U.S. Fish & Wildlife Service

Muskellunge (*Esox masquinongy*)

Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, November 2018
Revised, November 2019
Web Version, 5/1/2020

Organism Type: Fish
Overall Risk Assessment Category: High

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1 Native Range and Status in the United States

Native Range

From Froese and Pauly (2018a):

"North America: Native to St. Lawrence River - Great Lakes, Hudson Bay (Red River), and Mississippi River basins. […] Native populations are protected in portions of Tennessee and Ohio."

"[In Canada:] Known only from Ontario and Quebec."

"[In the United States:] Recorded from Ohio River drainage (including Cumberland and Tennessee rivers), upper Mississippi River drainage, the Great Lakes, southern Hudson Bay tributaries, and some northern Atlantic Coastal drainages [Etnier and Starnes 1993]."

From Fuller et al. (2018a):

"St. Lawrence River-Great Lakes and Mississippi River basins, from Quebec to southeastern Manitoba; south in the Appalachians to Georgia and in the west to Iowa (Page and Burr 1991). […] Although never reported from Mississippi, considering the fact that Muskellunge are (or were) native to the main Tennessee River, the species almost certainly historically entered the extreme northeastern part of that state (Gilbert, personal communication)."

Status in the United States

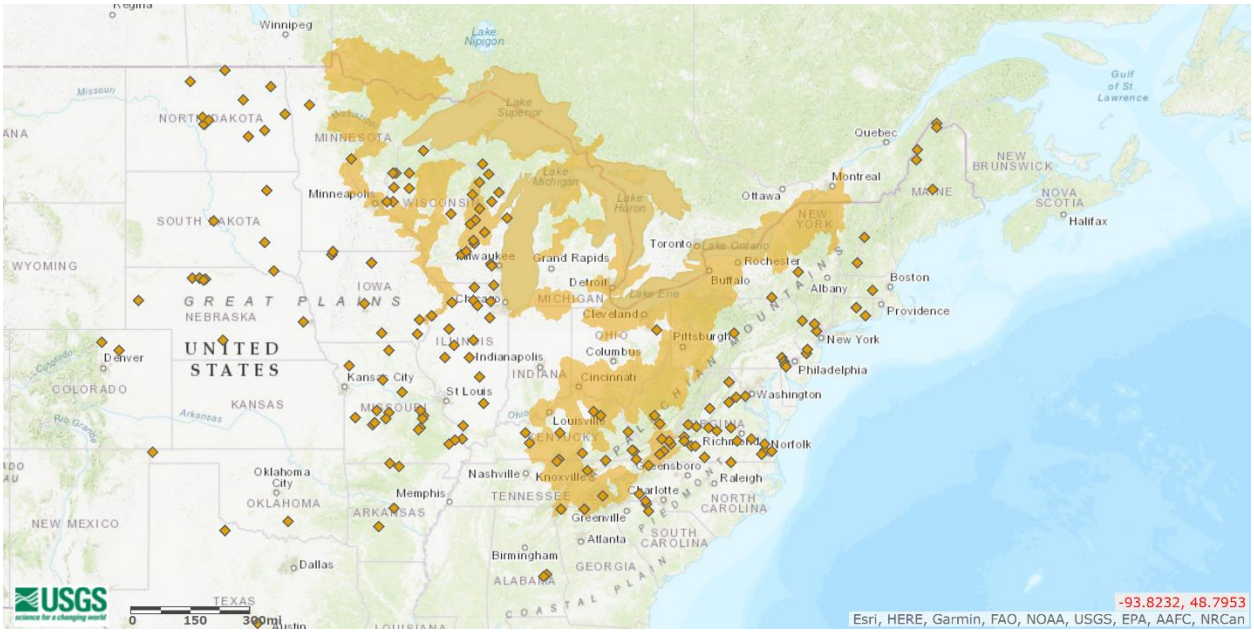

Figure 1. Map of the eastern contiguous United States showing the native range of *Esox masquinongy* (orange shaded area). Map from Fuller et al. (2018a). Some nonnative observations of this species are represented as orange diamonds, a full map of nonnative observations can be found in section 6.

From Froese and Pauly (2018a):

"North America: Native to St. Lawrence River - Great Lakes, Hudson Bay (Red River), and Mississippi River basins. Introduced elsewhere in the USA. Native populations are protected in portions of Tennessee and Ohio."

"Treated as endangered species by both the Wildlife Resources Agency and the Heritage Program [Tennessee] [Etnier and Starnes 1993]."

According to Fuller et al. (2018a), *Esox masquinongy* has been reported as non-native in the following States (years of reports and watersheds given after State name):

- Alabama (1992–1996; Lower Tallapoosa)
- Alaska (2018; Upper Kenai Peninsula)
- Arizona (1975; Lower Colorado Region)
- Arkansas (1973–1988; Bull Shoals Lake, North Fork White, Upper Ouachita)
- California (1893–1896; San Francisco Coastal South)
- Colorado (1993–1998; Cache La Poudre, South Platte)
- Connecticut (1851–1996; Lower Connecticut, Thames)
- Delaware (1965–1967; Brandywine-Christina)
- Georgia (1971; Middle Tennessee-Chickamauga, Ocoee)
- Illinois (1979–2011; Big Muddy, Copperas-Duck, Lower Fox, Lower Illinois-Lake Chautauqua, Lower Rock, Mackinaw, Skillet, Spoon, Upper Fox, Upper Illinois, Upper Kaskaskia)
- Iowa (1945–1995; Little Sioux, Lower Iowa, Middle Des Moines, Skunk, Upper Chariton, Winnebago)
- Kentucky (1986; Licking, Middle Green, Obey, Rough, Upper Cumberland)
- Maine (1984–1994; Headwaters Saint John River, New England Region, St. Francis River-Saint John River)
- Massachusetts (1969; New England Region)
- Michigan (1962; Brule)
- Minnesota (1982-2001; Red, St. Croix)
- Missouri (1966–1998; Bourbeuse, Harry S. Truman Reservoir, Lake of the Ozarks, Lower Chariton, Lower Missouri-Moreau, Meramec, Niangua, Pomme De Terre, Upper Chariton, Upper Grand, Upper Mississippi-Cape Girardeau, Whitewater)
- Nebraska (1958–2000; Lower Platte, Middle Niobrara, Middle North Platte-Scotts Bluff, Middle Platte-Buffalo, Missouri Region, Snake)
- New Jersey (1900 to 2012; Hackensack-Passaic, Mid-Atlantic Region, Raritan)
- New York (1985–1986; Upper Susquehanna)
- North Carolina (1976–1994; Roanoke, Roanoke Rapids, Upper Broad, Upper New, Upper Tennessee)
- North Dakota (1981–1999; Devils Lake, Middle Sheyenne, Painted Woods-Square Butte, Park, Pipestem, Red, Souris, Willow)
- Ohio (1935–1955; Grand, Mahoning)
- Oklahoma (1965–1985; Middle Washita, Upper Cimarron)

- Pennsylvania (1965–1999; Brandywine-Christina, Middle Delaware-Mongaup-Brodhead)
- South Carolina (1994–2009; Lower Broad, Upper Broad)
- South Dakota (1992–2001; Lewis and Clark Lake, Lower James, Missouri Region, Mud)
- Tennessee (1983–1986; Obey, Upper Clinch)
- Texas (1975–1998; Amistad Reservoir, Buchanan-Lyndon B. Johnson Lakes, Mud)
- Vermont (1840; Upper Connecticut-Mascoma, West)
- Virginia (1963–1994; Appomattox, Hampton Roads, James, Kanawha, Lower James, Lynnhaven-Poquoson, Maury, Middle James-Buffalo, Middle James-Willis, Middle New, Middle Potomac-Anacostia-Occoquan, Potomac, Powell, Rapidan-Upper Rappahannock, Roanoke, South Fork Holston, South Fork Shenandoah, Upper Clinch, Upper James, Upper New, Upper Roanoke)
- West Virginia (1986–1995; Big Sandy, Lower New, Potomac, Upper Kanawha)
- Wisconsin (1983–1986; Charles, Fox, Lower St. Croix, Lower Wisconsin, Northwestern Lake Michigan, St. Croix, Upper Fox, Upper Mississippi Region, Wolf)

From Fuller et al. (2018a):

"Reported from above areas [above list], some of which may have established populations. Extirpated in California (Hubbs et al. 1979) and in Georgia, where it has not been seen since 1957 (Dahlberg and Scott 1971b). About 25% of all Muskellunge populations in Wisconsin are the result of stocking (Becker 1983). Crossman and McAllister (1986) reported the species as introduced into the Souris and Red River drainage was a recent one. They were stocked in the Minnedosa and Assiniboine rivers, both tributaries of the Red River."

From NatureServe (2013):

"This fish has been introduced in numerous localities, including Atlantic Slope drainages south to southern Virginia, and southern and western U.S. (where introductions usually have not been successful) (Page and Burr 2011)."

"Forty-six percent (864 waters) of all North American Muskellunge waters have resulted from introductions (Kerr 2011)."

From Fuller et al. (2018b):

"Muskellunge appears on the IL list of species approved for aquaculture.

Muskellunge fishing is regulated by state laws and the species is frequently stocked by state agencies."

Means of Introductions in the United States

From Fuller et al. (2018a):

"Intentionally stocked for sportfishing. According to Pflieger (1997) this species was first stocked in Missouri reservoirs in 1966 for the purpose of providing another trophy-sized fish and a large predator capable of preying on the many Gizzard shad and other forage fish too large to be eaten by Largemouth bass. Muskellunge found in one Missouri creek had escaped from hatchery ponds (Pflieger 1997)."

"Wolter et al. (2013) examined demographics and rate of dam escapement at a reservoir in Illinois, finding 25% of the population escaped over the dam and suggested mitigation practices."

Remarks

From Fuller et al. (2018a):

"Natural hybridization between the Muskellunge and Northern Pike occurs in waters where both species are present resulting in the Tiger Muskellunge. Male hybrids are sterile and females are frequently fertile."

"The hybrid Tiger muskie (*Esox masquinongy* x *lucius*) is also present in the Great Lakes region, these grow faster and larger than either of the parent species, are characterized by dark stripes on a lighter background, have 5-6 sensory pores and are otherwise intermediate between the two parents in shape and coloring."

From Becker (1983):

"An artificial muskellunge x grass pickerel hybrid has been produced in Ohio (Tennant and Billy 1963)."

Esox masquinongy has been intentionally stocked outside its native range within the United States by State fishery managers to achieve fishery management objectives. State fish and wildlife management agencies are responsible for balancing multiple fish and wildlife management objectives. The potential for a species to become invasive is now one important consideration when balancing multiple management objectives and advancing sound, science-based management of fish and wildlife and their habitat in the public interest.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

Fricke et al. (2018):

"**Current status:** Valid as *Esox masquinongy* Mitchill 1824."

From ITIS (2018):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Deuterostomia
      Phylum Chordata
        Subphylum Vertebrata
          Infraphylum Gnathostomata
            Superclass Actinopterygii
              Class Teleostei
                Superorder Protacanthopterygii
                Order Esociformes
                Family Esocidae
                Genus *Esox*
                Species *Esox masquinongy* Mitchill, 1824

From Fuller et al. (2018a):

"Three subspecies are sometimes recognized: *Esox masquinongy masquinongy*, a spotted form which occurs in the St. Lawrence River and the Great Lakes and their tributaries; *Esox masquinongy immaculatus*, a form with either no pattern or barring which occurs in Wisconsin, Minnesota, northwestern Ontario, and southeastern Manitoba; and *Esox masquinongy ohioensis*, a form with bars or diffuse spots and blotches which occurs in the Ohio River and its tributaries (Becker 1983)."

Size, Weight, and Age Range

From Froese and Pauly (2018):

"Maturity: L_m 77.0 range ? - ? cm
Max length : 183 cm TL male/unsexed; [Page and Burr 1991]; common length : 95.0 cm TL male/unsexed; [Hugg 1996]; max. published weight: 31.8 kg [Tomelleri and Eberle 1990]; max. reported age: 30 years [Crossman 1996]"

From Fuller et al. (2018a):

"Individuals can live up to 30 years or more (Michigan DNR 2012)."

Environment

From Froese and Pauly (2018):

"Freshwater; demersal; non-migratory."

From Fuller et al. (2018a):

"Muskellunge are considered a coolwater species preferring temperatures from 0.55°C to 25.5°C despite optimum growth rates occurring at approximately 25.5°C. The species can withstand

temperatures up to 90°F. Compared to other species in the same habitat Muskellunge are more tolerant of low oxygen levels (Michigan DNR 2012; Becker 1983)."

Climate

From Froese and Pauly (2018):

"Temperate; 53°N - 30°N"

Distribution Outside the United States

Native

Part of the native range of *Esox masquinongy* is within the United States. See Native Range above for a full description of the native range.

From Froese and Pauly (2018):

"North America: Native to St. Lawrence River - Great Lakes, Hudson Bay (Red River), […]"

"[In Canada:] Known only from Ontario and Quebec."

From Fuller et al. (2018a):

"St. Lawrence River-Great Lakes […], from Quebec to southeastern Manitoba; […]"

Introduced

From FAO (2018):

"*Esox masquinongy* introduced to Morocco from United States of America
Date of introduction: 1964
[…]
Status of the introduced species in the wild : Not established"

From Andrews et al. (2018):

"The Muskellunge is a freshwater resident species in the SJR [Saint John River, New Brunswick, Canada]; it was originally introduced as part of a stocking program in a headwater lake during the late 1970s (Stocek et al. 1999). It has since expanded its range approximately 550 km downstream (Curry et al. 2007), and more recently, the species has been found reproducing downstream of the MGS [Mactaquac Generating Station] (K. Zelman, unpublished data)."

Means of Introduction Outside the United States

FAO (2018) lists the reason of introduction to Morocco as angling/sport.

Short Description

From Fuller et al. (2018a):

"Muskellunge, *Esox masquinongy*, are characterized by their elongate, moderately compressed and slightly flattened body. Oblique stripes, spots or blotches overlay the silver colored body, the belly is white in color with small spots. Fins are green or red-brown with dark blotches. The top of the head is unscaled and the snout is long and duckbill-like. The Muskellunge has a large mouth with strong canine teeth in its lower jaw and on the roof of its mouth. Its tongue features short, sharp brush-like teeth (Becker 1983)."

"While similar in appearance to the Northern pike (*Esox lucius*), Muskellunge can often be distinguished from pike based on coloration. Additionally, Muskellunge have 6-9 sensory pores on each side of their lower jaw whereas Northern pike have 5 or less pores. Muskellunge also have relatively pointed tail fins relative to a Northern pike (Minnesota DNR 2017)."

From Becker (1983):

"Body elongate, moderately compressed laterally, somewhat flattened dorsally. Average length approximately 813 mm (32 in). Greatest body depth into TL 6.1-9.7. Head length into TL 4-4.3; top of head unscaled, cheeks and opercles usually scaled on top half only. Snout long into head length 2.1- 2.3; snout flattened dorso-ventrally, duckbill-like. Mouth large, maxillary extending to midpoint or posterior edge of pupil. Lower jaw with large, strong canines (peglike posteriorly) and short, sharp, recurved brushlike teeth on roof of mouth and tongue. Sensory pores on undersurface of lower jaw (mandibular pores), usually 6-9 on each side. Gill rakers reduced to sharp, toothlike structures. Branchiostegal rays 16-19 on each side. Scales small cycloid, lateral series 147-155 (130-157); lateral line complete. Principal dorsal rays 15-19; principal anal rays 14-16; pectoral fin rays 14-19; pelvic fin rays 11-12; all of these more or less rounded on edge; caudal fin moderately forked, tips pointed, at least more so than in northern pike."

"Silvery background with dark, variable markings, often as oblique stripes, spots, or blotches, or even with scarcely any markings. Belly white with small spots. Fins green to red-brown with dark blotches. Young (less than 150 mm) with broad scalloped bars of olive green along sides and gold mid-dorsal stripe on back; belly white."

Biology

From Froese and Pauly (2018):

"Lives in clear vegetated lakes, quiet pools and backwaters of creeks and small to large rivers [Breder and Rosen 1966; Etnier and Starnes 1993]. Solitary, lurking hunter on other fishes as well as on ducklings, muskrats, and snakes. Oviparous, spawn in spring as the ice melts [Breder and Rosen 1966]."

"Some experts believe that some form of copulation happens during breeding of this species. The female turns on her side to expose her abdomen to the male who then swims against her in a forceful movement. Aftewards [*sic*], the female takes a rest and deposits her eggs in the sand. This whole activity is presumably repeated one more time [Breder and Rosen 1966]. Other

experts believe otherwise, that only a simple and simultaneous discharge of gametes happens during breeding [Breder and Rosen 1966]."

From Fuller et al. (2018a):

"Muskellunge are typically found in lakes with numerous submerged weed beds but can also be found in clear, sterile lakes with almost no weeds. Lakes with extensive, deep and shallow basins with tributary streams are preferred."

"Muskellunge spawn in the spring in shallow bays. Ideal temperature for spawning is 12.7°C. Eggs are scattered in shallow waters over submerged woody debris or over vegetation. Females produce 22,000-180,000 eggs which take 8-14 days to hatch. Young Muskellunge absorb the yolk sac after hatching and begin to prey on other organisms. Growth is rapid in the first three years, growth rate vary depending on water temperatures and available food. Females tend to grow faster and larger than males. As they grow larger, growth rates begin to level off. […] Reproduction can be limited by water temperatures below 10°C, fluctuating water temperatures, low oxygen, predation by fish and invertebrates on eggs and fry, prey availability, and hybridization with the Northern pike (Michigan DNR 2012; Becker 1983)."

"After hatching Muskellunge feed on other fish species including minnows and smaller Muskies. As they get larger, Muskellunge begin to prey on frogs, ducklings, and crayfish. Adult Muskellunge will consume fish up to a third their own length and prefer longer, cylindrical fish to spiny, deep bodied panfish. This preference is attributed to their metabolism which favors a single, large meal instead of multiple small ones (Michigan DNR 2012). Northern Pike, Yellow Perch, Walleye, Smallmouth Bass, Largemouth Bass, Rock Bass, sunfish, and other Muskellunge will prey on young Muskellunge. In hatcheries, giant water bugs, diving beetles, and large larvae of some insects were seen to be significant predators of recently hatched Muskellunge."

Human Uses

From Froese and Pauly (2018):

"Fisheries: commercial; aquaculture: commercial; gamefish: yes; aquarium: public aquariums"

"A commercial fishing once existe[d]; no longer occurring [Coker et al. 2001]."

From Fuller et al. (2018b):

"Muskellunge is a trophy fish which is considered the "premier challenge of freshwater angling," due to their scarcity, size, and fight (Michigan DNR 2012). Economic value of Muskellunge fishing to resorts, fishing goods stores and other associated businesses is high. Resident and nonresident fishermen spent an estimated $188.5 million in 1960 (Becker 1983)."

From Becker (1983):

"A major problem associated with the muskellunge stocking program is the 20-80% mortality which occurs within 3 weeks of stocking (Snow 1968)."

Diseases

Viral hemorrhagic septicaemia is an OIE-reportable disease (OIE 2019).

From Froese and Pauly (2018):

"Esocid lymphosarcoma retro-VLP, Viral diseases
Pike epithelial proliferation retro-VLP, Viral diseases"

Froese and Pauly (2017) list *Esox masquinongy* as a host for *Ergasilus caeruleus* and *Gyrodactylus fryi*.

From NatureServe (2013):

"Disease and pathogen issues are undoubtedly due to infections of Muskellunge in the Great Lakes by piscirickettsia (musky pox) and viral hemorrhagic septicaemia (VHS) over the past decade (Kerr 2011)."

Poelen et al. (2014) list *E. masquinongy* as a host for *Galoncus perniciosus*, *Neoechinorhynchus tenellus*, *Echinorhynchus salmonis*, *Tetraonchus loftusi*, *Megalogonia ictaluri*, *Cestrahelmins laruei*, *Azygia angusticauda*, *Azygia longa*, *Azygia* sp., *Gyrodactylus* sp., *Neoechinorhynchus rutile*, *Leptorhynchoides thecatus*, *Neoechinorhynchus cylindratus*, *Triaenophorus nodulosus*, *Triaenophorus crassus*, *Raphidascaris acus*, *Diplostomum* sp., *Phyllodistomum* sp., *Contracaecum* sp., feline roundworm (*Toxocara cati*), *Proteocephalus* sp., *Bothriocephalus* sp., *Hysterothylacium* sp., and *Toxascaris leonine*.

Threat to Humans

From Froese and Pauly (2018):

"Harmless"

3 Impacts of Introductions

From Snow (1968):

"The muskellunge stocked in Clear Lake were large enough at the time of stocking to utilize the fingerling bluegills. By the middle of the second summer the majority of the bluegill population was suitable prey for the fast-growing stocked muskellunge. There is little doubt that the bluegill population was utilized because it was of suitable size and abundance (85 to 95% of the total population).

The large numbers of extremely slow-growing bluegills in Clear Lake are an indication of very intense intraspecific competition. Since there was no appreciable change in growth and no drastic changes in abundance, there is no reason to believe that muskellunge stocking altered this competitive relationship even though muskellunge were stocked at several times the normal level. It may be that predator stocking never could be high enough, before other factors such as disease intervened to reduce the intensity of the intraspecific competition to the point where there is less competition, more food per fish and faster growth."

From Curry et al. (2007):

"Given these latter requirements [requirements of the model, diet composed of 100% Atlantic salmon smolts], it is highly improbable that muskellunge have a significant effect on the salmon population in this reach of the SJR [St. John River, New Brunswick]."

From Andrews et al. (2018):

"Thus, our findings corroborate those of Curry et al. (2007) [see above], who suggested that Muskellunge (and additionally Striped Bass as per this study) likely have only very little impact on Atlantic Salmon in the area downstream of the MGS [Mactaquac Generating Station]."

From Gammon and Hasler (1965):

"Two small northern Wisconsin lakes containing perch and bass were stocked with young muskellunge and the changes in population density, growth rate and length-weight relationship were measured. Within a year, perch in one lake decreased from 31,000 individuals to a density which was too low to estimate. Three years lapsed before a comparable reduction occurred in the other lake. Population levels of largemouth bass decreased because of the virtual absence of small bass surviving to the third summer of life, although several strong year classes were produced. Population levels of smallmouth bass increased significantly because of a net increase in recruitment, although no strong year classes were observed. The difference [*sic*] responses of these two species [largemouth and smallmouth bass] appear to be related to differences in the schooling tendencies and habitat preferences of the young. The growth rate of one- and two-year-old perch increased after the reduction in the number of perch. The length-weight relationship of all species remained unchanged."

4 History of Invasiveness

Esox masquinongy has a long history of introduction through stocking for fishery management purposes. It has also been introduced to areas by escaping from stocked locations. Peer-reviewed studies have shown that *E. masquinongy* has little to no impact on a native species of concern in one introduced location. However, in other areas, introduction of *E. masquinongy* led to significant reduction in the abundance of one native species and significantly shifted population demographics and abundances of two other species. Negative impacts of introduction have been shown in peer-reviewed literature for this species, therefore the history of invasiveness is high.

5 Global Distribution

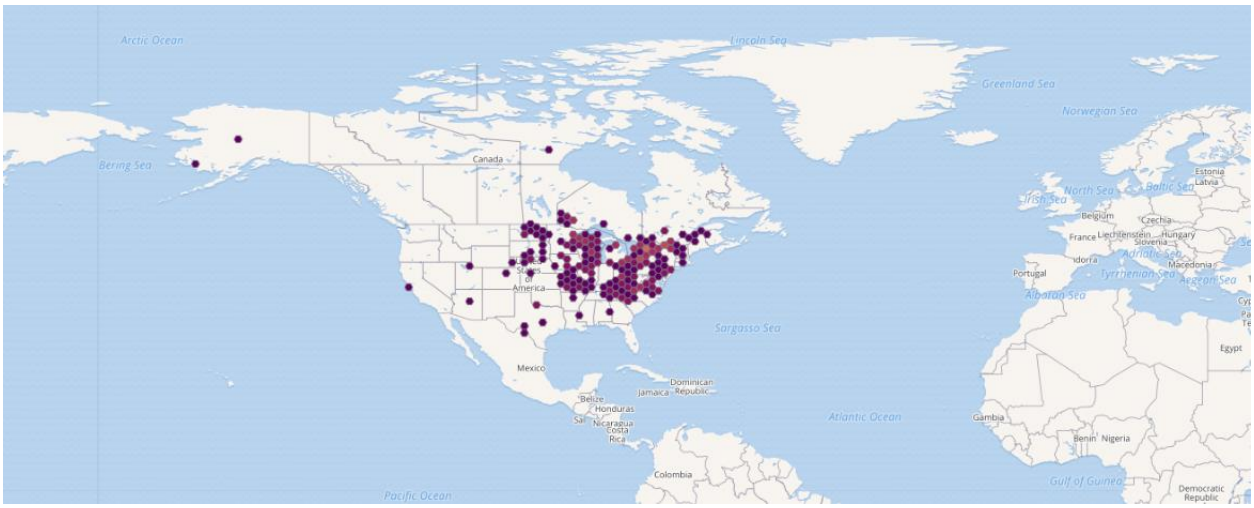

Figure 2. Known global distribution of *Esox masquinongy*. Locations are in the United States and Canada. Map from GBIF Secretariat (2018). The locations in Alaska, California, and Utah were not used to select source points for the climate match, they do not represent wild, established populations.

6 Distribution Within the United States

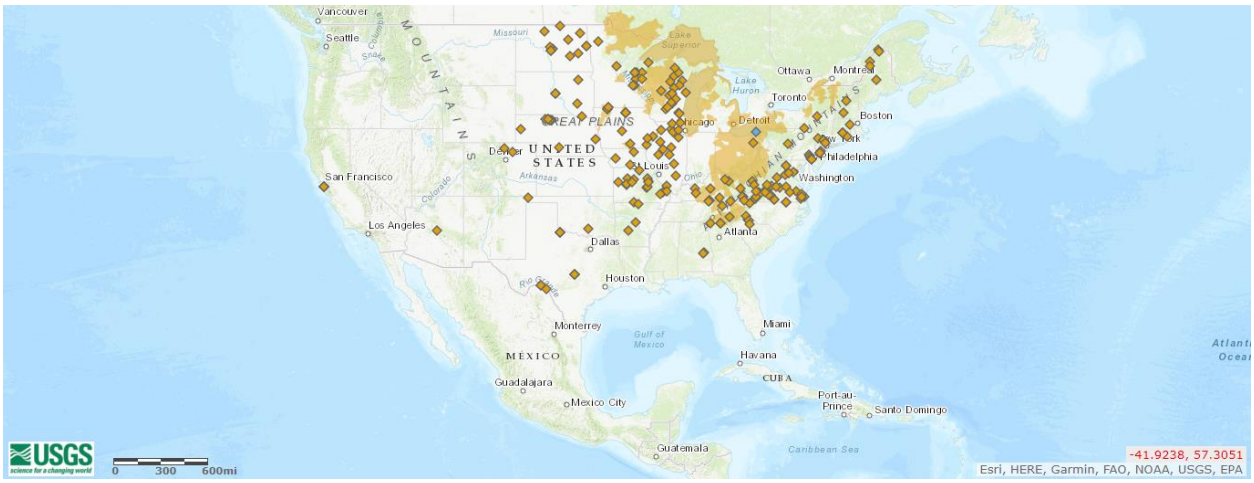

Figure 3. Known distribution of *Esox masquinongy* in the contiguous United States. Shaded orange areas in the east and midwest represent the native range of the species. Map from Fuller et al. (2018a). Locations in Arizona, Arkansas, California, Delaware, Georgia, Massachusetts, and southern Oklahoma were not used to select source point in the climate match; the points do not represent currently established wild populations. Locations in Alabama, Colorado, Connecticut, southern Illinois, and Texas were not used to select source points; the points represent populations sustained by stocking.

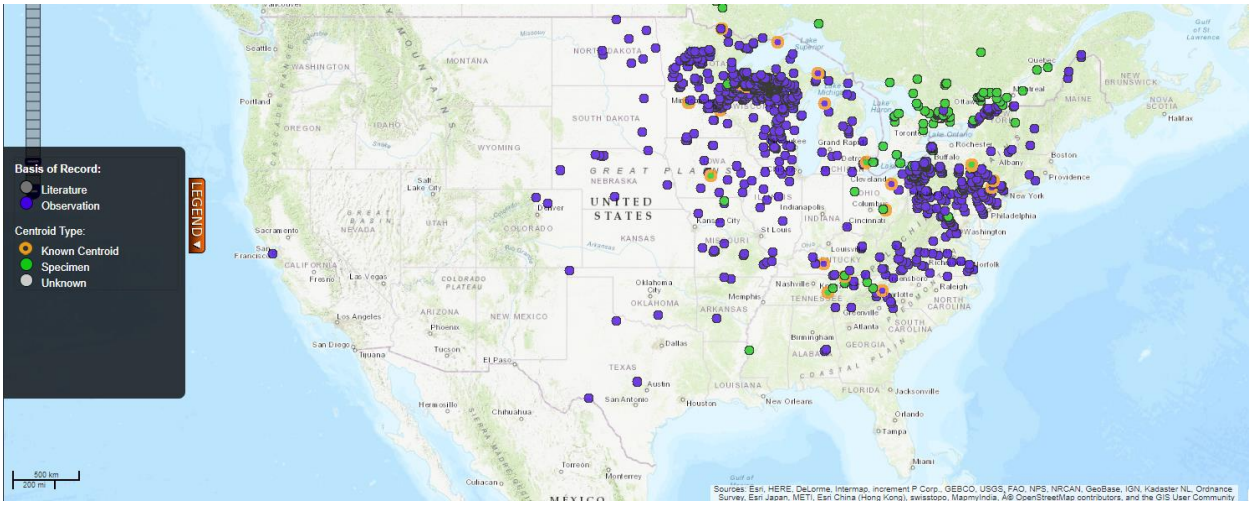

Figure 4. Additional known distribution of *Esox masquinongy* in the contiguous United States. Map from BISON (2018). Locations in Arizona, Arkansas, California, Delaware, Georgia, Massachusetts, and southern Oklahoma were not used to select source point in the climate match; the points do not represent currently established wild populations. Locations in Alabama, Colorado, Connecticut, southern Illinois, and Texas were not used to select source points; the points represent populations sustained by stocking.

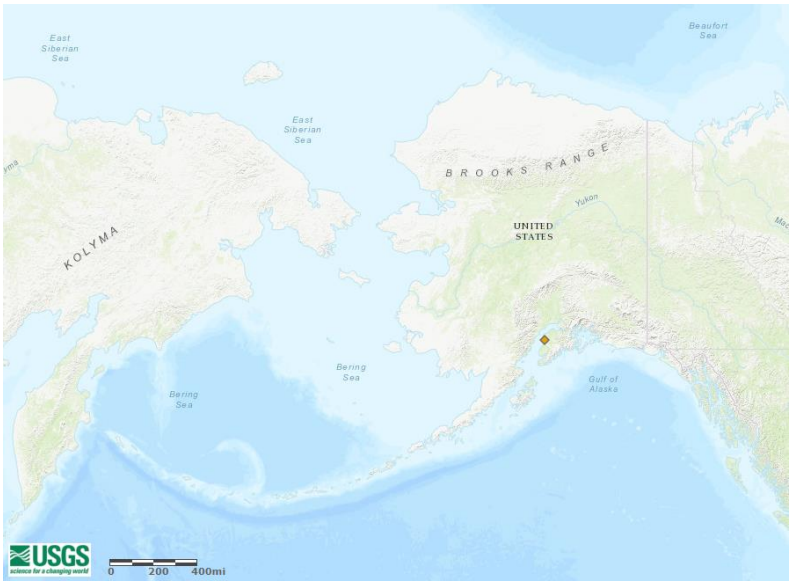

Figure 5. Known distribution of *Esox masquinongy* in Alaska. Map from Fuller et al. (2018a). The location was not used as a source point in the climate match; the introduction did not result in an established population.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Esox masquinongy* was high for much of the contiguous United States. The area of high match stretched from Maine to southern Georgia in the east and west to Montana and parts of northern Texas. The native range of the species includes parts of the high match areas: St. Lawrence River, Great Lakes basin, and northern Mississippi basin. There were areas of low match in southern Florida and Texas. The western edge of the contiguous United States also had a low match, from Washington to southwestern Arizona. All other areas had a medium match. The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for contiguous United States was 0.723, high (score of 0.103 and greater are classified as high). All States had high individual climate scores except for Nevada which had a medium individual score, and California, Oregon, and Washington which had low individual scores.

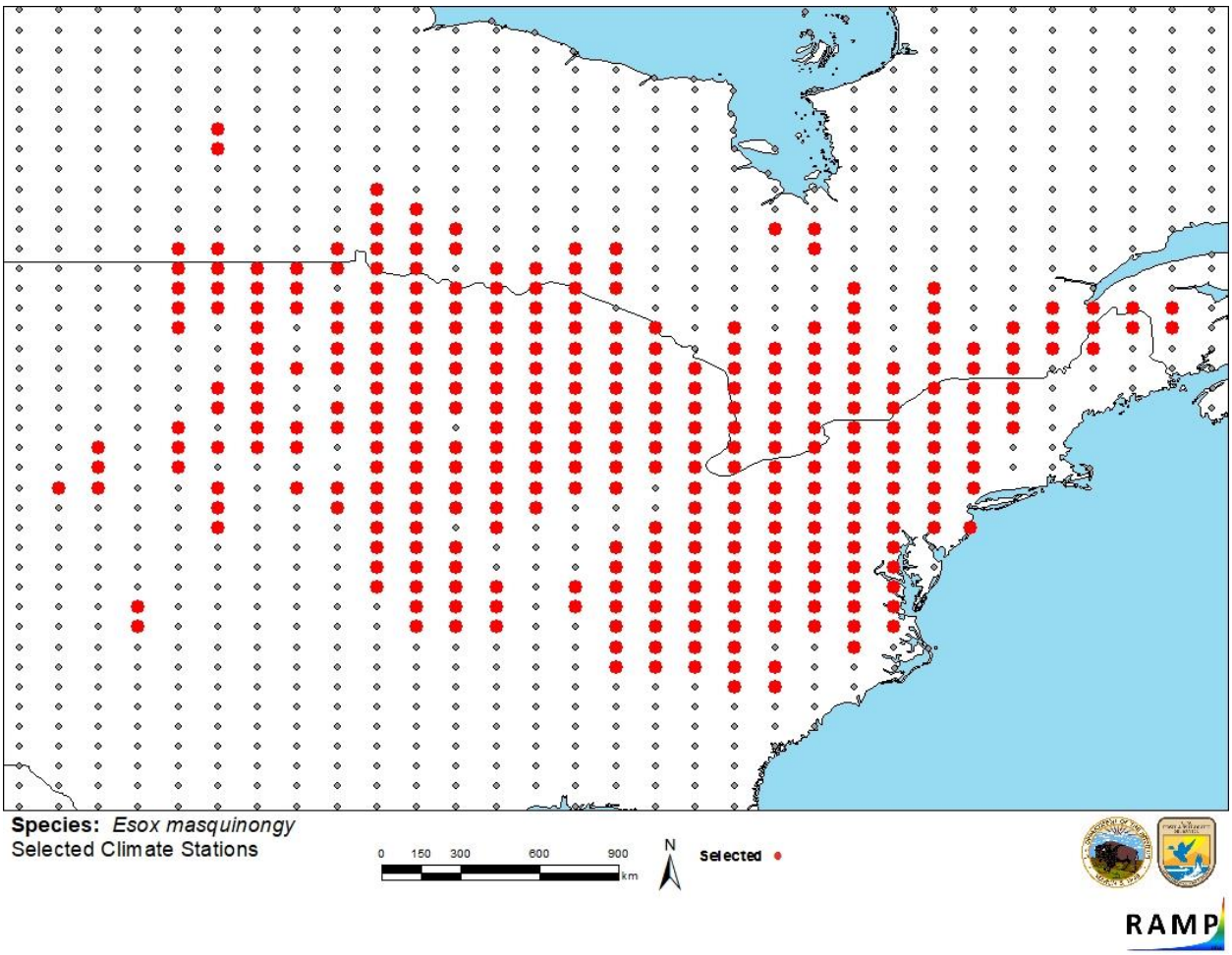

Figure 6. RAMP (Sanders et al. 2018) source map showing weather stations in North America selected as source locations (red; Canada, United States) and non-source locations (gray) for *Esox masquinongy* climate matching. Source locations from BISON (2018), Fuller et al. (2018a), and GBIF Secretariat (2018). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

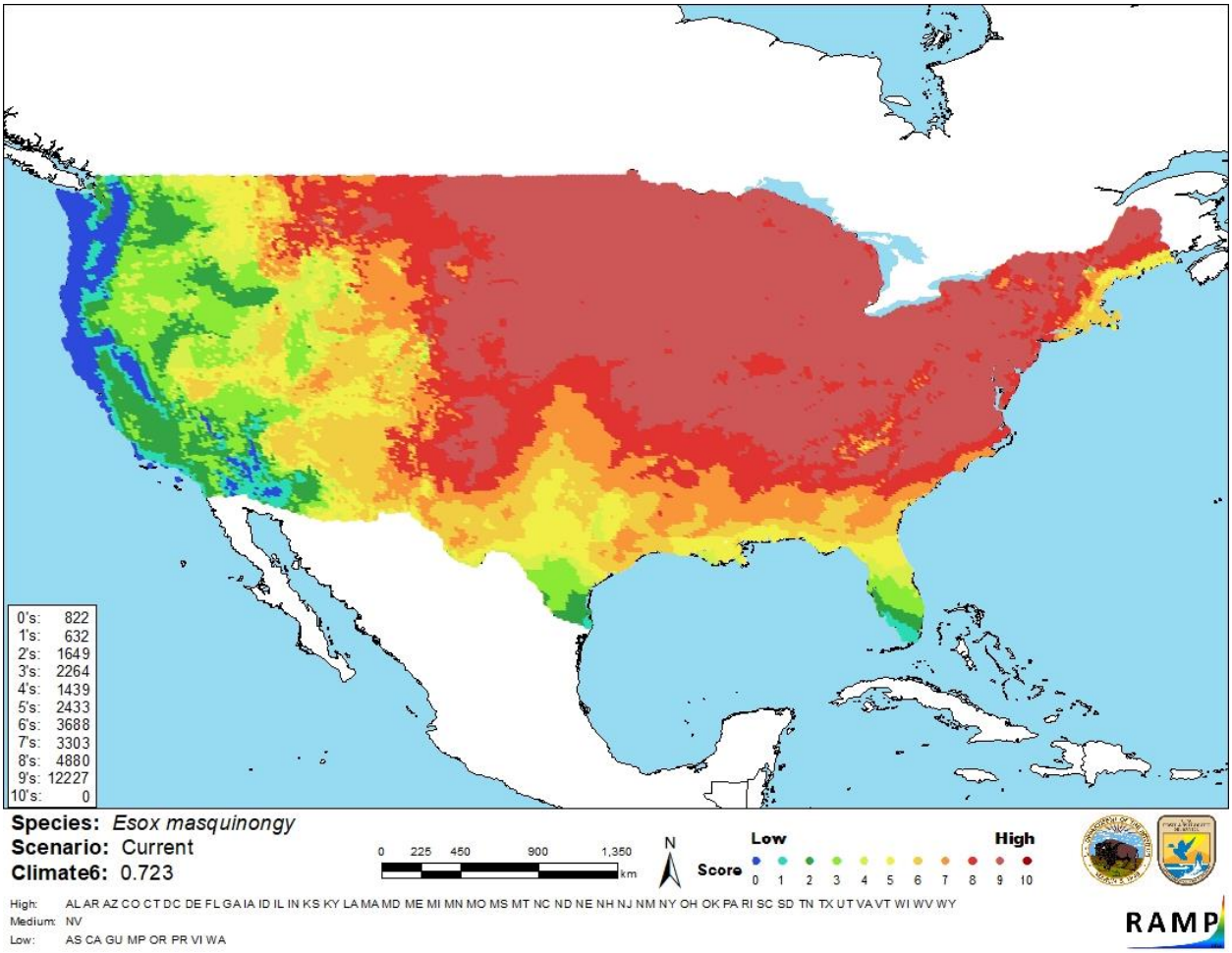

Figure 7. Map of RAMP (Sanders et al. 2018) climate matches for *Esox masquinongy* in the contiguous United States based on source locations reported by BISON (2018), Fuller et al. (2018a), and GBIF Secretariat (2018). 0/Blue = Lowest match, 10/Red = Highest match.

The High, Medium, and Low Climate match Categories are based on the following table:

Climate 6: (Count of target points with climate scores 6-10)/(Count of all target points)	Overall Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

8 Certainty of Assessment

The certainty of assessment is medium. There is quality information available about the biology and ecology of *Esox masquinongy*. Records of introduction were found. Some information was available regarding impacts of introduction. Information on impacts was from peer-review sources but the information was conflicting, suggesting that impacts may differ depending on specific conditions. The certainty is reduced from high to medium due to that reason.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Muskellunge (*Esox masquinongy*) is a large predatory fish native to northern basins in the eastern United States. Muskellunge is a popular sport fish and has been stocked around the country to support recreational fishing. The history of invasiveness is high. There is a long history of deliberate introductions of *E. masquinongy* both within and outside of the native range of the species. Some of the introductions have resulted in established populations. A few sources state that *E. masquinongy* has had no or virtually no impact on native fish species. One source provided information that *E. masquinongy* caused a significant decline in yellow perch populations in two lakes where *E. masquinongy* was introduced. The overall climate match with the contiguous United States was high, both in its native range around the Great Lakes and it areas outside its native rage. Much of the eastern two-thirds of the contiguous United States had a high climate match. The certainty of assessment is medium because some studies indicated virtually no impact on native species. The overall risk assessment category is High.

Assessment Elements

- **History of Invasiveness (Sec. 4): High**
- **Overall Climate Match Category (Sec. 7): High**
- **Certainty of Assessment (Sec. 8): Medium**
- **Remarks/Important additional information:** *Esox masquinongy* can be infected with Viral hemorrhagic septicaemia, an OIE-reportable disease.
- **Overall Risk Assessment Category: High**

10 Literature Cited

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 11.

Andrews SN, Zelman K, Ellis T, Linnansaari T, Curry RA. 2018. Diet of striped bass and muskellunge downstream of a large hydroelectric dam: a preliminary investigation into suspected Atlantic salmon smolt predation. North American Journal of Fisheries Management 38:734–746.

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