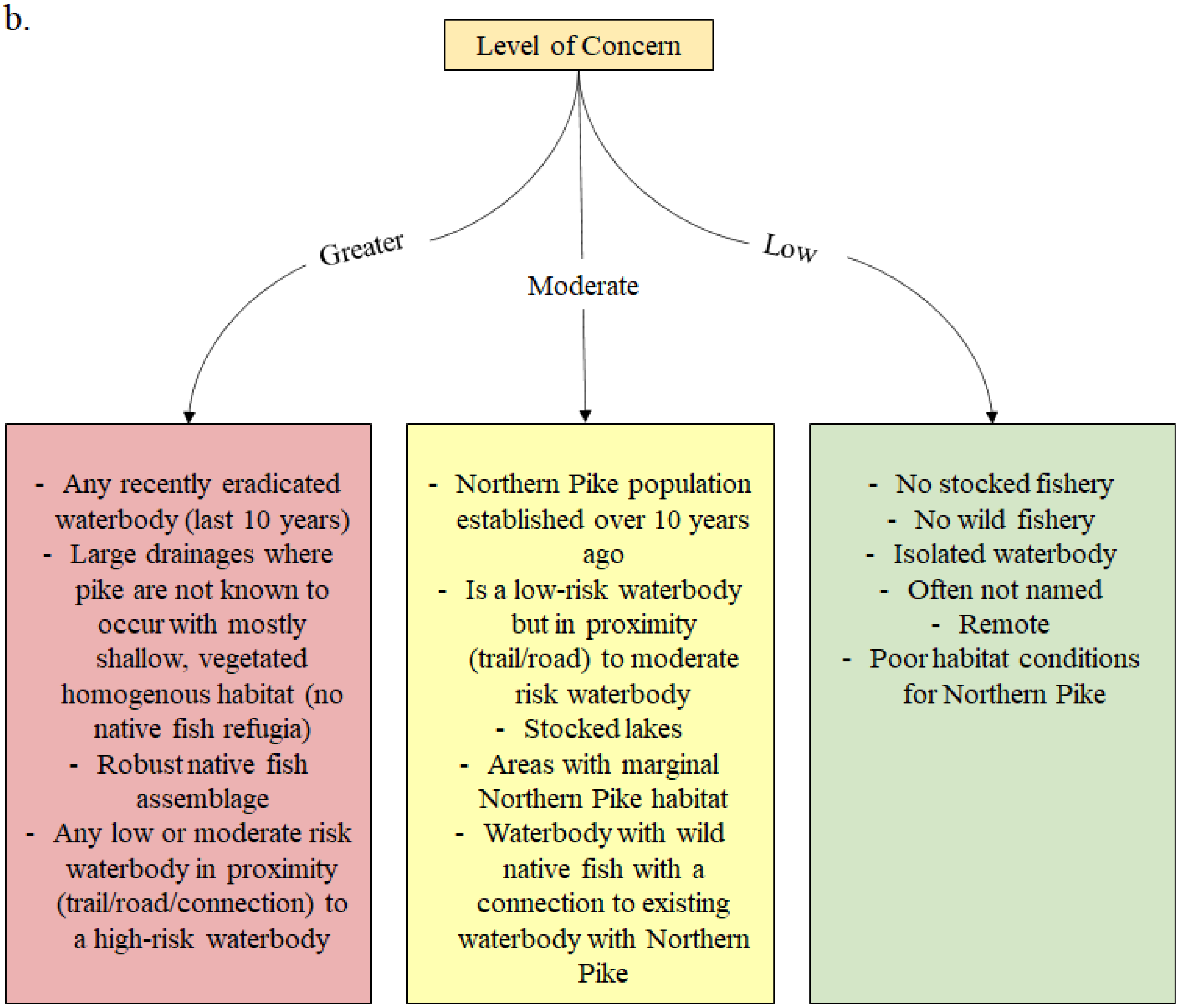
2.2 Decision Guidance for Selecting Early Detection Tools

This plan section establishes the framework for responding to new invasive Northern Pike reports, which is a critical element to ensuring response across jurisdictional boundaries. The procedures follow the flowcharts below (Figure 21a-d). The flowcharts guide users through the process of assessing the confidence in the report, level of concern, and taking actions accordingly. Once users reach the end of the flowcharts, they are directed to either determine the response plan with the land manager, use one of the SOPs at the end of this document, or take no further action. Blue boxes are major decision points, boxes in red involve steps with greater concern and urgency, boxes in yellow involve steps with moderate concern and urgency, and boxes in green involve steps with less concern and urgency.

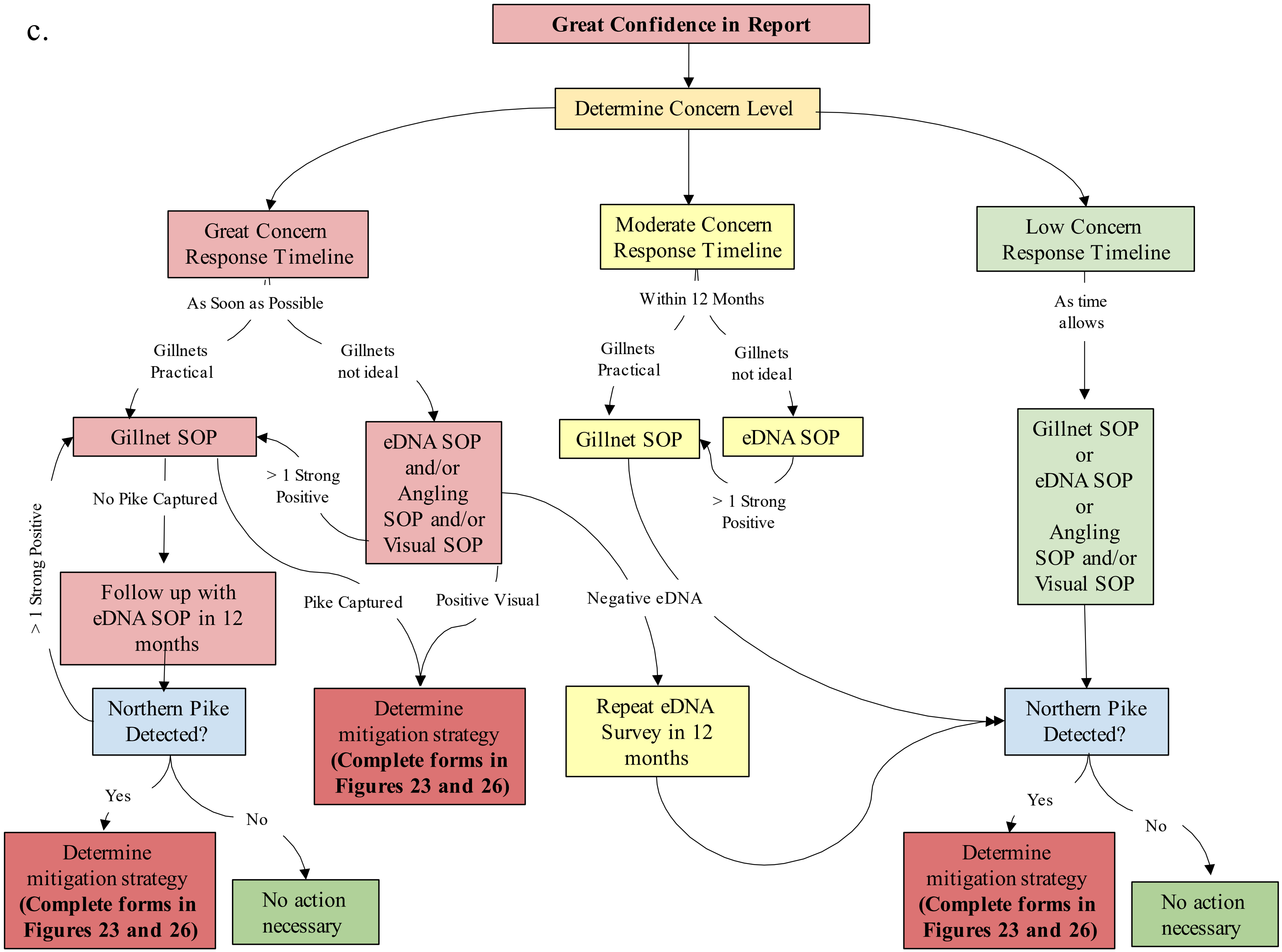
a.

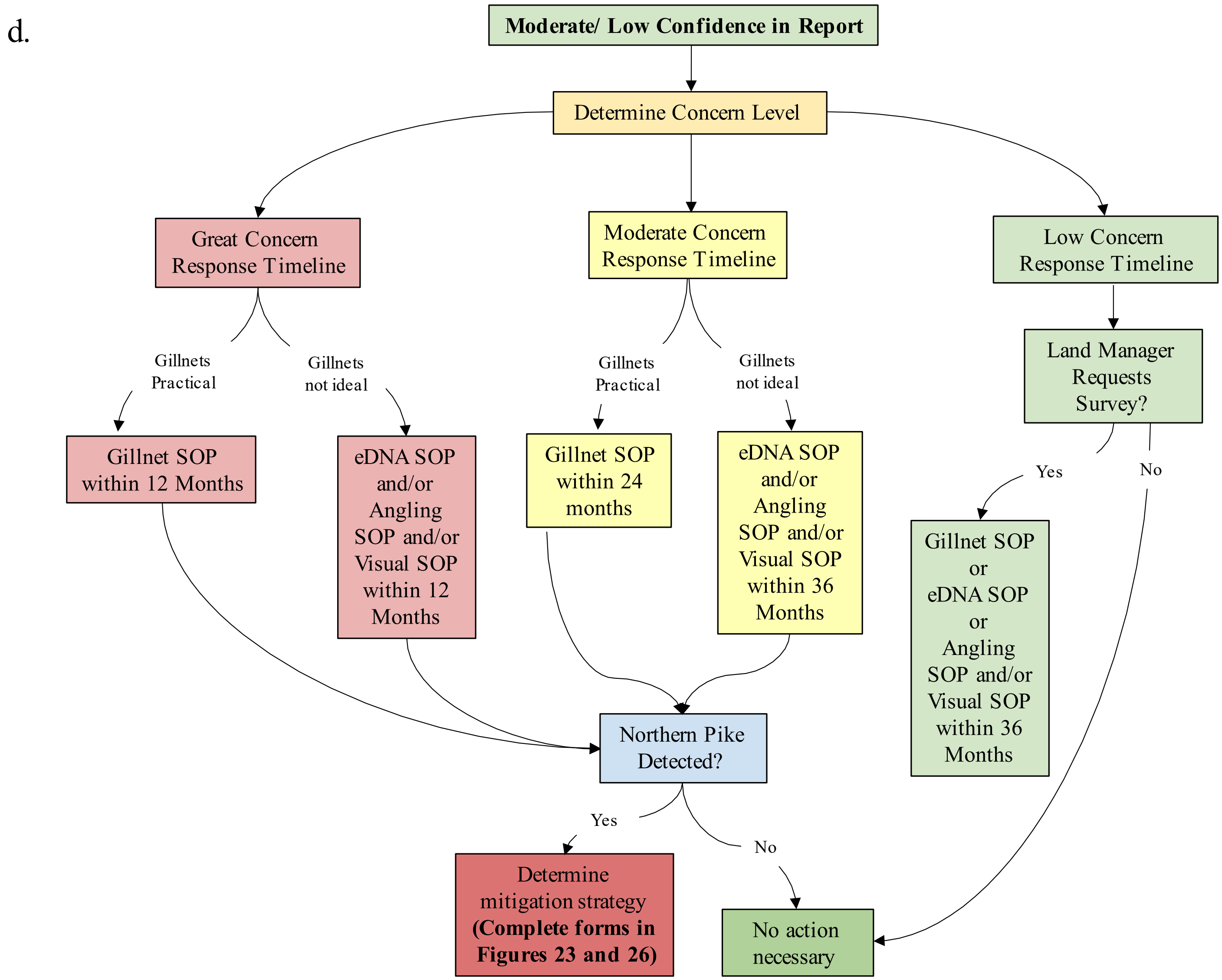


b.


Level of Concern
Greater
Moderate
Low
- Any recently eradicated waterbody (last 10 years)
- Large drainages where pike are not known to occur with mostly shallow, vegetated homogenous habitat (no native fish refugia)
- Robust native fish assemblage
- Any low or moderate risk waterbody in proximity (trail/road/connection) to a high-risk waterbody
- Northern Pike population established over 10 years ago
- Is a low-risk waterbody but in proximity (trail/road) to moderate risk waterbody
- Stocked lakes
- Areas with marginal Northern Pike habitat
- Waterbody with wild native fish with a connection to existing waterbody with Northern Pike
- No stocked fishery
- No wild fishery
- Isolated waterbody
- Often not named
- Remote
- Poor habitat conditions for Northern Pike

c.


Great Confidence in Report
Determine Concern Level
Great Concern Response Timeline
Moderate Concern Response Timeline
Low Concern Response Timeline
As Soon as Possible
Within 12 Months
As time allows
Gillnets Practical
Gillnets not ideal
Gillnets Practical
Gillnets not ideal
Gillnet SOP
eDNA SOP and/or Angling SOP and/or Visual SOP
Gillnet SOP
eDNA SOP
Gillnet SOP or eDNA SOP or Angling SOP and/or Visual SOP
> 1 Strong Positive
> 1 Strong Positive
> 1 Strong Positive
No Pike Captured
Follow up with eDNA SOP in 12 months
Pike Captured
Positive Visual
Negative eDNA
Northern Pike Detected?
Determine mitigation strategy (Complete forms in Figures 23 and 26)
Repeat eDNA Survey in 12 months
Northern Pike Detected?
Yes
No
Determine mitigation strategy (Complete forms in Figures 23 and 26)
No action necessary
Yes
No
Determine mitigation strategy (Complete forms in Figures 23 and 26)
No action necessary



Note: a. Determine confidence in report, b. Determine level of concern, c. Decision tree for high confidence reports, d. Decision tree for low confidence reports.

Figure 21a-d. Decision matrices to guide response actions

The Standard Operating Procedures (SOPs) pertinent to this section describe consistent standards for response to be followed by plan partners when responding to new Northern Pike reports. **For non-ADF&G partners, Aquatic Resource Permits are required for any surveys where fish are handled**. The process for obtaining these permits is as follows:

Description of Aquatic Resource Permits

An Aquatic Resource Permit (ARP) is required for any activity to collect fish not covered by current sport, personal use, and commercial regulations. Additionally, an ARP is needed if one wishes to transport, import, export, or propagate fish. ADF&G only issues ARPs to organizations and individuals engaged in legitimate scientific or educational, propagative, or exhibition activities, and who meet other requirements stated in the department's regulation. If issued an ARP, reports on the activities conducted under the permit are required.

ARPs will include details on the methods and means (i.e., gear) of capture, numbers of animals, locations, and seasons in which collection can occur. Permits will also address the final disposition of the animals captured. The disposition of the specimens can vary but generally specimens are either: 1) killed at the collection site; 2) caught, measured, sampled, and released unharmed at the collection site, or 3) transported live to an aquarium in a secure facility with the specimens never being allowed to leave that site alive.

Specimens are only allowed to be transported live to an aquarium if research requires keeping live specimens for some duration after capture or the exhibition of live specimens is necessary for educational purposes. The ARP will specifically address the live holding of fish and their allowed dispositions.

Any species, or progeny of species, remaining alive at the end of the permit effective period will need to be held under a subsequent permit, if issued, or destroyed as directed. Plan accordingly and apply for a subsequent permit in a timely manner **before** the expiration of the current permit.

Application Forms

- Aquatic Resource Permit (ARP) Application
- Aquaria Supplement
- Transport Supplement for Propagative Projects with Release
- Transport Supplement for Export or Propagative Projects Without Release

Application Review Period

Once a complete application packet is received, the ADF&G Commissioner, or delegate, will approve, condition, or deny a permit application no later than 45 days. Any requests for changes or additions to an issued permit can be made to ADF&G's Permit Coordinator. Amendments may be required to go through the entire review process again**. For this reason, in the near term, non-ADF&G plan partners should work directly with ADF&G to mobilize response.** The AKISP Invasive Northern Pike Committee chair will work to obtain an emergency ARP for committee organizations who could potentially encounter Northern Pike during remote field work. If an emergency ARP was in place, partners could immediately respond. Should an emergency ARP be authorized, it will be included in plan updates.

2.3 Early Detection Tools

Early Detection Survey Data Collection

Regardless of the response methods chosen, consistency in data collection is needed for repeatability of future surveys, allow for data comparisons across partners, and to develop a comprehensive database of biotic and abiotic information from suspected Northern Pike waters for future use. SOP 1: Northern Pike Survey and Monitoring Data Collection identifies the standards for field data collection on habitat, water quality, bycatch, and Northern Pike collected. These same standards can also be applied to proactively monitoring for Northern Pike from waters from which they are not known to occur.

Gillnets

The use of gillnets is a reliable method for confirming Northern Pike presence and is widely used by Northern Pike biologists in Alaska (i.e., Massengill et al. 2020, Bradley et al. 2020b, Schwanke 2012, Roach 1997). Gillnetting to detect invasive Northern Pike populations has been used in Southcentral since the late 1990s, but netting techniques, recommended net specifications, and methods to quantify effective netting effort have evolved and improved over time. Catchability of Northern Pike in gillnets has also been evaluated in waters where Northern Pike are native (Pierce and Tomcko 2010). SOP 2: Gillnet Use for Early Detection Surveys Combines lessons learned over the last decade of invasive Northern Pike surveying in Southcentral and published recommendations and provides guidance for plan partners to effectively use gillnets when surveying for new Northern Pike populations.

eDNA

Environmental DNA (eDNA) is a relatively new method for confirming Northern Pike presence and has been widely used by fisheries biologists in Alaska (Sepulveda et al. 2018, Dunker et al. 2016) and elsewhere in the Pacific northwest (Carim et al. 2019) since the initial eDNA marker for Northern Pike was developed (Olsen et al. 2015). eDNA has been in practice since the early 2000's (Ficetola et al. 2008). The general concept is that organisms shed cells, excrement, gametes, etc. into the environment, and DNA from field samples can be amplified in a lab to determine the presence of a species without physically having a specimen in hand. eDNA can be more sensitive for detecting rare taxa, such as a newly invading species, than traditional fisheries techniques (Jerde et al. 2011). While eDNA is an excellent tool for early detection surveys for Northern Pike, caution should be exercised because it is easy to contaminate samples. Management considerations, based on eDNA results, should also be carefully evaluated because positive results only establish that Northern Pike DNA has been detected, not necessarily that a live physical fish is present (See SOP 3: Decision Guidance).

In Southcentral Alaska, this distinction has been difficult to discern at times. For example, following a Northern Pike eradication project on the Kenai Peninsula (Soldotna Creek Northern Pike Eradication), eDNA survey results consistently showed positive detections despite thousands of netting hours failing to detect Northern Pike post-eradication (Massengill, personal observation). In this instance, it is thought that sediment-released DNA confounded interpretation of results – Northern Pike DNA was present, but not live fish. However, in over 40 lakes on the Kenai Peninsula that were sampled for Northern Pike eDNA with comparable efforts (Dunker et al. 2016), only one lake failed to yield positive eDNA results when a single physical Northern Pike was later found (North Vogel Lake; 38 acres and ~410 gillnet hours). In every other lake where Northern Pike presence was confirmed with net catches, the eDNA results aligned (Massengill and Dunker, personal observations). Therefore, eDNA is considered a reliable tool for early detection of Northern Pike so long as potential confounding factors such as sample contamination, proximity to other Northern Pike waters, or sediment-trapped eDNA is taken into consideration when interpreting results and determining any management actions that come from positive detections (Goldberg et al. 2016; Sepulveda et al. 2022). Despite the potential challenges in interpreting eDNA results within a management context, eDNA is a very useful early screening tool (Sepulveda et al. 2020), and in cases where bycatch potential prohibits gillnet surveys, it is the preferred option for early detection Northern Pike surveys. Therefore, SOP 3: eDNA Use for Early Detection Surveys provides guidance for plan partners on consistent and best practices for using eDNA when surveying for new Northern Pike populations in Southcentral Alaska, for interpreting results, and for using those results to trigger management actions.

Hook and Line

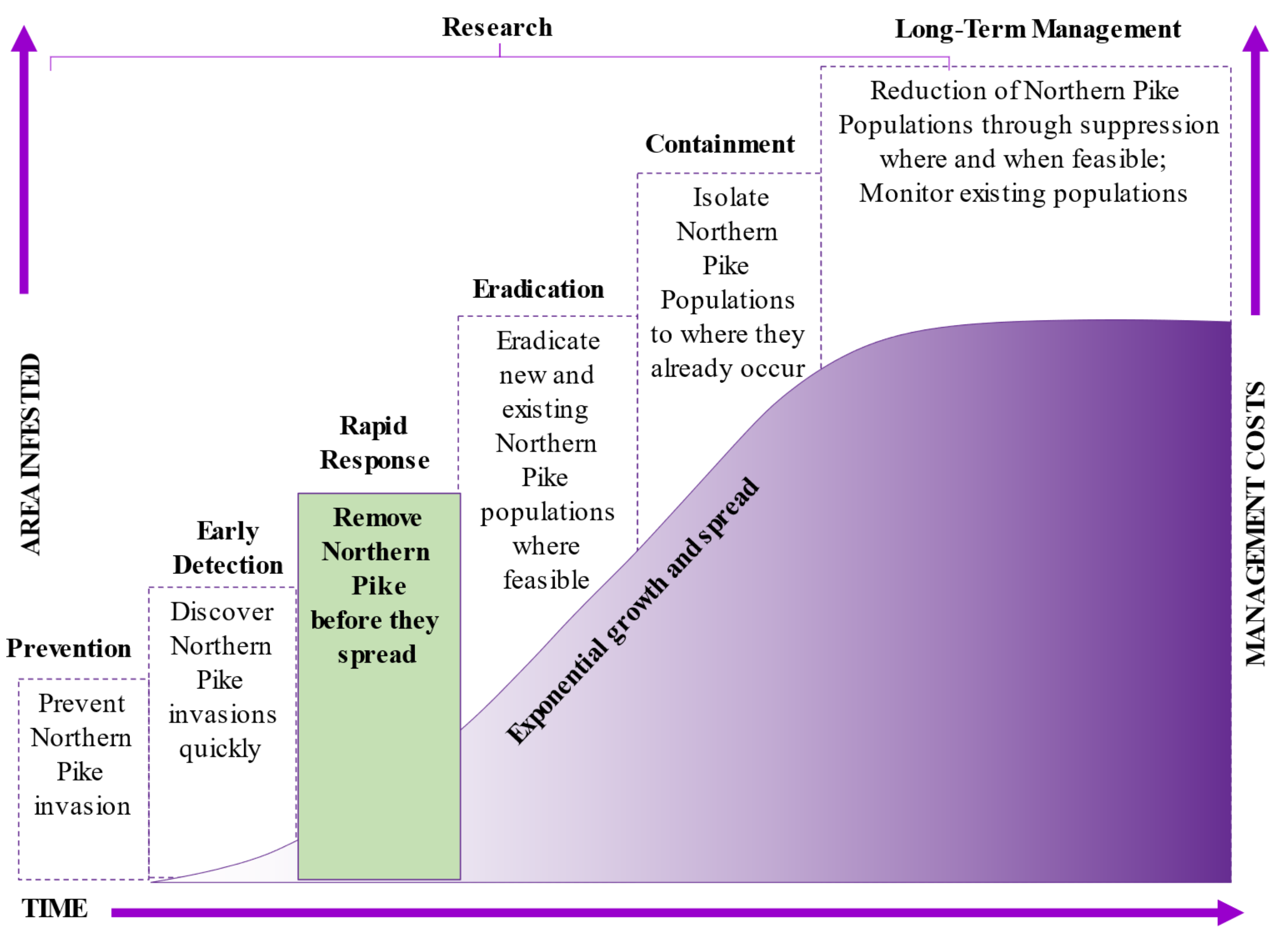
In cases where gillnetting is not an ideal option for early detection surveys due to bycatch concerns or other factors, and eDNA surveys are impractical due to confounding factors, cost, or other considerations, angling surveys using hook and line may be the best opportunity to detect new Northern Pike populations. In Southcentral Alaska, hook and line has traditionally captured far fewer Northern Pike than gillnets when both survey methods are applied congruently (TTCD and ADF&G WCI Northern Pike data, unpublished). When specifically tested, angling has not been found to detect trends in Northern Pike populations at the same level that gillnetting surveys can, and Northern Pike catchability is highly variable with angler skill (Pierce and Tomcko 2003). However, in the case of using hook and line for early detection surveys, there is potential value. It is not uncommon for new Northern Pike reports to first be detected by recreational anglers posting on social media (Dunker, personal observation), a phenomenon also recognized for early detections of other non-native fishes (i.e., Banha et al. 2015). Therefore, angling is a useful early detection tool, both by the public if they are knowledgeable of where to report their observations and through strategic hook and line surveys by plan partners. Using hook and line methods for targeted Northern Pike surveys is described in detail in SOP 4: Hook and Line Surveys for Early Detection.

Visual Surveys

In general, visual surveys for Northern Pike are less reliable but should not be discounted as an option for early detection surveys. The benefits to visual surveys are that they incur minimal costs and have no bycatch concerns. Visual surveys can span from observations made into clear water from a boat to scuba diving or snorkeling along transects (which has not yet been used for Northern Pike in Alaska). However, when done from an observer on a boat, this survey method is qualitative and best suited to occur in tandem with other on-going survey methods, or opportunistically when surveying for other AIS. A small number of Northern Pike populations in Southcentral have been discovered through visual observation (i.e. Rollercoaster Lake, TTCD, personal observations), and it is noted that most surveys for the invasive aquatic plant, elodea, that occur in known Northern Pike waters have had Northern Pike visually observed in them during the surveys (TTCD, unpublished). SOP 5: Visual Surveys for Early Detection outlines best practices for conducting visual surveys for Northern Pike from a boat, with a submersible ROV, or by snorkeling.

STEP 3: Rapid Response

Once a new Northern Pike population has been identified through early detection surveys, rapid response is the next line of defense in preventing that population from establishing and/or spreading (i.e., Beric and MacIsaac 2015). Rapid response requires both proactive planning and streamlined communication for management actions. It is essential that plan partners communicate efficiently about new Northern Pike populations and that public communication, when warranted, is coordinated and consistent. This section provides guidance on public and media communication when responding to new Northern Pike populations in populated residential areas or in other waters that generate public interest. With respect to fisheries management it provides recommendations for sportfish hatchery stockings in Northern Pike waters, and finally, this section includes guidance on how to determine where a Northern Pike population falls along the invasion curve for response. Application of the following sections on eradication, containment, and long-term management can be selected using this guide. Ideally, rapid response will lead to eradication of the population or containment to keep it from spreading to vulnerable habitats. However, management options will vary depending on the individual circumstances of the water body.



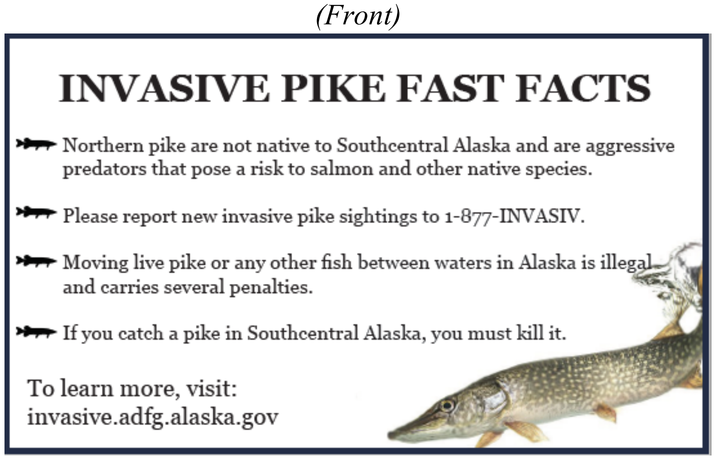
3.1 Partner Communication

When a new Northern Pike population has been confirmed by a plan partner, the reporting process will be followed and the ADF&G Region II (Southcentral) Invasive Species Coordinator (907-267-2889) will ensure the information is distributed appropriately among plan partners. Plan partners and other relevant communities with jurisdiction for the area will be immediately notified. The new population will be added to the Invasive Northern Pike GIS Map (Invasive Northern Pike in Southcentral Alaska (arcgis.com). Further plans for that water body will be discussed in AKISP Invasive Northern Pike Committee meetings, both regularly scheduled or specially designated meetings that could be called to focus on the situation.

3.2 Public Communication

For general public communication about confirmed Northern Pike populations in Southcentral, the most up-to-date resource is the Invasive Northern Pike GIS Map (Invasive Northern Pike in Southcentral Alaska (arcgis.com). Outreach cards with the QR code to the map and important messages will be distributed to plan partners to display at information/visitor centers and to provide to interested members of the public (Figure 22).

(Front)



(Back)

Figure 22. Invasive Northern Pike outreach card for distribution

Communication Plans

For all high-profile Northern Pike population confirmations, plan partners with jurisdiction for the area are encouraged to develop communication plans. Before implementing outreach efforts, communication plans should be shared with plan partners as needed, roles and responsibilities should be identified, and a preferred internal communication method should be established. A basic outline of a communication plan that can be modified to meet individual needs includes the following:

Issue: Invasive Northern Pike have been confirmed in [*X waterbody*]

Goal: To provide notice to the [*identified audience*] that the invasive Northern Pike population has been confirmed and to direct public inquiry to the [appropriate point of contact (*appropriate personnel for the plan partner with jurisdiction)*]

Spokesperson: Identify the primary point of contact and how to contact them. Generally, the spokesperson will be an invasive species staff member (i.e., the person with the most direct involvement or that confirmed the Northern Pike population) for the partner organization with jurisdiction.

Stakeholders: Identify relevant stakeholders who may be involved or impacted by Northern Pike in the waterbody. Consider who might support or oppose the treatment of the confirmed Northern Pike infestation.

Background: Brief description about Northern Pike in Southcentral (i.e., invasive, predators on salmon and other native fish, applicable details, or history about the waterbody); include a statement that Northern Pike are native to northern and western AK but were illegally introduced to Southcentral and harm native fishes.

Message: This section is best organized in bullet points for each message. Refer to and include key messages from the Prevention Section as appropriate.

- Include a message about why the community should care.
- List upcoming plans, if any, the partner organization has for managing the population.
- List any upcoming meetings or opportunities for public comment if applicable
- Include a message about where to report a new observation of Northern Pike.
- Include a message that it is illegal to move live Northern Pike in Alaska.
- Include a message to contact the spokesperson for more information.

External Communication: Identify how the messages will be disseminated to the public.

Internal Communication: Identify how the messages will be disseminated within the organization and/or AKISP Invasive Northern Pike Committee.

Timing: Clearly identify the timing during which the outreach will be conducted; be strategic and consider any follow-up that may be needed.

3.3 Media Communication

In all circumstances where mass media is chosen as a communication tool, a full communication plan **should** be written in advance to prepare for interviews and align messaging across partner organizations and/ or spokespeople. The messages identified in the communication plan should be the primary points to convey during the interview.

News Release

A news release (or press release, depending on organization preference) is the appropriate method to solicit media interest. The news release should utilize the communication plan for message planning and organization. The news release should be issued on official letterhead for the respective partner organization writing the plan and include the spokesperson contact information, background, and messages from the communication plan. Partners should then follow their own organization policies for issuing the news release. Partners are also encouraged to e-mail the news release to the AKISP Invasive Northern Pike Committee to keep all partners informed and to the general AKISP listserv if desired.

Media Contact Communication

Before contacting media outlets, partners should clarify whether they are required to report their contacts with media outlets and should follow their internal processes for this and are encouraged to participate in professional media trainings. However, for cases that involve multiple partners or jurisdictions, interviewees are highly recommended to e-mail the involved parties a summary of the interview. Post-interview summaries should include:

- Date and time of the interview
- Contact information for the person interviewed
- Media outlet, reporter, and their contact information
- Summary of the reporter's questions
- Summary of the information provided to the reporter
- Recommend any potential follow-up

Follow-Up

In cases where the community is involved or expressed strong opinions, there should be a degree of follow-up. Stakeholders who were actively involved should be informed of final decisions and outcomes. This has the added benefit of fostering relationships with the target audiences. Follow-up can be variable and include such formats as e-mail, phone call, social media posts, or updates during existing community meetings and forums.

In tandem with communications planning for new Northern Pike introductions, management decisions regarding recreational fisheries in the waterbody may also be necessary. This is considered in the next section (ADF&G Hatchery Stockings in Northern Pike Waters) but depending on the situation may require additional outreach and messaging in public and media communications.

3.4 ADF&G Hatchery Stockings in Northern Pike Waters

One element of rapid response that is unique to ADF&G is how to proceed with hatchery stockings of recreational fisheries in lakes where Northern Pike are introduced. ADF&G's Sport Fish Division is mandated in statue (AS16.05.092) to provide recreational fishing opportunity, and this is accomplished through ADF&G policies. These policies have shifted over time, and some decisions made decades ago would not be made today. For example, *native* populations of Northern Pike in Interior Alaska were once removed to allow for hatchery stockings of Rainbow Trout. Ironically, Rainbow Trout were not native to the waters where this occurred. Even today, there can be confusion about Alaska's current stocking policies where Rainbow Trout continue to legally be stocked outside their native range in Alaska.

While stocking hatchery-produced Rainbow Trout in this capacity can appear to conflict with policies and actions taken toward invasive Northern Pike in Alaska, there are substantial differences. As stated, the Alaska Legislature has directed ADF&G to enhance and create fishing opportunities through hatcheries for food production and economic benefit. ADF&G policies dictate how this is accomplished to minimize impacts on wild fish populations (i.e., stocking by lake type and using triploid or all female fish) and defining best practices (using local stocks when possible and programs to minimize disease and genetics concerns). Although ADF&G may stock fish in areas where they are not native, extensive measures are now taken to protect wild fish and prevent spread and natural reproduction of the hatchery-produced fish. Additionally, hatchery programs are internally and publicly reviewed and permitted to ensure they conform to Alaska statute and regulations. In contrast, none of these protections are in place when the public moves fish between waters, and that is why non-permitted translocations of any aquatic species is strictly prohibited in Alaska (5AAC 75.055). Therefore, while *historic* conflicts with current policies must be acknowledged, the state's stocking policies today are rigorously controlled and enacted to provide recreational fishing opportunities for Alaskans and reduce angling pressure on wild fish. To that end, deciding how to proceed with hatchery stockings in waters where Northern Pike are illegally introduced can be challenging.

Decisions on hatchery stockings are made by sport fish managers in each ADF&G office and published in a five-year statewide stocking plan (22region2.pdf (alaska.gov)). Within each 5-year period, deviations in stocking locations from those published in the statewide stocking plan require public notification. As of 2022, there are relatively few stocked lakes with invasive Northern Pike present. In the Mat-Su, these include: Lalen Lake, Memory Lake, Prator Lake, South Rolly Lake, Tanaina Lake, West Beaver Lake, and Crystal Lake. In Anchorage, only Sixmile Lake has Northern Pike but is not yet confirmed to have a reproducing population, and no Kenai Peninsula stocked lakes are known to harbor Northern Pike.

Stocking decisions in invasive Northern Pike waters have varied from immediate discontinuation of hatchery stockings, to shifting hatchery products to less vulnerable prey, to continuing with the statewide stocking plan as published. Habitat conditions of the lakes (i.e., degree of Northern Pike spawning and rearing habitat), use of angler harvest as a tool for Northern Pike removal, and vulnerability of proximate waters are all factors that are considered in ADF&G's stocking decisions when Northern Pike are found. Under this management plan, ADF&G area managers will continue to consider the unique conditions of a lake to determine the appropriate course of action with stocking it. When feasible, hatchery stockings are recommended to temporarily pause to allow for rapid response to the invasive Northern Pike while minimizing waste of hatchery fish through response activities. As with all newly introduced Northern Pike populations, eradication is the goal so that hatchery stockings can resume as soon as possible. For Northern Pike populations that are well established, area managers will base stocking decisions on lake conditions and upcoming plans for Northern Pike management in the lake. As a general guideline, it is recommended that stockings temporarily discontinue one year prior to any planned Northern Pike eradication effort to allow time for anglers to harvest what remains and reduce waste of hatchery fish. It is also recommended that stockings are reduced within a year of new Northern Pike suppression efforts, again to reduce hatchery bycatch. The objective in both scenarios is to resume hatchery stockings as quickly as possible to levels identified in the statewide stocking plan so that angling opportunity for hatchery fish is maximized, and waste of hatchery fish as prey for Northern Pike is minimized.

3.5 Response Guidance

For newly discovered Northern Pike populations, the optimal goal is eradication and preventing it from spreading elsewhere. However, each waterbody will present unique challenges that makes standardization of management strategies challenging. While flexibility is needed, the following guidance illustrates patterns in the criteria typically considered in Northern Pike response decisions. Among the most important of these are:

- Accessibility of the waterbody
    - Is the waterbody located on the road system, or is it remote?
    - If remote, can it be accessed by floatplane, boat, or snow machine?
    - In general, the more accessible a site, the more easily eradication can be staged.
- Complexity of the habitat
    - Is the waterbody a small, closed lake, or is it an interconnected mosaic of lakes, streams and wetlands?
    - Typically, Northern Pike are relatively simple to eradicate from small (< 100 acre) closed lakes.
    - Conversely, the larger and more complex the system, the more difficult Northern Pike eradication is to achieve.
- Feasibility of eradication
    - Northern Pike population characteristics:
        - Is it a low-density population? Is there evidence of Northern Pike reproduction?
        - If there is an established reproducing population, are the Northern Pike well-distributed throughout the drainage?
    - Consider all the field logistics, permit requirements, public opinions, staff availability, resources, etc. to gauge how feasible successful eradication could be.
- Cost of eradication
    - Project cost is a considerable factor in Northern Pike response as rapid response funding is not always available, and larger projects typically require successful solicitation of funding.
    - Smaller projects that can be accomplished with existing funds can be responded to quickly and, therefore, have the greatest likelihood of eradication success.

Invasive Northern Pike Situation Assessment. The following invasive Northern Pike situation assessment form (Figure 23) can be used to record site conditions and inform where on the spectrum (Figures 24-25), the site falls for determining next steps for management. This form is available in the plan supplemental materials.

INVASIVE NORTHERN PIKE SITUATION ASSESSMENT

Date _______ **Waterbody Name:** ______________________

Have Northern Pike ever been eradicated here? **Yes** __ **No** __

Is a bathymetric map available? **Yes** __ **No** __

Acres: ____________________

Max Depth: _______________

Accessibility (Scale 1-10): _____________

Means to access water body? ____

Is the water body open or closed? **Open** __ **Closed** __
(Regular status, not during flood stage)

If open, are Northern Pike isolated to one lake or dispersed? **Isolated** __ **Dispersed** __

If isolated, can temporary barriers be used to contain the Northern Pike population? **Yes** __ **No** __

If open, on a scale of 1-10, how expansive is the connectivity? _________________________
(Example: 1- Cheney Lake, 10- Sustina River)

On a scale of 1-10, how complex is the habitat? ____
(1 - minimal littoral zone/ steep drop off, isolated - 10 - All vegetated, shallow, wetlands)

Are there conservation concerns in the waterbody? **Yes** __ **No** __
(Ex. Wilderness area, endangered species presence)

Transportation costs to site:	**High**	__	**Medium**	__	**Low**	__
Cost to eradicate:	**High**	__	**Medium**	__	**Low**	__
Are native fish present?			**Yes**	__	**No**	__
Post-eradication, is fishery restoration needed? (Native fish rescue required, or could native fish return naturally?)			**Yes**	__	**No**	__

On a scale of 1-10, how much risk does this Northern Pike population pose for other drainages?
(i.e.., how likely is it that Northern Pike will spread to vulnerable habitats from this location?

Scale: _________

NOTES:

Resources:
ADF&G maintains bathymetric maps for select lakes.
Wetland Mapper: https://www.fws.gov/wetlands/data/mapper.html
Northern Pike Mapper: Invasive Northern Pike in Southcentral Alaska (arcgis.com)
Google Earth: https://www.google.com/earth/versions/

Figure 23. Invasive Northern Pike situation assessment form

Management Strategy Guidance. Figure 24 illustrates how the response guidance criteria and situation assessment, together, can direct the appropriate Northern Pike management response. For example, easily accessible waters with simple habitat complexity, newly establishing populations, basic logistics, and lower eradication costs will be ideal candidates for successful eradication. On the other end of the spectrum, eradication is much more difficult in very remote complex drainages with high-density and well distributed Northern Pike populations. Drainages with complicated access logistics, those that have significant permit requirements and/ or public concern, as well as those requiring high project costs are also less likely to be eradicated with present tools and may be best suited for long-term management/suppression. Whenever feasible the Northern Pike population should be contained as best as possible to limit its spread. If native fish are present in the waterbody, native fish protection, rescue and/ or restoration should be considered regardless of the management action chosen, especially if there are any conservation concerns for the native populations. As will be discussed throughout the remainder of this Northern Pike Management Strategy Section, different tools are available to be implemented within each stage of response, and some of these tools can be used across strategies. (Figure 25).

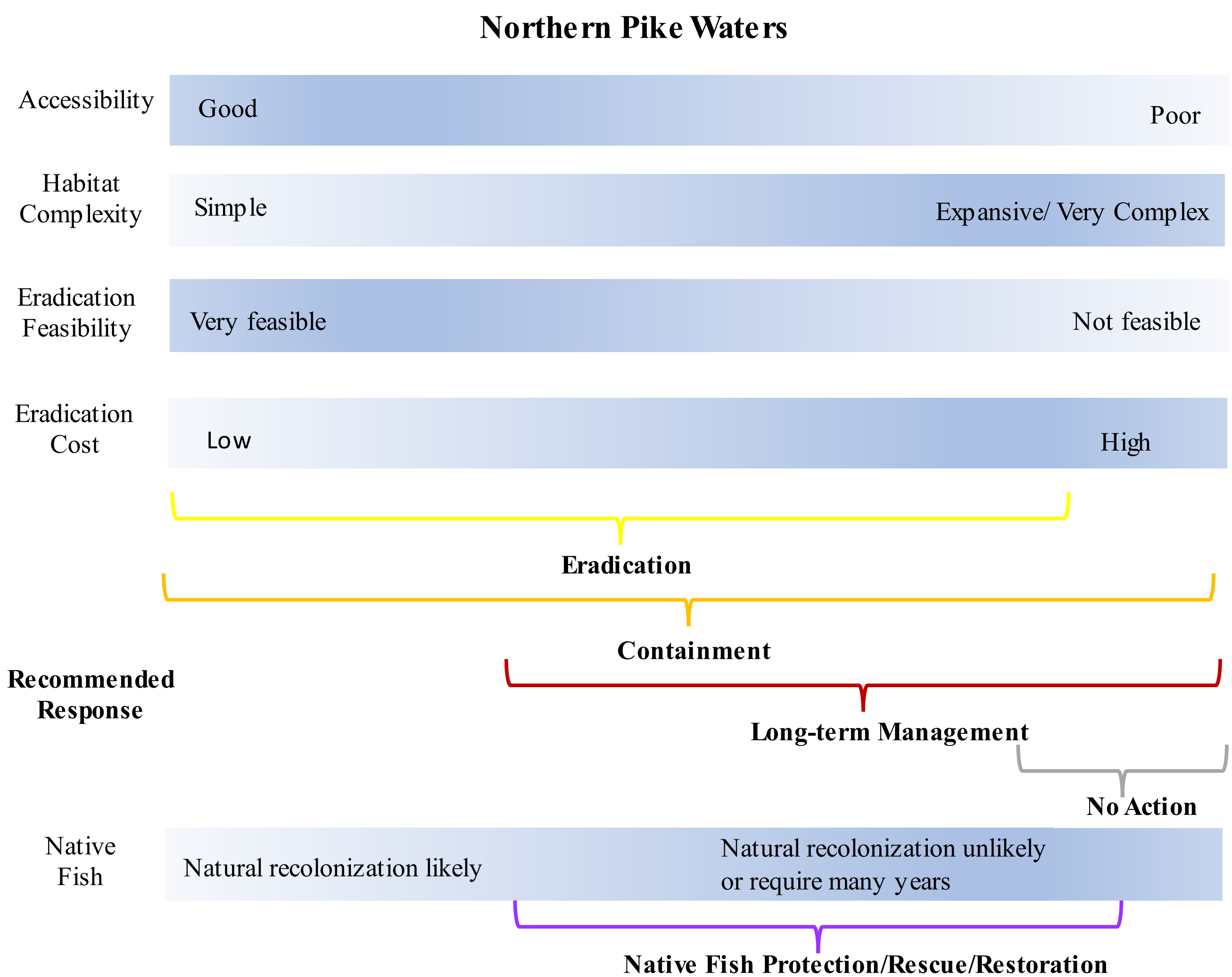


Figure 24. Guidance on selecting the appropriate management strategy for response

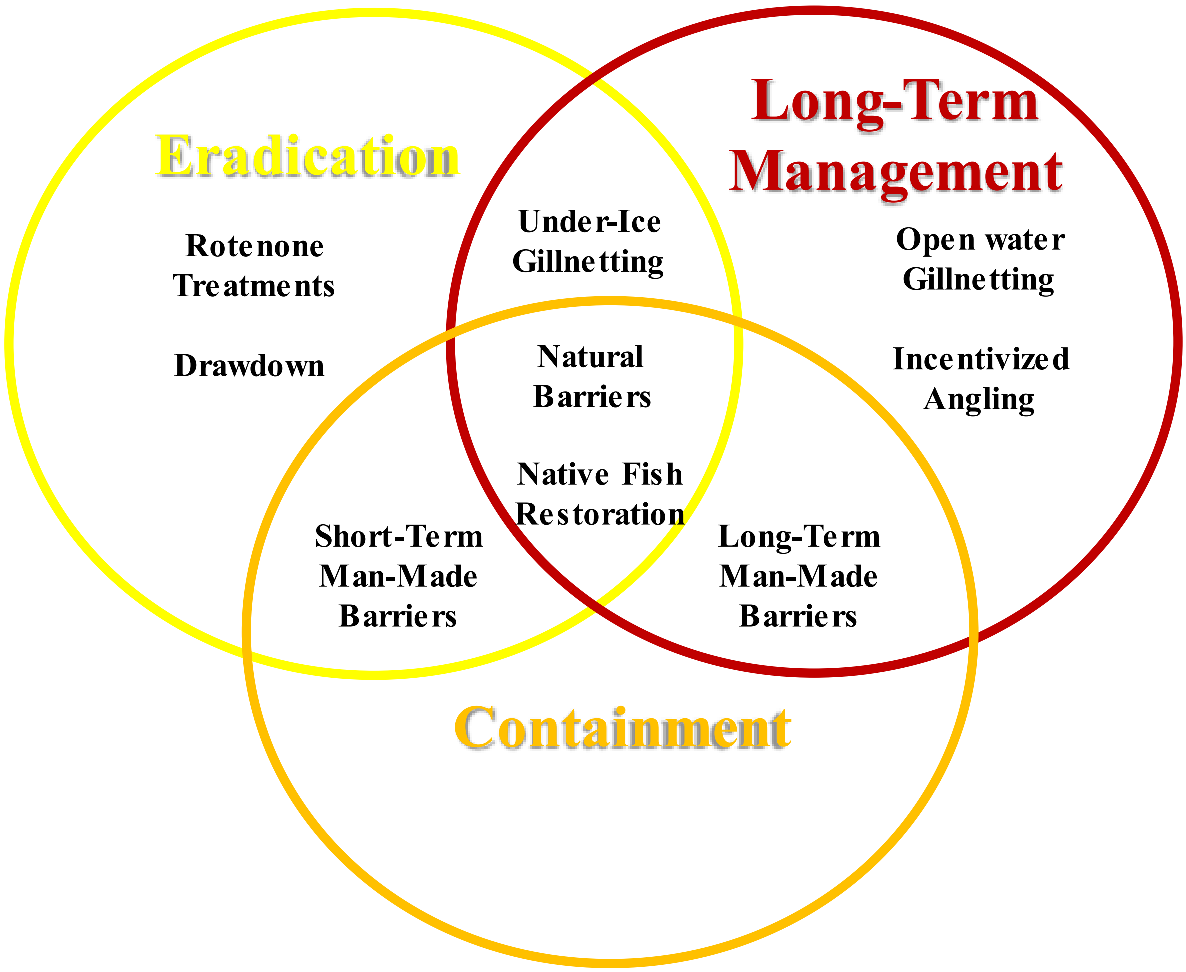


Figure 25. Management tools that can be selected for different management strategies

Response Plan Framework. Once a management strategy has been selected, the following response plan framework (Figure 26) can be used to organize the next steps among partner organizations. This framework provides a succinct record of the project need and can be used as a basis for developing grant proposals and/ or permit applications. All partners involved in a response project should have access to the most current version and retain a copy of this framework document for their records. A blank copy of the form can be found in the plan supplemental materials. This response plan framework can also be used to refine the messages for public communication about the response.

INVASIVE NORTHERN PIKE RESPOSNE FRAMEWORK

List the goals and objectives for the response to this infestation.
Objectives should follow the SMART format: Specific, Measurable, Achievable, Relevant, Time-bound

The primary objective of rapid response actions should be eradication whenever possible. However, eradication may not be feasible. In such cases, alternative objectives could include immediate actions taken to:

- Prevent further spread
- Contain invasive Northern Pike in known areas of infestation

Infestation location

Waterbody name:
Nearest town/city:
GPS Coordinates of wetland:

Extent of infestation

What is the approximate size of the impacted area?
Is the waterbody connected to any other body of water by in/out flows, canals, tributaries, etc.?
Is the water body used for recreation? List activities (ex: fishing, float planes, etc.)
Are there impediments to accessing the site?

Current Actions

Are there any response actions currently taking place at the infestation site? (Ex: treatment for other invasive species, containment, control activities).

Planned Actions

What response action was chosen for this infestation?
What resources are needed for the response?
What resources are readily available?
For resources not readily available, how can they be obtained?
What actions are needed to limit non-target impacts (e.g. carcass removal, etc.)?

Permitting and regulations (select those that apply)

- ☐ ADEC Pesticide Use Permit required   Invasive Fish General Permit applies? Y/N
- ☐ Alaska Board of Fisheries Approval
- ☐ ADEC wastewater discharge permit
- ☐ Federal National Environmental Policy Act Categorical Exclusion
- ☐ Federal National Environmental Policy Act Environmental Assessment
- ☐ Federal National Environmental Policy Act Environmental Impact Statement
- ☐ Federal Section 7 Consultation
- ☐ ADF&G Aquatic Resource Permit
- ☐ Minimum Requirements Analysis (for infestations in Wilderness)
- ☐ Other:

Personnel

Who will be the responsible lead(s) in charge of overseeing the entire response action?

	Name	Agency	Contact Info	Role
1)				
2)				

Who will be responsible for acquiring the needed resources?

	Name	Agency	Contact Info	Role
1)				
2)				

Who will be responsible for overseeing outreach and communication to shareholders, partners, and the public?

	Name	Agency	Contact Info	Role
1)				
2)				

If necessary, who will be responsible for obtaining permits?

	Name	Agency	Contact Info	Role
1)				
2)				

List other individuals directly involved in the response and their roles *(extra lines can be added)*

	Name	Agency	Contact Info	Role
1)				
2)				

Funding

What is the estimated level of funding needed to implement this rapid response?
What funding sources can be used to support this response effort?
Who will be responsible for securing funding for this response effort?

Timeline

When will permits be applied for?
When are permits anticipated to be obtained?
Goal date for implementing action(s)?

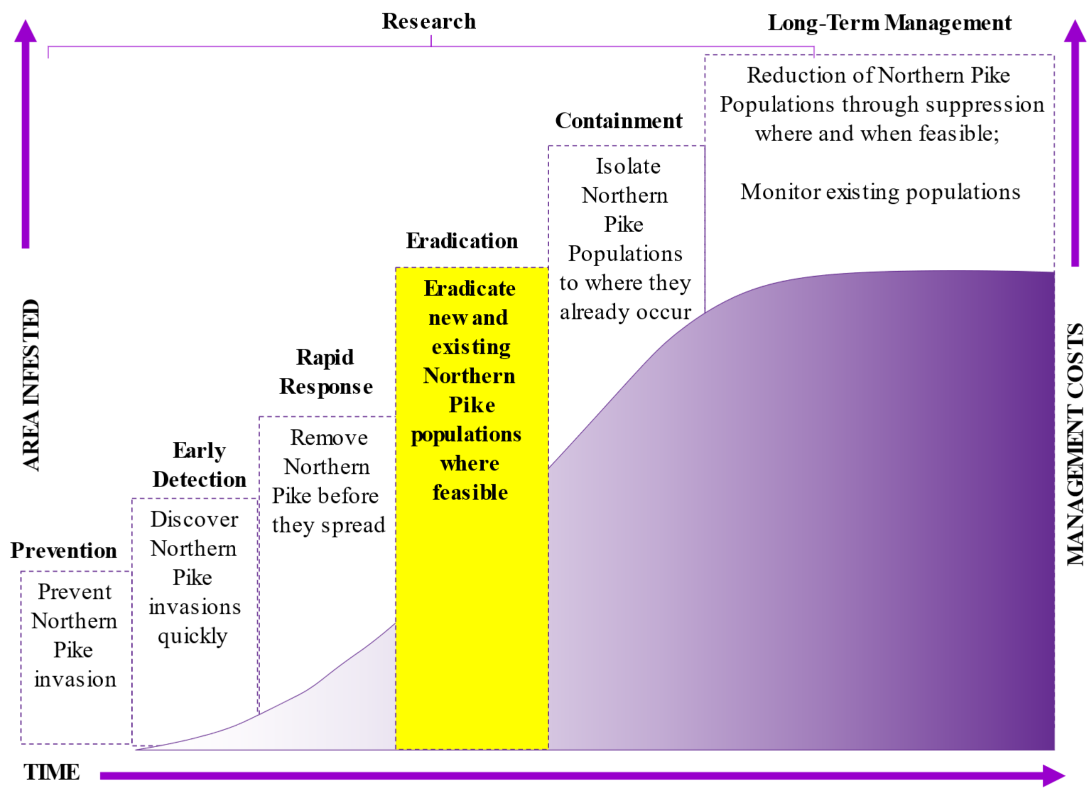
Figure 26. Invasive Northern Pike response framework form

STEP 4: Eradication

The preferred management strategy for invasive Northern Pike response is **eradication**, defined as the complete removal of all individuals in a population. Eradication eliminates the threat that a population will continue expanding and is often more economical in the long-term than population suppression. The goal of early detection and rapid response of any invasive species is always to eradicate it before it spreads and requires longer-term management (i.e., Parkes and Panetta 2009, Reaser et al. 2020). Unfortunately, because Northern Pike have been spreading in Southcentral for decades, many Northern Pike waters are currently beyond the 'eradication' stage of the invasion curve with current technologies. However, as feasible, eradication should be the goal for all newly identified Northern Pike introductions and any older populations where eradication can be reasonably accomplished. Among the challenges with eradication are that there are few tools available to completely remove invasive Northern Pike populations. The eradication tools endorsed under this plan are piscicides, (i.e. rotenone), intensive under-ice gillnetting, and in some cases, drawdown of waterbodies. This section describes the processes involved in monitoring waters in preparation for eradication and provides overviews and permitting requirements of the suggested eradication tools. Finally, this section discusses native fish restoration following Northern Pike eradications. Technical details on how to conduct eradication activities in the field can be found in SOPs #6-10 in the SOP section of this plan.

STEP 4: ERADICTATION SOPs

SOP 6: Bathymetric Mapping of Northern Pike Waters
SOP 7: Rotenone Use for Northern Pike Eradication
SOP 8: Under-ice Gillnets for Northern Pike Eradication
SOP 9: Drawdown for Northern Pike Eradication
SOP 10: Native Fish Restoration



4.1 Monitoring

To conduct an effective Northern Pike eradication project, significant advanced planning and site monitoring is necessary. The following is a list of recommended pre-eradication site monitoring activities:

- Water quality monitoring (temperature, specific conductance, pH, and dissolved oxygen) from 1-meter increments in the deepest part of a lake for one year before and after Northern Pike eradication. Measurements can be taken with a handheld device such as a YSI or Hydro lab.
- In lotic systems, flow rates should be monitored seasonally. If stream gauge equipment is not available, consult the USGS (https://waterdata.usgs.gov/ak/nwis/current/?type=flow) to determine the closest monitoring gauge to the site and/or arrange for assistance collecting flow rate data. This should begin at least one year prior to Northern Pike eradication.
- Pre-eradication surveys of native fish present in the waterbody following protocols in SOP:1
- Pre- and post-eradication aquatic invertebrate surveys. The scale of these surveys will depend on the needs of the project and permitting requirements, but generally these surveys are meant to document species (or most reasonable taxonomic level) presence before and after eradication activities. See Finlayson 2018 for further guidance and Massengill 2022 for a recent example of invertebrate surveys conducted for Northern Pike eradication.
- Bathymetric survey and map of the eradication site. See SOP: 6 for technical details with bathymetric mapping. This will be used to determine acreage and volume of the water body and, in the case of rotenone treatments, will be critical for determining product quantity calculations.
- Become familiar with the field site through foot, boat, and/or aerial surveys to note important features such as beaver dams, springs, small seepages, wetlands, and connected or ephemerally connected ponds. These should be identified with a GPS and incorporated into project planning.
- In the case of rotenone treatments, collect pre-and post-water samples for chemical analysis. See SOP: 7 for technical details.
- Post-eradication fish surveys should be conducted in accordance with SOP:1 every three years to document recovery of the native fish populations and ensure Northern Pike do not return.

4.2 Rotenone

Rotenone is a naturally occurring compound derived from the roots of tropical plants in the genera *Derris*, *Lonchocarpus* or *Tephrosia*. It has been used for centuries by Indigenous cultures in Central and South America to catch fish for food. Rotenone has been used as a piscicide by fishery management agencies in the U.S. since the 1930s to remove unwanted or invasive fish.

Currently, rotenone is available and is registered by the U.S. Environmental Protection Agency (EPA) as a restricted-use pesticide for fish management (EPA 2007). Rotenone is lethal to fish because it is readily absorbed through the gills where it instantly enters the blood stream and inhibits cellular respiration (Ling 2003, Marking and Bills 1976). At the concentrations used for invasive fish eradications, the piscicide is not harmful to birds, mammals or adult life stages of most amphibians, but is lethal to plankton and many macroinvertebrates (Vinson et al. 2010). Rotenone is unlikely to enter ground water as it is strongly binds to soil organics and, because it is naturally broken down by photolysis, thermal degradation, and other biotic and abiotic factors, it does not persist long-term in the environment. In Alaska, rotenone applied in cold water is typically detoxified within 5 to 8 months (Couture et al. 2022, Redman et al. 2020), and warmwater applications are completely detoxified within weeks or less (ADF&G, personal observations).

Rotenone products come in both liquid and powdered formulations. Powdered formulations are typically 100% ground plant material having the consistency of a slightly fibrous powder and has a tan color. The concentration of the active ingredients (rotenone and rotenone cube resins) in powdered products varies by production lot, but approximates 6-9% and 5-14%, respectively. Several varieties of liquid rotenone formulations are available. Most liquid formulations contain about 5% rotenone and 5% rotenone cube resins. The liquid formulations have viscosities much like cooking oil. The additives found in liquid formulations are intended to improve its emulsification and synergistic effects to fish (Schnick 1974).

Rotenone piscicides are a Restricted Use Pesticide (RUP). The Alaska Department of Environmental Conservation (ADEC) requires anyone purchasing, applying, or handling piscicides to be a certified pesticide applicator with an aquatic category certification. For information on becoming an Alaska pesticide applicator go to: Becoming a Certified Applicator (alaska.gov). The ADEC Pesticide Control Program provides a list of pesticides registered for use in Alaska (Chemical Name (kellysolutions.com); only these products are lawful to purchase and use.

The amount of rotenone product needed for a specific treatment is determined by the size of the treatment area (water volume for lakes, discharge for streams) and the rotenone target concentration. For cost reference, in 2021 the State of Alaska purchased two rotenone-based piscicides: CFT Legumine™ 5% liquid rotenone and Prentox™ Rotenone Fish Toxicant Powder™. The cost for each piscicide was $133.17/gallon and $7.76/pound, respectively, not including shipping. By applying these prices, the estimated product cost to treat one acre-foot of water at a target concentration of 40ppb of rotenone (a typical concentration used for Northern Pike eradication), was $35.51 for 0.27 gallons of CFT Legumine™ and $12.83 for 1.9 pounds of Prentox™.

Most rotenone treatments require substantial permitting or similar authorizations from Federal, State, Tribal and local governments, and private land managers. The following describes all the permits and authorizations that may be necessary for eradication projects involving rotenone:

Federal level

National Environmental Policy Act (NEPA): If a federal nexus exists for a rotenone project (i.e., funding or land ownership) this mandates NEPA compliance, and in most cases, that means an environmental assessment (EA), or Categorical Exclusion (CE) must be submitted to the reviewing federal agency. In Alaska many rotenone projects are funded, in part, by grants awarded by the Alaska Sustainable Salmon Fund (AKSSF). The AKSSF manages the State of Alaska allocation of the federal Pacific Coastal Salmon Recovery Fund (PCSRF) administered by National Oceanic and Atmospheric Administration Fisheries (NOAA).

The applicable federal agency (i.e., USFWS, NOAA. etc.) will review the NEPA Document (EAs have been most commonly required to date) and determine whether a "Finding of No Significant Impact" (FONSI) is warranted. If a FONSI is issued, that will conclude the Federal approval process for the EA. If a FONSI is not issued due to concerns that cannot be addressed by an EA revision, an environmental impact statement (EIS) may be required.

In some instances, a categorical exclusion (CE) may be granted by the responsible federal agency. A CE is a class of actions that a federal agency has determined do not individually or cumulatively have a significant effect on the human environment and for which, therefore, neither an EA nor an EIS are required. It is necessary to consult with the federal nexus agency to see if an EA or CE is applicable. An EA requires substantial effort to draft and is usually done in coordination with the reviewing federal agency. Typically, when an EA is required, the entire EA process can take about a year to complete. The EA is often accompanied with a public scoping and commenting period. For an example of a recent EA for an Alaska rotenone project see: http://www.adfg.alaska.gov/index.cfm?adfg=rotenone.currentprojects.

APDES: An Alaska Pollutant Discharge Elimination System (APDES) general permit authorization is required to regulate source discharges of pollutants associated with the application of biological pesticides or chemical pesticides that leave a residue. This permit is commonly called the Pesticide General Permit (PGP). The PGP applies statewide except for lands within the Metlakatla Indian Reserve and the Denali National Park Reserve.

The PGP covers point source discharges of pollutants associated with the application of biological pesticides or chemical pesticides that leave a residue from the following use patterns:

- mosquito and other flying insect pest control,
- aquatic weed and algae control,
- **aquatic nuisance animal control; and**
- forest canopy pest control.

Pesticide residue includes that portion of a pesticide application that is discharged from a point source to waters of the United States and no longer provides pesticidal benefits. It also includes any degradants of the pesticide.

To determine if a Notice of Intent (NOI), or a summary of requirements under the PGP are needed, see: https://dec.alaska.gov/water/wastewater/stormwater/pesticide/pgp-tool/ to access an interactive tool to help determine compliance needs. Most entities that are a federal or state agency whose role is as a decision-maker will be required to submit an NOI, develop a Pesticide Discharge Management Plan, submit an Annual Report, and pay an annual permit fee.

Army Corps of Engineers (ACOE): Most projects involving chemical removal of invasive fish in Alaska do not require ACOE permits. The Corps regulates the discharge of dredged and/or fill material into waters of the U.S., including wetlands, under Section 404 of the Clean Water Act.

The placement of structures, such as picket weirs, would not be a regulated activity, as they would not constitute a discharge of fill material. However, if structures are placed in such a manner to have the 'effect of fill', that would be regulated, and a DA (Dept. of Army) permit would be required (i.e., layers of wood that impede the movement of water between the lake and stream; essentially, the material would be a dam). If placement of structures requires the discharge of fill into waters of the U.S., including wetlands, to hold them in place, a DA permit would be required for that activity.

The exception to the above is in relation to navigable or tidally influenced waters. A DA permit is required for the discharge of dredged and/or fill material, the placement of structures, or any work that would affect the course, condition, or capacity of a water under Section 10 of the Rivers and Harbors Act of 1899. The type of permit required would depend upon the activity, the type of impact (discharge of fill, placement of structures, temporary vs. permanent impacts, etc.) and the resource that would be impacted.

Further information regarding the U.S. Army Corps of Engineers, Alaska District, Regulatory Program can be found at: https://www.poa.usace.army.mil/Missions/Regulatory/. Permitting requirements for a project can be determined here:
https://www.poa.usace.army.mil/Missions/Regulatory/Regulatory-Contacts/.

State Level

ADEC PUP: The application of pesticides to waters in the State of Alaska requires an ADEC Pesticide Use Permit (PUP). Information about obtaining an ADEC PUP is provide here: Obtaining a Pesticide Use Permit (alaska.gov). In some cases, a General Permit (GP) may be issued instead of a PUP. Currently, a general permit exists for the application of specific products containing rotenone to control invasive fish. This general permit can only be used for projects overseen by ADF&G. To apply pesticides under this GP, an applicant must submit a completed and signed application for coverage and receive a confirmation letter and project tracking number. Details on GP's can be found here: General Permits for Pesticide Application (alaska.gov).

The PUP permit requires a significant investment of time to complete, and both a PUP and GP have public notice requirements. The PUP also has a public commenting period and post-commenting hold period prior to issuance and is a more involved process. Rotenone projects operating under a PUP or GP require post-treatment reporting (Report of the Treatment Results) to ADEC by January 31 the year following the rotenone application and each year thereafter for the duration of the permit period.

Alaska Department of Natural Resources (ADNR) Land Use Permit (LUP): In many instances an ADNR LUP may be necessary for a rotenone treatment. Consult the ADNR Division of Land, Mining and Water to see if a LUP is needed. ADNR assesses landownership status and title rights within the treatment area to decide if a LUP is warranted. For more LUP information see: Lands Section Permitting – Alaska Division of Mining, Land, and Water

ADFG Fish Habitat Permit: If a rotenone project involves water withdrawal or an activity that may impact fish passage (i.e., culvert installation, temporary diversion, barriers) and the waterbody supports fish, an ADF&G Fish Habitat Permit is needed. For more information on ADF&G Fish Habitat permits see: Fish Habitat Permits, Alaska Department of Fish and Game.

ADFG Aquatic Resource Permit (ARP): An Aquatic Resource Permit (ARP) is required for any activity to collect fish, amphibian, shellfish, or marine aquatic plants that is not covered by current sport, personal use, aquatic farm, and commercial regulations. Additionally, an ARP is needed to transport, import, export, or propagate fish. In most instances, an ARP will be needed for a rotenone project if fish are being collected and utilized for bioassay and caged sentinel uses, or, to collect native fish for rescue purposes (such as temporary relocation to a safe area) or to relocate/release fish for posttreatment restoration including brood stock collection purposes. For more ARP information see: Licenses & Permits, Alaska Department of Fish and Game or refer to the ARP section of this plan.

ADFG Board of Fisheries (BOF), ADFG Commissioner and Sport Fish Division Director consent: Per Alaska statue (AS 16.35.200 – Use of poison to kill predatory animals), approval must be granted by the Alaska Board of Fish prior to conducting a rotenone treatment. It is also customary that approval be granted by the ADF&G Commissioner and the ADF&G Division of Sport Fish Director. Requests for these approvals should be coordinated well in advance of the project by contacting the ADF&G Sport Fish Division Regional Invasive Species Coordinator.

Rotenone Use in Alaska

As discussed in the plan background, rotenone has been used to eradicate invasive Northern Pike in Alaska over 25 times since 2008 (Table 3). It was also commonplace decades ago for rotenone to be used to clear lakes ahead of ADF&G stockings with hatchery products, ironically, as discussed earlier, to remove native Northern Pike and other fish in Interior lakes (Doxey 1991) and sticklebacks throughout Southcentral lakes. Despite the complexity of planning and permitting for projects involving rotenone today, it is among the most reliable tools for fish eradication. The state's earliest treatments for Invasive Northern Pike populations involved very small, closed lakes, both to provide current applicators small-scale opportunities to learn the rotenone process, and to gauge public acceptance of its use. Over time, the scale and complexity of rotenone treatments for invasive Northern Pike in Southcentral Alaska has increased, with the largest project (Soldotna Creek on the Kenai Peninsula) treating 7 lakes, over 20 miles of flowing waters, and 200 acres of wetlands over the course of 4 years. This project also included substantial native fish restoration. The success of this project demonstrated that rotenone could, within reason, be used to eradicate Northern Pike on a drainage scale (Massengill 2022).

In addition to the complexity of rotenone projects in the field, public resistance to the use of pesticides is common, and project planners must consider stakeholder concerns and do their best to address them. The rotenone stewardship program: Rotenone Stewardship Program (fisheries.org) is an excellent information source for all aspects of rotenone treatments, including public outreach and education about rotenone. Within this plan, SOP: 7 provides technical guidance on conducting rotenone treatments in Alaska. Finally, in most cases, communication plans and, if warranted, news releases should be developed and distributed before rotenone treatments. These documents can be modeled off those discussed under Rapid Response.

4.3 Under Ice Netting

If using piscicides is not feasible or desired, an alternative Northern Pike eradication method is to use gillnets beneath the ice during late winter and early spring to capture either all the Northern Pike or at least enough to thwart successful spawning. This method can also be applied to long-term suppression projects.

Ideally, for this method to be effective in *eradicating* a population, it should be employed very early in the Northern Pike invasion to a new waterbody; otherwise, it is most effective for suppression. The goal with under-ice gillnetting is to remove Northern Pike before they can successfully spawn, or at least before there is a well-established population. Because Northern Pike are spring spawners, and spawning in Alaska often begins under the ice, nets are typically set late in the winter and either pulled right before the ice becomes unsafe or left in the water until ice-out. The challenge of leaving the nets in the water without checking until open water is that it can be difficult to know for certain if Northern Pike were caught given their rate of decomposition. In Southcentral Alaska, Northern Pike carcasses have been documented to fully decompose in nets within two months (Dunker et al. 2016). However, net checks can be done by pulling and resetting nets until the nets ice-in, or with use of an ROV camera underwater to view net catches (SOP 8).

To date, there have been a few applications of this method for Northern Pike eradication. The first time this was used, Northern Pike were illegally re-introduced to Cheney Lake in Anchorage three years after their eradication with rotenone. Nets were fished all winter from December 2011 until ice-out 2012. Two Northern Pike were caught. No other Northern Pike have been reported since, so the removal of those two individuals is thought to have prevented spawning if any other Northern Pike remained after the nets were pulled. Under-ice gillnetting has also been used in Sand Lake in Anchorage. This is another case of an illegal re-introduction of Northern Pike several years after they were eradicated with rotenone. In this case, under ice nets fished in the spring of 2019 captured one Northern Pike (based on photo evidence, it is suspected to have been the fish observed by an angler and triggered the Northern Pike report). No other Northern Pike have been caught since; however, eDNA monitoring detected Northern Pike eDNA for two seasons following this. For this reason, gillnetting and monitoring for Northern Pike will continue in this lake until there are more conclusive results. In other examples, under-ice gillnetting successfully eradicated invasive Northern Pike in Tiny Lake (2011), Hall Lake (2011) and Warfle Lake (2017). These three lakes are on the Kenai Peninsula, and all were low density Northern Pike populations (n<30), with few juveniles indicating poor reproduction. Finally, the last example is also from an Anchorage-area Lake. Northern Pike were recently (~2020) illegally introduced to Sixmile Lake on Joint Base Elmendorf-Richardson (Brandt, personal communication). Under-ice gillnetting in spring 2021 captured several Northern Pike, all within the same 1–2-year-old cohort. Under-ice netting in spring 2022 only captured one Northern Pike. Monitoring will continue, but it is anticipated that gillnetting efforts will prevent spawning and establishment of Northern Pike in Sixmile Lake.

One primary consideration when deciding to use under-ice gillnetting for Northern Pike eradication is bycatch. A benefit to this strategy is that waterfowl are not exposed to the nets unless ice-out occurs before the nets are pulled. This reduces the chances of waterfowl entanglements. However, fish bycatch can be significant. For lakes with wild salmonids, bycatch concerns should be carefully considered. For lakes stocked with hatchery fish, project leads should work with ADF&G Sport Fish Division area managers on decisions to use this method. Significant fish bycatch makes the nets much less efficient to check and limits their effectiveness in catching Northern Pike. Bycatch is also wasteful. All these factors should be considered when planning under-ice gillnetting efforts. SOP 8 describes the technical details and other factors that should be considered when planning under-ice gillnet projects for Northern Pike eradication.

4.4 Drawdown

As discussed earlier, Northern Pike spawn in the early spring, during and after ice out. In Southcentral Alaska, that is typically during the month of May. In several Southcentral Alaska lakes, Northern Pike have been observed spawning in open water at lake outlets in early May while the lake was still covered with ice. The spawning period lasts for 2-4 weeks, with eggs hatching around 13-16 days after fertilization (Priegel and Krohn 1975, Wright and Shoesmith 1988). Survival rates can be highly variable between the egg and fry stage, with siltation, sudden temperature change, and water level fluctuation being significant contributing factors to egg mortality (Hassler 1970). Submerged aquatic vegetation has been documented as being very important for successful spawning, with highest egg densities occurring in the densest areas of vegetation (Wright and Shoesmith 1988). Post hatching, water level is still an important factor affecting survival of larval Northern Pike as these shallow vegetated areas are important habitats for feeding and rearing (Franklin and Smith 1963). As a result, one idea for the control of Northern Pike populations is reducing water levels in water bodies during the egg and larval development stage post spawn in the spring, which could induce high mortality rates on that year class, potentially causing a year class failure.

At Shell Lake, near Skwentna, AK, CIAA has been suppressing the Northern Pike population by deploying gillnets during the summer months. From 2014–2019 gillnets were deployed for an average of 16,000 net/hours each summer capturing a minimum of 575 Northern Pike in 2018 and a high of 1,729 Northern Pike in 2015 with an average catch of over 1,000 Northern Pike for all those years. Environmental data including the water level at the lake outlet were collected for each year of the project and, during the summer of 2019, CIAA recorded the largest early summer water level drop that had been documented during the project. The following season (2020) CIAA captured a mere 34 Northern Pike despite deploying nets for 16,256 hours. Of the 27 Northern Pike for which age could be determined, only one was age-1 from the 2019 year-class. This suggests that the reduction in water levels in 2019 during the critical stage of egg and/or larval developed likely caused a year class failure. During the summer of 2021 CIAA deployed nets for nearly 10,000 hours capturing only 9 Northern Pike. Though other factors could have possibly impacted the Northern Pike population at Shell Lake, there was a spawning failure for this population of Northern Pike in 2019, and possibly in 2020 because of low spawner density, that has resulted in the reduction of CPUE at Shell Lake, to a catch rate that is 98% lower than it was in 2019, and over 99.7% times smaller than it was at the onset of Northern Pike suppression activities. Correspondingly, estimated Northern Pike consumption of salmonids is down 90% from the start of the suppression (Courtney et al. 2018).

Though the water level drop in 2019 was caused by the natural phenomenon of drought, it shows the potential for water level manipulation as it relates to Northern Pike spawning success. This suggests there could be other areas where Alaska fisheries biologists could use this information to gain an advantage in other waterbodies where invasive Northern Pike are being suppressed. In systems where there are means to alter the water level of the lake through natural or artificial blockages, alterations of those blockages cold be used to aid in the control of Northern Pike spawning success following spring spawning events and reduce Northern Pike populations further than they could be via gillnetting alone, potentially leading to recruitment failures that crash the population. When implementing drawdown as a management tool the ADF&G Habitat Division should be consulted to determine if a Fish Habitat Permit (FHP) is needed (Habitat Permits, Alaska Department of Fish and Game). SOP: 9 details how to conduct effective drawdown efforts.

4.5 Native Fish Restoration

Restoration of native fish communities impacted by Northern Pike is a critical action to consider. The preservation or restoration of the native fish community present prior to Northern Pike invasion is often the fundamental objective driving the decision to eradicate Northern Pike. To date, most invasive Northern Pike eradication efforts have involved at least some level of native fish restoration. These actions have spanned from replacing sticklebacks in eradicated lakes (Bell et al. 2016, Heins et al. 2016) to stocking hatchery fish post-eradication for recreational fishery enhancement (i.e., Massengill 2014a, Massengill 2014b), to pre-eradication rescue and temporary offsite holding of native fish for reintroduction after the rotenone degrades (i.e., Massengill, 2022, Massengill 2017b), to reintroduction of native fish from nearby waters post Northern Pike-eradication (Massengill, In Preparation). Decisions on the most appropriate level of restoration is situation dependent. Generally, the following criteria should be considered in evaluating native fish restoration options:

Native Fish Rescue Criteria

Non-game fish: Native non-game fish are critical to the natural ecological function of a waterbody. For example, sticklebacks, provide an important forage base for piscivorous waterfowl as well as salmonids. When non-game fish species (e.g., sticklebacks, sculpins, suckers, whitefishes, etc.) are identified as being historically present in the waterbody (as determined through historical records or recent surveys using minnow traps, gillnets, or visual observations) these species should be restored posttreatment, particularly to closed lakes where natural recolonization is unlikely to occur unless active restoration efforts are taken.

Partnerships among agencies and entities to restore fish populations is encouraged and has been very productive. ADF&G has had success partnering with researchers in the field of evolutionary ecology to conduct stickleback reintroductions as part of their research investigations (Bell et al. 2016, Heins et al. 2016, Massengill, In Prep). Non-game fish species are often abundant in neighboring waters and can usually be sourced for reintroduction. The goal is to provide enough fish to seed new self-sustaining populations. In open systems where good connectivity of surface waters exists between the water being restored and other waters with healthy native fish populations, the reintroduction of native fish species may be unnecessary due to natural recolonization via dispersal from connected waters. Post-treatment monitoring to detect fish species presence will confirm whether natural recolonization of all native fish species is occurring. If it is not, then the release of absent species can usually be achieved by actively relocating individuals collected from within or near the same drainage.

Hatchery salmonids: Generally, lakes that were stocked with hatchery fish prior to Northern Pike eradications are similarly restocked post-eradication. The species and hatchery products chosen are determined by the ADF&G sport fish area managers with management jurisdiction for the waterbody. Generally, hatchery stocking is only permitted at waters with some form of public access, see ADF&G statewide stocking plans for more information: http://www.adfg.alaska.gov/index.cfm?adfg=fishingSportStockingHatcheries.stockingPlan).

Native salmonids: In some instances, closed lakes where invasive Northern Pike are eradicated do not have public access or a history of supporting native sport fish populations. This was the case with a large Northern Pike eradication effort at a group of lakes near Tote Road in Soldotna. Because invasive Northern Pike supported a popular sport fishery in this lake complex for decades, there was concern that the successful removal of Northern Pike may be thwarted by reintroductions of Northern Pike by people wanting to sustain a sport fishery there.

Many of the Tote Road area lakes have no public access and few lakeside residents wanted to permit public access which is required for stocking hatchery-reared fish. A compromise was pursued by ADF&G whereby native salmonids from a nearby drainage were relocated to these lakes to establish a replacement sport fishery (Massengill *In Preparation*). This tactic of relocating fish to supply fisheries in lakes without public access should be employed carefully, and only employed in special cases, as the effort needed to conduct wild native salmonid introductions is high and public expectations for a similar response for future projects may be impractical. Of note, introductions of native salmonids to closed lakes is unlikely to produce self-sustaining populations due to inadequate spawning habitat and other constraints to their life history. The creation and maintenance of a long-term native salmonid sport fishery requires periodic releases of new fish. ADF&G guidelines for lake stocking densities for salmonids are available (Havens et al. 1995).

Pre-treatment rescue of native fish: When possible, collection and temporary relocation of representatives of the native fish assemblage should occur if the affected fish population(s) are potentially genetically unique, have a conservation concern, occur in a protected area (i.e., designated wilderness), or otherwise identified as a preservation priority. An example of an effort to preserve native fish populations prior to a rotenone treatment in a wilderness area is available (Miller Creek Drainage, treated in 2021). Efforts to preserve a genetically unique Arctic Char (*Salvelinus alpinus*) strain in a Northern Pike-invaded lake is described in Massengill 2017b. Another Northern Pike removal project involved the drainage-wide preservation and restoration of native fish populations in Soldotna Creek, a Kenai River tributary. This native fish preservation and restoration component was a critical project element desired by stakeholders during project scoping, and the restoration effort involved the collection and safe relocation of tens of thousands of native fish over a multi-year period (Massengill 2022).

Natural recolonization of native fish: Alternatively, or in addition to rescuing fish before treatment, open systems can often recolonize naturally with native salmonids and other species if such species are available in connected waters. Depending on the system, this recolonization may take many years to achieve historical fish abundances and population structure. Natural recolonization of native fish may be initially slow as there can be a very limited forage base to support many fish following a rotenone application to remove invasive fish. Some forage items (e.g., zooplankton, macroinvertebrates, etc.) may recover from rotenone applications at different rates. However, Northern Pike eradication projects occurring in Soldotna Creek drainage and Stormy Lake (Kenai Peninsula) indicate natural recolonization of some species of juvenile salmonids can begin immediately following the complete degradation of rotenone (Massengill 2022, Massengill 2017b). The key element to facilitating natural recolonization is ensuring there is adequate fish passage to the waters being restored. For example, beaver dams may need to be continually breeched for a period to encourage native fish reentry. If natural fish passage is not possible, project leads should strongly consider pre-treatment native fish rescue so there are fish available for restoration. Periodic fish surveys are useful to monitor the status of recovering native fish populations. On the Kenai Peninsula, ADF&G conducts posttreatment native fish surveys of all restored waters to assess species presence, catch-per-unit-of-effort (CPUE) and length frequency data. Surveys are accomplished using gillnet and minnow traps, surveys are scheduled to occur every three years for at least a nine-year period post removal of the invasive fish population (Massengill et al. 2020).

Permits

ADF&G Aquatic Resource Permits (ARP) are required of any entity that collects and/or transports live fish. See ADF&G Aquatic Resource Permits for details.

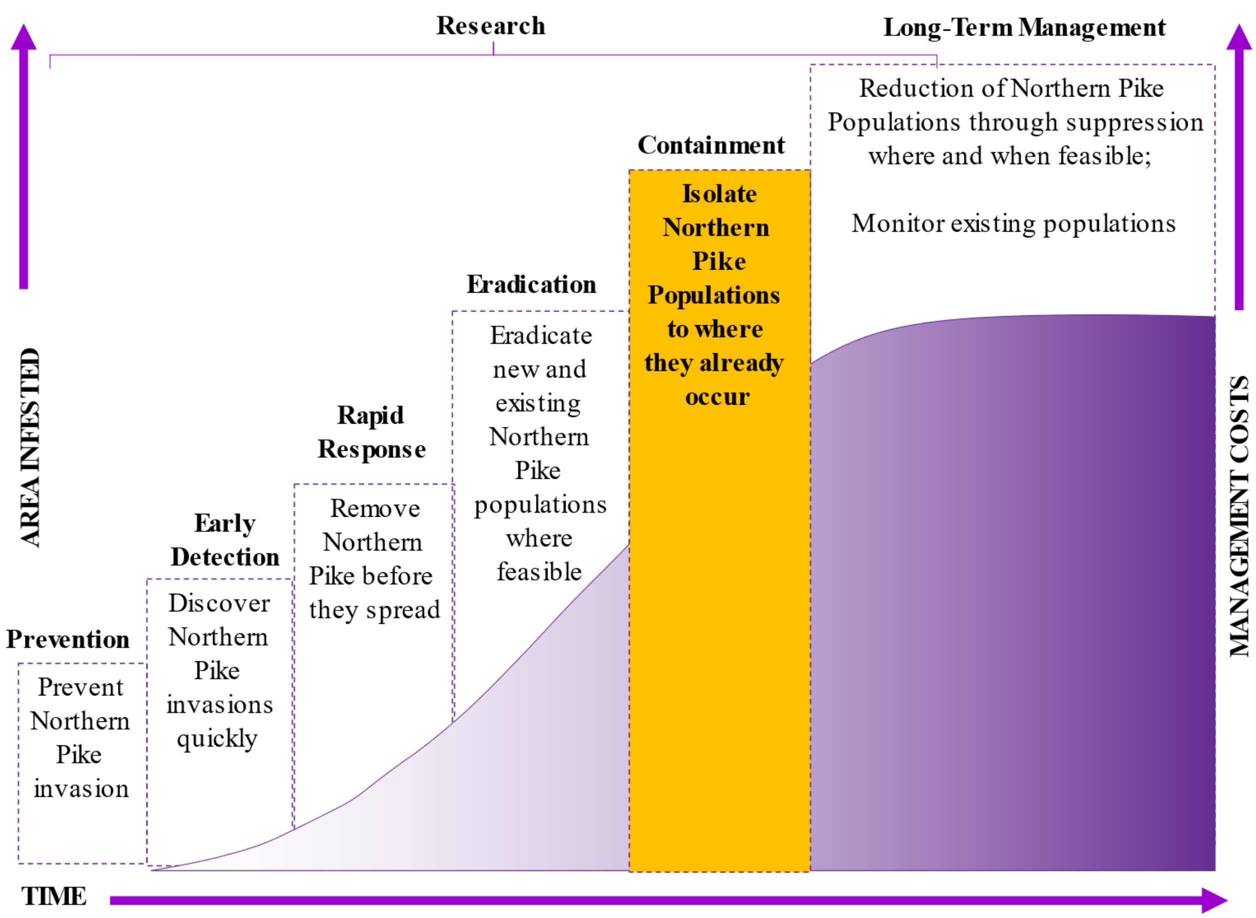
SOP: 10 identifies the methods and details that should be considered when conducting post-Northern Pike eradication native fish restoration.

STEP 5: Containment

When attempts to prevent Northern Pike introductions and rapid response to new invasions is not successful, or if eradication for new or existing Northern Pike populations is infeasible, the next stage of management is to contain the population as best as possible. Containment options can vary in temporal scale and are often situationally dependent. This section describes emerging science and concepts for containment barriers that may be considered for Northern Pike in the future. SOP: 11 then describes current options for temporary and natural containment barriers and optimal conditions for using them.

STEP 5: Containment SOPs

SOP 11: Use of Barriers to Contain Northern Pike Populations



5.1 Barriers

Containment of invasive Northern Pike populations is a necessary management step to prevent them from spreading (Spens et al. 2007), but how best to do this is a challenging topic that will be improved upon for years to come. In general, fisheries professionals consider impediments to fish passage, such as perched culverts, significant ecological problems, and for good reason. However, in the case of invasive species, these impediments have sometimes slowed down their spread (McLaughlin et al. 2013). When Elwha dam was removed in Washington state, there was concern that non-native Brook Trout (*Salvelinus fontinalis*) could spread. Fish passage programs are now considering invasive organisms as a variable in project design and prioritization (Tummers and Lucas 2019), and in Alaska, invasive Northern Pike populations are now recognized as an important consideration in local salmon passage initiatives (Alaska Stream Crossing Workshop, March 2022).

In areas where Northern Pike are invasive, there is growing desire to design and install specific barriers that could inhibit or greatly reduce Northern Pike from spreading (Wood Environment Solutions 2021). This could serve the basic need for containment or pave the way for eradications that might otherwise be infeasible. Because of the complexity and connectivity of waterbodies containing Northern Pike in Southcentral Alaska, eradication efforts have not been pursued in many areas due to the risk of reinvasion. While fish barriers could be installed downstream of an eradication project to prevent reinvasion, research on barrier designs that will allow passage of native resident and anadromous species while still blocking Northern Pike is a critical need.

The use of natural and artificial barriers to protect native fishes against invaders has been used effectively to preserve genetically pure populations of native Cutthroat Trout (*Oncorhynchus clarkii*) subspecies against Brook Trout, Brown Trout (*Salmo trutta*), and Rainbow Trout (*Oncorhynchus mykiss*) in the Rocky Mountains (Behnke and Zarn 1976, Thompson and Rahel 1998, Novinger and Rahel 2003). Because isolation management with barriers typically prevents upstream fish movement, its efficacy as an option to control invasive species where migratory native species are present is low. However, if the invasive species has considerable behavioral and physiological differences compared to the desired native species, then barriers can be designed to take advantage of these discrepancies (Lavis et al. 2003, Holthe et al. 2005). For example, Northern Pike are ambush predators often displaying fidelity to limited areas for long periods with major movements mostly associated with spawning or travel to and from overwintering areas (Rutz 1996, Roach 1998). In contrast, many Alaskan salmonid species actively forage for prey and undergo extensive spawning migrations that often involve overcoming natural obstacles such as waterfalls (Lauritzen et al. 2010). These innate differences in life history and thus physiology indicate that Northern Pike may be unable to navigate relatively short vertical barriers that salmonids ascend with ease, making a species-specific barrier a potential option. Whereas Northern Pike have been documented to successfully navigate through moderately sloped (15-30% incline) vertical slots and weir fishways with water velocities up to 107 cm/s (Schwalme et al. 1985, Ovidio and Philippart 2002), their ability to ascend vertical drop has only recently been initiated and predictive studies have assumed that Northern Pike are unable to ascend many such structures (Diebel 2013). Therefore, barriers that combine a high velocity channel followed by a vertical drop, similar to the design of Gardunio (2014) to exclude Burbot (*Lota lota*) and White Sucker (*Catostomus commersonii*), could provide an element of redundancy that first exhausts or even deters Northern Pike, and reduces the likelihood that Northern Pike reach the base of the barrier and successfully ascend the vertical drop component. This redundancy in design could also combat inevitable hydrologic, seasonal, and climactic variation, and lend flexibility in habitats where only one element can be constructed (Gardunio 2014).

The maximum swimming and leaping capabilities of Northern Pike must be determined to confidently design barriers that will exhaust Northern Pike and prevent barrier ascent. While methods for predicting such parameters exist from fish length and projectile motion equations (Powers and Orsborn 1985,Meixler et al. 2009), empirically-derived parameter values often differ from model predictions (Burford et al. 2009, Neary 2012). As a result, relying solely on model predictions may lead to barrier designs that block all fishes; therefore, quantifying Northern Pike performance limitations via empirical observations is essential.

Recent developments in fish passage studies have led to standardized methods with which to measure the leaping abilities of fishes using adjustable waterfall designs (Kondratieff and Myrick 2005), and swimming performance with swim chambers and open channel flumes (Katopodis and Gervais 2016). While literature on fish jumping ability is sparse, a general trend across taxa is that high waterfall heights and shallow pool depths reduce passage success (Stuart 1962, Kondratieff and Myrick 2005). Other physical factors that impact fish barrier ascension include water temperature (Ficke and Myrick 2011, Gardunio 2014), waterfall width (Brandt et al. 2005), water velocity of the waterfall (Lauritzen et al. 2010), waterfall crest velocity, turbulence (Gardunio 2014) and waterfall crest depth (Powers and Orsborn 1985, Gardunio 2014). Biological factors that affect fish barrier ascension include fish total length (Moran-Lopez and Tolosa 2017), fish density in the plunge pool (Kondratieff and Myrick 2006), and fish condition as measured by relative weight (Gardunio 2014). Consideration of physical and biological factors is necessary in leaping experiments to accurately estimate barrier parameters that will block fish movement under optimum conditions.

Fish swimming performance in relation to barrier passage is a heavily researched topic, as many barriers must be engineered to facilitate fish swimming around or up the barrier rather than jumping over it (Powers and Orsborn 1985, Ovidio and Philippart 2002, Peake 2008a, Peake 2008b, Katopodis and Gervais 2016). Swim chambers and open channel flumes have emerged as important apparatus to quantify fish physiological attributes of interest. Recent research through UAF sought to explore questions of physiological limitations of Northern Pike and their leaping abilities to lay the groundwork from which Northern Pike-specific barrier designs may be developed for Southcentral Alaska drainages and elsewhere Northern Pike are invasive (Cubbage et al. 2022, *In Prep*). By quantifying Northern Pike leaping and swimming limitations and comparing them to known limitations for salmonids, barriers could be designed to block Northern Pike passage while allowing native fishes to pass. The benefits of installing barriers include:

1) Northern Pike will not have access to shallow vegetated spawning and rearing habitat,
2) juvenile salmonids will be protected from Northern Pike predation,
3) management can be justified upstream of barriers because reinvasion is unlikely,
4) native fishes can re-establish naturally or with assistance.

Evaluations of system characteristics such as the amount of salmonid spawning and rearing habitat, potential overlap of salmonid and Northern Pike habitat, and spatially-explicit estimates of vulnerability to Northern Pike invasions have been conducted in the region of concern (Jalbert et al. 2021), and this information may be used to prioritize barrier placement in the most vulnerable habitats.

Preliminary results from *Cubbage et al. 2022, In Prep* suggest that the impassability of certain barrier heights is mainly dependent on barrier height, pool depth, and Northern Pike size, whereas the flow rates tested did not affect leaping success. In general, as barrier height increased and pool depth decreased, leap success declined. Large Northern Pike required deeper pool depths to have similar leap success as small Northern Pike for similar barrier heights. Individual characteristics such as Northern Pike sex, age, body condition, or metabolic capacity did not affect leap success; however, Northern Pike that grew faster for a given age had greater leap success. This suggests that Northern Pike in ideal conditions that promote fast growth, such as in Southcentral Alaska where Northern Pike predate on abundant salmonid prey, may have small gains in leaping ability that should be accounted for in barrier designs. It must be clarified that these research findings are preliminary as data analysis for this project is on-going as of the writing of this plan. This study serves as a foundation for which future research will depend. In addition to establishing these benchmarks, the study authors will prepare a model that plan partners can use to enter in relevant variables (barrier height, pool depth, and Northern Pike size) to predict the probability of successful passage of Northern Pike. This model, as well as manuscripts from this work, will be incorporated into future versions of this plan.

In the near-term, once manuscripts of this work have been published, next steps for project managers should include researching trade-offs of Northern Pike exclusion barriers relative to other ecological concerns (i.e., movement of native fishes). Locations of interest for Northern Pike passage barriers need to be identified. Studies that evaluate Northern Pike and native species passage rates over test barriers using PIT tag studies in the field are also necessary. Finally, drainage-specific engineering schematics should be solicited to determine feasibility of installing Northern Pike barrier structures. Undoubtably, installation and maintenance of Northern Pike barriers is anticipated to be costly and require substantial permitting through the National Environmental Policy Act where federal nexus applies and in accordance with state (Example Restoration Projects - Fish Passage Improvement Program, Alaska Department of Fish and Game) and federal (National Fish Passage Program | U.S. Fish & Wildlife Service (fws.gov) stream passage programs.

The information contained within this plan section is considered preliminary and will be greatly expanded on as more is learned. In this plan version, SOP 11: Use of Barriers to Contain Northern Pike Populations serves as a first step and discusses the use of different barriers that can be used within a project area to contain Northern Pike until eradication can remove their populations. This SOP will be updated with considerations and decision guidance for more permanent barrier options when more information is available.

STEP 6: Long-Term Management

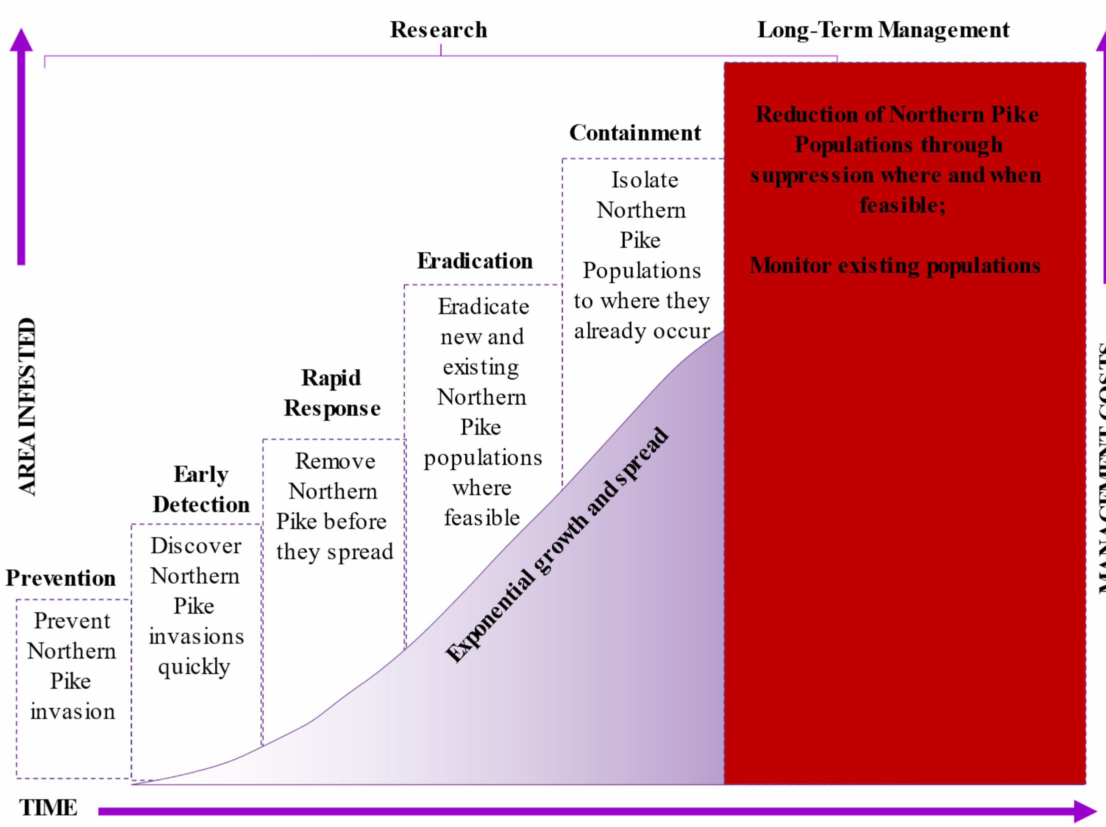
The final stage of the invasion curve and the focus of this section involves long-term management. Long-term management of invasive Northern Pike populations takes places when there are no feasible options to eradicate or contain them, or if successful containment creates new opportunities. Typically, long-term management options are needed in spatially expansive, highly interconnected habitats such as in the western Susitna Basin. In Alaska, long-term management of invasive Northern Pike has spanned from large-scale suppression programs using gillnets to reduce populations (i.e., Bradley et al. 2022a, Rutz et al. 2020a, Bradley et al. 2020a, Wizik 2018), to using angler harvest as a strategy of population reduction (Bradley et al. 2022a), to monitoring known populations until resources for suppression become available (Bradley et al. 2020b), to no action at all. For all long-term management projects, standardized data collection is ideal for replicating efforts across partners, or for future research to improve suppression success. This section describes the use of gillnets and angling harvest incentives for Northern Pike population suppression. SOPs 12, 13, and 14, discuss the technical approach for data collection and using these methods. The protocols described in SOP: 1 are relevant for monitoring known populations until further management action can be implemented.

STEP 6: Long Term Management: Suppression SOPs

SOP 12: Data Collection During Northern Pike Suppression
SOP 13: Use of Gillnets for Northern Pike Suppression
SOP 14: Angling Incentive Programs for Northern Pike Suppression

STEP 6: Long Term Management: Monitoring SOP

SOP 1: Northern Pike Survey and Monitoring Data Collection



6.1 Suppression

Data collection

Regardless of which organization is carrying out Northern Pike suppression, consistency in data collection is needed for repeatability of future efforts, data comparisons across time, and to develop data-driven targets to improve the success and efficiency of future Northern Pike suppression projects. SOP 12: Data Collection During Northern Pike Suppression identifies the standards for data collection on Northern Pike and bycatch (similar to SOP 1: Early Detection Survey Data Collection) but includes additional focus on gear parameters and set timing. SOP 12 also provides guidance on how to begin new Northern Pike suppression projects with mark-recapture studies to estimate initial Northern Pike population sizes for use as benchmarks when evaluating long-term success of suppression.

Gillnets

Northern Pike suppression can incorporate different strategies with passive removal being the most widely-used approach in Alaska (Dunker et al. 2020) and elsewhere in the western U.S. (Carim et al. 2022, Zelasko et al. 2016). The longest-term Northern Pike suppression program in Alaska occurs in the Alexander Creek drainage which is one of the most heavily impacted systems in the Susitna Basin. Salmon populations there had been predicted to be completely lost without intervention (Sepulveda 2014). To prevent this from happening, ADF&G now conducts an annual gillnet suppression program that began in 2011 to reduce Northern Pike abundance in side-channel sloughs along Alexander Creek. The primary objective is to bolster salmon productivity in the system to sustainable levels by reducing Northern Pike predation on juvenile salmon (Bradley et al. 2022a, Rutz et al. 2020a). Northern Pike stomach analyses and aerial index surveys have confirmed a gradual return of adult Chinook salmon to former spawning grounds and juvenile Chinook salmon reoccurring throughout the entire river corridor (Rutz et al. 2020a), though interannual patterns in both Northern Pike CPUE and salmon abundance remain highly variable (Bradley et al. 2022a). Other species like Arctic grayling and rainbow trout have increased in abundance as indicated by gillnet bycatch in recent years. However, the interannual variability in data trends suggests the need for obtaining baseline population estimates before beginning suppression projects. This baseline information, though potentially more costly to collect, is highly encouraged for any plan partner beginning future Northern Pike suppression projects because it allows for population size comparisons before, during, and following the suppression efforts.

Beginning in 2018 and 2019, new Northern Pike suppression programs were initiated in the Threemile Lake complex and Chuitbuna Lake, respectively, on the west side of Cook Inlet in a partnership between the Tyonek Tribal Conservation District (TTCD), the Native Village of Tyonek (NVT) and ADF&G. These areas are significant because they are at the invasion front of Northern Pike in this region. It is presently unknown if these Northern Pike populations are the result of illegal anthropogenic introductions or migrations through Cook Inlet from the Susitna River. Based on lessons learned from Alexander Creek, the Threemile and Chuitbuna Northern Pike suppression projects began with mark-recapture studies to determine the baseline population estimates of Northern Pike and to assist with long-term evaluation of the Northern Pike suppression project (Bradley et al. 2020a).

In addition, Northern Pike suppression has occurred as funding has allowed since 2014 in Shell, Whiskey, Hewitt, and Chelatna lakes and their outlet creeks in a partnership between ADF&G and the Cook Inlet Aquaculture Association (CIAA) (Dunker et al. 2020, Wizik 2020). All these lakes are significant sockeye salmon producers for the Susitna drainage. While some of the lakes, Chelatna in particular, are deep enough to allow habitat segregation between sockeye and Northern Pike, sockeye are heavily depredated during both smolt out migrations through outlet streams and juvenile fry recruitment to the pelagic lake habitat. Northern Pike suppression efforts in these lakes have been designed to mitigate these effects. In Shell Lake, Northern Pike suppression appears to have been particularly effective as only few Northern Pike are now being caught in annual gillnetting efforts (Wizik 2020).

One of the drawbacks of using gillnets to suppress Northern Pike is that gillnets are not very effective in selecting small young-of-the-year Northern Pike (Pierce and Tomcko 2003) leading to potential interannual rebounds in recruitment. CIAA had reported greater success in juvenile Northern Pike capture using small mesh nets (See SOP 13). Other potential drawbacks are that size selectivity from the gillnets and exploitation could increase the rate of stunting in the Northern Pike population, causing earlier maturation and increasing the density of smaller age classes of Northern Pike (Ylikarjula et al. 1999, Goedde and Coble 1981, Kipling and Frost 1970) that most often target juvenile salmonids (Cathcart 2019, Glick and Willette 2016, Sepulveda 2014). Further, it is unclear if reducing the abundance of Northern Pike can equate to greater salmonid survival. Decreasing the amount of intraspecific competition among Northern Pike for prey could have the potential to render the surviving Northern Pike more efficient predators (Eklov 1992,Nilsson and Bronmark 1999). However, despite these potential and recognized limitations, adaptive long-term term management using gillnet suppression is warranted to continue trying to reduce the impact of Northern Pike on native fish (Dunker et al. 2018a). Improving suppression programs remains an important priority for invasive Northern Pike research in Southcentral Alaska.

Angling/ Incentives

Angler incentive programs have been used for various reasons by fisheries managers across the U.S. using different methods depending on objectives, species, and unique geographic conditions. In Alaska, incentivized harvest has been used a couple times, but only once for Northern Pike (Bradley et al. 2022a). In this instance, it was used to increase harvest in a specific location, again, Alexander Lake. Because Northern Pike are invasive, there need to be special considerations when implementing incentivized harvest programs. For instance, it is important to emphasize that programs like these are not considered bounties. A general bounty on Northern Pike in Southcentral Alaska could be problematic for two primary reasons. First, because there are native populations of Northern Pike in Alaska that are accessible by floatplane, there would be no way of determining if the harvested Northern Pike came from the invasive range or were captured within the native range. Placing a monetary value on all Northern Pike would not only be wasteful if they came from the native range but would potentially be an incentive for over-harvest in their native range. Second, it would provide a monetary incentive for people to move Northern Pike in the invasive range to establish new populations for financial gain that are more easily accessible. In some locations, such as in the Columbia River, true bounty programs have increased harvest of invasive Northern Pike (Holly McClellan, Coleville Tribe, Personal Communication), but in that region there are not native populations of Northern Pike to complicate the program. In Alaska's Alexander Lake program, there were significant targets and controls including the use of PIT Tags to ensure that rewards were only offered for Northern Pike harvested from that location (Bradley et al. 2022a). This program only operated for one season due to funding cuts, but it serves as model by which similar future angling incentive programs for Northern Pike can be based. SOP 14 discusses the technical aspects of incentivizing Northern Pike harvest for population suppression.

6.2 Monitoring

Due to the scale of invasive Northern Pike establishment, particularly in the Mat-Su, there is not capacity to actively reduce Northern Pike in every infested waterbody. In many cases, particularly where access is difficult or response resources are a limiting factor, populations can either be monitored over time, or no action will take place at all until the waters can be prioritized for management.

Monitoring for Northern Pike, as discussed earlier, is most typically done for early detection and rapid response purposes for stopping new invasions. However, long-term monitoring can also occur in known Northern Pike waters to track changes in Northern Pike abundance, size structure, diets, and co-occurring species over time. These data are particularly useful when determining new invasive Northern Pike management project priorities. The data collection protocols described in SOP 1 are the same as should be used for long-term monitoring of known invasive Northern Pike populations. The difference is that the frequency of monitoring surveys should be based on the level of concern the Northern Pike population poses (Figure 21a).

Monitoring Frequency

For waters of greatest concern, annual monitoring surveys are recommended until targeted management actions are taken. For any waters from which Northern Pike have been previously eradicated, surveys every three years are recommended to ensure these waters remain Northern Pike-free. Northern Pike populations that are of moderate concern to fisheries managers are recommended for monitoring at least every five years, and populations that pose the least concern should be scheduled for routine monitoring at least once a decade (Figure 27).

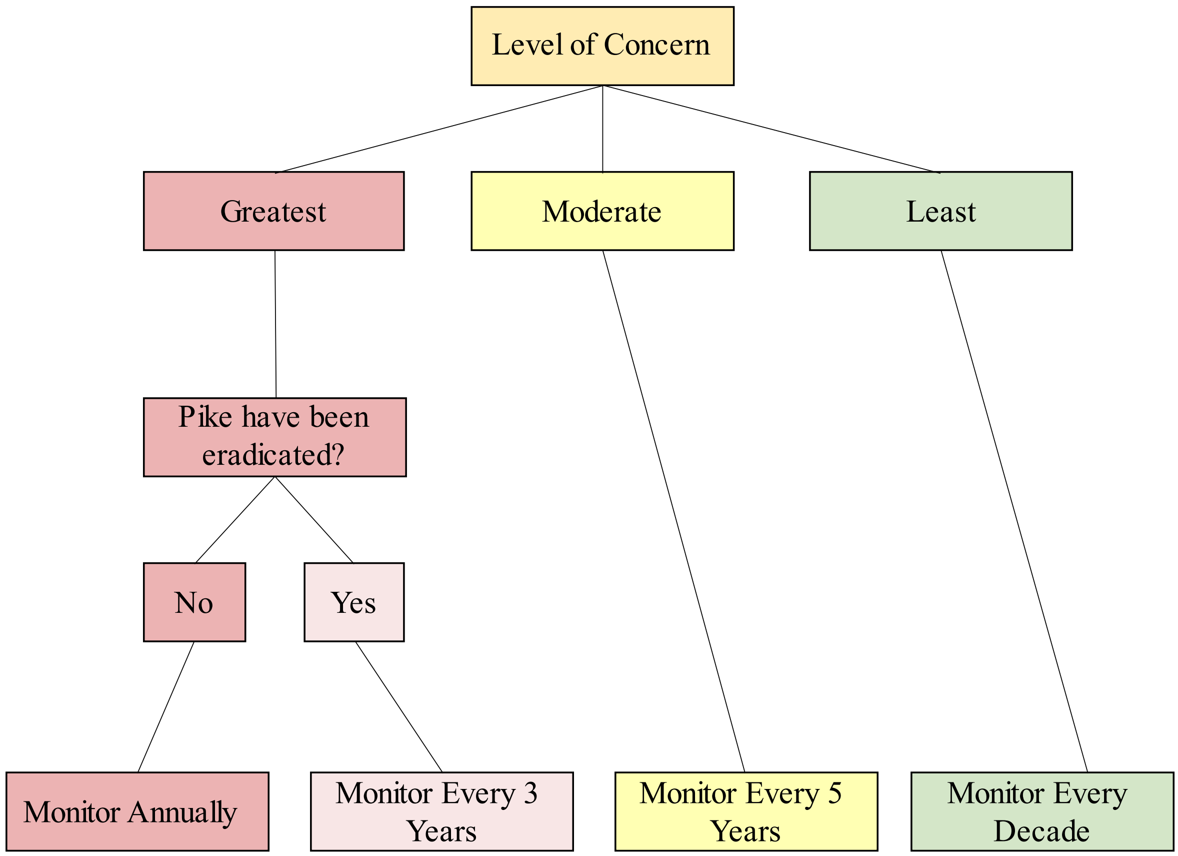
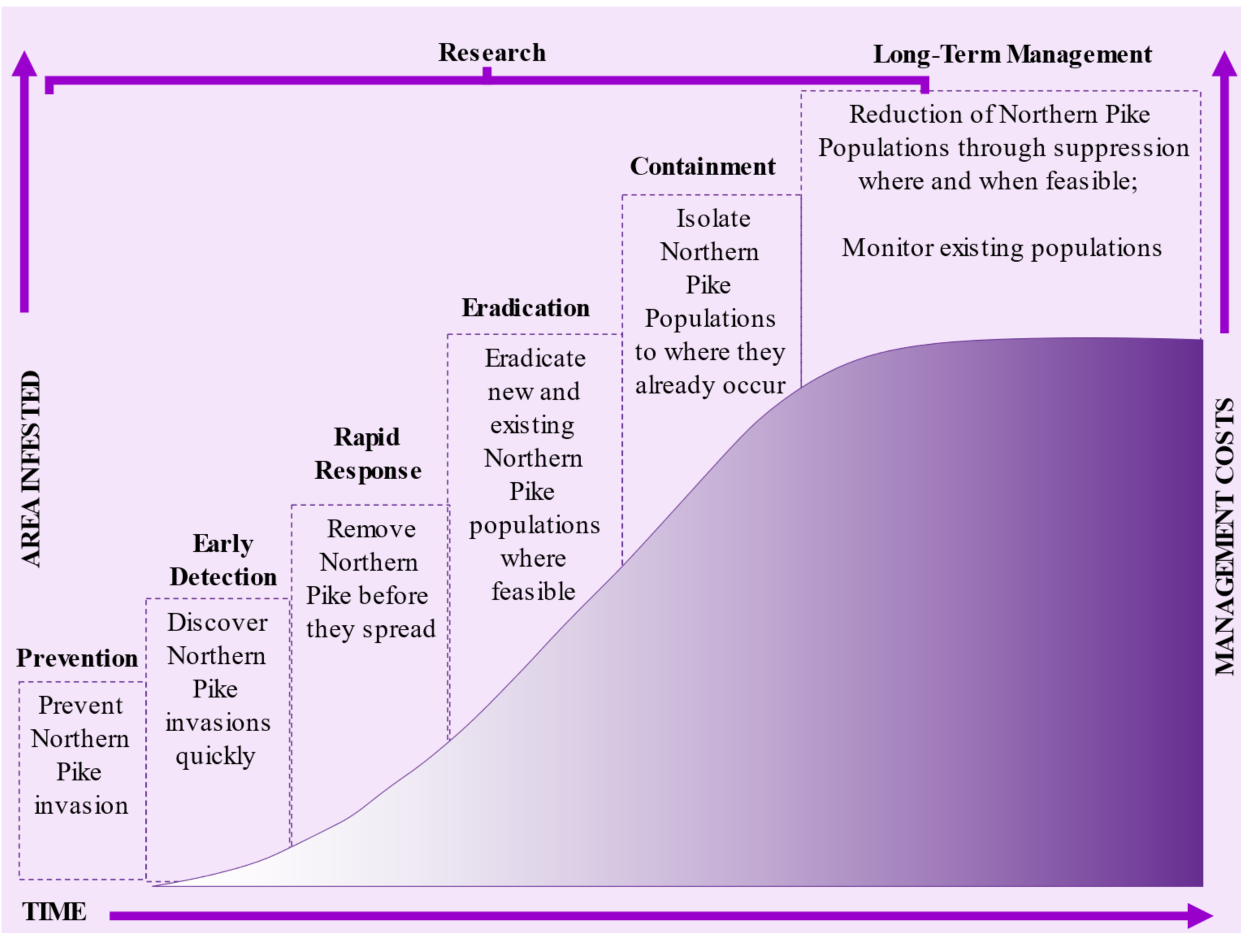


Figure 27. Northern Pike population monitoring frequency guidance

STEP 7: Research

Within this plan structure, the topic of invasive Northern Pike research follows long-term management, but its place is not intended as the final step in this process. Quite the contrary, research is interwoven into every aspect of invasive Northern Pike management in Alaska. In this section, the field of invasion biology as a scientific discipline is introduced and discussed. Future research areas and needs are then identified to help organize plan partners in addressing critical questions that can improve management strategies for invasive Northern Pike, both in Alaska and elsewhere, and contribute to the growing science on aquatic invasion biology. The areas of study and lists of questions posed in this discussion are meant as a starting point. As research on Northern Pike in Southcentral Alaska continues, further questions will evolve and be included in updates to this management plan.



7.1. Invasion Biology as a Scientific Discipline

Biological invasions of non-native species are a leading cause of ecosystem alteration and native species extinctions (Diamond 1989). Despite the contemporary importance of invasions, the roots of invasion biology as a scientific discipline are much older. Like much in western scientific thinking, some of the earliest specific thoughts on invasion biology can be attributed to Charles Darwin. Writing in *On the Origin of Species* (Darwin 1859), Darwin contemplated the pattern whereby a foreign species of plant could supplant a native species, with an appreciable tone of both wonder and concern. True to his nature, Darwin was intrigued by this seemingly inconsistent pattern especially considering his predictions that native species ought to be more 'fit' in their local environment through the process of natural selection. Charles Elton who wrote an influential monograph called *The ecology of invasions by plants and animals* (Elton 1985), is often credited with galvanizing invasion biology into a distinct discipline (Simberloff 2011). Although many of the specific hypotheses postulated by Elton have failed to be supported by evidence, many of his ideas have withstood the test of time (e.g. Levine and D'Antonio 1999). Elton's work thoroughly embraced the concept of invasions being dynamic probabilistic events as well as natural experiments to understand fundamental ecological questions, reflecting the era of its time. More recently attention has turned to questions of evolution in the context of invasions (Sax et al. 2007).

The heuristic framework of invasions as stage-based probabilistic events has emerged as a tenant of invasion biology (see review by Lockwood et al. 2013) and provides a useful starting point to understand invasion success and failures. Although the naming of stages differs some among authors, they generally follow the progression of:

1. ***Introduction***. Non-native species are transported intentionally or unintentionally by humans through a variety of vectors. Some of the most common and widely studied vectors of unintentional introductions are ballast water introductions to regions such as San Francisco Bay, which is among the world's most heavily invaded estuaries on Earth. Intentional introductions of non-native species for use in agriculture, aquaculture, or pet-trades remain a widespread vector. For a discussion of vectors of the Northern Pike invasion in Alaska, see the Pathways Analysis discussed earlier in this management plan.

2. ***Establishment.*** Introduced species become self-sustaining in their new habitats, growing in population number and in body size, which in turn increases competition for resources.

3. ***Spread.*** Competition for limited resources, such as space for rearing or access to food, leads to density-dependent movement away from original sites of introduction and initiates the process of introduction of new locations. Spread, also termed dispersal, is usually thought to be positively associated with density (occurs more when local sites are saturated), but can occur through other behavioral mechanisms, such as social behavior, that results in negative density-dependent dispersal.

4. ***Impact.*** This is the most important stage of invasion and the most difficult to quantify. Increasingly, species are judged not on their foreign origins but on the impacts, they have on their recipient ecosystems. This stage of the process explicitly acknowledges that not all non-native species have appreciable effects and provides useful application in aiding the prioritization of locations where impacts are, or predicted to be, large.

The stage-based framework of invasion has stimulated widespread research to understand the factors that influence the probabilistic passage of each stage. For example, Kolar and Lodge (2002) applied a variety of life history and ecological traits to a list of potential invaders to the Great Lakes to predict the outcomes of introduction successes and failures. In a more holistic example, Olden et al. 2011 quantified factors associated with all stages of invasion of non-native crayfish in Wisconsin and used the approach to identify lakes that were likely to have invasive crayfish pass through all stages and have the highest impact on native species. In this spirit, Jalbert et al. (2021) applied a stage-based approach in a Bayesian statistical framework to predict the probability of Northern Pike occurrence and overlap with salmonids (a measure for potential impact) in 200 m reaches of rivers throughout the Mat-Su watershed.

7.2. Identified Research Gaps and Themes

With the framework of invasions as probabilistic stages, this discussion seeks to identify research needs in the context of the on-going Northern Pike invasion to Southcentral. During development of this management plan, an interdisciplinary team of plan partners from the UAF, USGS, USFWS, and ADF&G met frequently to discuss research needs to advance scientific knowledge of the invasion biology of Northern Pike and how to use that knowledge to advance management capabilities to reduce their impacts (visualized in Figure 28). First, the team began by articulating the overarching objective that research seeks to address. This discussion galvanized around “the conservation of native fishes with emphasis on salmonids.” Next, the team reversed engineered the problem by articulating specific goals, such as “minimize impacts” of invasive Northern Pike (shown in gold), and then identified management actions (green), the tools needed (blue), gaps in our knowledge (aqua), and finally, specific research areas (red).

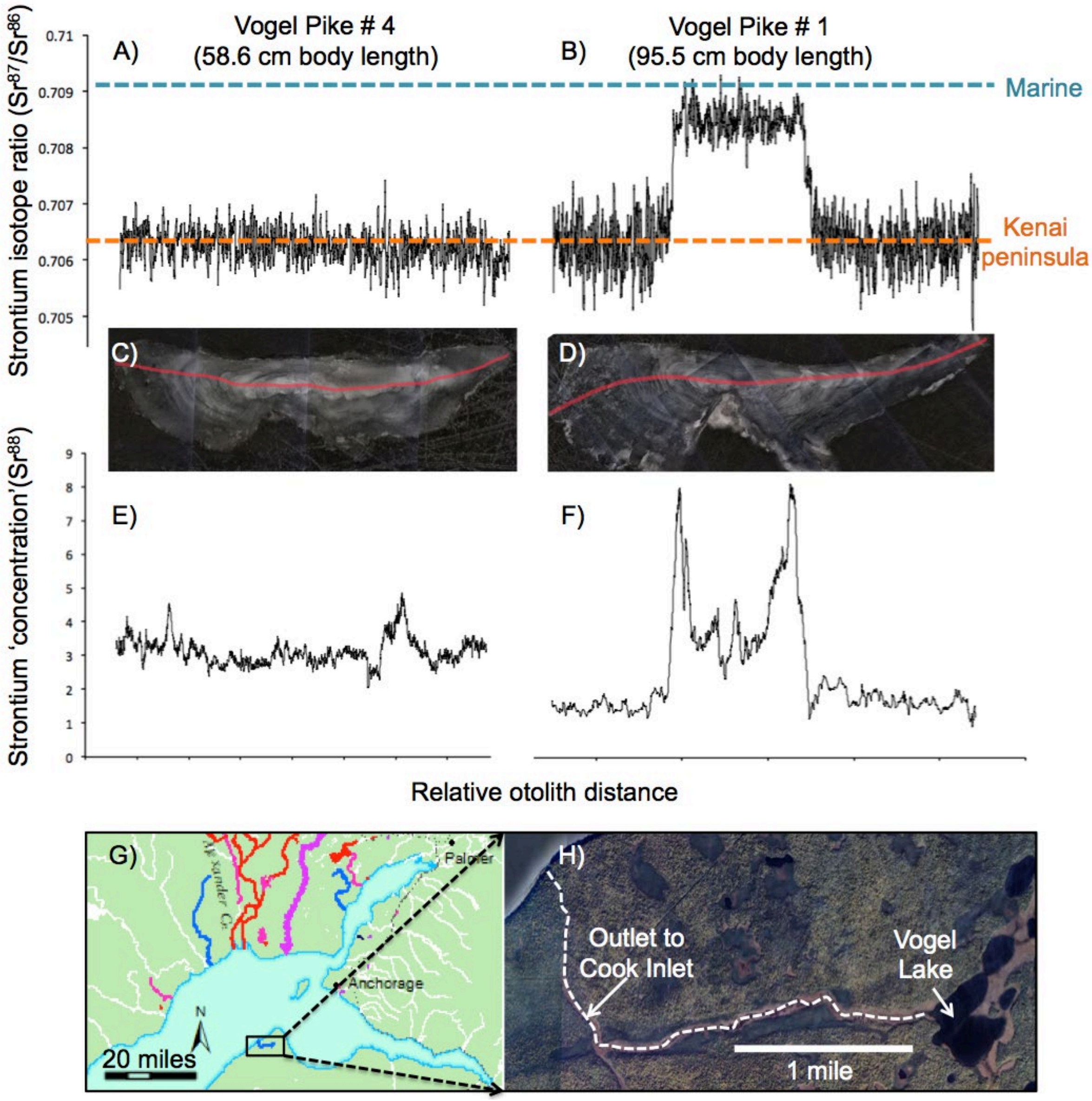
Figure 28. Invasive Northern Pike research needs

7.3. Future Invasive Northern Pike Research Questions

The following poses the most pressing questions, and by extension, the research gaps and tools needed to achieve management actions, goals, and native fish conservation. The order of questions presented is arbitrary and should not be taken as a prioritization as all are identified as urgent.

I. What factors influence the dispersal/spread of Northern Pike?

Knowledge about Northern Pike movement and dispersal in Southcentral Alaska is severely limited. Key information includes understanding of size and age-specific movements, the influence of biotic (e.g. competition or threat of cannibalism) and abiotic (e.g. water levels and temperatures) drivers, seasonality, inter-annual variation, and role of physiology and morphology. Tools to explore these questions should include traditional fisheries approaches such as directional trapping and tagging/tracking with radio or acoustic telemetry. Recent technological advances in (Strontium Sr) isotope ecology and Sr and oxygen isotope mapping is particularly promising for resolving origins of dispersing individuals, especially in the absence of genetic structure or other tracking information (Britton et al. 2022, Britton et al. 2021, Funck et al. 2021, Bataille et al. 2020). Analyses of Northern Pike otoliths provide a unique perspective into life-time movement ecology and can be used to infer dispersal ecology (Figure 29). Bulk carbon and nitrogen stable isotope analyses have become a routine, quick, and relatively cost-effective way of understanding food web connections and feeding ecology. Isotope ecology is also rapidly advancing and state-of-the art applications relevant to Northern Pike include carbon and nitrogen isotope analyses of serially sampled layers of fisheye lenses to track an individual’s diet over its lifetime. Also compound specific isotope analyses of individual amino acids can provide a deeper dive into food web and feeding ecology as well as establishing trophic level without surveying the entire food web.



Note: Strontium isotope ratios (Sr^{87}/Sr^{86}) (A,B) and strontium 'concentration' (Sr^{88}) (E,F) from otoliths (C, D) of two Northern Pike (Vogel Northern Pike # 4 – 58.6 cm and Vogel Northern Pike # 1- 95.5 cm) removed from Vogel Lake on the Kenai Peninsula (G [scale bar = 20 miles],H) measured using a laser ablation multi-collector inductively coupled plasma mass spectrometer at the Alaska Stable Isotopes Facility, University of Alaska Fairbanks (see Leppi et al., 2022 for a detailed description of equivalent methods used). Vogel Northern Pike # 4 had very similar otolith micro-chemical characteristics to four other Northern Pike also removed from Vogel Lake with fork lengths ≤68.0 cm. Their micro-chemical characteristics were consistent with being residents in Vogel Lake, with strontium isotope values similar to the freshwater values for the region (orange dashed line – from Bataille et al., 2020 supplemental data) for the duration of the life of the fish represented in the otolith (C). In contrast the largest Northern Pike removed from Vogel Lake (Vogel Northern Pike #1 – 95.5 cm fork length) had high strontium isotope values (B) and concentrations (F) towards the central part of the otolith (D) representing the earlier life stages of the Northern Pike and are consistent with having spent at least part of its early life in marine or semi-marine conditions (blue dashed line – from Bataille et al., 2020 supplemental data). The only access to marine conditions from Vogel Lake is via an outlet (white dashed line) leading to the Cook Inlet (H). Contact mjwooller@alaska.edu for the original data.

Figure 29. Otolith microchemistry showing a marine signature from a Northern Pike

II. **To what extent does rapid adaptation/evolution mediate the impacts of Northern Pike?**

Among the best examples of rapid adaptation in nature come from the unplanned experiments represented by biological invasions (Westley 2011). Adaptive phenotypic plasticity to novel conditions likely aids to facilitate establishment through and influences the future evolutionary trajectory of invasive populations. Adaptive genetic change is associated with increased dispersal ability of some invaders, and the evolved increase in competitive advantage is a frequently involved hypothesis to understand changes in invader impacts. Although much has been learned about the rate of divergence in fitness-associated traits between invasive and native populations of Northern Pike, it is currently unknown whether changes reflect genetic adaptation vs. plasticity, nor are the limits to adaptation understood. Understanding the potential for plasticity or evolution to facilitate dispersal through nearshore, estuarine habitats is a particularly pressing question in the light of evidence suggesting dispersal through marine corridors. Finally, virtually nothing is known about the potential for salmon and other native fishes to behaviorally adapt to novel Northern Pike predators, through increased escape behaviors or reduced use of certain habitats (i.e., the ecology of fear).

III. **When eradication is not possible, what level of suppression of Northern Pike is required to achieve a desired outcome for native fishes?**

What are the objectives of suppression actions? Often the goal is to remove as many Northern Pike as possible given logistical, budgetary, or other constraints, but the ecological consequences of given levels of suppression are poorly understood. Ecologically based objectives to inform suppression efforts are not available. The use of bioenergetic approaches to quantify changes in total or per capital consumption by Northern Pike on native fishes is a promising approach as done by Courtney et al. 2018. Additional steps to link changes in Northern Pike abundance as a result of suppression to consumption and, ultimately, to metrics of population productivity (e.g., numbers of smolts produced per watershed) are needed.

IV. **How are Northern Pike interacting with other non-native species?**

Non-native species have the potential to facilitate or impede the success of other non-native invading species. Although facilitation has been demonstrated in some systems leading to concerns of so called ‘invasional meltdown’ (sensu Simberloff and Von Holle 1999), many examples of inhibition are also known. It is currently unknown how invasive Northern Pike will interact, either positively or negatively, with other potential invaders. Given the strong ecological associations of Northern Pike and aquatic vegetation for spawning and early life history development, investigations of how Northern Pike interact with *Elodea* and other non-native aquatic invasive plants are urgently needed. Beyond interactions with plants, it is not known how introduced Northern Pike are interacting with other non-native fishes (e.g., Alaska Blackfish *Dallia pectoralis*) where they co-occur.

V. **When and where might we expect that climate warming will exacerbate the impacts of Northern Pike?**

Climate change is occurring, and the rate of change is even more rapid in Alaska and northern latitudes than other regions. Water temperature and streamflow are ‘master variables’ that influence the abundance and distribution of aquatic life and are shifting rapidly in the context of global change. Water temperature is profoundly important and directly linked to metabolic processes such as respiration and digestion, which in turn can influence consumptive demands for predators such as Northern Pike. Importantly, small changes in temperature can have disproportionate effects on physiology given non-linear relationships between temperature and metabolic processes. Several ecological questions need to be addressed. For example, how much might the consumption demands of Northern Pike change in the face of climate warming? What systems are most sensitive to climate warming? What temperatures do Northern Pike experience in Alaska watersheds, and do efforts to monitor water temperatures effectively capture this experience? Will changes in streamflow facilitate dispersal by creating seasonal connections between sub-basins, or will reduced flow and increased drought limit dispersal in invaded systems?

VI. Is coexistence between Northern Pike and native fishes possible? If so, at what spatial and temporal scales? If not, why not?

Northern Pike and native fishes coexist throughout much of Alaska. For example, Northern Pike and salmon are integral members of the fish communities of the Yukon River and Kuskokwim River watersheds. In Bristol Bay, where Northern Pike are native, the returns of sockeye salmon have been at recording breaking levels in recent years. Thus, coexistence is possible in at least some watersheds, over certain scales of time and space. Again, numerous questions need to be addressed. Besides the established variable of habitat heterogeneity, what other factors determine coexistence or exclusion at the spatial scales of watersheds, stream reaches, or individual habitat units? Is coexistence transitory in time or truly sustainable?

Prioritization Process for New Projects

Scoring Matrix

In 2010, an ADF&G committee created a scoring matrix to objectively prioritize invasive Northern Pike projects (Table 8). This matrix was designed to ask "yes" or "no" questions pertaining to a proposed project concept or proposal. The committee worked together to assign priority levels and weighted scores for each question in the matrix. Low, medium, high, and very high priority-level questions were weighted with 1, 5, 10, and 30 points, respectively. When answering the matrix questions for a proposed project, all "yes" answers received the point values assigned by the subcommittee for those questions. All "no" answers received zero points. After all questions in the matrix were answered for a proposed project, the sum of the point values provided an overall project score (Table 9).

This matrix has now been adapted to function in the same capacity for in the AKISP Invasive Northern Pike Committee. The matrix is available as an Excel file in the plan supplementary materials (Northern Pike Prioritization Matrix), with point calculations pre-programmed; however, table 8 illustrates its structure. The matrix includes 60 questions. Individually, no one question can completely alter the outcome of a project's score. However, together, the criteria can help illustrate the importance of a particular project concept.

The need for prioritizing projects arises when funding and resources are low, and it becomes beneficial for the AKISP Invasive Northern Pike Committee to be collaborative and strategic when applying for project grants (Appendix 1). A project with a high score should be given consideration before a project that scores lower. However, there are other factors such as implementation cost, public processes, permitting timelines, and stipulations within requests for proposals that may lead to implementing a lower ranking project before a higher ranking one. In particular, the scoring matrix naturally scores Northern Pike eradication projects much higher than suppression, and research and monitoring projects generally score much lower. For this reason, projects should be prioritized within categories (i.e., **eradication**, **containment**, **suppression**, **monitoring**, **research**, and **outreach**) so that comparisons of scores is more meaningful. Generally, grant opportunities favor proposals of certain categories, so using this matrix to prioritize projects within categories is ideal.

The following describes each topic in the scoring matrix and the rationale for why it was included.

Recreational Fisheries: Questions pertaining to this category address details about historic fisheries in the proposed project area and intent of the project to restore those fisheries.

Northern Pike Impacts: This series of questions address Northern Pike abundance and impacts on wild fish populations, potential for loss of native fisheries, and association with escapement goal concerns.

Education and Outreach: These questions pertain to educational opportunities the project may provide, stakeholder involvement, and opportunities to demonstrate new Northern Pike control or eradication techniques.

Habitat Significance: Questions in this category address details about open and anadromous systems, the ability of a project to prevent the spread of Northern Pike, and potential effects on other species.

Project Area Characterization: This section prioritizes projects in habitat types that are most vulnerable to Northern Pike establishment.

Cultural Significance: These questions relate to cultural, subsistence, or user group concerns from Northern Pike in the proposed project area.

Economic Impacts: These questions specifically address economic concerns with Northern Pike in the proposed project area.

Knowledge Gain: Questions in this category address what can be learned from implementing the proposed project.

Feasibility: These questions address project feasibility through location and access, ability to permanently remove or contain the Northern Pike, and ability to achieve project results relative to funding availability.

Permitting and Inter-Agency Cooperation: These questions address permitting needs, potential for collaboration, and relation to existing watershed plans.

AKISP Invasive Northern Pike Committee Significance: This section validates that the proposed project is consistent with the mission of the AKISP Invasive Northern Pike Committee.

Prioritization Process

During biennial review processes of this plan, a subcommittee of the AKISP Invasive Northern Pike Committee will form to score proposed project concepts ahead of large funding calls. This will help to proactively align project partnerships and limit funding competition among plan partners. Before this meeting, brief project SOWs consisting of no more than a 1-page project description and estimated budget will be solicited from members of the AKISP Invasive Northern Pike Committee. The subcommittee will score these project ideas using the matrix and organize them into a format similar to Table 9. These updated priorities will be distributed via the Northern Pike committee listserv to inform all partners on which projects the committee endorses for grant solicitation. The lead organization submitting the SOW will be responsible for applying for the grants to fund the project. Between these dedicated biennial meetings, new projects can be added to the priority list as needed by identifying them during regular Northern Pike committee meetings. It is possible that continued experience using the matrix among the AKISP Invasive Northern Pike Committee may result in future adjustments to some matrix questions.

Table 8. Invasive Northern Pike project prioritization matrix

Questions/ Criteria	Priority Level (Low, Med, High)	Weighted Score	Enter 1/ 0 (Yes = 1) (No = 0	Score Value
Recreational Fisheries				
Pre-Northern Pike introduction, historic fishing level in the water body was low (≤ 200 days)	Low	1		0
Pre-Northern Pike introduction, historic fishing level in the water body was medium (> 200 - < 1,000 days)	Medium	5		0
Pre-Northern Pike introduction, historic fishing level in the water body was high (> 1,000 days)	High	10		0
Is a goal of the project to restore opportunity for a non-Northern Pike fishery?	Medium	5		0
Is the water body currently and/ or formerly stocked by ADF&G?	Medium	5		0
Have stocking levels in the water body been altered because of Northern Pike presence?	Medium	5		0
Northern Pike Impacts				
Do Northern Pike in the water body directly threaten a wild fishery in that water?	High	10		0
Do Northern Pike in the water body threaten a wild fishery that is in close proximity (five miles or less)?	High	10		0
Have regulations for wild sport fisheries exceeding 1,000 angler-days been restricted because of Northern Pike in this waterbody?	High	10		0
Have wild sport fisheries receiving under 1,000 angler-days of effort been restricted because of Northern Pike in this waterbody?	Low	1		0
Have available data indicated that a wild fish population has been eliminated associated with Northern Pike presence?	High	10		0
Have available data indicated that a wild fish population has been impacted associated with Northern Pike presence?	Medium	5		0
Has the public indicated concern over the Northern Pike population in this water body?	Medium	5		0
Do Northern Pike represent > 50% of the catch in a netting survey or from other available data?	High	10		0
Do Northern Pike represent 25-50% of the catch in a netting survey or from other available data?	Medium	5		0
Do Northern Pike represent < 25% of the catch in a netting survey or from other available data?	Low	1		0
Is there an anticipated negative impact to a sport fishery associated with Northern Pike in this waterbody?	High	10		0
Is an imminent loss of a wild stock associated with Northern Pike in this drainage expected?	Very High	30		0
Does the area management biologist associate Northern Pike with an inability to meet an escapement goal in this drainage?	High	10		0
Does this water body contain a BOF-stock of yield or management concern?	High	10		0
Eliminating Northern Pike in this project area removes the Northern Pike threat in the entire management area (i.e., Kenai Pen.)	Very High	30		0
Education and Outreach				
Are there opportunities to use this project as an educational outreach tool to increase public awareness?	High	10		0
Are we demonstrating a new Northern Pike control strategy to stakeholders?	Medium	5		0
Does the project foster public understanding and awareness of invasive species	Medium	5		0
Has there already been stakeholder input desiring a project of this nature?	High	10		0

Continued Next 2 Pages

Habitat Significance

Is the project area within an open system?	High	10		0
If successful, can this project prevent Northern Pike distribution throughout the drainage?	Very High	30		0
Is the project area within an anadromous system?	High	10		0
Are wild, resident non-game fish species present?	Medium	5		0
If in a closed system, does the project have the potential to reduce native fish populations?	Medium	-5		0
Will the project improve habitat for threatened or endangered species populations?	High	10		0
The project is expected to have a measurable, positive outcome for fisheries.	High	10		0

Project Area Characterization (*Type 1 - Suitable Northern Pike habitat, Type 2 – Marginal habitat, Type 3 - Poor Northern Pike habitat*)

(Lakes/ Wetlands)				
Is it a Type 1 Lake or wetland - Eutrophic and primarily shallow (≤ 15 feet) with abundant vegetation throughout?	High	10		0
Is it a Type 2 Lake - Mesotrophic and primarily deep (> 15 feet) with vegetation covering 50% or more of the lake?	Medium	5		0
Is it a Type 3 Lake - Oligotrophic and primarily deep (> 15 feet) with wither sparse or no aquatic vegetation)?	Low	1		0
(Rivers and Streams)				
Is the waterbody primarily Type 1- Low stream slope (0.0 - 0.5%) with abundant vegetation and is capable of supporting rearing coho (e.g. Moose River, Alexander River)?	High	10		0
Is the waterbody primarily Type 2 with some type 1- Moderate stream slope (0.51 - 2.0%) with semi-permanent woody debris and back-waters sloughs and is capable of supporting rearing coho (e.g. Deshka River)?	Medium	5		0
Is the waterbody primarily Type 2 - Moderate stream slope (0.51 - 2.0%) with semi-permanent woody debris and is capable of supporting rearing coho (i.e. Campbell Creek)?	Medium	5		0
Is the waterbody a combination of Types 2 & 3 - High stream slope (> 2.0%) and slow back-water sloughs capable of supporting rearing coho (e.g., Willow Creek?)	Medium	5		0
Is the waterbody primarily Type 3 - Clear, high stream slope (> 2.0%) with few slower back-waters (e.g. the Little Susitna River)?	Low	1		0
Is the waterbody exclusively Type 3 - High stream slope (> 2.0%) with extensive glacial turbidity (e.g. Klutina River)?	Low	1		0

**** Rearing Coho share the same habitat requirements as Northern Pike and are a good indicator of Northern Pike habitat suitability and potential overlap.*
NOTE: If project includes work in both categories, score both. Otherwise, score one or the other only.

Cultural Significance

Are indigenous cultural activities (e.g. fish camps, etc.) threatened by Northern Pike in this water body?	High	10		0
Does the project benefit subsistence fisheries?	High	10		0
Is a goal of the project to provide economic benefits for citizens, communities, or industries?	High	10		0
Are any user groups negatively affected by the Northern Pike presence?	High	10		0

Economic Impacts

Has input been received from local businesses/property owners that they are experiencing a negative financial effect from Northern Pike in this water body?	High	10		0
Does the project protect commercially important species?	High	10		0

Knowledge Gain				
Will project goals, objectives, and tasks within the project plan strive to improve understanding of Northern Pike behavior or distribution in local waters?	Medium	5		0
Do project goals strive to improve understanding of control, containment, or eradication techniques for Northern Pike?	High	10		0
Will the project include a follow-up assessment to measure the effects of the management action?	Medium	5		0
Do project goals strive to quantify fish population/economic losses resulting from invasive Northern Pike?	Medium	5		0
Feasibility				
Does the water body have public access?	High	10		0
Is the water body on the road system?	Low	1		0
Is it technically feasible that the Northern Pike population could be **permanently** removed or contained if the project is implemented?	High	10		0
Is there a history of reintroductions of Northern Pike in this area?	High	-10		0
Can the project achieve its goals within the funding period?	Low	1		0
Does the project achieve long-term program goals within a decade of the funding period? (i.e., reestablish wild fish populations)	High	10		0
Can the project begin when funding is received?	Medium	5		0
Permitting and Inter-agency Cooperation				
Does the project provide opportunities to partner or collaborate with other agencies or organizations?	Low	1		0
Is the NEPA process required for this project?	Low	-1		0
Is there reason to believe there would be a conflict with an existing coastal, watershed or restoration plan?	High	-10		0
AKISP Northern Pike Committee Significance				
Is the project programmatically/ scientifically aligned with AKISP Invasive Northern Pike Committee mission?	High	10		0

**** Low = 1 Medium = 5 High = 10**

SCORE				

Table 9. Northern Pike projects initiated using the prioritization matrix between 2011 - 2021

Northern Pike Priorities by Project Scope

Project	Score	Partner	Completed	Project Cost	Funding Source	Status
ERADICATION PROJECTS:						
Stormy Lake	257	ADF&G, USFWS	2012	$ 297,612	*ANSTF, USFWS*	*Complete*
Otter Lake	253	JBER, ADF&G	2015	$ 140,600	*PMAC*	*Complete*
Soldotna Creek Drainage	261	ADF&G	2017	$1,069,525	*AKSSF, GF, USFWS*	*Complete*
Tote Road Lakes	172	ADF&G	2019	$ 217,000	*AKSSF, GF*	*Complete*
Anderson and Kings Lakes	287	ADF&G	2020	$ 243,000	*AKSSF, GF*	*Complete*
Miller Creek Drainage	283	ADF&G, USFWS, KWF	2021	$405,000	*AKSSF, GF*	*Complete*
Fire Creek Drainage	237	ADF&G	2022	$ 134,439	*AKSSF, F&G*	*In Progress*
SUPPRESSION PROJECTS:						
Alexander Creek	282	ADF&G	Annual	$ 2,194,065	*AKSSF, Mat-Su, GF, SWG*	*In Progress*
Hewitt, Whiskey, Shell Lakes	277	CIAA, ADF&G	Annual	$ 291,800	*AKSSF, GF, CIAA*	*In Progress*
Threemile/ Chuitbuna/ Rollercoaster Lakes	302	TTCD, NVT, ADF&G	Annual	$ 141,000	*BIA*	*In Progress*
MONITORING PROJECTS:						
Kenai Peninsula Long-Term Monitoring	149	ADF&G	Annual	$ 192,000	*DJ*	*In Progress*
Mat-Su/ Anchorage Long-Term Monitoring	207	ADF&G	Annual	$ 280,000	*SWG*	*In Progress*
RESEARCH PROJECTS:						
Alexander Creek Northern Pike Movement Study	232	ADF&G	2012	$ 126,684	*AKSSF, GF*	*Complete*
Alexander Creek Northern Pike Diet and Bioenergetics	NA	USGS, ADF&G	2013	$363,215	*AKSSF, GF*	*Complete*
Evaluate Control Techniques (Hydrogun); Northern Pike Movements in Whiskey, Hewitt, Chelatna Lakes	NA	USGS, CIAA, ADF&G	2014	$859,854	*AKSSF, CIAA, GF*	*Complete*
Cottonwood Creek Drainage Northern Pike Assessment	287		2014	$ 63,430	*Mat-Su*	*Complete*
Kenai eDNA Study	238	ADF&G, USFWS, USGS	2016	$ 39,480	*USFWS, ANSTF*	*Complete*
Northern Pike Sex Marker	52	ADF&G	2022	$ 29,100	*ANSTF*	*In Progress*
Threemile/ Chuitbuna Invasive Northern Pike Assessment	207	TTCD, NVT, ADF&G	2018/2019	$ 47,000	*BIA*	*Complete*
Northern Pike Genetics and Intrinsic Potential Modelling	NA	UAF, ADF&G	2019	$110,200	*USGS, COOP*	*Complete*
Northern Pike Physiology and Barrier Leaping Success	NA	UAF, ADF&G, USFWS	2022	$218,554	*USFWS*	*Complete*
Deshka Pike Feeding Ecology/ Warming Water Temps	NA	UAF, USFWS	2022	$141,510	*USFWS*	*In Progress*
Northern Pike Salinity Trials	NA	ADF&G	2022	MCD Grant	*AKSSF*	*Complete*
TOTAL				***$ 8,464,949***		

NOTE: See *Appendix 1 (Funding Guidance)* *for funding source acronyms.*

Roadmap of Work to Accomplish

During this plan period (2022-2030), multiple efforts across all invasive Northern Pike management strategies are already underway or identified as needed (Figure 28). Figure 30 serves as a basis for the roadmap of work the AKISP Invasive Northern Pike Committee intends to accomplish under this plan. These targets are dependent upon funding, and new projects will be added during biennial prioritization processes. Therefore, adjustments to this plan are expected, but this vision begins a coordinated approach for plan partners to work together to mitigate the impacts of invasive Northern Pike in Southcentral Alaska. It is important to note that assigned timeframes are tentative and that research topics are not specifically time bound. Lead partner agencies for each project will be determined in AKISP Invasive Northern Pike committee meetings but will follow jurisdictions and project histories. Generally, ADF&G will lead Northern Pike eradication efforts, and outreach, containment, suppression, and monitoring will be based on project history and partner capacity. Research topics will be explored as funding opportunities arise, but UAF is anticipated to lead many of the research investigations with assistance from partners as applicable.

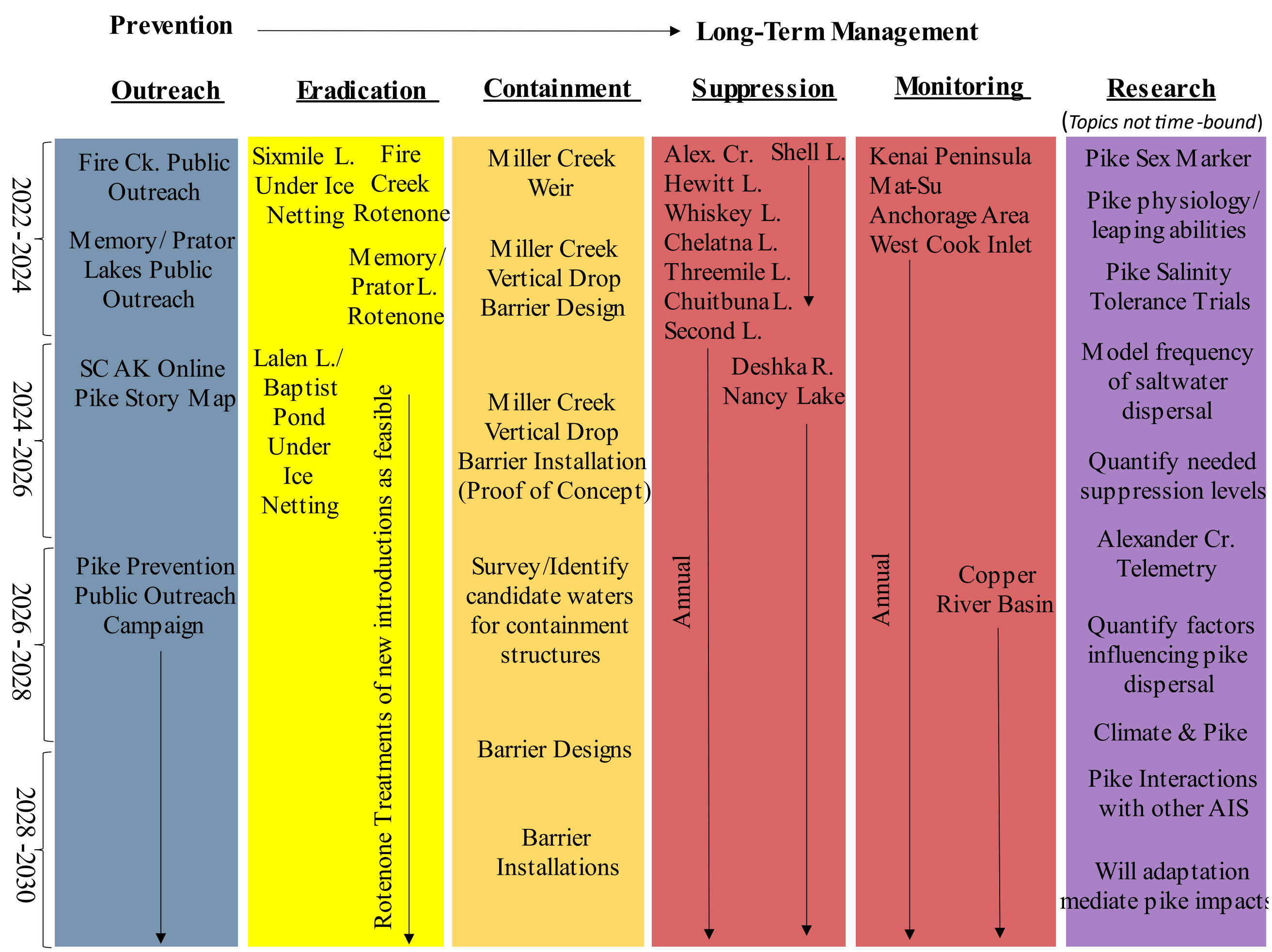


Figure 30. Northern Pike project targets by management strategy: 2022 - 2030

Summary

This "Technical Guidance and Management Plan for Invasive Northern Pike in Southcentral Alaska: 2022-2030" essentially provides a "How To" Manual for everything pertaining to invasive Northern Pike management in Southcentral Alaska. The overarching purpose of this plan is to assist partners in approaching Northern Pike management efficiently, consistently, and collaboratively through the standardization of methods and the sharing of expertise and resources. In doing so, this plan coordinates all partner organizations so that data collection and project execution is consistent and useful to the entire community of partners collectively working to protect salmon and other native fish populations from losses due to Northern Pike predation. It is the committee's sincere desire that the guidance provided throughout this plan is helpful, not only in directly advising invasive Northern Pike operations in Southcentral Alaska, but for providing reference for other agencies and organizations tackling similar challenges with invasive Northern Pike throughout the globe.

This plan frames invasive Northern Pike response in the context of the established stages of invasive species management: Prevention, Early Detection, Rapid Response, Eradication, Containment, and Long-term Management. Each of these plan sections describe the protocols that are recommended for adoption by plan partners pertaining to each stage of a Northern Pike invasion to a Southcentral Alaska waterbody. As pertinent, these protocols and discussions are further elaborated on in the technical SOPs that follow. These recommendations are made to enhance consistency among the AKISP Invasive Northern Pike Committee's efforts, but it is understood that these recommendations are to be adaptive and continually improved upon. To that end, this management plan is to be considered a 'living' document with regular updates by the AKISP Invasive Northern Pike Committee Chair, biennial review by the AKISP Invasive Northern Pike Committee, and major revision at the beginning of each new decade. The AKISP Invasive Northern Pike Committee is grateful for the work and dedication of an exceptional team of committed partners and individuals who will be working together for years to come to reverse the negative impacts of this invasive species.

Acknowledgements

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Standard Operating Procedures

SOP 1: Northern Pike Survey and Monitoring Data Collection

Gear Recommendations

<u>Required:</u>
Data book or data sheets
Measuring Board (mm)
Scalpel or knife
Gloves
Capture Gear

<u>Optional:</u>
Balance
Knife (for otoliths)
Thermometer (°C),
YSI or Hydrolab
GPS
Identification keys
Whirl pack bags/ envelopes
Forceps
Camera
Whatman Cards (for fin clips)

Methods

All early detection monitoring surveys for Northern Pike should collect the following data. **<u>Variables in bold must be collected.</u>** *<u>Variables in italics are recommended:</u>*

1) **Sample #**
   Not recorded in the field but in the data file, this keeps a chronological list of samples that connects to individual Northern Pike dissection data.
1) **Response Organization**
   List the plan partner conducting the survey.
2) **Sampler Initials**
   Record the initials of each personal assisting with the survey.
3) **Survey Date and Start Time**
   Record the date and time when the survey begins (M/D/Y HH:MM). Note: it is recommended to record start and end time for each net/trap/observation as outlined in the following datasheet.
4) **Survey Date and End Time**
   Record the date and time when the survey ends (M/D/Y HH:MM).
5) **Water Body Name**
   Record the location name. If a waterbody does not have an official name, record coordinates either collected by GPS or estimated in Google Earth.
6) ***GPS Coordinates***
   Record GPS coordinates where gear is set using dd.ddddd
7) **Capture Gear**
   Record the capture gear used for the survey. In survey notes, include details such as mesh size, lure types, or any other pertinent detail that could affect catch.
8) **Net or Trap Number**
   Record a unique number for each net, trap, angler, or observer used in the survey.
9) **Number of each species captured**
   Record tallies of each species captured per net/trap. Provide totals by species in the data.
10) *Air temperature (°F)*
   Record temperature in °F at the time of the survey.

11) *Precipitation*

List if raining or snowing.

12) *Wind*

Record wind speed from a local weather app or anemometer.

13) *% Overcast*

Estimate cloud cover.

14) *Barometric Pressure*

Record pressure from a local weather app.

15) Water temperature (°C)

Record surface temperature from the shoreline using a hand-held thermometer, YSI, or hydro lab. Note the time.

16) Maximum Depth/ or Flow Rate

If known or available with bathymetric maps, record the maximum depth (M) of lentic waters. For lotic waters, record the flow rate at the time the survey begins (cf/s).

17) Substrate Type

Record if littoral substrate is primarily sand, gravel, muck, etc.

18) % Vegetation

Estimate how much of the waterbody has submerged and/or emergent vegetation.

19) Inlet/Outlet

Record if the waterbody is connected to others or is a closed lake/system.

20) Habitat Notes

Note the sampler's opinion on if the water body is good or poor Northern Pike habitat, or a mixture of both; Note whether the water body has been mapped.

NORTHERN PIKE SURVEY AND MONITOR NET FORM									Page _____ of _____
	WATERBODY: SAMPLERS:		SECTION # :			CAPTURE DEVICE:			START DATE: STOP DATE:
NET #	GPS LOCATION LAT./LONG. (dd.ddddd)	START TIME:	STOP TIME:	# Northern Pike	Bycatch species				Notes
	Air Temp: Precipitation: Wind: % Overcast: Barometric Pressure:		Water Temp: Max Depth/Flow: Substrate Type: % Vegetation:						Habitat Notes:

SOP1.1. Standardized field data form for Northern Pike surveys

All early detection monitoring surveys for Northern Pike should collect the following **individual Northern Pike** data**.** **<u>Variables in bold must be collected.</u>** <u>*Variables in italics are recommended whenever practical:*</u>

21) Fork length

Measure each Northern Pike to fork length in mm (SOP1.4).

22) Stomach contents

All Northern Pike captured must be dissected for stomach contents, and all contents should be enumerated to the lowest taxonomic level practical (SOP1.5). *Note: After dissection, puncture the swim bladder if returning carcasses to the water body.*

23) Sex

Record if the Northern Pike is female, male (SOP1.6), or unidentified if in doubt.

24) Maturity

Record if the Northern Pike is mature or immature. Immature Northern Pike will be juveniles with unidentifiable gonads.

25) Condition

Record if the Northern Pike is green (gametes present but not expressed when squeezed), ripe (ready to spawn and express gametes when squeezed) or spent (no gametes expressed when squeezed and, during dissection, visually reduced (males) or absent (females)). The spawning period for Northern Pike is between late April and June, so this is when condition would be noted.

26) Weight

Record the mass of each Northern Pike in grams using a digital balance or hand-held fish scale.

27) Otoliths

Northern Pike otolith bones should be removed and archived for ageing and/ or microchemistry analysis. Otoliths are removed by turning the Northern Pike onto its dorsal side. Remove the gill rakers to expose the spinal column in front of the inner ear and brain. Where the spinal column changes in color from white to grayish, make a slit with a knife. Gently press on the knife to crack the spine. Carefully open to expose the otoliths (SOP1.7). Use sharp forceps to remove them and store them in a whirl pack bag or small coin envelope. Attempts should be made to collect both otoliths. Record the survey and location data on the sample. This is particularly important if the first could be a founder of the population.

28) Cleithra

Remove at least one cleithrum bone from each Northern Pike caught for ageing. The cleithra are located behind the gill plates. They can be removed by running a finger behind the bone and gently pulling up and peeling it away from the tissue (SOP1.7). The cleithra can be stored in the freezer in whirl packs or coin envelopes. To age, they should first be cleaned by simmering in hot water until the tissue is easily brushed off. They should be allowed to dry for at least 24 hours before attempting to age. Additional details can be found in Euchner 1988. This is particularly important if the first could be a founder of the population.

29) Fin clip for genetics

Cut a tissue sample from the pelvic fin of each Northern Pike and affix it to a Whatman Card. Be sure to record the Whatman Card barcode number and fish position (#1-10) in the data. Store the cards on silica packets until they can be transferred to a genetics lab (SOP1.9). If gear is available, genetic samples are highly recommended for collecting and archiving.

30) Deformities

If the Northern Pike has any deformities, obvious external pathogens, diseases, or unusual characteristics, include these in the data notes and take pictures.

31) Notes

Include any pertinent notes or details regarding the Northern Pike or survey in the data file.

NORTHERN PIKE DISSECTION FORM													Page _____ of _____
WATERBODY: SAMPLERS:				SECTION # :						START DATE: ________________________ STOP DATE: _________________________			
Fish # (NP Only)	NET #	FISH SPECIES	FORK LENGTH (mm)	WEIGHT (g)	SEX (M, F, U)	Maturity (I or M)	Condition (G, R, S)	Stomach contents (Y/N)	STOMACH CONTENT	Cleithra? (Y/N)	# Otos (0,1,2)	Whatman Card #	Whatman Fish # (1-10)

Common abbreviations for species. KS=king salmon; SS=silver salmon; RS=red salmon; CS=chum salmon; PS=pink salmon; UNS=unknown salmon; UNF=unknown fish; WF=white fish; LNS=long nose sucker; SB=stickleback; RT=rainbow; GR=grayling; NP=northern pike; BB=burbot; DV=dolly varden; SC=sculpin; PL=pacific lamprey; LCH=leech; PDB=predacious diving beetle, FRG=frog. Other catch could be: macro invertebrates, rodents, other mammals, birds

SOP1.2. Standardized field data form for Northern Pike dissections (Spring spawning season: April - June)

NORTHERN PIKE DISSECTION FORM											Page _____ of _____
WATERBODY: SAMPLERS:				SECTION # :			START DATE: ________________________ STOP DATE: _________________________				
Fish # (NP Only)	NET #	FISH SPECIES	FORK LENGTH (mm)	WEIGHT (g)	SEX (M, F, U)	Stomach contents (Yes/No)	STOMACH CONTENT	Cleithra? (Y/N)	# otos (0,1,2)	Whatman Card #	Whatman Fish # (1-10)
Common abbreviations for species. KS=king salmon; SS=silver salmon; RS=red salmon; CS=chum salmon; PS=pink salmon; UNS=unknown salmon; UNF=unknown fish; WF=white fish; LNS=long nose sucker; SB=stickleback; RT=rainbow; GR=grayling; NP=northern pike; BB=burbot; DV=dolly varden; SC=sculpin; PL=pacific lamprey; LCH=leech; PDB=predacious diving beetle, FRG=frog. Other catch could be: macro invertebrates, rodents, other mammals, birds.											

SOP1.3. Standardized field data form for Northern Pike dissections (non-spawning season: July-March)

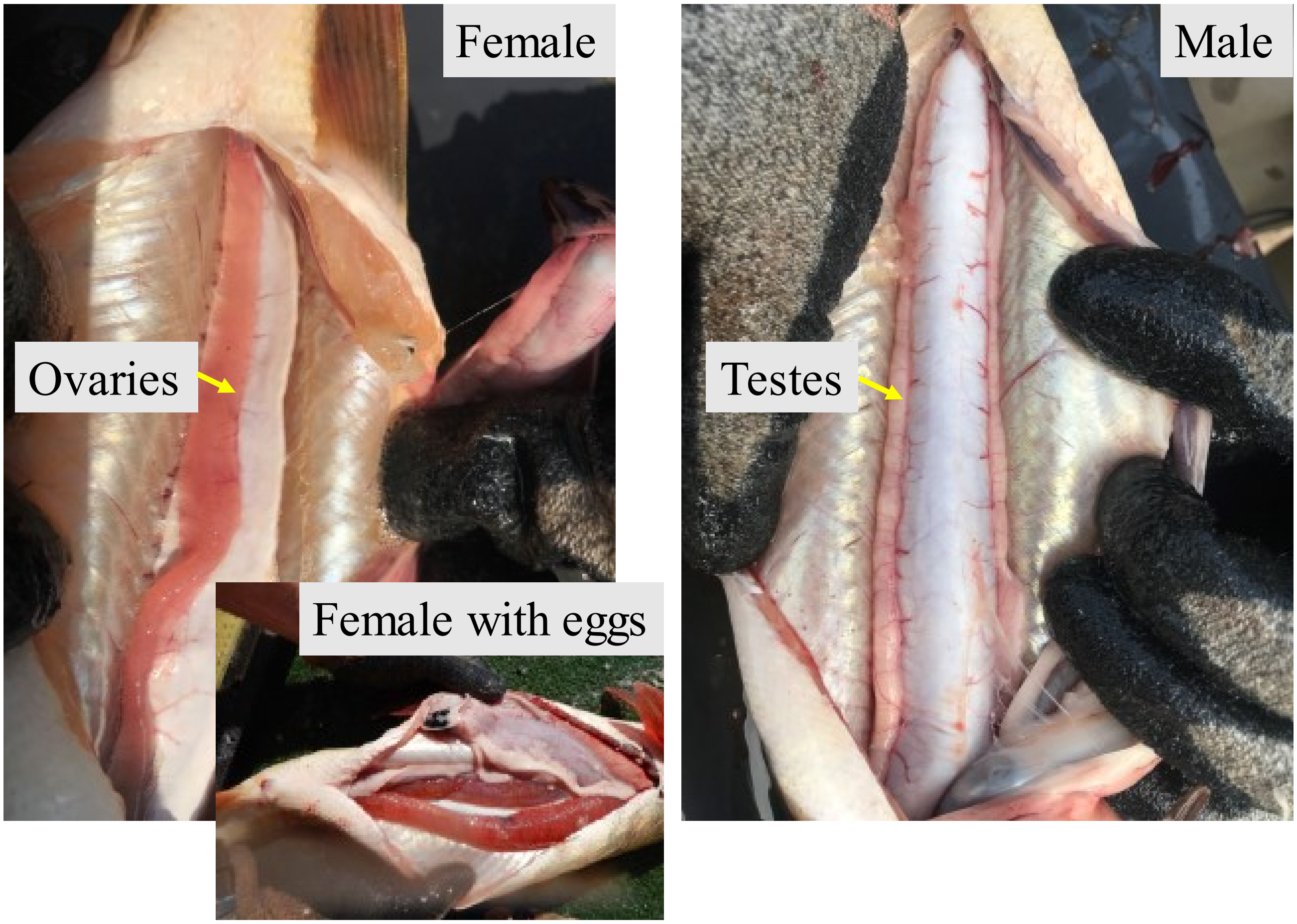
Note: Data sheets (SOP1.1 – SOP1.3) for print are available in the supplemental materials for the plan.

SOP1.4. Fork length measurement guidance. Measurement is taken from tip of nose to the tail form indicated by an arrow in the photo above

SOP1.5. Field photos of common prey items found in Southcentral AK Northern Pike stomachs

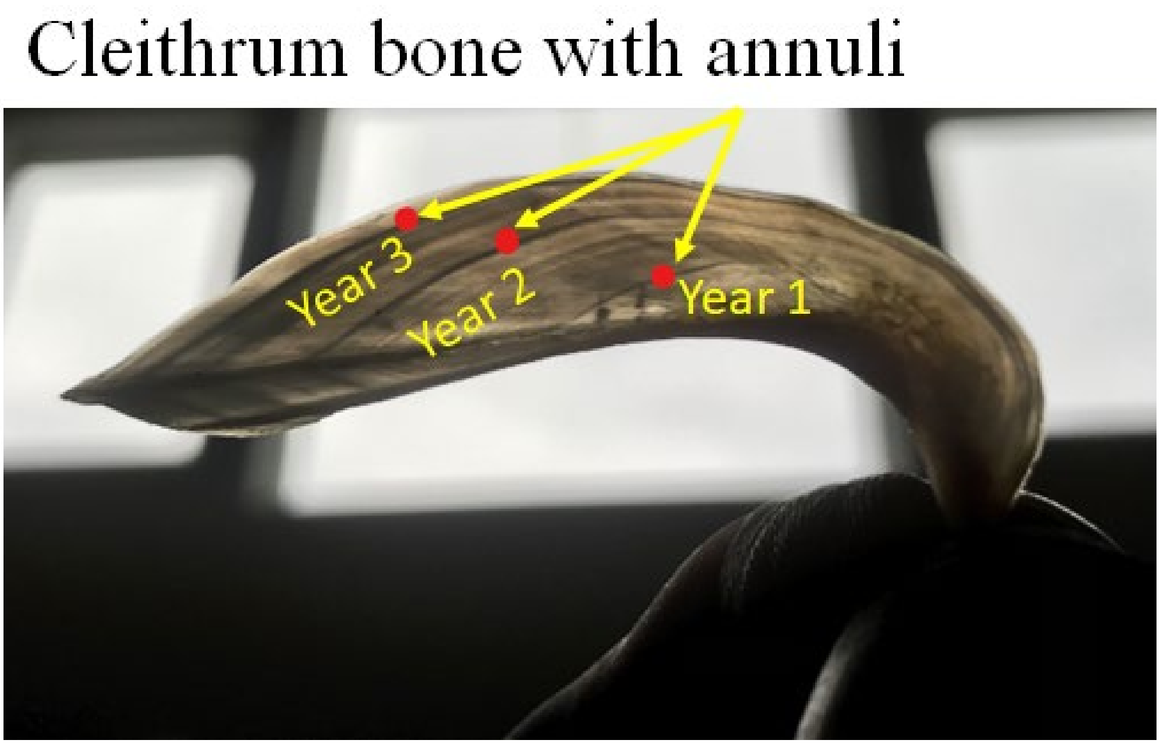
A. Coho salmon, B. Sticklebacks, C. Chum salmon, D. Chinook salmon, E. Rainbow Trout, F. Longnose sucker, G. Lamprey/ Amocoetes, H. Scuplin, I. Scuds, J. Dragonfly larvae. K. Water boatman, L. Damselfly larvae, M. Predacious diving beetle, N. Leaches, O. Water tiger, P. Ducklings, Q. Shrew, R. Wood frogs.

Further ID guidance common fish in Alaska can be found here: Juvenile Salmonid and Small Fish Identification Aid (alaska.gov). For macroinvertebrate ID guidance, see: 1-4 Keys.indd (state.mn.us).



SOP1.6 Northern Pike sex determination guidance

SOP1.7 Location of otoliths in a Northern Pike.



SOP1.8 Location of cleithra in a Northern Pike

Adult Finfish Tissue Sampling for DNA Analysis

ADF&G Gene Conservation Lab, Anchorage

I. General Information

We use fin tissues as a source of DNA to genotype fish. Genotyped fish are used to determine the genetic characteristics of fish stocks or to determine stock compositions of fishery mixtures. The most important thing to remember in collecting samples is that **only quality tissue samples give quality results**. If sampling from carcasses: tissues need to be as "fresh" and as cold as possible.

Preservative used: Silica desiccant bead packet dries and preserves tissues for later DNA extraction. Quality DNA preservation requires **dry storage** (with desiccant packs) in Pelican case or watertight file box.

II. Sampling Method

Pelvic fin located below axillary spine.

To secure fins to card for handling, place one staple across fin clip (shown above).

III. Sampling Instructions

- **Prior to Sampling:**
  - Set up workspace and fill out required collection information (upper left-hand corner and latitude/longitude).
  - Place Whatman genetic card (10WGC) on mini clipboard flat for easy access. One Whatman card per scale card. Same card can be used throughout same day.

- **Sampling:**
  - Wipe excess water and/or slime off the pelvic fin prior to sampling to avoid getting excess water or fish slime.
  - Fin clip will be taken from lower portion of the pelvic fin.
  - Cut off a portion of the fin clip using Fiskar scissors to get roughly a ¾ - 1" **inch maximum** piece and/or about the size of a small fingernail (see cutting line to left in orange).
  - Place one clipped fin tissue onto appropriate grid space. Follow sampling order printed on card - **do not deviate**. If large tissue sample, center tissue diagonally on grid space.

  - **Only one fin clip per fish into each numbered grid space.**

  - Fin clips will stick to the 10WGC grid card (see photo).
  - **Staple** fin clip to card; this secures the fin for handling in lab.
  - **DO NOT** staple landscape cloth to paper edge.
  - Sampling complete.
  - Periodically, wipe or rinse the scissors with water so not to cross contaminate samples.
  - Insert the 10WGC card inside Pelican case and layer with blotter cards and desiccant packs.
  - Close and secure the lid of Pelican box so drying begins.
  - Data to record: Record **each fin clip number to paired data** information (i.e. location, lat./long., sample date(s), etc.). Electronic version preferred.

- **Loading Pelican Case:**
  - 1st card: Remove blotter papers and desiccant packs (remove plastic) from Pelican case. Place first card in Pelican case with tissues facing up. Next, place blotter paper directly over card and place one 2 desiccant packs on top. Close and secure lid so drying begins.
  - Up to 4 cards can be added per case. Add them so **tissue samples always face the desiccant pack** through blotter paper: 2nd card facing down between desiccant packs; 3rd card facing up between desiccant packs; and 4th card facing down on top of second desiccant pack. Close and secure Pelican case after inserting each card.
  - All cards must **remain in Pelican 1400 case at all times** to dry flat.

- **Post-sampling storage:**
  - Store dried 10WGC tissue cards in Pelican box at room temperature or below. Two-four desiccant packs fit inside Pelican 1400 case. This helps flatten the cards as they dry out over time.

- **Shipping at end of the season:**
  - Keep all **dried** cards layered inside Pelican box with secured lid, pack inside priority mailing box with returning sampling supplies.

IV. Supplies included in sampling kit:

1. Scissors - for cutting a portion of lower tip of selected fin.
2. Stapler – for stapling fin clip to card; secures for handling
3. Staples – for stapling
4. Whatman genetics card (10WGC) – holds 10 fish/card.
5. Silica packs – desiccant removes moisture from samples.
6. Pelican case – overnight dry storage "day use" (small 1150).
7. Pelican case – long term dry storage prior return shipment (1400).
8. Blotter cards – insert between 10WGC and desiccant pack.
9. Zip ties – to secure closure of the Pelican case for return shipment.
10. Laminated "return address" labels.
11. Sampling instructions.
12. Pencil

V.

Return to ADF&G Anchorage lab:
ADF&G – Genetics
333 Raspberry Road
Anchorage, Alaska 99518

Lab staff: 907-267-2247
Judy Berger: 907-267-2175
Freight code: ________

Data Storage

During this plan period, all Northern Pike survey data collected by plan partners will be entered into a centralized file for comparisons and use in research. The data file is in Excel file titled "Northern Pike Survey Database" and is provided with the supplemental materials with this plan. Plan partners are encouraged to enter their data directly into the file following each survey. When that is not possible, data can be provided to the AKISP Northern Pike Committee chair for data entry. The data file includes fields for all the variables identified in the Numbers 1-32 in the Methods. The Excel file contains two data entry worksheets: Survey Data and Northern Pike Data. A metadata worksheet is also included to provide data entry instructions. In addition, the data include fields for "Sample Event #", "Northern Pike #". The Sample Event # and Northern Pike # are to be filled in using sequential order following the previous data entered in the file. These numbers connect the Survey Data with the individual Northern Pike Data.

SOP 2: Gillnet Use for Early Detection Surveys

Gear Recommendations

Note: See SOP 1 for Data Collection Sampling Gear

Open Water Netting:
Buoys
Line
Net Anchors
Safety Shears/ Scissors
Bathymetric Map
Buckets
Net Picking Tool
Bird Rescue Kit (scissors, blanket to cover bird, protective gloves and goggles)
Gillnets:

- 120' Long x 6' Deep Mono Experimental Gill Nets
- Six 20' Panels (All Sq. Measure): 3/4" #69, 1" #104, 1-1/4" #104, 1-1/2" #104, 1-3/4" #104, 2" #177, hung with #9 twine with intervals of 8”
- Leadline/ Bottom Rope: 50lb Lead core (50lb Sink/600')
- Floatline/ Top Rope: 1/2" Foam core Rope (20lb Sink/600')
- Breastline/ Side ropes: 1/8" solid braid nylon tied and spliced with #9 twine on an 8" guideline

Under Ice Netting:
Small Tow Behind Sled
Underwater HOV and Controller
Portable Ice hut/House (*optional)*
Bathymetric Map
Handheld Digital Depth Sounder
350 ft Floating Line to tether ROV to net
5lb small Boat Anchors *for the ends of each net*
Large Buoy (agency labeled) *for marking net(s*)
Nils Ice Saw (i.e., www.nilsmaster.com)
Ice “Spud” / Ice Chisel/ Ice Tongs
Ice Auger and Fuel
Ice Scoop(s) *to clean ice holes*
Snow Shovels
Wooden Stakes/Lath for marking holes
Signage to warn anglers and recreationists
Glow Sticks or Strobes *for directing the ROV*
Paracord or Line *for the glow sticks*
Small lead weights
Several Large Pieces of Blue Foam *high density*
insulation wall board form
Waterproof Insulated Gloves
Gillnets:

- 3/8” Floating Foam Core Line
- #30 lb Lead Line
- 4’ Deep Panel Size
- 1.25” Mesh Size
- 100’-150’ Long

Methods

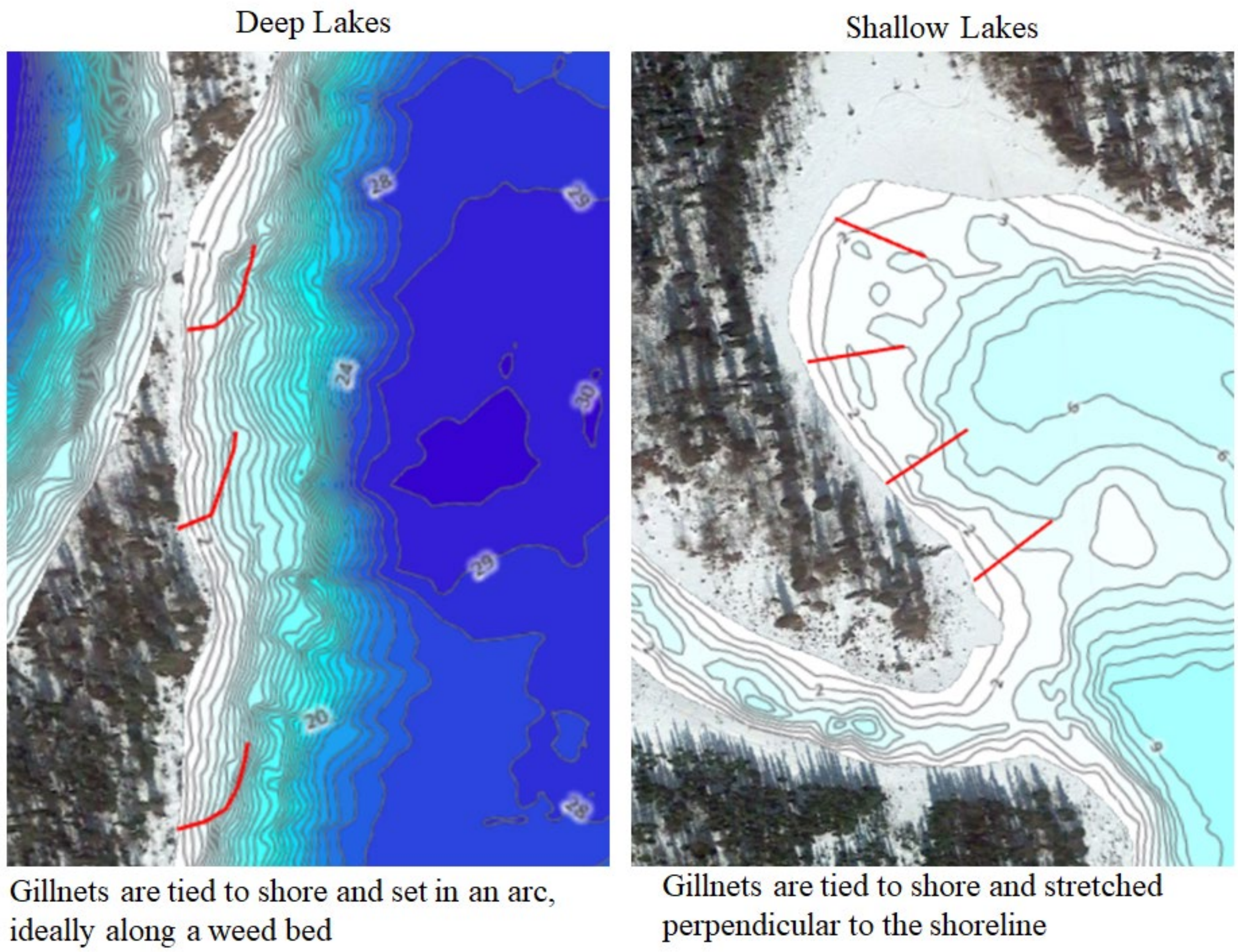
Open Water Netting

When using gillnets for Northern Pike detection, surveyors should use nets with consistent specifications so that data are comparable between waterbodies (Pierce et al. 1994). Experimental variable mesh gillnets are recommended for Northern Pike surveys because their catches can be most representative of the population structure in the water body (Pierce 2012). The recommended specifications for experimental gillnets for Northern Pike early detection surveys are listed in the gear recommendations above. Note that recommended net specifications may differ for Northern Pike suppression projects than for detection surveys. In addition to the use of consistent gear, the following netting methods should be followed as practical.

Net Placement:

To maximize encounter potential with Northern Pike, gillnets should target standing or emergent vegetation beds and natural chokepoints within waterbodies, mostly avoiding deep open waters. Whenever possible, nocturnal net sets, especially in clear water, should be used as Northern Pike are most mobile at dawn and dusk (Beaumont et al. 2003). In clear waters during sunny, calm conditions, net avoidance by Northern Pike can be a potential source of survey error, though this can be mitigated by placement near vegetation (Cook and Bergersen 1988).

Effective net orientation is dependent on the bathymetry of the waterbody. When setting nets from a boat in areas with high littoral relief, one end of each net should be tethered near shore, then the nets should be fed out perpendicular to shore, preferably to the outer edge of a littoral vegetation bed, or where the water depth begins to exceed the net depth. At this point the net is angled to be oriented more parallel to the shoreline where the remainder of the net is set either along the outer edge of littoral vegetation bed or along a similar depth contour (SOP2.1a). Where possible, stretching the net adjacent along the edge of a weed bed helps the lead line of the net to sink to the bottom rather than hang up on vegetation. For waters that are shallower and have lower littoral relief, nets can be tied off on shore and stretched perpendicular through weed beds (SOP2.1b). When setting nets during the open water season, attach a buoy to the untethered free end of the net so the net can be easily retrieved. Contact information for the partner organization conducting the survey should be listed on the buoy. Small anchor weights can also be attached to the lead line to secure the net on the bottom, but only if waterfowl usage of the lake is low as unweighted nets many improve survival for bycatch. In a two-person netting crew, one person drives the boat while the other deploys the net from the bow. Usually this is best done as the boats backs away from shore in reverse. The crew member deploying the net should take care to guide the net as it feeds out from its container so that the cork and lead lines remain separated. This will avoid twists and entanglements in the net.



SOP2.1 Guidance for setting open water gillnets in shallow and deep lakes

Seasonality

The time of year can affect netting success for Northern Pike. Northern Pike are ambush predators that are often sedentary when not feeding, spawning, or migrating to overwintering areas (Banktoft et al. 2012). This can affect how well Northern Pike recruit to nets. Temperature, dissolved oxygen and prey preference are also significant drivers of Northern Pike movements, especially for larger individuals that tend to move offshore to feed on larger fish and seek cooler water to slow metabolism (Pierce et al. 2013).

In Alaska, Northern Pike typically spawn from ice-out through early June, so targeting surveys during this timeframe may increase chances of detection. During spring surveys, targeting emergent and submerged weed beds is important for encountering spawning fish. During the summer and fall, a mix of net orientations incorporating both weed beds and deeper areas may encounter Northern Pike occupying different depths as waters begin warming and stratifying (Pierce et al. 2013). In Southcentral Alaska, Northern Pike have been observed occupying shallow waters and weed beds year-round (Massengill 2017a). Northern Pike also sometimes move to overwintering areas seeking adequate dissolved oxygen (DO). Some wintering areas may be quite shallow, but Northern Pike will occupy them if there is sufficient water circulation and DO and ice-build is not limiting (Scanlon 2009, Kobler et al. 2008, Taube and Lubinski 1996).

Net Retrieval:

When retrieving a net, carefully approach the buoy so that the crew member at the bow can retrieve it. To avoid tangling the net, keep the cork and lead lines separated as the net is gathered into its storage container. Remove fish that are captured, placing Northern Pike in a container for sampling and carefully removing and releasing native fish that are alive. For time efficiency when working fish that are extensively entangled, first allow the net to untwist as much as possible. Determine what side of the net the fish is primarily trapped in and then carefully work the mesh over the gill plate. It can help to keep a tub of water in the boat when trying to release live native fish. The fish can breathe in the tub while being freed from the mesh, and this is more comfortable than leaning over the gunnel of the boat to untangle the fish while keeping the fish submerged. The tub can then be used to hold native fish until they recover, thus increasing their survival chances. In cases where a fish is entangled beyond what is practical to untangle by hand, use safety shears to cut individual mesh lines to facilitate removal. For net longevity, this should be avoided whenever possible, but this is especially helpful when releasing live avian bycatch. Crews should remove plant and woody debris as much as possible while retrieving nets**. In waters where invasive plants such as elodea are present, nets MUST not be used in other waters until the nets have been rinsed with 2% bleach solution for at least two minutes and thoroughly inspected to ensure no plant material remains**. Prior to a survey, the Department of Natural Resources Plant Material Center (907-745-4469) should be contacted to inquire if invasive plants are known to exist in the survey location.

Under Ice Netting

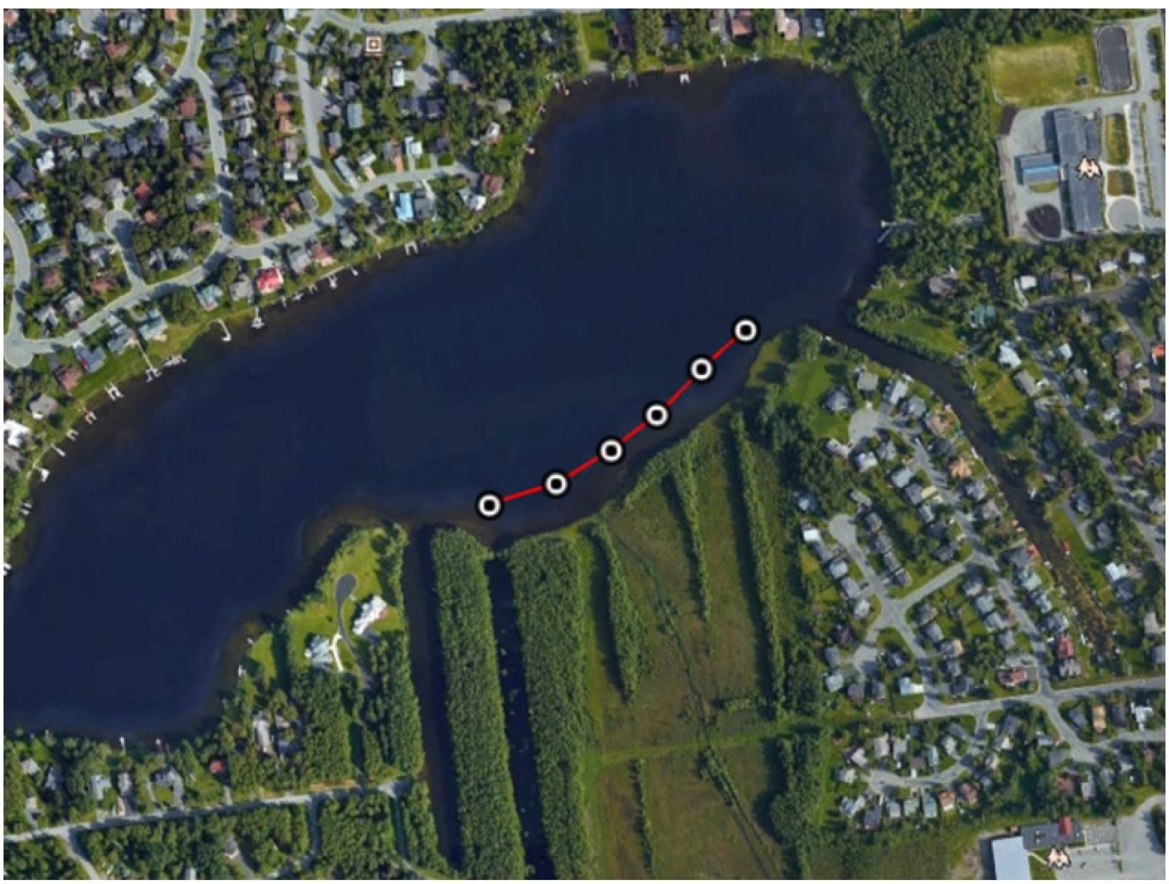
In some cases, setting gillnets under the ice may be a preferrable alternative to open water netting. Reasons for this can include time of year of the Northern Pike report, easier access over frozen ground via snow machine in the winter, requirement of a lengthy netting period, elimination of avian bycatch concerns, or to reduce conflicts with water recreationists. The disadvantage is that once nets are set, they can become encrusted in the ice and may not be retrievable until ice-out, which pending the circumstances, may be the desired duration. A second consideration is if nets are pulled after a long period of time, the likelihood of retrieving data from the catch is reduced due to decomposition, predation, etc. These potential disadvantages can be mitigated in two ways: First, by setting the nets in a location where the depth of the water column below the ice is greater than the depth of the gill net, which prevents the cork line from touching the bottom of the ice. The second is by setting the nets late in the winter when ice is no longer substantially building and checking them frequently. Both require relatively frequent net checks (at least once every 1-3 days depending on ambient temperatures). This has the potential benefit of occurring near the early spawning period for Northern Pike, so Northern Pike may be more mobile and likely to encounter the net.

Net Placement

For under ice net sets, nets can be strung together and set parallel to the shoreline in areas of the lake with the best Northern Pike habitat. It is important to avoid areas which may contain underwater snags, such as downed trees. The simplest way to deploy under ice nets is with the use of an underwater remove operated vehicle (ROV). First cut two holes in the ice at a distance approximately the length of the net (i.e., a 120' net would require two holes spaced ~110-115 feet apart). The holes need to be about 2'x3' to accommodate the ROV. With a crew of two people, attach a rope to the ROV and drive it from one hole to the other. Depending on water clarity, glow sticks may need to be placed in several holes (2 to 4) between the main holes to assist with ROV navigation. With the rope now under the ice between the holes, tie one end of the rope to the gillnet float line. Pull the rope from the other end to stretch the net beneath the ice. One person from the crew pulls the rope from the far hole while the other feeds the net into the first hole. On each end, the cork line is run though a piece of blue foam which will remain on top of the hole to provide insulation from freezing. The cork line is tied to a wooden stake which lays on top of the foam and prevents the cork line from falling into the water. The blue foam is then covered with snow, and the area should be marked for public safety purposes. The foam is not required if nets are intended to remain deployed all winter.

Net Retrieval

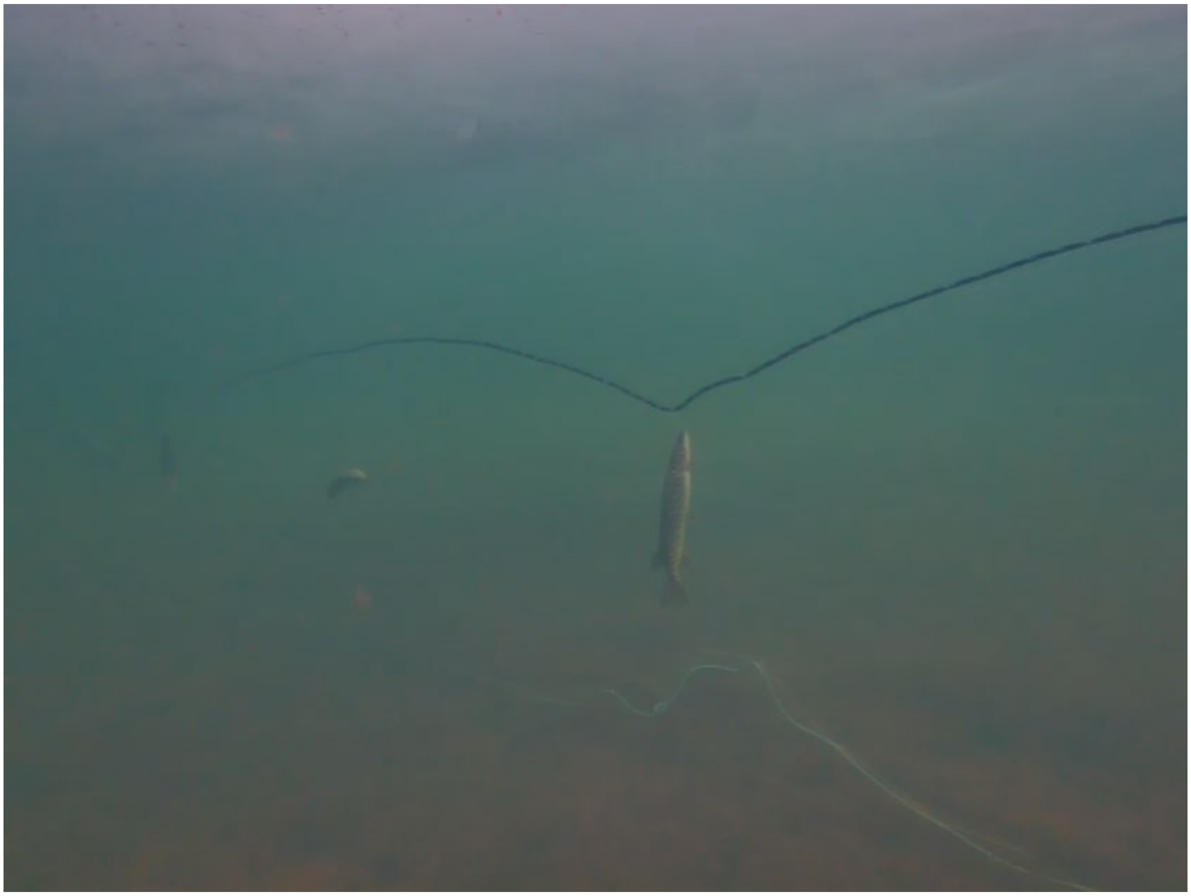
To check nets set beneath the ice, uncover both holes and attach a rope to one end of the gillnet. Pull the net out from the other hole. Once the whole net is checked, simply pull the rope from the other side, and feed the gillnet back into the water.



Under ice nets can be tied together and set parallel to the shoreline.

Note: Red lines indicate gillnets while dots represent holes in the ice and net ends where they can be retrieved from the surface.

SOP2.2 Gillnet orientation for under-ice nets sets



SOP2.3 Northern Pike caught in an under-ice gillnet

Calculating Needed Netting Effort:

As part of this SOP, a detection probability calculator was developed to inform the amount of netting effort needed to detect Northern Pike at a population size specified by the user (i.e, n=X individuals), littoral acreage of the water body, desired probability of detection, and number of gillnets used (Table 7). This tool was developed using Microsoft Excel and is calculated based on population estimates generated from the Threemile and Chuitbuna Northern Pike datasets collected for invasive Northern Pike suppression evaluations (Dunker et al. 2018b). Using this baseline, the tool estimates detection probabilities based on estimated littoral area, defined for the purpose of this plan as waters < 4 m (Pierce and Tomcko 2010). Determining the littoral area of the lake to be sampled is dependent on the availability of bathymetric information. If the lake has been mapped, a bathymetric map can be generated in Biobase™ for import to Google Earth. In Google Earth, the polygon tool can be used to draw the area < 4 m, and Google Earth will calculate the acreage that can then be input into the calculator. If the lake has not been mapped, the aerial imagery in Google Earth can be used to insert the polygon tool over areas of visible vegetation along the shoreline to approximate the littoral area.

The Northern Pike Detection Sampling Effort Calculator was developed by ADF&G Research and Technical Services and can be found with the plan supplemental materials. Plan partners planning Northern Pike detection surveys using gillnets are encouraged to use this tool to calculate needed netting effort.

Estimating Required Net-Hours	
Inputs:	*Example*
Littoral Acres (<4 m)	25
Desired Prob. Of Detection:	0.8
Population Size:	5
Number of Nets:	10
Outputs:	
Net-Hours	211.8
Soak Time (hrs):	21.2
Soak Time (days):	0.9

Note: The catchability coefficient (0.038) used in the model was estimated by performing linear regression of CPUE (dependent variable) against density (Independent variable) using data from the Threemile and Chuitbuna systems.

SOP2.4 Example frame of the netting effort calculator (inputs by the user in yellow, outputs in green)

Considerations:

- Use the Northern Pike Detection Sampling Effort Calculator to determine the quantity of netting effort. Net quantity and duration is variable based on user inputs to the estimator tool. Netting effort varies based on 1) detection probability desired, 2) littoral area and 3) estimated size of the Northern Pike population. Nets should be distributed throughout the lake but should target the best Northern Pike habitat. A recommended strategy is to measure the shoreline distance in Google Earth and divide the lake perimeter into one-mile sections. After dividing the lake into these sections, identify the best habitat (i.e. weed beds) within each section to deploy the nets.
- Whenever possible, overnight sets are preferred, but site-specific conditions such as fish and avian bycatch, high recreation, or float plane use may preclude overnight sets from being feasible. In these cases, diurnal net sets are recommended with a crew of two who can attend the nets while set to release bycatch and answer any questions from the public.
- The Probability of Detection Calculator should be used to inform needed netting effort. However, if bycatch is a concern, as a general guideline, an experienced crew of two can usually monitor up to ten nets at a time pending lake size and distance between sets. This guideline should be factored into the number of days allocated to the survey.
- Under certain circumstances, gillnets may not be a viable option if bycatch potential could cause a conservation concern. In these cases, follow the recommendations in the Decision Response Matrix and select a different survey format.
- If a shorter net is needed in an area of the lake, the net can be set in a tight U-pattern which keeps the net in a smaller area while keeping all mesh sizes fishing. Always keep notes in the data about the configuration of net sets (parallel to shore around vegetation, perpendicular to shore, U-shape, or any other pattern used).
- In cases where bycatch potential is unknown, a test gillnet survey can be run for up to four hours using a reduced number of nets. If the bycatch rate of salmonids and/ or waterfowl is significant, the gillnet survey can be aborted and replaced with an alternative

survey method or reduced and combined with another method. Prior to surveys, samplers are encouraged to discuss bycatch thresholds with ADF&G Sport Fish area managers (Contact Information: Southcentral - Sport Fishing Information, Alaska Department of Fish and Game) for the water body in question to determine the acceptable level of salmonid bycatch. The test survey could be used to estimate how much netting can be conducted without exceeding the agreed-upon bycatch threshold.

- For high-risk waters, it may be desirable to map the lake immediately to better determine littoral area for the Northern Pike Detection Sampling Effort Calculator and to identify the ideal netting locations based on vegetation presence. ADF&G has the capacity to map lakes. For plan partners desiring a bathymetric map before surveying, coordinate with ADF&G if equipment is lacking. Alternatively, when littoral area is unknown and lake mapping prior to the survey is not feasible, using the polygon tool with summer Google Earth maps can be an alternative method for estimating littoral area and presence of visible weed beds.
- If the gillnet survey is conducted and no Northern Pike are captured, refer to the Decision Response Matrix for next steps.
- In cases where only one Northern Pike is detected, the survey may need to be repeated to determine if a reproducing population is present.
- For surveys where multiple Northern Pike are captured, it is recommended to continue netting to gather data on population structure, but the duration of the survey is then up to the discretion of the lead project biologist.

SOP 3: eDNA Use for Early Detection Surveys

Gear Recommendations

Offsite Filtration
GPS
Nitrile Gloves
Sharpies
Coolers
1-liter Nalgene Bottles
GeoTech Peristaltic Pump(s)
Masterflex silicone tubing
1.2 µ Whatman Glass Microfiber Filters
Nalgene Analytical Test Filter Funnels
Nalgene Filter Funnel Adapters
Plastic Disposable Forceps
Falcon Tubes
Bleach
Paper Towels
Garbage Bags

Onsite Filtration (Optional)
Smith-Root eDNA Sampler Backpack
eDNA Sampler - Smith-Root
1.2 µ Filters in Self-Preserving Filter Packs
EDNA SELF-PRESERVING FILTER PACK (smith-root.com)
GPS
Nitrile Gloves
Sharpies
Cooler
Falcon Tubes

Methods and Best Practices

Fisheries and Oceans Canada recently published a thorough review and guidance document on the use of targeted eDNA analysis for the management of aquatic invasive species (Abbott et al. 2021). This document is available at: Guidance on the Use of Targeted Environmental DNA (eDNA) Analysis for the Management of Aquatic Invasive Species and Species at Risk (westernregionalpanel.org). This guidance, along with lessons learned from previous eDNA applications in Alaska, serve as the basis for this SOP.

Field Sampling

Seasonality

eDNA detection probability is directly proportional to the rate from which an organism releases DNA into the water (Abbott et al. 2021). eDNA detection is inversely proportional to the rate at which DNA is lost through sedimentation, degradation, or excessive dilution. With Northern Pike, there are several environmental factors that can affect this. Northern Pike shed DNA into the water through feces, urine, scales, mucus, gametes, and carcasses. Theoretically, concentrations of Northern Pike DNA in littoral zones of lakes could be higher during spring spawning (i.e., Tsuji and Shibata 2021) than during other times of the year, making spring through early summer an ideal time to conduct an eDNA survey. eDNA from Northern Pike excrement and scales, however, would be present throughout the year and potentially more concentrated at higher water temperatures (Toshiaki et al. 2019), though eDNA degrades slower in cooler temperatures or under lower UV conditions (Strickler et al. 2015). In Alaska, sediment-trapped DNA has yielded positive eDNA results from waters where no live Northern Pike were ever detected. In waters with no prior Northern Pike record, timing surveys following wind storms or after fall turnover could increase the potential for positive eDNA detection given the potential for these environmental events to resuspend DNA (i.e, Harrison et al. 2019). However, if the goal of the survey is to determine continued or new Northern Pike presence in waters where Northern Pike have been previously eradicated (Dunker et al. 2016), timing surveys during or immediately following wind or turnover events should be avoided so that resuspended sediment-derived DNA does not confound interpretation of results.

Contamination Prevention

A significant potential source of error in eDNA surveys comes from sample contamination. Because eDNA analysis detects trace DNA, very low levels of contamination can cause positive results that aren't representative of live Northern Pike; therefore, strict contamination prevention practices must be adhered to (Goldberg et al. 2016). Sample contamination for Northern Pike generally occurs in one of two ways: 1) Northern Pike DNA externally introduced to the waterbody via boat, life jackets, waders, gillnets, coolers, other gear or improperly sterilized equipment, or even carcasses deposited from anglers filleting Northern Pike caught elsewhere and 2) cross contamination between waterbodies or sample locations within waterbodies. Once samples are collected from the field, contamination can also occur during laboratory processing if proper quality control is not exercised (See Laboratory Processing below).

As this SOP is primarily geared toward eDNA survey protocols, best practices to avoid contamination will focus on field sample collection and filtering rather than laboratory QA/QC. Best practices to avoid field contamination of samples include:

- Training all personnel on the importance of avoiding contamination prior to the survey.
- Using disposable gloves and changing them frequently, ideally between each sample collected and subsequently when each sample is later filtered. If location within a site (the water body sampled) is not significant to the survey, changing gloves after each sample is less important. However, not changing gloves between samples carries the potential of inflating the proportion of samples within the sites that are positive if cross-sample contamination occurs. This will depend on the goals of the survey. The most conservative approach is to change gloves between handling each sample.
- Prior to any eDNA survey, thoroughly clean all field equipment using at least a 2% bleach solution. This should include washing the boat to be used, waders, boots, life jackets, etc. if this gear has been previously used in known Northern Pike waters.
- If not using a filtering backpack, it is best to use new commercial-grade Nalgene water bottles for each survey; however, bottles can be reused if properly sanitized. This is the same for filter cups used while filtering samples. To sanitize this equipment, either soak in 20% commercial-grade bleach (sodium hypochlorite) solution for a minimum of 10 minutes and thoroughly dry, then expose used equipment to a UV sterilizer for a minimum of 10 minutes per exposure side.
- Avoid collecting water samples immediately alongside the boat or the sampler's waders. Try to collect samples at least an arms-length away to minimize DNA potentially transported by the boat hull or sampler.
- If gillnets for Northern Pike have been used in the waterbody, wait at least 2 months before eDNA sampling to avoid DNA introduced from the nets confounding results.
- When filtering samples, ensure the pump space is sterilized before beginning to process samples.

- Replace filter cups between samples, use new disposable or sterilized forceps after contact with a filter, place filters in sealed falcon tubes before recording sample data, and, again, change gloves before handling the next sample.
- Include blanks (contamination controls) in your survey to increase confidence in results and/ or isolate where contamination may have occurred.
    - Equipment Blank: Prior to the survey, fill at least two bottles with DI or distilled water. Keep one in the bottom of the boat and the other in the cooler used to store the samples.
    - Field Blank: Bring DI or distilled water on the survey. During the survey, fill a sample bottle with this water instead of lake water using the same protocols employed during the rest of the survey.
    - Pump Blank: After processing every 10 samples, fill an unused sample bottle with DI or distilled water and filter it using the same procedure as all other samples.

Calculating Needed Netting Effort:

One of the most complex questions in designing Northern Pike detection eDNA surveys is to determine the quantity of samples and water volume needed to adequately make determinations of Northern Pike presence. Currently, there is no set standard nor any practical way to set such a standard across all eDNA practitioners and taxa. Therefore, for this SOP guiding Northern Pike surveys in Alaska, a detection probability calculator has been developed to inform the amount of eDNA sampling suggested to reasonably detect Northern Pike presence. Littoral surface acreage of the water body, desired probability of detection, and suspected Northern Pike population size are inputs the user can enter to generate the estimated number of 1-L samples needed to detect Northern Pike at those levels (SOP 3.1). This eDNA sampling estimator was developed by ADF&G Research and Technical Services using Microsoft Excel and is calculated based on the Northern Pike eDNA study conducted by Dunker et al. 2016.

An Excel file containing this calculator "Northern Pike Sampling Effort Calculator", can be found in the supplemental plan materials or acquired by contacting the AKISP Invasive Northern Pike Committee Chair. The pertinent worksheet for this SOP is titled "eDNA Effort Calc". Partners planning Northern Pike detection surveys using eDNA are encouraged to use this calculator to help inform sample quantity.

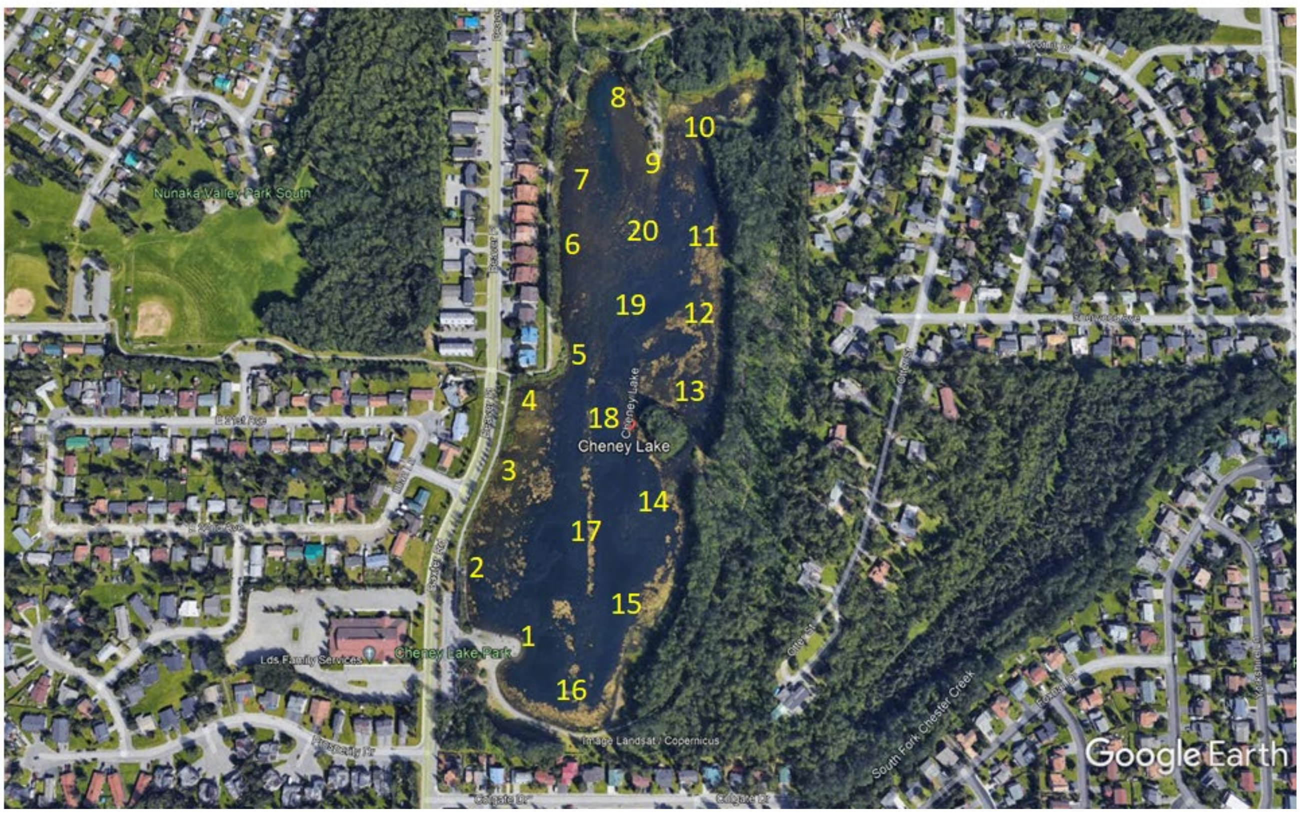
Estimating Required Number of eDNA samples	
Inputs:	*Example*
Littoral Acres (<4 m)	25
Desired Prob. Of Detection:	0.8
Population Size:	5
Outputs:	
Number of Samples	20

SOP3.1 Example frame of the eDNA Effort Calculator (inputs by the user in yellow, outputs in green)

Sample Collection – 1 Liter Bottles

Once the quantity of samples needed for the survey is determined, it is useful to plot sample numbers on a Google Earth map of the water body for navigation in the field (SOP3.2). Following all previously described best practices to avoid contamination, single 1-L surface water grab samples should be collected corresponding to each sample location on the map. Sterile Nalgene bottles should be used for sample collection unless using an eDNA backpack. To further avoid contamination, it can be helpful to have previously labeled sample bottles with the date, location, and sample number prior to the survey. After each sample is collected, use a GPS to record waypoints corresponding to the sample number for the survey record as well as for repeatability of the survey if needed. Store collected samples in a dark cooler until filtering. All filtering should take place within 24 hours of sample collection.

Cheney Lake eDNA Northern Pike Survey



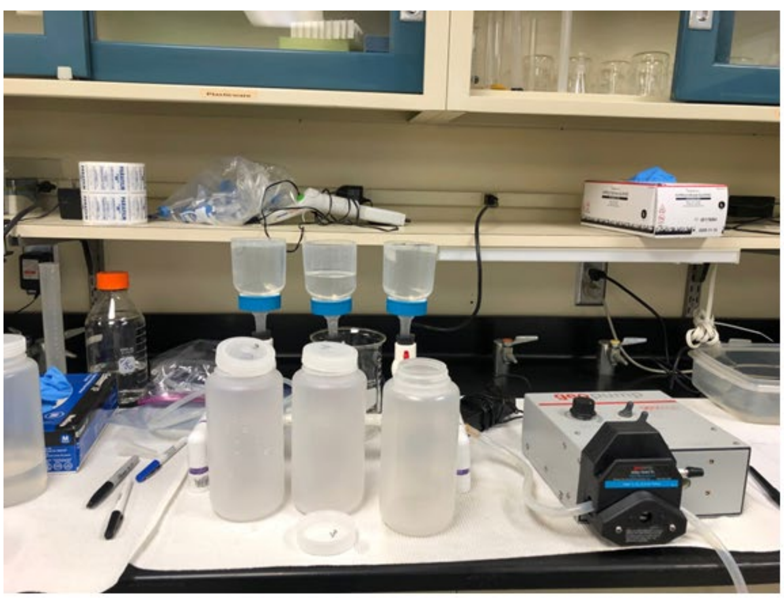
SOP3.2 Example of a pre-survey plan for collecting 1-L eDNA samples in the field

Filter Processing

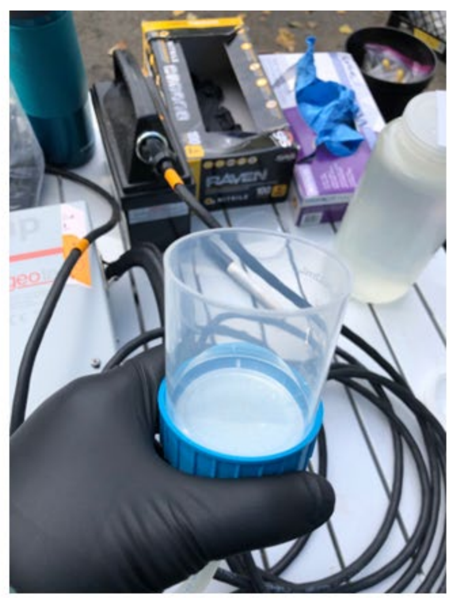
Water samples should be temporarily stored on ice in a cooler or in a refrigerator and filtered within 24 hours of collection. 1.2μ Whatman glass filters have been successfully and efficiently used for Northern Pike eDNA surveys in Alaska, though the pore size and filter medium can be up to the user. The goal is to not lose eDNA through the filter, but the trade-off with smaller pore sizes and other mediums (i.e., mixed ester nitrocellulose) is that filters can easily clog and greatly prolong filtering time. Filters and filtering supplies are available from all major science supply distributors.

The following steps describe the procedure for filtering samples collected in Nalgene bottles:

1) Set up sterile filtering stations in either a lab or in the field. The workspace and filtering equipment MUST be free of any potential Northern Pike contamination. Set up a peristaltic pump (SOP 3.3) and connect it to a power source. Use a section of silicone tubing to attach to the pump for draining the water.
2) Before beginning, with nitrile gloves, replace the filter backings that come with the filter cups with the 1.2µ Whatman glass filters. Put the filter cup cap back on until use.
3) Attach a sterile filter funnel adapter to the end of the silicone tubing that will attach to the filter cups.
4) Use new nitrile gloves and sterile disposable forceps when handling each sample.
5) Turn on the pump and ensure it is pulling water. The speed dial may need to be adjusted.
6) Once the pump in ready, grab a pre-set-up filter cup and filter each 1-Liter sample. If the filter clogs, it may not be possible to filter the entire sample, though most samples should filter fully with Whatman glass filters.
7) When the sample has been filtered, stop the pump. Remove the filter cup and either recycle or store it for later sterilization. Use new forceps to gently remove the filter from the bottom of the filter cup, and place into a sterile falcon tube.
8) Seal the tube and record the sample number directly on it with a sharpie. Also, record which pump and sampler processed each sample on a datasheet or sample log.
9) Each sampler should run a pump blank with distilled water after every 10 samples to isolate where contamination occurred Contamination is indicated if PCR processing detects positive results in blanks.
10) Grab a new sample, switch nitrile gloves, and repeat until all samples are complete.
11) When finished processing the samples, immediately transport filters to an eDNA lab for PCR processing. It is ideal not to freeze samples more than once, as the process of freezing and thawing further degrades DNA. If samples must be mailed to a lab, store with silica packets and express mail them.



Peristaltic Pump for filtering water samples



Filter Cup w/ Whatman Glass Filter

Sample Collection/Onsite Filtering – eDNA Sampler Backpack

Using an eDNA backpack (eDNA Sampler - Smith-Root), can be a more efficient way to filter larger quantities of water if project budgets allow for this equipment (Starting cost for a unit is $6,800). Among the benefits of these machines are that the backpack samplers can both collect water and filter it onsite. This can greatly reduce contamination potential, though all previously mentioned contamination-avoidance best practices should be adhered to when switching and storing filters. Determining sample location and quantity can be planned in a similar manner as projects that collect samples by hand in bottles. The primary manufacturer of these units, Smith Root, suggests filtering 1-5L, or until the filter clogs at each site. Again, the general rule of thumb among eDNA practitioners is that the more water that can be filtered, the better the odds are of detecting eDNA. If quantifying the effort using the calculator in SOP3.1, note that calculator is programmed for determining the quantity of 1-L sample to use. If estimating the probability of detection is important for the needs of the survey, then simply use the backpack to filter 1-L samples at each site. However, if determining that probability is of little consequence for the needs of the survey, the recommendation is to filter as much water as possible with the backpack per site until the filter clogs. The instruction manual for using the Smith Root eDNA sampler backpack is included in the supplemental materials with this plan. Tutorial videos can also be viewed here:
www.smith-root.com/support/tutorials. Refer to the user manual on best practices for replacing or decontaminating hosing between use.

SOP 3.4. Smith Root eDNA sampler backpack for onsite sample filtration

Laboratory PCR Processing *(For Laboratory Reference Only)*

DNA extractions are performed with Qiagen DNeasy Blood and Tissue Kits (Qiagen©) according to the manufacturer's instructions and stored at −80 °C. One extraction blank (diH20) is included per batch of extracted field samples. All extractions and plate pipetting are done in rooms reserved for extracting eDNA samples and PCR prep, respectively, where no PCR products or other sources of high concentration DNA are handled. The EluCOI assay (Olsen et al. 2015) is conducted using a Real-Time PCR system. PCRs consist of 20 µl included 10 µl of TaqMan Environmental Master Mix 2.0, 2.6 µl sterile water, 2 µl of 10x TaqMan Exogenous IPC Reagents (VIC probe), 0.4 µl of Exogenous IPC DNA, 1 µl COI (20x) assay (primers at 18 µM, probe at 5 µM), and 4 µl of DNA extract. The PCR cycle conditions are as follows: 95ºC for 10 min followed by 50 cycles of 95ºC for 15s and 60ºC for 1m. A minimum of 3 non-template controls (NTC, 4 µl diH20 in place of template) and 3 internally blocked controls (IBC, 4 µl Exo IPC Block in place of template) are included on each 96-well PCR plate. LinRegPCR v2017.0 (Tuomi et al. 2010, Ruijter et al. 2009) was used to correct ROX- normalized baselines and determine a common threshold fluorescence. Each 96-well PCR plate includes at least three synthetic standards which were used to adjust separately run plates using Factor q v2016.0 (Ruijter et al. 2015). Samples should be run in at least triplicate during qPCR. Technical replicates with $12 < Cq < 40$ and PCR efficiencies between 1.4- 2.2 are considered positive.

Record Keeping

Individual Survey Records

The eDNA Reporting Template used in Abbott et al. 2021 is recommended for use by project managers to keep detailed records on each survey (SOP3.5). A copy of this digital form is included with the plan supplementary materials, but it can also be found online: Guidance on the Use of Targeted Environmental DNA (eDNA) Analysis for the Management of Aquatic Invasive Species and Species at Risk (westernregionalpanel.org) (Abbott et al. 2021, Annex 1.eDNA Reporting Template). The eDNA processing lab should fill out sections I, III, and IV. The field lead (i.e. project biologist) should fill out section II. Field project leads should work with the labs to ensure these records are complete, and digital copies of completed forms should be retained by the project manager for each survey.

eDNA Survey Database

Pertinent information from the eDNA Reporting Template should be entered into a centralized file for use by all partners and researchers. The file structure for this database is provided in the plan supplemental materials. The AKISP Invasive Northern Pike Committee Chair will solicit and compile all eDNA data entered in this format for annual submission to the Invasive Species Monitoring Data Portal maintained by UAA. Field leads should work with their eDNA lab to ensure all fields are filled out. The field lead will enter the site and sample data while the lab will fill in the PCR results. The sample data to be entered by field leads include: *sample #, location, sample volume, filter type, pore size, collection date, season, collectors, agency*, and *comments*. The remaining fields are for PCR run results and should be filled out by the lab. These include: *R1.1CT, R1.2CT, R1.3CT, R1.IPC, R1. Call, Avg. CT, R2.1CT, R2.2CT, R2.3CT, R2.IPC, R2. Call, Final Call, Run 1 Sta*t, and *ReRun Stat*. Upon completing lab analysis, the datafile should be sent back to the project lead and forwarded to the AKSIP Northern Pike Committee Chair for compilation and submittal to the Invasive Species Monitoring Data Portal.

eDNA Reporting Template

I. eDNA Testing Sample Submission Information

Report Title:			
Project Number:		**Date of Final Reporting:**	
Service Provider Information	Type: Select From Dropdown Contact Name: Address: Contact Phone: Contact Email: LAB ACCREDITATION / CERTIFICATION:	Requesting Organization Information	Organization Name: Contact Name: Contact Phone: Contact Email:

Executive Summary - Study Objectives, Rationale, and Main Finding(s) derived from both eDNA samples and controls

Appendices (Required)	Check to confirm inclusion	Appendices (Additional)
Appendix 1: Maps of the study sites and sampling locations	☐	*Appendix 5:*
Appendix 2: Contamination prevention procedures	☐	*Appendix 6:*
Appendix 3: qPCR protocol	☐	*Appendix 7:*
Appendix 4: Metadata and qPCR data	☐	*Appendix 8:*

II. Study Design and eDNA Sampling

A. Study information	*A.1 Species targeted (common and Latin):*	
	A.2 Study objectives:	Select From Dropdown
	A.3 Geographic location and/or region:	
	A.4 Sampling date (range):	Start: Finish:
	A.5 Sample types:	Select From Dropdown
	A.6 Mapping databases (list all):	
B. Study design	*B.1 Type(s) of ecosystem:*	Select From Dropdown
	B.2 Sampling design (how does sampling optimize species detection for study goal?):	
	B.3 Number of sites sampled:	
	B.4 Number of stations sampled within sites (add explanation for variation among sites):	
	B.5 Number of field sample replicates:	
	B.6 Time series (number of times sites and stations were sampled):	
	B.7 Environmental conditions, relevant observations, and additional field data:	
	B.8 Field blanks and field controls (describe and give numbers):	
C. eDNA sample collection	*C.1 Env. sample collection method:*	Select From Dropdown
	C.2 Volume / weight sampled:	
	C.3 Sample depth(s):	
	C.4 Field sample storage/time to processing:	
	C.5 Sample processing method (list disposable equipment; preservative used):	Select From Dropdown
	C.6 Filter type and pore size:	
	C.7 Sample preservation:	Select From Dropdown

(Continued next page)

III. eDNA Sample Analysis - Laboratory Methods			
D. DNA extraction	*D.1 Name of commercial kit or protocol:*		
	D.2 Reference protocol:		
	D.3 DNA extraction controls:		
	D.4 Proportion of total sample:		
	D.5 DNA elution volume:		
	D.6 Extracted eDNA storage conditions:		
E. qPCR assay	*E.1 Assay Name:*		
	E.2 Assay Type:	Select From Dropdown	
	E.3 Level of assay validation:	Select From Dropdown	
	E.4 Specificity data:		
	E.5 Dilution and volume of DNA used:		
	E.6 qPCR positive and negative controls:		
	E.7 Technical replicates per sample:		
	E.8 Inhibition tests:		
	E.9 Number of qPCR cycles:		

IV. Summary of eDNA Results		
F. Reporting control results	*F.1 Criteria to determine if controls passed or failed:*	
	F.2 Positive control results (report each type separately):	
	F.3 Negative control results (report each type separately):	
	F.4 Failed controls (report and explain):	
G. Reporting eDNA sample results	*G.1 Calculated LOD:*	
	G.2 QA/QC qPCR results:	
	G.3 Other qPCR results:	
	G.4 Determination of sample-level results:	
	G.5 Determination of station-level results:	
	G.6 Determination of site-level results:	
H. Closing statements	*H.1 Disclaimer (any additional information to help explain results for any samples, stations, or sites):*	
	H.2 Summary of eDNA detection:	
	H.3 Future recommendations:	

SOP 3.5. eDNA Reporting Template Form. Sections I, III, and IV should be filled out by the eDNA processing lab; Section II should be filled out by the field lead for the project

Downloads of this form can be found here: eDNA-Reporting-Template.pdf (dfo-mpo.gc.ca)

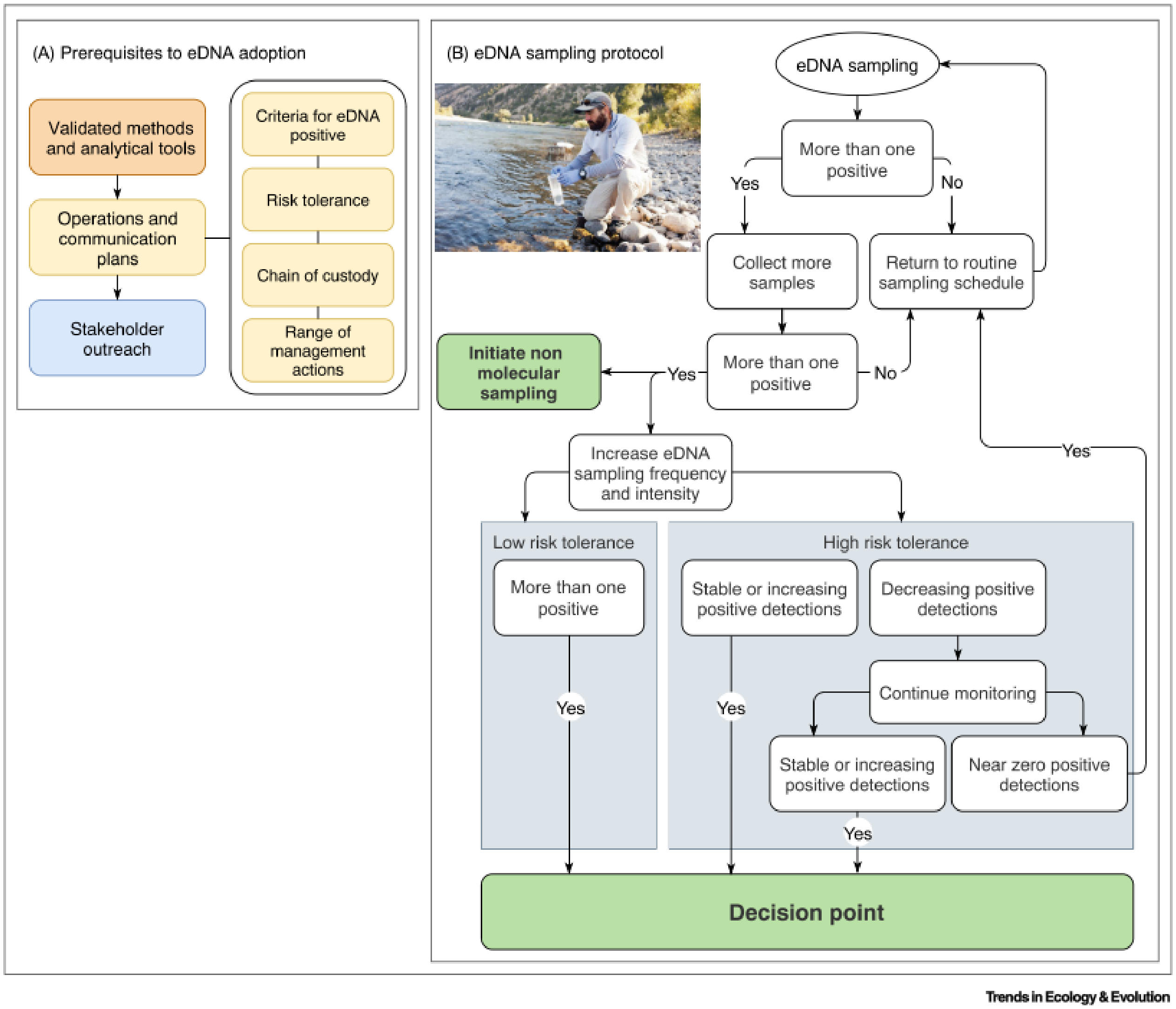
Considerations:

- For early detection where rapid results are needed, coordinate with laboratories in advance to determine which lab can best meet the timelines needed for returning results.
- It is important to understand terminology pertaining to eDNA:
  - A positive eDNA result in a location from which no live Northern Pike is found is not a "false positive" as the Northern Pike DNA was correctly detected, even if it was not from the presence of a live Northern Pike. This scenario would be termed "False Positive Inference".
  - False Positive Inference – positive result, but sufficient non-eDNA data for confidence that target species is not actually there.
  - False Positive Test: Cases in which observation-level error can be clearly demonstrated
  - Presumed Positive – No non-molecular confirmation
- Repeating samples with similar results increases confidence for management decisions stemming from eDNA surveys.

Decision Guidance:

When an eDNA survey produces positive detections for Northern Pike, the next step is determining how to proceed with management actions given the results. Plan section 2.2 Decision Guidance (Figure 20c, d) illustrates this is an early detection context. The general recommendation is to only act if there is > 1 strong positive. A strong positive, for this purpose, is defined as a sample registering a positive result for at least 2 of 3 PCR cycles for 2 runs. If this criterion is met more than once in a waterbody, then following up with gillnet surveys in the next step. If the gillnet survey fails to detect Northern Pike, then the eDNA survey should be repeated. If, however, gillnetting is not an option for follow-up, then interpreting eDNA results in a manner that triggers a management response is more critical. Sepulveda et al. 2022 provides an excellent decision-support tree to guide fishery managers in making management decisions based on eDNA surveys. Their recommendations are to adopt standardized protocols for field collection of eDNA samples, validate eDNA assays, develop consistent use of terminology and procedures for reporting results, develop communication plans, identify risk tolerance for error, and develop a decision tree that incorporates multimethod surveillance results with risk tolerance. This SOP incorporates the recommendations in Sepulveda et al. 2022, and their decision tree is provided to guide management decisions for Northern Pike (SOP 3.6).

Using the decision tree from Sepulveda et al. 2022 (SOP3.6), the prerequisites (Panel A) are identified throughout this management plan. This SOP describes the recommended sampling protocols and best practices and establishes that > 1 strong positive eDNA result is required to trigger the next level of surveying and/or management action. This is further refined by the risk tolerance for fishery managers if results were incorrect (Panel B). For waters that are of greatest concern (Figure 20a), meaning that the Northern Pike population poses a significant risk to fisheries, there would be low risk tolerance, and the positive eDNA detections would be sufficient to trigger management action as discussed in plan section 3.5 Response Guidance. For waters that are of moderate or lower concern (Figure 20a), risk tolerance for error would be higher, and more eDNA monitoring would be recommended before making management decisions.



SOP 3.6. Management decision tree following eDNA detection. Used with permission from Sepulveda et al. 2022

Communication Planning

The final consideration with eDNA is how best to communicate about positive results. In cases involving other invasive species, such as dreissinid mussels, there have been several scenarios involving media reports of mussels found in recreationally significant waters, based on eDNA, but no infestations were ever found. In extreme cases, this triggered significant response activities and costs that were unwarranted. To avoid similar scenarios with Northern Pike detections in Southcentral Alaska, the recommendations in plan sections 3.1 Partner Communication and 3.2 Public Communication should be strictly adhered to. With positive eDNA results, especially where a live fish is not in hand, communications should remain internal to the involved partner organizations until a follow-up survey plan or management action has been selected and partners have developed a Communication Plan. Once a communication plan is finalized, public outreach can commence in whatever manner is most appropriate for the circumstances and water body in question.

SOP 4: Hook and Line Surveys for Early Detection

Gear Recommendations

Open water

Fishing license
Boat (including as needed: outboard motor, fuel line/gas tank, life jackets, paddles, and anchor)
Boat tool kit
Knife
Heavy action spinning rods *(i.e., ~7 feet long, rated for 15-30 lb. test fishing line)*
Reels *(filled with braided fishing line or low-stretch monofilament, 15 lb. test or heavier)*
Wire leaders 18-in length with 30 lb. test or greater
Fish jaw spreader
Needle nose plier
Assortment of fishing lures: *weedless spoons, weedless floating mice and floating frog lures, various spinner baits (i.e., bass-type spinners, hardware spinners (i.e., Mepps Aglia spinners in sizes 3-5), soft-body imitation minnows/worm lures, top water buzz baits, etc.)*
Tackle box
Hook sharpening file
Polarized sunglasses
Landing net
Bathymetric map of waterbody
GPS
Catch/sampling forms/pencils
Kevlar fillet gloves *(for protecting fingers from Northern Pike teeth during hook removal or dissection)*
Fish tote
Dissection kit

Under Ice

Fishing license
Ice auger, 8" diameter or larger (additional fuel or batteries as needed auger extension for deep ice)
Ice scoop
Ice chisel
Snow shovel
Small sled to carry all the gear
Tip-ups *(5 per survey crew member or based on regulations or ARP permit stipulations; tip-up, heavy braided waxed line preferred, 40lb)*
Quick-strike leaders *(double treble hook for fishing bait)*
Dead herring or similar bait
Knife
Ice fishing jigging rods
Terminal jigging tackle *(small spoons, jigging Rapala, treble hooks, lead weights)*
Bathymetric map of waterbody
GPS
Catch/sampling forms/pencils
Dissection kit
Lead clip-on style depth finder
Lead split shot
Hook sharpener
Fish jaw spreader
Gaff hook
Snowmachine where applicable
Needle nose pliers
Hand warmers (optional)
Ice fishing shanty (*optional*) with heater

Methods

Overview

Hook and line fishing can be used for Northern Pike detection surveys to confirm presence or collect specimens/samples for research purposes. The efficiency of hook and line fishing is usually low compared to gillnetting, and small Northern Pike (<300 mm) can be difficult to catch using hook and line. Regardless, hook and line fishing can be an effective sampling method under the right conditions. Some research suggests that in small waterbodies, exceptional Northern Pike catch efficiency rates can be attained by hook and line fishing. For example, one study reports that all 20 Northern Pike stocked into a manmade pond were caught at least once during an open water season, with one being caught seven times (Weithman and Anderson 1978). A Michigan study reports two anglers caught 28% of a pond's Northern Pike population in eleven hours while applying less than 2.5 hours of angling/acre (Latta 1972).

Detection Survey Planning

When trying to confirm a Northern Pike population at very low abundance, hook and line fishing is rarely selected as the primary survey tool due to its relative inefficiency compared to gillnetting. However, in situations where gillnet bycatch issues are a high concern or when safety issues exist over the use of nets or other gear types, hook and line fishing may serve as a primary survey/detection tool. Hook and line fishing can be done alone or in conjunction with other survey methods such as gillnetting, fyke/hoop netting, visual surveys or following eDNA surveys when the inadvertent introduction of eDNA contamination to a site is no longer a concern. When using hook and line fishing as the primary detection tool, samplers should consider factors to improve capture efficiency because a low-density population could be very difficult to detect. Factors to consider include the timing of the survey, how to focus effort on the most optimal Northern Pike habitat available, distributing the effort well within the optimal habitat, and expending enough effort to provide a reasonable opportunity for detection.

Beyond population abundance level, the success of hook and line fishing for Northern Pike is dependent on multiple conditions such as the season and time of day, water quality, prey resources, lake morphology, and available habitat/cover. For novice anglers, there are many online resources to learn how timing and environmental factors can be leveraged to increase hook and line angling success, some suggested sources specific to Northern Pike angling include:

1) https://freshwaterfishingadvice.com/best-time-day-Northern Pike-fishing/
2) https://www.in-fisherman.com/editorial/Northern Pike-weather-pattern/156887
3) https://strikeandcatch.com/best-time-of-day-for-Northern Pike-fishing/
4) https://usangler.com/Northern Pike-fishing-tips-techniques/

An ADF&G video is also available that explains hook and line fishing techniques for Northern Pike:

https://www.youtube.com/watch?v=89t8nNWIGs8

Prior to starting any hook and line survey, collect any available fishery information for the waterbody of interest. There are ADF&G fishery resources available online that can be used to investigate sport fishing harvest data, known freshwater fish distribution, and lake bathymetry maps. Links to these resources are provided here, respectively:

1) ADF&G Alaska Statewide Harvest Survey: (https://www.adfg.alaska.gov/sf/sportfishingsurvey/index.cfm?ADFG=region.home
2) ADF&G Alaska Freshwater Fish Inventory: https://www.adfg.alaska.gov/index.cfm?adfg=ffinventory.interactive
3) ADF&G Alaska Lake Database : http://www.adfg.alaska.gov/SF_Lakes/

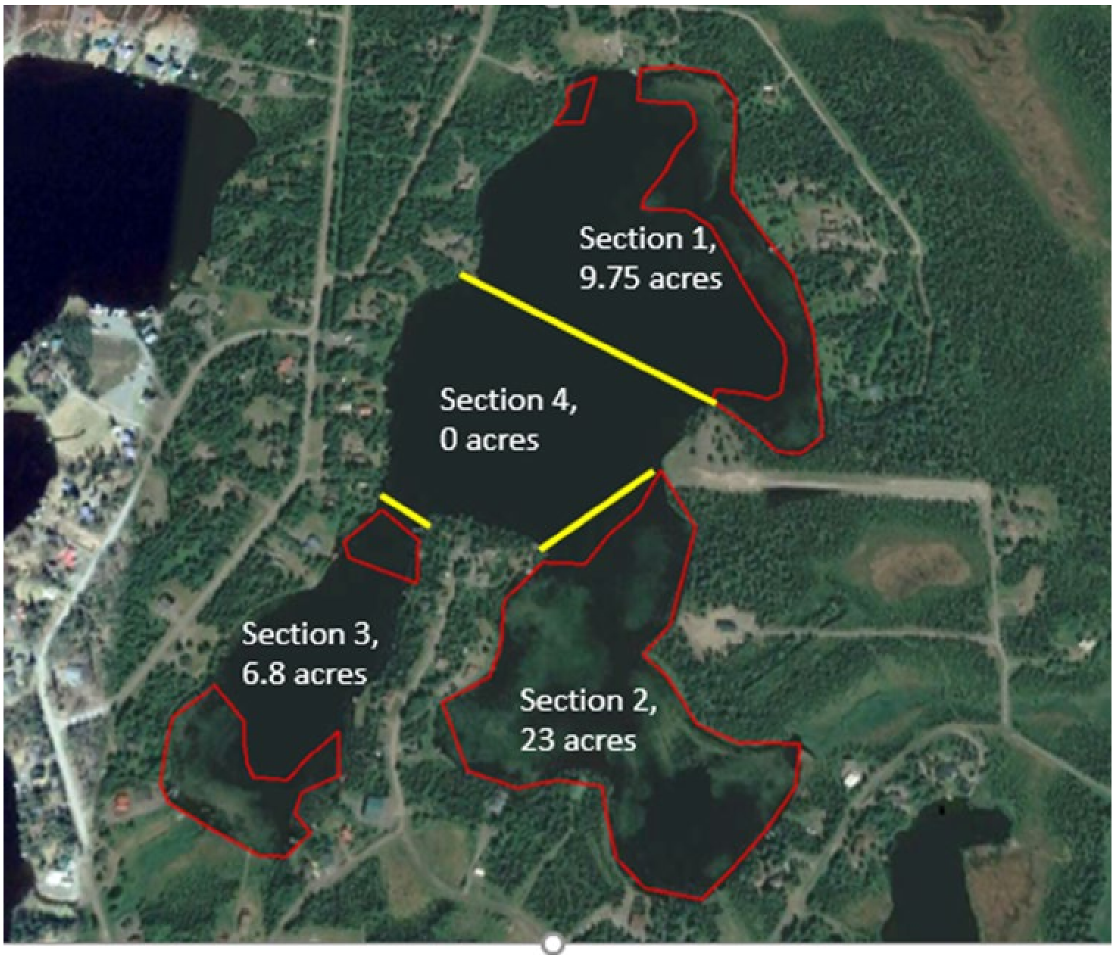
Another source of information are interviews with residents or fishing guides that have personal experience in the area and who may provide insight and suggestions about fishing locations or tackle that could improve detection probability.

Objective criteria and standard methodology for using hook and line fishing as a species detection survey tool is lacking. Still, it is advisable that hook and line sampling be approached systemically to increase detection probability. One approach is to divide the waterbody into sections using natural lake features such as bays and points, then apply sampling effort in each section proportional to the amount of optimal Northern Pike habitat estimated in that section relative to the entire lake. Optimal Northern Pike habitat can be considered highly vegetated littoral waters (> 25% vegetative cover) at depths < 4 m.

Determining the total sampling effort to apply to a lake is a subjective exercise and is often a function of available resources. For very large waterbodies (> 500 acres) where a suspected Northern Pike population may be at a very low abundance, hook and line sampling may be too inefficient to consider as a viable detection tool as it may take hundreds or more hours of fishing to detect a single Northern Pike, if at all. If hook and line fishing is selected as the primary detection survey tool, a suggested guideline for the minimum amount of effort on small to medium sized lakes (20 - 500 surface acres) by a team of two anglers, is 24 hours (2 days * 2 anglers * 6 hrs. daily fishing effort per angler). At small waterbodies (< 20 acres), 12 total hours of sampling effort is suggested as the minimum effort. If resources are available, especially when compelling evidence exists that Northern Pike are likely present, more effort than these suggested minimums should be considered. Ice fishing, to be discussed later in more detail, inherently lends itself to fishing multiple lines, thus greatly increasing effort potential, but at a cost of being less mobile. Fishing multiple and/or unattended ice-fishing lines, if outside sport fishing regulations, must be done under an ADF&G Aquatic Resource Permit (Licenses & Permits, Alaska Department of Fish and Game).

To devise a systemic detection survey strategy, larger lakes should be divided into survey sections to plan how much effort is required in each lake section based on the available Northern Pike habitat. Resources are readily available for obtaining lake maps that can be used to plan lake survey section boundaries and to help estimate the optimal Northern Pike habitat available in each lake section. Resource agency-produced bathymetric maps or Google Earth imagery are good resources. SOP 6 describes how to create a bathymetric map electronically using a chart plotter and ciBioBase™ data processing services. Google Earth™ software can be useful for estimating the surface area of a lake or lake section and can be used to visually measure areas of visible vegetation beds to estimate optimal Northern Pike habitat area. Summertime Google

Earth™ imagery of clear lakes produces the best results for identifying aquatic vegetation beds and estimating its area. Google Earth™ Ruler tools (i.e., Path and Polygon) allow measurement of distance and area, respectively. Using the Polygon tool, users can use mouse controls to encircle visible vegetation beds, and area is automatically calculated. To estimate the total surface acreage of an entire waterbody, trace the shoreline using the polygon tool. An example of using Google Earth™ to estimate the areas of optimal Northern Pike habitat found in lake sections are shown in SOP4.1.



SOP4.1 Example of a Google Earth™ lake image coped into a Microsoft PowerPoint slide and divided into four survey sections by inserting yellow lines, the optimal Northern Pike habitat estimated for each section is outlined in red

In SOP4.1, the Google Earth™ Polygon tool was used to estimate area of visible optimal habitat (i.e., visible vegetation beds). Polygon encircled areas (within red borders) show the visible optimal habitat in each lake section. The total area of visible optimal Northern Pike habitat estimated for the entire lake is 39.5 acres and was calculated by summing the estimated optimal habitat of each lake section (9.75 acres +23 acres +6.8 acres +0 acres). To determine the hook and line survey effort required for each lake section, the area of optimal habitat is calculated based on its proportion of optimal habitat in the lake. For example, the area of optimal habitat estimated for Section 1 is ~9.75 acres and represents ~25% of the optimal habitat found in the entire lake (9.75 acres/39.5 acres = 0.25). The sampling effort needed for Section 1 would be

25% of all surveying effort. The total lake area is about 100 acres, and the suggested minimum total sampling effort for a lake of this size is 24 hours. Therefore, hook and line fishing effort in Section 1 would be about six hours (24hrs * 0.25 = 6 hours). Effort needed for other sections would be estimated accordingly and would sum to 24 hours. Note that in Section 4, no optimal habitat was estimated so no hook and line effort would be required. This strategy focuses fishing effort on the areas most likely to harbor Northern Pike. Despite planning how much effort to expend in each lake section and identifying optimal Northern Pike habitat, do not overlook opportunities observed in the field to fish in cover or other lake features that show promise despite being outside the previously identified areas. In some waterbodies little or no vegetation beds or other optimal Northern Pike habitat may be identifiable anywhere. In these situations, dividing the waterbody into sampling sections based on lineal shoreline or littoral areas (<4m in depth) is recommended.

Hook and Line Specimen Collections

Hook and line fishing is commonly used to collect Northern Pike specimens for movement and abundance studies and to collect biological data (length, age, stomach contents, weight, tissue, etc.) useful for assessing population structure, genetic structure, or feeding habits. Experimental designs, particularly for population abundance experiments using mark-recapture methods, generally adhere to similar strategies to distribute fishing/sampling effort as described in the detection survey methods. Specifically, experimental design for mark-recapture experiments usually employs dividing a waterbody into discrete sampling sections and systematically fishing each section. Fishing effort will commonly be weighted during sampling to concentrate effort in areas experiencing higher catch rates while ensuring all areas receive some level of sampling effort (Albert and Tyers 2018; Bradley et al. 2022b, Wuttig 2015). This distinguishes hook and line fishing strategies for specimen collections from detection surveys in that effort is applied proportional to the optimal habitat in each section during detection surveys versus being focused to areas where catch rates are highest when collecting specimens for abundance estimates or population structure assessments.

Open Water Fishing Methods

Prior to starting a hook and line detection survey (or specimen collection effort), it may be beneficial to first conduct an onsite visual assessment of the waterbody by slowly boating around its perimeter and visible weed beds. Visual assessments help identify areas of optimal Northern Pike habitat or other physical features that may attract Northern Pike (tributary mouths, woody debris, concentrations of prey). Sometimes visual assessments result in the direct observations of Northern Pike, particularly in clear waters with moderate to high Northern Pike abundances (Massengill, personal observation 20 April, 2021). In highly stained or turbid waters, a visual assessment may be less useful for observing Northern Pike or submerged vegetation beds, Still, visual assessments can aid in identifying exposed vegetation beds, woody debris, and shoreline slopes that provide potential structure for targeting fishing effort. While hook and line fishing, an electronic fathometer is useful to focus fishing in the littoral areas, especially where water clarity is poor.

Northern Pike are known to be indiscriminate feeders and are generally considered easier to catch with hook and line gear relative to many other freshwater fish. Still, during sub-optimal fishing conditions (i.e., stormy weather, high water events, periods of poor water quality, or when the Northern Pike population is at very low abundance), hook and line anglers may struggle to detect Northern Pike regardless of effort.

A variety of terminal tackle should be available to samplers surveying for Northern Pike using hook and line. Northern Pike often hold in heavy vegetation, so weedless lures or single or double hook lures are best when fishing these areas to reduce snagging. Standard terminal tackle may include flashy/noisy topwater lures like buzz baits, weedless and floating frog and mice lures, weedless spoons, bass-style single-hook bladed spinners with skirts, and various soft-bodied rubber worms and fish baits attached to a jig head. When fishing alongside defined weed edges or in areas with little vegetated cover, lures with multiple treble hooks (i.e., Rapalas baits, diving plugs, etc.) may be productive; however, be aware that treble-hooked lures can easily cause injury to non-target fish. Examples of common terminal tackle for Northern Pike for open-water fishing are shown in SOP4.2.

Bladed spinner bait with skirting

Buzz bait

Mepps™ Aglia spinner

Top water mouse lure

Top water frog lure

Top water popper

Spoon (Daredevil)

Red eye weedless spoon

Weedless spoon (Johnson silver minnow)

Weedless jig with skirt

Rubber worm “Texas Rig”

Rubber bait/spinner as a weedless hook set-up

SOP4.2. Examples of terminal tackle for Northern Pike open water fishing

Lure and hook sizes for Northern Pike can be scaled up compared to sizes typically fished for rainbow trout and similar resident species. Larger lure sizes are less likely to attract bites from non-Northern Pike fish. If bycatch of other fish species is of high concern, anglers may find that lures longer than several inches in length reduces bycatch rates while still being productive for Northern Pike. Most lures used for Northern Pike open water fishing will be 3-5 inches in length.

Common fishing reels come in two general designs: spinning reel and bait caster. Spinning reels are easier to learn how to use and are recommended for anglers without bait casting experience. Preferred reel sizes for Northern Pike are in the "medium to large" size range and numerically listed as sizes within the 3500-7000 range or sometimes listed in a different scale in the 35-70 range. Reels should be spooled with low-stretch monofilament line or braided line. Limiting line stretch helps with getting a good hook set as Northern Pike mouths are very hard and toothy. Weak hook penetration is probably responsible for more missed opportunities to land a hooked Northern Pike than any other cause. Keep the line drag set high on the reel. A properly set drag for Northern Pike will have enough resistance that it is difficult to pull line off the reel using one hand; however, the drag shouldn't be set so tight that it could break the fishing line before yielding. Keep all fishing hooks razor sharp, and frequently sharpen hooks with a hook file if lures are hitting rocks or gravel while fishing.

Use a stiff medium-heavy or heavy action rod when fishing for Northern Pike as heavier rods improve hook sets. Fishing rods in the seven to eight-foot length range are recommended. Anglers should be very assertive in their hook set. To get a good hook set, keep the rod tip lowered to about shoulder height (or lower) while retrieving a lure and always try and keep some tension in the line during the retrieve. A loose or slack line is more difficult to get a good hook set with. When setting the hook, quickly reel up any slack in the line while quickly swinging the rod tip upward, almost as if trying to yank the fish out of the water.

When fighting a hooked Northern Pike, it is crucial that the angler keep the rod tip pointed at an upward angle and to keep tension on the line. Failure to maintain an upward angle of the rod can lead to break offs. If a hooked fish tries to run, let it run and let the drag work to tire it out. Play the fish by reeling when it moves towards you or when you can reel it towards you without straining the fishing line. It is also important that when trying to land/net a fish to not lift any part of the fish out of the water, especially the head. Keep the fish fully in the water while fighting it. Lifting it even partially out of the water often leads to more violent shaking behavior and increases the chance of a hook pullout or the line snapping. When netting fish, it is best to try and tire the fish first then lead the fish into the net headfirst. For additional assurance of landing hooked Northern Pike, the use of swiveled steel fishing leaders will reduce the Northern Pike biting through fishing line. Leaders with breaking tests of 30 lbs. or more are recommended, both for open water and ice fishing. Leaders should be at least 12 inches long. On larger fish that are harder to control, it may be wise to tilt the lower unit of the outboard motor out of the water to avoid catching the fishing the line.

Open water angling for Northern Pike should be done from a boat whenever possible because boat fishing allows improved water access and coverage. It works best to have two or more anglers per boat as one angler is needed to operate the boat, and it is easier to net a fish with two people. While hook and line fishing, it is beneficial that anglers switch up the terminal tackle occasionally to increase the odds of discovering a specific color, size, or presentation that may appeal to a Northern Pike at that time. Northern Pike are ambush hunters and are attracted primarily by movement and water disturbances and will often curiously follow a lure before deciding to strike. Lure speed retrieval and depth can be important, so varying these may help trigger a strike. Often a Northern Pike will be lying in ambush and will burst towards a lure creating a surface swirl. Sometimes a Northern Pike may just follow a lure and create a trailing surface wake. Polarized sunglasses help with seeing a Northern Pike that may be holding in cover or following a lure. While fishing, anglers should be stealthy and try and keep loud noises to a minimum as some Northern Pike can spook easily. Ease the boat up to a new fishing spot. If using an anchor, lower it gently into the water, and try casting towards potential Northern Pike cover from a good distance away.

The use of scents and bait (i.e., herring head) or tipping the hook with a small attractor (i.e., rubber tail) or piece of bait can encourage a strike from an otherwise reluctant Northern Pike. If a missed strike is observed, it should be followed with repeated casts as often a Northern Pike will take a lure after passing or missing it several times. It is not uncommon for a Northern Pike to follow a retrieved lure to the boat and fail to strike. When this occurs, sometimes a strike can be elicited if the angler thrusts the rod below the waterline, about foot, and sweeps the rod tip in a figure eight pattern repeatedly. When doing a figure eight pattern there should only be a foot or two of fishing line between the rod tip and lure. The use of polarized sunglasses is very helpful for spot trailing fish or observing boat-side fish.

Successful boat angling for Northern Pike often involves anglers positioning themselves with the boat just outside of a weed bed or other structure (i.e., submerged tree, beaver cache, creek mouth), and casting towards shore or across the structure or tributary mouth then retrieving the lure back towards them. If fishing near weed beds be sure to work the lure alongside or through the beds. Lure retrieval speed for bladed lures (i.e., spinners and buzz baits) should be moderate to fast while floating lures like imitation mice, frogs or poppers can be slowly retrieved and occasionally paused and twitched to mimic a struggling animal. Sinking jig heads tipped with rubber worms, twister tails or rubber bait fish imitations can be retrieved slowly and twitched and jerked to illicit strike responses. If jigs are rigged to be weedless (i.e., Texas-Rig), that can be a good choice when fishing in very heavy vegetation. Most Northern Pike fishing in Southcentral Alaska occurs in waters <10 feet in depth. Northern Pike can often be seen in waters less than a foot deep or hiding in such dense vegetation it would be difficult to get a boat through it, hence the need for weedless terminal tackle in these situations.

Ice Fishing Methods

Previously described methods for calculating hook and line effort needed for a detection survey is the same when ice fishing. The waterbody is divided into sampling sections, and fising effort is calculated according to the available optimal habitat in each section.

Some advantages to ice-fishing are that this method allows very precise targeted fishing at a specific location, the ability to fish multiple lines at once, the option to fish unattended lines (if permitted) and is a method for fishing where boat access may not be an option. Ice fishing can also occur during known periods of high Northern Pike feeding activity (i.e., early winter new ice, late-winter pre-spawn). Cons to ice fishing may include challenging weather conditions, potential need for specialized equipment (i.e., ice-auger, snowmachine or sled to haul equipment, tip-up fishing rigs, a heat source and shelter for fishing in severe cold, etc.,) and the inability to rapidly fish anywhere as opposed to open water fishing from a mobile boat.

Often Northern Pike residing in large lakes during the summer can be found in similar locations during the hard water season (Massengill 2017a, Rutz et al. 2020b). However, many standing aquatic plant beds that provide cover to Northern Pike during open water may senesce and collapse during the fall, so Northern Pike can become widely distributed or concentrated in other available cover. In some drainages, Northern Pike migrate during fall or early winter to overwintering areas with adequate oxygen (Albert and Tyers 2020, Taube and Lubinski 1996). Often, dissolved oxygen levels drop precipitously during late winter, especially in the deeper parts of eutrophic lakes and ponds, so fishing shallower depths (< 2 meters) can sometimes be more productive. If dissolved oxygen concentrations in late winter are a concern, a dissolved oxygen meter can be a useful tool to identify well-oxygenated zones to focus fishing effort on. Good places to target Northern Pike with ice fishing gear are along the edges of weed beds and along shoreline slopes in the water depths of 2–10-feet below the ice. Sometimes deeper river and lake channels with some water flow through will attract large numbers of overwintering Northern Pike that are seeking refuge from low water quality in shallower areas lacking flow.

A very effective method for Northern Pike ice-fishing is the use of a tip-up. A tip-up describes a variety of hook and line ice fishing devices that are designed to passively fish and raise a flag that signals the angler when a fish has taken the bait or lure. Most tip-up fishers use bait, like a dead herring, that is hooked to a “quick-strike” rig. A quick-strike rig is usually two treble hooks attached by steel leaders, sometime with a flashing blade added to increase visual appeal (SOP4.3).

SOP4.3 Example of a dead bait fish attached to a Quick-Strike rig that uses a pair of treble hooks attached by leader material

Two treble hooks increase the likelihood of the fish being hooked before completely swallowing or spitting out the bait and allows the angler to set the hook soon after a strike. A good description for a quick-strike rig is available online: https://www.in-fisherman.com/editorial/quick-strike-rig-Northern_Pike/155877. Jigging sticks and ice fishing rods (short fishing rod with reel) can also be effective hook and line ice fishing devices for Northern Pike. Ice fishing rods and jigging sticks are intended to be fished by hand or held in a rod holder near the ice fishing hole, as opposed to a tip up which straddles the ice fishing hole and does not require the angler to hold it or place it in holder. Pictures of various ice fishing rods and tip ups are shown in SOP4.4.

One notable difference when fishing with a tip up or jigging stick compared to using an ice fishing rod is that, when fishing a tip up or jigging stick, the fishing line is usually retrieved by hand. Fishing with an ice fishing rod is different because a reel is used to retrieve the line and the rod provides tension to help tire and direct the fish. Ice fishing line for Northern Pike should be braided or low-stretch monofilament. Heavier test line (~40 lb. test) is advised for ice fishing because more force may be required to direct a fish into an ice hole for recovery or to retrieve a fish that has entangled in vegetation below the ice. Waxed braided line helps to prevent the line from freezing in clumps or sticking to the ice.

Jigging Rapala™

Northland™ airplane jig

Doctor spoon™

Jigging head with blade

Bay de Noc™ Swedish pimple

Rapala™ rattlin rap lure

SOP4.4. Examples of terminal tackle for Northern Pike ice fishing. Bait is typically added

Ice fishing terminal tackle/bait should be fished about halfway in the water column. Fishing too deep may obscure the bait/lure from a sight-hunting Northern Pike, particularly if standing vegetation is dense lower in the water column. When fishing with an ice fishing rod or jigging stick, strikes can be encouraged by alternately jigging the bait/lure, then letting it remains still for a short period of time. Northern Pike are mostly daylight and crepuscular feeders and feeding action can be good anytime there is visible light.

Large ice holes allow for better ease in bringing a hooked fish through the ice. For this reason, an 8-inch or larger auger drill size is recommended. When fishing multiple tip ups, which can greatly increase catch probability, try to spread them out over a large area along weed edges or other features like the top edges of drop-offs where Northern Pike may be hunting.

SOP4.4. Various ice fishing devices from top to bottom: 1) regular tip up, 2) tip up with freeze protection shield, 3) ice fishing rod and reel combo, and 4) ice fishing jigging stick

Generally, terminal tackle for ice fishing is similar and sometimes identical to tackle used for open water fishing. Recommended terminal tackle for ice fishing includes lead-head jigs, airplane jig, imitation fish jigging lures (i.e., jigging Rapala™ or Rattle Rap), heavy spoons quick-strike rigs. Bait should be used in conjunction with all ice-fishing terminal tackle. A description of ice fishing gear and constructing DIY jigging rods is: https://files.dnr.state.mn.us/education_safety/education/minnaqua/icefishing/jigglesticks.pdf

SOP 5: Visual Survey for Early Detection

Gear Recommendation

Polarized sunglasses
Shallow drafting watercraft (for silent movement through the water)
  Rafts, canoes, or single-person pack rafts
  Paddles or push-pulls
GPS
Lake Map
Data Sheet

Optional:
Underwater or weatherproof camera
Underwater drone with camera
Dry suit
Snorkel/ fins
Underwater flashlight

Methods

Boat Surveys

Northern Pike are generally observed in the water in shallow, weedy, areas. Timing the survey to take place on calm sunny days will provide the best conditions for visually spotting Northern Pike. Before the survey, become familiar with the waterbody on Google Earth if a bathymetric map of the waterbody is unavailable. Use Google Earth to map the survey route or identify the location zones of the waterbody that should be targeted for the survey. Again, visual surveys should focus on the areas Northern Pike would be expected to be in (shallow, weedy littoral zones or weedy lake inlets and outlets). At a minimum, the survey should cover at least two passes along the shoreline. If the relief of the lake is gradual, or the lake is very shallow throughout, consider adding perpendicular transects in addition to the shoreline in all areas for where the bottom can be seen. It is also recommended to thoroughly survey by grid patterns any shallow weed beds and warm shallow bays. Shallow waters are typically considered less than 2 m, and polarized sunglass lenses are usually able to see to this depth in clear waters.

Slowly motoring along the survey route is fine. However, visual surveys may be best conducted slowly from a canoe, raft or kayak. The watercraft chosen will depend on the size and access of the survey lake. If a suspected Northern Pike is seen, the surveyor should try and photograph it. Distinguishing photographs of both the Northern Pike and the lake would provide an ideal record of the confirmation.

Longnose Sucker

Burbot

Alaska Blackfish

Threespine Stickleback

SOP5.1. Alaska blackfish and threespine stickleback images to show identification distinction from Northern Pike

It is essential that the surveyor is familiar with distinguishing identification characters of Northern Pike, such as their elongate body shape, snout, and rear dorsal fin, and color pattern. Having a “search image” or “mental image” in mind before beginning the survey can be helpful. Sometimes new observers mistake stickleback or Alaska blackfish for young-of-the year (YOY) Northern Pike. YOY Northern Pike will never be observed at the abundances that sticklebacks typically are, and because of their rapid growth rate, juvenile Northern Pike are only the size for stickleback for a matter of weeks after they hatch. Larger individuals of Alaska blackfish may be more difficult to distinguish from YOY Northern Pike at first glance, but blackfish are typically darker in coloration, have a blunter snout and a homocercal (rounded) caudal fin, whereas Northern Pike have heterocercal (lobed) caudal fin.

Specifically, Northern Pike can be differentiated from other species by these characteristics:

- Color: Northern Pike have dark olive green to greenish-brown back and sides as a background to either pale yellow to white spotting and / or horizonal striations or a combination of both.
- Shape: Northern Pike will have a long shape profile, with a pointed tapered head. The head is triangular and almost flat with eyes located closer to the top.
- Fin Placement: Somewhat unique to Northern Pike compared other species in Southcentral, their dorsal fin is positioned far aft on the body near the tail and somewhat large. It is directly opposed under the body by the anal fin in the same size and position.

- Location: When conducting a visual survey in daylight, Northern Pike will most likely be encountered in or very near vegetation in shallow water or close to shore.
- Behavior: Often Northern Pike will lay completely still or very slowly swim away when you encounter them up close. They will often be solitary unless encountered during spring spawning. Many other species encountered in the shallows during daylight surveys (e.g., long nose suckers, rainbows) will be in small schools and will dart away quickly and erratically.

Snorkel Surveys

Another option for visual surveys is to incorporate snorkeling to get a better under water view. If chosen as the visual survey method, surveyors should work in groups of at least two. Because Alaska's waters are usually cold, consider using dry suits for the survey. If the waterbody is small, the shoreline and/ or transects can be swam in a similar fashion to the boat surveys. However, if it is a larger lake, target the shallow weedy bays, inlets, and outlets for snorkeling and swim transects. Under water cameras are highly recommended to take photo evidence of observations. Sunlit conditions are ideal, again, for snorkeling. However, late evening snorkel surveys with a dive light might also yield better opportunity to visually find a Northern Pike.

Considerations:

- Visual surveys cause zero impact to the waterbody, residents, birds, and other native fish.
- It is low cost, typically only requiring staff time and transportation to the site.
- Consideration and planning must be given to the size and scale of the visual survey on the waterbody. This can have many contributing factors from size and depth of the waterbody, size of littoral zone/Northern Pike habitat, and how much effort can be provided to the survey (i.e., whether it should be repeated, and at what interval during the open water period).
- Timing visual surveys soon after ice-out may yield greater chances of observing Northern Pike due to their movements during spawning.
- Very early morning is also best as Northern Pike are most active at this time. Avoid surveys during the middle of the afternoon (typically the hottest part of the day), or after a period of rain that increases turbidity. Under optimal site conditions, middle of the day surveys can still be useful, especially in early spring as the Northern Pike will likely be stationary and potentially more easily encountered.
- As feasible, try to observe as far up into the emergent vegetation to shore as possible.
- Visual surveys are the least aggressive of the survey tools described in this plan. The absence of Northern Pike observations during the survey does not mean there are no Northern Pike. Rather, it would be an option to opportunistically confirm Northern Pike presence if an observation was made. Because of this, visual surveys are ideal for incorporating alongside other survey methods like gillnetting, especially if crews are on site while the gillnets are deployed, or while mapping for bathymetric surveys, or while conducting elodea surveys. This survey method can be opportunistically implemented by various partners that are near or on a waterbody of interest, perhaps with different objectives, but can look and report to the plan partners upon return from the field.
- Visual surveys can allow observations of recreational use, float plane traffic, waterfowl, etc. in a waterbody; all data that can be helpful in evaluating how best to proceed with follow-up detection methods.

SOP 6: Bathymetric Mapping of Northern Pike Waters

Gear Recommendations

Biobase™ Subscription
Lowrance Charter Plotter
Transducer
Transducer Mount
Mounting Hardware
Hull Sealant
Pelican Case
12V Battery
Trickle-style Battery Charger
Eyelet-style Wire Connectors
Ruler
10-mm Nut Driver
Rite in the Rain Book
16 or 32 GBSD or micro-SD card
Fuse (5 amp)

Methods

Equipment Set-Up

The following describes the equipment and set up needed to begin bathymetric mapping of lakes.

Biobase™ subscription: BioBase - Plans (biobasemaps.com)

Plan: *Habitat+* which for Government agencies, NGO's, and academic organization; currently free
based on usage and data storage.

Lowrance Charter/Fish finder and transducer:

The Biobase™ mapping program requires the use of Lowrance brand-specific chart plotters. Current recommendations are HDS Live lineup (HDS-7 LIVE with Active Imaging 3-in-1 | Lowrance USA) with transducer. Screen size is up to operator, with consideration given to vessel (i.e., canoe vs. large boat). Larger screens (such as in the HDS-9 LIVE model) accommodates a split screen feature.

Transducer mount:

The operator can decide on preference for mounting the transducer to their boat. The transducer typically comes with instructions and a plate mount. The user needs to supply the mounting hardware and sealant to seal the hull. Generally, there will only be one vessel used for mapping, or each vessel would need its own transducer. Also, the transducers tend to be very sensitive to scratches or impact damage from typical field work on a work vessel. An alternative is to use a modular mount. This allows the transducer to be used on multiple boats and can also help protect it from damage when not in use.

SOP 6.1. Transducer mounted to a boat

SOP 6.2. Transducer mounted to a canoe

Pelican Case:

This can be set up to the operator's preference. It is ideal to have the mapping unit self-contained and protected from the elements. A medium-sized Pelican-style hard case works well to have the chart plotter attached to the base of the case with the mounting bracket that is supplied with the unit. The case should also contain a 12-volt DC battery of appropriate size to power the chart plotter for a minimum of 8 hours run time based on the chart plotter amperage usage. An ideal battery is: Duracell Ultra 12V 20AH Deep Cycle AGM SLA Battery with M5 Insert Terminals - SLADC12-20C or Duracell Ultra 12V 35AH General Purpose AGM SLA Battery with M6 Insert Terminals - SLAA12-35C) for longer-duration use. It is best to have a battery with threaded bolt insert terminals to allow the chart plotter power supply cables to be secured to by eyelet-style wire connectors and a secure power supply to the chart plotter. Trickle style battery chargers specific to deep cycle batteries (12V 1.25 Amp Charger - DBT021-0128) are recommended to recharge deep cycle batteries from a regular 120V outlet or generator if remote.

SOP 6.3. Example of the pelican case set up for the mapping unit

SOP 6.4. Recommended battery charger

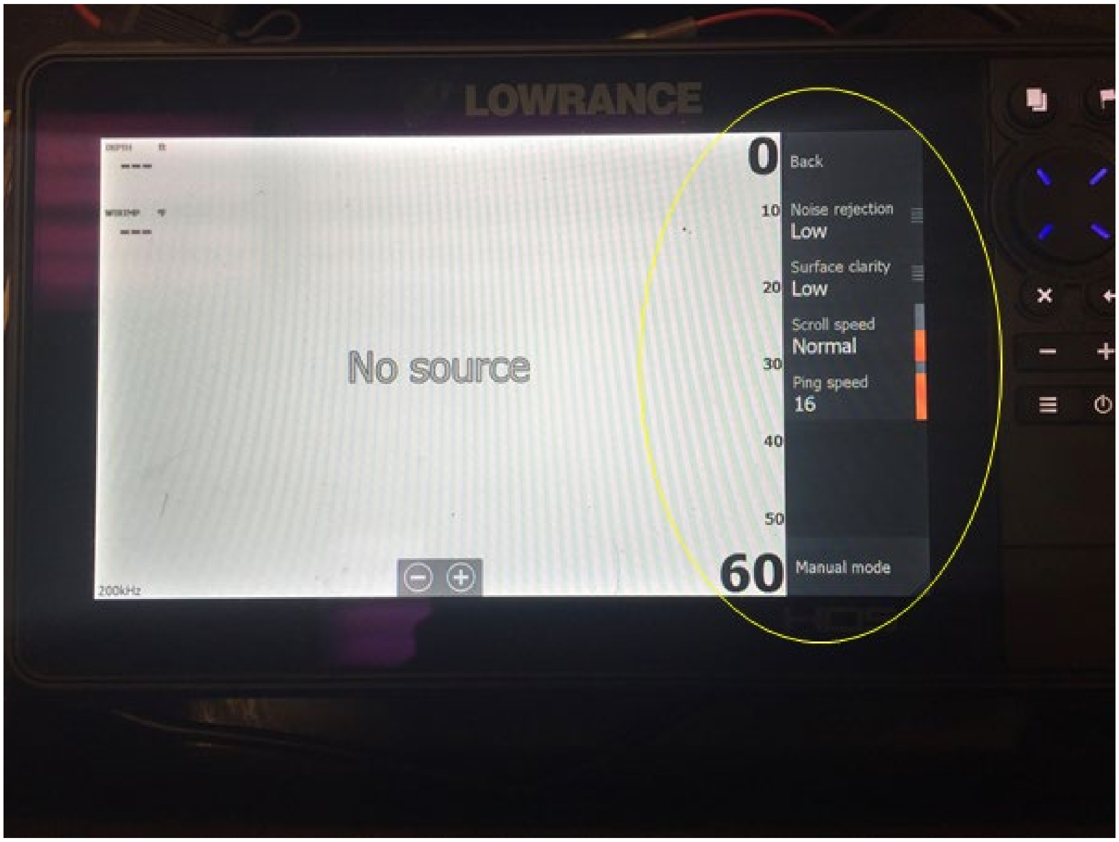
Tools:

- Measuring device such as a small ruler to measure the distance the transducer is placed below the waterline to record the depth offset to later input in the Biobase™ programming.
- Small nut driver sized to the threaded bolt terminal inserts for tightening the wire eyelet leads to the battery terminals, typically 10mm.
- Rite in the Rain logbook and pencils to record and make notes of each mapping "trip" (see methods section below).
- SD or micro-SD cards, whichever is appropriate for your chart plotter (at least 2). Biobase™ suggests using a card size of 32 GB, and no larger.
- Spare fuse (typically 5amp) for your power supply cable; in line fuse should also be included.

The Biobase™ program has a user manual that goes into detail on using the program, mapping protocols and settings on the chart plotter, uploading data, etc. It can be found on the Biobase™ website, BioBase - Support Resources (biobasemaps.com) or directly as a downloadable PDF at SDL LiveContent Architect. It is highly recommended that users review this document before mapping in the field and uploading data/trips into the program as it provides excellent guidance.

Data Collection

At the waterbody, make sure all equipment is running and the transducer is mounted securely and correctly based on Biobase™ guidelines. Once on the water, confirm there is a satellite connection to the chart plotter and that all parameters/settings are correct within the chart plotter's System settings. Begin mapping by circumnavigating the shoreline of the waterbody (or waterbody section) keeping the vessel as close to the contour of the shoreline as possible. Care should be taken to not strike the transducer on any underwater obstacles (rocks, sunken trees, old dock pilings) as they are very sensitive to scratches and could become unusable. To mitigate this issue, orientating the vessel direction such that the transducer is on the non-shore side of the vessel. Also, it is typical for the transducers to only be accurate and able to record data at depths greater than 2 ft. Thus, this should be your minimum starting depth contour to follow.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0
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Surface clarity
Low
Scroll speed
Normal
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16
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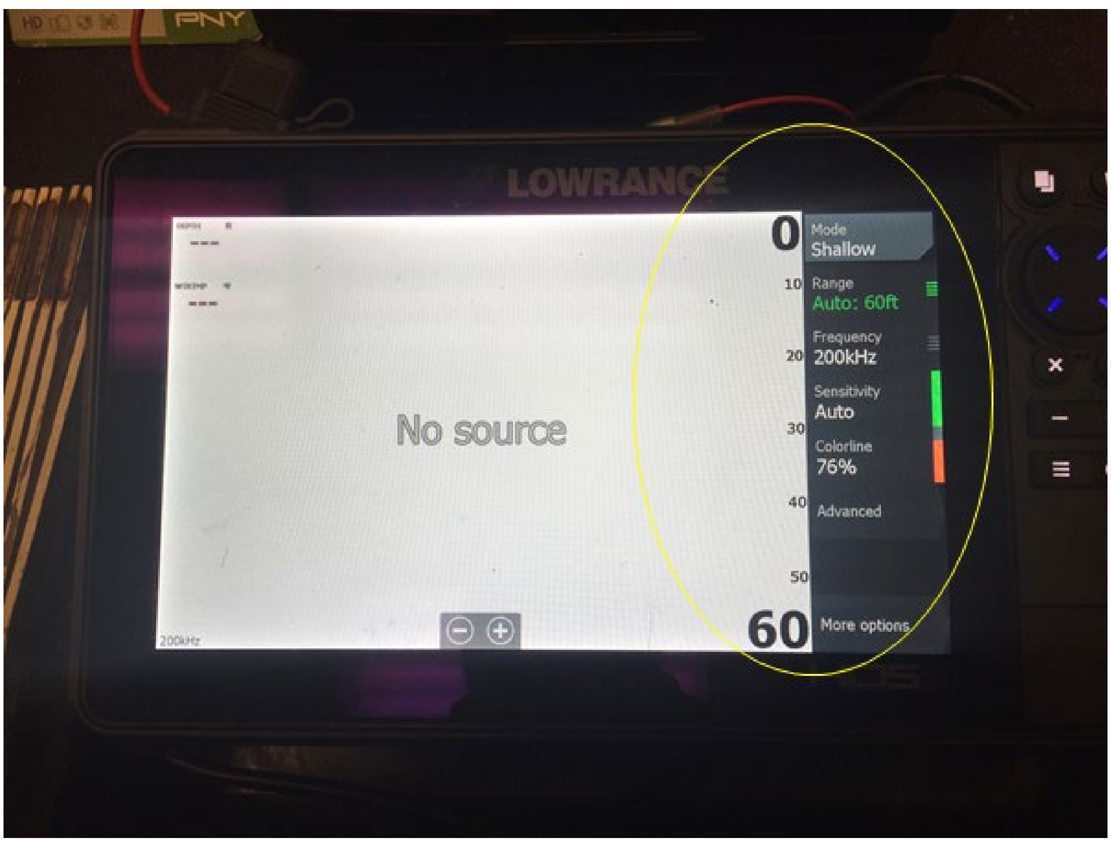
60
Manual mode
200kHz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Range
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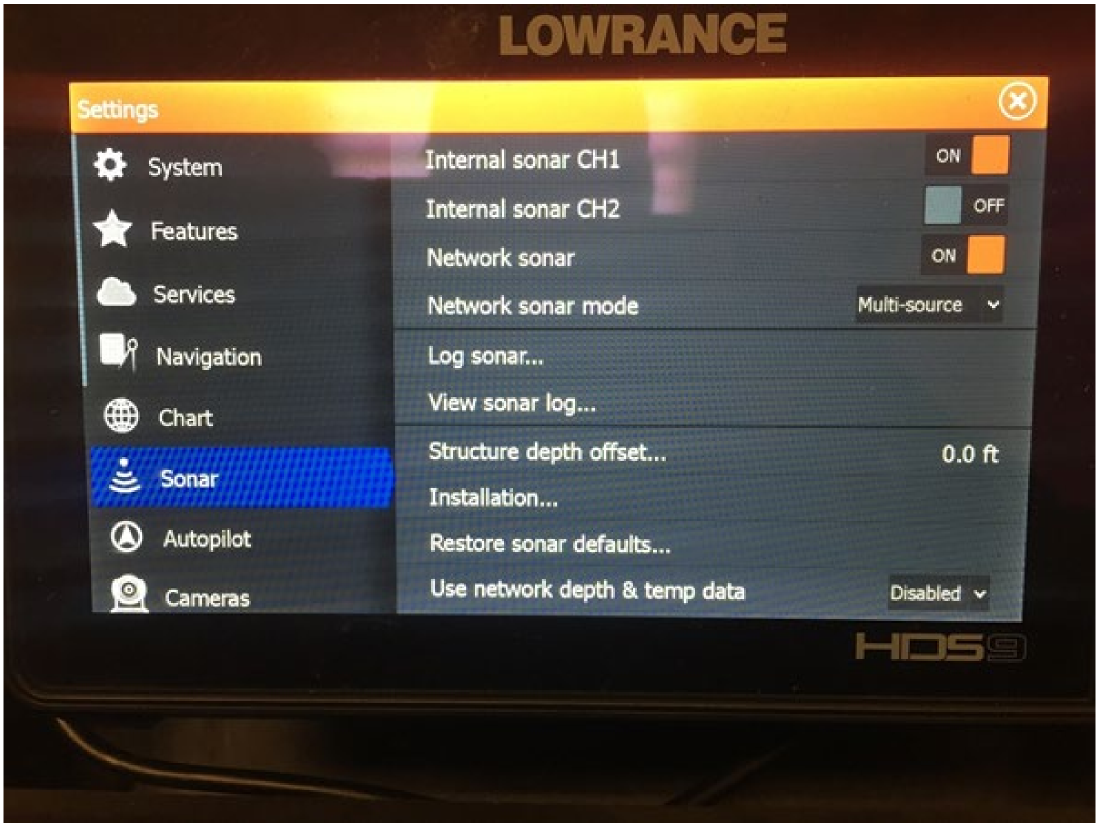
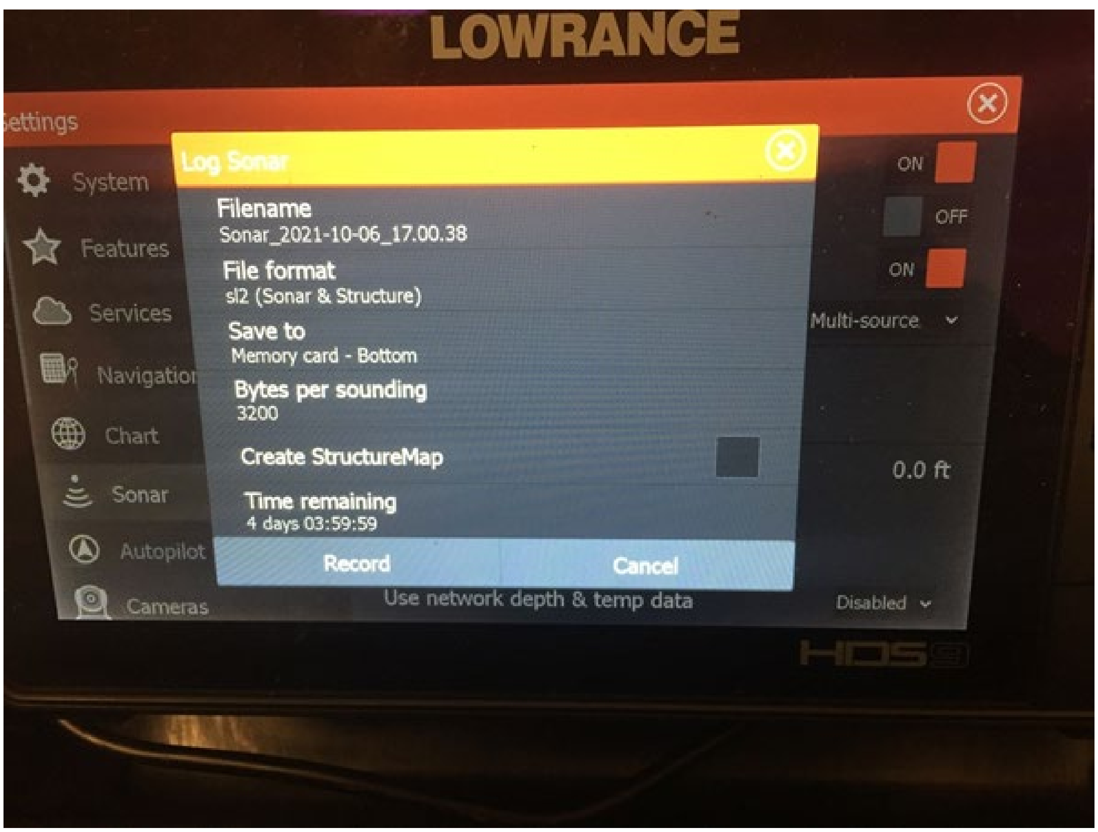
50
60
More options
200kHz

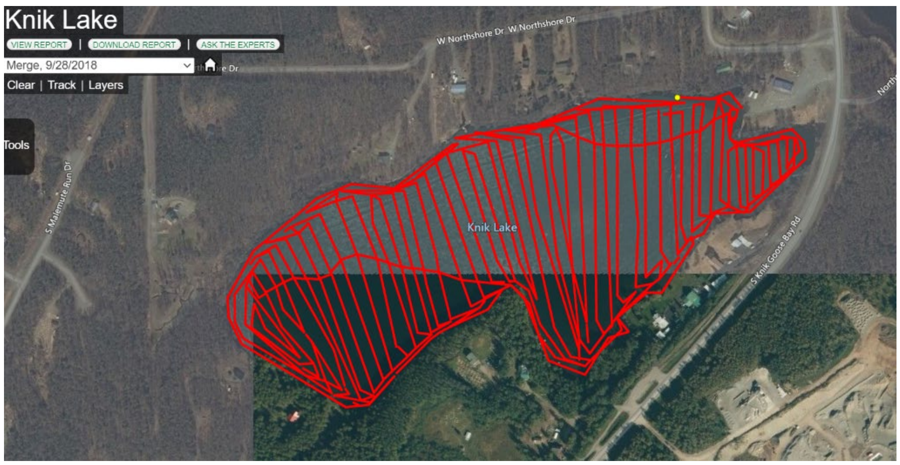




SOP6.5. Lowrance recommended screen settings

This perimeter transect should be performed at least twice around the waterbody. The second lap can be moved offshore from the first transect by about 20 to 30 meters (60-100 ft). Biobase™ advises the transects can be as far as 40 meters apart. If the shoreline is such that it drops off deep quickly, the closer distance would be advised for a more accurate bottom topography.

After the perimeter has been mapped, the operator can begin to make the transects perpendicular to the shoreline. This can be accomplished in many ways and is typically driven by the shape of the waterbody's shoreline outlined by the first two perimeter transects. These methods are discussed in detail in the Biobase™ manual referenced earlier.



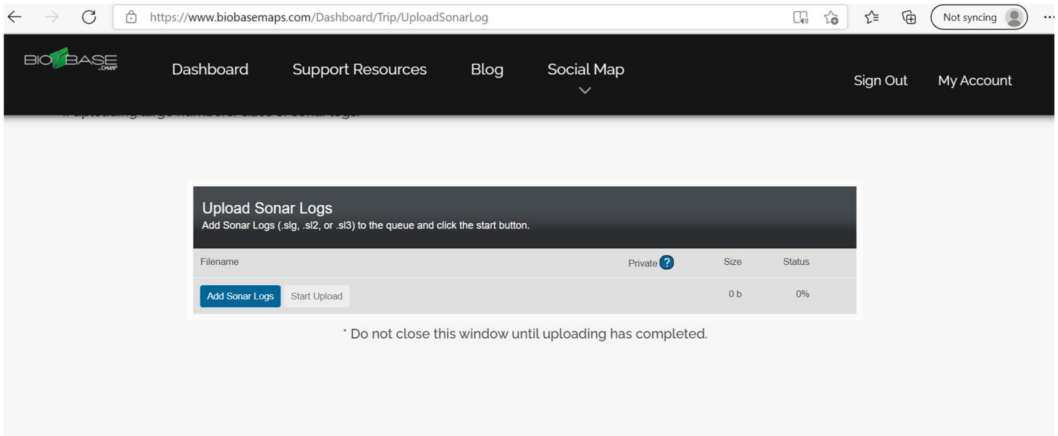
SOP6.6. Example showing optimal coverage in a lake during mapping.

Additional recommendations for accurate mapping:

- Measure the depth the transducer sits below the waterline when the boat is level in the water, typically a distance of 8 to 12 inches. Record this information for input of an Offset later in the Biobase™ mapper upload.
- Map with the 'tracks feature' enabled on the chart plotter. Similar to any GPS, this will leave a visual line of all the trails and transect driven on the lake.
- Keep the speed of the vessel under 5 mph.
- Keep the "ping rate" of the chart plotter at a minimum of 15 pings per second.
- Keep the file/trip size to around 150 MB each. Name each trip by the lake name and date of mapping, section number, and ascending trip number for that section. Example: NANCY LK 6-24-2021-S1-1
- Keep the distance between transects to around 100 ft. Biobase™ suggests 40 meters.
- Try to overlap at least one shoreline circumnavigated transect with each turn of the perpendicular transects.
- Pick a fixed object (i.e. single tree, house, dock, etc.) and aim the vessel straight at it to produce straight transect lines, then pick a similar object on the opposite shore. Repeat this over and over, moving over roughly 100ft down the waterbody shore and picking a new shoreline object for the next "lap" or transect.
- Check the transducer and make sure it is level with the bottom of the boat and clear any weeds if the vessel passes through heavy vegetation or accidently strikes an underwater object.

- Again, the Biobase™ website, YouTube channel, and User Manual is a wealth of information on executing the mapping of various waterbody types and scenarios.
- After completing the transect to fully cover the waterbody, pan out and review the tracks on the GPS and see if any holes or voids exist in the transects. If so, motor over to cover those before leaving the lake.

Upon returning to the office, access the Biobase™ website portal and upload the raw data for processing. This process is detailed on the Biobase™ website BioBase - Solutions - GIS Services (biobasemaps.com), and a customer service representative (1-651-204-0640) is always available to help with this process.



SOP6.6. Screen Shot of Data Upload Portal.

Considerations:

When evaluating a waterbody to be mapped several criteria should be considered:

- Is there legal public access? If not, can access be granted from the private landowner(s)?
- Is the location remote (fly-in) or road accessible? Boat launch? Are there any motor restrictions? Is it a large lake which will require several days of mapping or small enough to be accomplished in a day? This information will likely influence the size of the mapping equipment needed, vessel type (boat, canoe, inflatable raft), transducer setup, and number of batteries to have in the field.
- Is the waterbody affected by large seasonal water fluctuations or tidal changes? This can be compensated for later in the Biobase™ program. If possible, plan to map during the high-water period of the season to capture the maximum volume calculations. This will have implications for possible rotenone treatments. Also, vegetation growth should be considered as dense vegetation can greatly affect the accuracy and quality of the mapping in shallow water. However, this can be mitigated later in the Biobase™ program.
- Timing the mapping to minimize boat traffic is ideal as it requires the vessel to stay on transit lines and circumnavigate the shoreline closely.
- The main goal of mapping suspected or confirmed Northern Pike waters is to get exact water volume measurements for later calculations of rotenone treatments for eradication. However, depending on time of year of the mapping, the information gained on lake vegetation and bottom composition can be extremely informative for effective suppression netting efforts. Therefore, it is advised to map the waterbody before beginning any eradication or suppression project.

SOP 7: Use of Rotenone for Northern Pike Eradication

Gear Recommendations

Equipment and supplies needed for rotenone applications can be grouped into three categories: a) rotenone products, b) safety supplies including personal protective equipment (PPE), and c) rotenone application/deactivation equipment and supplies.

Rotenone Products:
Liquid or Powdered Rotenone (see USA Rotenone Registrants | Rotenone Stewardship Program (fisheries.org for current manufacturers)

Safety Products:
Chemical-Resistant Coveralls
chemical-Resistant Gloves
Full-Face Shield or Splash Goggles
Chemical-Resistant Boots
N-95 Respirator (Liquid Rotenone Applications)
Full-Face Respirator as Required by Labeling (Powdered Rotenone Applications)
Life Jackets
Eye Wash
First Aid Kit
Product Safety Data Sheet (SDS)
Two-Way Radios
Fire Extinguisher

Rotenone Application Equipment:
Rotenone Manual
Impermeable Spill Barrier
Rotenone Signage
Application Boats
Pump Systems (See Methods)
Drip Stations
Backpack Sprayers
Buoys
Water Sample Bottles
Tools
Lake Maps
Buckets

Rotenone Products

Of the available liquid rotenone formulations, CFT Legumine™ has been used extensively by ADF&G for Northern Pike eradication because of its very low content of petroleum distillates and slightly higher relative density than water (1.02) https://www.zoecon.com/sds-label which is useful for deep water applications as it can sink and infiltrate the water column. Beginning in 2022, Prenfish™ Liquid Rotenone will be used due to a supply chain reduction in CFT Legumine™ availability. Powdered rotenone products such as Prentox™ are less expensive but are potentially more hazardous to applicators because of the increased potential for inhalation risk (Ling 2003). Powdered rotenone products don't contain additives to improve emulsification or potency to fish.

The ADEC Pesticide Control Program provides a list of pesticides registered for use in Alaska. Only these products are lawful to purchase and use. The Pesticide Control Program provides an online search tool to inform which pesticides are registered: Chemical Name (kellysolutions.com). When using the search tool, the user can search by the chemical name of the product's active ingredient. For example, if a user is seeking to find which rotenone-based piscicides are registered in Alaska, the user should conduct the search by using the chemical name "rotenone". A list of the registrants who supply rotenone-based piscicides in north America is provided by the American Fisheries Society's Rotenone Stewardship Program website: USA Rotenone Registrants | Rotenone Stewardship Program (fisheries.org)

Permits Requirements

Most rotenone treatments require substantial permitting or similar authorizations from Federal, State and local governments and private land managers. All potential permits are listed here, but detailed descriptions of all Federal and State permits can be found in the Rotenone Description in the Eradication section of the plan.

Federal level

NEPA: National Environmental Policy Act

APDES: An Alaska Pollutant Discharge Elimination System (APDES) general permit authorization

ACOE: Army Corp of Engineers

State Level

ADEC PUP or GP: AK Department of Environmental Conservation Pesticide Use Permit or General Permit

ADNR LUP: AK Department of Natural Resources Land Use Permit

ADFG FHP: AK Department of Fish and Game Fish Habitat Permit

ADFG ARP: AK Department of Fish and Game Aquatic Resource Permit

BOF (Board of Fisheries)**, ADF&G Commissioner,** and **Sport Fish Division Director consent**

Local Government and Private Landowners: Rotenone project supervisors should research the landownership adjacent to and within the treatment area to determine if additional local level permitting is required from private landowners (i.e., tribal organizations or municipal governments such as boroughs and cities. Land ownership can often be determined online through interactive mapping software provided by local governments. Other options to confirm landownership is to directly contact the land managers of local government and tribal organizations. Another potential land ownership research tool is called the Alaska Mapper which is an online interactive mapping service provided by ADNR to query, research and verify land ownership and land use: Home Page - Alaska Mapper

Another important step at the local level is to determine if human drinking water sources exist near the treatment area could be impacted by the treatment. The rotenone SOP Manual (Finlayson 2018) provides guidance on different approaches used to accomplish this. If the treatment is occurring in a populated area, it is useful to determine the location and depths of private wells and locations of public drinking water sources. Publicly available well log data recorded by ADEC can be used to inform whether surface waters to be treated with rotenone have connectivity to water tables used for drinking water. ADNR hydrologists have, upon request, provided such expert analysis. Generally, the hydrologist uses water flow and well log data to determine if there is a confining subsurface layer that separates well water sources from surface waters. It is noteworthy that the EPA's 2007 registration of rotenone determined there is no drinking water concern when rotenone concentrations are $\leq$ 40ppb:

https://archive.epa.gov/pesticides/reregistration/web/pdf/rotenone_red.pdf. During 2021-22, the EPA began conducting a new registration of rotenone; therefore, drinking water standards and other rotenone treatment requirements could change.

Public Scoping Guidance

Most rotenone projects should involve a public scoping process early in the planning stage. Public scoping can serve many purposes that include, among many things, a method to identify issues of concern, a means for information-sharing and inclusion with stakeholders, and to fulfill permitting requirements. Because rotenone is a pesticide, projects involving their use are often contentious and controversial. Experience has shown that contacting private landowners and other stakeholders early in the planning process helps to develop trust which can often help build support and consensus for a project. While not every stakeholder will be supportive of a rotenone project, proper scoping can lead to a level of acceptance even by those opposing the project, especially when stakeholders feel their concerns are heard and honestly addressed. Experience gained during scoping meetings for Alaskan rotenone projects suggests successful meetings are often a result of following some simple guidelines. Some suggested guidelines are provided below:

Public Meeting Guidelines

1) Identify and contact all potential stakeholders including those who may not be supportive of the project. Often scoping involves pre-meeting stakeholder interviews and/or surveys to identify issues and concerns that can be addressed during the meeting.
2) Provide a convenient time and location (physical or virtual location) for the scoping meeting(s).
3) Advertise the scoping meeting well and describe its purpose.
4) The meeting should clearly inform stakeholders of the objectives and agenda.
5) Clearly identify the problem (i.e., invasive Northern Pike endangering native fish populations) and who is responsible for addressing the problem.
6) Utilize a meeting facilitator who can explain the meeting format and rules and enforce them during the meeting (i.e., only one person speaks at a time, adhere to meeting timeline, etc.). The facilitator can summarize the meeting objectives and agenda and can describe how and when comments can be provided during the meeting along with an explanation of what project steps are expected after the meeting.
7) Discuss the various control options considered and why rotenone treatment is the best option.
8) Discuss how native fisheries and other resources may ultimately benefit from the rotenone treatment.
9) Provide contact information for presenters and other project-related authorities and any informational handouts that are deemed useful.
10) Comments provided by stakeholders during a meeting should be recorded, preferably summarized in written format for all to see during the meeting so participants know their concern is heard.
11) Provide an opportunity for accepting written comments.
12) Be respectful and understand that everyone’s opinion is important.

Many helpful guides for successful meeting facilitation are available online, an example of such a guide is provided here: How to Facilitate a Meeting Successfully - A Baker's Dozen Tips - PlannersWeb.

Project Planning

It is imperative before considering a rotenone project for Northern Pike eradication that the distribution of the population is fully assessed along with potential pathways for population expansion or reintroduction. Various assessment/survey methods described elsewhere in this document (SOP:1, SOP:15) address how such surveys can be accomplished. Once population distribution is assessed, it then is necessary to determine if removing the population with rotenone is feasible and have a high probability for success. Small, closed lakes are relatively straightforward to treat with rotenone and affordable, but treatments become increasingly more difficult with increases in the size and complexity of the invaded habitat which also affects costs. Large, open systems where dense vegetation and extensive connectivity exists will require more effort and resources to effectively treat, and it may be unfeasible. Sometimes it is possible to use temporary fish barriers to create smaller more manageable rotenone treatment areas that can be treated incrementally over multiple years. An example of this strategy is described in Massengill 2022.

When a decision is made to conduct a rotenone treatment, multiple treatment-related tasks will need to be coordinated. These tasks are wide-ranging and include the planning for pretreatment and posttreatment environmental and biological data collection, scoping, permitting, acquiring funding, procuring equipment and supplies, organizing staff training and safety meetings, contracting support services, acquiring and maintaining pesticide applicator certifications, drafting a treatment plan, conducting bioassays, evaluating the treatment's success, and determining how to restore native fish populations. Guidance for how these tasks may be accomplished are found in the Rotenone SOP Manual (SOP Manual | Rotenone Stewardship Program (fisheries.org), the AFS training course, and by referencing ADF&G restoration reports (Massengill In Preparation, Massengill 2022, Massengill 2014a, Massengill 2014b) and archived treatment plans that are available upon request by contacting ADF&G Sport Fish Division Regional Invasive Species Coordinator in Anchorage, Alaska. However, procedures for best practices while conducting rotenone treatments are discussed below:

Methods

Applicator Safety

Wearing Personal Protective Equipment (PPE) is required whenever handling rotenone products per product labeling directions. In addition, various spill and emergency supplies should also be available whenever these products are applied or transported. Minimum PPE for rotenone handlers/applicators includes chemical-resistant coveralls, chemical-resistant gloves, a full-face shield or splash goggles, chemical-resistant boots and a respirator type listed in the product label. Waders can be substituted for coverall bottoms. Workers who handle/load containers of rotenone are also required to wear a chemical resistant splash apron. A long sleeve shirt, full pants, and socks are required to be worn underneath PPE.

It is advisable to use hearing protection when working with loud application equipment (i.e., gas-powered pumping apparatuses, outboard motors, or aircraft). Life jackets should always be worn when working on the water. Prior to wearing a respirator, OSHA requires the worker be fit tested on the respirator and to receive a health evaluation. Often the health evaluation is a medical questionnaire which may include a pulmonary function test. These services are provided by private companies such as Beacon Occupation Health and Safety Services Occupational Health and Safety Services - Beacon (beaconohss.com) although other businesses in Alaska may provide this service.

Although not inclusive, primary rotenone-related safety and emergency supplies that should be readily available during rotenone transport, handling, or application include:

1) Emergency eye wash bottle,
2) First aid kit,
3) First aid directions for rotenone exposures,
4) Spill response directions and emergency contact numbers,
5) Spill kit (i.e., shovel, absorbent material, bleach or activated charcoal to deactivate rotenone, container for placing spilled material, extra PPE and eyewash, warning signage, and a fire extinguisher).
6) Copies of safety data sheets (SDS) and product labels for each piscicide
7) Communication devices
8) Fire extinguisher

Applicator Training

Beyond providing PPE and coordinating respirator fit and medical testing, it is the responsibility of the rotenone project supervisor to ensure all applicators and handlers receive the proper hazard communication training described in the document titled 'Planning and Standard Operating Procedures for The Use of Rotenone In Fish Management', hereafter referred to as the Rotenone SOP Manual (Finlayson 2018). The Rotenone SOP Manual is considered part of the product labeling for rotenone piscicides and provides essential information for planning any rotenone treatment. The Rotenone SOP Manual is available as a free online download: SOP Manual | Rotenone Stewardship Program (fisheries.org). ADF&G has created a Microsoft PowerPoint presentation based upon the hazard communication example provided in the Rotenone SOP Manual which, this presentation, in part, satisfies hazard communication requirements. A copy of this presentation can easily be tailored to an individual project and is available in the supplemental materials with this plan or upon request by contacting the ADF&G Sport Fish Division Regional Invasive Species Coordinator in Anchorage, Alaska (907-267-2889). All workers using or handling rotenone also must be trained on the calibration, use, and cleaning of rotenone application equipment including how to clean and dispose of used rotenone containers.

Rotenone product labeling generally describes how each product can be applied and deactivated. In addition, the Rotenone SOP Manual has detailed information about equipment and methods for applying and deactivating rotenone. The Rotenone SOP Manual also addresses all aspects of rotenone treatment planning, execution, monitoring requirements and much more. It is strongly advised that anyone planning and/or supervising a rotenone project become intimately familiar with the contents of both the rotenone product labels, the Rotenone SOP Manual, and complete a 4.5-day training course titled "Planning & Executing Successful Rotenone and Antimycin Projects". Training opportunities for the course are posted by the American Fisheries Society's (AFS) Rotenone Stewardship Program website: Planning & Executing Successful Rotenone & Antimycin Projects | American Fisheries Society.

Rotenone piscicides are a Restricted Use Pesticide (RUP), in Alaska the Alaska Department of Environmental Conservation (ADEC) requires anyone purchasing, applying, or handling rotenone piscicides to be a certified pesticide applicator with an aquatic category certification. For information on becoming an Alaska pesticide applicator go to: Becoming a Certified Applicator (alaska.gov).

Rotenone Storage

Rotenone storage and transport requires adherence to product labeling and ADEC pesticide regulations. ADEC pesticide regulations are available online: Exam Study Materials (alaska.gov). In general, rotenone should be stored in a secure and locked enclosure, kept at temperatures ≥ 40F, and stored so that any spill can be contained. An exception to these storage requirements is when rotenone is temporarily stored onsite (i.e., in the field) wherein the piscicide can be stored next to the treatment waterbody atop an impermeable barrier, with the perimeter bermed, such that any spillage can only drain into the treatment waterbody. Similarly, any transferring of rotenone piscicides between containers must be done within a spill containment area. Examples of ADFG piscicide safety and spill response protocols can be found in treatment plan appendices which are available upon request by contacting the ADF&G Sport Fish Division Regional Invasive Species Coordinator in Anchorage, Alaska (907-267-2889). Rotenone storage sites require appropriate warning signage and downloadable signage templates are available through ADEC: Certified Pesticide Applicators (alaska.gov).

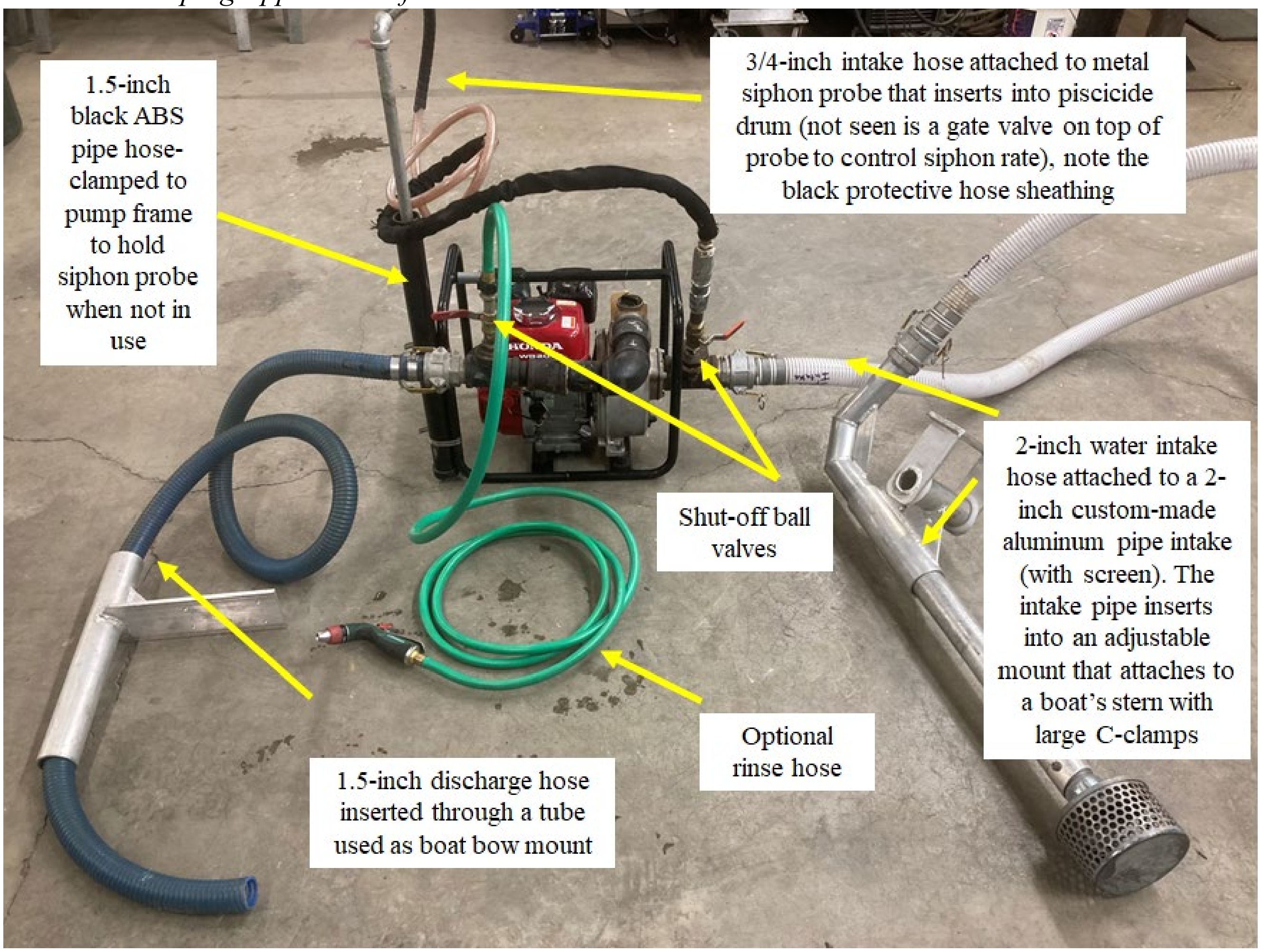
Rotenone Application

A variety of application equipment and techniques are commonly used to apply rotenone-based piscicides. The application equipment that has been used in Alaska include a) boats equipped with pumping apparatuses for lake treatments, b) portable drip stations for stream treatments, c) backpack sprayers for small wetlands, streams and spot treatments, d) mixture balls (a powdered rotenone mixture) for small springs, seeps or tributary treatments, and e) aerial (helicopter) spraying for large and/or remote wetlands or anywhere where other access modes are difficult (SOP7.1-SOP7.11).

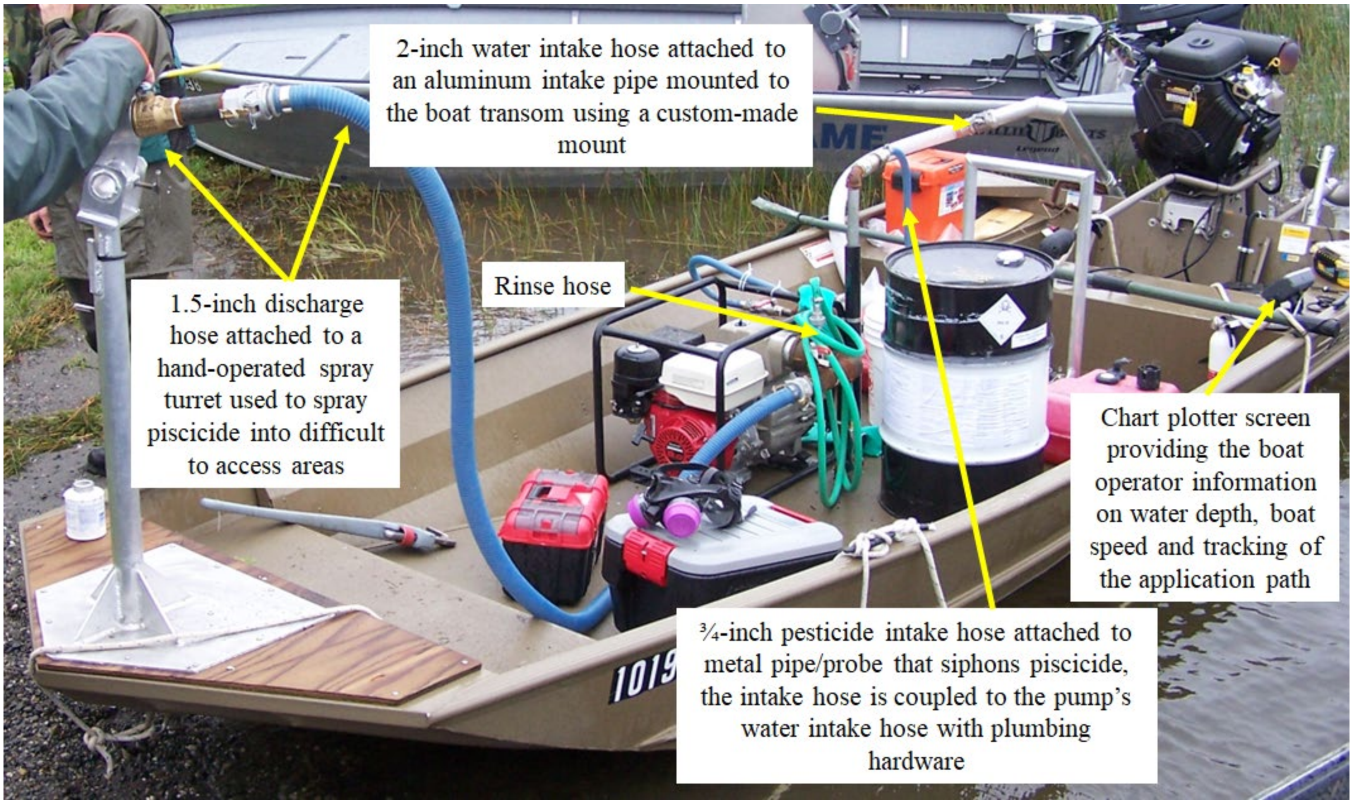
In most instances, liquid and powdered rotenone piscicides require premixing with water according to product labeling prior to application. For boat applications, the use of a gas-powered pumping apparatus usually accomplishes the premixing and delivery of the rotenone mixture. Portable, gas-powered pumps, once equipped with the proper accessories, can premix the pesticide (liquid or powdered) with site water and function as a 'semi-closed' pump system which eliminates direct handling of the piscicide by applicators.

Boats are the primary application/delivery vessels to apply piscicides to large waterbodies. The most common pumping apparatuses for Alaska boat-based applications are gas-powered pumps with 2-inch intakes that provide output pressures of 35-170 psi and have maximum discharge rates of 50-150 gpm. There are many varieties of gas-powered pumps; however, centrifugal (impellor), self-priming pumps are recommended. Gas-powered pumps are categorized by intended use. Common centrifugal pump categories include a) water pumps, b) general-purpose pumps, c) trash pumps, and d) high-pressure pumps. All these pump categories are capable of premixing and applying liquid and powdered rotenone-based piscicides. General-use and water pump categories are the most used. Trash pumps, often more expensive, provide comparative performance to water and general use pumps but are generally easier to disassemble to remove debris when clogged. Trash pumps are designed to pump suspended solids which is a consideration for treating extremely muddy or vegetated environments. High-pressure pumps (>60 psi output) with discharge rates of >100 gpm are recommended by the Rotenone SOP Manual for siphoning and applying powdered piscicides. Powdered piscicides can also be applied using pumps categorized as water, general-purpose, and trash pumps although they are likely to result in a moderately slower application rate. Detailed information about rotenone application equipment and methodology is provided in the Rotenone SOP Manual. Below are images with descriptions for the various rotenone application equipment and delivery methods used in Alaska since 2008.

Rotenone Pumping Apparatuses for Boats

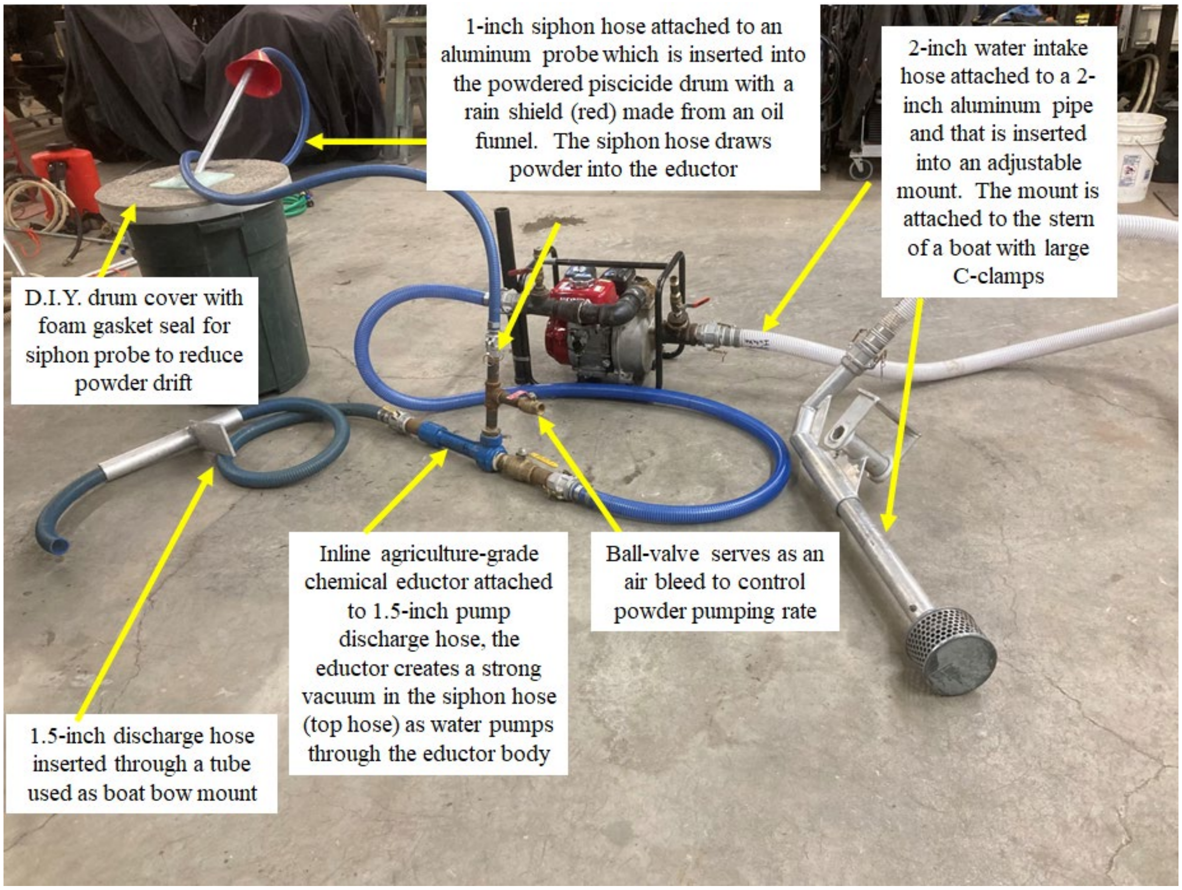


SOP7.1. Example of a gas-powered pumping apparatus for applying liquid piscicide that can be installed in an outboard boat



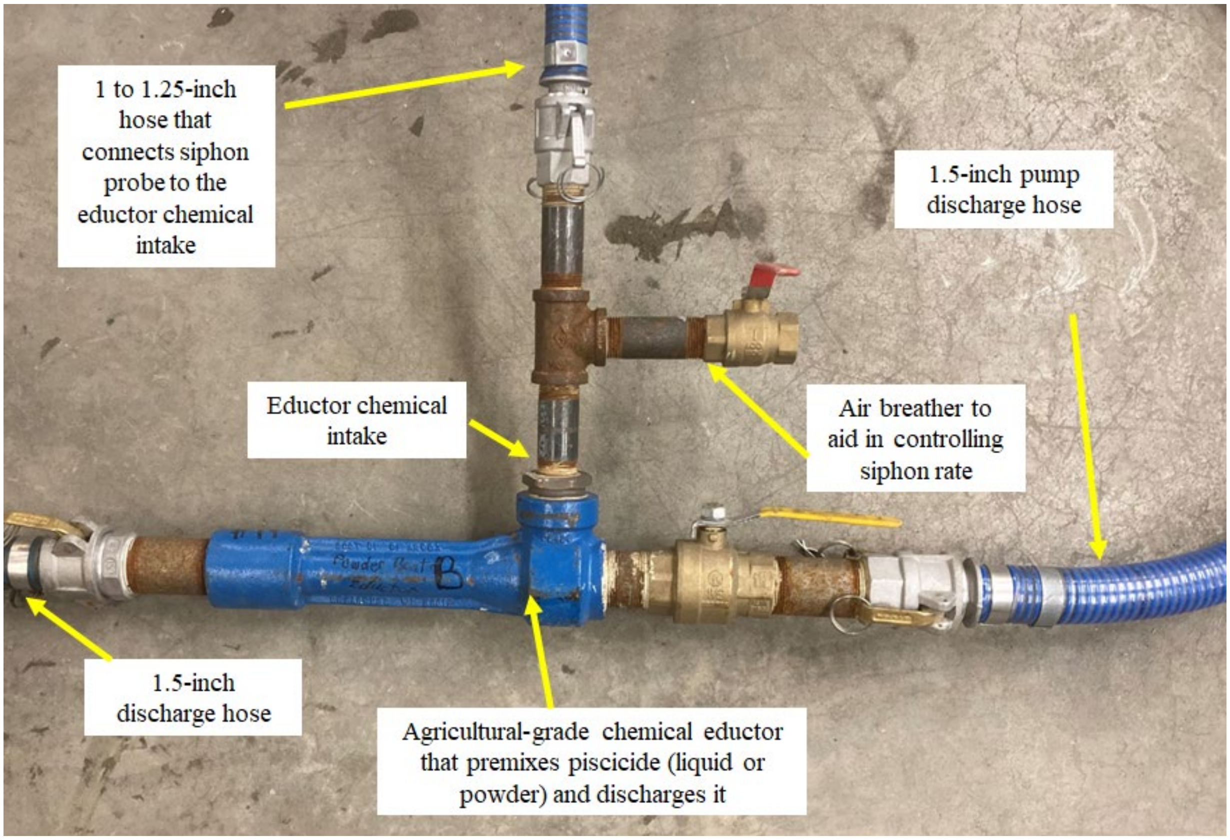
SOP7.2. Example of a boat equipped with a liquid piscicide pump system capable of spraying hard-to-access areas using a hand-operated spray turret


SOP7.3. Rotenone application boat that is custom equipped for deep water applications. Rotenone premixture is discharged from pipes that can be lowered 18-feet below the water surface using a hand-operated winch and bridle assembly. The use of weighted hoses can also be used to apply rotenone to deep water strata to promote better piscicide distribution. Underwater drag on submerged pipes or hoses require a much slower boat speed



SOP7.4. Example of a gas-powered pumping apparatus used to apply powdered when installed in an outboard boat

SOP7.5. Outboard boat applicators applying powdered piscicide by siphoning the powder from a drum with a probe (aluminum tube) that is connected by hose to an eductor that is powered by pump discharge. The eductor premixes the powder with lake water and discharges the slurry through a hose attached near the boat's bow. Three applicators are shown working, one as the boat operator, a second to control the siphon probe, and a third to break-up clumped powder by agitating the piscicide drum with a bat so it can be siphoned more easily



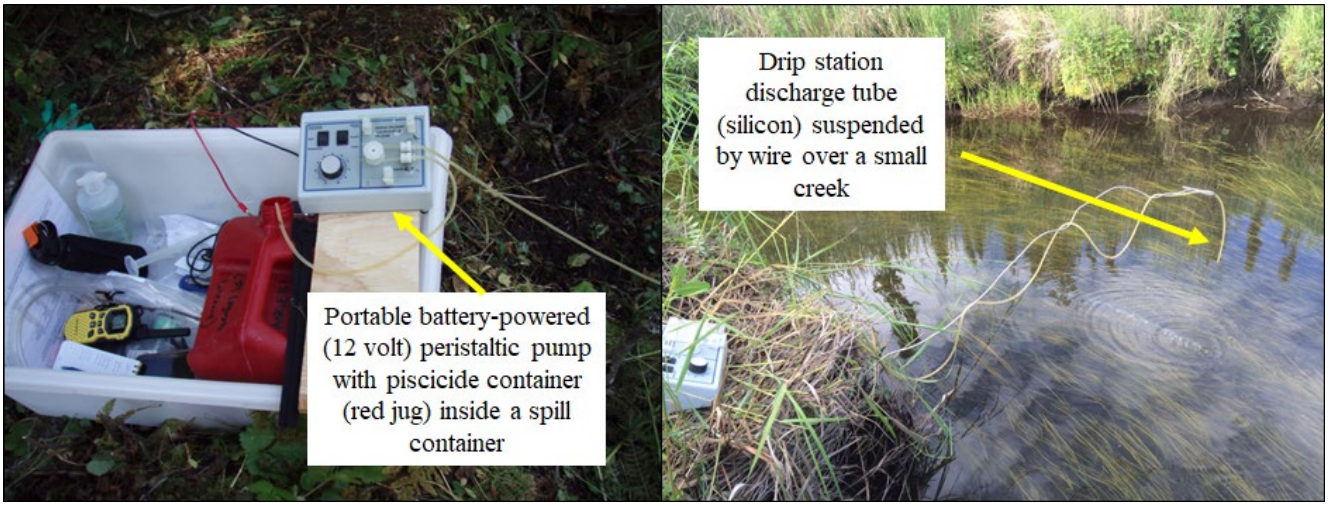
SOP7.6. Close-up of an agricultural-grade chemical eductor used to siphon powered or liquid chemicals and mix it with water using pump discharge. This eductor was purchased from Dultimeier Sales, Omaha Nebraska

SOP7.7. Battery-powered (12-volt) on -demand hand-held sprayer gun with a 45-gallon mixing tank. When applying piscicide in large areas of dense aquatic vegetation and/or shallow mucky areas, a mixing tank filled with a piscicide premixture can eliminate pump clogging issues common to gas-pump systems. A mixing tank is ideally used with a non-outboard watercraft (i.e., canoe, airboat) that reduces disturbance to lake sediments. Suspension of organic sediment can reduce rotenone's efficacy

Backpack Sprayer

SOP7.8. Backpack sprayer with a four-gallon tank with a filter located in the spray handle, this filter location allows for fast inspection and cleaning, as opposed to a filter located inside the spray tank. Backpack sprayers are useful for small wetlands and spot treatments where access by foot is preferred

Rotenone Drip Station



SOP7.9. Portable drip station for applying liquid piscicide to a stream. Drip stations typically run continuously for 4 to 8 hours and multiple drip stations, when needed, should be spaced apart a distance equal to 1-2 hours of stream travel. Sentinel fish held just upstream of each drip station will indicate the effectiveness of the treatment by the drip station upstream of it

Rotenone Mixture Ball

SOP7.10. A rotenone mixture ball placed in a spring by hand (gloved). The mixture ball consists of rotenone powder, clean sand and unflavored gelatin wrapped in cheese cloth and bundled with cotton string, creating a biodegradable package. Suspension of mixture balls midway in the water column, by tethering to a wooden stake, is recommended for areas where the mixture ball could sink into sediment

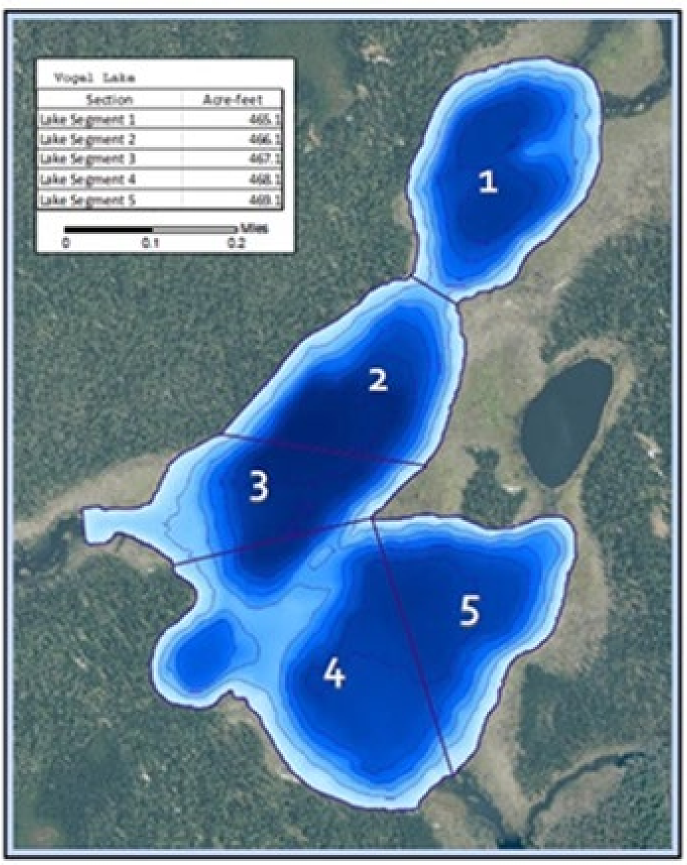
Helicopter/Aerial Sprayer

SOP7.11. Helicopter equipped for aerial spraying. To accommodate helicopter spraying, project leaders, in coordination with the pilot, should identify suitable helicopter staging areas and provide access to a clean water source for refilling the sprayer mixing tank. Aerial applications can be the only practical application method for treating large, remote wetlands. Aerial pesticide applications done in Alaska require the pilot to be an ADEC certified applicator with an aerial category license

Ensuring Proper Rotenone Mixing

Uniform mixing of piscicide in a waterbody ensures optimal results for eradication of the target species. Shallow waters (< 15 feet) can usually be adequately treated with just a near-surface piscicide application. Prop wash, wind generated waves and boat wakes can greatly help distribute the piscicide. To ensure deep water (> 15 feet) is adequately treated, it is recommended to apply the piscicide to different lake strata (i.e., 0-15 feet, > 15). Applying piscicide via submerged weighted hoses or pipes are methods used to accomplish this. Water resistance will force evenly heavily weighted hoses to flag towards the lake surface, so frequent stopping of the boat progress allows the hose to fall back down so the piscicide is delivered to the desired depth. SOP7.3 shows a deep application water boat system that utilizes well pipe that can be lowered up to 18 feet. This system keeps the pipe from flagging due to water resistance, but boat speeds must be kept low. Natural factors can also aid in mixing of the piscicide. Weak or absent lake thermoclines or treating during a thermocline turnover can be leveraged to aid in improved piscicide mixing to deep water. Strong winds following an application have demonstrated a remarkable ability to homogenize rotenone concentrations in lakes.

To distribute rotenone more evenly throughout a lake, it is helpful to partition the lake into sections using buoys. Partitioning a lake with buoys can be done just prior to treatment, but the calculations to determine how much product is required for each section should be done well in advance. For deep lake areas (>15 feet), consider estimating how much product would be required in a section by 15-foot depth strata, and apply the rotenone using deep water application methods for strata > 15 feet.

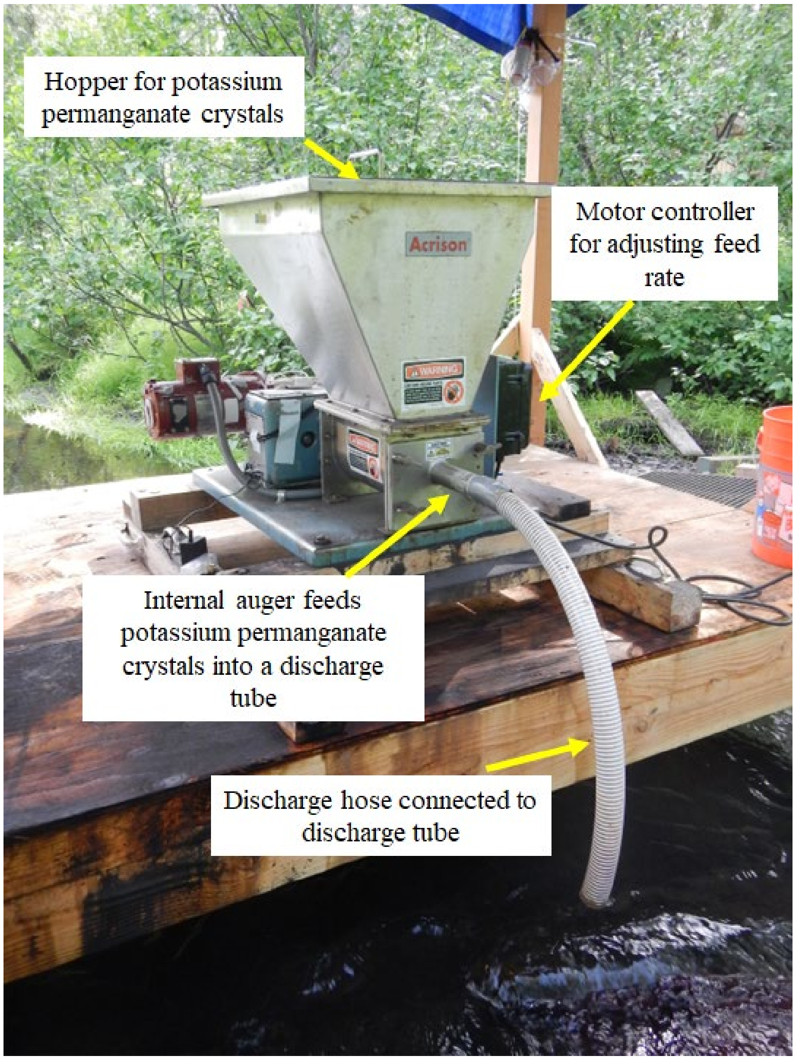


SOP7.12. Lake partitioned by volume to inform how much rotenone distribution for even coverage and mixing

Rotenone Deactivation

Rotenone deactivation is required whenever rotenone can travel outside the treatment area at a concentration ≥2.0ppb after dilution. Sufficient dilution can sometimes occur if a treated stream mixes with a larger untreated stream (see the Rotenone SOP Manual for how to calculate rotenone dilation, Finlayson 2018). Beyond dilution <2.0ppb, the only strategy to quickly deactivate rotenone is to apply potassium permanganate to rotenone-treated waters. Rotenone deactivation using potassium permanganate is primarily used to deactivate rotenone in flowing waters that could carry the rotenone outside the treatment area. Descriptions of the methods for using potassium permanganate to deactivate rotenone is described in the Rotenone SOP Manual, and its use for some rotenone projects conducted in Alaska are described in ADFG reports (Massengill 2022, Massengill 2017b) SOP7.12 show an example of a chemical feeder ADFG used to apply potassium permanganate to deactivate rotenone in small streams.

R*otenone Deactivation Station*



SOP7.12. Rotenone deactivation station for dispensing potassium permanganate into a stream to deactivate the rotenone before it can travel beyond the treatment area. This feeder, an Acrison™ Model 105 Volumetric Feeder, is powered with a portable generator (not pictured). Calculations to determine the need to deactivate and the dispensing rate of potassium permanganate are found in the Rotenone SOP Manual

Equipment Calibration

Rotenone application and deactivation equipment must be calibrated prior to use. Calibration is simply determining the rate of product application (amount applied/time). Application rates are needed to apply the piscicide uniformly at the desired concentration. Spreadsheets are available to help calculate most applicated-related math problems presented by rotenone projects. These spreadsheets are designed to help with the following:

1) Determine the amount (and cost) of piscicide product(s) based on water volume, the target rotenone concentration, and unit cost of the piscicide.
2) Determine guideline application boat speeds to achieve a more uniform rotenone application based on the target rotenone concentration, lake depth, section, and rotenone pumping rate.
3) Determine drip station rotenone application rates based on stream discharge and target rotenone concentration for flowing water treatments.
4) Determine the rate for applying potassium permanganate to a stream to deactivate rotenone.
5) Calculate the time to recharge a lake impoundment based on drawdown height lake and tributary inputs.
6) Posttreatment success evaluation effort needed for gillnet or eDNA sampling based on waterbody size, estimated population of surviving Northern Pike, and the desired probability of detection.

ADFG also has guidelines on how to operate, calibrate and maintain various rotenone application-related equipment such as gas-powered boat-based pumping systems, backpack sprayers, portable 12-volt powered rotenone drip stations, and rotenone deactivation stations. The spreadsheets and guidelines are available with the plan supplemental materials, or upon request by contacting ADF&G Sport Fish Division Regional Invasive Species Coordinator in Anchorage, Alaska.

Rotenone Degradation Testing

Rotenone monitoring is an essential aspect of a rotenone treatment. Rotenone monitoring informs the applicator of the peak rotenone concentrations achieved and its persistence. At a minimum, collect pretreatment and posttreatment water samples from every waterbody treated during the project, and where applicable, from representative water wells adjacent to the treatment area. Pretreatment samples are used to verify the absence of rotenone. Post-treatment sampling is done to verify peak rotenone concentration and persistence. Ideally, each waterbody treated should be periodically monitored for rotenone content posttreatment until the rotenone has fully degraded. For very large water bodies, it is best to collect samples from each major lake basin. It is also informative to collect posttreatment lake water samples from both surface and deep-water strata to establish how well the rotenone is distributed. Similarly, in lengthy streams, collecting water from multiple sites along its reach is preferred.

Caged sentinel fish can also serve as indicators of rotenone distribution and lethality, but sentinel fish observations can't provide precise rotenone concentrations, and the use of sentinel fish is often logistically challenging, especially when monitoring over an extended period and during winter ice-cover.

A rotenone sampling event can be as simple as a discrete grab sample from a single location for a small waterbody, but for a large waterbody, collecting multiple samples during a sampling event is best to assess rotenone distribution. Multiple discrete water samples collected dispersed throughout a waterbody provides the highest resolution of insight into rotenone concentrations and distribution but can greatly increase lab processing costs. Sometimes the most cost-effective and practical sampling approach is to determine the "average" rotenone concentration in a lake by collecting just a single composite sample during a sampling event. A composite sample is a water sample representing equal parts water collected from two or more locations. The more locations represented in the sample the more likely it represents the average rotenone concentration in the lake. A good strategy for sampling large waterbodies where composite sampling is being done is to collect two composite samples per lake, one representing shallow water and another representing deep water. Doing so provides an adequate representation for the average rotenone concentration present in shallow and deep lake strata.

The frequency of sampling events is usually based on funding ability and the observed rate of rotenone degradation between previous sampling events. Warm water treatments usually result in dramatically faster degradation rates compared with cold water treatments, so plan the frequency of sample collections accordingly to ensure understanding of the rotenone persistence. Details on rotenone sampling protocols recently used in Alaska are found in ADF&G reports (Massengill In Preparation, Massengill 2022). More rotenone monitoring information is provided in the Rotenone SOP Manual. Most commonly, water samples are collected in amber 1-liter bottles and deep-water collections can be made with a Kemmerer sampling tube (i.e., KEMMERER - Water Sampler (usenvironmental.com).

Few analytic laboratories provide services for rotenone analysis service. Some laboratories are listed in the AFS Rotenone Stewardship Program website: [Analytical Laboratories | Rotenone Stewardship Program (fisheries.org)](). Since 2018, the University Alaska Anchorage (UAA) Chemistry Department has offered this service to ADF&G (Redman et al. 2020). Lab costs for out-of-state lab processing has sometimes exceeded $400/sample. Processing costs at UAA have varied but is generally far lower. Contact laboratories for pricing estimates.

Considerations:

Rotenone treatments can present many challenges including those which are technical, logistical, environmental, administrative, and regulatory in nature. The following are some suggestions that may help in the planning and executing of a rotenone project.

- (Partnerships) Many decisions must go into deciding whether a rotenone treatment should occur including assessing its feasibility, weighing of scoping outcomes and considering the threat posed by not doing the treatment. The planning of a rotenone treatment often develops within a partnership setting. Partnerships between government entities and/or NGO's can be very beneficial and may result in the pooling of resources, expertise, and often financial support. It is strongly recommended that once the need for a rotenone project is agreed upon within a partnership, clarification of each of the partners roles and duties be jointly developed and formally agreed upon in a written work plan, MOU, cooperative agreement, or similar document.
- (Advance Planning) When possible, begin planning for large rotenone projects a year or more in advance of the targeted treatment date so there is adequate time to complete tasks like scoping, permitting, pretreatment biological and environmental data collection, procurement of supplies, and staff training. Also, shipping of rotenone is expensive, and delays are common. Sometimes shipping delays take weeks or more. This should be accounted for during project planning.
- (Treatment Timing) Treatment timing is an important aspect in project planning. The timing of a rotenone treatment can affect native fish populations, the amount of rotenone needed, the persistence of rotenone, the effectiveness of the treatment, impacts to water recreationist, and dead fish nuisance issues. In particular, cold water/fall treatments can be an attractive time for treatment as the rotenone can be expected to persist for 1 to 7 months (Massengill In Preparation, Massengill 2022, Massengill 2017b, Massengill 2014a). Such long persistence makes it highly unlikely Northern Pike could survive. Rotenone persisting under the ice, while adjacent shallow wetlands freeze-out, can potentially force fish that are surviving in these wetlands into rotenone exposure, as deepening ice forces them out to shallow vegetated areas that are difficult to treat with rotenone. Some agencies capitalize on the long persistence of rotenone afforded by cold water treatments to reduce the amount of rotenone needed (and cost) as less rotenone is required when long exposure helps to offset the high rotenone tolerance of some fish species (Flammang and Sobotka 2014).

Dead fish tend to sink in cold water (Bradbury 1986) which can help reduce nuisance dead fish odors or animal scavenging. Cold water treatments generally occur when most water recreation has concluded for the season. Often migratory waterfowl presence is less just prior to freeze-up. Some life stages of aquatic invertebrates are in diapause during cold weather which may provide some protection from rotenone (Dalu et al. 2015). Advantages to warm water rotenone treatments are that the rotenone will typically deactivates in days or weeks, sometimes the half-life of rotenone in warm water is measured in hours (Gilderhus et al. 1986). In some situations, fast rotenone deactivation may be a desirable project trait.

Often summer conditions cause water levels to be low which can reduce the amount of piscicide needed. Perhaps one of the most significant considerations for the timing of a rotenone treatment is if the timing can reduce the treatment's effect on native fish populations. For example, understanding the seasonal presence of native fish in a drainage (i.e., juvenile salmonid emigration, juvenile salmon rearing, spawning salmon, emergence from eggs) can inform when a rotenone treatment may occur and cause the least impact to fish populations.

- (Treatment Success Evaluations) The success of a rotenone treatment at eradicating the entire targeted Northern Pike population should be done using multiple lines of evidence. Tools to help achieve an evidence-based assessment can include rotenone bioassays that determine the minimum effective dose (MED) for the target species, observations of caged sentinel fish placed throughout the treatment area, lab analysis of rotenone concentrations to verify if lethal rotenone concentrations were achieved, posttreatment gillnet and/or eDNA surveys, visual observation surveys, and public reports.

SOP 8: Use of Under-Ice Gillnets for Northern Pike Eradication

Gear Recommendations

- See SOP 2 for gear recommendations for under ice gillnet placement.

Methods

Open Water Gillnet Deployment Before Freeze-Up

This scenario applies when deploying gillnets in a waterbody just prior to freeze up in late fall. Typically, this occurs between late September and mid-October in Southcentral Alaska but can vary from year to year. This option is beneficial when the goal is to have the longest netting period possible while minimizing or eliminating bycatch of migratory waterfowl and diving birds such as loons. To that end, it is ideal for nets to be deployed within a day or two of ice forming on the waterbody. Often, this may require breaking the first "skim" ice and then deploying the gillnets. This begins the under-ice netting as soon as possible and allows for the maximum number of days fishing under ice until nets can be retrieved at ice-out.

Another benefit of this method is that it allows you to deploy the gillnets in visually confirmed areas of optimal Northern Pike habitat within the waterbody. Open water placement is also more time efficient than under ice net deployment. The nets will likely freeze into the ice layer as the ice builds throughout the winter unless the nets are set very deep. Deep net sets that do not freeze into the ice layer can be checked periodically throughout the winter. However, the tradeoff is that setting nets deep enough to not freeze in will likely be outside of optimal Northern Pike habitat and, therefore, less effective. Even though nets frozen into the ice cannot be pulled for net checks, ADF&G has successfully checked nets using a submersible ROV/drone to drive along the net, though this is highly dependent on individual lake conditions and visibility. When setting the nets, they should be anchored on both ends and buoyed on at least one end with identification and contact information of the lead organization or the project.

SOP8.1. Submersible drone ROV that can be used for under-ice net checks and deployment

As discussed, the nets should be set in the littoral zone (< 4m) to maximize the likelihood of catching as many Northern Pike as possible. GPS coordinates of nets should be taken during deployment, and records should be kept on general net locations to prevent losing nets or "ghost nets" fishing. The number of nets deployed, and total net days should be calculated using the Northern Pike Detection Sampling Effort Calculator in SOP 2. The calculator was developed to inform sampling effort for early detection Northern Pike surveys, but it can also be used for post-Northern Pike eradication monitoring surveys or evaluations, and, in this case, for setting targets to maximize the potential for eradicating Northern Pike populations with under ice-gillnetting. The calculator (Northern Pike Sampling Effort Calculator) is available with the plan supplementary materials and can be found in the worksheet titled "Netting Effort Calc". Using this calculator to set targets for maximum catches, recommendations are to input the littoral acreage of the lake, maximize the probability of detection (enter **0.999** for this), enter a population size of **1** to obtain the most conservative effort estimate possible and then enter the number of nets available for the under-ice deployment. In the example provided in SOP8.1, a lake with approximately 30 littoral acres, with 10 nets set beneath the ice, would need to need to fish for about one month to theoretically maximize eradication potential. Setting nets during open water, just prior to freeze-up, for the full winter season would far exceed this target by several months. This can be viewed as beneficial because any added effort just maximizes potential for eradication success. However, project managers may decide that deploying nets later in the winter, under this example scenario, would be preferred. Regardless, follow-up monitoring surveys (Figure 26) are recommended following under-ice gillnetting for Northern Pike eradication for ensuring eradication success.

Estimating Required Net-Hours	
Inputs:	*Example*
Littoral Acres (<4 m)	30
Desired Prob. Of Detection:	0.999
Population Size:	1
Number of Nets:	10
Outputs:	
Net-Hours	5,453
Soak Time (hrs):	545.3
Soak Time (days):	22.72

Note: The catchability coefficient (0.038) used in the model was estimated by performing linear regression of CPUE (dependent variable) against density (Independent variable) using data from the Threemile and Chuitbuna systems.

SOP8.2 Example frame of the netting effort calculator (inputs by the user in yellow, outputs in green)

When pulling the gillnets in the spring, every effort should be made to retrieve them within a day or two of ice-out, or there will likely be avian bycatch. Field crews should expect the nets to be very full of numerous fish (Northern Pike and fish bycatch), and the fish will be in varied states of decomposition, sometimes fully decomposed and falling out of the nets or unidentifiable. The nets can also sometimes be damaged from the ice.

Under-Ice Gillnet Deployment After Freeze-Up

See 'Under Ice Netting' methods in SOP 2 for images and information on deploying gillnets beneath the ice. This can be done any time after the ice is safe enough to be on. When setting gillnets through the ice, it is recommended to keep net sets to around 60-to-80-meter sections as this is about the maximum distance that the gillnet can be reasonable pulled under the ice for deploying or checking. While it is easier/faster to set all the nets connected to each other, minimizing the number of holes that need to be cut in the ice, netting effort should be spaced around the waterbody to maximize chances of eradication.

Considerations:

There are several factors to determine if a waterbody is a good candidate for under ice netting with the goal of eradication. There are also several considerations or concerns that would prompt this method versus a more traditional open water pesticide treatment.

- Candidate lakes for under ice eradication are small with simple benthic structure.
- These lakes would be shallow throughout much of the lake, allowing very little refuge from the gillnets because the Northern Pike spawning / rearing habitat and can be fully inundated with gillnets.
- Ideal candidate lakes would be shallow enough throughout that the nets can reach throughout the entire water column.
- The ideal waterbody will have a relatively low density of Northern Pike with minimal spawning habitat/ recruitment.
- This method is a good option for lakes with new, not-yet established Northern Pike populations because it can thwart successful spring spawning by removing enough mature fish.
  Under ice netting can be a favorable option for eradication because it is a passive approach with respect to staff time. Once the gillnets are set either in the late fall prior to freeze up or under the ice, minimal to no effort is needed to fish the nets. It is optional to check the nets during the winter season if the partner organization has access to an underwater ROV.
- Minimal to no permitting is required for this eradication method compared with chemical treatments.
- There are no bird bycatch concerns if nets are retrieved immediately at ice out in the spring; this is a significant benefit over open-water netting.
- There is no collateral harm to macroinvertebrates compared with chemical treatments.
- There are minimal affects to anglers and lake residents as the nets are fishing unseen.
- Cost is substantially lower than a chemical treatment.
- In lakes with poor growth rates, young of year or juvenile fish may be too small for the ¾" mesh, so netting may need to occur for multiple winters for complete eradication. All mature fish would have to be removed before spawning to prevent a new batch of juveniles, otherwise eradication will never occur.

SOP 9: Drawdown of Waterbodies for Northern Pike Eradication

Gear Recommendations

- See SOP 1 for guidance on Northern Pike data collection
  **Demographic data collected on captured Northern Pike will help guide timing of the draw-down*
- See SOP 13 for guidance on using gillnets for long-term Northern Pike suppression
  **Ensure that the appropriate amount of gillnet effort is being applied at the site to reduce the population to the maximum extent*
- Staff gauge installed at the lake outlet
- Hand tools for altering beaver dams

Methods

Initial suppression of the Northern Pike population in a waterbody should follow standard operating procedures laid out in this plan. All recommended data collection should occur as the suppression project proceeds including sex, age and length data for all Northern Pike captured, as well as environmental data including water levels and temperature.

Gillnetting of Northern Pike should begin as close to ice-out as possible to determine the spawning timing of the Northern Pike in that system. If female Northern Pike captured during the onset of netting are found to be devoid of eggs it should be assumed that the Northern Pike have already spawned under the ice or very near to the date of ice-out. If the female Northern Pike captured in a system after ice-out are still found to be gravid at the time of capture, they are likely actively spawning.

Northern Pike suppression using SOP 13 should occur annually for several years, or until data collected from the Northern Pike population indicates that CPUE has leveled off and the majority of Northern Pike in the population are age-1 and 2-fish with very few large mature adults being captured. During the summer preceding the draw-down, the suppression crew should exert the maximum amount of pressure on the Northern Pike population as is possible by deploying gillnets throughout the summer including August when Northern Pike typically show a resurgence in activity following the hottest portion of the season. This will reduce the number of spawners the following spring.

During spring following the year of maximum gillnet pressure, water in the given lake should be drawn down as much as possible by removing whatever blockages exists at the lake outlet. If the blockage is a flow-control structure the crew should remove the maximum number of dam boards allowed by the Fish Habitat Permit (FHP) issued by ADF&G Habitat Division, for that structure. If the blockage is natural, such as a beaver dam, the structure should be altered by creating at least one 2–3 foot notch in the center of the dam to drawdown the lake. More notches may be needed if the impounded water body is larger and has deeper vegetated areas where spawning likely occurred. The crew should work to maintain this notch as beavers repair the dam.

Following the removal of the water blockage, the water should be kept low through mid-summer or as long as is practical. If the blockage is a flow-control, boards should only be re-installed when water levels begin to increase in the lake as to not disrupt flows to the outlet stream. If the blockage is a beaver dam, the beavers should be allowed to repair the notch during late summer. Throughout the process, water levels should be documented to determine the effectiveness of the drawdown.

This process may need to be repeated for several years in a row depending on site specific conditions and the Northern Pike population dynamics. Because YOY Northern Pike are very difficult to capture, assessment of the drawdown success is best done the following summer. This can be done by collecting age data on captured Northern Pike and determining the relative abundance (if any are present) of age-1 fish. The absence or highly reduced number of age-1 fish would indicate the drawdown the previous year had an impact on that year's recruitment. If the drawdowns occur multiple years, assessments should continue by examining the ages of captured Northern Pike to ensure the cohorts from the years drawdowns occurred, are either not present or highly reduced.

Depending on that success, Northern Pike netting effort can likely be reduced in future years and serve as a monitor of production or continued Northern Pike presence rather than a tool of suppression. Ideally, the Northern Pike population would be reduced to a point where extirpation is possible with additional gillnet effort and/or the effect that they are having on juvenile salmonids is negligible.

Considerations:

- These methods should be used at lacustrine sites with invasive Northern Pike where: the lake has an outlet stream or streams, Northern Pike spawning is known to occur in the littoral zone, the shoreline offers a gradual sloped descent into the lake, Northern Pike suppression activities have already been undertaken so that the Northern Pike population is comprised of mainly young small fish, and the outlet can be partially blocked to raise the water level of the lake. Water impoundment in the lake could occur via natural phenomenon such as beaver dams, or man-made flow control structures with removable dam boards.
- After enough gillnet pressure has been applied to a Northern Pike population, (typically after several seasons of intensive netting), suppression activities generally reach a stage where the average size and age of Northern Pike in that population is severely reduced in comparison to the previous demographics of the original population. Once a Northern Pike population has been suppressed to this point, most of the Northern Pike in the system will be age-1 or 2 with few remaining large spawners captured each year. At this point in the life of a suppression project, catches are expected to remain relatively stable as the number of Northern Pike captured each year are replaced by new recruits. These recruits also may exhibit increased growth rates and early sexual maturity in the absence of a large population of adult Northern Pike. They will likely be enabled to persist at this level; even when faced with gillnet pressure unless there is a disruption in the spawning success of the remaining Northern Pike.
- Some of the most critical factors in the spawning success of Northern Pike are to have high water levels at the time of spawning that remain stable or rise during the post

spawning period (Johnson 1957, Inskip 1982, Casselman 1996). High water provides Northern Pike access to flooded vegetation ideal for the deposition of eggs and the near-shore vegetated habitats provide rearing juvenile Northern Pike with cover for hunting prey as well as protection from predators. Steep water level drops following Northern Pike spawning activities have the potential to disrupt the hatching of Northern Pike eggs by drying out the macrophyte beds on which they were laid. Additionally, the drying of nearshore habitats forces any juvenile Northern Pike that may have survived to move out of their shallow protected nursery habitat thus increasing their vulnerability to predation.

- By allowing blockages at the outlets of these lakes to hold back water over winter and releasing water as soon as possible following ice-out, these draw-down events could be used to reduce the proliferation of Northern Pike by attacking them at the egg/larvae stage when they are most vulnerable. The reduction in Northern Pike recruitment could then lead to a further reduction in Northern Pike and their inferred consumption on juvenile salmonids and possibly lead to the extirpation of Northern Pike in systems where drawing down spring water levels is possible.
- Under very rare circumstances (i.e., very small ponds or small lakes in non-residential areas), water may be physically pumped out to drain the lake and desiccate the Northern Pike or lower the water level to reduce the amount of rotenone that is needed to adequately treat it. This is ideal for circumstances where funding is limited and there is a place to drain water without causing flooding. In this manner, drawdown can lead to quicker eradication, though the application of this is very limited.
- Altering the water level in a water body by a few feet may have a significant impact on surrounding landowners or other users of the water body. For example, lowering the water level by a couple feet may expose navigational hazards, or make it impossible for boats/float planes to pull up to docks. Alternatively, raising the water level may flood someone’s private property and cause damage. It will be important to discuss this option with surrounding landowners before taking this action.

SOP9.1. Water control structure with boards that can be removed to reduce water level

SOP9.2 Notching a beaver dam to reduce water levels

SOP9.3. Pumping water from a pond to drain it

SOP 10: Native Fish Restoration Following Northern Pike Eradication

Gear Recommendations

Non-Electric Juvenile Fish Capture

Minnow traps
Bait (salmon roe)
Bright colored flagging
Large live box (e.g., perforated 55-gallon plastic drum and t-posts used near the fish collection site)
Coolers (hand-transporting fish to release site)
Aerators/ batteries
5-Gallon Buckets (perforated and unperforated)
Laminated juvenile fish ID sheets
Rite-N-Rain™ notebook and pencils
Site map
Disposable gloves (i.e., latex or nitrile)
Insulated rubber gloves (for cold conditions)
Small aquarium nets
Dip nets for large fish
Bug spray
Sunscreen
Polarized sunglasses
Bear spray or other wildlife deterrent
Electronic communication device
Copy of ARP permit
Laminated sign (contact/information display for transport vehicle)
Fyke nets with 1/8th inch mesh
Stakes for supporting fyke net
Zip ties for securing fyke net wings to stakes
Waders and wading boots (boot studs are helpful)

Open Water Netting (Adult Fish Capture)
Buoys
Line
Net Anchors
Entanglement/ gillnets (sized for target species)
Safety shears
Bathymetric map
Coolers
Aerators/ batteries
5-Gallon buckets
Insulated tote for large fish transport
Large fish holding boat live box
Dipnets
Laminated juvenile fish ID sheets
Write in the Rain Notebook™
Rubber and disposable gloves
Net picking tool
Bird kit (scissors, blanket, gloves, goggles)
Fish enclosure *(if temporary onsite holding is needed to stockpile fish catch)*
Bathymetric map
Spare line (parachute cord or similar)
Bug spray
Sunscreen
Electronic communication device
Life jackets
Boat tool kit
Polarized sunglasses
Push pole (if appropriate)
Copy of ARP permit
Rite-N-Rain™ notebook and pencils

Hook and line

Fishing rod, reel, line, and dipnet
Terminal tackle /bait
Long-neck needle nose pliers
Aerators/ batteries
Livewell for vehicle transport of fish *(e.g., insulated, and aerated tote or large cooler)*
Large fish holding live box (for onsite holding)
Laminated fish ID sheets
Copy of ARP permit
Write in the Rain Notebook™
Rubber or disposable gloves
Bug spray

Sunscreen
Electronic communication
Fyke nets with 1/8th inch mesh
Stakes for fyke net
Zip ties for securing fyke net wings to stakes
Life jacket if in a boat

(Optional)
Electrofishing equipment *(must have certified electro fisher leading electrofishing efforts)*
Fyke nets with 1/8th inch mesh including wings Fyke net staking, stake driver, zip ties for securing fyke net to stakes
Measuring board

Methods

An important step when planning a Northern Pike eradication project is to collect baseline data to determine fish composition, run timing, distribution, and population structure within the area targeted for Northern Pike removal. Although this baseline may have been altered by the presence of Northern Pike, it still provides information that can be useful. Sources for information on the native fish community may include published and unpublished agency reports and records collected by fish and habitat managing agencies. Usually there is a need to conduct surveys to get more current information. These surveys could include the use of gillnets, weirs, backpack electrofishing, minnow traps, fyke nets and hook and line efforts. It is recommended to use multiple gear types when conducting surveys to detect species presence and to sample across seasons. The use of varied gear and temporal strata can reduce sampling bias. Bathymetric maps are helpful for planning capture techniques and sampling locations. Discussion with plan partners on successful strategies used in the past can assist in development of restoration objectives and plans for new projects.

Optimally, project planning should strive to reduce life history disruption and handling stress of native fish being surveyed or collected for restoration. Considerations may include timing (cool conditions are typically less stressful to fish) and locations when fish are most efficiently captured. For example, it could be beneficial to plan the native fish collection/rescue, or invasive fish eradication work, so the timing of the action minimizes impacts to seasonally present fish like out-migrating salmon smolt or returning spawning salmon.

If the waters to be restored have good surface water connectivity to a different waterbody having robust populations of non-sport fish (e.g., stickleback, sculpin, suckers), it is reasonable to spend most native fish collection efforts targeting salmonids if they are present. Salmonids are typically in higher demand for human use and have slower reproductive cycles than some non-salmonids like stickleback. If the waterbody where Northern Pike removal will occur is a closed system and/or natural recolonization of native fish is unlikely for other reasons, it becomes increasingly important to collect representative fish of all species from the waterbody targeted for restoration prior to the removal of Northern Pike.

Native fish capture methods (adapted from Massengill 2017b)

Juvenile fish capture

- Minnow trapping (adapted from Meyer 2021)
    - Minnow traps baited with cured, disinfected salmon eggs are very effective at capturing juvenile salmonids, and most other finfish. Stickleback can recruit effectively to unbaited traps as they are attracted to most underwater structure. Typically, the minnow trap catch is temporarily held onsite near the capture location in a live box or bucket until the fish can be transported to their long-term holding site where they will reside until conditions in the treated waterbody are suitable for reintroduction (i.e., the rotenone has degraded). Whenever holding fish onsite ensure there is adequate water flow through the container to ensure oxygen levels remain sufficient.
- Electrofishing
    - Electrofishing streams is another collection method to consider for juvenile fish. Utilizing this method, along with other capture gear, increases the likelihood that all available species are collected. Some cryptic species such as lamprey ammocoetes are inherently difficult to collect using most gear types; however, electrofishing has been shown to be an effective method for juvenile lamprey collection (Moser et al. 2007).

Minnow Trapping

Electrofishing

SOP10.1 Capture methods for juvenile fish

Adult fish capture

- Gillnets
  - When using gillnets, the net mesh should be sized appropriately for the target species. Variable mesh gillnets, often referred to as experimental gillnets, are helpful for collecting a variety of fish size classes. Nets are usually set with a 2-person crew operating an outboard motorboat, but non-motorized boats are not uncommon to use in areas restricted to foot access. To set a gillnet, the net is usually tethered to shore at one end and the remaining net is stretched out away from shore by a crew member feeding the net from the boat bow while the boat operator reverses the boat. Depending on water depth and site characteristics, the net may be stretched entirely perpendicular to shore, or set in a hockey stick pattern by first setting perpendicular to shore then turning parallel to set along a weed line or depth contour. The buoy aids in visually relocating the net for retrieval. Gillnets must be monitored frequently to reduce injury to the fish. To improve fish survival, it is best to quickly cut the net off severely entangled fish versus spending a longer time untangling the fish, and to keep the fish submerged in water during removal. Keeping a tote filled with water in the boat is useful for processing caught fish, and frequent refreshing of the water is advised.
- Entanglement nets
  - Net mesh should be sized appropriately for the target species. Entanglement nets are fished in the same fashion as gillnets. When fishing entanglement nets, the net hanging depth or fishing depth may need to be tailored to specific conditions or species. For instance, when targeting species in deep offshore water a net that hangs deeper in the water column, or a sinking net can be more productive than a floating net or one with a shallow hanging depth.
- Fyke nets
  - Fyke nets come in a variety of sizes and should be selected and deployed based on site-specific waterbody characteristics. In lakes, fyke nets are most effectively set along a gradual shoreline in depths of 2 to 5 feet (depending on the size of the net), or in relatively shallow entrances to bays and outlets where the net is of sufficient size to mostly block the entrance.
  - To set a fyke net, attach the center lead of the fyke net offshore in a depth less than the height of the net and pull the fyke net body taught in the orientation desired. Tether the mouth end of the net to stakes set on each side of the fyke net mouth. Depending on the site, the fyke net body orientation may vary relative to the shoreline. Often, setting the body of the net parallel to shore with the leads (wings) of the fyke net stretched perpendicular to the shore will cause fishing traveling parallel to the shoreline along a depth contour to encounter a lead and be directed into the mouth of the fyke net. Setting the fyke net wings in a V-trap formation aids in funneling fish towards the mouth entrance. When fishing natural funnel areas (entrances to bays, gaps in weed lines, outlets, etc.,) attach the leads to opposite shorelines or weed edges and center the mouth of the fyke net in the entrance to intercept fish traveling through the entrance. Often the most effective approach is to have two fyke nets facing opposite from one another with the two cod ends together to capture fish moving in either direction.

- Purse Seiner
    - One native fish capture method used in the past in Stormy Lake on the Kenai Peninsula (Massengill 2017b) was a purse seiner. During this effort, a commercial jitney seiner and crew were contracted to spend 8 hours fishing in waters between 10 and 40 feet in depth to capture Arctic char. Specifics of this method can be adapted to target certain species and depths depending on the waterbody and target species. This method was not as successful as others (Massengill, personal communication).
- Hook and line
    - Generally, collecting native fish by [hook and line](#) is less efficient than other methods and is best used in combination with them. The largest benefit to hook and line sampling is it can be less stressful to fish than netting and trapping. To reduce stress on fish, anglers should always use single, barbless hooks. This method is ideal to employ if volunteers are being used to capture fish and can be done from shore.

SOP10.2. Capture methods for adult fish

Transport and Holding

Small lakes or ponds adjacent to, or in proximity to the treatment area can be excellent options for temporarily holding rescued native fish until the rotenone degrades in the treatment area. Waterbodies selected for native fish holding should have a few important characteristics including being devoid of invasive Northern Pike, and sufficient food and dissolved oxygen, particularly during winter periods if the rescued fish will be overwintered. Sampling potential fish holding waters for water quality during late winter prior to the removal effort will inform if water quality is adequate to support rescued fish when dissolved oxygen is typically the lowest. Surveying aquatic invertebrates in potential fish holding waters is also informative to determine if fish forage items are available. Prey requirements for many fish species in Alaska tend to decrease significantly over winter as cold temperatures decrease their metabolic demands. Fish that are held in net pens and unable to freely forage may need to be provided supplemental feed.

Coolers are an easy way to transport small numbers of fish from the collection site to the holding site. Coolers used for this purpose should be outfitted with battery-powered aerators to ensure there is adequate oxygen in the water for holding fish. When possible, avoid collecting and holding fish during warm conditions due to the increased likelihood for low dissolved oxygen, thermal stress, and higher incidence of diseases and parasites.

Restocking Abundance

Approaches to restocking native fish will be project dependent. Often collecting as many representative fish as possible with available time and resources is the best approach (Massengill, Personal Communication). When resources allow, population modeling can be done to estimate the population recovery time needed for different target species. Population recovery modeling was done for rainbow trout in the Miller Creek Watershed on the Kenai Peninsula (Boersma 2020). This modeling utilized historic rainbow trout demographic data extracted from previous reports and predicted population effects based on projected abundance of Northern Pike. Impacts of different Northern Pike management scenarios (no action, gill netting for suppression, rotenone application with restocking) were modeled to assess their efficacy for Northern Pike control and resulting abundance of rainbow trout

Large Fish Enclosure | Large Fish Tote | Juvenile Fish Enclosures

SOP 10.3. Examples of enclosures for native fish rescue

Considerations:

- Entanglement nets are generally less stressful to fish because the net mesh is designed to entangle fish by the snout instead of the body or head. Entanglement nets can be made from either monofilament or multifilament mesh.
- To date, fish rescue stocking rates have been based on the premise of catching as many of each native species as feasible prior to Northern Pike eradication. In the future, it may be beneficial to develop a model or tool for informing re-introduction targets based on water body characteristics and life histories of the rescued species.

SOP 11: Use of Barriers for Northern Pike Containment

Gear Recommendations

Fyke nets
Rebar or fencing stakes
Zip ties
Parachute cord
Entanglement nets
Weir panels or pickets
Sandbags
Landscape cloth
Screen fencing
Chicken wire
Hand tools

Methods

As discussed in the section 5.1 Barriers, this SOP is a basic description of existing options for containment of Northern Pike populations and will be expanded on in future versions of this plan. In this SOP, three categories of existing and available barrier types will be described: man-made short term, natural, and man-made long-term.

Man-Made Short-Term Barriers:

Temporary barriers are generally used before, during, and after an eradication project until Northern Pike eradication has been confirmed. These barriers are typically removed following Northern Pike eradication confirmation to facilitate native fish recovery. The primary barriers used for temporary containment of Northern Pike include: fyke nets, entanglement nets, weirs, and fences (SOP11.1).

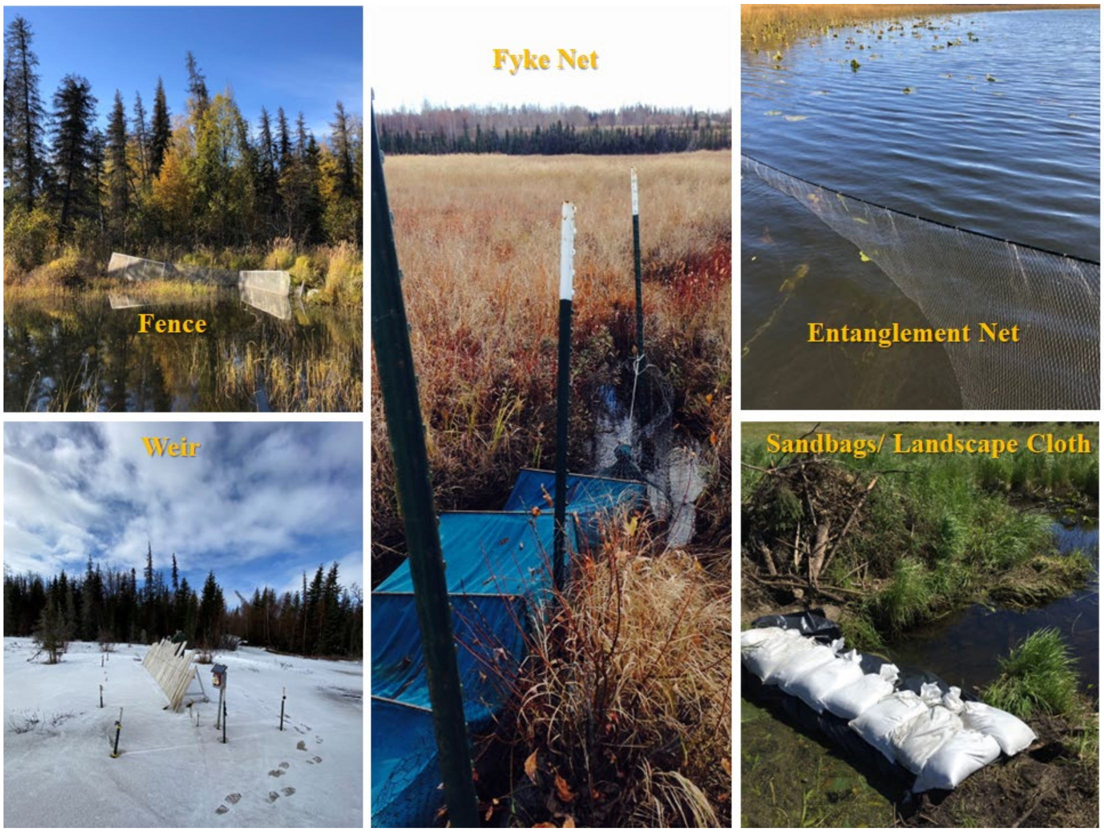
Fyke nets: Fyke nets are a type of fish trap that consist of a long netting bag usually with several netting cones fitted inside the netting cylinder or rectangle. This makes it simple for a fish to enter the trap, but more difficult for them to leave. The net sections are mounted on a framework of ridged rings and includes mesh wings of varying lengths that can help funnel fish into the trap. A benefit to fyke nets is that they can be checked, and bycatch can often be released alive. The main drawbacks to the use of fyke nets is that they require substantial maintenance, from checking the traps, removing debris accumulating on the net, and repairing holes. Fyke nets can be used in the inlets and outlets of lakes to temporarily prevent Northern Pike from moving out of the lake, especially as it is being treated with rotenone. The fyke net can be set with the fish trap facing either upstream or downstream. Regardless of the direction, the wings must be firmly secured to the rebar or fencing stakes. Rocks placed along the bottom of the wings can help secure them to the bottom. Water depth and substrate hardness are limiting factors to where fyke nets can be securely set to be fish tight, and these nets are susceptible to damage from animals like river otters or beavers. Incorporating a more durable fencing material around the fyke net, such as chicken wire, can help prevent mammals from getting in the net or chewing through the netting.

Entanglement Nets: Entanglement nets are fine mesh nets, similar to gill nets, that entangle any fish swimming into them. These nets can be used either alone or in combination with other barrier types. To make them fish tight, they should be firmly secured to both sides of an inlet/outlet stream with rebar or fence stakes. The netting can be layered to increase the strength of the barrier. These nets are very effective in catching fish, and bycatch in the nets for short durations can usually be released alive. However, the nets will capture debris and may eventually fail if too much debris collects in them. For this reason, entanglement nets are best used for temporary blockage of Northern Pike during a rotenone treatment where flow is minimal.

Sandbags/ Landscape Cloth: Another option for temporary containment of Northern Pike is to build a barrier with sandbags placed on top landscape cloth at lake inlets/outlets. These barriers can have greater longevity than using nets, but they are labor intensive to install and typically require subsequent reinforcement with additional sandbags, especially as water height increases or the original structure settles into sediment. These barriers are ideal to use when the containment needs extend beyond an individual eradication project, such as in the case of multi-year efforts (i.e, Massengill 2021). One potential drawback is that impounding lake outlets can raise the water level of lakes. This should be carefully considered if there are residences or properties in the vicinity that could be flooded. If so, there may be a need to regularly monitor water levels and remove sandbags if necessary.

Weirs: Installing a picket weir is another option for longer-term temporary containment. As with sandbag barriers, weirs can be labor intensive to install and are a more expensive option. While weirs can be installed in most streams, access to a weir site should be an important consideration as weirs require regular maintenance to clear debris and/ or reinforce during high water periods. Among the benefits of using picket weirs for temporary containment of Northern Pike is that they are non-lethal, and native fish can be passed over the weir. There are multiple options for this including fish traps and video surveillance, but this still requires manual passage of the fish. Without manual fish passage, the weir can impede native fish movements in a drainage, just as they do for Northern Pike. The importance of this should be considered by fishery managers with jurisdiction for the area. The installation and maintenance of a picket weir for Northern Pike will depend greatly on the characteristics of the individual water body and the local fish populations. When considering a weir as a containment option, it is ideal to solicit the help of fishery biologists experienced in weir design and installation.

Fences: The final temporary barrier option to consider is the use of fencing to block off an inlet or outlet of a lake. Fencing functions in a similar manner as a picket weir but is generally the better option for a narrow outlet and minimal flowing water. Temporary fences are useful for longer-term durations but, as with all other options, require occasional removal of debris, and they are susceptible to damage from larger animals like bear or moose. There are many different variations of fending that can be used, made of different types of material and mesh size. It’s important that the mesh size is small enough to prevent passage of juvenile Northern Pike and the edges/bottom of the fence is secured to the substrate/shoreline to prevent fish from moving around the fence.



SOP11.1. Examples of short-term man-made barriers for Northern Pike containment

Natural Barriers:

Natural barriers are those that are of natural origin and, while they may not prevent all Northern Pike movement, they provide considerable help in slowing down Northern Pike movements to new waters. Barriers in this category include velocity barriers, natural waterfalls, salinity barriers and beaver dams (SOP11.2). Depending on conditions, these may or may not be able to be enhanced or adjusted.

Velocity Barriers: Velocity barriers, for this SOP, are impediments to Northern Pike movement via natural features causing high velocity water which Northern Pike cannot pass through, due to the high gradient and/ or constriction of the river channel. Northern Pike are not well adapted to high velocity waters and are thus unlikely to spend much time in them. Katopodis and Gervais (2016) provide an online modeling tool for determining the % number of individuals by fish species and length that can move an inputted distance under different steam velocities (Fish Swimming Performance User Guide (fishprotectiontools.ca)). Using this model, water velocities at 3.3 m/s are considered unpassable for 97.5% of 400 mm Northern Pike (Katopodis and Gervais 2016). This limit is based off an incredibly conservative input of swimming 1 meter. If swimming 20 meters, 97.5% of 400 mm Northern Pike would be impeded by 1.6 m/s. Project managers can use this model to inform where velocity barriers might occur in a watershed that has Northern Pike.

Natural Waterfalls: A waterfall effectively functions as a natural vertical drop barrier that impedes the ability of Northern Pike to move over it.

Salinity Barriers: As has been discussed elsewhere in the plan, Northern Pike are not tolerant of fully marine conditions, so salinity can function as a barrier, even though Northern Pike are capable of surviving and moving through brackish conditions under approximately 15 ppt (Jacobsen and Engstrom-Ost 2018). Time of year and current patterns that affect salinity levels in Cook Inlet are factors that influence when or if salinity is a prohibitive barrier to Northern Pike dispersal. Further research on this is needed as it is now confirmed that Northern Pike can invade drainages via low salinities in Cook Inlet (i.e., Miller Creek Drainage). Fully marine conditions > 15 ppt are considered above the physiological limits for Northern Pike, but during the spring of 2022, a research study will aim to answer how long Northern Pike can survive in different salinity levels (*Massnegill, 2022 In Prep*). This study will help pinpoint Cook Inlet drainages that may be vulnerable to Northern Pike invasion and those where salinities should likely be an effective barrier.

Beaver Dams: Beaver dams are a very common and natural impediment to fish passage, particularly for species that are poor jumpers like Northern Pike. In drainages where beaver dams exist, these can be used and/or potentially reinforced to contain Northern Pike within part of a drainage. In the case of the Northern Pike invasion to the Miller Creek Drainage on the northern Kenai Peninsula, beaver dams are believed to be the reason Northern Pike were not widespread in the drainage before their eradication.

SOP11.2. Examples of natural barriers for Northern Pike containment

Long-Term Man-Made Barriers

This category of barrier will again be expanded upon in future versions of this plan using data and conclusions from Cubbage 2022 et al. (*In Prep*). Long-term man-made barriers are those that maximally prevent passage of Northern Pike, though may still allow passage for native fish species. Primary long-term man-made barriers considered here are vertical drop barriers.

Vertical Drop Barriers: Vertical drop barriers are those that create an impediment by requiring Northern Pike to leap over a structure to move upstream. In some cases, perched culverts can function in this capacity, but because of detrimental impacts of culverts to other native fishes, vertical drop barriers need to be designed to minimize impacts to native fish and maximize potential to block Northern Pike. Northern Pike have evolved to thrive in low velocity/stagnant vegetated waters, so it is believed they have limited physical ability and/or behavioral desire to ascend high gradient waters/leap over barriers relative to other species. Again, this is the crux of the research begun by Cubbage et al. 2022 *In Prep*. Another potential drawback of vertical drop barriers is the potential for erosional changes to a stream. Next steps are to identify potential locations for vertical drop barriers and consult with engineering firms on barrier design schematics that may be able to minimize this. Future versions of this SOP will include greater detail on vertical drop barrier designs for different stream types and decision-making guidance on when and how they should be used.

SOP11.3. Examples of vertical drop barriers for Northern Pike containment

Considerations:

- Barriers chosen will be highly dependent on the hydrologic and habitat conditions of individual Northern Pike waters.
- While Northern Pike passage can be inhibited, there is always a chance a barrier will fail or not be 100% fish tight; therefore, including barriers in project design should not be a substitute for regular monitoring.
- Seasonal variations in water conditions can have large impacts on the effectiveness of barriers and should be taken into consideration and planned for accordingly.
- The use and design of Northern Pike barriers is an area of research that will continue.
- Fish Habitat permits from ADF&G will likely be needed for man-made barriers. Consult with local agencies for any additional permitting needs.

SOP 12: Data Collection During Northern Pike Suppression

Gear Recommendations

- See SOP 1 for gear list and Northern Pike dissection guidance.
- SOP 13 details gillnetting procedures for Northern Pike suppression.

Methods

All Northern Pike suppression projects should collect the following data**.**
Variables in bold must be collected. *Variables in italics are recommended:*

1) **Sample ID #**
   This is a unique sample ID number that is pertinent to a specific project, typically incorporating site #s, date, and Northern Pike # per net set.
2) **Organization**
   List the plan partner running the suppression project.
3) **Crew Initials**
   Record the initials of each person in the field crew.
4) **Water Body Name**
   Record the location name.
5) **Survey Date and Start Time**
   Record the date and time when the net set begins (time first net is deployed, M/D/Y HH:MM).
6) **Survey Date and End Time**
   Record the date and time when the last net in the set is checked (M/D/Y HH:MM).
7) *Total Hours Fished*
   This is calculated automatically in the database if the formula is copied down the column.
8) *Total Net Hours*
   This is calculated automatically in the database if the formula is copied down the column.
9) **Number of Nets**
   Record the number of nets used in the net set.
10) **Region #**
   This is specific to the project and is the general region the net set is in. For example, this could be identified by a field camp or lake section.
11) **Site #**
   This is specific to the project and lists the site the net set is in. For example, this could be an individual slough # or a river mile.
12) **# of Northern Pike**
   Record the total number of Northern Pike captured in the nets at the site.

13) Bycatch

List totals of bycatch in the net set.

14) Notes

Record any additional relevant information about the net set.

15) NORTHERN PIKE 0.75, 1.0, 1.25, 1.5, 1.75, 2.0

If using variable mesh gillnets, record the number of Northern Pike caught in each of the panels. This can be entered into notes in the catch data sheets and separated in the database.

Pike Suppression Catch Form Date Checked ______ ________ Samplers__________ Region # Page #

SAMPLE ID #	Site #	TIME SET	TIME CHECKED	# of Nets	# Northern Pike			Write in Bycatch Species								Comments (Mesh net catches, nets added/pulled, pictures)

SOP12.1. Standardized field data form for Northern Pike catches during suppression efforts

All Northern Pike suppression projects should collect the following **individual Northern Pike** data**. <u>Variables in bold must be collected.</u>** *<u>Variables in italics are recommended whenever practical:</u>*

16) Northern Pike #

Chronological number of Northern Pike for each net set.

17) Fork length

Measure each Northern Pike to fork length in mm

18) Sex

Record if the Northern Pike is female, male, or unidentified if in doubt.

19) Maturity

Record if the Northern Pike is mature or immature.

20) Condition

Record if the Northern Pike is green (no gametes present), ripe (ready to spawn) or spent (no gametes). The spawning period for Northern Pike is between late April and June, so this is when condition would be noted, otherwise note this as N/A.

21) Weight

Record the mass of each Northern Pike in grams.

22) Otoliths

Record Yes or No if otoliths were collected. If collected, write the Site #, Northern Pike #, and date on the otolith envelope.

23) Cleithra

Record Yes or No if cleithra were collected. If collected, write the site #, Northern Pike #, and date on the otolith envelope.

24) *Age*

Enter the Northern Pike age if determined by cleithra analysis.

25) Stomach contents

All Northern Pike captured must be dissected for stomach contents, and all contents should be enumerated to the lowest taxonomic level practical

26) Deformities

If the Northern Pike has any deformities, obvious external pathogens, diseases, or unusual characteristics, include these in the data notes and take pictures.

27) Notes

Include any pertinent notes or details regarding the Northern Pike or net set in the data file.

28) GPS Coordinates

Maintain a list of project Site #s and GPS coordinates for each.

Northern Pike Stomach Sampling Form							Region #:	
Date:		Site # :					Samplers:	Page:
Pike #	Sample ID #	Fork Length (mm)	Sex (M, F, U)	Maturity (M or I)	Weight (g)	Stomach content (Y or N)	Stomach Content	Comments about fish or stomach content; I.E. : Tag #, deformatie

SOP12.2. Standardized field data form for Northern Pike dissections during suppression projects

Note: Data sheets (SOP12.1 and SOP12.2) for print are available in the supplemental materials for the plan.

Data Storage

During this plan period, all Northern Pike suppression data collected by plan partners will be entered into a centralized file for use in research to improve suppression targets and success. The data file is in Excel titled "Northern Pike Suppression Database" and can be found in the plan supplemental materials. Plan partners are encouraged to enter their data directly into the file following field work. When that is not possible, data can be provided to the AKISP Northern Pike Committee chair for data entry. The data file includes fields for all the variables identified in the Numbers 1-28 in the Methods. The Excel file contains three data entry worksheets: Suppression Data, Northern Pike Dissection Data, and Site Numbers. A metadata worksheet is also included to provide data entry instructions. All projects should submit data to the committee chair by December 1st annually for compilation in a master file for research needs.

Considerations:

- Project managers with on-going suppression projects can continue using data files and datasheets designed for those projects. However, if possible, provide data to the AKISP Northern Pike Committee chair for re-formatting in the database. All new suppression projects should aim to use the database structure and data sheets to store suppression data for consistency among new efforts.

SOP 13: Use of Gillnets for Northern Pike Suppression

Gear Recommendations

Required:
Gillnets
Data book or data sheets
Measuring Board (mm)
Scalpel or knife
Gloves
Thermometer (°C),
YSI or Hydrolab
GPS
Identification keys
Whatman cards
Whirl pack bags/ envelopes
Forceps

Optional:
Balance
Tweezers (for otoliths)
Camera
Whatman Cards (for fin clips)

Methods

Pre-Suppression Assessment

If possible, a pre-assessment of the Northern Pike population before suppression should be conducted to determine the length/age structure and population size. This serves two purposes. First, it provides a baseline on the population from which to assess the success or progress of the suppression project. Second, it helps determine the level of netting effort required to meet removal objectives. The methods for conducting population estimates depend highly on the type of system, ranging from small, closed waterbodies (Bradley et al. 2020a,Gutierrez and Bernard 2020, Albert 2022), to larger semi-closed systems (Dunker et al. 2018b), to spatially expansive and complex systems (Albert and Tyers 2020, Albert and Tyers 2018). A common statistical method for conducting population estimates in closed systems is a Peterson 2-event mark-recapture estimator (Seber 1982, available Amazon.com: Estimation of Animal Abundance: 9781930665552: Seber, G. A. F.: Books), Seber 1986). However, there are several assumptions that must be met:

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 Northern 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 Northern Pike will not affect the probability of capture during the second event,
4. Marked Northern Pike will be identifiable during the second event,
5. All marked Northern 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.

The population pre-assessment will determine the average and ranges of Northern Pike sizes expected to be encountered during the suppression project. This will help determine what net configurations will be most effective, keeping in mind that the size structure of the Northern Pike population will likely shift to a smaller average size class after several seasons of heavy suppression (Bradley et al. 2022a, Rutz et al. 2020a).

Gillnet Suppression

Various approaches can be used when conducting Northern Pike suppression with gill nets. Research is still needed in Alaska to assess what impacts different levels of suppression have on a Northern Pike population, but similar studies have been conducted on the Yampa River in Colorado (Zelasko et al. 2016, Zelasko et al. 2015). Over a 7-year period, removal rates of Northern Pike in the Yampa averaged 30-32% causing a total annual mortality of 60- 82%. They found that populations increased anywhere from 375% to 1000% following removal efforts, primarily from recruitment and immigration. Ultimately the recruitment rates and immigration rates exceeded the removal and mortality rates, preventing the decline in overall population. However, it was noted that removal was still necessary to reduce competition and predation on native species within a given year. In Southcentral Alaska, Northern Pike recruitment and immigration rates vary highly depending on the available habitat, and hence, there is great need for focused local research in this arena. Historically, in Southcentral AK, two general approaches have been used for determining netting effort.

***Percent/number Reductions*:** The first approach is that netting occurs until a capture/removal threshold is obtained. The Alexander suppression project originally incorporated a netting effort that continued until catches in a given slough were reduced 85% from peak daily catches (Rutz et al. 2020a). For example, if 50 Northern Pike were captured in a slough in a day, netting continued until daily catches fell below 8 Northern Pike. This proved difficult for field crews to follow so this approach was abandoned in 2019. One benefit to this approach is the population is reduced by a similar amount each year. Responses of the population at that given removal rate can be monitored, and the removal rate can be adjusted accordingly. However, planning the field season can be difficult because duration of the project depends on catch rates, which can be highly variable year to year, and creates logistical, staffing, and budget restraints.

***Systematic Approach*:** The second approach is a systematic approach with a pre-determined level of netting for a set number of days, regardless of catch rates. The benefit to this approach is that project leaders can plan specific field dates for their crews. The primary drawback is that the same amount of netting effort occurs in years of high and low Northern Pike abundance, meaning efforts may not meet removal objectives. This has been the approach taken by TTCD and ADF&G in Threemile and Chuitbuna lakes (Bradley et al. 2022b).

***Hybrid Approach*:** One example of a hybrid approach taken is in Alexander Creek (Bradley et al. 2022a). Each slough is netted for 3 days in a row, and then the nets are pulled and moved to another slough. However, if on the 3rd day, total catches in the slough remain at or above 5 Northern Pike, the nets remain fishing until catches fall below 5 Northern Pike. The nets can also be pulled prior to 3 days if the total daily catch is zero Northern Pike, or there is excessive bycatch. The benefit of this approach is for sloughs that continue to produce significant catches, suppression will continue while sloughs that don't produce as many Northern Pike will receive less effort. This allows that effort to be directed elsewhere, increasing efficiency.

Individual Northern Pike suppression projects will have to select their approach based on the habitat of the waterbody and the goals and objectives of the program. Regardless of the chosen approach, project managers should make the greatest effort possible to pre-determine how to evaluate the success of their suppression efforts before projects begin. Future versions of this plan will include research-directed guidance to help improve these assessments.

Net mesh Size Recommendations

Various configurations and specifications of gillnets have been used for a variety of reasons. Recently, field crews have documented catches of Northern Pike per various mesh sizes to determine what, if any, optimum mesh size there is (ADF&G, unpublished data). Tests were conducted during the Threemile and Chuitbuna Lake suppression projects in 2021 using variable mesh gillnets with the dimensions listed in SOP 2 for open water netting (Bradley et al. 2022b). In Threemile Lake, 914 Northern Pike were captured with an average length of 354 mm FL. The 1" mesh panel had the highest catch rates, capturing 36% of all the Northern Pike. However, the ¾" and 1-1/4" mesh was also significant with each panel capturing 26% of the Northern Pike. Together, those three smallest mesh panels captured 88% of the Northern Pike, despite making up only 50% of the net. In Chuitbuna Lake, 158 Northern Pike were captured, but the average length was 480 mm FL. As a result, the larger mesh panels proved useful in capturing Northern Pike. The 1", 1-1/4", 1-1/2" and 1-3/4" mesh all had similar catch rates. The ¾" and 2" mesh had the lowest catch rates. Pierce et al. (1994) describes a length/mesh perimeter ratio which highlights the most effective mesh size for each size class:

$$\frac{L}{P} = ratio$$

Where L = Total length (TL) of Northern Pike and P = perimeter of mesh (i.e., 25 mm bar mesh has a 100 mm perimeter).

For example, the ratio of a 350 mm TL Northern Pike captured in the 25 mm mesh is 3.5. The most effective ratios ranged from 3.2 to 4.5 with peak selectivity ranging from 3.5 to 3.7 (Pierce et al. 1994). This can be back calculated to determine what size class each mesh size is most effective at capturing (SOP13.1).

SOP13.1. Peak Northern Pike size selectivity (total length mm) of different mesh sizes based on length/perimeter ratios of 3.5 to 3.7.

Mesh size	19 mm (3/4")	25 mm (1.0")	31 mm (1-1/4")	38 mm (1-1/2")	44 mm (1-3/4")	51 mm (2.0")
Mesh perimeter	76 mm	100 mm	124 mm	152 mm	176 mm	204 mm
Total Length (mm)	266–281 mm	350–370 mm	434–458 mm	532–562 mm	616–651 mm	714–754 mm

Additionally, this study noted whether the captured fish were tangled in the net or wedged in the mesh. For the most effective capture ratios, 'wedging' was the predominant means of capture. As the ratios increased (larger Northern Pike relative to mesh size), capture efficiencies decreased, and most of the fish were captured via entanglement rather than becoming wedged. Therefore, when larger Northern Pike were captured in smaller mesh, they were predominantly tangled as they are too large to fit inside the mesh. However, this is a less effective means of capture than them becoming wedged in the larger mesh sies. Future research in Alaska will document specific sizes of Northern Pike captured in each mesh size. However, the initial results appear to closely resemble that of Pierce et al (1994).

When deciding which net mesh(s) to use, it's important to first decide between single mesh or multiple mesh sizes. The main advantage to using single-mesh nets is cost as these are much less expensive than nets with multiple panels. The more panels in a gill net, the more costs increase. However, one of the advantages to using multiple panels with different mesh sizes is expanding peak selection to a wider range of Northern Pike sizes.

If using single mesh nets, mesh size should be chosen based on the highest selectivity for the average-sized Northern Pike in the system (SOP13.1). When selecting multiple panels, the middle-sized mesh should be based on the average length of the population utilizing SOP13.1, and then include other panels with mesh sizes both above and below that. For example, if using a 3-panel net for a population with an average length of 450 mm, select the 31 mm (1 ¼") mesh as the middle panel, and add the 25 mm (1") and 38 mm (1 ½") panel on either side of it.

Net Length Recommendations

Various lengths of gillnets have been used in Northern Pike suppression projects. ADF&G uses a standard 120 ft. long gillnet, but other organizations prefer shorter nets, such as 50 ft. For waterbodies with limited Northern Pike habitat, or lakes with steep drop-offs near the shore, shorter nets are effective. This is because the longer net stretched will likely extend beyond the Northern Pike habitat. Additionally, 50 ft. nets are less expensive and lighter than longer nets, so this should be considered if budget or weight are constraints within a project. However, in waters with expansive Northern Pike habitat with lots of shallow littoral area, the full length of longer nets is beneficial to maximize catches. If a variety of habitat is available in the system, including expansive shallow littoral areas where a whole 120 ft. net can occupy Northern Pike habitat, that net length is recommended for use.

Net Sets

Site-specific habitat characteristics will likely dictate how gillnets are set to maximize Northern Pike capture rates and reduce bycatch potential. However, a general rule of thumb is to have at least one end tied somewhere to shore to secure the net, and the other end can be left loose attached to a buoy to assist in relocating it (SOP13.2). If using experimental or multi-mesh nets, the side with the smallest mesh should be secured to shore. This is because the smaller Northern Pike tend to occupy the shallowest water closest to shore.

Flowing Waters

In flowing waters, it is important to avoid flowing water for two main reasons. First, this is often where bycatch will be the highest, particularly for Arctic Grayling and Rainbow Trout, if they are present in the system. Second, debris can quickly accumulate on the gillnets rendering them less effective and difficult to clean. The example in SOP13.2 is a net set in a slough, or old river channel, and the net is set on the inside bend. Generally, the inside bend is where weedy vegetation occurs with a gradually sloping shoreline. The outside bend is generally an old cut bank which often has deeper water, a lack of vegetation, and old trees/snags underneath the water. Those areas are best avoided when netting. Additionally, by keeping the net closer to shore, bycatch is minimized as other fish are often in the deeper water.

SOP13.2. Gillnet set in a lotic system on an inside bend of an old river channel, which is outside of the main river flow. This is a multi-mesh net with the small mesh side tied to shore and the net following the edge of the weed line

Lakes

In lakes, the bottom bathymetry and vegetation often dictate whether the net should be "hockey stick-shaped" or stretched straight out from shore (SOP 2.1). If the littoral area/vegetation extends the length of the net from shore, the net can be stretched straight out (SOP13.3). If the depth drops off quickly, the net should be "dog legged" to keep the net in the littoral area (<4m) (SOP 2.1). In both cases, if multi-mesh nets are used, the smallest mesh should be the end towards the shore.

SOP13.3 Deploying a gillnet in a lentic system with an orientation directly perpendicular to the shore extending through the littoral area/vegetation

The number of nets to set depends on a variety of factors, but in general 10 to 20 nets are manageable by a crew of two people in a day. Catch rate is one of the most important factors, with 150-200 Northern Pike being about the maximum number a crew of two can process in a day, depending on what data is being collected. If otoliths, cleithra, and genetics are to be collected, 100 Northern Pike would likely be the maximum that can be processed in a day by a crew of two. Additional details for setting open water gillnets can be found in SOP 2.

Duration of Net Sets

In general, nets are most effective when fished overnight. However, in instances of severe bycatch concerns or in populated areas with potential recreational user conflicts, nets can be set during the day and closely monitored. At a minimum, nets should be checked at least once every 24 hours.

Considerations:

- Generally, netting is most effective in the spring during the spawning period and immediately afterward (May and June).
- Capturing Northern Pike pre-spawn is ideal to maximize the impact on the population, but it is often difficult to deploy gillnets in hard to access areas water bodies soon enough after ice-out.
- Later in the summer, Northern Pike tend to move into deeper waters to find cooler temperatures. Nets may need to be set in deeper waters during warm water conditions.

SOP 14: Angling and Incentive Programs for Northern Pike Suppression

Gear Recommendations

PIT Tags
PIT Tag gun
Handheld PIT Tag reader

Methods

Incentive programs for invasive Northern Pike should take place in specific water bodies where the intention is to increase harvest or obtain information about the population. To do this, Northern Pike should be tagged beforehand to ensure captured fish only come from this location. There are various tags that can be used, but the two primary types are Floy tags and Passive Integrated Transponder (PIT) Tags (SOP14.1), each with their own pros and cons. The primary benefit of Floy tags is they are inexpensive. However, they are externally visible, and anglers can determine if a fish is tagged or not. Generally, these tags are inserted along the base of the dorsal fin. Usually when Floy tags are used in these types of programs, anglers remove the Floy tag and mail them in. However, an angler would have no incentive to provide information on captured Northern Pike if no tags were detected. Also, there is no guarantee that the Northern Pike was killed while the floy tag was removed. While it is illegal to release a captured Northern Pike alive in Southcentral, there would be no additional incentive to kill an untagged Northern Pike.

Cost is the primary con for PIT tags; however, they have several important benefits and are relatively inexpensive. First, the tags are not detectible without a PIT Tag reader, meaning the angler is not aware if a captured Northern Pike is tagged or not. Second, the tags are very small and can be inserted in the cheek of the Northern Pike (SOP14.2). By injecting the tag there, anglers can turn in just the heads, making for easier transport, and this ensures the Northern Pike must be killed. Additionally, by keeping the tags hidden, anglers are incentivized to participate with any Northern Pike they capture which increases the information that can be collected regarding overall harvest.

Floy Tags

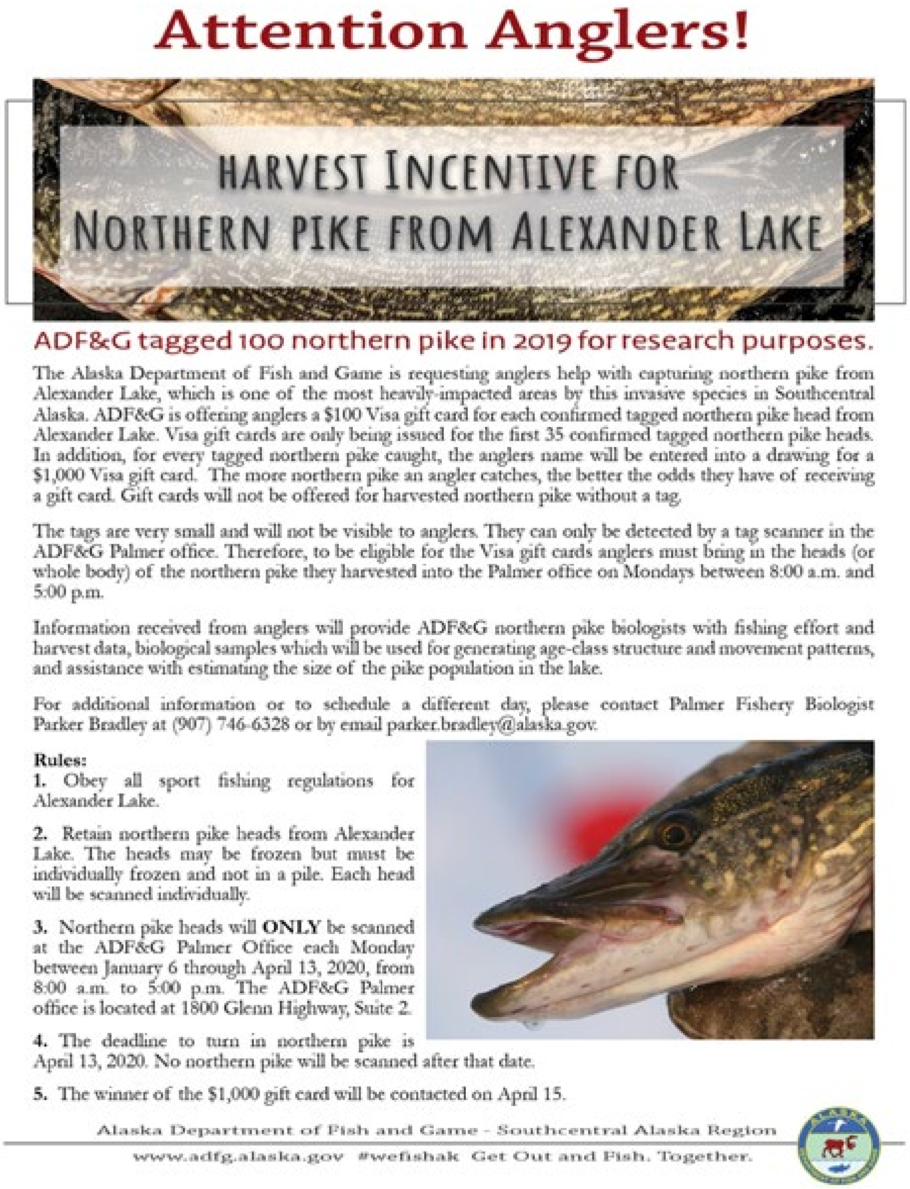
PIT Tags

SOP14.1. Images of Floy Tags and PIT Tags

SOP14.2. Inserting a PIT tag in the cheek of a Northern Pike

The number of tags deployed in the Northern Pike population should be high enough that tag returns are anticipated, but not so high that number of returned tags would exceed the program budget. For example, for the Alexander Lake incentive program, 93 Northern Pike were tagged which was estimated to be 1-3% of the population. For every 100 Northern Pike turned in, it was estimated there would be 1-3 tags. Of the 499 Northern Pike captured and brought in for tag scanning, 13 had tags (tag rate of 2.6%). There are various ways to assess the success of the program, primarily by using the information collected from anglers. A suite of questions can be asked of each angler participating such as: fishing effort and if they would have fished as long, or at all, without the program. This helps determine how much additional harvest occurred because of the program. Additionally, final cost per fish removed can be easily determined and compared to other removal efforts and costs. This will help determine if it indeed makes financial sense to continue, or if adjustments should be made to the incentive program.

Rules of the program should be clearly stated so anglers are aware of what they need to do to participate. Specific locations and times should be identified and clearly expressed where anglers can submit tags and captured fish. Finally, it should be well advertised to maximize public participation. For example, flyers such as in the example provided in SOP14.3 advertising the program should be posted on social media and in sporting goods stores, agency information offices, etc. to increase reach for acquiring participants.



SOP14.3. Example flyer advertising Alexander Lake angler incentive program

Considerations:

- The reward for tagged Northern Pike should be carefully considered. It should be of enough value that anglers have an incentive to participate, but also within budget limitations. Additionally, the source of the funding is critical to consider, and rewards originating from federal funds are generally prohibited. The entity conducting the program should ensure an appropriate funding source is used.
- When ADF&G conducted the angler incentive program on Alexander Lake, prepaid Visa gift cards were awarded to anglers who participated and captured a tagged Northern Pike. These cards were purchased with state funds and because they could be used anywhere that accepted credit cards, there was no vendor preference by the state.

Appendix 1: Funding Guidance

Grant	Source	Proposals Due	Award Range	Match Requirement	Project Focus
AK Sustainable Salmon Fund (AKSSF)	NOAA	June	> $30,000	35%	Eradication
www.aksstf.org/CFP/					
Aquatic Nuisance Species Task Force (ANSTF)	USFWS	N/A	Varies	N/A	Appropriation to states for invasive species work
Aquatic Nuisance Species Task Force | U.S. Fish & Wildlife Service (fws.gov)					
Multiple Grants Available	National Fish and Wildlife Foundation (NFWF)	October	$50,000 - $200,000	50%	Suppression, Eradication, Research
Apply for a Grant | NFWF					
State Wildlife Grants (SWG)	Federal Aid/ USFWS	N/A	Varies	N/A	Appropriation to implement state Wildlife Action Plan
State Wildlife Grants | U.S. Fish & Wildlife Service (fws.gov)					
Dingell-Johnson (DJ) Sport Fish Restoration	Federal Aid/ USFWS	N/A	Varies	N/A	Appropriation to enhance recreational fisheries
Sport Fish Restoration | U.S. Fish & Wildlife Service (fws.gov)					
Mat-Su National Fish Habitat Partnership	National Fish Habitat Partnerships (NFHP)/ NOAA	September	Up 50 $75,000	50%	Outreach, Suppression, Eradication, Research
Mat-Su Basin Salmon Habitat Partnership – Working for thriving fish, healthy habitats, and vibrant communities in the Mat-Su Basin (matsusalmon.org)					
Kenai National Fish Habitat Partnership	National Fish Habitat Partnerships (NFHP)/ NOAA	September	Up to $75,000	50%	Outreach, Suppression, Eradication, Research
Kenai Peninsula Fish Habitat Partnership – A conservation partnership on the Kenai Peninsula, Alaska (kenaifishpartnership.org)					
Environmental Biology	National Science Foundation (NSF)	Varies	Up to $250,000	N/A	Research
Division of Environmental Biology (DEB) | NSF - National Science Foundation					
Integrative Organismal Systems	National Science Foundation (NSF)	Varies	Up to $250,000	N/A	Research
Division of Integrative Organismal Systems (IOS) | NSF - National Science Foundation					
BIA Invasive Species Program	Bureau of Indian Affairs (BIA)	January	$2,500 - $250,000	N/A	Invasive Species on Tribal Lands
Invasive-species-program.pdf (nafws.org)					
General Restoration	Exxon Valdez Oil Spill (EVOS)	March	Varies	N/A	Habitat restoration on lands and waters in the Exxon Valdez oil spill area
Invitations for Proposals - Exxon Valdez Oil Spill Trustee Council (state.ak.us)					

Appendix 2: AKISP Northern Pike Committee Support Letter for Grant Applicants

(File included in the plan supplemental materials)

AKISP
ALASKA INVASIVE SPECIES PARTNERSHIP

Date

Attention
Address

Greetings,

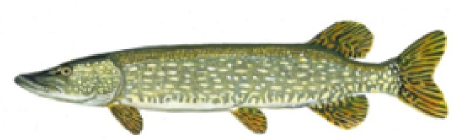
On behalf of the Alaska Invasive Species Partnership, Invasive Northern Pike Committee, we would like to share our support for the proposed project entitled "Project Title" submitted by List PIs and Affiliation(s). As a collaborative partner on invasive northern pike management in Southcentral Alaska, PIs and/or Affiliation has made significant contributions to the conservation of salmonids and other native fish in Alaska through their (Describe past project accomplishments).

This proposed project aims to (Describe proposed project goals).

We believe this project will be invaluable to the mission of the AKISP Invasive Northern Pike Committee's work: to protect and restore the ecological and economic interests of Alaska from invasive northern pike. Further, this plan aligns with the goals and objectives of AKISP's Management Plan for Invasive Northern Pike in Southcentral Alaska. We enthusiastically endorse this proposal for funding through (Name funding source) and thank you for your consideration of their proposal.

Respectfully,

Kristine J. Dunker, Chair
Invasive Northern Pike Committee
Alaska Invasive Species Partnership



Appendix 3: Cooperative Agreement Template

Alaska Dept. of Fish and Game
Cooperative Agreement Request (COOP)

Cooperative agreements (SOP iii-320) are **project specific** agreements between agencies in which specific **project** related stipulations, conditions, or arrangements are agreed upon. A COOP is distinguished from a professional service contract in that both parties provide some level of effort, although not necessarily equal, and both parties receive some benefit, either directly or indirectly.

Authority comes from Alaska Statutes (AS) 16.05.050(12) "to enter into cooperative agreements with agencies of the federal government, educational institutions, or other agencies or organizations, when in the public interest, to carry out the purposes of this title."

Cooperative Agreements cannot be used to circumvent the procurement process.

Reference Number (assigned by DAS)
Date Required Division Pick one
Encumbrance (GAE) Number Federal or Grant Funded ☐ YES %
(If applicable, attach a Subrecipient/Vendor Determination form) Financial Coding:

Title of Cooperative Project	ADF&G Project Leader Primary Point of Contact
Name and Address of Cooperator City State Zip Phone Email	Cooperator Project Leader Name Phone Email Cooperator's Authorized Signatory (Mandatory) Name Phone Email

What is the anticipated term of the COOP? From: to: normally 3-5 years if applicable.

Do you anticipate annual renewals? if yes how many? *annual renewals are discouraged due to administrative requirements

What is the total cost to ADF&G for this COOP?

Cooperative Agreements which involve any expenditure by ADF&G must be deemed exempt from the Alaska Procurement Code or the project is standard contract and must follow the procurement rules regarding bidding and or single source requirements.

Which Specific Exemption are you claiming for this COOP?

- ☐ AS 36.30.850.b(20) research projects funded by money received from the federal government or private grants.
- ☐ AS 36.30.850.b(30) contracts with a regional development organization as defined by AK DCED.
- ☐ AS 36.30.850.c contracts with other government agencies.
- ☐ AS 36.30.850.d complying with the terms of a grant, gift, bequest, cooperative agreement, or federal assistance agreement.
- ☐ Other; please describe:

Division Approval

15. DIVISION APPROVAL NAME	
DIVISION APPROVAL TITLE	Date

1

Alaska Dept. of Fish and Game
Cooperative Agreement Request (COOP)
Page 2

Please describe the purpose of this agreement in several paragraphs.

What are your detailed project objectives?

Please provide a list of tasks, equipment, labor, deliverables, or other efforts that ADF&G is contributing to the project.

Please provide a list of tasks, equipment, labor, deliverables, or other efforts that the cooperator is contributing to the project.

Please document any additional Scope of Work items

Please provide name, phone and email for any additional contacts you would like documented in the agreement. (Financial (AP/AR), etc.)

If this agreement is federally funded or a subaward please provide a detailed description of the fund source. for example, Grantor, CFDA#, % Fed / % Fish Game, Fed award ID number (FAIN) and any other pertinent information.

Financial Considerations – If this is a simple payment for work performed contract, please provide your payment terms below. If the payment terms are detailed, then please attach a spreadsheet showing the project budget and milestones.

Please submit this form in *.doc format along with the following as applicable to dfg.contracting@alaska.gov

- Any proposals from the Cooperator
- Funding information or Grant Backup
- Subrecipient/Vendor Determination form
- Indirect Cost Agreements from the Cooperator
- Any other pertinent information

Appendix 4: Training and More Information Links

Plan Partners:
Home Page, Alaska Department of Fish and Game
Alaska | U.S. Fish & Wildlife Service (fws.gov)
Home | Cook Inlet Aquaculture Association (ciaanet.org)
Tyonek Tribal Conservation District | Tyonek Tribal Conservation District (ttcd.org)
Home Page - Kenai Watershed Forum
Adam Sepulveda, Ph.D. | U.S. Geological Survey (usgs.gov)
Peter Westley | College of Fisheries and Ocean Sciences (uaf.edu)
Matthew Wooller | College of Fisheries and Ocean Sciences (uaf.edu)
Jeffrey A. Falke | Institute of Arctic Biology - Faculty (uaf.edu)
J. Andrés López | College of Fisheries and Ocean Sciences (uaf.edu)
Patrick Tomco, Ph.D. | Department of Chemistry | University of Alaska Anchorage

Hazard Analysis Critical Control Point Planning:
HACCP Training Information
Link to HACCP Template

Rotenone/ Pesticide Certification:
DEC Certified Pesticide Applicator Training Information
Planning & Executing Successful Rotenone & Antimycin Projects | American Fisheries Society
Search Tool for Current Certified Applicators
Rotenone Stewardship Program (fisheries.org)

eDNA:
Guidance on the Use of Targeted Environmental DNA (eDNA) Analysis for the Management of Aquatic Invasive Species and Species at Risk (westernregionalpanel.org)
Environmental DNA - Smith-Root

Interactive Maps:
Alaska Fish Resource Monitor (arcgis.com)
http://www.adfg.alaska.gov/SF_Lakes/
Invasive Northern Pike in Southcentral Alaska (arcgis.com)

Lower 48 Northern Pike Management:
Economics of the Northern Pike Invasion in the Columbia River Basin.pdf (nwcouncil.org)
Northern Pike | Washington Department of Fish & Wildlife
Kalispel Tribe of Indians - Northern Pike Suppression - UCUT
Northern Pike Invade Upper Columbia River (nwcouncil.org)
Risk-Assessment-and-Northern-Northern Pike-Suppression-in-the-Lower-Columbia-Rive....pdf (syilx.org)

Other Relevant Management Plans:
Alaska aquatic nuisance species management plan
Management Plan for Invasive Northern Pike in Alaska **
https://www.maine.gov/dep/water/invasive species/rrp_part2final.pdf (Maine Rapid Response Protocol for AIS Fauna (Appendix B, Table 2.B.1)**
** See for detailed descriptions of other management techniques not considered in this document

Appendix 5: Supplemental Materials List

These materials are available on the thumb drive provided to plan partners with the digital document. To request a drive, contact Kristine Dunker at: kristine.dunker@alaska.gov.

SECTION 1.2: Outreach

- Northern Pike Image Library

SECTION 3.5 Response Guidance

- Invasive Northern Pike Situation Assessment Form
- Response Framework Form

Prioritization Process for New Projects:

- Project Scoring Matrix for Prioritization

SOP1: Data Collection for Early Detection Surveys and Monitoring:

- Field Data Sheets for Invasive Northern Pike Surveys and Monitoring
- Gillnetting and eDNA Effort Calculator
- Database for Northern Pike Surveys

SOP3: eDNA Use for Early Detection Surveys:

- eDNA Reporting Template (Abbott et al. 2021)
- Gillnetting and eDNA Effort Calculator
- Gillnetting and eDNA Effort Calculator Methods Description
- Smith Root Backpack eDNA Sampler Instruction Manual
- Database for Northern Pike eDNA Surveys

SOP7: Rotenone Use for Northern Pike Eradication

- Rotenone Training Materials

SOP12: Data Collection During Northern Pike Suppression:

- Field Data Sheets for Invasive Northern Pike Suppression Projects
- Database for Northern Pike Suppression Efforts

Appendix 2:

- Grant Support Letter
- Funding Guidance Table

Appendix 4:

- ADF&G Guidance on Cooperative Agreements vs. Memorandums of Understanding
- Cooperative Agreement Form for ADF&G

Literature Cited:

- PDFs of Citations

Revisions:

- Spreadsheet for submitting comments and suggestions for future plan revisions

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