

Ruffe Control Program- Summary of Actions Report, 2023

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Prepared on behalf of partners and contributors to the Ruffe Control Program

Prepared for the National Aquatic Nuisance Species Task Force

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Introduction

“The Eurasian Ruffe (*Gymnocephalus cernua*), [hereafter referred to as “ruffe”] a Eurasian fish of the perch family, was introduced to North America in the 1980's, most likely through the ballast water of an oceangoing vessel from a Eurasian port (Pratt et al. 1992) (Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS) 2023). Ruffe larvae were first collected in Duluth Harbor in 1986. By 1990, ruffe were the most abundant fish in samples taken from the harbor, and their abundance continued to increase until 1995 (Edwards 1995).” (Ruffe Control Committee 1996). Since then, ruffe populations have remained stable, and even declined, in the Saint Louis River Estuary (SLRE) (Gutsch, dissertation 2017; Mike Seider, personal communication, United States Fish and Wildlife Service (USFWS) Ashland, January 2024).

The invasion of ruffe in the Great Lakes sparked a multiagency, international collaboration effort to control and mitigate their spread through the Great Lake basin. In 1991, the Great Lakes Fishery Commission (GLFC) organized the Ruffe Task Force (RTF) to analyze the potential impact ruffe could have on North American fisheries. They concluded that “the ruffe is a serious threat and unless prompt measures are taken to prevent its further spread, the ruffe will continue to be transported or migrate to new sites in the Great Lakes and much of North America (RTF 1992).” (Ruffe Control Committee 1996).

In 1992, the national Aquatic Nuisance Species Task Force (ANSTF) determined that the situation with ruffe legally fulfilled the requirements for the creation of the Ruffe Control Committee (RCC). This committee was tasked with refining the control program, assisting in soliciting comments on the control program, identifying cooperators to conduct the control program and its actions, and provide oversight of the program should it be approved by the national ANSTF. After much deliberation, and solicitation and addressing of comments, the Ruffe Control Program (RCP) was formally published in 1996. Unfortunately, by the time this program was published, ruffe had already spread along the southern shoreline of Lake Superior and had established populations in Lake Huron. The idea of eradication was no longer feasible, and management strategies shifted to containment and slowing any further spread (RCC 1996).

This program identified eight (8) objectives Great Lakes partners needed to address to contain the spread of ruffe: 1) population reduction, 2) ballast water management, 3) population investigation, 4) surveillance, 5) fish community management, 6) education, 7) bait fish management, and 8) Chicago Sanitary and Ship Canal. The program also identified eleven (11) research needs that would provide necessary information for managers to effectively control Ruffe: 1) distribution of ruffe, 2) environmental determinants, 3) effects of ruffe colonization, 4) characterization of ruffe genetics, 5) chemical control measures, 6) attractants and repellants, 7) ballast water management, 8) biological control, 9) characteristics of ruffe in baitfish commerce, 10) dispersal barrier in the Chicago Sanitary and Ship Canal, and 11) ecological theory for fish community resilience in the face of ruffe invasion and colonization (RCC 1996).

Over the last 37 years since the invasion of ruffe in Duluth Harbor, Minnesota (MN), and most notably in the last 27 since the implementation of the RCP, state, provincial, tribal, and federal governments in conjunction with other partners, have taken actions to address each of the objectives and research needs outlined in the control program. In 1997, Tom Busiahn summarized the management of ruffe up to that point and concluded that “the focus of ruffe control is now likely to shift to preventing their spread to the inland lakes and Mississippi River system” (Busiahn 1997). However, there has been no

summary report since. This document is an attempt to compile and summarize actions since the ruffe invasion in 1986 through a library search, literature review, partner contributions, interviews and consultation with representatives of each agency. Though this document may never encompass 100% of every action taken, it is an exhaustive summarization meant to capture the facts of key actions that address each of the program's objectives and research needs.

Objectives

Objective 1: Population Reduction

Eliminate or reduce reproducing populations, using appropriate technologies, where feasible.

Background

The purpose of this objective was to identify vulnerabilities in the existing ruffe populations and act upon them to reduce or eradicate them. It was suggested that this may be done through the use of physical, chemical, or biocontrol methods. Fishery agencies were encouraged to pursue research projects to develop and test physical and chemical methods of efficiently and selectively removing ruffe with minimal impact on the rest of the fish community. State agencies had the authority to decide if piscicide treatments were to occur within their jurisdictions, in consultation with affected Native American tribes. The USFWS was instructed to assist the States with conducting and assessing treatments, if they occurred. In addition, researchers were encouraged to seek new methods to selectively kill ruffe, even by means of parasites or pathogens.

In addition to actions related to direct physical population reduction, there have been many actions indirectly related to population reduction, some of which may overlap with other objectives but have been incorporated under "Population Reduction", including rapid response protocols, action plan initiatives, and state management plans and goals.

Actions

Michigan

In 1996, Michigan Department of Environmental Quality (MDEQ) published the Michigan Nonindigenous Aquatic Nuisance Species State Management Plan (MDEQ 1996). This report identified Ruffe as an aquatic nuisance species (ANS) in Michigan (MI) waters, and at an estimated \$24-214 million annual cost of damage to Great Lakes fisheries (Leigh 1998), identified ruffe as an important topic for discussion for interstate and interagency management committees. Multiple actions were laid out to be taken by the state of MI, including the exploration and development of an interstate decision-making protocol for ANS management, encouraging interstate decision-makers to develop a specific protocol in the Great Lakes for controlling ruffe. For more information, refer to this report (MDEQ 1996).

In 2002, this plan was updated and published by Michigan's Office of the Great Lakes (MOGL) (an office of MDEQ) as Michigan's Aquatic Nuisance Species State Management Plan Update: Prevention and Control in Michigan Waters (MOGL 2002). This report was a cooperative effort between MDEQ, Michigan Department of Natural Resources (MIDNR), and Michigan Department of Agriculture and Rural Development (MDARD). It provided an update on the activities and goals by the State of Michigan since the previous report in 1996. These updates included pre-invasion assessments of Lake St. Clair in the Huron-Erie corridor to determine the impacts of ruffe on the fish community, though to date, Ruffe have

not invaded Lake St. Clair. In addition, the actionable items were updated to address the next steps in ANS and ruffe management. Though many actions were identified for ANS, three actions included language specific for ruffe: 1) addressed preventing the spread of ruffe through education, 2) called for managers to ensure ruffe are not distributed as baitfish, and 3) ensured Michigan's continued support of USFWS efforts to encourage and foster voluntary compliance with the ruffe control activities on Lake Superior. For more information, refer to this report (MOGL 2002).

This plan was updated once more in 2013 and published by MDEQ as Michigan's Aquatic Invasive Species State Management Plan 2013 Update. It was a cooperative effort between MDEQ, MIDNR, MDARD, and Michigan Department of Transportation (MDOT) and approved by the ANSTF. It outlined three goals related to ruffe management including: 1) limiting the dispersal of established ruffe populations throughout Michigan waters, 2) development of a statewide interagency early detection and rapid response (EDRR) program to address new invasions, and 3) managing and controlling ruffe to minimize the harmful environmental, economic, and public health effects resulting from established populations. For more information, refer to this report (MDEQ 2013).

In 2014, the Michigan Invasive Species Program published the Status and Strategy for Eurasian Ruffe Management, which provided in-depth information about ruffe in MI, including identification, distribution, management, and control options. In this report, MI mentions that containing the spread of ruffe is a top priority for the state. It highlights that natural resource agencies in all Great Lakes states and Ontario have made it illegal to transport ruffe, or harvest baitfish from ruffe-infested waters. This report identifies physical, biological, and chemical means for controlling ruffe, though more data is needed to determine the effectiveness of these options. For more information, refer to this report (Michigan Invasive Species Program 2014).

Communication with MIDNR (Lucas Nathan, Seth Herbst, personal communication, July 2023) confirms that MIDNR has focused on preventing the spread of ruffe in MI waters as part of a pathway-focused approach as specified in the Aquatic Invasive Species State Management Plan (MDEQ 2013).

Minnesota

Beginning in 1993, the Minnesota Department of Natural Resources (MNDNR) published annual Exotic Species Reports. These reports, mandated by the Minnesota State Legislature, provided an update on the status of exotic species in Minnesota (MN) waters. At the end of each of these reports, there is a section dedicated to ruffe status and management. For more information, refer to these reports, accessible through the MNDNR website (www.dnr.state.mn.us).

In 1998, the MNDNR published the Nonindigenous Fish in Inland Waters: Response Plan to New Introductions (Hirsch 1998). This plan describes the actions and goals to prevent invasive species, such as ruffe, from entering inland waters. For more information, refer to this report (Hirsch 1998).

Minnesota Invasive Species Advisory Council (MISAC) published A Minnesota State Management Plan for Invasive Species in 2009. This report outlines the strategic plan for managing invasive species in MN and identifies four desired outcomes and action items for each: 1) prevention, 2) EDRR and containment, 3) management of invasive species, and 4) leadership and coordination. For more information, refer to this report (MISAC 2009).

This plan was updated in 2022, when MISAC published A Minnesota Management Plan for Invasive Species (2022). This states the continued importance of controlling invasive species, including ruffe, and updates the action items of the four goals outlined in the previous plan (MISAC 2009). For more information, refer to this report (MISAC 2022).

Minnesota DNR's website page describing ruffe

(<https://www.dnr.state.mn.us/invasives/aquaticanimals/ruffe/index.html>) states "There is no known effective population control for ruffe in natural water bodies at this time, therefore, efforts are focused on preventative strategies". This highlights the measures taken by the Great Lakes states to implement preventative measures rather than direct removal efforts of established populations.

Communication with MNDNR (Deserae Hendrickson, Doug Jensen, personal communication July, August 2023) confirms that a majority of the ruffe management conducted by the MNDNR falls within their standard fisheries assessments and there has been no direct removal efforts of ruffe conducted by MNDNR.

Wisconsin

In 2003, Wisconsin Department of Natural Resources (WDNR) in cooperation with University of Wisconsin Sea Grant (WISG) and Great Lakes Indian Fish and Wildlife Commission (GLIFWC) published Wisconsin's (WI) Comprehensive Management Plan: To Prevent Further Introductions and Control of Existing Populations of Aquatic Invasive Species. Within this report, as is similar to other Great Lakes states, there is no specific management plan implemented to reduce ruffe populations, and although there have been considerations to chemical/piscicide control methods, those have never been implemented due to the negative impact on native and non-target species (WDNR 2003). For more information, refer to this report (WDNR 2003).

Communication with WDNR (Paul Piszczek, Dray Carl, personal communication, July 2023) confirms that although there have been historical assessments of ruffe population dynamics, there has been no direct removal efforts targeting ruffe by the WDNR.

Illinois

Illinois Department of Natural Resources (ILDNR) and Illinois-Indiana Sea Grant (IISG) published Illinois State Comprehensive Management Plan for Aquatic Nuisance Species in 1999. This report references several papers related to ruffe competition with native species and proposes an electric barrier in the Chicago Area Waterways System (CAWS) to prevent ruffe from entering the Mississippi River. For more information, refer to this report (Horner et al. 1999).

In 2014, there was a positive environmental DNA (eDNA) detection of ruffe in Calumet Harbor, Illinois (IL), Lake Michigan. This prompted activating the Great Lakes Mutual Aid Agreement for Aquatic Invasive Species for the first time since it was signed in 2014 (Council of Great Lakes Governors 2014). Response teams from ILDNR, Indiana Department of Natural Resources (INDNR), United States Geological Survey (USGS), Illinois Natural History Survey (INHS), USFWS, United States Army Corp of Engineers (USACE), MNDNR, MIDNR, GLFC, and Chicago Park District conducted sampling in Calumet Harbor from May 27 – May 29, 2014. This rapid response effort resulted in no ruffe detected, and to this day, there have been no ruffe recorded in IL waters (Irons and Newcomb 2014).

Communication with IL DNR (Kevin Irons, personal communication, July 2023) confirms that outside of prevention and rapid response efforts, there has been no effort to directly reduce or manage ruffe in IL waters due to ruffe being absent in any IL waters.

Indiana

In 2004, INDNR published the Indiana Aquatic Nuisance Species Management Plan. This plan describes the management of several ANS, including ruffe. It identifies seven goals for managing ANS, such as ruffe: 1) coordinate all efforts among agencies and organizations both within IN and with other states and nations to manage ANS, 2) prevent new introduction of ANS into Lake Michigan and Mississippi River basins of IN, 3) conduct monitoring programs to enhance early detection of introductions or invasions, 4) institute rapid response objectives to limit the cost of controlling new introductions, 5) limit the spread of established populations of ANS into uninfested waters of the state, 6) mitigate harmful ecological, economic, social, and public health impacts resulting from infestations of ANS, and 7) evaluate the effectiveness of the plan and use adaptive management strategies to update the plan during the initial implementation and after the five-year period of use. Each of these seven goals has specific objectives and action items attached to each. For more information, refer to this report (INDNR 2004).

In 2020, INDNR published the updated version of the previous plan as the Indiana Aquatic Invasive (AIS) Management Plan 2020. This plan consolidated the previous goals into three goals related to ruffe: 1) prevent new introductions and spread of established ruffe into Indiana waters, 2) conduct monitoring programs to enhance early detection of introductions or invasions, and 3) institute rapid response objectives to limit delays, confusion, and costs of controlling new introductions. For more information, refer to this report (INDNR 2020).

Communication with INDNR (Eric Fischer, personal communication September 2023) confirms that management surrounding ruffe in IN waters is targeted towards prevention rather than reduction, as ruffe remain absent in IN waters.

Ohio

Ohio Department of Natural Resources (OHDNR) published the Ohio State Management Plan for Aquatic Invasive Species in 2014. This plan states that although ruffe are not present in Ohio (OH) waters, it is a potential invader and is included in the five strategic goals this plan outlines. These goals encompass: 1) leadership, 2) prevention, 3) EDRR, 4) control and management, and 5) research and education. For more information on these goals and this plan, refer to this report (OHDNR 2014).

Communication with OHDNR (John Navarro, personal communication, July 2023) confirms that there has been no direct population reduction of ruffe in OH due to ruffe being absent in OH waters, and instead, efforts have emphasized prevention.

New York

In 2015, New York Department of Environmental Conservation (NYDEC) published the New York State Aquatic Invasive Species Management Plan. This plan, although not directly removing ruffe, identifies more than 50 actions to be taken to prevent aquatic invasive species (AIS), including ruffe, from spreading to New York (NY) waters. These actions include prevention, detection, and response actions to be taken in education and outreach, leadership, coordination, research, information, and regulatory/legislation. For more information, refer to this report (NYDEC 2015).

In 2018, NYDEC published the New York State Invasive Species Comprehensive Management Plan. This plan includes both aquatic and terrestrial invasive species and the framework is structured around eight initiatives: 1) continue to build partnerships and capacity, 2) commit to a centralized framework for sharing invasive species information, 3) set priorities for invasive species management and advance preparedness, 4) engage and inform the public, 5) advance prevention and early detection, 6) improve the response to invasive species, 7) recover ecosystem resilience, and 8) evaluate success. Through this framework, NYDEC strengthens its ability to respond and manage invasive species, including ruffe, though to date, ruffe have not been detected in NY waters. For more information, refer to this report (NYDEC 2018).

Funded by the New York State Environmental Protection Fund, the Invasive Species Grant Program increases NYDEC's ability to reduce the impact of invasive species, including ruffe, by partnering with municipalities, non-profits, and academic institutions to fund projects aimed at control, removal, research, and prevention. Since 2016, this program has funded more than \$6.5 million and partnered with 114 groups. For more information, visit their web page (<https://www.dec.ny.gov/animals/115742.html>).

Communication with NYDEC (Cathy McGlynn, Steve Pearson, personal communication September 2023) confirms that NY has focused management on prevention since ruffe remain absent in NY waters.

Pennsylvania

In 2006, the Pennsylvania Aquatic Invasive Species Management Plan Committee (PAAISMPC) published the Commonwealth of Pennsylvania: Pennsylvania Invasive Species Council Aquatic Invasive Species Management Plan. This plan was prepared for the Pennsylvania Invasive Species Council (PISC) and included representatives from the Pennsylvania Fish and Boat Commission (PFBC), Pennsylvania Department of Environmental Protection (PADEP), Pennsylvania Department of Agriculture (PADA), Pennsylvania Department of Conservation and Natural Resources (PADCNR), University of Pennsylvania, The Nature Conservancy (TNC), Pennsylvania Landscape and Nursery Association, Tilley's Nursery, and Pennsylvania Sea Grant (PASG). Though ruffe have never been found in Pennsylvania (PA) waters, this plan outlines eight objectives aimed at the management and prevention of AIS, including ruffe. For more information, refer to this report (PAAISMPC 2006).

Communication with Pennsylvania Fish and Boat Commission (PFBC) (Sean Hartzell, Kris Kuhn, personal communication, October 2023) confirms that PA has focused management on prevention, as ruffe remain absent in PA waters.

Ontario Ministry of Natural Resources and Forestry

Ontario Ministry of Natural Resources and Forestry (OMNRF) published their Invasive Species Strategic Plan in 2012 which identified four goals: 1) prevent, 2) detect, 3) respond, and 4) manage/adapt, and key actions, both in leadership and in policy, for each to manage invasive species, including ruffe. This plan helped build upon the existing framework for preventing and managing new and current invasive species. For more information, refer to this report (OMNRF 2012).

In 2022, Ontario's Invading Species Awareness Program, which is a partnership of the OMNRF and the Ontario Federation of Anglers and Hunters (OFAH) released their Angler Action Plan and Boater Action Plan. These plans highlight current laws and suggest actions, such as cleaning out a live well when moving to new water bodies, anglers and boaters can take to prevent the spread and introduction of

invasive species, including ruffe. For more information, refer to these reports (Ontario's Invading Species Awareness Program 2022a, 2022b).

Communication with OMNRF (Fritz Fischer, personal communication, August 2023) confirms that a majority of the management for ruffe has gone into prevention of further spread rather than direct population reduction.

Department of Fisheries and Oceans Canada

Communication with Department of Fisheries and Oceans Canada (DFO) (Dave Marson, Lisa O'Connor, personal communication, August, September 2023) confirms that although DFO conducts collaborative sampling for ruffe with OMNRF and USFWS, there is no direct management of ruffe by DFO.

National Aquatic Nuisance Species Task Force

The National Aquatic Nuisance Species Task Force, created under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (16 USC 4701-4741), has published strategic plans outlining actions that should be taken by different agencies to control invasive species, including ruffe. For more information, refer to these documents (ANSTF 2002, 2013, 2017, 2020).

Great Lakes Fishery Commission

"In 1991 the GLFC organized a special task force of fisheries biologists and administrators to evaluate the status of ruffe in the Great Lakes and to examine what threat it might pose to fishery resources" (Ruffe Control Committee 1996). This RTF published a report in 1992 called *Ruffe in the Great Lakes: A Threat to North American Fisheries*, which outlines actions and budgeting for controlling ruffe in the Great Lakes. For more information, refer to this report (RTF 1992).

In 1995, the GLFC Council of Lake Committees (CLC) made a recommendation to the national ANSTF to edit the Ruffe Control Strategy to better equip state government and other agencies for combating ruffe in the Great Lakes. This recommendation was aimed at three objectives: 1) prevent invasions of new species into the Great Lakes, 2) contain ruffe to the Great Lakes, and 3) continue to slow the spread of ruffe in the Great Lakes. There were five actions the CLC specifically recommended based on the current knowledge at the time: 1) chemical controls should not be used to control ruffe colonization of the Great Lakes because ruffe are no longer contained to Lake Superior (Lake Superior's cold, clear waters were thought to be a barrier). Efforts should instead center on preventing the spread of ruffe to inland and adjoining waters of the Great Lakes. 2) Ballast water management plans should be revised to include affected (Lake Huron) ports and should continue to slow the spread. 3) Research and assessment should focus on evaluating the impact of ruffe on fish communities. 4) Agencies should take any measure that will improve resilience of fish communities against invasion or domination by ruffe. 5) Agencies should educate the public about ruffe so that harvesters will be able to recognize, kill and report ruffe when caught. For more information, refer to this document (CLC 1995).

In 1997, the Committee of Advisors to the GLFC urged the GLFC to adopt a position to further prevent the spread of ruffe by implementing ballast water protocols for commerce on the Great Lakes. For more information, refer to this document (Committee of Advisors to the GLFC 1997).

Little River Band of Ottawa Indians

Efforts were made to consult with Little River Band of Ottawa Indians, but at the time of this writing, there has been no response in regards to ruffe management, sampling, or observations.

Grand Traverse Band of Ottawa and Chippewa Indians

Communication with Grand Traverse Band of Ottawa and Chippewa Indians (Erik Olsen, personal communication, September 2023) verifies that they have not conducted any ruffe related work, as ruffe are absent from Grand Traverse Bay.

Little Traverse Bay Band of Odawa Indians

Communication with Little Traverse Bay Band of Odawa Indians (Spencer McCormack, personal communication, October 2023) verifies that they have not conducted any ruffe related work.

Sault Saint Marie Tribe of Chippewa Indians

Communication with Sault Ste. Marie Tribe of Chippewa Indians (Jason Smith, personal communication, September 2023) verifies that they do not conduct any sort of management of ruffe, but rather collaborate with partners to implement AIS surveillance in the Saint Mary's River (SMR).

Bay Mills Indian Community

Communication with Bay Mills Indian Community (Paul Ripple, personal communication, October 2023) verifies that they do not conduct any sort of management of ruffe, but rather collaborate with partners to implement surveillance of AIS in the SMR.

Chippewa Ottawa Resource Authority

Communication with Chippewa Ottawa Resource Authority (CORA) Tribes (Tom Gorenflo, personal communication, October 2023) verifies that the CORA tribes do not conduct any direct management of ruffe, but rather collect them during non-ruffe targeted fisheries assessments.

Summary

Initially, this objective called for management agencies to research and implement control methods to directly reduce existing populations of ruffe. Though much research was conducted on physical and chemical control methods (Boogard 1996, Mayo 1998, Maniak 2000, etc.), none were found to be effective enough to control ruffe without significantly impacting native species, or requiring an unrealistic amount of effort, time, and money. Most management agencies focus their efforts on preventative strategies to slow the spread of ruffe throughout the Great Lakes basin, prevent spread to inland lakes and rivers, and effectively limit their population and impact on the ecosystem.

Objective 2: Ballast Water Management

Minimize the transport of ruffe from western Lake Superior through ballast water management and support the development of technologies to prevent transport.

Background

Commercial ships docking in Duluth, Superior, Thunder Bay, and other ports around the Great Lakes are a vector for the spread and introduction of AIS. Although some regulations had been implemented at the time of the Ruffe Control Plan, evidence still exists that ruffe were able to bypass the existing barriers and access the ballast tanks of ships, ready to be spread as the ships move from port to port. The ANSTF included this objective to build upon the existing regulations, technologies, and protocols to further prevent the spread of ruffe (along with other invasive species) through the ballast water of ships.

Actions

After the discovery of ruffe in Duluth Harbor, MN (Lake Superior) in 1986, Canada, the U.S., and other regulatory authorities administered additional ballast water regulations and protocols for commercial ships moving to, from, and within the Great Lakes.

In 1989, Canada established voluntary guidelines requesting all vessels entering the freshwaters of the St. Lawrence Seaway and the Great Lakes to perform ballast water exchanges at sea prior to entering. The idea behind this was that freshwater organism, which would have survived in the Great Lakes, would be dumped out at sea and die before reaching the freshwater of the Great Lakes. Any organisms taken into the ballast tanks of these ships at sea, would not be able to tolerate the freshwater of the Great Lakes and die when exposed to the freshwater (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

In 1991, the United States and Canada adopted joint voluntary guidelines for controlling ballast water in the Great Lakes for “each ship that carries ballast water and that, after operating on the high seas, is inbound for the Saint Lawrence River” (56 FR 11331). The ballast water management requirements included ballast water exchange as well as other general practices and compliance monitoring tools, such as recording ballast water exchange in the ship’s logbook and completing a Ballast-Water Exchange Report Form.

In 1993, the U.S. Coast Guard (USCG) promulgated regulations for oceangoing ships entering the Great Lakes. All ships thereafter must conduct ballast water exchange at sea prior to entering the St. Lawrence Seaway, which was enforced by inspection and testing of ballast water salinity by the U.S. and Canada Coast Guards (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023, 59 FR 18334).

In addition, in 1993 the Great Lakes Maritime Industry implemented the Voluntary Ballast Water Management Practices to specifically assist with control of Ruffe in Lake Superior ports. This voluntary ballast water management practice (BMP) called for minimizing the use of ballast water in Lake Superior, and if possible, conduct ballast water exchange in specific open water zones of the lake, in the hopes that any ruffe that made their way into the ballast tanks, would perish when dumped out in the open water of Lake Superior (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023). However, it should be noted that most lakercs (ships operating specifically within the Great Lakes) are not designed to conduct ballast water exchange.

In 2002, the St. Lawrence Seaway Requirement was put into place. This required all foreign flag ships entering the seaway to 1) comply with the current ballast water management plans, and 2) comply with all voluntary management practices (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

In 2004, the USCG promulgated the National Mandatory Ballast Water Requirements (69 FR 44952). This regulation required all oceangoing ships entering the Great Lakes to maintain a ballast water management plan (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

In 2005, the USCG No Ballast on Board (NOBOB) Ballast Best Management Practices were established, requiring all oceangoing vessels entering the Great Lakes to raise the salinity of their tanks, whether

pumpable or not, to at least 30 parts per thousand (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

In 2006, the Ballast Water Working Group was created, with representatives from the USCG, Transport Canada, Marine Safety, St. Lawrence Seaway Development Corporation, and the St. Lawrence Seaway Management Corporation. The purpose of this working group was to 1) assess and improve upon current ballast water management practices, and 2) coordinate compliance and enforcement of regulations to reduce AIS impacts due to ballast water (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023). During this time, Transport Canada issued a new regulation requiring all international vessels with NOBOB entering the St. Lawrence Seaway from beyond the Exclusive Economic Zone to engage in salt water flushing of ballast tanks.

In March 2008, the St. Lawrence Seaway Development Corporation, in coordination with the USCG, implemented a matching regulation requiring salt water flushing on inbound NOBOB vessels, requiring all oceangoing ships to conduct salt water flushing of their tanks at least 200 miles offshore. This would ensure that any organisms dumped at sea would not make their way into the St. Lawrence Seaway (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

Also in 2008, the U.S. Environmental Protection Agency (USEPA) finalized the Vessel General Permit (VGP), which required vessels to implement the USCG regulations in 33 CFR 151 and follow specific BMP's. The 2008 permit included specific requirements for individual states as part of the Clean Water Act Section 401(d) certification (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

In 2012, the USCG promulgated regulations that separated 33 CFR 151 into two subparts: 'C' for the Great Lakes and Hudson River and 'D' for waters of the United States. These regulations also included ballast water discharge standards but excluded vessels that exclusively operating in the Great Lakes (lakers) were exempt from the ballast water discharge standards.

In 2013, the USEPA published the follow-up 2013 VGP and continued the ballast water discharge standard exemption for lakers built before January 1, 2009, but included a requirement for new lakers to meet the discharge requirements. The 2018 VGP also continued mandatory BMPs.

In 2018, Congress passed Vessel Incidental Discharge Act (Title IX of the Frank LoBiondo Coast Guard Authorization Act of 2018) to establish uniform requirements for vessel discharges in the U.S. The USEPA was tasked with establishing the standards of performance, and then the USCG would establish the implementation regulations. In October 2020, the USEPA proposed the standards of performance for approximately 20 discharges, including ballast water (85 FR 67818). In October 2023, the USEPA published a supplemental notice on additional considerations for a few discharges, including existing laker continuing to be exempt from the discharge standards due to issues with the available technology. The USEPA has entered a consent to promulgate the standards of performance by fall 2023. The USCG cannot develop the implementation regulations until the USEPA has published the final standards of performance.

In 2021, Canada established the New Canadian Ballast Water Regulations SOR/2021-120, placing additional regulations on ballast water management in Canadian waters (Lake Superior Binational Program 2014, Great Lakes Seaway Ballast Water Working Group 2023).

The BMPs put in place for oceangoing vessels and lakerees have been successful. Ruffe have only been observed in Michigan, Minnesota, and Wisconsin and contained to the upper Great Lakes (GLANSIS).

Summary

Ballast water has been identified as a key vector for AIS not just in the Great Lakes, but worldwide (Mills et al. 1993, MacIsaac et al. 2002, David and Perkovic 2004). This objective aimed to prevent any further spread of ruffe and significantly reduce the amount of AIS entering the Great Lakes by establishing and enforcing regulations and ballast water management across international boundaries. Since the initiation of the ballast water regulations, studies on this vector show a significant reduction in the invasion and spread of AIS through ballast water (Bailey et al. 2011, Ricciardi and MacIsaac 2022). No new AIS has been identified in the Great Lakes since 2006. For more information regarding each of these regulations, ballast water management plans, and other supplemental information, refer to the websites for USCG (www.uscg.mil), Canadian Coast Guard (www.ccg-gcc-gc.ca), Transport Canada (www.tc.canada.ca), USEPA (www.epa.gov), Canadian Shipowners Association (www.lobbycanada.gc.ca), the Thunder Bay Harbour Association (www.porthunderbay.ca), Shipping Federation of Canada (www.shipfed.ca), Lake Carriers' Association (www.lcaships.com), Seaway Port Authority of Duluth (www.duluthport.com), US Great Lakes Shipping Association (www.usglisa.org), and Great Lakes St. Lawrence Seaway System (www.greatlakes-seaway.com).

Objective 3: Population Investigation

Continue to expand investigations of ruffe populations to evaluate the impact on affected fish communities and to provide information necessary to plan, implement, and evaluate control activities.

Background

Ruffe share many characteristics and are often compared to the Great Lakes native yellow perch (*Perca flavescens*), as they belong to the same family, Percidae. When ruffe were first discovered in Duluth Harbor, MN, it was feared that ruffe would occupy the same niche as yellow perch and outcompete their native counterpart. Their voracious appetite would negatively impact the fish community and displace many native species. The purpose of this objective was to conduct research to better understand how ruffe impact native fish communities, which could then inform management decisions to control them.

Actions

In 1995, a study by DeSorcie and Edsall found that young of year (YOY) ruffe readily consume lake whitefish (*Coregonus clupeaformis*) eggs, negatively impacting their recruitment (DeSorcie and Edsall 1995, Selgeby 1998). An additional study by Ogle et al. in 1995 found that although ruffe readily consume eggs, they consume larger portions of benthic invertebrates and compete with benthic feeding fish, such as yellow perch and trout perch (*Percopsis omiscomaycus*) (Ogle et al. 1995). Many more studies would go on to describe ruffe as voracious egg and benthic invertebrate predators (Selgeby 1998, Kangur et al. 2000, Kolar et al. 2002, Etheridge et al. 2011, Gutsch and Hoffman 2016) who compete with yellow perch and other native (Fullerton et al. 1998, Fullerton et al. 2000, Zhang et al. 2019, Newman et al. 2020) and established non-native (Savino et al. 2007) fish species.

Although there is evidence that ruffe compete with other species in the fish community, there is also evidence that the negative impacts ruffe are having on these communities is potentially less significant than other factors, such as natural density-dependent mortality (Bronte et al. 1998, Savino et al. 2007), and in some instances, ruffe may be outcompeted by established invasive species (Bauer et al. 2007, Peterson et al. 2011).

Interactions with predatory fish suggests that biological control of ruffe may not be effective, as dietary analysis of some piscivores shows a lack of ruffe in their diet (Mayo et al. 1998).

Research has also been conducted on habitat use by ruffe in the Great Lakes, showing a mixed preference for nearshore cobble substrate and macrophyte dense areas (Brazner et al. 1998, Bauer et al. 2007). Spreading along these nearshore habitats, ruffe invasion potential was found to be very high, with the potential to invade all five Great Lakes (Sieracki et al. 2014, Beletsky et al. 2017) and the ability to establish populations from just a few individuals (Drake 2005). At an estimated cost to actively manage ruffe in the Great Lakes at forty-four (44) times that of the cost to prevent (Leigh 1998), these studies support the notion that prevention and containment is a critical element to control the ruffe invasion (Drake 2005, Beletsky et al. 2017).

Minnesota Department of Natural Resource published the St. Louis Estuary Fisheries Management Plan in 2019. This plan outlines the management strategy, starting in 2019, moving forward, for maintaining and increasing populations of Walleye (*Sander vitreus*), Northern Pike (*Esox lucius*), Smallmouth Bass (*Micropterus dolomieu*), and Lake Sturgeon (*Acipenser fulvescens*) in the SLRE, Lake Superior. Although ruffe are not a critical component of this plan, the report does state that “[ruffe] do not appear to be a threat to fish community interactions at this time as this population has established a stable population size” (MNDNR 2019). For more information, refer to this report (MNDNR 2019).

Summary

Research to determine the full impact ruffe are having on native species and Great Lakes fish communities is ongoing. Studies have shown that upper trophic level interactions may have minimal impact on population abundance of ruffe, while ruffe continue to have negative impacts on native species by consuming eggs and competing for other resources. Though the impact from ruffe may not be as significant as initially thought, their invasion has still added an additional stressor on the fish community in every part of the Great Lakes they invade. To this day, preventing further spread and containing current populations continue to be a critical element in ruffe control activities.

Objective 4: Surveillance

Conduct surveillance sampling in likely locations to find newly established populations of ruffe and designate a single office to compile collections of ruffe.

Background

Surveillance provides up to date information on the spread of ruffe through the detection of newly established populations. At the time of the original Ruffe Control Plan (1996), USFWS had initiated surveillance in western Lake Superior (Slade and Kindt 1992), which then expanded to include all the Great Lakes. Surveillance in Canadian waters was conducted by OMNRF. From 1993 to 2016, ruffe surveillance in all the Great Lakes was reported jointly (Slade et al. 1994, Slade et al. 1995, Kindt et al.

1996). The purpose of this objective was to provide the most up to date information on the whereabouts of ruffe throughout the Great Lakes to allow managers to take necessary control actions.

Actions

Targeted ruffe surveillance was conducted by USFWS from 1992 to 2012. Beginning in 2013, ruffe surveillance continued to occur in Lake Michigan and Lake Huron, though much of the traditional ruffe surveillance conducted by USFWS surveillance throughout the Great Lakes as a whole has been rolled into a comprehensive early detection and monitoring program aimed at detecting a wider range of potential AIS. Surveillance locations for this comprehensive program are based in part on results from Tucker et al. 2022, which included ruffe on the list of "historic invaders" that were used to develop weighting factors to predict AIS introduction risk around the basin (Tucker et al. 2020). Since this surveillance was initiated in 1992, ruffe have been found spreading along the southern shoreline of Lake Superior to the SMR. There have also been isolated populations found in Green Bay (WI, Lake Michigan), Bay de Noc (MI, Lake Michigan), and Thunder Bay (MI, Lake Huron), though the population in Thunder Bay has since disappeared (Anjie Bowen, personal communication, 2023). For information specific to each year, refer to the annual reports put out by USFWS.

Monitoring of ruffe in Bay de Noc has been conducted by Michigan's Inland Status and Trends Program and Great Lakes Monitoring since 2009 (michigan.gov). In 2021, the ruffe population in Bay de Noc increased dramatically. Research to determine the cause is ongoing (Zorn and Kramer 2022).

Since 2013, DFO has conducted nearshore fish community assessments in Lake Huron, Erie, and Superior. Although not targeted ruffe surveillance, these assessments would detect ruffe should they invade coastal Canadian waters of these lakes (Trisiah Tugade, personal communication, July 2023). For more information, refer to the annual reports DFO publishes.

In 1996, the Michigan Aquatic Nuisance Species Management Plan published by MDEQ included an action to expand the statewide 'Self Help' zebra mussel monitoring to include additional ANS, such as ruffe. This would empower citizens to monitor inland lakes in MI and report any ANS presence. For more information, refer to this report (MDEQ 1996).

The Great Lakes Mutual Aid Agreement, signed in 2013, encouraged further cooperative actions by Great Lakes parties and foster mutual aid among parties to collectively respond and combat serious AIS threats to the Great Lakes. For more information, refer to this agreement (Great Lakes Governors and Premiers 2014).

This collaborative response was first activated when ruffe environmental DNA (eDNA) was found in Calumet Harbor, IL (Lake Michigan) in May 2014. An interstate, rapid response was initiated, including ILDNR, INDNR, USGS, INHS, USFWS, USACE, MNDNR, MIDNR, GLFC, and Chicago Park District, where intense sampling was conducted over the course of a couple days. Ultimately, no ruffe were captured, but this event showcased the cooperative ability for agencies and states across jurisdictions to rapidly respond to Great Lakes AIS threats. No ruffe have been detected in Calumet Harbor to this day. For more information, refer to the after-action report published by ILDNR (Irons and Newcomb 2014) and the paper published by Tucker et al. 2016.

The WIDNR conducted community assessments in nearshore Lake Superior using seines from 1980 to 2014, as well as ruffe specific populations estimates in the Iron River (WI) and Sand River (WI) in 1995. For more information on these surveillance efforts, refer to the WIDNR reports (Hoff et al. 2001).

Beginning in 1989, USGS conducted bottom trawls in the St. Louis River, Lake Superior to estimate population abundance and recruitment of ruffe. These efforts continued until 2001. For more information, refer to the USGS reports (usgs.gov).

The USGS Nonindigenous Aquatic Species (NAS) database has been compiling location and catch data for ruffe in the Great Lakes since it was created in 1990. This open access database has been useful for managers across jurisdictions to stay updated on the whereabouts of the ruffe invasion through time (<https://nas.er.usgs.gov/>). The GLANSIS serves as the Great Lakes node for the NAS database (<https://www.glerl.noaa.gov/glansis/>).

Summary

Surveillance is essential for tracking the invasion front of ruffe as they have moved from western Lake Superior, across the southern shoreline, and down into northern Lake Huron and Lake Michigan. This time sensitive information has allowed managers to respond to this threat in new locations to continue to slow and contain the ruffe invasion. Surveillance efforts continue to this day.

Objective 5: Fish Community Management

Recommend fish management practices that will improve resilience of fish communities against invasion or dominance by ruffe.

Background

“The goal [of this objective] should be a functional community that sustains itself with minimal human input. Exotics that are naturalized may be a part of that community. Planning for fish community resilience should seek to define desired conditions” (Ruffe Control Committee 1996)

“Ballast water management must be improved to prevent additional colonizations, and other vectors must be effectively regulated... If stocking predators, managers should consider stocking a species that is an effective ruffe predator... Aquatic habitat should be restored and protected to foster fish community resilience. Natural fish production can be restored by re-connecting segmented river systems” (Ruffe Control Committee 1996).

By taking action to improve the health of the ecosystem and the fish species that inhabit it, the fish community should be more resilient to the ruffe invasion. This section will focus on the efforts that have been taken to improve the Great Lakes ecosystems and fisheries threatened by ruffe.

Actions

As mentioned in the original plan, biological control can be a useful tool for managers to control an invasive species as part of an integrated pest management plan (Ruffe Control Committee 1996). Prior to and during the implementation of the original plan in 1996, some studies surrounding biological control of ruffe were conducted in Lake Superior. Ultimately, it was found that even when native predator abundance (walleye, northern pike, muskellunge (*Esox masquinongy*)) was artificially increased by restricting angling pressure and stocking fingerlings and adults, these native piscivores minimally

increased their predation on ruffe, as found in stomach content analyses, even though ruffe accounted for 73-90% of the available prey biomass (Selgeby and Edwards 1995, Ogle et al. 1996, Mayo et al. 1998).

The USEPA's Great Lakes Restoration Initiative (GLRI) has been funding projects in the Great Lakes since 2010. "The Great Lakes Restoration Initiative accelerates efforts to protect and restore the largest system of fresh surface water in the world – the Great Lakes. Built upon the foundation of the Great Lakes Regional Collaboration Strategy, GLRI answered a challenge of the governors of the Great Lakes states. Since 2010 the multi-agency GLRI has provided funding to 16 federal organizations to strategically target the biggest threats to the Great Lakes ecosystem and to accelerate progress toward achieving long term goals, including 1) fish safe to eat, 2) waters safe for recreation, 3) safe source of drinking water, 4) all Areas of Concern delisted, 5) harmful algae blooms eliminated, 6) no new self-sustaining invasive species, 7) existing invasive species controlled, and 8) native habitat protected and restored to sustain native species". From 2010 to 2021, GLRI received \$3.8 billion of funding. As of March 31, 2023, 7,563 projects have been funded across 16 federal agencies. For more information on these projects and GLRI, refer directly to the GLRI website (glri.us).

Summary

Fish community management through habitat and community restoration and protection increases the likelihood that a fish community can resist invasion. Great Lakes Restoration Initiative funding has provided funding for more than 7,000 projects that increase this resiliency across the Great Lakes region and continues to fund projects to this day.

Objective 6: Education

Develop and promote information and education programs to identify ruffe so that they will not be transported alive and so that they will be killed and reported if taken.

Background

Public understanding and support is critical to the success of the Ruffe Control Program. Anglers are often the best source for identifying invasions to new areas. Increasing public awareness and knowledge is crucial in preventing further spread of ruffe. The purpose of this objective was to push state, provincial, and federal agencies to work in collaboration with the Great Lakes Sea Grant Network (GLSGN) to increase public education surrounding ruffe.

Action

By the time the original plan was published in 1996, there had been some public education actions taken, including a "Ruffe Watch" card, a field guide to exotic species (A Field Guide to Aquatic Exotic Plants and Animals - MNDNR), an aquatic invasive species ruffe poster for bait shops (GLSGN), infested [Ruffe] waters public access signs (MNDNR) and other brochures published by the GLSGN. In addition, there were signs at boat landings, information in state and provincial angling regulation pamphlets, and a poster and video, "Little Fish: Big Problems" produced by USFWS (Ruffe Control Committee 1996).

In 1996, MDEQ identified ruffe as an ANS in their Michigan ANS State Management Plan. This action added ruffe to the public bulletin program 'What Recreational Boaters and Anglers Should Know', which

provides ANS information and preventative measures to boaters registered in the state of MI (MDEQ 1996).

The GLSGN has been critical in educating the public. In 1993, the MN Sea Grant (MNSG) published the Ruffe Watch Card in partnership with USFWS that is now accessible through many program offices within the GLSGN. This watch card provides awareness, general information, preventative measures, identification, and ways for public to report new sightings (Doug Jensen, MN DNR, personal communication, August 2023).

Many Sea Grant (SG) programs, state, federal, and provincial governments, and even some private agencies, published brochures and fact sheets and included ruffe into current outreach campaigns to increase public awareness and knowledge (OMNRF-MNSG 2001, PA Sea Grant 2013, Michigan Invasive Species Program 2014, USGS 2014, Alberta Invasive Species Council 2017, WISG 2018, Ontario's Invading Species Awareness Program 2021, Iowa DNR 2023).

Traveling education trunks, curriculum and lesson plans were also developed by the GLSGN for the classroom to assist teachers in bringing AIS and ruffe awareness to the younger generations with such material as the Exotic Aquatics Traveling Trunk (MNSG 1996), Aquatic Invaders Attack Pack (WISG 2018), Nab the Invader (IISG et al. 2015), Great Lakes Aquatic Invasive Species Lesson Plan (Ohio Sea Grant et al. 2020), and Ruffe Musical Chairs (Michigan Sea Grant 2023).

Summary

The GLSGN in collaboration with government and private agencies have included ruffe into current outreach campaigns while creating new outreach targeted specifically at ruffe. These programs target a broad audience, from children to adults, professionals to recreational anglers. Educating the public will continue to play an important role in preventing the spread of ruffe throughout the Great Lakes basin. Combining this outreach material with ruffe specific fishing regulations (ruffe are currently prohibited in all 10 Great Lakes jurisdictions – Tucker et al. 2021) has engaged the public in ruffe control. The success in preventing the spread of ruffe beyond the upper lakes and to inland waters of the Great Lakes region is likely due to creation and continuation of effective public education.

Objective 7: Bait Fish Management

Assist jurisdictions in developing model language for regulation of bait harvest and possession.

Background

"The live bait industry is a potential vector contributing to the spread of ruffe" (Ruffe Control Committee 1996). The live bait industry is a large economic component to the Great Lakes fishery, estimated at \$145 million (Meronek 1997). Many of the baitfish used in the Great Lakes are wild, thus providing a potential vector for ruffe to artificially spread through this industry. At the time of the original Ruffe Control Program (1996), MN, WI, and MI had already prohibited or restricted the taking of baitfish from Lake Superior including the St. Louis River. The purpose of this objective is to allow the baitfish industry to prosper while having a zero-tolerance policy for exotic species within the baitfish trade. Many states integrated ruffe into current exotic species laws, and even implemented specific laws regarding ruffe use as baitfish, possession of ruffe, and transport of ruffe through commercial and recreational vectors.

Actions

Minnesota

In 1993, Minnesota Administrative Rules Section 6266.0600 prohibited the possession or take of ruffe during commercial baitfish harvest of minnows in MN waters (State of Minnesota 1993). Minnesota also initiated Laws of Minnesota for 1993 Chapter 235 which authorized Minnesota State Conservation Officers and Peace Officers to conduct random watercraft inspections to identify exotic species transport, whether knowingly or not, and issue citations for unlawful practices. The fine for transporting ruffe on a public road was set at \$300 (State of Minnesota 1993). In 1996, Minnesota Invasive Species Laws included Rule 6216.0250: Prohibited Invasive Species. This rule listed ruffe as a prohibited invasive species, meaning it is unlawful to possess, import, purchase, transport, or introduce this species in MN (State of Minnesota 1996). Since 1993, MNDNR have included an excerpt in the Minnesota Fishing Regulations Guide that goes out to all recreational fishing license holders stating the specific laws surrounding ruffe and the prohibited possession and transport of this species (Minnesota DNR 2023). For more information, refer directly to these laws, rules, and regulations.

Wisconsin

In 2009, WIDNR passed Chapter NR 40: Invasive Species Identification, Classification, and Control under the Wisconsin Administrative Register 35.93. These rules made it illegal to possess, transport, transfer, or introduce certain invasive species in WI for both commercial businesses and recreational anglers, including ruffe. These rules also gave power to the WIDNR to inspect, sample, and control prohibited species, including those on private land. Prohibited species found on private land are subject to control actions ordered by the state to the landowner. In addition, these rules included requirements to remove aquatic plants and animals from boats, trailers, vehicles, and equipment prior to placing the vessel in any state water or transporting on any public road (State of Wisconsin 2009). Furthermore, the Wisconsin Fishing Regulations Guide lists a closed season for ruffe in all inland and Great Lakes waters and tributaries in WI to further prohibit any possession or transport of ruffe (WIDNR). For more information, refer directly to these laws, rules, and regulations.

Michigan

In 1994, the Michigan State Legislature passed Act 451 of 1994: Natural Resources and Environmental Protection Act (324.41303), forbidding the possession of any prohibited, including ruffe, or restricted species. (State of Michigan 1994). Banning the possession of ruffe through penalty of law would greatly reduce the potential for ruffe to spread through baitfish and angling. Since 1994, MIDNR includes an excerpt in the Michigan Fishing Guide, a handbook provided to all licensed recreational anglers in the state. This excerpt states that it is unlawful to possess or transport any live ruffe specimen, as well as other AIS (MIDNR 2023). For more information, refer directly to these laws, rules, and regulations.

Indiana

In 2002, ruffe were added to the INDNR Exotic Fish Rule (312 IAC 9-6-7). This rule makes it illegal to import, possess, propagate, buy, sell, barter, trade, loan, or release any of the 13 prohibited fish species in IN, of which ruffe are one of the listed species (INDNR 2002). Additionally, the Indiana Fishing Regulations Guide which is provided to all licensed recreational anglers in the state of IN includes an excerpt stating that it is illegal to possess ruffe in IN (INDNR 2023). For more information, refer directly to these laws, rules, and regulations.

Illinois

In 2015, IL passed the Illinois Injurious Species Regulation: 17 Illinois Administration Code Part 805, stating “Injurious species shall not be possessed, propagated, bought, sold, bartered, or offered to be bought, sold, bartered, transported, traded, transferred, or loaned...” and includes ruffe as an injurious species. In addition, the Illinois Fishing Regulations handbook, given to all licensed recreational anglers in the state, lists ruffe as a prohibited species to possess (ILDNR 2023). For more information, refer directly to these laws, rules, and regulations.

Ohio

In 2016, OH passed Ohio Rule 1501:31-19-01, Wild Animal Regulations. This rule states that “it is unlawful for any person to possess, import or sell exotic species of fish or hybrids thereof for introduction or to release into any body of water that is connected to or otherwise drains into a flowing upstream or other body of water that would allow egress of the fish into public waters, or waters of the state, without first having obtained permission of the chief. For the purposes of this rule, exotic species of fish are those fish which are not naturally found in the waters of the state of Ohio.” Since ruffe are not native or naturally found in OH waters, they are included in this rule. For more information, refer directly to this law.

New York

In 2014, NY passed the New York State Environmental Conservation Law – NYCRR Part 575 – Prohibited and Regulated Invasive Species. This law states that invasive species, of which ruffe are included, “cannot be knowingly introduced into a free-living state or introduced by a means that one should have known would lead to such an introduction”. For more information, refer directly to this law.

Pennsylvania

In 1990, PA passed Pennsylvania 58 PA. Code 63.46, 71.6, 73.1, which states “it is unlawful to possess the following live species in this [Pennsylvania] Commonwealth. It is unlawful to introduce or import the following live species into the waters of this [Pennsylvania] Commonwealth”. Ruffe are included on this list of species. In addition, the Pennsylvania Fishing Regulations handbook states it is “unlawful to possess, introduce, or import, transport, sell, purchase, offer for sale, or barter” for ruffe and other invasive species (PFBC 2023). For more information, refer directly to these laws, rules, and regulations.

Canada

The Canadian Fisheries Act was established in 1985. This federal law made it illegal to possess, transport, or release invasive fish, including ruffe. In 2015, this Act was amended with the Federal Aquatic Invasive Species Regulation. This amendment further regulated the control and prevention of AIS by placing stricter rules around the illegal importation, possession, transportation, release, and introduction of AIS. With this amendment, it became illegal to not only conduct any of these actions with a live specimen, but also with a dead specimen or any genetic material that might propagate the species. For more information, refer directly to these laws, rules, and regulations.

The Ontario Fishery Regulations, established in 2007, outlined rules for the use of baitfish in Ontario waters. In 2015, the Ontario Invasive Species Act was passed, placing stricter regulations on the prevention and control of invasive species in Ontario, including ruffe. This Act was amended in 2022 and recognized recreational watercraft as a vector for the spread of AIS. With this amendment, watercraft owners were required to clean and dry their vessels and equipment after removing it from the water.

The Ontario Fishing Regulations handbook states “it is against the law to possess, transport, or release live Ruffe..”. For more information, refer directly to these laws, rules, and regulations.

In 1990, the US government passed the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. This Act supported the prevention and control of invasive species in coastal inland waters, including the Great Lakes. This Act was amended with the National Invasive Species Act of 1996 which mandated regulations to prevent the introduction and spread of invasive species through ballast water in the Great Lakes. For more information, refer directly to these laws, rules, and regulations.

Summary

Since the invasion of ruffe in 1986, all Great Lakes states, provinces, and respective federal governments have enacted baitfish laws and rules to prevent further spread of ruffe and other AIS. The combination of baitfish regulations and blanket of laws and rules across the Great Lakes basin has addressed this objective to prevent the spread of ruffe beyond the areas they currently occupy through the baitfish pathway. The inclusion of current baitfish and possession laws in the publicly available fishing handbooks, which are given to all anglers when they purchase their recreational fishing license, have increased public awareness and engagement on ruffe. As these laws continue to receive amendments to this day, they become stronger and contribute to the future control of this species and other AIS threats in the Great Lakes.

Objective 8: Chicago Sanitary and Ship Canal

Consider options to prevent the movement of ruffe from the Great Lakes to the Mississippi watershed via the Chicago, Des Plaines, and Illinois Rivers.

Background

As it stands, there are five connecting waterways from which water in Lake Michigan enters the CAWS, and then flows into the Mississippi River basin. Though at the time of the original Ruffe Control Program, ruffe were of particular interest, there were also other AIS concerns with other species dispersing through the CAWS. An initial meeting took place in 1995 to discuss options for dispersal barriers in the CAWS and identify key stakeholders impacted by such options. The outcome of this meeting was the Ruffe Control Committee advising the national ANSTF to form a separate committee specific to the Chicago waterway, as it impacts 28 states and other agencies as water drains into the Mississippi River basin. The Ruffe Control Committee would maintain close communication with this Chicago Area Waterways Committee (CAWC). The Ruffe Control Committee also suggested that the USACE test different methods for dispersal barriers that could be put into place to prevent nonindigenous species from spreading through the CAWS.

Actions

At the time of this report, ruffe have not made their way as far south as the CAWS. Thus, little effort was conducted in the CAWS to specifically prevent the spread of ruffe from the Great Lakes into the Mississippi River basin. That said, ruffe have been identified as a moderate to severe threat if introduced into the Mississippi River basin (Jerde et al. 2010). However, risk of the movement of other AIS, including the zebra mussel (*Dreissena polymorpha*), round goby (*Neogobius melantostomus*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and other invasive species,

sparked the USACE, in cooperation and support with other agencies, to test an electric barrier in the CAWS as means to prevent ANS from crossing from the Great Lakes into the Mississippi River, and vice versa. This demonstration barrier (Barrier I) was installed in 2002 at Romeoville, IL within the Chicago Sanitary and Shipping Canal (CSSC), a part of the CAWS. This demonstration barrier paved the way for two improved and permanent barriers that were installed in 2009 and 2011 (Barrier IIA and IIB). In 2021 and 2023, Barrier I was made permanent with the installation of improved and permanent equipment, now called Barrier I North and Barrier 1 South, respectively. All CAWS electric barriers are still in operation today, operated and maintained by the USACE (usace.army.mil).

In 2014, the USACE published the Great Lakes and Mississippi River Interbasin Study (GLMRIS) Report which identified ruffe and other AIS as a risk for moving from the Great Lakes into the Mississippi River, and identified potential management actions for prevention and control (USACE 2014). For more information, refer directly to this report.

As requested, the Chicago Area Waterways System Advisory Committee (CAWSAC) was formed in 2014 and has since provided several consensus letters and technical reports to the US President and Congress on their recommendations for AIS control in the CAWS. Though ruffe are of some concern for movement through the CAWS, invasive carp has been the major concern and driven much of the work. For specific information on ANS control, refer to the technical report published by the committee in 2015 (CWASAC 2015).

In 2017, the USACE published GLMRIS – Brandon Road: The Great Lakes Mississippi River Interbasin Study, Brandon Road Draft Integrated Feasibility Study and Environmental Impact Statement – Will County Illinois. This report supported the notion of installing another barrier, this one in Joliet, IL at the Brandon Road Lock and Dam, as another means of preventing the movement of invasive species between the Great Lakes and the Mississippi River basin. This barrier is currently under construction, and includes sound, electricity, and a bubble curtain. The barrier is being installed on the Brandon Road Lock and Dam due to GLMRIS report, published by the USACE in 2013, which identified 18 connective waterways between the Great Lakes and the Mississippi River Basin, one of which is the Des Plaines River near Chicago, where the Brandon Road Lock and Dam is located.

Summary

Both the installation of several electric barriers and the creation of the CAWSAC fulfill the requests from the original Ruffe Control Program. Though the effectiveness these specific electric barriers would have on ruffe, should they ever invade as far south as the CAWS is unknown, there is some novel research suggesting electrical barriers are effective at inhibiting the movement of ruffe (Dawson et al. 2006). Albeit the main concern in the CAWS today is the movement of invasive carp, should ruffe invade the CAWS, the barrier system and CAWSAC are in place to respond.

Research Needs

1. Distribution of ruffe, including seasonal distribution in Lake Superior and its tributaries and diurnal distribution of larvae within the water column

There have been several research projects aimed at exploring ruffe distribution and drivers of distribution in Lake Superior and the Great Lakes as a whole. Brazner et al. 1998 suggested that degraded coastal and wetland habitat exacerbates ruffe invasion by driving out competition and providing ideal habitat for ruffe. By reversing habitat degradation, and thereby increasing the fish community resiliency to invasion, ruffe invasion in nearshore habitats of the Great Lakes can be mitigated (Brazner et al. 1998). In addition to habitat driven variables, Horns et al. 2000 looked at thermal distribution in Lake Superior tributaries and found that peak abundance of ruffe was not significantly driven by temperature (Horns et al. 2000). This study was supported by Gutsch and Hoffman (2016) when they found that ruffe exhibit a high amount of plasticity in their tolerance for a wide range of water quality parameters, diet, and dispersal periods. Their study suggested that ruffe are highly adapted for surviving and moving throughout the Great Lakes (Gutsch and Hoffman 2016). In 2017, Beletsky et al. found that larval distribution was heavily driven by currents in the lakes (Beletsky et al. 2017).

2. Environmental determinants of seasonal distribution and movements, including temperature, light, and other habitat characteristics

Environmental determinants of distribution and movement can be key in predicting when and where Ruffe will populate. A study by Edsall et al. in 1993 looked at thermal habitat preference of ruffe and how it overlapped with native species. They found that ruffe optimal growth occurred at the same temperature for optimal growth in walleye and yellow perch, suggesting that ruffe would likely inhabit the same thermal habitat as those two species (Edsall et al. 1993). Although optimal growth occurred at 22 Celsius (Edsall et al. 1993), Ogle et al. 1998 suggested that ruffe survive in a wide array of habitats and may not be limited to that specific thermal habitat (Ogle et al. 1998). Another study by Henson and Newman in 2000 found that ruffe metabolism and growth rates are well adapted for the cool waters of Superior, even more so than yellow perch, suggesting ruffe may proliferate in the cooler waters of the Great Lakes (Henson and Newman 2000). When looking at spawning temperatures, Brown et al. 1998 determined that ideal spawning occurred at 12 to 14 Celsius.

3. Effects of Ruffe colonization on aquatic biodiversity in Lake Superior bays and estuaries

A study by Edsall et al. 1993 found that the presence of ruffe significantly reduced yellow perch and forage fish abundance in the St. Louis River (Edsall et al. 1993), however a follow up study by Bronte et al. 1998 suggested that ruffe don't have as much of a negative impact as initially thought. Abundance and recruitment of native species was driven more by natural population dynamics than interactions with ruffe (Bronte et al. 1998). That being said, a study by Henson and Newman (2000) found ruffe metabolism and growth are well adapted for the cool waters of Lake Superior, even more than the

native yellow perch, suggesting ruffe will likely outcompete yellow perch in cooler areas of the Great Lakes (Henson and Newman 2000).

4. Characterization of the genetics of North American ruffe, and comparison to Eurasian populations

Stepien et al. 1998 used genetics to suggest that the Great Lakes ruffe came from the Danube River in Europe (Stepien et al. 1998). In 2005, Stepien et al. followed this up and suggested that Great Lakes ruffe genetic markers point to a single source invasion from the Elbe River drainage in Europe. The single source invasion and limited genetic diversity in the Great Lakes ruffe may contribute to their limited spread in the Great Lakes. This is in comparison to other Great Lakes invaders from the same region, the round goby and *Dreissenid sp.* mussels, who had multiple invasion sources and a greater genetic diversity in the Great Lakes, leading to quicker and much more widespread invasions (Stepien et al. 2005). This theory was supported by another study conducted by Stepien et al. in 2018. After roughly 30 years in the Great Lakes, the single source invasion and limited genetic diversity in the Great Lakes strain of ruffe have led to decreased numbers of ruffe in certain areas of the lakes. Stepien et al. suggested that their lack of genetic diversity is limiting their long-term invasion ecological success which is shown in their lack of ability to invade the lower Great Lakes (Stepien et al. 2018).

5. Development and registration of effective chemical control measures, for example bottom formulations of piscicides

Boogard et al. 1996 studied the effects of 3-trifluoromethyl-4-nitrophenol (TFM), a common lampricide, on Ruffe. They found that “although significant numbers of ruffe were killed at the TFM concentrations used to control sea lampreys, a higher concentration of TFM would be needed to eradicate ruffe from a stream. Even at higher concentrations, TFM treatments should allow selective removal of ruffe from river estuaries with only limited mortality among nontarget fishes” (Boogard et al. 1996). A study by Dawson et al. in 1998 found that the piscicides TFM, rotenone, antimycin, and bayluscide could be effective at treating localized ruffe populations (Dawson et al. 1998).

6. Identification and evaluation of attractants and repellents (eg pheromones, sound waves)

Maniak et al. (2000) found that injured ruffe exhibit an alarm pheromone, detected by other ruffe. This study suggested that “the specificity, potency, and nontoxic nature of the ruffe alarm pheromone, coupled with the fact that it can be easily collected, frozen, and applied, all suggests that this cue should be actively considered for use in an integrated pest control strategy for ruffe”.

7. Research on ballast water management options

Drake and Lodge (2004) found that reducing the number of port visits per ship had a greater impact on reducing the spread of invasive species than eliminating ports that have been epicenters for invasions.

Gray et al. (2007) suggested that open ocean ballast water exchange significantly reduced the vector of invasion for both pelagic and benthic freshwater species, a practice implemented in all Great Lakes ships beginning in 1993. With the current BMP's in place, no new AIS in the Great Lakes have been introduced via ballast water since 2006 (Canadian Environmental Protection Agency 2022).

8. Research leading to biological means of control

Several studies surrounding biological control of ruffe were conducted in Lake Superior. Ultimately, it was found that even when native predator abundance (walleye, northern pike, muskellunge) was artificially increased by restricting angling pressure and stocking fingerlings and adults, these native piscivores minimally increased their predation on ruffe, as found in stomach content analyses, even though ruffe accounted for 73-90% of the available prey biomass (Selgeby and Edwards 1995, Ogle et al. 1996, Mayo et al. 1998).

9. Describe characteristics of baitfish commerce in Great Lakes states, including harvest gear, sites, and quantities and commercial traffic patterns, and identify risk of ruffe transport

Michigan DNR (2014) states "Anglers are likely candidates for transporting [ruffe] to inland waters. [Ruffe] could accidentally be introduced or transported in live wells, bilge water, and bait buckets." New and improved legislation regulating the baitfish industry has restricted baitfish harvest from infested waters in the Great Lakes and significantly reduced any new introductions of ruffe throughout the Great Lakes basin.

10. Identify and test methods for implementing a dispersal barrier in the Chicago Sanitary and Ship Canal

Dawson et al. 2006 found that electrical barriers and air-bubble curtains used in their study were ineffective at completely blocking movement, but effective at inhibiting passage of ruffe (Dawson et al. 2006).

11. Develop ecological theory for fish community resilience in the face of colonization by ruffe, and recommend and test means of increasing resilience through fishery and habitat management

Bronte et al. 1998 suggests ruffe contribute to the decline of native species as an additional stressor, however, they are not solely responsible for significant declines. Newman et al. 2020 found that increasing ruffe density caused declines in yellow perch populations, suggesting that ruffe can outcompete yellow perch when food sources are limited. This has implications if ruffe invade areas of the Great Lakes, or inland lakes, containing high numbers of yellow perch. Since 2010, GLRI has provided more than \$3.8 billion worth of funding for restoration projects in the

Great Lakes that aim to increase the resilience of native fish communities ability to resist invasion by ruffe and other AIS. These efforts continue to this day.

Appendix A – Literature Cited

- Alberta Invasive Species Council. 2017. Ruffe *Gymnocephalus cernuus*. Fact Sheet.
- Aquatic Nuisance Species Task Force. 2007. Aquatic Nuisance Species Task Force Strategic Plan 2007 – 2012. Report.
- Aquatic Nuisance Species Task Force. 2013. Aquatic Nuisance Species Task Force Strategic Plan 2013 – 2017. Report.
- Aquatic Nuisance Species Task Force. 2020. Aquatic Nuisance Species Task Force Strategic Plan 2020-2025. Report.
- Bailey, S.A., M.G. Deneau, L. Jean, C.J. Wiley, B. Leung, and H.J. MacIsaac. 2011. Evaluating efficacy of an environmental policy to prevent biological invasions. *Environmental Science and Technology*. 45:2554-2561.
- Bauer, C.R., A.M. Bobeldyk, and G.A. Lamberti. 2007. Predicting habitat use and trophic interactions of Eurasian ruffe, round gobies, and zebra mussels in nearshore areas of the Great Lakes. *Biological Invasions*. 9:667-678.
- Beletsky, D., R. Beletsky, E.S. Rutherford, J.L. Sieracki, J.M., Bossenbroek, W.L. Chadderton, M.E. Wittman, G.M. Annis, and D.M. Lodge. Predicting spread of aquatic invasive species by lake currents. *Journal of Great Lakes Research*. 43(3):14-32.
- Boogard, M.A., T.D. Bills, J.H. Selgeby, and D.A. Johnson. 1996. Evaluation of piscicides for control of ruffe. *North American Journal of Fisheries Management*. 16:600-607.
- Brazner, J.C., D.K. Tanner, D.A. Jensen, and A. Lemke. 1998. Relative abundance and distribution of ruffe (*Gymnocephalus cernuus*) in a Lake Superior coast wetland assemblage. *Journal of Great Lakes Research*. 24(2):293-303
- Bronte C.R., L.M. Evrard, M.P. Brown, K. R. Mayo, and A.J. Edwards. 1998. Fish community changes in the St. Louis River Estuary, Lake Superior, 1989-1996: Is it ruffe or population dynamics. *Journal of Great Lakes Research*. 24(2):309-318.
- Busiahn, T. R. 1997. "Ruffe control: a case study of an aquatic nuisance species control program." *Zebra mussels and aquatic nuisance species*. Ann Arbor Press. p. 69-86.
- Canadian Coast Guard. www.ccg-gcc.gc.ca. Accessed August 2023. Webpage.
- Canadian Environmental Protection Agency. 2022. State of the Great Lakes. Report. <https://stateofgreatlakes.net/indicators/invasives/>. Accessed January 2024. Webpage.
- Canadian Shipowners Association. www.lobbycanada.gc.ca. Accessed August 2023. Webpage.
- Chicago Area Waterway System. 2015. Summary of technical evaluations. Report.
- Committee of Advisors to the Great Lakes Fisheries Commission. 1997. Resolution # 4: Ruffe. Letter.

- Council of Great Lakes Governors. 2014. Mutual Aid Agreement for Combating Aquatic Invasive Species Threats to Great Lakes – St. Lawrence River Basin. Agreement.
- David, M. and M. Perkovic. 2004. Ballast water sampling as a critical component of biological invasions risk management. *Marine Pollution Bulletin*. 49(4):313-318.
- Dawson, V.K., T.D. Bills, and M.A. Boogaard. 1998. Avoidance behavior of ruffe exposed to selected formulations of piscicides. *Journal of Great Lakes Research*. 24(2):343-350.
- Dawson, H.A., U.G. Reinhardt, J.F. Savino. 2006. Use of electric and bubble barriers to limit the movement of Eurasian ruffe (*Gymnocephalus cernua*). *Journal of Great Lakes Research*.
- DeSorcie, T.J. and T.A. Edsall. 1995. Feeding rate of young of the year ruffe on eggs of lake whitefish. *Journal of Freshwater Ecology*. 10(3):225-229.
- Drake, J.M. 2005. Risk analysis for species introductions: forecasting population growth of Eurasian ruffe (*Gymnocephalus cernuus*). *Canadian Journal of Fisheries and Aquatic Sciences*. 62(5):1053-1059.
- Drake, J.M. and D.M. Lodge. 2007. Hull fouling is a risk factor for intercontinental species exchange in aquatic ecosystems. *Aquatic Invasions*. 2(2):121-131.
- Edwards, A.J. 1995. Spatial changes in the distribution and abundance of ruffe (*Gymnocephalus cernuus*) and native fishes in the St. Louis River estuary 1989-94. M.S. Thesis, University of Minnesota-Duluth. 44 p.
- Etheridge, C.B., C. W. Bean, and C.E. Adams. 2011. An experimental approach to estimating vulnerability of European whitefish (*Coregonus lavaretus*) ova to predation by invasive ruffe (*Gymnocephalus cernuus*). *Ecology of Freshwater Fish*. 20:299-307.
- Fullerton, A.H., G.A. Lamberti, D.M. Lodge, and M.B. Berg. 1998. Prey preferences of Eurasian ruffe and yellow perch: comparison of laboratory results with composition of Great Lakes benthos. *Journal of Great Lakes Research*. 24(2):319-328.
- Fullerton, A.H., G.A. Lamberti, D.M. Lodge, and F.W. Goetz. 2000. Potential for resource competition between Eurasian ruffe and yellow perch: growth and RNA responses in laboratory experiments. *Transactions of the American Fisheries Society*. 129(6):1331-1339.
- Great Lakes Restoration Initiative. glri.us. Accessed September 2023. Webpage.
- Gray, D.K., T.H. Johengen, D.F. Reid, and H.J. MacIsaac. 2007. Efficacy of open-ocean ballast water exchange as a means of preventing invertebrate invasions between freshwater ports. *Limnology and Oceanography*. 52(6):2386-2397.
- Great Lakes Fisheries Commission Council of Lake Committees. 1995. Fishery management officials re-examine ruffe control strategy after the recent appearance of ruffe in Lake Huron. Press Release.
- Great Lakes Fisheries Commission Ruffe Task Force. 1992. Ruffe in the Great Lakes: A threat to North American fisheries. Report.

- Great Lakes Governors and Premiers. 2014. Mutual Aid Agreement for Combating Aquatic Invasive Species Threats to the Great Lakes-St. Lawrence River Basin. Agreement.
- Great Lakes Saint Lawrence Seaway System. www.greatlakes-seaway.com. Accessed August 2023. Webpage.
- Great Lakes Seaway Ballast Water Working Group. 2023. 2022 Summary of Great Lakes seaway ballast water working group. Report.
- Gutsch, M. and J. Hoffman. 2016. A review of ruffe (*Gymnocephalus cernua*) life history in its native vs non-native range. Reviews in Fish Biology and Fisheries. 26:213-233.
- Gutsch, M.K. 2017. The rise and fall of the ruffe (*Gymnocephalus cernua*) empire in Lake Superior. PhD Dissertation. University of Minnesota.
- Henson, F.G. and R.M. Newman. 2000. Effect of temperature on growth at ration and gastric evacuation rate of ruffe. Transactions of the American Fisheries Society. 129(2):552-560.
- Hirsch, J. 1998. Nonindigenous fish in inland waters: response plan to new introductions. Minnesota Department of Natural Resources. Special Publication Number 152. Report.
- Hoff, M.H., L.M. Evrard, and O.T. Gorman. 2001. Population dynamics of ruffe in the St. Louis River, Lake Superior, with special emphasis on recruitment. Presentation.
- Horner, R., R. Sparks, and P. Charlebois. 1999. Illinois state comprehensive management plan for aquatic nuisance species. Illinois Department of Natural Resources and Illinois-Indiana Sea Grant Report.
- Illinois Department of Natural Resources. 2015. Illinois Injurious Species Regulation: 17 Illinois Administration Code Part 805. Regulation.
- Illinois Department of Natural Resources. <https://dnr.illinois.gov/>. Accessed September 2023. Webpage.
- Illinois Indiana Sea Grant, Wisconsin Sea Grant, and New York Sea Grant. 2015. Nab the invader. www.iiseagrant.org. Accessed August 2023. Webpage.
- Indiana Department of Natural Resources. 2004. Indiana aquatic nuisance species (ANS) management plan. Report.
- Indiana Department of Natural Resources. 2020. Indiana aquatic invasive species (AIS) management plan (2020). Report.
- Indiana Department of Natural Resources. 2023. Indiana fishing regulations guide 2023-2024. Handbook.
- Iowa Department of Natural Resources. 2023. Iowa aquatic invasive species fact sheet: ruffe: *Gymnocephalus cernuus*. Fact Sheet.
- Irons, K. and T. Newcomb. 2014. Regional coordination efforts for aquatic nuisance species or aquatic invasive species. Presentation.
- Jensen, D.A. 1995. Eurasian ruffe watch card. Minnesota Sea Grant (X13).

- Jerde C.L., D.M. Lodge, A.R. Mahon, W.L. Chadderton, M.A. Barnes, and J. McNulty. 2010. Final report: aquatic invasive species risk assessment for the Chicago sanitary and ship canal. In: Report to the United States Army Corps of Engineers. Environmental Laboratories, Cooperative Environmental Studies Unit, Vicksburg
- Kangur, K., A. Kangur, and P. Kangur. 2000. Diet composition and food consumption level of ruffe, *Gymnocephalus cernuus*, in Lake Peipsi. Proceedings of the Estonian Academy of Sciences, Biology, and Ecology. 49(1):121-135.
- Kindt, K., S.M. Keppner, and G. Johnson. 1996. Surveillance for ruffe in the Great Lakes: 1995. USFWS. Report.
- Kolar, C.S., A.H. Fullerton, K.M. Martin, and G.A. Lamberti. 2002. Interactions among zebra mussel shells, invertebrate prey, and Eurasian ruffe or yellow perch. Journal of Great Lakes Research. 28(4):664-673.
- Lake Carriers' Association. www.lcaships.com. Accessed August 2023. Webpage.
- Lake Superior Binational Program. 2014. Lake Superior aquatic invasive species complete prevention plan. Lake Superior Lakewide Action and Management Plan. Report.
- Leigh, P. 1998. Benefits and costs of the ruffe control program for the Great Lakes fishery. Journal of Great Lakes Research. 24(2):351-360.
- MacIsaac, H.J., T.C. Robbins, and M.A. Lewis. 2002. Modeling ships' ballast water as invasion threats to the Great Lakes. Canadian Journal of Fisheries and Aquatic Science. 59:1245-1256.
- McLean M. 1997. Ruffe: a new threat to our fisheries. Minnesota Sea Grant Program as a Joint Project of the Great Lakes Sea Grant Network, 1993, 1994, 1997 (X07)
- Maniak, P.J., R.D. Lossing, and P.W. Sorensen. 2000. Injured Eurasian ruffe, *Gymnocephalus cernuus*, release an alarm pheromone that could be used to control their dispersal. Journal of Great Lakes Research. 26(2):183-195.
- Mayo, K.R., J.H. Selgeby, and M.E. McDonald. 1998. A bioenergetics modeling evaluation of top-down control of ruffe in the St. Louis River, western Lake Superior. Journal of Great Lakes Research. 24(2):329-342.
- Meronek, T.G., F.A. Copes, and D. W. Coble. 1997. A survey of the bait industry in the north-central region of the United States. North American Journal of Fisheries Management. 17:703-711.
- Michigan Department of Environmental Quality. 1996. Nonindigenous aquatic nuisance species (ANS) state management plan (1996). Report.
- Michigan Department of Environmental Quality. 2013. Michigan's aquatic invasive species state management plan 2013 update. Report.
- Michigan Department of Natural Resources. michigan.gov. Accessed August 2023. Webpage.
- Michigan Department of Natural Resources. 2023. 2023 Michigan fishing guide. Handbook.

- Michigan Invasive Species Program. 2014. State of Michigan's status and strategy for Eurasian ruffe management. Report.
- Michigan's Office of the Great Lakes. 2002. Michigan's aquatic nuisance species state management plan update: prevention and control in Michigan waters. Report.
- Michigan Sea Grant. 2023. Ruffe musical chairs. www.michiganseagrant.org. Accessed August 2023. Webpage.
- Mills, E.D., J.H. Leach, J.T. Carlton, and C.L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. *Journal of Great Lakes Research*. 19(1):1-54.
- Minister of Justice. 1985. Canadian Fisheries Act. Law.
- Minister of Justice. 2007. The Ontario Fishery Regulations, 2007. Law
- Minister of Justice. 2015. Canadian Fisheries Act: Federal Aquatic Invasive Species Regulation. Law.
- Minister of Justice. 2015. Ontario Invasive Species Act. Law.
- Minister of Justice. 2022. Ontario Invasive Species Act. Amendment. Law.
- Minnesota Department of Natural Resources. 1996. A field guide to aquatic exotic plants and animals. Brochure.
- Minnesota Department of Natural Resources. www.dnr.state.mn.us. Accessed August 2023. Website.
- Minnesota Department of Natural Resources. 2019. St. Louis Estuary fisheries management plan. Report.
- Minnesota Department of Natural Resources. 2023. <https://www.dnr.state.mn.us/invasives/aquaticanimals/ruffe/index.html>. Webpage. Accessed 27 July 2023.
- Minnesota Department of Natural Resources. 2023. Minnesota fishing regulations. Handbook.
- Minnesota Invasive Species Advisory Council. 2009. A Minnesota state management plan for invasive species. Report.
- Minnesota Invasive Species Advisory Council. 2022. A Minnesota state management plan for invasive species. Report.
- National Oceanic and Atmospheric Administration. Great Lakes aquatic nonindigenous species information system. <https://www.glerl.noaa.gov/glansis/>. Webpage. Accessed Dec 2023.
- Newman, R.M., F.G. Henson, and C. Richards. 2020. Competition between invasive ruffe (*Gymnocephalus cernua*) and native yellow perch (*Perca flavescens*) in experimental mesocosms. *Fisheries*. 5(4).
- New York Department of Conservation. 2014. New York State Environmental Conservation Law – NYCRR Part 575. Regulation.

- New York Department of Conservation. 2015. New York state aquatic invasive species management plan. Report.
- New York Department of Conservation. 2018. New York state invasive species comprehensive management plan. Report.
- New York State Department of Conservation. <https://www.dec.ny.gov/animals/115742.html>. Accessed August 2023. Webpage.
- Ogle, D.H., J. H. Selgeby, R.M. Newman, and M.G. Henry. 1995. Diet and feeding periodicity of ruffe in the St. Louis River Estuary, Lake Superior. *Transactions of the American Fisheries Society*. 124:356-369.
- Ogle, D.H., J.H. Selgeby, J.F. Savino, R.M. Newman, and M.G. Henry. 1996. Predation on ruffe by native fishes of the St. Louis River estuary, Lake Superior: 1989-1991. *Norther American Journal of Fisheries Management*. 16:115-123.
- Ohio Department of Natural Resources. 2014. State management plan for aquatic invasive species. Report.
- Ohio Department of Natural Resources. 2016. Ohio Rule 1501:31-19-01, Wild Animal Regulations. Regulation.
- Ohio Sea Grant, The Ohio State University, and Stone Laboratory. 2020. Great Lakes aquatic invasive species (AIS) lesson plan: eerie eight. Lesson Plan Activity.
- Ontario's Invading Species Awareness Program. 2021. Eurasian Ruffe. www.invadingspecies.com. Accessed August 2023. Webpage.
- Ontario's Invading Species Awareness Program. 2022a. Angler action plan.
- Ontario's Invading Species Awareness Program. 2022b. Boater action plan.
- Ontario Ministry of Natural Resources and Forestry and Minnesota Sea Grant. 2001. Ruffe watch. Brochure.
- Ontario Ministry of Natural Resources and Forestry. 2012. Ontario invasive species strategic plan. 2012. Report.
- Ontario Ministry of Natural Resources and Forestry. 2023. 2023 Ontario fishing: recreational fishing regulations summary. Handbook.
- Pennsylvania Department of Conservation and Natural Resources. 1990. Pennsylvania 58 PA. Code 63.46, 71.6, 73.1. Regulation.
- Pennsylvania Department of Conservation and Natural Resources. 2023. 2023 Pennsylvania fishing summary. Handbook.
- Pennsylvania Aquatic Invasive Species Management Plan Committee. 2006. Commonwealth of Pennsylvania: Pennsylvania Invasive Species Council aquatic invasive species management plan. Report.

- Pennsylvania Sea Grant. 2013. Eurasian ruffe *Gymnocephalus cernuus*. Fact sheet.
- Peterson, G.S., J.C. Hoffman, A.S Trebitz, C.W. West, and J.R. Kelly. 2011. Establishment patterns of non-native fishes: lessons from the Duluth-Superior harbor and lower St. Louis River, an invasion prone Great Lakes coastal ecosystem. *Journal of Great Lakes Research*. 37(2):349-358.
- Pratt, D.M., W.H. Blust, and J.H. Selgeby. 1992. Ruffe, *Gymnocephalus cernuus*: newly introduced in North America. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 1616-1618.
- Ricciardi, A. and H.J. MacIsaac. 2022. Vector control reduces the rate of species invasion in the world's largest freshwater ecosystem. *Conservation Letters*.
- Ruffe Control Committee. 1996. Ruffe control program plan. Report.
- Ruffe Task Force. 1992. Ruffe in the Great Lakes: a threat to North American fisheries. Great Lakes Fishery Commission, Ann Arbor, Michigan 48105. 144 p
- Savino, J.F., S.C. Riley, and M.J. Holuszko. Activity, aggression, and habitat use of ruffe (*Gymnocephalus cernuus*) and round goby (*Apollonia melanostoma*) under laboratory conditions. *Journal of Great Lakes Research*. 33(2):326-334.
- Seaway Port Authority of Duluth. www.duluthport.com. Accessed August 2023. Webpage.
- Selgeby, J. and A.J. Edwards. 1995. Status of ruffe in the St. Louis River estuary, 1994, with emphasis on predator prey relations. Presented at the Great Lakes Fishery Commission Lake Superior Committee meeting, March 29, 1995.
- Selgeby, J. 1998. Predation by ruffe (*Gymnocephalus cernuus*) on fish eggs in Lake Superior. *Journal of Great Lakes Research*. 24(2):304-308.
- Shipping Federation of Canada. www.shipfed.ca. Accessed August 2023. Webpage.
- Sieracki, J.L., J.M. Bossenbroek, and W.L. Chadderton. 2014. A spatial modeling approach to predicting the secondary spread of invasive species due to ballast water discharge. *PLoS ONE*. 9(12).
- Slade, J. and K. Kindt. 1992. Surveillance for ruffe in the upper Great Lakes: 1992. US Fish and Wildlife Service. Report.
- Slade J, S.M. Pare, and W.R. MacCallum. 1994. Surveillance for ruff in the Great Lakes: 1993. US Fish and Wildlife. Report.
- Slade, J.W., S.M. Pare, S.M. Keppner, and W.R. MacCallum. 1995. Surveillance for ruffe in the Great Lakes: 1994. US Fish and Wildlife. Report.
- Thunder Bay Harbour Association. www.portthunderbay.ca. Accessed August 2023. Webpage.
- Transport Canada. www.tc.ca. Accessed August 2023. Webpage.
- Tucker, A.J., W.L. Chadderton, C.L. Jerde, M.A. Renshaw, K. Uy, C. Gantz, A.R. Mahon, A. Bowen, T. Strakosh, J.M. Bossenbroek, J.L. Sieraki, D. Beletsky, J. Bergner, and D. Lodge. 2016. A sensitive environmental DNA (eDNA) assay leads to new insights on ruffe (*Gymnocephalus cernua*) spread in North America. *Biological Invasions*. 18:3205-3222.

- Tucker A.J., W.L. Chadderton, G. Annis, A.D. Davidson, J. Hoffman, J. Bossenbroek, S. Hensler, M. Hoff, E. Jensen, D. Kashian, S. LeSage, and T. Strakosh. 2020. A framework for aquatic invasive species surveillance site selection and prioritization in the US waters of the Laurentian Great Lakes. *Management of Biological Invasions* 11(3): 607–632
- Davidson, A. D., Tucker, A. J., Chadderton, W. L., Jensen, E., Weibert, C., & Death, R. 2021. Assessing progress in regulation of aquatic nonindigenous species across the multijurisdictional waters of the Laurentian Great Lakes, with emphasis on the live trade pathways. *Management of Biological Invasions*, 12(3).
- United States Army Corp of Engineers. 2013. Great Lakes and Mississippi River interbasin study report. Report.
- United States Army Corp of Engineers. 2017. GLMRIS – Brandon Road: Great Lakes Mississippi River interbasin study – Brandon Road draft integrated feasibility study and environmental impact statement – Will County, Illinois. Report.
- United States Army Corp of Engineers. usace.army.mil. Accessed August 2023. Webpage.
- United States Coast Guard. www.uscg.mil. Accessed August 2023. Webpage.
- United States Environmental Protection Agency. www.epa.gov. Accessed August 2023. Webpage.
- United States of America. State of Indiana. Indiana Department of Natural Resources. Exotic Fish Rule (312 IAC 9-6-7). 2002. Law.
- United States of America. State of Michigan. Act 451 of 1994: Natural Resources and Environmental Protection Act. Section 324.41303. 1994. Law.
- United States of America. State of Minnesota. Minnesota Department of Natural Resources. Minnesota Administrative Rules: Minnesota-Wisconsin Boundary Waters Commercial Regulations. 6266.0600. 1993. Law.
- United States of America. State of Minnesota. Laws of Minnesota for 1993. Chapter 235. 1993. Law.
- United States of America. State of Minnesota. Invasive Species Law: Prohibited Invasive Species. 6216.0250. 1996. Law.
- United States of America. State of Wisconsin. Wisconsin Department of Natural Resources. Invasive Species Identification, Classification, and Control. Wisconsin Administrative Register Chapter NR 40. 2009. Law.
- United States of America. 1990. Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. Law.
- United States of America. 1996. National Invasive Species Act of 1996. Law.
- United States Geological Survey. <https://nas.er.usgs.gov/>. Accessed August 2023. Webpage.
- United States Geological Survey. <https://www.usgs.gov/search?keywords=ruffe+st+louis+river>. Accessed September 2023. Webpage.

- US Geological Survey. 2014. *Gymnocephalus cernua* (Linnaeus, 1758): U.S. Geological Survey, nonindigenous aquatic species database. www.nas.er.usgs.gov. Accessed August 2023. Website.
- US Great Lakes Shipping Association. www.usglisa.org. Accessed August 2023. Webpage.
- Wisconsin Department of Natural Resources. 2003. Wisconsin's comprehensive management plan: to prevent further introductions and control existing populations of aquatic invasive species. Report.
- Wisconsin Department of Natural Resources. Guide to Wisconsin hook and line fishing regulations. Handbook.
- Wisconsin Sea Grant. 2018. www.seagrant.wisc.edu. Accessed August 2023. Webpage.
- Wisconsin Sea Grant. 2018. Aquatic invaders attack pack. www.seagrant.wisc.edu. Accessed August 2023. Webpage.
- Zhang, H., E.S. Rutherford, D.M. Mason, M.E. Wittmann, D.M. Lodge, X. Zhu, T.B. Johnson, and A. Tucker. 2019. Modeling potential impacts of three benthic invasive species on the Lake Erie food web. *Biological Invasions*. 21:1697-1719.
- Zorn, T. and D. Kramer. 2022. Fish community status in the Bay De Noc and nearshore waters of northern Lake Michigan – May 2022. Michigan Department of Natural Resources Report.

Appendix B – Abbreviations and Acronyms

AIS – aquatic invasive species

ANS – aquatic nuisance species

ANSTF – Aquatic Nuisance Species Task Force

BMP – ballast water management practice

CAWSAC – Chicago Area Waterways System Advisory Committee

CAWS – Chicago Area Waterway System

CLC – Great Lakes Fishery Commission Council of Lake Committees

CORA – Chippewa Ottawa Resource Authority

CSSC – Chicago Sanitary and Shipping Canal

CWAC – Chicago Waterways Advisory Committee

DFO – Department of Fisheries and Oceans Canada

DNR – Department of Natural Resources

eDNA – environmental DNA

EDRR – Early detection and rapid response

GLANSIS – Great Lakes Aquatic Nonindigenous Species Information System

GLFC – Great Lakes Fishery Commission

GLIFWC – Great Lakes Indian Fish and Wildlife Commission

GLMRIS – Great Lakes and Mississippi River Interbasin Study

GLRI – Great Lakes Restoration Initiative

GLSGN – Great Lakes Sea Grant Network

IL - Illinois

ILDNR – Illinois Department of Natural Resources

IISG – Illinois-Indiana Sea Grant

IN - Indiana

INHS – Illinois Natural History Survey

INDNR – Indiana Department of Natural Resources

MI – Michigan

MDARD – Michigan Department of Agricultural and Rural Development

MDEQ – Michigan Department of Environmental Quality

MDOT – Michigan Department of Transportation

MIDNR – Michigan Department of Natural Resources

MISAC – Minnesota Invasive Species Advisory Council

MN - Minnesota

MNDNR – Minnesota Department of Natural Resources

MNSG – Minnesota Sea Grant

MOGL – Michigan Department of Environmental Quality, Office of the Great Lakes

NAS – Nonindigenous Aquatic Species

NOBOB – no ballast on board

NY – New York

NYDEC – New York Department of Environmental Conservation

OFAH – Ontario Federation of Anglers and Hunters

OH - Ohio

OHDNR – Ohio Department of Natural Resources

OMNRF – Ontario Ministry of Natural Resources and Forestry

PA - Pennsylvania

PAAISMP – Pennsylvania Aquatic Invasive Species Management Plan Committee

PADA – Pennsylvania Department of Agriculture

PADCNR – Pennsylvania Department of Conservation and Natural Resources

PADEP – Pennsylvania Department of Environmental Protection

PASG – Pennsylvania Sea Grant

PFBC – Pennsylvania Fish and Boat Commission

PISC – Pennsylvania Invasive Species Council

RCF – Ruffe Control Program

RTF – Great Lakes Fishery Commission Ruffe Task Force

SG – Sea Grant

SLRE – Saint Louis River Estuary

SMR – Saint Mary’s River

TFM – 3-trifluoromethyl-4-nitrophenol

TNC – The Nature Conservancy

USACE – United States Army Corp of Engineers

USCG – United States Coast Guard

USEPA – United States Environmental Protection Agency

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

WI - Wisconsin

WIDNR – Wisconsin Department of Natural Resources

WISG – University of Wisconsin Sea Grant

VGP – Vessel General Permit

VIDA – Vessel Incidental Discharge Act

YOY – young of year

Appendix C – List of Solicited Consultants, Commentors, and Reviewers

Amanda Kunzmann, US Forest Service

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Appendix D – Ruffe Invasion Map

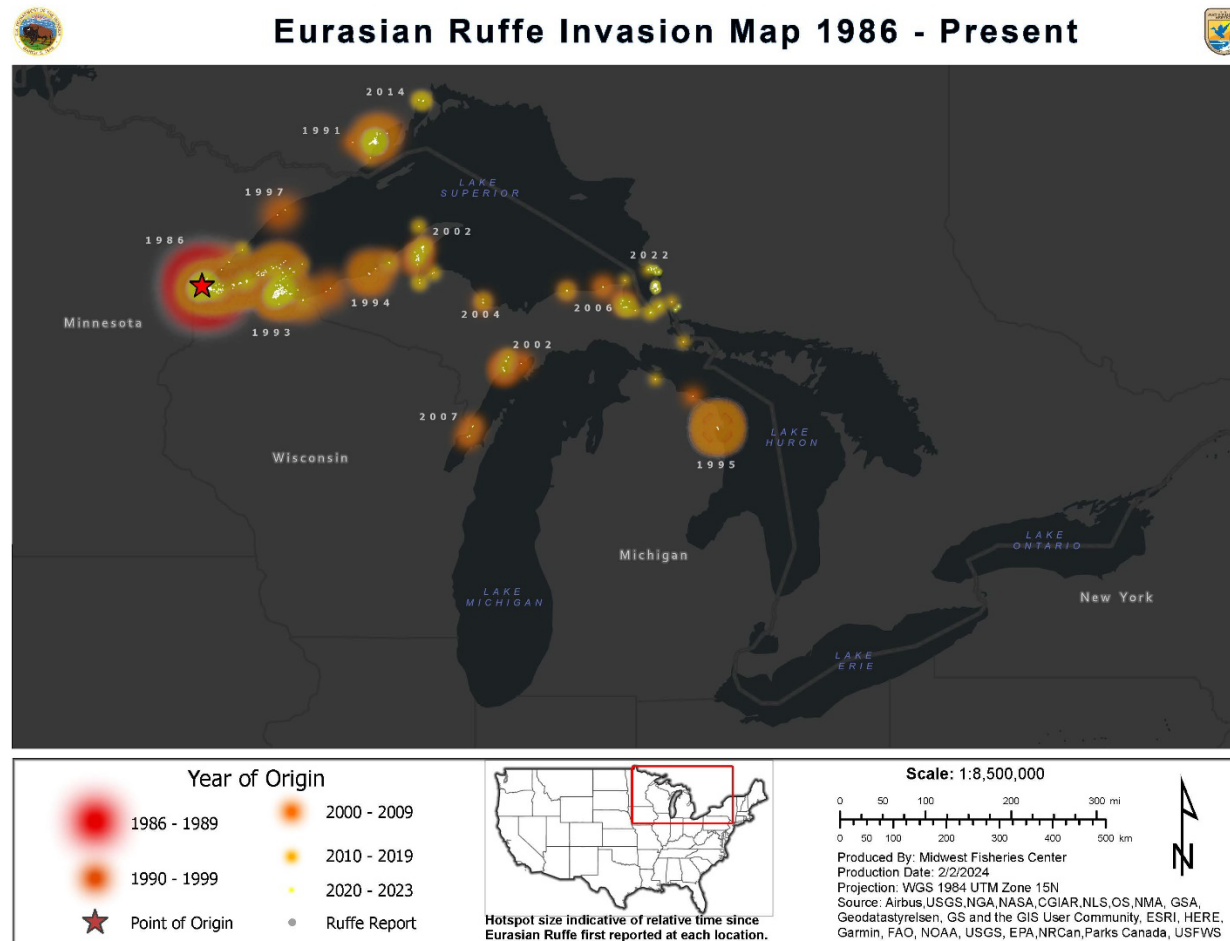


Figure Description. A map showing the spread of ruffe throughout the Great Lakes from 1986 to 2023. Data used to create this map comes from the USGS NAS database. *Map credit: Ross Reuhmann, USFWS. For more information on the map, please contact ross_reuhmann@fws.gov.*