U.S. Fish & Wildlife Service

Rainbow Smelt (*Osmerus mordax*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, November 2023
Revised, February 2024
Web Version, 8/11/2025

Organism Type: Fish
Overall Risk Assessment Category: High

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1 Native Range and Status in the United States

Native Range

From Taylor and Bentzen (1993):

"The rainbow smelt, *Osmerus mordax* (Mitchill), is an osmerid fish native to watersheds tributary to the Western Atlantic Ocean from New Jersey [United States] north to Lake Melville on the Labrador [Canada] coast (Scott and Scott 1988; Nellbring 1989)."

From NatureServe (2023):

"Occurs naturally in lakes and ponds in New Hampshire, Maine, New Brunswick, Nova Scotia, and Newfoundland (Buckley 1989)."

Status in the United States

Fuller et al. (2023a) report the native range of *Osmerus mordax* within the following States: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont.

From Rooney and Paterson (2009):

"[…] the expansion of rainbow smelt into the Laurentian Great Lakes is well documented. Rainbow smelt invaded the Great Lakes watershed through an intentional introduction to Crystal Lake, Michigan in 1912 (Creaser 1925). They were first reported from Lake Michigan, Lake Huron, Lake Superior, and Lake Erie in 1923, 1925, 1930, and 1935, respectively (Nellbring 1989). Rainbow smelt were first reported from Lake Ontario in 1929, and probably reached it by dispersal along natural waterways from the Finger Lakes, New York, where they were intentionally introduced in 1917 (Nellbring 1989). Mayden et al. (1987) inferred that rainbow smelt reached the Illinois River from Lake Michigan, but that most occurrences in the Mississippi-Missouri drainage basin resulted from introductions into two reservoirs. In 1971, rainbow smelt were intentionally introduced into Lake Sakakawea, North Dakota, and, in 1974, smelt were accidentally introduced to Lake Oahe, South Dakota (Mayden et al. 1987, Nellbring 1989). From these two reservoirs they have spread down the Mississippi River to St. Francisville, Louisiana (Suttkus and Connor 1979) and upstream as far as the North Peck Dam and the Yellowstone River, Montana (Franzin et al. 1994). More recently, rainbow smelt have invaded the Hudson Bay drainage basin, likely also assisted by intentional or accidental human transfer. […] In 1972, they were reported in the Rainy River system in Burntside Lake, Minnesota […] (Franzin et al. 1994). Rainbow smelt have since been captured in numerous lakes in the Hudson Bay drainage basin (Remnant et al. 1997), and are now reported in Hudson Bay (Franzin pers. com. 2007)."

From Fuller et al. (2023a):

"Introduced populations of this species have been very successful and the Rainbow Smelt is now established in the Great Lakes and in most rivers and lakes where introduced. […] Nevertheless, no adults of the Rainbow Smelt have been found in either Missouri (Pflieger 1997) or Tennessee (Etnier and Starnes 1993). As such, Pflieger (1997) concluded that populations in Missouri are maintained by the continued escape of fish from upstream reservoirs on the Missouri River. As of 1987, only one specimen had been taken from the Ohio River (Mayden et al. 1987). It is considered extirpated in Georgia; the species has not been observed in that state since its release (Dahlberg and Scott [1971])."

Additionally, Fuller et al. (2023a) report established nonnative populations of *Osmerus mordax* in Arkansas, Colorado, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Dakota, Vermont, Virginia, and Wisconsin. They report unknown or failed population status of introduced *O. mordax* in Idaho and Maryland.

This species may be available in trade in the United States in areas where it is legal.

From State of Vermont (2024):

"Rainbow smelt […] may be commercially sold as bait"

Regulations

Osmerus mordax is regulated in Colorado (CPW 2023), Minnesota (Minnesota DNR 2022), New Hampshire (NHFG 2022), Oklahoma (Oklahoma Secretary of State 2019), and Wisconsin (Wisconsin DNR 2022). Please refer back to state agency regulatory documents for details on the regulations, including restrictions on activities involving this species. While effort was made to find all applicable regulations, this list may not be comprehensive. Notably, it does not include regulations that do not explicitly name this species or its genus or family, for example, when omitted from a list of authorized species with blanket regulation for all unnamed species.

Means of Introductions within the United States

From Fuller et al. (2023a):

"The earliest known record [of introduction] is from 1912, when eggs were stocked in Crystal Lake, Michigan, which drains into Lake Michigan (Van Oosten 1937). Fish escaped into Lake Michigan and spread quickly throughout the Great Lakes and their tributaries (Creaser [1925]; Gerking 1945; Hubbs and Lagler 1947; Nelson and Gerking 1968; Christie 1974; Eddy and Underhill 1974; Smith 1979; Morrow 1980; Phillips et al. 1982; Cooper 1983; Emery 1985)."

"Two means have been proposed to explain the introduction of Rainbow Smelt into the Missouri and Mississippi rivers. It may have spread from Lake Michigan via the Chicago sanitary canal to the Illinois River and then to the Mississippi and Missouri rivers (Burr and Mayden 1980). Alternatively, the species may have gained access to these rivers as a result of a stocking at Lake Sakakawea, North Dakota, in 1971 (Bouc 1987; Mayden et al. 1987; Holton 1990). The second explanation seems more plausible because of a lack of records from the Illinois River."

"The species was originally introduced into Lake Sakakawea, North Dakota, as forage for Salmonids (Mayden et al. 1987)."

From Rooney and Paterson (2009):

"Rainbow smelt can also be transferred accidentally by humans. In New England, New York, and New Jersey, rainbow smelt introductions have been attributed to the escape of smelt used as live bait in recreational fishing (Halliwell et al. 2001). This is despite legislation and regulations prohibiting the transfer of live bait across jurisdictional boundaries (Litvak and Mandrak 1993). Other methods of accidental transfer include the release of fertilized eggs while cleaning sexually mature smelt (Evans and Loftus 1987) and the transfer of fertilized eggs attached to aquatic vegetation or rocks (Kircheis and Stanley 1981)."

Remarks

Due to taxonomic changes, there is confusion between *Osmerus mordax* and its congener *O. dentex*, which has a Pacific and Arctic distribution. The latter was formerly considered a subspecies of *O. mordax.* Information presented in this ERSS applies to the Atlantic-native *O. mordax.* Populations of *O. mordax* resident in lakes were formerly considered a separate species, *O. spectrum,* but are now synonymized with *O. mordax* (Fricke et al. 2023).

From Luey et al. (1982):

"Scott and Crossman (1973) and McAllister et al. (1980) divided the genus into two species, *O. eperlanus* of the European Atlantic coast and *O. mordax* of the Pacific, Arctic and western Atlantic coasts. The latter was separated into two sub species, *O. m. mordax* for the western Atlantic smelt, and *O. m. dentex* for the Pacific and Arctic forms."

From Dyldin et al. (2021):

"In the past (Nikolskii 1956; Klyukanov 1969, 1977; Pietsch et al. 2001; Gritsenko 2012), this species [*Osmerus dentex*] was recorded from Sakhalin [Russia] as *O. mordax* (non Mitchill, 1814), or as its subspecies *O. mordax dentex*. Recently, several authors (Bogutskaya et al. 2008; Pietsch et al. 2012; Dyldin & Orlov [2016]; Dyldin et al. [2018]) treated it as an independent species, *O. dentex*, on the basis of genetic and morphological differences."

From NatureServe (2023):

"Some lacustrine populations of dwarf rainbow smelt in Quebec, New Brunswick, and Maine were regarded as a separate species, *O. spectrum*, by Lanteigne and McAllister (1983). However, the 1991 and 2004 AFS checklists did not accept *O. spectrum* as a valid species because of the apparent multiple independent origins of the dwarf form (Robins et al. 1991,Nelson et al. 2004)."

"Pacific and Arctic populations that formerly were included in *O. mordax* are now included in a distinct species, *O. dentex* (Page et al. 2013)."

Sources disagree on the status of *Osmerus mordax* as native or introduced to Lake Ontario.

From Emery (1985):

"Hubbs and Lagler (1970) believed that rainbow smelt were endemic to Lake Ontario, and this hypothesis was also favored by Mackay (1963) and Smith ([1968]). Scott and Crossman (1973), however, believed that smelt most likely migrated into the lake by way of the extensive canal system in New York (Cayuga Lake to Cross Lake to Seneca River to Oswego River) that was connected to the Atlantic Ocean drainage."

From Mills et al. (1993):

"[…] origin of Lake Ontario populations has been debated. These populations are thought to have either been native to the lake or have migrated up the Erie Canal system from the Atlantic drainage. DeKay (1842), however, only noted rainbow smelt from coastal areas and does not record it from the upper Hudson River. At the time, the species was economically valuable in coastal markets. This coastal distribution suggests that rainbow smelt populations in the Lake Ontario basin in central New York are either not native or that they were overlooked in early surveys."

From Fuller et al. (2023a):

"Another alternative is that *O. mordax* migrated downstream from the upper Great Lakes, where it is considered nonindigenous."

Osmerus mordax 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

From ITIS (2023):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Deuterostomia
      Phylum Chordata
        Subphylum Vertebrata
          Infraphylum Gnathostomata
            Superclass Actinopterygii
              Class Teleostei
                Superorder Protacanthopterygii
                  Order Osmeriformes
                    Suborder Osmeroidei
                      Superfamily Osmeroidea
                        Family Osmeridae
                          Genus *Osmerus*
                            Species *Osmerus mordax*

According to Fricke et al. (2023), *Osmerus mordax* (Mitchill 1814) is the current valid name for this species.

The following synonyms of *Osmerus mordax* from Fricke et al. (2023) were used to search for information for this report: *Osmerus abbottii, Atherina mordax, Osmerus sergeanti, Osmerus spectrum,* and *Osmerus viridescens.*

Size, Weight, and Age Range

From Becker (1983):

"Average length 178mm (7in) TL [total length]."

From Fuller et al. (2023a):

"Size: Adult: 100 mm to 350 mm. […] They are sexually dimorphic, with females growing larger and living longer than males [McKenzie 1958; Bailey 1964]."

From Rooney and Paterson (2009):

"Under optimum conditions in large lakes, rainbow smelt may grow as large as 35.6 cm (Scott and Crossman 1998) and may live as long as 7+ years. In smaller lakes, maximum sizes may be substantially less (Scott and Crossman 1998)."

Environment

From Froese and Pauly (2023):

"Marine; freshwater; brackish; pelagic-oceanic; anadromous [Riede 2004]; depth range 0 - 425 m [Coad and Reist 2004], usually? - 150 m [Love et al. 2005]."

From Fuller et al. (2023a):

"Rainbow Smelt can either be anadromous or landlocked in freshwater. They inhabit a large portion of the water column that varies throughout their life. Young of the year Rainbow Smelt typically are found along shorelines in warmer waters 2 to 6 meters deep. Yearlings are found in cooler water within the pelagic zones of lakes (Rooney and Paterson 2009)."

"Rainbow Smelt can survive in a broad range of environmental conditions. They inhabit temperatures from -1.8°C to around 20°C (Nellbring 1989; Raymond 1995) […] A review of data from 8,842 Ontario lakes found that Rainbow Smelt were only caught in lakes with a pH>6 despite adequate opportunity to invade lakes with lower pH values (Evan and Loftus 1987)."

Climate

From Froese and Pauly (2023):

"Temperate; 6°C - 18°C [Scott and Crossman 1973]"

Distribution Outside the United States

Native

From Taylor and Bentzen (1993):

"The rainbow smelt, *Osmerus mordax* (Mitchill), is an osmerid fish native to watersheds tributary to the Western Atlantic Ocean from [United States] north to Lake Melville on the Labrador [Canada] coast (Scott and Scott 1988; Nellbring 1989)."

From NatureServe (2023):

"Occurs naturally in lakes and ponds in […] New Brunswick, Nova Scotia, and Newfoundland (Buckley 1989)."

Part of the native range for this species is within the United States; see section 1 for a complete description of the native range.

Introduced

From Fuller et al. (2023b):

"Introductions in inland Ontario Lakes"

From Rooney and Paterson (2009):

"The range of rainbow smelt […] has been greatly extended by a combination of human introductions and natural dispersal. Rainbow smelt are now present in many lakes throughout the St. Lawrence River drainage system, including all of the Laurentian Great Lakes, many large lakes [in Canada] such as Lakes Simcoe, Nipissing, Timiskaming, and Nipigon, and numerous small lakes (Evans and Loftus 1987). Smelt are also present in the Hudson Bay drainage basin and are found in lakes in […] north-western Ontario, and Manitoba, including Lake Winnipeg (Franzin et al. 1994) and the Nelson River system (Remnant et al. 1997)."

According to the Global Register of Introduced and Invasive Species (as reported in GBIF Secretariat 2023), *Osmerus mordax* is introduced in Mexico. However, no other information was found on the status of *O. mordax* in Mexico.

Means of Introduction Outside the United States

From Rooney and Paterson (2009):

"Human transfer has been the major force accelerating the range expansion of rainbow smelt (Daniels 2001, Evans and Loftus 1987, Halliwell et al. 2001, Kircheis and Stanley 1981). While this is mainly through intentional and accidental introductions, construction of canals to link previously isolated basins has also facilitated the dispersal of exotics."

Short Description

From Froese and Pauly (2023):

"Dorsal spines (total): 0; Dorsal soft rays (total): 8; Anal spines: 0; Anal soft rays: 12 - 16; Vertebrae: 58 - 70. Body elongate, laterally compressed, greatest depth at anterior of dorsal fin origin. Head moderate; eye moderately large; snout elongate, pointed. […] Teeth specially enlarged on tongue and front of vomer. Body color is pale green on back, with purple, blue, and pink iridescent reflections on the side when freshly caught."

Biology

From Froese and Pauly (2023):

"Inhabits cool clear lakes, medium to large rivers, and coastal waters [Page and Burr 2011]. A schooling species that occurs in midwater of lakes or inshore coastal waters [Scott and Crossman 1973] […] Coastal populations are anadromous [Page and Burr 2011]. Migrates up to 1,000 km upstream in rivers [Allen and Smith 1988]. […] Feeds on invertebrates such as amphipods, ostracods, aquatic insect larvae and aquatic worms [Scott and Crossman 1973]; food also include [sic] copepods, euphausiids, mysids and small fishes (silversides, mummichogs and herring) [Scott and Scott 1988; Etnier and Starns 1993]."

From Fuller et al. (2023):

"Spawning of Rainbow Smelt occurs after ice-out in early spring once water temperatures reach ~4.4°C with a peak at 10°C (Becker, 1983). In the Great Lakes, spawning occurs in tributary streams and occasionally on the shoreline. Eggs of the Rainbow Smelt are adhesive, negatively buoyant, and adhere to substrate until hatching 2 to 3 weeks later (Scott and Crossman 1973; Becker 1983). […] They are an important forage fish for many predators, including Atlantic Salmon (*Salmo salar*), Walleye (*Sander vitreus*), and Lake Trout (*Salvelinus namaycush*) (Gorman 2019)."

From NatureServe (2023):

"May first breed at age of 1 year in south, usually at 2 years or older in north (Buckley 1989)."

Human Uses

From NatureServe (2023):

"In New England, annual commercial landings reached 550,000 kg in 1889, then decreased to 215,250 kg in 1951-1954 and declined further to 69,700 kg in 1969-1971 (see sources in Morrow 1980)."

From Fuller et al. (2023a):

"This species is eaten by humans and used as bait for Salmonids and Walleye (Pflieger 1997)."

"This species has done so well in the Great Lakes that a commercial fishery targeting Rainbow Smelt has been operating there for many years (Smith 1985)."

This species may be available in trade in the United States in areas where it is legal.

From State of Vermont (2024):

"Rainbow smelt […] may be commercially sold as bait"

Diseases

No information was found associating *Osmerus mordax* with any diseases listed by the World Organization for Animal Health (2023).

According to Poelen et al. (2014), *Osmerus mordax* is a host for the following pathogens and parasites: Aquareovirus A, *Gluea hertwigi, Ascarophis arctica, Pseudoterranova decipiens*, *Ascaris, Camallanus, Acanthobothrium typicum, Contracaecum osculatum, Corynosoma, Cosmocephalus obvelatus, Ophiostoma, Dermocystidium, Ancyracanthus impar, Bothriocephalus, Derogenes varicus, Cystidicola stigmatura, Diplostomum, Echinorhynchus salmonis, Diplostomum spathaceum, Eudistoma, Ergasilus auratus, Eubothrium, Fasciola, Brachyphallus crenatus, Azygia longa, Leptorhynchoides thecatus, Echinorhynchus lateralis, Philometra agubernaculum, Proteocephalus tetrastomus, Eucoleus breviductus, Podocotyle olssoni, Proteocephalus, Yersinia ruckeri.*

Threat to Humans

From Froese and Pauly (2023):

"Harmless"

3 Impacts of Introductions

From Cornelius (2000):

"By the 1950s, habitat damage and overfishing had taken their toll on lake trout, whitefish, cisco, and blue pike populations. Invasion of the rainbow smelt may have been the death knell for these species due to smelt predation efficiency on larval fish."

From Fuller et al. (2023a):

"Dominant prey form for salmonids; contributed to extinction of Blue Pike; affect imperiled species ([USEPA] 2008; Crossman 1991). In the Great Lakes, Rainbow Smelt compete with Lake Herring *Coregonus artedii* for food (Becker 1983). Christie (1974) supplied some evidence to support this, correlating lake herring decline with smelt increases in most of the lakes. Todd (1986) also reported that smelt may be partially responsible for the decline of whitefish *Coregonus* spp. in the Great Lakes."

“Havey (1973) reported increased growth of landlocked Atlantic Salmon following the introduction of smelt as a forage species in a lake in Maine. Hrabik et al. (1998) found evidence of competition for food between introduced Rainbow Smelt and native Yellow Perch *Perca flavescens* in Wisconsin lake habitats. Stedman and Argyle (1985) found the diet of *O. mordax* to include young-of-the-year fish. The species that were consumed by *O. mordax* depended upon the prey availability (Stedman and Argyle 1985). Stedman and Argyle (1985) discovered that in Lake Michigan in late October of 1982, *O. mordax* consumed Bloaters (*Coregonus hoyi*) and Alewives (*Alosa pseudoharegus*). The authors also noted that although *O. mordax* does not appear to have had an impact on Bloater populations in the last five years, future impact is possible. A study on nighttime consumption of *O. mordax* in Lake Ontario revealed their primary food source to be Slimy Sculpin (*Cottus cognatus*) and opossum shrimp (*Mysis relicta*) (Brandt and Madon 1986). Juvenile Lake Trout (*Salvelinus namaycush*) rely heavily on *C. cognatus*, competing directly with *O. mordax*, while adult *S. namaycush* consume *O. mordax* (Brandt and Madon 1986). The authors point out that *S. namaycush* may be a keystone predator in the relationship between *O. mordax* and *C. cognatus*. Rainbow Smelt contain high levels of thiaminase, which reduces absorption and assimilation of thiamine in predators such as salmonids [and] can cause reduced body condition, swim performance, and other potential impacts (Houde et al. 2015).”

From Fuller et al. (2023b):

“Blukacz-Richards et al. (2017) identified a strong trophic interaction between mercury concentrations in Rainbow Smelt and herring gull (*Larus argentatus*) eggs in Lake Superior and Lake Ontario. However, trophic elevation in forage fish is unlikely to result in harmful bioaccumulation (Swanson et al. 2003, 2006).”

From Rooney and Paterson (2009):

“The growth rates and condition factors of predatory fish often increase following rainbow smelt introductions (e.g. Havey 1973, Johnson and Goettl 1999, Jones et al. 1994). These increases may not be sustainable, however, and introducing rainbow smelt as forage fish for sport or commercial fisheries is now widely cautioned against (Evans and Loftus 1987, Johnson and Goettl 1999, Kircheis and Stanley 1981, Nellbring 1989, Ricciardi 2005). In some cases, the introduction of rainbow smelt has resulted in declines of predatory fish populations (e.g. Mercado-Silva et al. 2007).”

“Rainbow smelt populations can be highly variable and prone to mass mortalities, making them an unstable source of food for piscivores (Havey 1973, Kircheis and Stanley 1981, Nellbring 1989). […] Fluctuations in rainbow smelt populations can negatively affect commercial and recreational fisheries where smelt have become the dominant forage species (e.g. Havey 1973, Johnson and Goettl 1999, Kitchell and Crowder 1986). In large lakes with high species diversity, piscivores may switch to feeding on native fish species but if exotic rainbow smelt have displaced native planktivores, a shift in diet may not be feasible.”

“In Harvey’s Lake, Pennsylvania, the introduction of rainbow smelt was followed by the extirpation of *L. kindtii* (Reif and Tappa 1966) and the replacement of larger-bodied *Daphnia pulex* by smaller-bodied *D. dubia* and *Bosmina longirostris*.”

“Rainbow smelt in Lake Ontario were found to have significantly higher concentrations of DDE and PCBs than *Mysis relicta*, which is the main source of food for many top predators in lakes without abundant planktivores (Kiriluk et al. 1995). As a result, smelt invasion may increase contaminant transfer to terminal predators. Evidence from 21 Ontario lakes supports this contention. The concentration of PCBs in lake trout tissue was 163% higher in lakes containing smelt than in smelt-free lakes when lakes without *M. relicta* were considered and 345% higher in lakes with smelt than in smelt-free lakes when lakes with *M. relicta* were compared (Vander Zanden and Rasmussen 1996).”

Osmerus mordax is regulated in Colorado (CPW 2023), Minnesota (Minnesota DNR 2022), New Hampshire (NHFG 2022), Oklahoma (Oklahoma Secretary of State 2019), and Wisconsin (Wisconsin DNR 2022). See section 1.

4 History of Invasiveness

The History of Invasiveness for *Osmerus mordax* is classified as High. Established nonnative populations have been documented in many areas of the United States and Canada. A variety of negative impacts of the introduction of *Osmerus mordax* have been documented, including fish and zooplankton community changes, changes in native piscivore diet, and bioaccumulation of contaminants. It is used as a bait fish in the United States and collected for human consumption.

5 Global Distribution

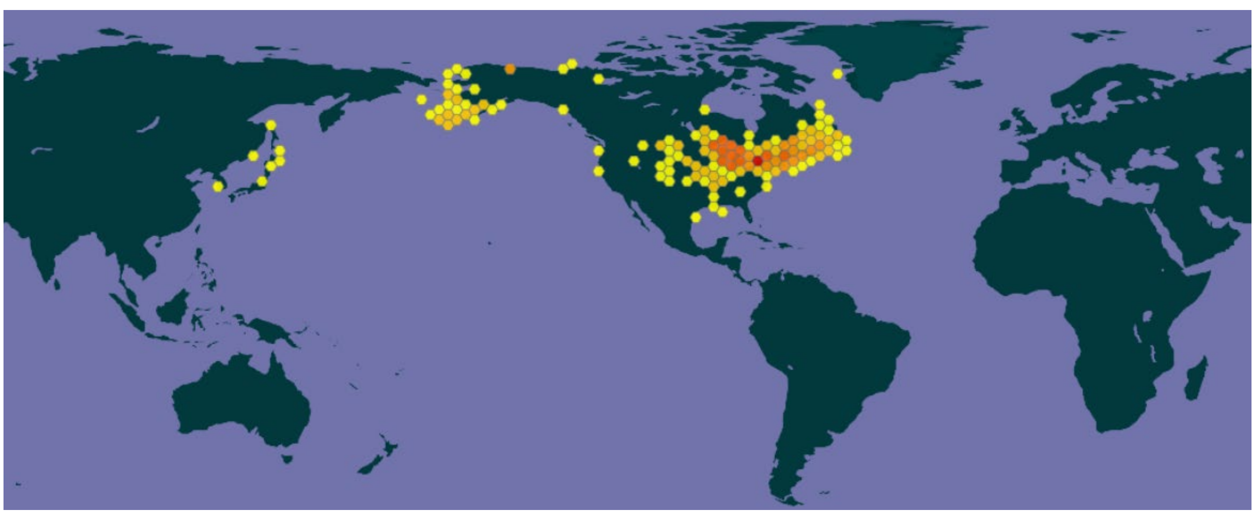

Figure 1. Reported global distribution of *Osmerus mordax*. Map from GBIF Secretariat (2023). Observations are reported from the United States, Canada, Japan, Korea, Russia. Pacific and Arctic occurrences of *O. mordax* may be misidentifications of congener *O. dentex* and were therefore excluded from the climate matching analysis. Occurrences on Hudson Bay and in Labrador north of Lake Melville are not known to represent established populations and were

excluded from the climate matching analysis. Because the climate matching analysis (section 7) is not valid for marine waters, no marine occurrences were used in the climate matching analysis.

6 Distribution Within the United States

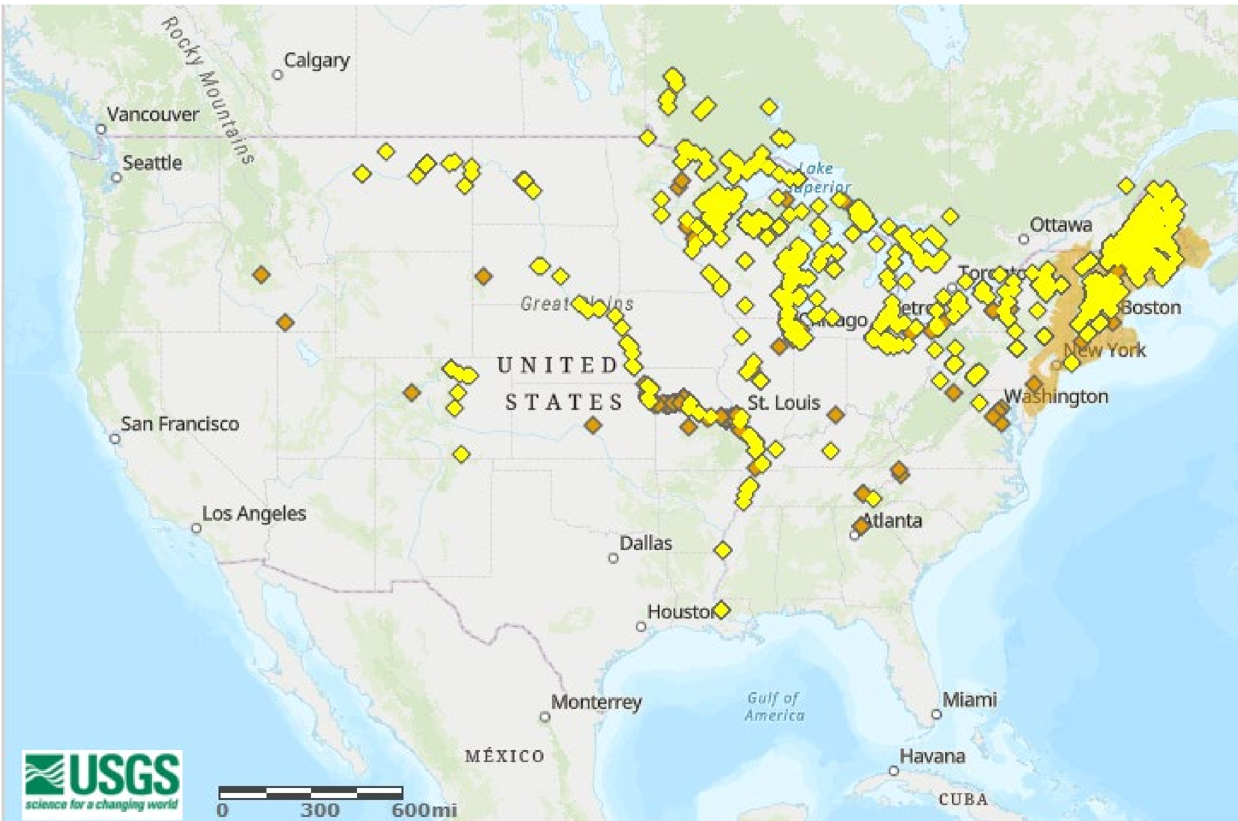

Figure 2. Reported distribution of *Osmerus mordax* in the United States. Map from Fuller et al. (2025). Orange shading (Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont) represents the native range of *O. mordax* in the United States. Yellow points (Arkansas, Colorado, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Dakota, Tennessee, Virginia, Vermont, Wisconsin) represent established populations of *Osmerus mordax* and orange points (Colorado, Connecticut, Georgia, Idaho, Illinois, Indiana, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New York, North Dakota, Ohio, Pennsylvania, South Dakota, Tennessee, Virginia, Wisconsin) represent failed populations or introductions with unknown status. Only points representing established populations were used to select source points for the climate matching analysis. Although some points in central Missouri are reported here as established populations, Fuller et al. (2023a) state that no adult *O. mordax* have been found in either location; because of this uncertainty, points from these two States were not used to select source points for the climate matching analysis. Because the climate matching analysis (section 7) is not valid for marine waters, no marine occurrences were used in the climate matching analysis.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Osmerus mordax* was high for most of the contiguous United States with some areas of medium and low climate match. The highest matches occurred from Maine south to Virginia, west to Montana and Colorado, and along the Lower Mississippi River to Louisiana; this area of highest match closely mimicked the current distribution (native range and introduced) of *O. mordax* in the United States. Areas of medium match were found in Florida, central to southern Texas, southern New Mexico, eastern Arizona, much of central and southern California, and the Great Basin. Areas of low match were found in southern Florida, the Sonoran Desert, the Cascade and Sierra Nevada ranges, and along the Pacific coast north of San Francisco Bay. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.807, indicating that Yes, there is establishment concern for this species outside its native range. The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). Establishment concern is warranted for Climate 6 scores greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024).

Projected climate matches in the contiguous United States under future climate scenarios are available for *Osmerus mordax* (see Appendix). These projected climate matches are provided as additional context for the reader; future climate scenarios are not factored into the Overall Risk Assessment Category for the contiguous United States.

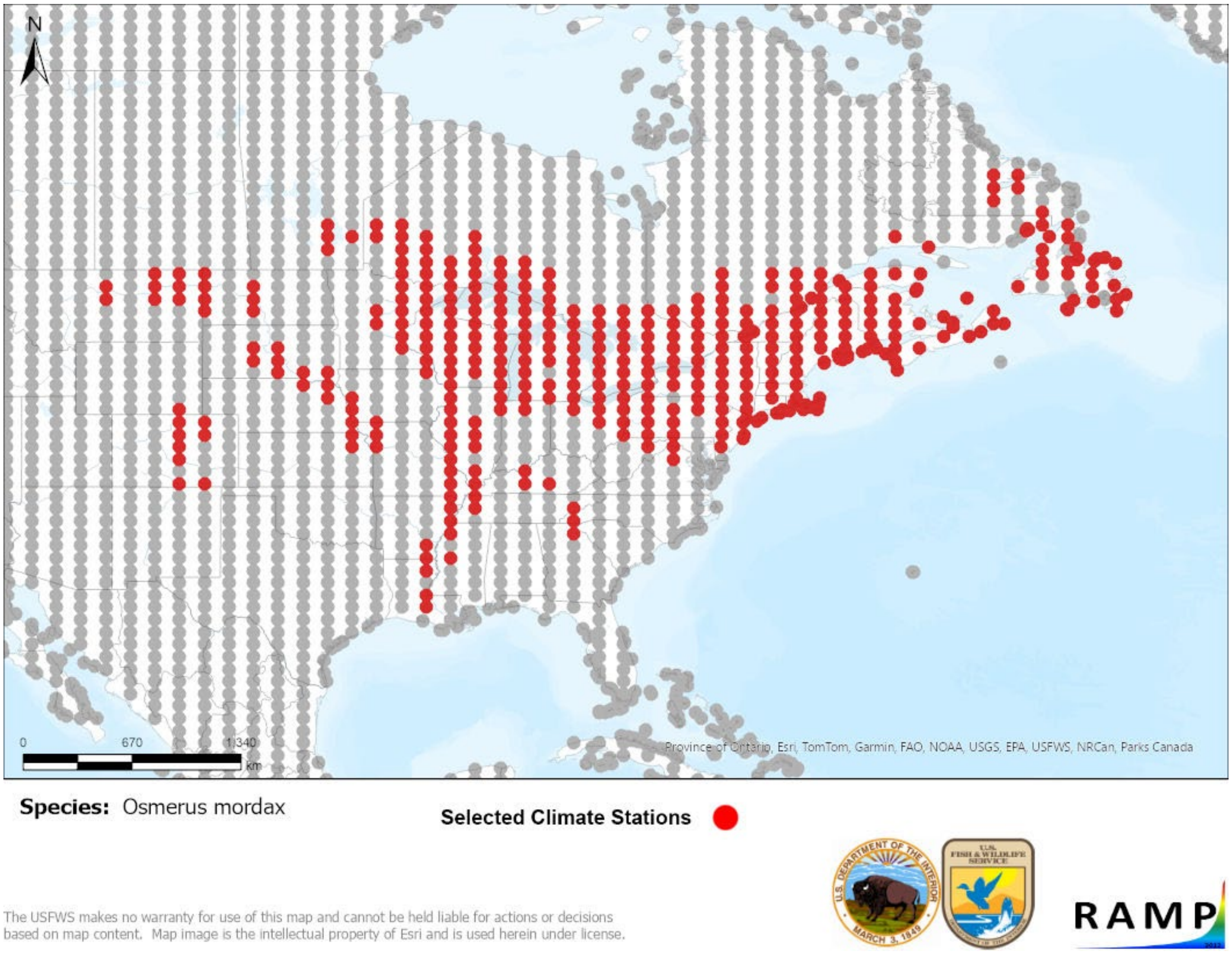

Figure 3. RAMP (Sanders et al. 2023) global source map showing weather stations selected as source locations (red; United States, Canada) and non-source locations (gray) for *Osmerus mordax* climate matching. Source locations from GBIF Secretariat (2023). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

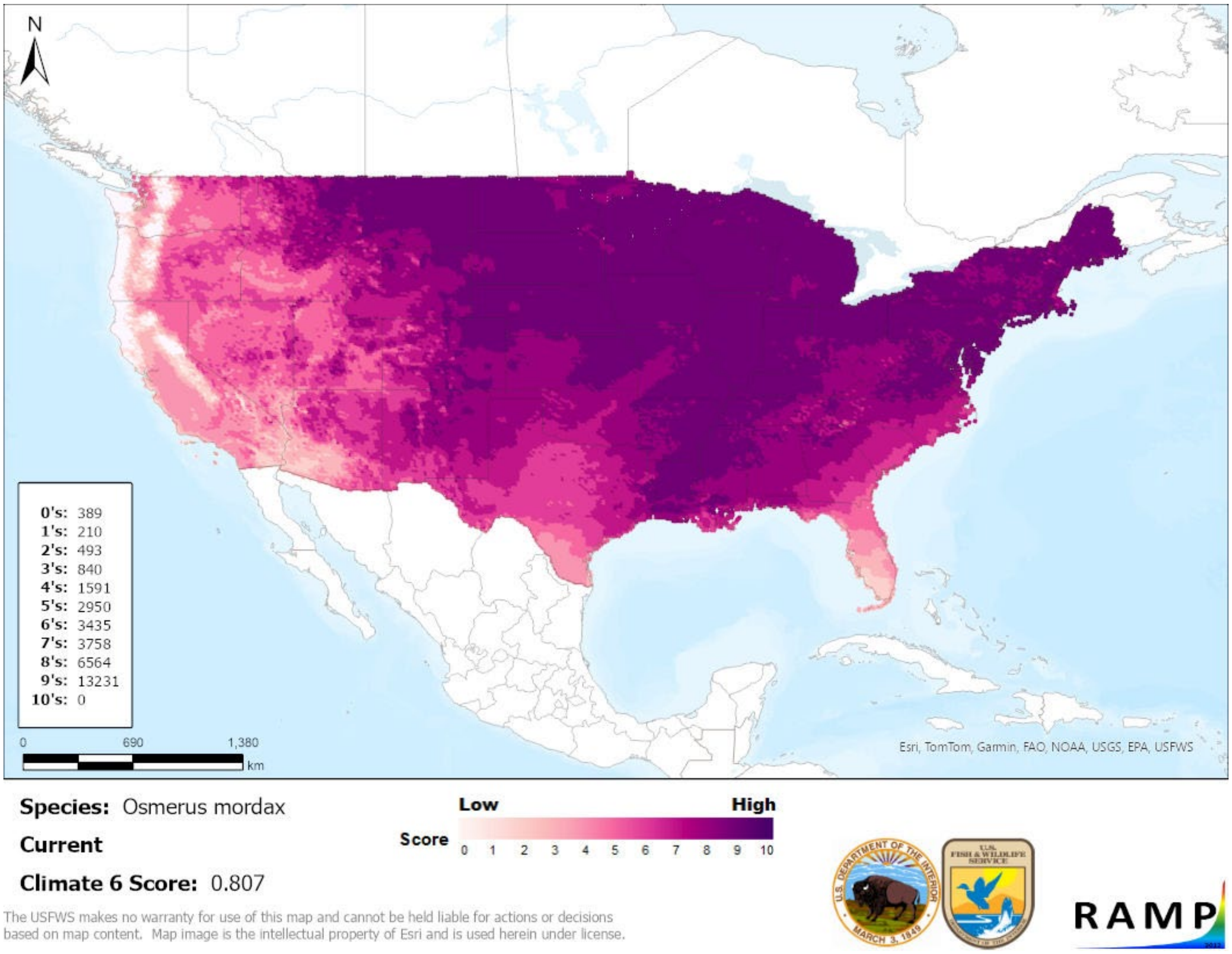

Figure 4. Map of RAMP (Sanders et al. 2023) climate matches for *Osmerus mordax* in the contiguous United States based on source locations reported by GBIF Secretariat (2023). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment for *Osmerus mordax* is classified as High. There is sufficient information regarding the species distribution and history of invasiveness, including multiple specific examples from scientifically defensible sources of the negative impacts this species has had where it has been introduced.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Osmerus mordax, the Rainbow Smelt, is a euryhaline fish that is native to Atlantic coastal areas and inland lakes of the United States and Canada. *Osmerus mordax* is commonly used as bait for fishing and is consumed by humans, and it has been introduced via stocking in many different areas of the United States as a forage fish. *O. mordax* has become established outside of its native range in both the United States and Canada. Although this species is utilized as a forage fish by game species in its nonnative environment, there have been negative impacts of its introduction, too. *O. mordax* alters food webs by preying on large-bodied zooplankton, and introduction of *O. mordax* has been linked to increased concentrations of bioaccumulating contaminants in native fish tissue. The History of Invasiveness for *O. mordax* is classified as High due to introduction and successful establishment outside its native range and substantial documentation showing the negative impacts of these introductions. The climate matching analysis for the contiguous United States indicates establishment concern for this species outside its native range, especially in the eastern and central United States around where the species is native or has established nonnative populations already. The Certainty of Assessment for this ERSS is classified as High due to there being sufficient information regarding the species distribution and history of invasiveness, including multiple, specific examples from scientifically defensible sources of the negative impacts this species has had where introduced. The Overall Risk Assessment Category for *Osmerus mordax* in the contiguous United States is High.

Assessment Elements

- **History of Invasiveness (see Section 4): High**
- **Establishment Concern (see Section 7): Yes**
- **Certainty of Assessment (see Section 8): High**
- **Remarks, Important additional information: Stocked in many areas throughout the United States as a forage fish. Consumed by humans.**
- **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.

Becker GC. 1983. Fishes of Wisconsin. Madison: University of Wisconsin Press. Available: https://search.library.wisc.edu/digital/AWFIWUVZSK4EFH9B/pages (November 2023).

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Appendix

Summary of Future Climate Matching Analysis

Future climate projections represent two Shared Socioeconomic Pathways (SSP) developed by the Intergovernmental Panel on Climate Change (IPCC 2021): SSP5, in which emissions triple by the end of the century; and SSP3, in which emissions double by the end of the century. Future climate matches were based on source locations reported by GBIF Secretariat (2023).

Under the future climate scenarios (figure A1), on average, high climate match for *Osmerus mordax* was projected to occur in the Appalachian Range, Great Lakes, Mid-Atlantic, Northeast, Northern Plains, and Southeast regions of the contiguous United States. Areas of low climate match were projected to occur in California, the Northern Pacific Coast, and Southern Florida regions. Climate match was lower under both 2085 scenarios, although the SSP5 scenario was noticeably lower than SSP3, while both 2055 scenarios showed similar patterns of climate match to each other. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.523 (model: UKESM1-0-LL, SSP5, 2085) to a high of 0.764 (model: IPSL-CM6A-LR, SSP3, 2055). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species under future scenarios. The Climate 6 score for the current climate match (0.807, figure 4) falls above the range of scores for future projections. The time step and climate scenario with the most change relative to current conditions was SSP5, 2085, the most extreme climate change scenario. Under all time step and climate scenarios only minor or no increases in the climate match relative to the current match were observed. Especially under the SSP5, 2085 scenario, areas within the Gulf Coast, Mid-Atlantic, Northern Plains, Southeast, Southern Plains, and Southwest saw a large decrease in the climate match relative to current conditions. Additionally, under one or more future scenarios, areas within the Appalachian Range, California, Colorado Plateau, Great Basin, Great Lakes, Northeast, and Western Mountains saw a moderate decrease in the climate match relative to current conditions. Additional, very small areas of large or moderate change may be visible on the maps (figure A3).

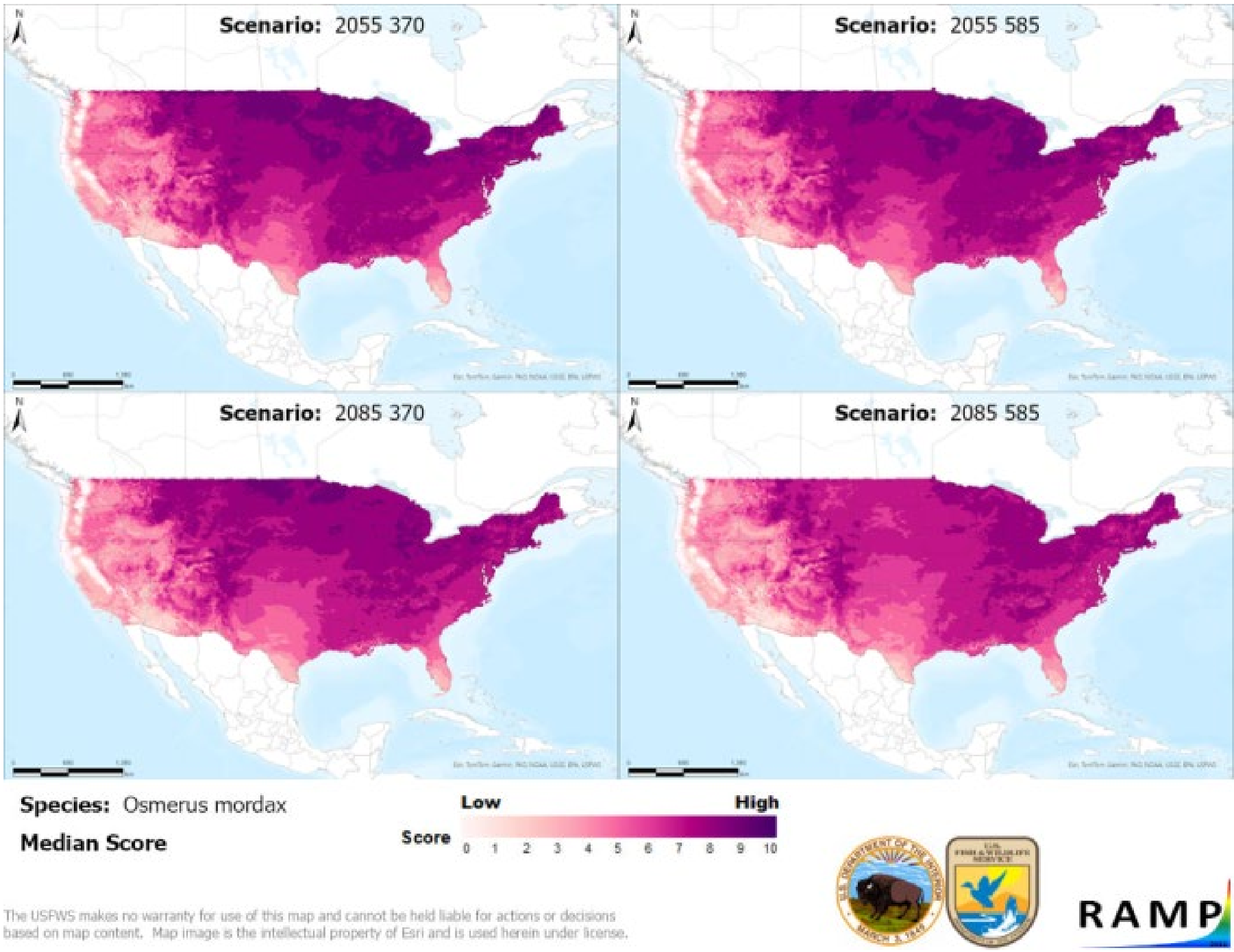

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Osmerus mordax* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2023). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

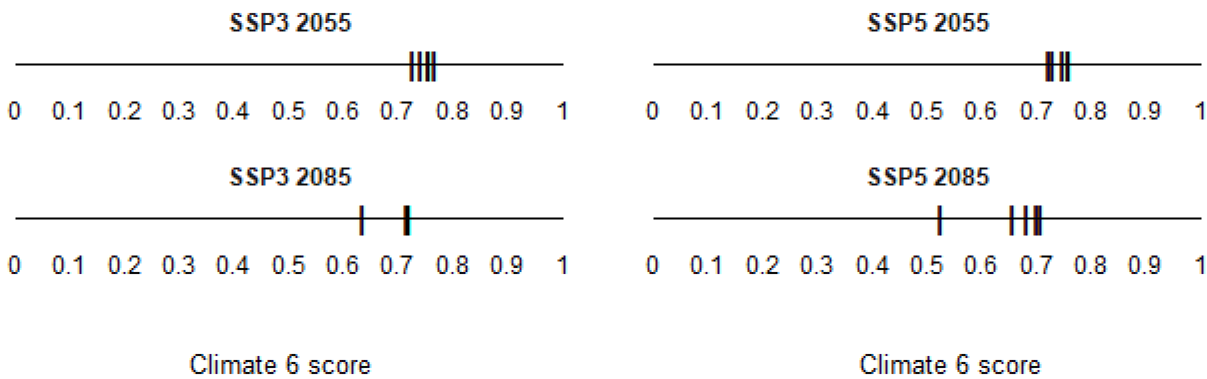

Figure A2. Comparison of projected future Climate 6 scores for *Osmerus mordax* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0.

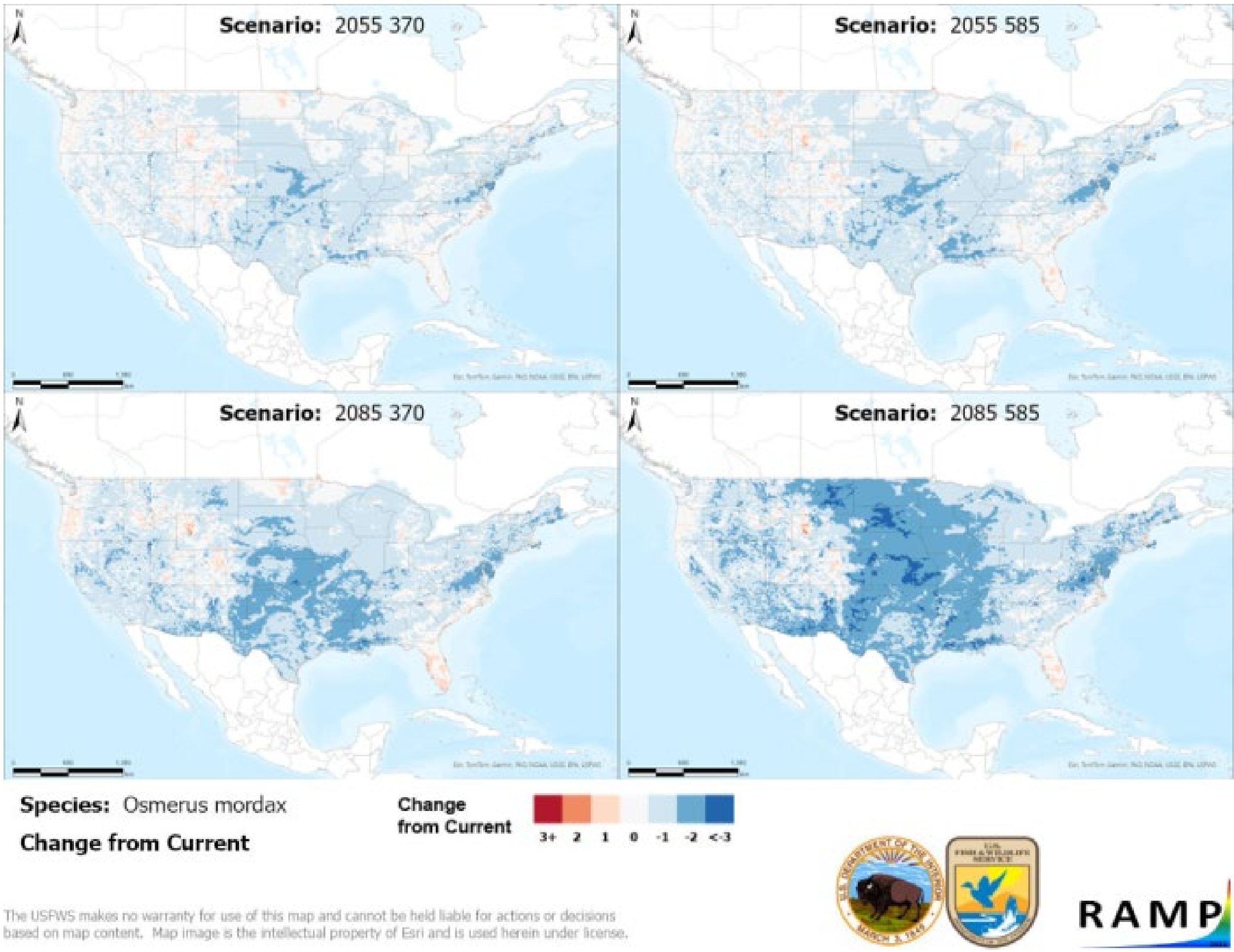

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 4) and the median target point score for future climate scenarios (figure A1) for *Osmerus mordax* based on source locations reported by GBIF Secretariat (2023). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. Shades of blue indicate a lower target point score under future scenarios than under current conditions. Shades of red indicate a higher target point score under future scenarios than under current conditions. Darker shades indicate greater change.

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