U.S. Fish & Wildlife Service

# Ruffe (*Gymnocephalus cernua*)
## Ecological Risk Screening Summary

**U.S. Fish and Wildlife Service, February 2023**
**Revised, March 2023, June 2024**
**Web Version, 7/10/2024**

Organism Type: Fish
Overall Risk Assessment Category: High

Photo: Tiit Hunt. Licensed under CC BY-SA 3.0 US. Available: http://www.tsusinvasives.org/home/database/gymnocephalus-cernua (February 2023).

# 1 Native Range and Status in the United States

## Native Range

From Freyhof and Kottelat (2008):

"Austria; Azerbaijan; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; China; Croatia; Czechia; Denmark; Estonia; Finland; France; Georgia; Germany; Hungary; Italy; Kazakhstan; Latvia; Liechtenstein; Lithuania; Luxembourg; Moldova; Mongolia; Montenegro; Netherlands; North Macedonia; Norway; Poland; Romania; Russian Federation; Serbia; Slovakia; Slovenia; Sweden; Switzerland; Ukraine; United Kingdom; Uzbekistan."

From Froese and Pauly (2023a):

"Europe: Caspian, Black, Baltic and North Sea basins; Great Britain; north to about 69° N in Scandinavia. Asia: Aral Sea basin, Arctic Ocean basin eastward to Kolyma drainage."

"Occurs in adjacent or contiguous drainage basins to Afghanistan [Coad 1981]."

"Occurs in Erqishi and Yili rivers and Ulungur lake [China; Walker and Yang 1999]."

"Found from waters on the borders of Iran or confluent with Iranian drainages."

"Present in Neusiedler See [Austria; Wolfram-Wais et al. 1999]."

"Occurs in Odra and Morava river basins [Czech Republic; Hanel 2003]."

"Occurs throughout [Denmark] except Bornholm and Vendsyssel [Frier 1994]."

"[In Estonia:] Commercially taken from Lake Peipus [Anonymous 1999]. Abundant in the Gulf of Riga and common in Gulf of Finland [Ojaveer and Pihu 2003]."

"Occurs through the country [Finland] except in the northern Lappland."

"[In Germany:] Rhine common, Neckar rare [Günther 1853]. Found in the Elbe estuary [Thiel et al. 2003]."

"Known from Danube [Hungary; Kottelat and Freyhof 2007]."

"Southern tip of Norway."

"[In Russia:] Known from Arctic Ocean basin eastward to Kolyma drainage [Kottelat and Freyhof 2007; Muus and Dahlström 1968; Bogutskaya 2005]. Recorded from rivers Don [Bogutskaya and Naseka 2002a], Kuban [Bogutskaya and Naseka 2002b], Volga [Bogutskaya and Naseka 2002c] and Onega [Bogutskaya 2005]."

"Danube area of Serbia [Gerstmeier and Romig 1998]."

"Known from Bruunsviken Bay, Uppland Sweden [Near 2002]. Found in the southern Bothnian Sea [Sweden; Thorman 1986]."

## Status in the United States

According to Fuller et al. (2023), occurrences of *Gymnocephalus cernua* have been reported from the following States (years of reports and watersheds given after State name):

- Michigan (1994-2019; Betsy-Chocolay, Black-Presque Isle, Cheboygan, Keweenaw Peninsula, Lake Huron, Lake Michigan, Lake Superior, Lone Lake-Ocqueoc, Ontonagon, St. Marys, Sturgeon, Thunder Bay, Waiska)

- Minnesota (1986-2016; Beaver-Lester, Lake Superior, St. Louis)
- Wisconsin (1986-2016; Bad-Montreal, Beartrap-Nemadji, Lake Michigan, Lake Superior, St. Louis)

Simpson et al. (2023) classify *G. cernua* as having a self-sustaining population in the United States outside of captivity or cultivation.

From Fuller et al. (2024):

"The ruffe was first identified by Wisconsin DNR in specimens collected from the St. Louis River at the border of Minnesota and Wisconsin in 1987 (Pratt 1988; Pratt et al. 1992; Czypinski et al. 1999, 2000, 2001, 2003). Following that report, reexamination of archived samples revealed misidentified larval specimens of ruffe had been collected from the same area in 1986 (Pratt 1988). The ruffe subsequently spread into Duluth Harbor in Lake Superior and several tributaries of the lake (Underhill 1989; Czypinski et al. 1999, 2000, 2004; Scheidegger, pers. comm.; J. Slade, pers. comm.). It is found in the Amnicon, Flag, Iron, Middle, Raspberry, and Bad rivers, Chequamegon Bay, and Apostle Islands National Lakeshore in Wisconsin (Czypinski et al. 1999, 2000, 2001, 2003, 2004; Tilmant 1999). In August 1994, it was found in Saxon Harbor, Wisconsin, and in the upper peninsula of Michigan at the mouths of the Black and Ontonagon rivers (K. Kindt, pers. comm.). In the lower Peninsula of Michigan along Lake Huron, the first three specimens were caught at the mouth of the Thunder Bay River in August 1995 (K. Kindt, pers. comm.). This species has also been collected in Michigan in Lake Michigan, Lake Superior, Torch Lake, Little Bay de Noc in Escanaba, Big Bay de Noc, Misery River, Ontonagon River, Thunder Bay, and Sturgeon River Sloughs (Czypinski et al. 1999, 2000, 2001, 2003, 2004; A. Bowen, pers. comm.; Pearce, pers. comm.; Zorn, pers. comm.)."

No records of *Gymnocephalus cernua* in trade in the United States were found.

## Regulations

State regulations for *Gymnocephalus cernua*, the synonym *G. cernuus*, and for the common name Ruffe were found. While effort was made to find all applicable regulations, this list may not be comprehensive.

*G. cernua* is listed as a prohibited species in Arkansas (Arkansas Game and Fish Commission 2022), Maryland (Code of Maryland Regulations 2022), Michigan (Michigan Compiled Laws 2022), Montana (Montana Department of Fish, Wildlife, and Parks 2022), New Hampshire (New Hampshire Fish and Game Department 2022), Oregon (Oregon Department of Fish and Wildlife 2022), Rhode Island (Rhode Island Department of Environmental Management 2022), and Utah (Utah Division of Wildlife Resources 2020).

*G. cernua* is listed as an invasive species in Indiana (Indiana Department of Natural Resources 2022), Iowa (Iowa NRC 2022), Idaho (Idaho Department of Agriculture 2022), Minnesota (Minnesota Department of Natural Resources 2022), Ohio (Ohio Department of Natural Resources 2022), Pennsylvania (Pennsylvania Fish and Boat Commission 2022), Texas (Texas Parks and Wildlife 2022), and Wisconsin (Wisconsin Department of Natural Resources 2022).

*G. cernua* is listed as an aquatic nuisance species in North Dakota (North Dakota Game and Fish Department 2019).

*G. cernua* is a regulated invasive species in New York (New York DEC 2022).

*G. cernua* is listed as an injurious species in Illinois (Illinois Department of Natural Resources 2015) and Tennessee (Tennessee Wildlife Resources Agency 2022).

Additionally, possession of *G. cernua* is unlawful in Colorado (Colorado Parks and Wildlife 2022) and North Carolina (North Carolina Department of Environmental Quality 2022) and is regulated by permit in Virginia (Virginia Department of Wildlife Resources 2020).

## Means of Introductions in the United States

From Fuller et al. (2023):

"The ruffe was probably introduced via ship ballast water discharged from a vessel arriving from a Eurasian port, possibly as early as 1982-1983 (Simon and Vondruska 1991; Ruffe Task Force 1992). Within the Great Lakes, the species' spread may have been augmented by intra-lake shipping transport (Pratt et al. 1992; Stepien et al. 1998). Recent genetic research has indicated that the origin of ruffe introduced to the Great Lakes was southern Europe, not the Baltic Sea as previously believed (Stepien et al. 1998)."

From CABI (2023):

"The transoceanic introduction of *G. cernuus* into the North American Great Lakes is thought to be via the ballast water of ships (Simon and Vondruska, 1991). DNA analysis shows that the *G. cernuus* population in the Great Lakes originated from a single founding population source from the Elbe River drainage, Germany (Stepien et al., 2002). Since their discovery in western Lake Superior in 1987, *G. cernuus* has spread, most likely unaided, approximately 400 miles along the shore by colonizing tributary after tributary (Slade et al., 1994). They have also spread to other areas of Lake Superior (Thunder Bay, ON, Canada) and to Lakes Michigan and Huron (Kindt et al., 1996), most likely in the ballast water of ships."

From Beletsky et al. (2017):

"Model results compared favorably to observed spread of ruffe and *Dreissena spp.* mussels in Lake Michigan. Our modeling effort suggests that larval advection by lake currents is an important AIS dispersal mechanism in the Great Lakes."

## Remarks

This ERSS was previously published in June 2015. Revisions were completed to incorporate new information and conform to updated standards.

From Ontario Federation of Anglers and Hunters (2023):

"[The] Ontario government, and some American States, have banned the possession and sale of live or dead Eurasian ruffe, and using ruffe as bait."

# 2 Biology and Ecology

## Taxonomic Hierarchy and Taxonomic Standing

From Froese and Pauly (2023b):

"Animalia (Kingdom) >Chordata (Phylum) >Vertebrata (Subphylum) >Gnathostomata (Superclass) >Pisces (Superclass) >Actinopterygii (Class) >Perciformes (Order) >Percoidei (Suborder) >Percidae (Family) >Percinae (Subfamily) >*Gymnocephalus* (Genus) >*Gymnocephalus cernua* (Species)"

From Fricke et al. (2023):

"Valid as *Gymnocephalus cernua* (Linnaeus 1758)"

Database and literature searches for this ERSS were conducted using the valid scientific name *Gymnocephalus cernua* and synonyms *G. cernuus* and *Acerina cernua*.

## Size, Weight, and Age Range

From Froese and Pauly (2023a):

"Maturity: $L_m$ [length at maturity] 10.5 [cm] range ? - ? cm
Max length : 25.0 cm TL [total length] male/unsexed; [Muus and Dahlström 1968]; common length : 12.0 cm TL male/unsexed; [Muus and Dahlström 1968]; max. published weight: 400.00 g [Muus and Dahlström 1968]; max. reported age: 10 years [Kottelat and Freyhof 2007]."

## Environment

From Froese and Pauly (2023a):

"Freshwater; brackish; benthopelagic; pH range: 7.0 - 7.5; dH [water hardness] range: 8 - 12; potamodromous [Riede 2004]; depth range 2 - 85 m [Vostradovsky 1973]."

"Larval survival is poor below 10°C and above 20°C [Kottelat and Freyhof 2007]."

## Climate

From Froese and Pauly (2023a):

"Temperate; […] 74°N - 43°N, 6°W - 169°E"

## Distribution Outside the United States

### Native

From Freyhof and Kottelat (2008):

"Austria; Azerbaijan; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; China; Croatia; Czechia; Denmark; Estonia; Finland; France; Georgia; Germany; Hungary; Italy; Kazakhstan; Latvia; Liechtenstein; Lithuania; Luxembourg; Moldova; Mongolia; Montenegro; Netherlands; North Macedonia; Norway; Poland; Romania; Russian Federation; Serbia; Slovakia; Slovenia; Sweden; Switzerland; Ukraine; United Kingdom; Uzbekistan."

From Froese and Pauly (2023a):

"Europe: Caspian, Black, Baltic and North Sea basins; Great Britain; north to about 69° N in Scandinavia. Asia: Aral Sea basin, Arctic Ocean basin eastward to Kolyma drainage."

"Occurs in adjacent or contiguous drainage basins to Afghanistan [Coad 1981]."

"Occurs in Erqishi and Yili rivers and Ulungur lake [China; Walker and Yang 1999]."

"Found from waters on the borders of Iran or confluent with Iranian drainages."

"Present in Neusiedler See [Austria; Wolfram-Wais et al. 1999]."

"Occurs in Odra and Morava river basins [Czech Republic; Hanel 2003]."

"Occurs throughout [Denmark] except Bornholm and Vendsyssel [Frier 1994]."

"[In Estonia:] Commercially taken from Lake Peipus [Anonymous 1999]. Abundant in the Gulf of Riga and common in Gulf of Finland [Ojaveer and Pihu 2003]."

"Occurs through the country [Finland] except in the northern Lappland."

"[In Germany:] Rhine common, Neckar rare [Günther 1853]. Found in the Elbe estuary [Thiel et al. 2003]."

"Known from Danube [Hungary; Kottelat and Freyhof 2007]."

"Southern tip of Norway."

"[In Russia:] Known from Arctic Ocean basin eastward to Kolyma drainage [Kottelat and Freyhof 2007; Muus and Dahlström 1968; Bogutskaya 2005]. Recorded from rivers Don [Bogutskaya and Naseka 2002a], Kuban [Bogutskaya and Naseka 2002b], Volga [Bogutskaya and Naseka 2002c] and Onega [Bogutskaya 2005]."

"Danube area of Serbia [Gerstmeier and Romig 1998]."

"Known from Bruunsviken Bay, Uppland Sweden [Near 2002]. Found in the southern Bothnian Sea [Sweden; Thorman 1986]."

### Introduced

From Froese and Pauly (2023a):

"Native to UK but introduced to Loch Lomond [Adams 1991]. Introduced in northern Great Britain [Kottelat and Freyhof 2007]."

"[In Canada,] Introduced only into Ontario [Coker 2001; Robins et al. 1991]."

"Found in Lake Superior (Thunder Bay) […]"

"Established and is expanding in northeastern Italy. Naturalized in 1985 [Bianco and Ketmaier 2001]."

"Considered in Rhine-Meuse waters as native species but established as non-native species in: Bretagne, Loire, Vendée-Charente, Adour-Garonne, Rhône, Corse waters [France]."

According to CABI (2023), *G. cernua* was introduced and is now established in the Camargue region in France, Lake Constance in Germany, and in parts of Norway outside of its native range.

From Kuljanishvili et al. (2021):

"This species was recorded in the wild for the first time by Epitashvili et al. (2020) in the Rioni River of western Georgia."

From Tarkan et al. (2022):

"Recently, several populations of this species have been recorded from the Turkish region of Thrace (the European part of Turkey), which represents the species' southernmost geographic range of expansion in Europe, where it is non-native."

"One of the most recent records of this species has been from an artificial pond in northeast Algeria, which represents the southernmost point of the species' range of expansion (Arab et al. 2020)."

Establishment of *G. cernua* in Algeria could not be confirmed.

## Means of Introduction Outside the United States

From CABI (2023):

"The introduction of *G. cernuus* outside their native range has been accidental. The mechanism of introduction is unknown in many cases; however, introductions into England, Wales and

Scotland are thought to be from their use as live bait for northern pike (*Esox lucius*) fishing (Maitland and East, 1989; Winfield, 1992)."

From Tarkan et al. (2022):

"[...] the most likely explanation for the non-native dispersion of *G. cernua* within Turkey's Thrace appears to be natural spread through connected river systems (i.e. River Maritza)."

## Short Description

From Froese and Pauly (2023a):

"Dorsal spines (total): 11 - 19; Dorsal soft rays (total): 11-16; Anal spines: 2; Anal soft rays: 5 - 6; Vertebrae: 35 - 36. Distinguished uniquely from its congeners by its body depth 24-27% SL [standard length]. Differs further from other members of the genus by the combination of having a flank yellowish with numerous, small, irregular, dark blotches and having 11-16 dorsal spines [Kottelat and Freyhof 2007]. Caudal fin with 16 to 17 rays [Keith and Alardi 2001]. Dorsal fins are fused. Color brownish with dark spots [Muus and Nielson 1999]."

From Simon and Vondruska (1991):

"In particular, ruffe superficially resemble johnny darters as yolk-sac larvae, and walleye, yellow perch, and logperch at lengths greater than 10 mm."

From Ontario Federation of Anglers and Hunters (2023):

"Ruffe resemble young walleye, yellow perch and trout perch, but they differ from these species in the following ways:

- Their perch-like body is less than 20 centimetres long, with glassy eyes and a down-turned mouth.
- Their colouring is olive-brown on their back, with pale sides.
- Their two dorsal fins are joined; the first fin has 11-16 stiff, sharp spines with rows of dark spots between them, and the second dorsal fin has soft, flexible rays.
- There are also sharp spines on their anal fins and gill covers.
- They have no scales on the head."

## Biology

From Fuller et al. (2023):

"The diet of ruffe changes throughout the course of development, becoming more benthic in nature with increasing size (Ogle et al. 2004). Copepoda, *Daphnia* spp., and *Bosmina longirostrus* dominated the overall diet of larval ruffe in the St. Louis Harbor (Ogle et al. 2004). Chironomids and the bottom-dwelling larvae of other insects, mainly mayflies and stoneflies, were frequently consumed in fresh water and, with increasing body size, became increasingly important in the diet of ruffe (Hölker and Thiel 1998). In laboratory experiments, Fullerton et al. (1998) found that ruffe preferred soft-bodied macroinvertebrates. Histological examination of ruffe from the Duluth-Superior Harbor population revealed that the spawning period extended from late April through mid-June in 1994 (Leino et al. 1997). Ruffe is often associated with bottom waters and can tolerate lacustrine and lotic systems and depths to 85 m (Sandlund et al. 1985). The species' intolerance to deeper waters may limit its range of potential suitable habitat to Lake Erie, southern Lake Michigan, and shallow waters of the other Great Lakes (U.S. EPA 2008)."

From Froese and Pauly (2023a):

"Inhabits eutrophic lakes, lowland and piedmont rivers. Most abundant in estuaries of large rivers, brackish lakes with salinities up to 10-12 ppt [parts per thousand] and reservoirs. In general, its abundance increases with increased eutrophication [Kottelat and Freyhof 2007]. Reported to prefer still or slow-flowing water with soft bottom and without vegetation [Kottelat and Freyhof 2007] and deep water with deposits of sand and gravel [Vostradovsky 1973]. Can tolerate some degradation of the environment [Billard 1997]. Can co-exist in deep lakes with *Perca fluviatilis*. Both species partly occur at different depths with *Gymnocephalus cernua* being more abundant in deeper layers [Kottelat and Freyhof 2007]. The membranous external walls of the head canals of this species provide high directional sensitivity; can feed at night in the dark using the lateral line system; feeds on zooplankton, chironomids, oligochaetes and amphipods [Collette et al. 1977]. Pelagic in coastal lakes and tidal estuaries, preying on zooplankton and fish. Spawns on a variety of substrates at depths of about 3 m or less [Kottelat and Freyhof 2007]. White to yellow eggs in sticky strands are found on rocks and weed in shallow water [Pinder 2001]. […] Females live up to 10 year [sic] while males up to 7 years [Kottelat and Freyhof 2007]."

"Eggs turn adhesive on contact with water and stick to stones or plants. Females lay eggs in two or more portions, usually separated by about 30 days in summer. First portion of eggs is larger the [sic] second portion. Larvae without or with only a brief, pelagic larval stage, switching early to benthic life, secretive and solitary, not forming schools."

From Adams and Maitland (1998):

"Natural hybridization between ruffe and perch [*Perca fluviatilis*] has been recorded in the past. Regan (1911) cites a 1907 reference for perch and ruffe hybrids in the Danube, noting that 'these hybrids are not fertile per se, but are quite fertile with either parent!'"

## Human Uses

From Froese and Pauly (2023a):

"Fisheries: minor commercial; gamefish: yes; bait: usually"

From GISD (2023):

"In some eastern European countries it is considered a delicacy"

## Diseases

**No information was found associating *Gymnocephalus cernua* with any diseases listed by the World Organisation for Animal Health (2022).**

Poelen et al. (2014) indicate that *Gymnocephalus cernua* has the following parasites: *Acanthocephalus anguillae, Acanthocephalus lucii, Allocreadium isoporum, Anguillicola crassus, Apophallus donicus, Apophallus muehlingi, Ascaris acerinae, Ascaris velocissima, Azygia lucii, Biacetabulum appendiculatum, Bucephalus polymorphus, Bunocotyle cingulata, Bunodera luciopercae, Camallanus lacustris, Coitocaecum skrjabini, Corynosoma magdaleni, Corynosoma semerme, Corynosoma strumosum, Cosmocephalus obvelatus, Cotylurus pileatus, Cotylurus variegatus, Crowcrocaecum skrjabini, Cyathocephalus truncatus, Cystidicoloides tenuissima, Dactylogyrus amphibothrium, Dactylogyrus anchoriformis, Dactylogyrus difformis, Dactylogyrus haplogonus, Dactylogyrus hemiamphibothrium, Desmidocercella numidica, Diphyllobothrium dendriticum, Diphyllobothrium latum, Diplostomum baeri, Diplostomum chromatophorum, Diplostomum clavatum, Diplostomum commutatum, Diplostomum gasterostei, Diplostomum gavium, Diplostomum helveticum, Diplostomum indistinctum, Diplostomum mergi, Diplostomum pungitii, Diplostomum spathaceum, Diplostomum volvens, Diplozoon paradoxum, Discocotyle sagittata, Echinorhynchus bothniensis, Echinorhynchus cinctulus, Eubothrium crassum, Eubothrium rugosum, Eustrongylides excisus, Eustrongylides mergorum, Gyrodactylus cernuae, Gyrodactylus longiradix, Gyrodactylus luciopercae, Gyrodactylus markevitschi, Gyrodactylus rarus, Hepaticola petruschewskii, Hysteromorpha triloba, Ichthyobronema hamulatum, Ichthyocotylurus pileatus, Ichthyocotylurus platycephalus, Ichthyocotylurus variegatus, Metagonimus yokogawai, Metorchis xanthostomus, Neoechinorhynchus rutili, Neogryporhynchus cheilancristrotus, Nicolla skrjabini, Nicolla testiobliqua, Paracoenogonimus ovatus, Paracuaria tridentata, Paratenuisentis ambiguus, Phyllodistomum angulatum, Phyllodistomum folium, Phyllodistomum megalorchis, Phyllodistomum pseudofolium, Phyllodistomum simile, Pomphorhynchus laevis, Porrocaecum crassum, Posthodiplostomum brevicaudatum, Posthodiplostomum cuticola, Proteocephalus cernuae, Proteocephalus filicollis, Proteocephalus longicollis, Proteocephalus osculatus, Proteocephalus percae, Proteocephalus torulosus, Pseudoterranova decipiens, Raphidascaris acus, Rhabdochona denudata, Rhipidocotyle campanula, Rhipidocotyle illense, Schulmanella petruschewskii, Sphaerostomum bramae, Sphaerostomum globiporum, Triaenophorus nodulosus, Tylodelphys clavata,* and *Tylodelphys podicipina*.

## Threat to Humans

From Froese and Pauly (2023a):

“Potential pest”

# 3 Impacts of Introductions

The following quotations describe documented, ***actual*** impacts of introduction for *Gymnocephalus cernua*.

From Fuller et al. (2023):

"The ruffe has affected fish populations in other areas where introduced. In Scotland, native perch populations declined, and in Russia whitefish numbers have declined because of egg predation by ruffe (McLean 1993)."

From CABI (2023):

"*G. cernuus* have been implicated in population declines of native fish by egg predation (Adams and Tippet, 1991) and competition for food (Kozlova and Panasenko, 1977; Mattila and Bonsdorf, 1989; Bergman, 1991) in some European waters where they have been introduced."

"There is no evidence that *G. cernuus* has had a negative impact on biodiversity."

From Fuller et al. (2024):

"In Lake Superior, consumption of cisco (*Coregonus artedii*) eggs by ruffe has been documented at a level which could impact the population over winter months ([Selgeby] 1998). Ogle et al. (1995) studied the diet of introduced ruffe inhabiting the St. Louis estuary. Their findings indicated that the species preys heavily on benthic insects, thereby suggesting that ruffe competes for food with yellow perch [*Perca flavescens*], trout-perch [*Percopsis omiscomaycus*], and other native benthic-feeding fishes."

From Newman et al. (2020):

"To examine competitive interactions between invasive ruffe and native yellow perch, individually marked perch and ruffe were placed in mesocosms in a small lake. […] Yellow perch growth was significantly lower in the presence of ruffe (ANOVA, $p = 0.005$) than in treatments containing only perch. […] Growth rates of both ruffe and perch declined when ruffe density was increased ($t$ test, $p = 0.006$). However, neither ruffe nor perch growth was affected by increasing perch density. Total stomach content mass of perch was significantly decreased by ruffe in both years ($p < 0.02$), but no effects of ruffe on the composition of perch diets were observed. Ruffe growth and food consumption was greater than that of perch for both experiments. Ruffe can outcompete yellow perch when both species depend on a limited benthic food resource."

From Adams and Tippett (1991):

"Loch Lomond, one of the few British strongholds of the powan, *Coregonus lavaretus* (L.), has recently been colonized by the ruffe, *Gymnocephalus cernuus* (L.). The ruffe are now widespread, abundant and one of the commonest fish in Loch Lomond. Analysis of the gut contents of these fish caught on powan spawning grounds in Loch Lomond showed that they, as well as native brown trout, *Salmo trutta* L., and powan themselves, prey upon powan ova. Ruffe maintained a high winter feeding rate compared with powan and trout and fed on a broad range of benthic prey, of which powan ova formed the greatest biomass (84% of total diet) and dominated the diet numerically (57% of prey items). The observed incidence of powan ova consumption by ruffe was significantly greater than that of both brown trout and powan (P <0001). […] The overall effects of ruffe predation on the spawning success of powan have yet to be established. However, high ova mortality from sources other than ruffe, coupled with a large ruffe population with a high predation rate on spawning grounds compared with native predators, means that ruffe predation on ova is likely to be an important influence on recruitment to the powan population in Loch Lomond in the future."

From Adams and Maitland (1998):

"[The] potential for feeding competition between ruffe and other species would appear to be considerable. Despite this, the diet of both brown trout [*Salmo trutta*] and ruffe and perch [*P. fluviatilis*] and ruffe caught at the same time, in the same place showed no significant overlap, indicating that these species do not share a common resource."

"Using published data for the diet of perch collected prior to the arrival and establishment of a large ruffe population in Loch Lomond, the diet of perch was compared prior to the possibility of any competitive interaction between perch and ruffe. The data very clearly indicate that, at least for the size ranges of the two species examined in this study, there is no resource overlap and thus it must be concluded that there is no feeding competition interaction between these species."

"Direct predation by piscivorous ruffe on other species is not the only ruffe-induced predation effect that has been demonstrated in Loch Lomond. Changes in the diet of piscivorous birds and northern pike would appear to amount to considerable predation relief for the native species that comprised the diet of fish predators before the arrival of ruffe (powan [*Coregonus lavaretus*] for northern pike [*Esox lucius*] and roach, *Rutlius rutilus*, for herons, (the diet of cormorants prior to the arrival of ruffe is unknown))."

"[Although] the changes in species interactions and their consequences described here cannot be considered of positive benefit they may not all be, at least in the short term, deleterious and some changes that could have positive benefit to some members of the native community have been identified. Fourthly, from data presented here […] it is obvious that there has been a shift in the main energetic pathways in the food-chain in Loch Lomond."

The following quotations describe theorized, ***potential*** impacts of introduction for *Gymnocephalus cernua*.

From Fuller et al. (2024):

"Ruffe was first discovered in the St. Louis River, a tributary to western Lake Superior, in the mid 1980s; by 1991, it was the most abundant fish in this area (Bronte [et al.] 1998). The increase in ruffe was concurrent with declines in several fish species, including yellow perch (*Perca flavescens*), emerald shiner (*Notropis atherinoides*), and trout-perch (*Percopsis* *omiscomaycus*) (Bronte [et al.] 1998, McLean 1993). However, there was a lack of clear causal evidence between the two events (Bronte [et al.] 1998)."

"Savino and Kolar (1996) conducted a laboratory study to test for food competition between ruffe and yellow perch. They found that competition could occur between the two species, but that the outcome was not always clear, as each species exhibited competitive advantages and disadvantages (Savino and Kolar 1996). Fullerton et al. (1998) also concluded that similarities in dietary preferences and feeding rates of ruffe and yellow perch suggest a strong possibility for interspecific competition."

"When ruffe first invaded Lake Superior, it was thought that this species could generate a considerable cost for recreational fishing, particularly by causing a decline in yellow perch (*Perca flavescens*) populations (Leigh 1998). Under a moderate scenario of spread and impact, it was predicted that ruffe could generate costs in excess of $500 million by 2050 (Leigh 1998). However, these concerns have yet to be confirmed as the extent of ruffe's contribution to declines in native fish populations remains undecided (Czypinksi et al. 2007). Ruffe abundance appeared to remain stable or decline annually in Lake Superior as late as 2001-2005 (Czypinski et al. 2007, Gorman et al. 2010)."

From Fuller et al. (2023):

"Ruffe exhibits rapid growth and high reproductive output, and adapt [sic] to a wide range of habitat types (McLean 1993); therefore the species may pose a threat to native North American fish. Yellow perch *Perca flavescens*, emerald shiners *Notropis atherinoides*, and trout-perch *Percopsis omiscomaycus* have all declined since the introduction of this fish, although the association is not clear (McLean 1993). There is much concern that ruffe may have a detrimental effect on more desirable species in Lake Superior, such as yellow perch and walleye, by feeding on the young of these species (Raloff 1992), or by competing for food (McLean 1993). Savino and Kolar (1996) conducted a laboratory study to test for competition for food between ruffe and yellow perch. They found that competition could occur between the two species but that the outcome would not always be clear. Each species exhibited competitive advantages and disadvantages. Ogle et al. (1995) studied the diet of introduced ruffe inhabiting the St. Louis estuary. Their findings indicated that the species prey heavily on benthic insects thereby suggesting that ruffe compete for food with yellow perch, trout-perch, and other native benthic-feeding fishes. Fullerton et al. (1998) also observed that similarities in dietary preferences and in feeding rates of ruffe and yellow perch suggest a strong possibility for interspecific competition. Ruffe hold an advantage over native perch in their ability to better select moving objects under relatively dim light conditions or at high turbidity. Kolar et al. (2002) found that in a laboratory setting, ruffe exhibited higher consumption rates of benthic invertebrates than yellow perch in darkness over bare cobble and complex substrates. Ruffe has a very sensitive lateral line system and night adapted vision, and is more adapted to foraging under poor light conditions that [sic] yellow perch (Hölker and Thiel 1998). In a study of ruffe predation by native pike, bass, bullhead, walleye, and perch, Mayo et al. (1998) found that though ruffe comprised 71-88% of prey species biomass, all five of the selected predators ate ruffe at lower proportions, preferentially selecting native fish species."

From Ontario Federation of Anglers and Hunters (2023):

"This species has the potential to affect ecosystems in the following ways:

- They negatively impact native sportfish populations, such as, yellow perch by directly competing for food, habitat or through heavy predation of native sportfish eggs.
- Ruffe can very quickly become the most dominant fish in local areas because of their rapid reproductive and growth rates. This puts pressure on native species and contributes to their decline."

From CABI (2023):

"While it is not always possible to extrapolate negative interactions documented in laboratory studies to impacts in the wild, several studies conducted in mesocosms or in the laboratory suggest that *G. cernuus* will out-compete native yellow perch (*Perca fluvescens*) (Fullerton et al., 1998; Schuldt et al., 1999; Fullerton et al., 2000; Henson and Newman, 2000). However, one laboratory study suggested that if *G. cernuus* and yellow perch share a habitat, competition for space will be weak or absent and competition for food may occur when food is limiting because neither species has a clear advantage in its ability to consume invertebrates in any habitat (Fullerton and Lamberti, 2006). The general conclusion from the International Symposium on the Biology and Management of Ruffe is that the invasion of *G. cernuus* to new waterbodies may not be as great a threat to yellow perch, walleye (*Sander vitreum*), *Coregonus* spp., and other native fish as was first thought (Adams and Maitland, 1998; Gunderson et al., 1998; Kovac, 1998; Ogle, 1998; Popova et al., 1998; Winfield et al., 1998)."

From NatureServe (2023):

"Introduced populations may reduce food resources for native fishes. May have caused a dramatic decline in the perch population in Loch Lomond, Scotland. Expansion of ruffe population in the Great Lakes poses a serious threat to populations of walleye, perch, and various forage fishes. In Duluth Harbor, Lake Superior, populations of yellow perch, trout-perch, black bullhead, and most minnows declined as the ruffe population increased (Boogaard et al. 1996)."

*Gymnocephalus cernua* is listed as an invasive, prohibited, or regulated species in the following states: Arkansas (Arkansas Game and Fish Commission 2022); Colorado (Colorado Parks and Wildlife 2022); Idaho (Idaho Department of Agriculture 2022); Illinois (Illinois Department of Natural Resources 2015); Indiana (Indiana Department of Natural Resources 2022); Iowa (Iowa NRC 2022), Maryland (Code of Maryland Regulations 2022); Michigan (Michigan Compiled Laws 2022); Minnesota (Minnesota Department of Natural Resources 2022); Montana (Montana Department of Fish, Wildlife, and Parks 2022); North Carolina (North Carolina Department of Environmental Quality 2022); North Dakota (North Dakota Game and Fish Department 2019); New Hampshire (New Hampshire Fish and Game Department 2022); New York (New York DEC 2022); Ohio (Ohio Department of Natural Resources 2022); Oregon (Oregon Department of Fish and Wildlife 2022); Pennsylvania (Pennsylvania Fish and Boat Commission 2022); Rhode Island (Rhode Island Department of Environmental Management 2022); Tennessee (Tennessee Wildlife Resources Agency 2022); Texas (Texas Parks and Wildlife 2022); Utah

(Utah Division of Wildlife Resources 2020); Virginia (Virginia Department of Wildlife Resources 2020); Wisconsin (Wisconsin Department of Natural Resources 2022).

# 4 History of Invasiveness

The history of invasiveness for *Gymnocephalus cernua* is High because this species has been introduced into multiple areas and there are documented negative impacts of introduction from peer reviewed sources. *Gymnocephalus cernua* has been introduced to several countries accidentally via ballast water and use as a live bait for fishing; the species has also expanded its introduced range through natural dispersal. The most commonly observed impacts of introduction are heavy egg predation and food competition with native species. Some authors have tied these impacts directly to population declines in native species such as yellow perch (*Perca flavescens*) and whitefish (*Coregonus* spp.), but others debate the strength of the connection between the impacts observed and population-level decline of native species.

# 5 Global Distribution

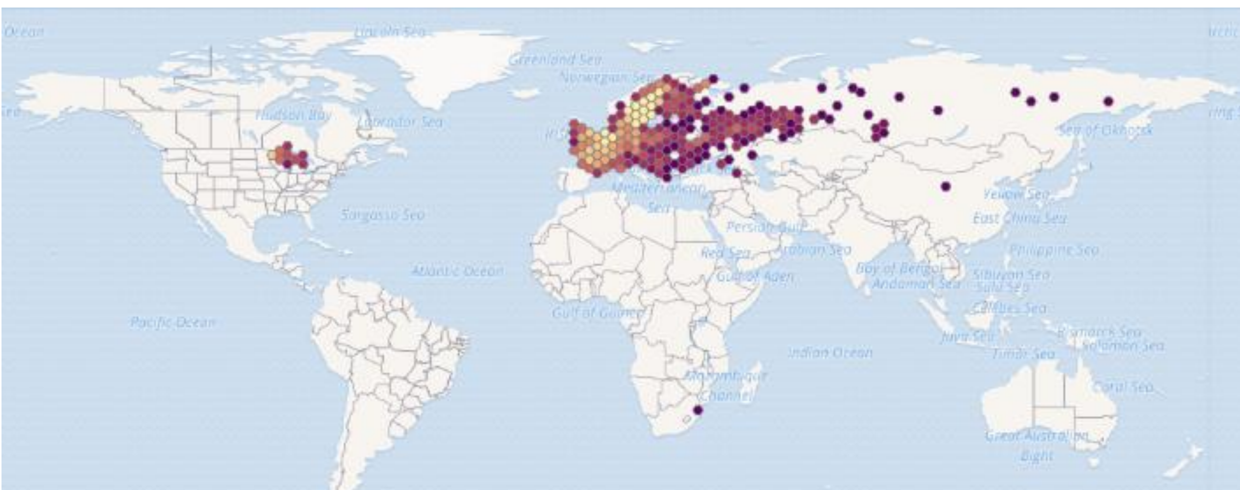


**Figure 1**. Known global distribution of *Gymnocephalus cernua.* Observations are reported from Europe, Asia and the United States. Map from GBIF Secretariat (2024). The points in South Africa and in Whitney Township, Michigan, represent preserved specimens and were not included in the climate match. The point in China represents the country centroid rather than a specific occurrence location and was not included in the climate match.

No georeferenced occurrences were found for the following countries within the native range: Azerbaijan, China, Kazakhstan, Latvia, Mongolia, and Uzbekistan.

Additional georeferenced occurrences from Székely (1995; Hungary), Györe et al. (1999; Hungary), Tarkan et al. (2022; Turkey), and Fuller et al. (2024; Cheboygan, Michigan) were used to supplement GBIF Secretariat (2024) occurrences in selecting source locations for the climate matching analysis.

# 6 Distribution Within the United States

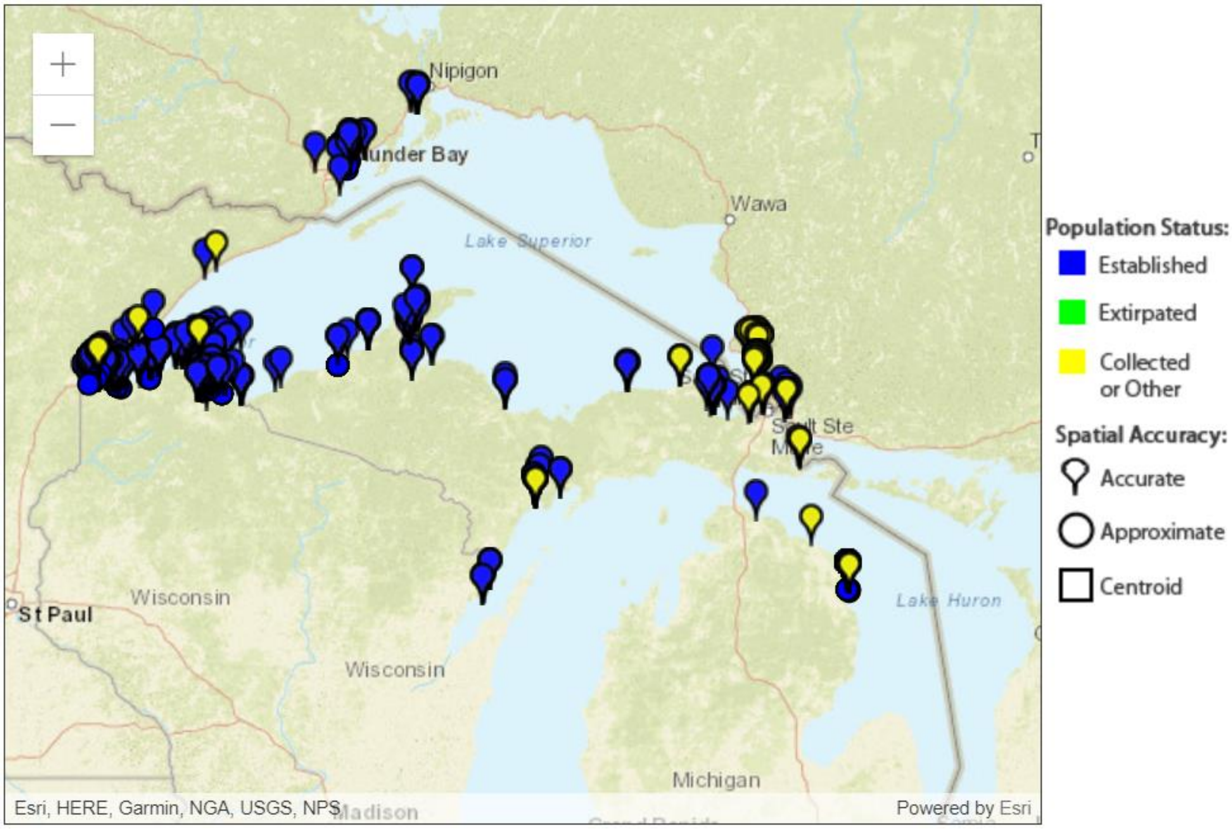


**Figure 2.** Reported distribution of *Gymnocephalus cernua* in the United States (Great Lakes region) and adjacent Canada, showing collection locations and established populations. Map from Fuller et al. (2024). Only established populations were used to select source locations for the climate matching analysis.

# 7 Climate Matching

## Summary of Climate Matching Analysis

The climate match for *Gymnocephalus cernua* was generally high for the contiguous United States with few areas of low and medium climate match being found along the northern Pacific Coast, Sonoran Desert, Gulf Coast, and peninsular Florida. The highest climate matches were found in the northern Great Lakes region, where *G. cernua* is already established, as well as in small areas in the central Appalachian Mountains, the eastern shore of Puget Sound, Washington, and near Santa Fe, New Mexico. The overall Climate 6 score was 0.879, indicating that Yes, there is establishment concern for this species. 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 *Gymnocephalus cernua* (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.

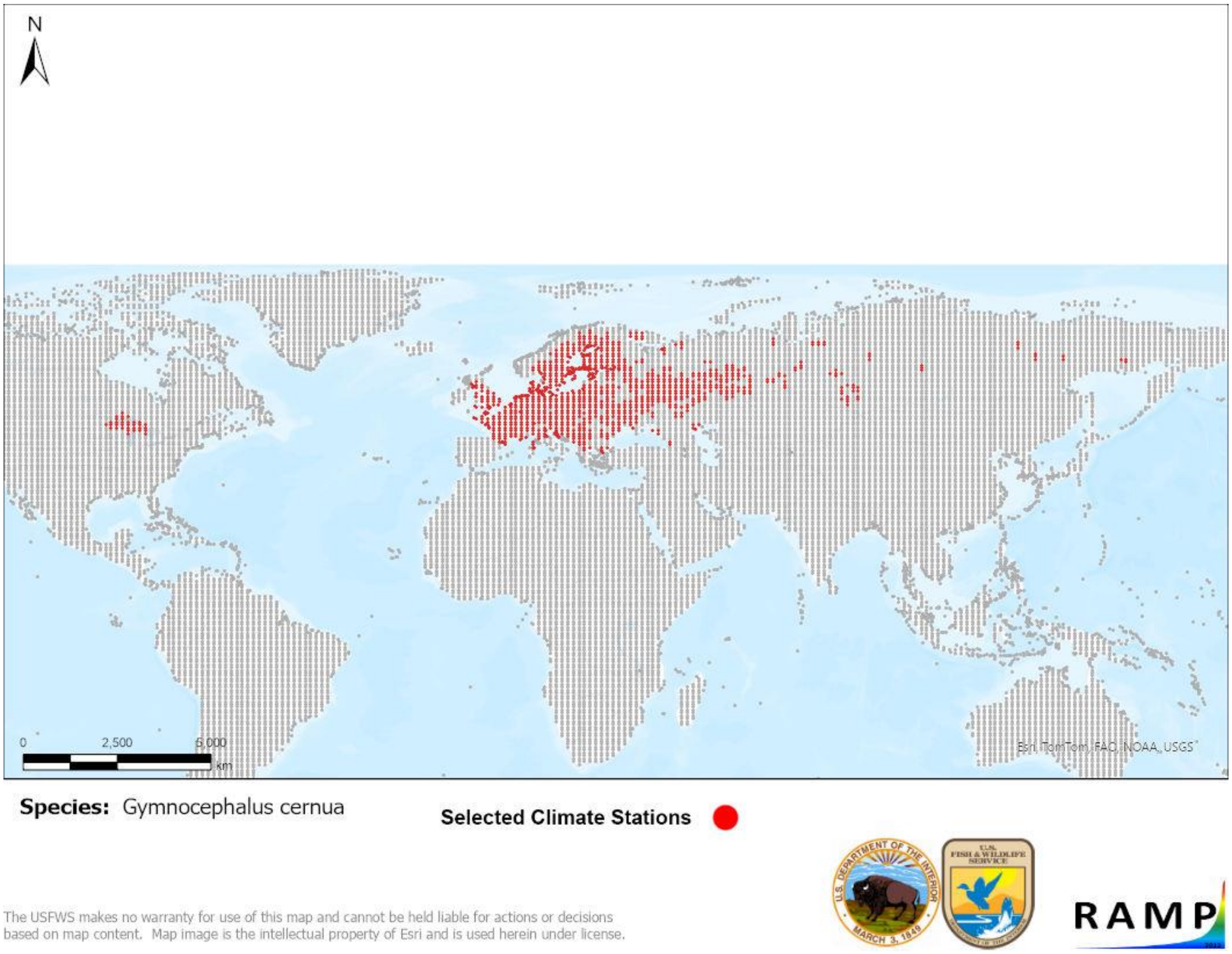


**Figure 3.** RAMP (Sanders et al. 2023) source map showing weather stations in North America, Asia, and Europe selected as source locations (red; United States, Canada, Russia, Georgia, and throughout Europe except for Ireland, northern Scandinavia, and the Iberian, Italian, and southern Balkan peninsulas) and non-source locations (gray) for *Gymnocephalus cernua* climate matching. Source locations from GBIF Secretariat (2022). Additional source locations from Székely (1995; Hungary), Györe et al. (1999; Hungary), Tarkan et al. (2022; Turkey), and Fuller et al. (2024; Cheboygan, Michigan). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

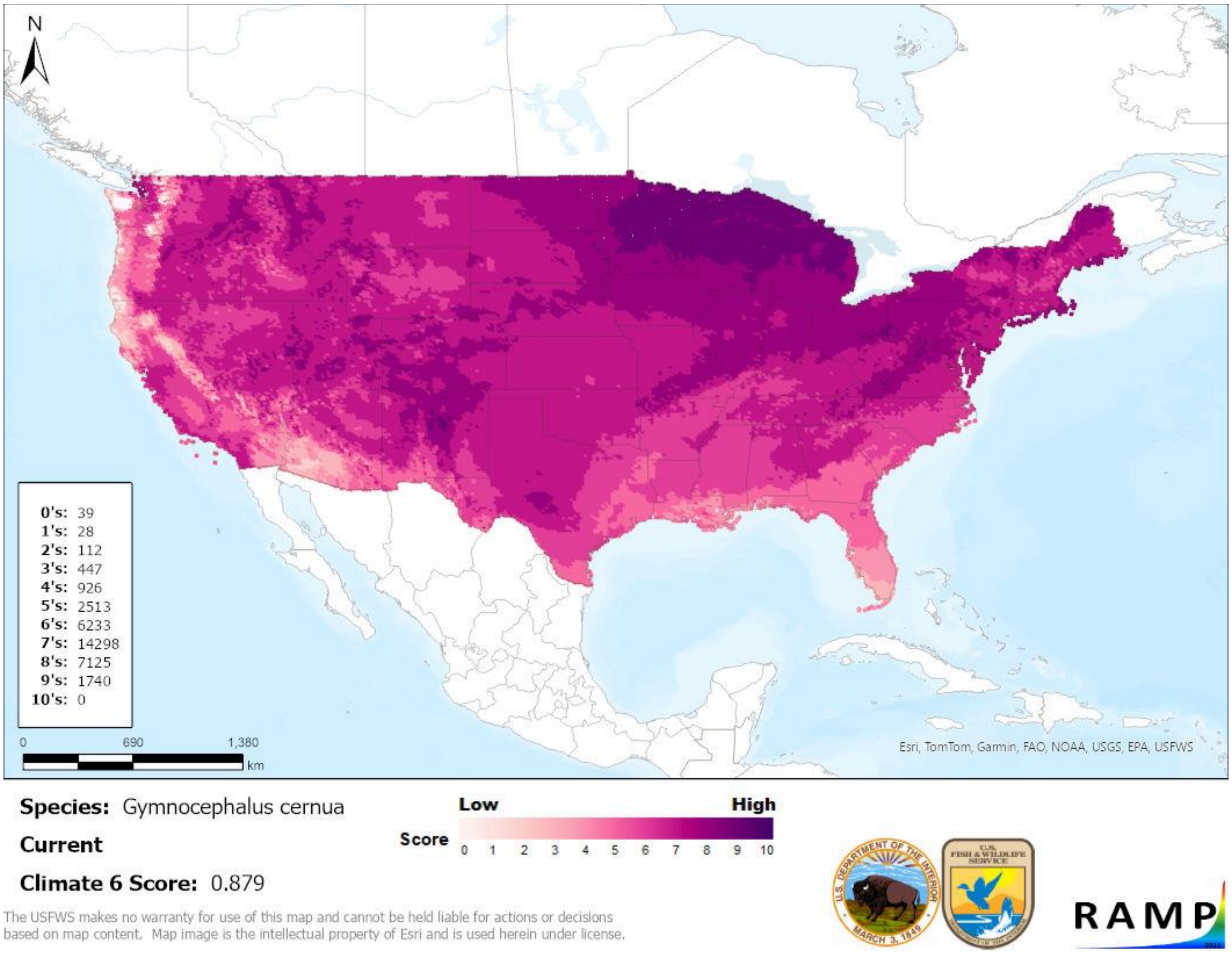


**Figure 4**. Map of RAMP (Sanders et al. 2023) climate matches for *Gymnocephalus cernua* in the contiguous United States based on source locations reported by GBIF Secretariat (2024), Székely (1995), Györe et al. (1999), Tarkan et al. (2022), and Fuller et al. (2024). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

# 8 Certainty of Assessment

The certainty for this assessment is Medium. There is quality information available about the biology and ecology of *Gymnocephalus cernua*. Records of introduction, vectors, and establishment were found in several countries outside of the native range for *Gymnocephalus cernua*. Several peer-review sources documented the impacts of *Gymnocephalus cernua* introductions, along with potential additional impacts. However, several authors have expressed uncertainty about the strength of the connection between population level declines of native species and the observed impacts of *G. cernua* on these populations (egg predation and food competition). For that reason, the Certainty of Assessment is classified as Medium.

# 9 Risk Assessment

## Summary of Risk to the Contiguous United States

*Gymnocephalus cernua*, Ruffe, is a freshwater and brackish water fish native to numerous countries in Europe and Asia. It has been introduced accidentally via ballast water or intentionally as a bait species in the Great Lakes region of North America, France, Italy, Turkey, Algeria, and in areas outside of its native range in Germany, Georgia, Norway, and the United Kingdom. Most of these introductions have resulted in population establishment. The History of Invasiveness for *G. cernua* is classified as High due to its documented predation on eggs of native fish species and competition for their food resources, potentially contributing to native species declines. The transportation, possession, and sale of *Gymnocephalus cernua* has been regulated by more than twenty U.S. States and one Canadian province because of these documented negative impacts. The climate matching analysis for the contiguous United States indicates establishment concern for this species. The climate match was high across most of the contiguous United States, and especially where the species is already established in the northern Great Lakes region. The Certainty of this Assessment is Medium due to some disagreement in the literature about the degree to which *G. cernua* has contributed to native species declines. The Overall Risk Assessment Category for *G. cernua* 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): Medium**
- **Remarks/Important additional information: None**
- **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.**


Adams CE, Maitland PS. 1998. The ruffe population of Loch Lomond, Scotland: its introduction, population expansion, and interaction with native species. Great Lakes Restoration 24(2):249–262.

Adams CE, Tippett R. 1991. Powan, *Coregonus lavaretus* (L.), ova predation by newly introduced ruffe, *Gymnocephalus cernuus* (L.), in Loch Lomond, Scotland. Aquaculture and Fisheries Management 22:239–246.

Arkansas Game and Fish Commission. 2022. Certain exotic species prohibited. Arkansas Game and Fish Commission Code Book 26.13.

Beletsky D, Beletsky R, Rutherford ES, Sieracki JL, Bossenbroek JM, Chadderton WL, Wittmann ME, Annis GM, Lodge DM. 2017. Predicting spread of aquatic invasive species by lake currents. Journal of Great Lakes Research 43:14–32.

[CABI] CAB International. 2023. *Gymnocephalus cernuus* (ruffe) [original text by Gunderson J]. CABI Invasive Species Compendium. Wallingford, United Kingdom: CAB International. Available: https://www.cabi.org/isc/datasheet/80729 (February 2023).

Code of Maryland Regulations. 2022. Classification of nonnative aquatic organisms. Section 08.02.19.04.

Colorado Parks and Wildlife. 2022. Possession of aquatic wildlife. 2 Code of Colorado Regulations 406-0, Article VIII #012.

Freyhof J, Kottelat M. 2008. *Gymnocephalus cernua*. The IUCN Red List of Threatened Species 2008: e.T9568A13002898. Available: https://www.iucnredlist.org/species/9568/13002898 (February 2023).

Fricke R, Eschmeyer WN, van der Laan R, editors. 2023. Eschmeyer's catalog of fishes: genera, species, references. California Academy of Science. Available: http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp (February 2023).

Froese R, Pauly D, editors. 2023a. *Gymnocephalus cernua* (Linnaeus, 1758) Ruffe. FishBase. Available: https://www.fishbase.us/summary/SpeciesSummary.php?ID=4474&genusname=Gymnocephalus&speciesname=cernua&AT=gymnocephalus+cernua&lang=English (February 2023).

Froese R, Pauly D. 2023b. *Gymnocephalus cernua* (Linnaeus, 1758). World Register of Marine Species. Available: http://www.marinespecies.org/aphia.php?p=taxdetails&id=405451 (February 2023).

Fuller P, Jacobs G, Larson J, Makled TH, Fusaro A. 2023. *Gymnocephalus cernua*. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=7 (February 2023).

Fuller P, Jacobs G, Larson J, Makled TH, Fusaro A. 2024. *Gymnocephalus cernua* (Linnaeus, 1758). Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database, and Ann Arbor, Michigan: NOAA Great Lakes Aquatic Nonindigenous Species Information System. Available: https://nas.er.usgs.gov/queries/greatLakes/FactSheet.aspx?Species_ID=7&Potential=N&Type=0&HUCNumber=DGreatLakes (June 2024).

GBIF Secretariat. 2024. GBIF backbone taxonomy: *Gymnocephalus cernua* (Linnaeus, 1758). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5209574 (June 2024).

[GISD] Global Invasive Species Database. 2023. Species profile: *Gymnocephalus cernuus*. Gland, Switzerland: Invasive Species Specialist Group. Available: http://www.iucngisd.org/gisd/speciesname/Gymnocephalus+cernuus (February 2023).

Györe K, Sallai Z, Csikai Cs. 1999. Data to the fish fauna of the River Tisza and its tributaries in Hungary and Romania. Pages 455–470 in Hamar J, Sárkány-Kiss A, editors. The Upper Tisza Valley: preparatory proposal for Ramsar site designation and an ecological background Hungarian, Romanian, Slovakian and Ukrainian co-operation. Szolnok, Hungary: Tisza Klub for Environment and Nature, and Târgu Mureş, Romania: Liga Pro Europa.

Idaho Department of Agriculture. 2022. Rules governing invasive species and noxious weeds. Idaho Administrative Code 02.06.09.

Illinois Department of Natural Resources. 2015. Injurious species. 17 Illinois Administrative Code chapter 1, part 805.

Indiana Department of Natural Resources. 2022. Aquatic invasive species possession rules. Indianapolis: Indiana Department of Natural Resources. Available: https://www.in.gov/dnr/fish-and-wildlife/files/fw-AIS_PossessionRules.pdf (February 2023).

Iowa [NRC] Natural Resource Commission. 2015. Aquatic invasive species. Iowa Administrative Code 571-90.

Kuljanishvili T, Mumladze L, Japoshvili B, Mustafayev N, Ibrahimov S, Patoka J, Pipoyan S, Kalous L. 2021. The first unified inventory of non-native fishes of the South Caucasian countries, Armenia, Azerbaijan, and Georgia. Knowledge & Management of Aquatic Ecosystems 422:32.

Michigan Compiled Laws. 2022. Transgenic and nonnative organisms. Chapter 324, part 413.

Minnesota Department of Natural Resources. 2022. Minnesota invasive species laws. Saint Paul: Minnesota Department of Natural Resources. Available: https://www.dnr.state.mn.us/invasives/laws.html (February 2023).

Montana Department of Fish, Wildlife, and Parks. 2022. Exotic wildlife. Administrative Rules of Montana 12.6.22.

NatureServe. 2023. *Gymnocephalus cernua*. NatureServe Explorer: an online encyclopedia of life. Version 7.1. Arlington, Virginia: NatureServe. Available: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.103960/Gymnocephalus_cernua (February 2023).

New Hampshire Fish and Game Department. 2022. The importation, possession and use of all wildlife. New Hampshire Code of Administrative Rules Fis 800.

New York [DEC] Department of Environmental Conservation. 2022. Prohibited and regulated invasive species. 6 New York Codes, Rules and Regulations 575.3.

Newman RM, Henson FG, Richards C. 2020. Competition between invasive ruffe (*Gymnocephalus cernua*) and native yellow perch (*Perca flavascens*) in experimental mesocosms. Fishes 5(4):33.

North Carolina Department of Environmental Quality. 2022. Possession of certain fishes. 15A North Carolina Administrative Code 10C .0211.

North Dakota Game and Fish Department. 2019. ANS species list. Bismarck: North Dakota Game and Fish Department. Available: https://gf.nd.gov/ans/species (February 2023).

Ohio Department of Natural Resources. 2022. Ohio's injurious aquatic invasive species. Publication 5490 R0120. Available: https://ohiodnr.gov/static/documents/wildlife/fish-management/Injurious%20Aquatic%20Invasive%20Species.pdf (February 2023).

Ontario Federation of Anglers and Hunters. 2023. Eurasian ruffe *Gymnocephalus cernuus*. Available at: http://www.invadingspecies.com/eurasian-ruffe/ (February 2023).

Oregon Department of Fish and Wildlife. 2022. Importation, possession, confinement, transportation and sale of nonnative wildlife. Oregon Administrative Rules 635-056.

Pennsylvania Fish and Boat Commission. 2022. Aquatic invasive species. Harrisburg: Pennsylvania Fish and Boat Commission. Available: https://www.fishandboat.com/Resource/AquaticInvasiveSpecies/Pages/default.aspx (February 2023).

Poelen JH, Simons JD, Mungall CJ. 2014. Global Biotic Interactions: an open infrastructure to share and analyze species-interaction datasets. Ecological Informatics 24:148–159.

Rhode Island Department of Environmental Management. 2022. Rules and regulations governing importation and possession of wild animals. 250 Rhode Island Code of Regulations 40-05-3.

Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.

Simon TP, Vondruska JT. 1991. Larval identification of the ruffe, *Gymnocephalus cernuus* (Linnaeus) (Percidae: Percini), in the St. Louis River Estuary, Lake Superior drainage basin, Minnesota. Canadian Journal of Zoology 69(2):436–442.

Simpson A, Fuller P, Faccenda K, Evenhuis N, Matsunaga J, Bowser M. 2022. United States Register of Introduced and Invasive Species. Version 2.0. Reston, Virginia: U.S. Geological Survey. Available: https://doi.org/10.5066/P9KFFTOD (February 2023).

Székely Cs. 1995. Dynamics of *Anguillicola crassus* (Nematoda: Dracunculoidea) larval infection in paratenic host fishes of Lake Balaton, Hungary. Acta Veterinaria Hungarica 43:401–422.

Tarkan AS, Emiroğlu Ö, Aksu S, Başkurt S, Aksu İ, Vilizzi L, Yoğurtçuoğlu B. 2022. Coupling molecular and risk analysis to investigate the origin, distribution and potential impact of non-native species: an application to ruffe *Gymnocephalus cernua* in Turkey. The European Zoological Journal 89:109–121.

Tennessee Wildlife Resources Agency. 2022. Rules and regulations of live wildlife. Rules of the Tennessee Wildlife Resources Agency 1660-01-18.

Texas Parks and Wildlife. 2022. Invasive, prohibited and exotic species. Austin: Texas Parks and Wildlife. Available: https://tpwd.texas.gov/huntwild/wild/species/exotic/prohibited_aquatic.phtml (February 2023).

[USFWS] U.S. Fish and Wildlife Service. 2024. Standard operating procedure: how to prepare an "Ecological Risk Screening Summary." Version 3.

Utah Division of Wildlife Resources. 2020. Collection, importation, possession (CIP). Administrative rule R657-3.

Virginia Department of Wildlife Resources. 2022. Importation requirements, possession, and sale of nonnative (exotic) animals. 4 Virginia Administrative Code 15-30-40.

Wisconsin Department of Natural Resources. 2022. Invasive species identification, classification and control. Wisconsin Administrative Code NR 40.

World Organisation for Animal Health. 2022. Animal diseases. Paris: World Organisation for Animal Health. Available: https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-diseases/ (December 2022).

# 11 Literature Cited in Quoted Material

**Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.**

Adams CE. 1991. Shift in pike, *Esox lucius* L., predation pressure following the introduction of ruffe, *Gymnocephalus cernuus* (L.) to Loch Lomond. Journal of Fish Biology 38(5):663–667.

Anonymous. 1999. Systematic list of Estonian fishes. World Wide Web Electronic Publication, 14 January 2000. [Accessed by source author.]

Arab IY, Arab A, Kara HM. 2020. Range expansion of the ruffe (*Gymnocephalus cernuus*) to the southern Mediterranean: first record in Koudiat Medouar reservoir, Algeria. Journal of Applied Ichthyology 36:705–708.

Bergman E. 1991. Changes in abundance of two percids, *Perca fluviatilis* and *Gymnocephalus cernuus*, along a productivity gradient: relations to feeding strategies and competitive abilities. Canadian Journal of Fisheries and Aquatic Sciences 48:536–545.

Bianco PG, Ketmaier V. 2001. Anthropogenic changes in the freshwater fish fauna of Italy, with reference to the central region and *Barbus graellsii*, a newly established alien species of Iberian origin. Journal of Fish Biology 59:190–208.

Billard R. 1997. Les poissons d'eau douce des rivières de France. Identification, inventaire et répartition des 83 espèces. Lausanne: Delachaux & Niestlé.

Bogutskaya NG, Naseka AM. 2002a. Regional check-lists: Don River drainage area. In website and database: "Freshwater fishes of Russia": a source of information on the current state of the fauna. Zoological Institute RAS. [Source did not provide full citation for this reference.]

Bogutskaya NG, Naseka AM. 2002b. Regional check-lists: Kuban River drainage area. In website and database: "Freshwater fishes of Russia": a source of information on the current state of the fauna. Zoological Institute RAS. [Source did not provide full citation for this reference.]

Bogutskaya NG, Naseka AM. 2002c. Regional check-lists: Volga River drainage area. In website and database: "Freshwater fishes of Russia": a source of information on the current state of the fauna. Zoological Institute RAS. [Source did not provide full citation for this reference.]

Bogutskaya NG. 2005. Compilation of 70 ecoregion in Russia with about 700 species. Compilation of Nina Bogutskaya. Excel file. [Source did not provide full citation for this reference.]

Boogaard MA, Bills TD, Selgeby JH, Johnson DA. 1996. Evaluation of piscicides for control of ruffe. North American Journal of Fisheries Management 16:600–607.

Bronte CR, Evrard LM, Brown WP, Mayo KR, Edwards AJ. 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.

Coad BW. 1981. Fishes of Afghanistan, an annotated check-list. Publications in Zoology National Museum Canada 14:23.

Coker GA, Portt CB, Minns CK. 2001. Morphological and ecological characteristics of Canadian freshwater fishes. Ottawa: Fisheries and Oceans Canada.

Collette BB, Ali MA, Hokanson KEF, Nagiec M, Smirnov SA, Thorpe JE, Weatherly AH, Willemsen J. 1977. Biology of the percids. Journal of the Fisheries Research Board of Canada 34:1891–1899.

Czypinski GD, Bowen AK, Goehle MA, Brownson B. 2007. Surveillance for ruffe in the Great Lakes, 2006. Ashland, Wisconsin: U.S. Fish and Wildlife Service.

Czypinski GD, Bowen AK, Goehle MA, Cogswell S, MacKay B. 2004. Surveillance for ruffe in the Great Lakes, 2003. Ashland, Wisconsin: U.S. Fish and Wildlife Service.

Czypinski GD, Bowen AK, Sowinski MP, MacKay B. 2003. Surveillance for ruffe in the Great Lakes, 2002. Ashland, Wisconsin: U.S. Fish and Wildlife Service.

Czypinski GD, Hintz AK, Keppner SM, Paleczny E. 1999. Surveillance for ruffe in the Great Lakes, 1998. Ashland, Wisconsin: U.S. Fish and Wildlife Service.

Czypinski GD, Hintz AK, Weimer MT, Dextrase A. 2000. Surveillance for ruffe in the Great Lakes, 1999. Ashland, Wisconsin: U.S. Fish and Wildlife Service.

Czypinski GD, Hintz AK, Weimer MT, Dextrase A. 2001. Surveillance for ruffe in the Great Lakes, 2000. Ashland, Wisconsin: U.S. Fish and Wildlife Service.

Epitashvili G, Geiger MF, Astrin JJ, Herder F, Japoshvili B, Mumladze L. 2020. Towards retrieving the Promethean treasure: a first molecular assessment of the freshwater fish diversity of Georgia. Biodiversity Data Journal 8:e57862.

Frier JO. 1994. Danmark. Danske ferskvandsfisk og deres udbredelsesområde. Pages 83–99 in Frier JO, editor. Truede ferskvandsfiskearter i Norden. Copenhagen: Nordisk Ministerråd. TemaNord 1994:625. [In Danish.]

Fullerton AH, Lamberti GA. 2006. A comparison of habitat use and habitat-specific feeding efficiency by Eurasian ruffe (*Gymnocephalus cernuus*) and yellow perch (*Perca flavescens*). Ecology of Freshwater Fish 15:1–9.

Fullerton AH, Lamberti GA, Lodge DM, Berg MB. 1998. Prey preferences of Eurasian ruffe and yellow perch: comparison of laboratory results with composition of Great Lakes benthos. Journal of Great Lakes Research 24:319–328.

Fullerton AH, Lamberti GA, Lodge DM, Goetz FW. 2000. Potential for resource competition between Eurasian ruffe and yellow perch: growth and RNA responses in laboratory experiments. Transactions of the American Fisheries Society 29:1331–1339.

Gerstmeier R, Romig T. 1998. Die Süßwasserfische Europas: für Naturfreunde und Angler. Stuttgart: Franckh-Kosmos Verlag.

Gorman OT, Ebener MP, Vinson MR, editors. 2010. The state of Lake Superior in 2005. Ann Arbor, Michigan: Great Lakes Fishery Commission. Special Publication 10-01.

Gunderson JL, Klepinger MR, Bronte CR, Marsden JE. 1998. Overview of the international symposium on Eurasian ruffe (*Gymnocephalus cernuus*) biology, impacts, and control. Journal of Great Lakes Research 24:165–169.

Günther A. 1853. Die Fische des Neckars. Stuttgart: Verlag von Ebner & Seubert.

Hanel L. 2003. The ichthyofauna of the Czech Republic: development and present state. Matthias Belivs University Proceedings 3:41–71.

Henson FG, Newman RM. 2000. Effect of temperature on growth at ration and gastric evacuation rate of ruffe. Transactions of the American Fisheries Society 129:552–560.

Hölker F, Thiel R. 1998. Biology of ruffe (*Gymnocephalus cernuus* (L.)): a review of selected aspects from European literature. Journal of Great Lakes Research 24:186–204.

Keith P, Allardi J. 2001. Atlas des poissons d'eau douce de France. Paris: Muséum national d’Histoire naturelle. Patrimoines Naturels 47.

Kindt K, Keppner SM, Johnson G. 1996. Surveillance for ruffe in the Great Lakes, 1995. Ashland, Wisconsin: U.S. Fish and Wildlife Service, Ashland Fishery Resources Office.

Kolar CS, Fullerton AH, Martin KM, Lamberti GA. 2002. Interactions among zebra mussel shells, invertebrate prey, and Eurasian ruffe or yellow perch. Journal of Great Lakes Research 28:664–673.

Kottelat M, Freyhof J. 2007. Handbook of European freshwater fishes. Berlin: Publications Kottelat, Cornol and Freyhof.

Kovac V. 1998. Biology of Eurasian ruffe from Slovakia and adjacent central European countries. Journal of Great Lakes Research 24:205–216.

Kozlova MF, Panasenko VA. 1977. Annual food consumption of bream (*Abramis brama*) and ruffe (*Acerina cernua*) populations in the Courland Lagoon (Kurshskiy Zaliv). Journal of Ichthyology 17:382–388.

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.

Leino RL, McCormick JH. 1997. Reproductive characteristics of the ruffe, *Gymnocephalus cernuus*, in the St. Louis River estuary on western Lake Superior: a histological examination of the ovaries over one annual cycle. Canadian Journal of Fisheries and Aquatic Sciences 54:256–263.

Maitland PS, East K. 1989. An increase in numbers of ruffe, *Gymnocephalus cernuus* (L.), in a Scottish loch from 1982 to 1987. Aquaculture and Fisheries Management 20:227–228.

Mattila J, Bonsdorff E. 1989. The impact of fish predation on shallow soft bottoms in brackish waters (SW Finland): an experimental study. Netherlands Journal of Sea Research 23:69–81.

Mayo KR, Selgeby JH, McDonald ME. 1998. A bioenergetics modeling evaluation of top-down control of ruffe in the St. Louis River, western Lake Superior. Journal of Great Lakes Research 24:329–342.

McLean M. 1993. Ruffe (*Gymnocephalus cernuus*) fact sheet. Duluth: Minnesota Sea Grant Program, Great Lakes Sea Grant Network.

Muus BJ, Dahlström P. 1968. Süßwasserfische. München: BLV Verlagsgesellschaft.

Muus BJ, Nielsen JG. 1999. Sea fish. Hedehusene, Denmark: Scandinavian Fishing Year Book.

Near TJ. 2002. Phylogenetic relationships of *Percina* (Percidae: Etheostomatinae). Copeia 2002:1–14.

Ogle DH, Selgeby JH, Savino JF, Newman RM, Henry MG. 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 DH. 1998. A synopsis of the biology and life history of ruffe. Journal of Great Lakes Research 24:170–185.

Ogle DH, Ray BA, Brown WP. 2004. Diet of larval ruffe (*Gymnocephalus cernuus*) in the St. Louis River harbor, Lake Superior. Journal of Great Lakes Research 30:287–292.

Ojaveer E, Pihu E. 2003. Estonian natural fish waters. Pages 15–27 in Ojaveer E, Pihu E, Saat T, editors. Fishes of Estonia. Tallinn: Estonian Academy Publishers.

Pinder AC. 2001. Keys to larval and juvenile stages of coarse fishes from fresh waters in the British Isles. Cumbria, United Kingdom: Freshwater Biological Association.

Popova OA, Reshetnikov YS, Kiyashko VI, Dgebuadze YY, Mikheev VN. 1998. Ruffe from the former USSR: variability within the largest part of its natural range. Journal of Great Lakes Research 24:263–284.

Pratt D. 1988. Distribution and population status of the ruffe (*Gymnocephalus cernua*) in the St. Louis estuary and Lake Superior. Ann Arbor, Michigan: Great Lakes Fishery Commission. Research Completion Report.

Pratt DM, Blust WH, Selgeby JH. 1992. Ruffe, *Gymnocephalus cernuus*: newly introduced in North America. Canadian Journal of Fisheries and Aquatic Sciences 49:1616–1618.

Raloff J. 1992. From tough ruffe to quagga; intimidating invaders alter earth's largest freshwater ecosystem. Science News 142:56–58.

Regan CT. 1911. The freshwater fishes of the British Isles. London: Methuen.

Riede K. 2004. Global register of migratory species - from global to regional scales. Bonn, Germany: Federal Agency for Nature Conservation. Final Report R&D-Projekt 808 05 081.

Robins CR, Bailey RM, Bond CE, Brooker JR, Lachner EA, Lea RN, Scott WB. 1991. Common and scientific names of fishes from the United States and Canada. American Fisheries Society. Special Publication 20.

Ruffe Task Force. 1992. Ruffe in the Great Lakes: a threat to North American fisheries. Ann Arbor, Michigan: Great Lakes Fishery Commission.

Sandlund OT, Naesje TF, Klyke L, Lindem T. 1985. The vertical distribution of fish species in Lake Jmosa, Norway as shown by gillnet catches and echo sounder. Institute of Freshwater Research, Drottningholm 63:136–149.

Savino JF, Kolar CS. 1996. Competition between nonindigenous ruffe and native yellow perch in laboratory studies. Transactions of the American Fisheries Society 125:562–571.

Selgeby J. 1998. Predation by ruffe (*Gymnocephalus cernuus*) on fish eggs in Lake Superior. Journal of Great Lakes Research 24(2):304–308.

Schuldt JA, Richards C, Newman RM. 1999. Effects of Eurasian ruffe on food resources and native yellow perch in experimental mesocosms. Bulletin of the North American Benthological Society 16:163.

Slade JW, Paré SM, MacCallum WR. 1994. Surveillance for ruffe in the Great Lakes, 1993. Ashland, Wisconsin: U.S. Fish and Wildlife Service, Ashland Fishery Resources Office.

Stepien CA, Dillon AK, Chandler MD. 1998. Genetic identity, phylogeography, and systematics of ruffe *Gymnocephalus* in the North American Great Lakes and Eurasia. Journal of Great Lakes Research 24:361–378.

Stepien CA, Taylor CD, Dabrowska KA. 2002. Genetic variability and phylogeographical patterns of a nonindigenous species invasion: a comparison of exotic vs. native zebra and quagga mussel populations. Journal of Evolutionary Biology 15:314–328.

Thiel R, Cabral H, Costa MJ. 2003. Composition, temporal changes and ecological guild classification of the ichthyofaunas of large European estuaries - a comparison between the Tagus (Portugal) and the Elbe (Germany). Journal of Applied Ichthyology 19:330–342.

Thorman 1986. Physical factors affecting the abundance and species richness of fishes in the shallow waters of the southern Bothnian Sea (Sweden). Estuarine, Coastal and Shelf Science 22:357–369.

Tilmant JT. 1999. Management of nonindigenous aquatic fish in the U.S. National Park System. National Park Service.

Underhill JC. 1989. The distribution of Minnesota fishes and late Pleistocene glaciation. Journal of the Minnesota Academy of Science 55:32–37.

Vostradovsky J. 1973. Freshwater fishes. London: The Hamlyn Publishing Group.

Walker KF, Yang HZ. 1999. Fish and fisheries in western China. FAO Fisheries Technical Papers 385:237–278.

Winfield IJ. 1992. Threats to the lake fish communities of the U.K. arising from eutrophication and species introductions. Netherlands Journal of Zoology 42:233–242.

Winfield IJ, Rösch R, Appelberg M, Kinnerbäck A, Rask M. 1998. Recent introductions of the ruffe (*Gymnocephalus cernuus*) to *Coregonus* and *Perca* lakes in Europe and an analysis of their natural distribution in Sweden and Finland. Journal of Great Lakes Research 24:235–248.

Wolfram-Wais A, Wolfram G, Auer B, Mikschi E, Hain A. 1999. Feeding habits of two introduced fish species (*Lepomis gibbosus*, *Pseudorasbora parva*) in Neusiedler See (Austria), with special reference to chironomid larvae (Diptera: Chironomidae). Hydrobiologia 408/409:123–129.

# 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 (2024), Székely (1995), Györe et al. (1999), Tarkan et al. (2022), and Fuller et al. (2024).

Under the future climate scenarios (figure A1), on average, high climate match for *Gymnocephalus cernua* was projected to occur in the Great Lakes region of the contiguous United States. There were additional scattered areas of high match in the Western Mountains and Colorado Plateau regions under all scenarios. Areas of low climate match were projected to occur in the Southern Florida region, with additional smaller areas of low match along the Sierra Nevada and Cascade Mountains in the western United States. Areas of high match contracted northward when comparing SSP3 to SSP5 and timesteps 2055 to 2085. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.250 (model: UKESM1-0-LL, SSP5, 2085) to a high of 0.806 (model: MPI-ESM1-2-HR, 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 (0.879, 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 increases in the climate match relative to the current match were observed. However, under the 2085 time step, areas within the Appalachian Range, Colorado Plateau, Great Lakes, Gulf Coast, Mid-Atlantic, Northern Plains, Southeast, Southern Plains, and Southwest saw a large decrease in the climate match relative to current conditions. Additionally, areas within California, the Great Basin, Northeast, Southern Atlantic Coast, Southern Florida, and Western Mountains saw a moderate decrease in the climate match relative to current conditions under the 2085 SSP5 scenario. Additional, very small areas of large or moderate change may be visible on the maps (figure A3).

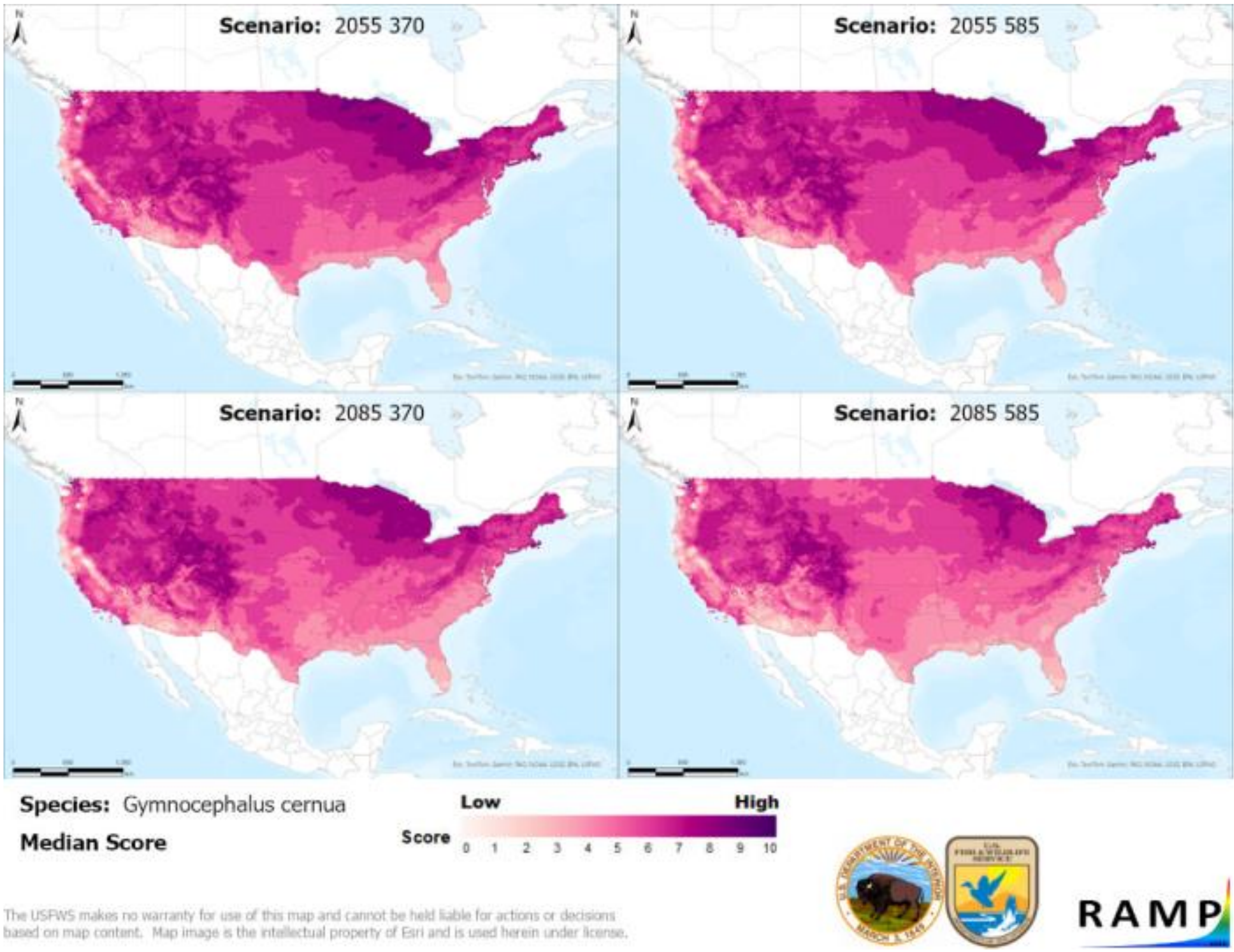


**Figure A1.** Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Gymnocephalus cernua* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2024), Székely (1995), Györe et al. (1999), Tarkan et al. (2022), and Fuller et al. (2024). 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.

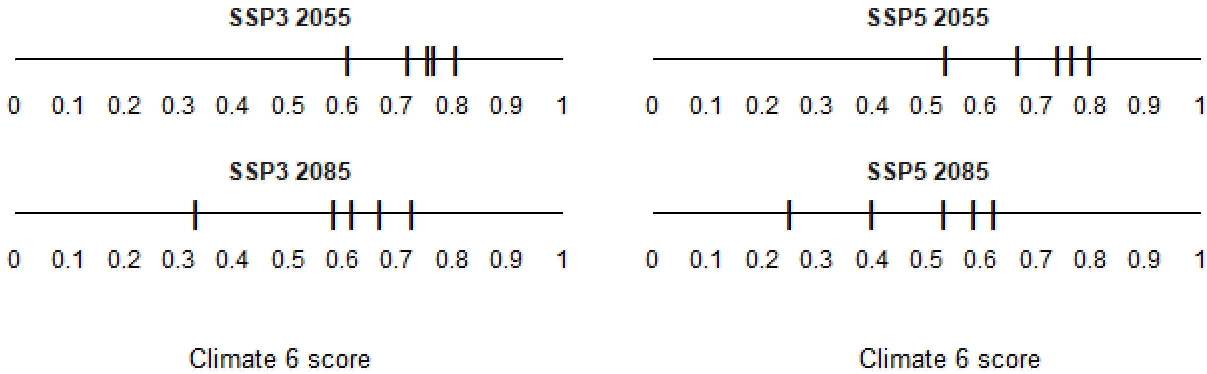


**Figure A2.** Comparison of projected future Climate 6 scores for *Gymnocephalus cernua* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 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.

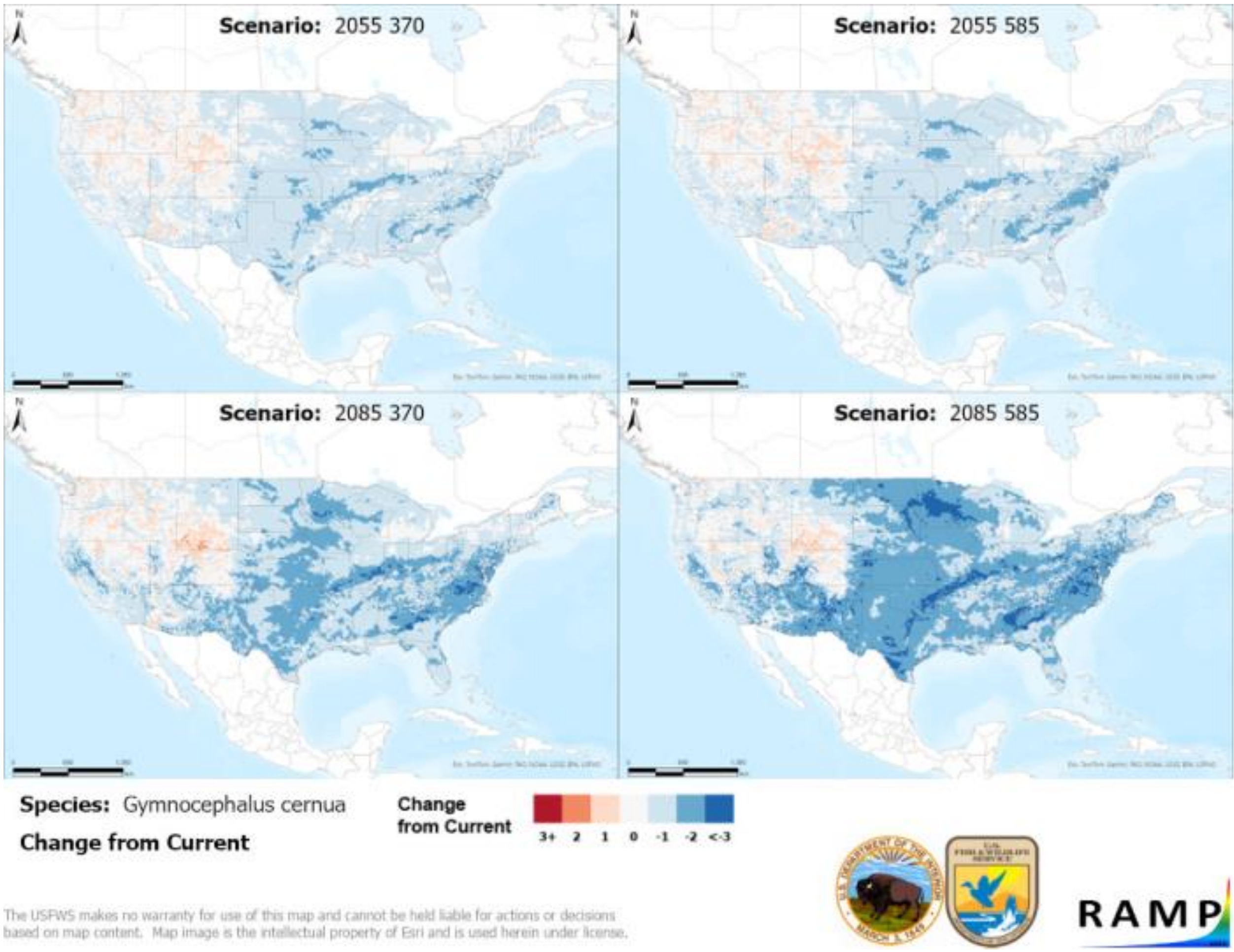


**Figure A3.** RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 4) and the median target point score for future climate scenarios (figure A1) for *Gymnocephalus cernua* based on source locations reported by GBIF Secretariat (2024), Székely (1995), Györe et al. (1999), Tarkan et al. (2022), and Fuller et al. (2024). 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.

## Literature Cited

Fuller P, Jacobs G, Larson J, Makled TH, Fusaro A. 2024. *Gymnocephalus cernua* (Linnaeus, 1758). Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database, and Ann Arbor, Michigan: NOAA Great Lakes Aquatic Nonindigenous Species Information System. Available: https://nas.er.usgs.gov/queries/greatLakes/FactSheet.aspx?Species_ID=7&Potential=N&Type=0&HUCNumber=DGreatLakes (June 2024).

GBIF Secretariat. 2024. GBIF backbone taxonomy: *Gymnocephalus cernua* (Linnaeus, 1758). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5209574 (June 2024).

Györe K, Sallai Z, Csikai Cs. 1999. Data to the fish fauna of the River Tisza and its tributaries in Hungary and Romania. Pages 455–470 in Hamar J, Sárkány-Kiss A, editors. The Upper Tisza Valley: preparatory proposal for Ramsar site designation and an ecological background Hungarian, Romanian, Slovakian and Ukrainian co-operation. Szolnok, Hungary: Tisza Klub for Environment and Nature, and Târgu Mureş, Romania: Liga Pro Europa.

[IPCC] Intergovernmental Panel on Climate Change. 2021. Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder HP, Kessler M. 2018. Data from: Climatologies at high resolution for the earth's land surface areas. EnviDat. Available: https://doi.org/10.16904/envidat.228.v2.1.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder P, Kessler M. 2017. Climatologies at high resolution for the Earth land surface areas. Scientific Data 4:170122.

Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.

Székely Cs. 1995. Dynamics of *Anguillicola crassus* (Nematoda: Dracunculoidea) larval infection in paratenic host fishes of Lake Balaton, Hungary. Acta Veterinaria Hungarica 43:401–422.

Tarkan AS, Emiroğlu Ö, Aksu S, Başkurt S, Aksu İ, Vilizzi L, Yoğurtçuoğlu B. 2022. Coupling molecular and risk analysis to investigate the origin, distribution and potential impact of non-native species: an application to ruffe *Gymnocephalus cernua* in Turkey. The European Zoological Journal 89:109–121.