European Bitterling (*Rhodeus amarus*)

Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, May 2011
Revised, July 2019
Web Version, 4/9/2020

Photo: Viridiflavus. Licensed under Creative Commons Attribution-Share Alike 3.0 Unported. Available: https://commons.wikimedia.org/wiki/File:BittervoornRhodeusAmarusVrouwtje.JPG. (July 2019).

1 Native Range and Status in the United States

Native Range

This screening considers *R. amarus* as having a native range within Europe and Asia Minor, following to the most recent accepted taxonomy, see "Remarks" below for more information.

From Froese and Pauly (2019):

"Europe: central and eastern Europe and northern Asia Minor [Kottelat 2006]. Basins of North, southern Baltic, Black, western and southern Caspian and Aegean Seas (from Maritza to Struma

drainages); Mediterranean basin, only in northern Rhône (France) and Drin drainages (Alabania [*sic*], Montenegro, Macedonia)."

"This species has become scarce [in the Czech Republic], especially in the drainage areas of the rivers Labe and Odra [Lusk et al. 2004]."

"Occurs in the northeast quarter [of France] ([Muus and Dahlström 1968; Billard 1997] as *Rhodeus sericeus*). Found in northern Rhône; […]. Vulnerable [Keith et al. 1992]. Its biotope has to be protected ("arrêté du 8-12-1988). In "Annexe II de la Directive Habitats-Faune-Flore" and in "Annexe III de la Convention de Berne" [Keith and Allardi 2001]."

"Known from the Danube drainage [Germany] [Kottelat and Freyhof 2007]. Endangered in 1984 ([Gerstmeier and Romig 1998] as *Rhodeus sericeus*)."

"Occurs in the Megali Prespa Lake [Greece] [Crivelli et al. 1997]."

"[In Montenegro] Known from the Drin drainage [Kottelat and Freyhof 2007]. Recorded from the Strymonikos Gulf ([Koutrakis et al. 2000] as *Rhodeus sericeus*)."

"Known from the European Russia [Reshetnikov et al. 1997]."

From Freyhof and Kottelat (2008):

"Basins of North, southern Baltic, Black, western and southern Caspian and Aegean Seas (south to Pinios drainage); Mediterranean basin, only in northern Rhône (France) and Drin drainages (Albania, Montenegro, Macedonia)."

From Kozhara et al. (2007):

"Shatunovsky et al. (1988) defined the species [*Rhodeus amarus*] as being ″rather rare″ in the Moscow province (Oka River basin) [western Russia] whilst, according to Sokolov & Tsepkin (2000), the number of bitterlings in the Moskva River and most of its tributaries had increased dramatically in the recent years. These data are particularly interesting, as the Moscow province is likely the northernmost part of the bitterling range in the whole Caspian Sea catchment area."

"Due to first bitterling record in the Volgograd Reservoir [western Russia] soon after construction of the Volga-Don shipping canal in 1952 (see Zhulidov et al. 2005), we believe that the bitterling is unlikely to be a native species in the lower Volga River section and consider this canal as possible invasion corridor."

Froese and Pauly (2019) list *Rhodeus amarus* as native to Iran, Turkey, Albania, Austria, Belarus, Belgium, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, France, Germany, Greece, Hungary, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Netherlands, Poland, Romania, European Russia, Serbia (and Kosovo), Slovakia, Slovenia, Switzerland, and Ukraine.

Some researchers consider the native range of *R. amarus* to be restricted to Ponto-Caspian and Aegean regions (southeastern Europe and adjacent regions of Asia Minor) with expansion into western and central Europe only occurring within the last 300 years (Van Damme et al. 2007).

Status in the United States

From Schofield et al. (2005):

"The only known introductions of Bitterling into the U.S. were in the state of New York. The species was introduced into the Sawmill and Bronx rivers sometime before 1925 (Dence, 1925; Myers, 1925). No Bitterling have been collected in the Sawmill River since 1951, and that population is assumed to be extirpated (Schmidt and others, 1981). In the early 1980s, the Bronx River population was estimated to number only about 900 individuals and inhabit 1-2 km of the river (Schmidt and McGurk, 1982). Although native mussels (needed for reproduction) still occur in the Bronx River, the population of Bitterling appears to be declining (R. Schmidt, personal commun., 2005; J. Rachlin, personal commun., 2005)."

According to Nico and Fuller (2019), the introduction to the Sawmill River was recorded as *Rhodeus amarus*.

From FAO (2019):

"*Rhodeus sericeus* introduced to United States of America from Europe
Date of introduction: 1920s […] Status of the introduced species in the wild: Established […]
The introduced species is established through: Natural reproduction"

The above quotation from FAO (2019) states that *R. sericeus* was introduced from Europe. This introduction may refer to *R. amarus*, based on the range of the species and due to confusion around the taxonomy of these two closely related species. See "Remarks" for more information.

No records of *Rhodeus amarus* for sale within the United States were found. However, a listing for a bitterling assortment, described as *Rhodeus* sp., was found for sale (LiveAquaria 2019).

Means of Introductions in the United States

From FAO (2019):

"Reasons of Introduction: 1) ornamental"

From Kozhara et al. (2007):

"The release from hobby aquaria may be another "transport vector" which could especially be important for long distances dispersal; this is the most plausible explanation of the bitterling introduction to the USA (Bade 1926), […]"

Remarks

There is considerable confusion around the taxonomy of *R. amarus*. *Rhodeus amarus* is commonly confused with *Rhodeus sericeus* or sometimes considered the same species. However, the current valid taxonomy considers them two separate species, primarily due to a wide geographic gap between European and East Asian ranges of bitterling. This screening considers *R. amarus* as having a native range within Europe and Asia Minor, following to the most recent accepted taxonomy. However, much of the literature refers to *R. sericeus* as the bitterling whose native range spans throughout parts of Europe (for example see quote from FAO (2019) in Status in the United States, above). This screening will follow current accepted taxonomy and information pertaining to populations in Europe will be considered valid for *R. amarus*. When there is a discrepancy between the species identified in the literature and the interpretation used in this screening, an explanation is provided below the corresponding quotation referring the reader to this section for more detail. The following quotations within this section will provide more information on the history of the taxonomic naming of bitterlings.

From Smith et al. (2004):

"The classification of the European bitterling has been problematic, because of its discontinuous distribution across its range. In the west of its distribution, it is found in Europe and Asia Minor. In the east, bitterling are reported from the River Amur system [forming the border of the Russian Far East and China], Sakhalin Island and rivers emptying into Peter the Great Bay and Sea of Japan (Holčík, 1999). Western populations are sometimes considered a separate species, *R. amarus* Bloch, distinct from the eastern *R. sericeus*. The western species was later reduced to a subspecies of the eastern, with the designation *R. sericeus amarus* (Bloch) (Svetovidov & Eremeev, 1935). However, Holčík & Jedlička (1994) demonstrated that the characters used to separate the eastern and western species/subspecies were size and temperature dependent and could not be reliably used to separate the two, reverting to the designation *R. sericeus* for both the eastern and western populations. In a recent review of the taxonomy of European freshwater fish, Kottelat (1997) re-classified the western bitterling as *R. amarus*, but without clear justification."

From Bogutskaya and Komlev (2001):

"The Amur common bitterling was described as *Cyprinus sericeus* by Pallas (1776) from River Onon (Upper Amur system) and the European bitterling, *Cyprinus amarus*, some years later by Bloch (1782) from River Elbe. They were considered to be close or conspecific by many authors, for example, Dybowski (1869, 1877) and Warpachowski (1887). The study by Svetovidov and Eremeyev (1935) showed that European and Asian bitterlings are slightly different in some characters and proposed to give them a rank of subspecies of one and the same species. According to their data, *Rhodeus sericeus sericeus* is characterized by *D* III 9, 10 (11); *A* III 8-10; *sq. l.* 36-40; *l. l.* 5-10 (on the average 6.58), while *Rhodeus sericeus amarus* has a lower number of pored scales (*l. l.* 4 to 6, averaging 5.24) as well as a slightly longer and deeper head and a longer caudal peduncle. Besides these, Svetovidov and Eremeyev (1935) considered *Rhodeus sinensis* Günther, 1868 to be a subspecies of *R. sericeus* which is only different in having a wider 3rd infraorbital bone."

"*Rhodeus sericeus* and *R. amarus* are treated again as distinct species by Kottelat (1997) since the Europen [*sic*] and East Asian stocks are unarguably distinct lineages separated for an estimated 2 to 4 million years (data from Holčík, Jedlička, 1994) by 4000 km. Having based on data of these authors, Kottelat considered them to be diagnosable by modal values of lateral line pored scales (4-6 in *R. amarus* vs. 6-7 in *R. sericeus*, ranges 0-9 and 4-10 respectively) and gill-rakers (10-12, vs. 12-14; ranges 9-13, vs. 9-16). The author realizes that the differences between the two stocks are slight but, to his opinion, when taken together with the huge geographic distance they give enough reason for considering both stocks as two species under the Phylogenetic Species Concept."

From Bohlen et al. (2006):

"The reconstruction of the phylogenetic relationships of bitterlings from the EMZS (European-Mediterranean zoogeographic subregion) and the Amur basin revealed that the bitterlings from the Amur form the sister-clade to all bitterlings from the EMZS. This finding contradicts the former hypothesis that based on morphological investigations that the populations in East Asia derived from European populations. Our genetic data show four major lineages within the EMZS, indicating the existence of a higher diversity than previously known. We suggest to used [*sic*] for the East Asian populations the scientific name *Rhodeus sericeus*, for the population in the River Vardar in Greece *R. meridionalis* [a separate population from the one mentioned in Greece in "Native Range" above], for the population from River Notabeni in Georgia *R. colchicus* and for the populations from Central and Eastern Europe *R. amarus*."

From Bryja et al. (2010):

"*R. amarus* populations decreased considerably during the 1970s and 1980s, especially in western Europe, and were included in most European conservation lists, including the EC Habitat Directive (Lelek 1987; Kirchhofer & Hefti 1996; European Commission 2002). However, the trend recently appears to have reversed; population numbers of *R. amarus* have increased throughout Europe and the extent of its distribution now considerably exceeds its recent formerly described range (Kottelat & Freyhof 2007; Kozhara et al. 2007)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From Fricke et al. (2019):

"**Current Status:** Valid as *Rhodeus amarus* (Bloch, 1782)."

From ITIS (2019):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Deuterostomia
      Phylum Chordata
        Subphylum Vertebrata

Infraphylum Gnathostomata
Superclass Actinopterygii
Class Teleostei
Superorder Ostariophysi
Order Cypriniformes
Superfamily Cyprinoidea
Family Cyprinidae
Genus *Rhodeus* Agassiz
Species *Rhodeus amarus* (Bloch, 1782)

Size, Weight, and Age Range

From Froese and Pauly (2019):

"Maturity: L_m 5.5, range 3 - 6 cm
Max length : 11.2 cm TL male/unsexed; [Verreycken et al. 2011]; common length : 5.0 cm TL male/unsexed; [Muus and Dahlström 1968]; max. reported age: 5 years [Vostradovsky 1973]"

"Live span is exceptionally up to 5 years but most individuals do not survive the year of their first reproduction and population sizes fluctuate greatly over the years [Kottelat and Freyhof 2007]."

Environment

From Froese and Pauly (2019):

"Freshwater; benthopelagic; depth range 0 - ? m."

From Van Damme et al. (2007):

"[…] has an optimum temperature for reproduction (23 ºC) […]"

From Kozhara et al. (2007):

"On the other hand, the bitterlings reach high numbers in estuarine habitats, i.e. in the South Bug estuary and in the Don River delta near Azov [southwestern Russia] in a zone with frequent brackish water inflow (see also Koutrakis et al 2000). In the coastal zone of the Azov Sea, the water salinity ranges from 3,4 to 10,1 g dm^{-3} in spring and from 5,6 to 12,3 g dm^{-3} in autumn (our unpublished data)."

Climate/Range

From Froese and Pauly (2019):

"Temperate; 60°N - 40°N"

From Van Damme et al. (2007):

“The European bitterling is undoubtedly thermophilic; the northern limit of its distribution is not defined by geography but by climate, approximately coinciding with the 16 ºC July isotherm.”

Distribution Outside the United States

Native

This screening considers *R. amarus* as having a native range within Europe and Asia Minor, following to the most recent accepted taxonomy, see “Remarks” above for more information.

From Froese and Pauly (2019):

“Europe: central and eastern Europe and northern Asia Minor [Kottelat 2006]. Basins of North, southern Baltic, Black, western and southern Caspian and Aegean Seas (from Maritza to Struma drainages); Mediterranean basin, only in northern Rhône (France) and Drin drainages (Alabania [*sic*], Montenegro, Macedonia).”

“This species has become scarce [in the Czech Republic], especially in the drainage areas of the rivers Labe and Odra [Lusk et al. 2004].”

“Occurs in the northeast quarter [of France] ([Muus and Dahlström 1968; Billard 1997] as *Rhodeus sericeus*). Found in northern Rhône; […]. Vulnerable [Keith et al. 1992]. Its biotope has to be protected ("arrêté du 8-12-1988). In "Annexe II de la Directive Habitats-Faune-Flore" and in "Annexe III de la Convention de Berne" [Keith and Allardi 2001].”

“Known from the Danube drainage [Germany] [Kottelat and Freyhof 2007]. Endangered in 1984 ([Gerstmeier and Romig 1998] as *Rhodeus sericeus*).”

“Occurs in the Megali Prespa Lake [Greece] [Crivelli et al. 1997].”

“[In Montenegro] Known from the Drin drainage [Kottelat and Freyhof 2007]. Recorded from the Strymonikos Gulf ([Koutrakis et al. 2000] as *Rhodeus sericeus*).”

“Known from the European Russia [Reshetnikov et al. 1997].”

From Freyhof and Kottelat (2008):

“Basins of North, southern Baltic, Black, western and southern Caspian and Aegean Seas (south to Pinios drainage); Mediterranean basin, only in northern Rhône (France) and Drin drainages (Albania, Montenegro, Macedonia).”

Froese and Pauly (2019) list *Rhodeus amarus* as native to Iran, Turkey, Albania, Austria, Belarus, Belgium, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, France, Germany, Greece, Hungary, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Netherlands, Poland, Romania, European Russia, Serbia (and Kosovo), Slovakia, Slovenia, Switzerland, and Ukraine.

Some researchers consider the native range of *R. amarus* to be restricted to Ponto-Caspian and Aegean regions with expansion into western and central Europe only occurring within the last 300 years (Van Damme et al. 2007).

Introduced

From Froese and Pauly (2019):

"Discovered in a small pond north of Copenhagen [Denmark] in October 1997. Apparently introduced, but the large number of specimens, the age and size range, ovipositor females, and presence of bivalves essential for spawning, all indicate that spawning has taken place in the pond. The number of lateral line scales allies the population to the European subspecies *R. sericeus amarus* [now valid as *R. amarus*] [Møller and Menne 1998]."

"An introduced species [in Estonia] [Kottelat and Freyhof 2007]. Occurrence not supported by [Anonymous 1999; "Systematic list of Estonian fishes" which does not include *R. amarus*]." (No further information could be found about the presence of *R. amarus* in Estonia.)

"Introduced to northern Italy [established] [Kottelat and Freyhof 2007]. Recorded from northeastern Italy and is locally dominant along with the topomouth gudgeon and gambusia [Bianco 2014]."

"This [*Rhodeus amarus*] has been translocated to areas within the country, rapidly expanded its range and is now widely established in the country [in Russia] [Bogutskaya and Naseka 2002]. Has become invasive in Don and Kuban drainages in southern Russia [Kottelat and Freyhof 2007]."

"Introduced to Great Britain [established] [Kottelat and Freyhof 2007]. […] Introduced range in England linked to presence of Unionid mussels."

"Introduced to Crimea [Ukraine] [Kottelat and Freyhof 2007]."

From Freyhof and Kottelat (2008):

"Invasive in France in southern Rhône and west of Seine, in southern Russia in Don and Kuban drainages. Introduced to Great Britain and northern Italy."

From Kozhara et al. (2007):

"According to Dgebuadze & Skomorokhov (2002), bitterlings were never recorded in the Glubokoye Lake [Russia] located about 60 km west of Moscow City until the first record in 2000 when the bitterling was already found to be a common fish in the lake."

"In 1999, we simultaneously and independently discovered the bitterling in two different sections of the Kuban River basin [Russia, north of Black Sea] situated well apart from each other: the delta and the foothill zone of the Laba River, the largest tributary of the Kuban River […] (Kozhara & Poznyak 2001, see also Pashkov et al. 2004, Pashkov 2005). Moreover, A.

Zhulidov had captured 8 bitterling specimens in the lower Kuban River near Temryuk [Russia] yet in 1996, but these data remained hitherto unpublished. Although Vasil'eva (2003) considered the bitterling as a new native species for the Kuban River basin, the regional and national checklists of the fish fauna published in Russia until late 1990s show that this species has never been recorded in the Kuban River basin (Berg 1949, Troitsky & Tsunikova 1988, Yemtyl 1997, Reshetnikov 1998, 2003). It is highly unlikely that it might have occurred but was overlooked as the basin is in faunistic respect thoroughly and frequently investigated. The bitterling appeared to be very common in both Kuban sites mentioned above and we therefore suggest that it may have entered the basin even before 1996."

"A single bitterling specimen was captured in the inland Maly Uzen River in the Saratov province [western Russia] in 1990 during our ichthyological survey […]. As the bitterling was never registered east of the Volga River basin, we assume that it has arrived in the Maly Uzen River via the Volgograd Reservoir through the irrigation canal network."

"In 2002, we recorded bitterlings in the upper reaches of the Kara-Sal River [western Russia], a lower Don River tributary from where it was previously unknown […]. […] Despite this, the bitterling has spread upstream successfully. Two damaged bitterling specimens have been reported in 1994 at the water intake of the Konakovo thermoelectric power station near the Ivankovo Reservoir [western Russia] on the upper Volga River (Yakovlev et al. 2001). Presumably bitterlings have penetrated into the upper Volga from the Oka River basin [western Russia] via the Moskva-Volga canal, although this is an upstream migration through a series of dams. It remains unclear, whether this species has formed a self-sustaining population in the upper Volga River basin."

"Furthermore, the bitterling has been recently registered in small rivers and ponds of the Ararat valley in the Republic of Armenia. Bitterlings presumably have arrived from the Aras River, and seem to continue spreading (Pipoyan 1996, Pipoyan & Tigranian 2002). A very interesting record in its spread is the recent finding of this species in the upper Ural River tributaries (Chibilev 2004). The bitterling had never been known from the Ural River basin [north of the Caspian Sea in western Kazakhtstan into southern Russia] (Shaposhnikova 1964) and the way of its penetration to this river system remains unclear."

Means of Introduction Outside the United States

From Kozhara et al. (2007):

"There might be two principal ways of bitterling spread outside its historical range. Firstly, it actively spreads throughout continuous waterway systems, both downstream and upstream, and the general increase in bitterling numbers undoubtedly favour its range extension. In particular, the high abundance of bitterling larvae and early juvenile fish in the drift communities noted in some lowland rivers suggests that drifting can also be a successive way of dispersal across the floodplain (Reichard et al. 2002). However, countercurrent upstream migration evidently prevails now in the bitterling dispersal throughout Russia and adjacent countries."

"Secondly, an unintentional introduction of this species may be assumed. The bitterling is a popular object of aquaculture and, moreover, it is of some importance for anglers as a bait fish

(Aslanidi & Shavkin 1999, Sokolov & Tsepkin 2000). Bait transport may be responsible for short-distance spread between isolated water bodies and for "spread" across migration barriers such as river dams. Dgebuadze & Skomorokhov (2002) supposed bait as introducing vector of the bitterling into the Glubokoye Lake (Moscow province). The release from hobby aquaria may be another "transport vector" which could especially be important for long distances dispersal; this is the most plausible explanation of the bitterling introduction to […] Britain (Wheeler & Maintland 1973) and other European countries where it has been successfully established in the wild."

"This rapid bitterling expansion appears to take place quite independently and synchronically in geographically distant basins: in the upper and lower Volga River basin, the Kuban River in Russia and the Aras River drainage basin in Armenia. Therefore, we assume that a global or macroregional factor triggers the spread of the bitterling. Since the geographical distribution of this species suggests that its dispersal northwards and eastwards is limited by low temperatures, we speculate that the climate change in Europe may be one possible factor to support its spread."

From Froese and Pauly (2019):

"May have been introduced [to the UK] for ornamental reasons."

From Van Damme et al. (2007):

"Adult bitterling resemble juvenile common carp and share similar habitat preferences. Thus, when young carp 'seed' were collected and stored in vats or the flooded compartments of river barges used for transporting live fish it is probable that bitterling were often exported with them."

Short Description

From Froese and Pauly (2019):

"Dorsal spines (total): 3; Dorsal soft rays (total): 8-10; Anal spines: 3; Anal soft rays: 8 - 10; Vertebrae: 34 - 36. Caudal fin with 19 to 20 soft rays. Differs from *Rhodeus meridionalis* by having sub-inferior mouth (vs. terminal), rostral cap covering all or at least more than half of upper lip (vs. only upper part of upper lip) [Kottelat and Freyhof 2007]."

From Van Damme et al. (2007):

"Adult bitterling resemble juvenile common carp and share similar habitat preferences."

"During the spawning season males develop bright nuptial coloration […]"

Biology

From Froese and Pauly (2019):

"Occurs most abundantly in still or slow-flowing water with dense aquatic vegetation and sand-silt bottom as lowland ponds, canals, slow-flowing rivers, backwaters and oxbows, where

mussels are present [Kottelat and Freyhof 2007]. Found among plants over sand and muddy bottoms in shallow waters. Remarkable for its habit of deposing its eggs in the cavity of bivalves (*Unio*). Feeds mainly on plants and to a lesser degree on worms, crustaceans, and insect larvae."

"Spawns in clear, slow-running or still water, often with a muddy bottom. The presence of nearby freshwater mussels is of vital importance."

From Freyhof and Kottelat (2008):

"Spawns for the first time at one year and about 30-35 mm SL. Lives exceptionally up to five years but most individuals do not survive the year of their first reproduction and populations sizes fluctuate greatly over the years. Spawns in April-August."

From Van Damme et al. (2007):

"During the spawning season males develop bright nuptial coloration and defend territories around mussels. Female bitterling develop long ovipositors that they use to place their eggs onto the gills of a mussel through the mussel's exhalant siphon. Males fertilize the eggs by releasing sperm into the inhalant siphon of the mussel, so that water filtered by the mussel carries the sperm to the eggs. Between 1 and 6 eggs are released each spawning, and mussels may contain over 250 developing embryos on their gills. Embryos reside inside the mussel for approximately 1 month during which time they develop into actively swimming larvae."

Human Uses

From Froese and Pauly (2019):

"Fisheries: of no interest; aquarium: commercial; bait: occasionally"

"Formerly used for pregnancy tests: females injected with urine from pregnant women protruded their ovipositors [Maitland and Campbell 1992]."

Froese and Pauly (2019) state that *Rhodeus amarus* is exported from Austria for the ornamental trade.

From Kozhara et al. (2007):

"The bitterling is a popular object of aquaculture and, moreover, it is of some importance for anglers as a bait fish (Aslanidi & Shavkin 1999, Sokolov & Tsepkin 2000)."

Diseases

No records of OIE reported diseases (OIE 2019) were found for *Rhodeus amarus*.

According to Poelen et al. (2014) *Rhodeus amarus* can be a host to the following parasites: *Gyrodactylus rhodei* and *Ligula intestinalis*.

Threat to Humans

From Froese and Pauly (2019):

"Harmless"

3 Impacts of Introductions

This screening considers *R. amarus* as having a native range within Europe and Asia Minor, following to the most recent accepted taxonomy, see "Remarks" above for more information.

From Reichard et al. (2006; concerning populations in central Europe where *R. amarus* may not be native):

"The relationship between *R. sericeus* [possibly referring to *R. amarus*] and mussels has popularly been considered mutualistic on the premise that bitterling use mussels as spawning sites, while the mussel benefits by using bitterling as hosts for their glochidia (e.g. Wheeler, 1978). However, recent studies have shown the evidence for a mutualistic relationship to be weak."

"In the present study, we found experimental evidence for a direct cost to mussels associated with hosting *R. sericeus* [possibly referring to *R. amarus*] embryos. Mussels that hosted *R. sericeus* embryos suffered significantly reduced growth over the entire growing season […]. Because there is strong evidence across several unionid mussel species (including our study species) that mussel size is positively correlated with fecundity (Bauer, 1994), any reduction in mussel growth will directly translate into a fitness cost. This result demonstrates that *R. sericeus* are parasites of their mussel hosts, at least in Europe."

"*Rhodeus sericeus* [possibly referring to *R. amarus*], as a recent invader of Central and West Europe, may represent a parasite exploiting host populations that did not have sufficient time to evolve counter adaptations."

The following information details ***potential*** impacts. No information about actual demonstrated impacts from introductions were found.

From Bryja et al. (2010):

"Notably, *R. amarus* is a parasite of threatened and declining populations of unionid mussels (Karatayev et al. 1997; Reichard et al. 2006) and, at least in western and central Europe [may be outside native range according to Van Damme et al. 2007], appears to use evolutionary naive hosts for oviposition (Reichard et al. 2007, 2010). Recent research on bitterling has addressed the co-evolutionary relationship between these fish and freshwater mussels (Reichard et al. 2006, 2007, 2010). Proper resolution of the phylogeographical and historical status of the European bitterling will be crucial to an understanding of the evolutionary context of their relationship with freshwater mussels and impacts upon them."

From Van Damme et al. (2007):

"Bitterling embryos may also have an adverse effect on mussel physiology; possibly competing with their host mussel for oxygen (Smith et al. 2001), or affect mussel gill filtration (Stadnichenko and Stadnichenko 1980). In addition, the presence of developing embryos of bitterling on the gills of mussels halts mussel growth, and may thereby affect their fecundity (Reichard et al. 2006). Thus, it would appear that the bitterling is a parasite of mussels, at least in the west of their distribution. Ongoing research suggests the relationship may vary, depending on the duration of historical association between bitterling and mussel populations."

From Kozhara et al. 2007:

"However, in some other countries, such as the United Kingdom, the species [*Rhodeus amarus*] has established successfully and is already considered as potential threat [potential parasitization of unionid mussels] to local species (see Reichard et al. 2006, 2007). For example, in the United Kingdom the bitterling is subject to the Wildlife and Countryside Act 1981 (WCA) regulating the cultivation and release of nonnative fish species into the wild."

The following information uses the name *Rhodeus sericeus,* but based on information in the texts these populations are most likely correctly identified as *R. amarus*. To clarify, Schmidt and McGurk (1982) and Reichard et al. (2006) both use the species name *R. sericeus,* but also refer to the species as the "European bitterling". The European bitterling is now considered to be *R. amarus* (see "Remarks" for more information). Further, Breder (1933) uses the species name *R. amarus* to discuss the introduction of bitterling to the United States. This information also pertains to ***potential*** impacts or lack of impacts from introductions and shows no scientifically defensible documented impacts.

From Schmidt and McGurk (1982; concerning the population in the Bronx River, New York):

"Bitterlings [possibly referring to *R. amarus*] feed primarily on diatoms and the digestive system is typical of a surface scraping herbivore. Impact of this exotic species on the ecosystem appears minimal. It is unlikely that the species would cause appreciable negative impact on any habitat in the northeastern United States."

"The bitterling's small size and herbivorous diet preclude the species from being a serious predator on other fishes. It is unlikely that it would compete with native species for food since only the golden shiner may possibly utilize the same food source (Scott & Crossman, 1979). Its small population size would indicate that the bitterling could not possibly reduce the standing crop of diatoms in the river."

From Breder (1933):

"Since *Rhodeus* in Europe [possibly referring to *R. amarus*] is definitely known to regularly use both *Unio pictorum* (Linnaeus) and *Anodonta cygnea* (Linnaeus) [unionid mussels in the native range of *R. amarus*] at least, it would seem that a large variety of mussels can serve satisfactorily for the reproductive needs. Wording it another way, it seems unlikely that the particular

distribution of any of the numerous species of larger fresh-water bivalves restricts the distribution of this cyprinid."

"In the due course of time post larval bitterling appeared [in the observation aquarium], presumably incubated within the shells of either *Unio complanatus* (Dillwyn) or *Anodonta cataracta* Say, or both [both native to the United States where *R. amarus* is not native]. These, the offspring of not more than five females, numbered about one hundred."

4 Global Distribution

Figure 1. Known global distribution of *Rhodeus amarus*. Observations are in New York, the United Kingdom, France, Belgium, Luxembourg, the Netherlands, Germany, Demark, Switzerland, Italy, Austria, Czech Republic, Poland, Estonia, Belarus, Ukraine, Slovakia, Hungary, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, Kosovo, Romania, Bulgaria, Macedonia, Albania, Greece, Turkey, and Iran. Map from GBIF Secretariat (2019). The point located in the ocean off the coast of France was not used to select source points for the climate match because there is no evidence suggesting that this species is found in a marine environment. The points located in the United States (New York) were not used to select source points for the climate match because the population in Sawmill River is assumed to be extirpated since the 1950s. There were no points available for the population in the Bronx River. The location in Estonia was not used to select source points for the climate match because it is unknown if *R. amarus* has established a population in that country.

Additional known observations of *Rhodeus amarus* in Russia and Ukraine were given in Kozhara et al. (2007).

5 Distribution Within the United States

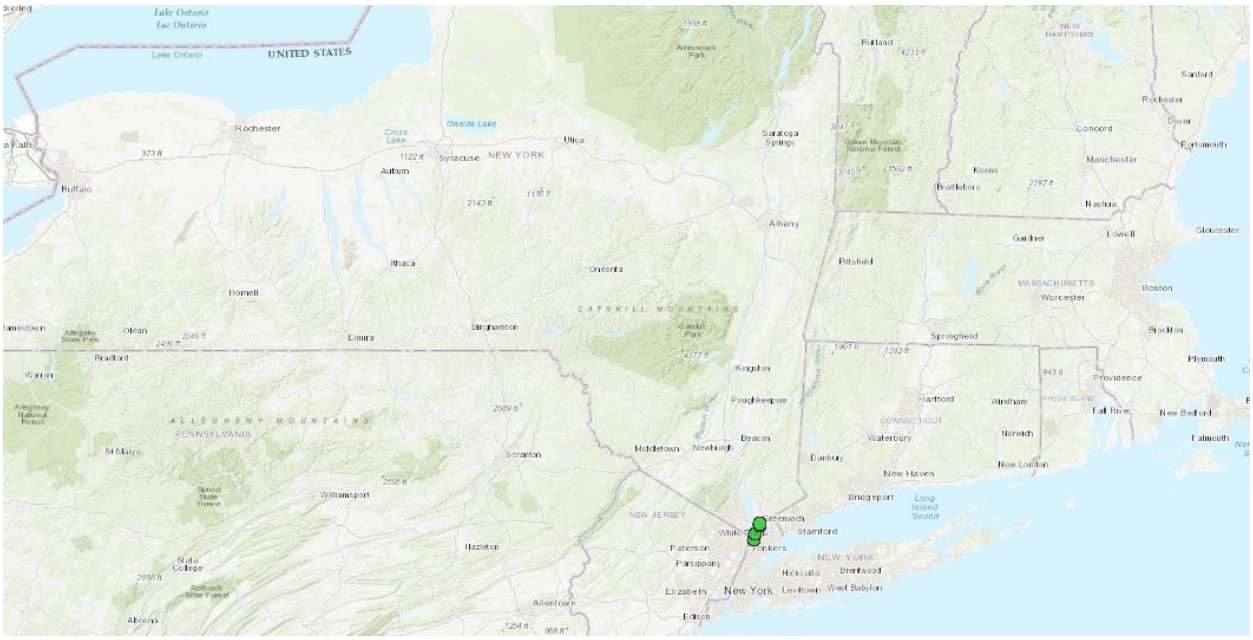

Figure 2. Known distribution of *Rhodeus amarus* in the United States. Locations are all in New York. Map from BISON (2019). The points located in New York were not used to select source points for the climate match because the population in Sawmill River is assumed to be extirpated since the 1950s. All points represent specimens collected in the Sawmill River where the species is extirpated; there were no georeferenced observations found representing the population in the Bronx River.

6 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Rhodeus amarus* was medium to high for most of the contiguous United States. There were small areas of low climate match in the in the Pacific Northwest, southern Arizona, the Gulf Coast, and southern Atlantic Coast. Areas of high match were concentrated in coastal southern New England, the Great Lakes basin, southern Appalachian Mountains, and in scattered pockets in the western plains and Rocky Mountains. The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for the contiguous United States was 0.585, high (scores 0.103 and greater are classified as high). All States had high individual Climate 6 scores except for Georgia, South Carolina, and Texas, which had medium scores, and Alabama, Florida, Louisiana, and Mississippi, which had low scores.

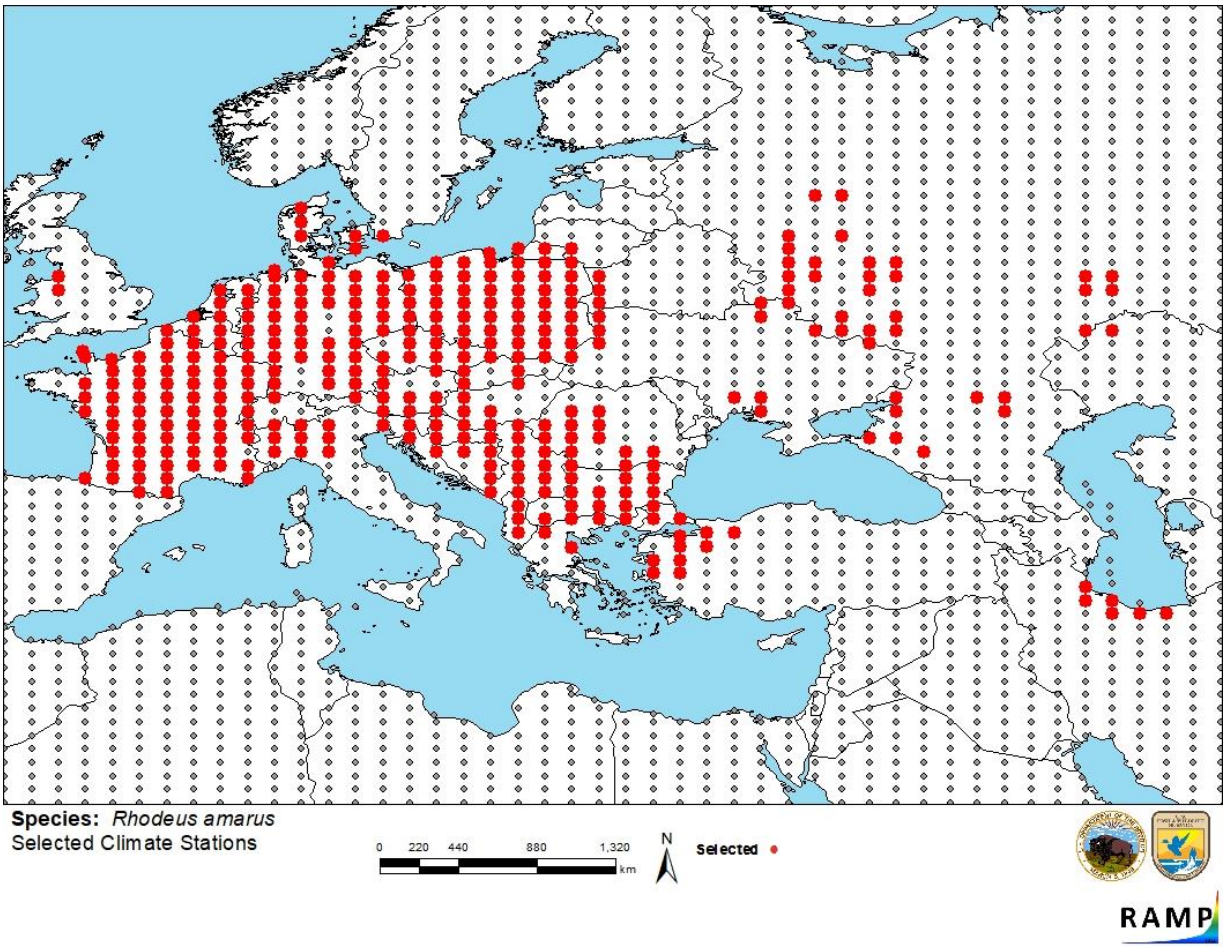

Figure 3. RAMP (Sanders et al. 2018) source map showing weather stations selected as source locations (red; United Kingdom, France, Belgium, Netherlands, Switzerland, Italy, Luxembourg, Germany, Austria, Czech Republic, Denmark, Poland, Slovakia, Belarus, Lithuania, Slovenia, Hungary, Ukraine, Romania, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Macedonia, Bulgaria, Greece, Turkey, Russia, Kazakhstan, Iran) and non-source locations (gray) for *Rhodeus amarus* climate matching. Source locations from Kozhara et al. (2007) and GBIF Secretariat (2019). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

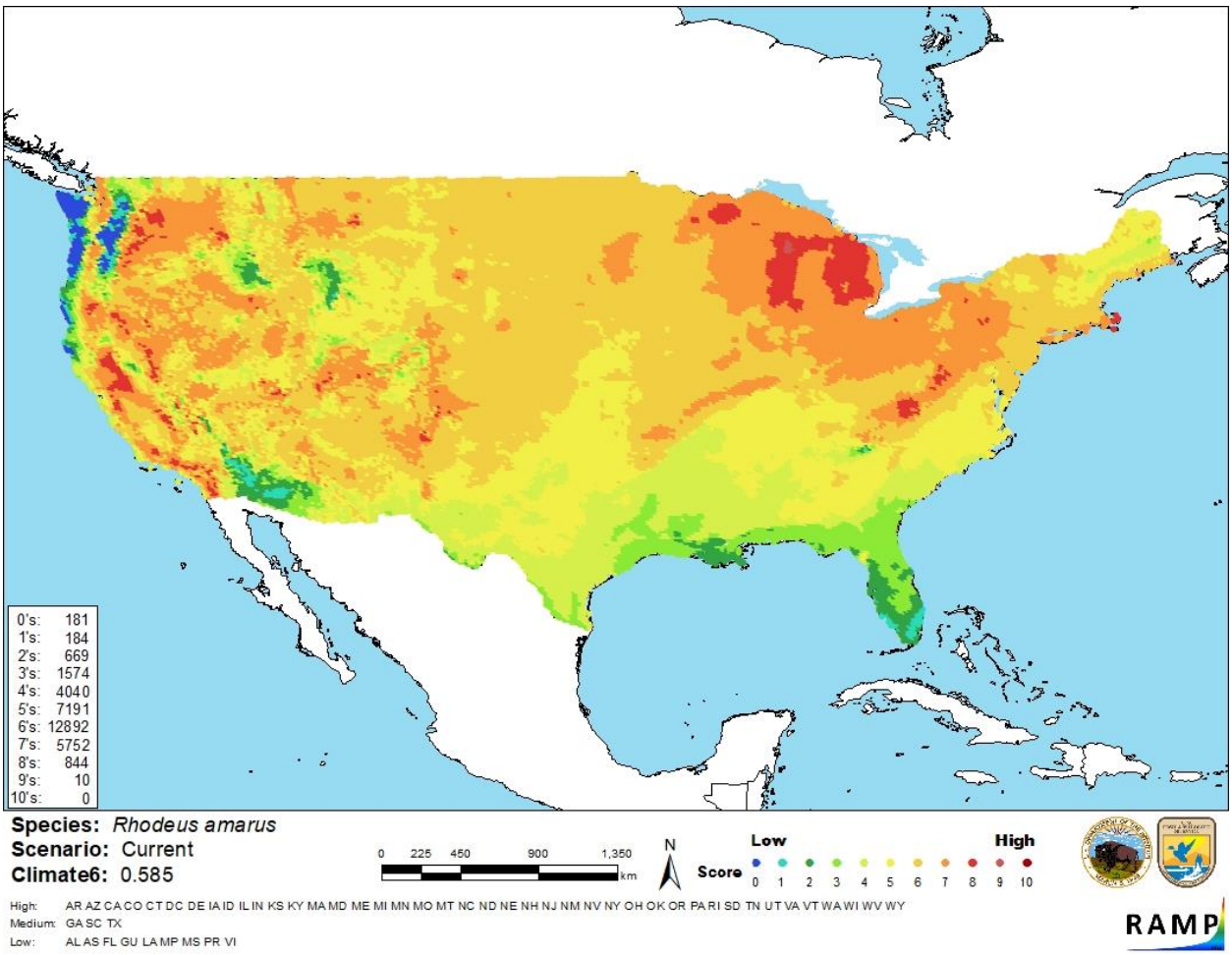

Figure 4. Map of RAMP (Sanders et al. 2018) climate matches for *Rhodeus amarus* in the contiguous United States based on source locations reported by Kozhara et al. (2007) and GBIF Secretariat (2019). Counts of climate match scores are tabulated on the left. 0= Lowest match, 10=Highest match.

The "High", "Medium", and "Low" climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

7 Certainty of Assessment

The biology and ecology of *Rhodeus amarus* is well documented. Due to a history of taxonomic confusion (see Remarks, above), *R. amarus* has been commonly confused with the related *R. sericeus*. This causes some discrepancies with information found in the literature and difficulty in determining which species the information actually pertains. One peer-reviewed, scientifically defensible study documenting negative impacts from an introduction was found.

However, this information was published using the name *R. sericeus*. Based on the information in the paper the authors of this screening believe that paper to actually refer to *R. amarus*. Additionally, based on all available information it is uncertain that the population of *R. amarus* studied in that paper is actually outside the native range for the species. There were many records that speculated about potential impacts and mechanisms for impact. Certainty of assessment for *Rhodeus amurus* is Medium.

8 Risk Assessment

Summary of Risk to the Contiguous United States

European bitterling (*Rhodeus amarus*) is a minnow species native to much of eastern Europe and western Asia. The method of reproduction is worth noting as it parasitizes unionid mussels with its eggs and larvae. *R. amarus* also has a history of human usage in the ornamental trade, in aquaculture, and as bait fish. The history of invasiveness is High. The species has been introduced outside of its native range in Europe and western Asia and has established populations. It was probably introduced to New York (some uncertainty if introductions are *R. amarus* or *R. sericeus*). If this is the species that was introduced, there is a possibility of a persisting population in the Bronx River. In a European location that may be outside the native range, the parasitic spawning method of the fish reduces mussel fitness and potentially abundance as mussels parasitized during *R. amarus* reproduction showed significantly reduced growth. The overall climate match was high for the contiguous United States. Small areas of low match could be found in coastal areas of the Southeast and in pockets in the west; everywhere else had medium and high matches. The certainty of assessment is medium. Scientifically defensible information on impacts of introductions was available but there is also the difficulty in determining what information actually pertains to *R. amarus* due to the long history of taxonomic confusion with *R. sericeus*. The overall risk assessment category is High.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): Medium**
- **Remarks/Important additional information:** Often confused with *Rhodeus sericeus*.
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

BISON. 2019. Biodiversity Information Serving Our Nation (BISON). U.S. Geological Survey. Available: https://bison.usgs.gov. (July 2019).

Bogutskaya, N. G., and A. M. Komlev. 2001. Some new data to morphology of *Rhodeus sericeus* (Cyprinidae: Acheilognathinae) and a description of a new species *Rhodeus*

colchicus, from west Transcaucasia. New Contributions to Freshwater Fish Research 287:81–97.

Bohlen, J., V. Šlechtová, N. Bogutskaya, and J. Freyhof. 2006. Across Siberia and over Europe: Phylogenetic relationships of the freshwater fish genus *Rhodeus* in Europe and the phylogenetic position of *R. sericeus* from the River Amur. Molecular Phylogenetics and Evolution 40:856–865.

Breder, C. M., Jr. 1933. *Rhodeus sericeus* spawning in American mussels. American Society of Ichthyologists and Herpetologists 3:147–148.

Bryja, J., C. Smith, A. Konečný, and M. Reichard. 2010. Range-wide population genetic structure of the European bitterling (*Rhodeus amarus*) based on microsatellite and mitochondrial DNA analysis. Molecular Ecology 19(21):4708–4722.

FAO (Fisheries and Agriculture Organization of the United Nations). 2019. Database on introductions of aquatic species. FAO, Rome. Available: http://www.fao.org/fishery/introsp/search/en. (December 2019).

Freyhof, J., and M. Kottelat. 2008. *Rhodeus amarus*. The IUCN Red List of Threatened Species 2008: e.T135635A4167105. Available: https://www.iucnredlist.org/species/135635/4167105. (July 2019).

Fricke, R., W. N. Eschmeyer, and R. van der Laan, editors. 2019. Eschmeyer's catalog of fishes: genera, species, references. Available: http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp. (July 2019).

Froese, R., and D. Pauly, editors. 2019. *Rhodeus amarus* (Bloch, 1782). FishBase. Available: https://www.fishbase.de/summary/Rhodeus-amarus.html. (December 2019).

GBIF Secretariat. 2019. GBIF backbone taxonomy: *Rhodeus amarus* (Bloch, 1782). Global Biodiversity Information Facility, Copenhagen. Available: https://www.gbif.org/species/2360842. (July 2019).

ITIS (Integrated Taxonomic Information System). 2019. *Rhodeus amarus* (Bloch 1782). Integrated Taxonomic Information System, Reston, Virginia. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=163610#null. (July 2019).

Kozhara, A. V., A. V. Zhulidov, S. Gollasch, and M. Przybylski. 2007. Range extension and conservation status of the bitterling, *Rhodeus sericeus amarus* in Russia and adjacent countries. Folia Zoologica 56:97–108.

LiveAquaria. 2019. Bitterling – assorted. Petco Wellness, Rhinelander, Wisconsin. Available: https://www.liveaquaria.com/product/1602/?pcatid=1602. (December 2019).

Nico, L., and P. Fuller. 2019. *Rhodeus sericeus* (Pallas, 1776). U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=643. (December 2019).

OIE (World Organisation for Animal Health). 2019. OIE-listed diseases, infections and infestations in force in 2019. Available: http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2019/. (July 2019).

Poelen, J. H., J. D. Simons, and C. J. Mungall. 2014. Global Biotic Interactions: an open infrastructure to share and analyze species-interaction datasets. Ecological Informatics 24:148–159.

Reichard, M., M. Ondračková, M. Przybylski, H. Liu, and C. Smith. 2006. The costs and benefits in an unusual symbiosis: experimental evidence that bitterling fish (*Rhodeus sericeus*) are parasites of unionid mussels in Europe. Journal of Evolutionary Biology 19:788–796.

Sanders, S., C. Castiglione, and M. H. Hoff. 2018. Risk Assessment Mapping Program: RAMP, version 3.1. U.S. Fish and Wildlife Service.

Schmidt, R. E., and J. McGurk. 1982. Biology of the European bitterling *Rhodeus sericeus* (Pisces: Cyprinidae) in the Bronx River, New York, USA: an apparently benign exotic species. Biological Conservation 24:157–162.

Schofield, P. J., J. D. Williams, L. G. Nico, P. Fuller, and M. R. Thomas. 2005. Foreign nonindigenous carps and minnows (Cyprinidae) in the United States - a guide to their identification, distribution, and biology. U.S. Geological Survey, Scientific Investigations Report 2005–5041.

Smith, C., M. Reichard, P. Jurajda, and M. Przybylski. 2004. The reproductive ecology of the European bitterling (*Rhodeus sericeus*). Journal of Zoology (London) 262:107–124.

Van Damme, D., N. Bogutskaya, R. C. Hoffmann, and C. Smith. 2007. The introduction of the European bitterling (*Rhodeus amarus*) to west and central Europe. Fish and Fisheries 8:79–106.

10 References Quoted But Not Accessed

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.

Anonymous. 1999. Systematic list of Estonian fishes. Online. (January 2000).

Aslanidi, K., and V. Shavkin. 1999. Presnovodnye ryby [Freshwater fishes]. Ayris, Moscow. (In Russian.)

Bade, E. 1926. The central European Bitterling found in the States. Bulletin - New York Zoological Society 29:205–206.

Bauer, G. 1994. The adaptive value of offspring size among freshwater mussels (Bivalvia; Unioidea). Journal of Animal Ecology 63:933–944.

Berg, L. S. 1949. Ryby presnykh vod SSSR i sopredel'nykh stran [Fishes of freshwaters of the USSR and adjacent countries]. Izd. Akad. Nauk SSSR. Moscow-Leningrad, 2:469–925. (In Russian.)

Bianco, P. G. 2014. An update on the status of native and exotic freshwater fishes of Italy. Journal of Applied Ichthyology 30(1):62–77.

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

Bloch, M. E. 1782. Naturgeschichte der auslandischen Fische, volume 7. Auf Kosten des Verfassers und in Commission bei dem Buchhändler Hr. Hesse, Berlin.

Bogutskaya, N. G., and A. M. Naseka. 2002. An overview of nonindigenous fishes in inland waters of Russia. Proceedings of the Zoological Institute Russian Academy of Sciences 296:21–30.

Chibilev, E. A. 2004. Ikhtiofauna rek museya-zapovednika "Arkaim" (2003) [The ichthyological fauna of rivers in the "Arkaim" museum reserve (2003)]. Pages 127–128 *in* The problems of preserving biodiversity of the southern Ural. Regional scientific-practical conference, abstract book. Ufa, Russia. (In Russian.)

Crivelli, A. J., G. Catsadorakis, M. Malakou, and E. Rosecchi. 1997. Fish and fisheries of the Prespa lakes. Hydrobiologia 351:107–125.

Dence, W. A. 1925. Bitter carp (*Rhodeus amarus*) from New York State waters. Copeia 142:3

Dgebuadze, Yu., and M. O. Skomorokhov. 2002. Ikhtiologicheskie issledovaniya na ozere Glubokom: nekotorye itogi i perspektivy [Ichthyological studies on Lake Glubokoe: some results and perspectives]. Proceedings of the Hydrobiological Station "Lake Glubokoe" 8:142–149. (In Russian.)

Dybowski, B. N. 1869. Vorlaufige Mittheilungen uber die Fischfauna des Ononflusses und des Ingoda in Transbaikalien. Verhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft 19:945–958. (In Russian.)

Dybowski, B. N. 1877. [Fishes of the Amur water system], volume 7. Izvestiya Sibirskogo Otdeleniya Russkogo Geograficheskogo Obshchestva. (In Russian.)

European Commission. 2002. Reference list of habitat types and species present in the continental region. Available: http:// ec.europa.eu/environment/nature/natura2000/.

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

Holčík, J. 1999. *Rhodeus sericeus*. Pages 1–32 *in* P. M. Bănărescu, editor. The freshwater fishes of Europe. AULA-Verlag, Wiebelsheim, Germany.

Holčík, J., and L. Jedlička. 1994. Geographical variation in some taxonomically important characters of fishes: the case of bitterling *Rhodeus sericeus*. Environmental Biology of Fishes 41:147–170.

Karatayev, A. Y., L. E. Burlakova, and D. K. Padilla. 1997. The effects of *Dreissena polymorpha* (Pallas) invasion on aquatic communities in Eastern Europe. Journal of Shellfish Research 16:187–203.

Keith, P., and J. Allardi, coordinators. 2001. Atlas des poissons d'eau douce de France. Muséum national d'Histoire naturelle, Paris. Patrimoines naturels 47:1–387.

Keith, P., J. Allardi, and B. Moutou. 1992. Livre rouge des espèces menacées de poissons d'eau douce de France et bilan des introductions. Muséum national d'Histoire naturelle, Paris, Secrétariat de la Faune et de la Flore, Conseil Supérieur de la Pêche, CEMAGREF and Ministère de l'Environment,

Kirchhofer, A., and D. Hefti. 1996. Conservation of endangered freshwater fish in Europe. Birkhauser Verlag, Basel, Switzerland.

Kottelat, M. 1997: European freshwater fishes. Biológia (Bratislava) 52 (Supplement 5):1–271.

Kottelat, M. 2006. Fishes of Mongolia. A check-list of the fishes known to occur in Mongolia with comments on systematics and nomenclature. The World Bank, Washington, D.C.

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

Koutrakis, E. T., A. K. Kokkinakis, E. A. Eleftheriadis, and M. D. Argyropoulou. 2000. Seasonal changes in distribution and abundance of the fish fauna in the two estuarine systems of Strymonikos Gulf (Macedonia, Greece). Belgian Journal of Zoology 130:41–48.

Kozhara, A. V., and V. G. Poznyak. 2001. The bitterling *Rhodeus sericeus amarus* (Bloch) (Pisces, Cyprinidae) in the Kuban River basin. Pages 95–96 *in* 1st US–Russia invasive species workshop, Borok, Russia, the book of abstracts.

Lelek, A. 1987. Threatened fishes of Europe, volume 1. Aula-Verlag, Wiesbaden, Germany.

Lusk, S., L. Hanel, and V. Lusková. 2004. Red list of the ichthyofauna of the Czech Republic: development and present status. Folia Zoologica 53(2):215–226.

Maitland, P. S., and R. N. Campbell. 1992. Freshwater fishes of the British Isles. HarperCollins Publishers, London.

Myers, G. S. 1925. Introduction of the European bitterling (*Rhodeus*) in New York and of the rudd (*Scardinius*) in New Jersey. Copeia 140:20–21.

Møller, P. R., and T. Menne. 1998. Bitterling *Rhodeus sericeus* (Pallas, 1776) - føste fund i Danmark. Flora Fauna 104(2):29–34.

Muus, B. J., and P. Dahlström. 1968. Süßwasserfische. BLV Verlagsgesellschaft, München, Germany.

Pallas, P. S. 1776. Riese durch verschiedene Provinzen des Russischen Reichs. Kaiserlichen academie der Wissenschaften, St. Petersburg, Russia. (In German.)

Pashkov, A. N. 2005. Species diversity and biological features of the introduced fishes in the coastal zone of the Azov and Black Sea (within the Krasnodar province, Russia). Pages 263–276 *in* Ecosystem investigations of the environment and biota of the Azov Sea Basin and the Kerch Strait, volume VII. Russian Academy of Science, Murmask Marine Biological Institute, Kola Science Centre, Apatity, Russia.

Pashkov, A. N., G. K. Plotnikov, and I. V. Shutov. 2004. Novye dannye o sostave i rasprostranenii vidov-akklimatizantov v ihtiocenozah vodoyomov Servo-Zapadnogo Kavkaza [New data on the species composition and distribution of introduced species in the ichthyocenoses of inland water bodies of north-western Caucasus]. Izvestia Severo-Kavkazskogo Nauchnogo Centra Vysšey Školy, Yestestvennye Nauki 1:46–52. (In Russian.)

Pipoyan, S. H. 1996. Novyi dla fauny Armenii vid – gorchak *Rhodeus sericeus amarus* [A new species for the ichthyofauna of Armenia – the bitterling *Rhodeus sericeus amarus*]. Voprosy Ikhtiologii 36:710–712. (In Russian.)

Pipoyan, S. H., and E. A. Tigranian. 2002. Sovremennaya ikhtiofauna Armenii [The present-day ichthyofauna of Armenia]. Voprosy Ikhtiologii 42:601–604. (In Russian.)

Reichard, M., P. Jurajda, and M. Ondračková. 2002. Interannual variability in seasonal dinamics [*sic*] and species composition of drifting young-of-the-year fishes in two European lowland rivers. Journal of Fish Biology 60:87–101.

Reichard, M., M. Przybylski, P. Kaniewska, H. Liu, and C. Smith. 2007: A possible evolutionary lag in the relationship between freshwater mussels and European bitterling. Journal of Fish Biology 70:709–725.

Reichard, M., M. Polačik, A. S. Tarkan, R. Spence, Ö. Gaygusuz, E. Ercan, M. Ondračková, and C. Smith. 2010. The bitterling- mussel coevolutionary relationship in areas of recent and ancient sympatry. Evolution 64:3047–3056.

Reshetnikov, Yu. S., editor. 1998. Annotirovannyi katalog kruglorotykh i ryb kontinentalnykh vod Rossii [Annotated checklist of cyclostomata and fishes of the continental waters of Russia]. Izd. Nauka, Moscow. (In Russian.)

Reshetnikov, Yu. S., editor. 2003. [Atlas of Russian freshwater fishes, volume 1, 2nd edition]. Izd. Nauka, Moscow. (In Russian.)

Reshetnikov, Y. S., N. G. Bogutskaya, E. D. Vasil'eva, E. A. Dorofeeva, A. M. Naseka, O. A. Popova, K. A. Savvaitova, V. G. Sideleva, and L. I. Sokolov. 1997. An annotated check-list of the freshwater fishes of Russia. Journal of Ichthyology 37(9):687–736.

Schmidt, R. E., J. M. Samaritan, and A. Pappantoniou. 1981. Status of the bitterling, *Rhodeus sericeus*, in southeastern New York. Copeia 1981:481–482.

Scott, W. B., and E. J. Crossman. 1979. Freshwater fishes of Canada, 2nd edition. Bulletin of the Fisheries Research Board of Canada 184:1–966.

Shaposhnikova, G. H. 1964. Biologiya i raspredelenie ryb v rekakh ural'skogo tipa [Biology and distribution of fish in the Ural-like rivers]. Nauka, Moscow. (In Russian.)

Shatunovsky, M. I., E. N. Ognev, L. I. Sokolov, and E. A. Tsepkin. 1988. Ryby Podmoskovya [The fishes of the Moscow region]. Nauka, Moscow. (In Russian.)

Smith, C., K. Rippon, A. Douglas, and P. Jurajda. 2001. A proximate cue for oviposition site choice in the bitterling (*Rhodeus sericeus*). Freshwater Biology 46:903–911.

Sokolov, L. I., and E. A. Tsepkin. 2000. Istoricheskiy obzor antropogennykh izmeneniy ikhtiofauny rek Tsentral'nogo regiona Rossii (na primere basseyna Moskvy-reki i drugikh rek Podmoskov'ya) [Historical survey of anthropogenic changes in the ichthyofauna of rivers in the Central region of Russia (by an example of the Moskva River basin and other rivers of the Moscow region)]. Voprosy Ikhtiologii 40:166–175. (In Russian.)

Stadnichenko, A. P., and Y. A. Stadnichenko. 1980. The effect of bitterling larvae on the lamellibranch mollusk Unio rostratus gentilis Haas. Gidrobiologicheskii Zhurnal 17:57–61. (In Russian.)

Svetovidov, A. N., and G. K. Eremeev. 1935. [On the European and Amur bitterling (*Rhodeus sericeus*)]. Doklady Akademii Nauk SSSR 1:582–587.

Troitsky, S. K., and E. P. Tsunikova. 1988. Ryby basseynov nizhnego Dona i Kubani [Fishes of the lower Don and the Kuban River basins]. Rostov Publishing House, Rostov-on-Don, Russia. (In Russian.)

Vasiľeva, E. D. 2003. Main alterations in ichthyofauna of the largest rivers of the northern coast of the Black Sea in the last 50 years: a review. Folia Zoologica 52:337–358.

Verreycken, H., G. Van Thuyne, and C. Belpaire. 2011. Length-weight relationships of 40 freshwater fish species from two decades of monitoring in Flanders (Belgium). Journal of Applied Ichthyology 2011:1–5.

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

Warpachowski, N. A. 1887. Über die Gattung *Hemiculter* Bleek. und über eine neue Gattung *Hemiculterella.* Pages 13–24 *in* Bulletin of the Imperial Academy of Sciences of St. Petersburg, volume 32. Akademiia Nauk SSSR, Saint Petersburg, Russia. (In French.)

Wheeler, A. C. 1978. Key to the fishes of Northern Europe: a guide to the identification of more than 350 species. Frederick Warne Publishers, London.

Wheeler, A., and P. E. Maintland. 1973. The scarcer freshwater fishes of the British Isles I. Introduced species. Journal of Fish Biology 5:49–68.

Yakovlev, V. N., Yu. V. Slynko, and V. I. Kiyashko. 2001. Annotirovannyj katalog kruglorotykh i ryb vodoyemov Verkhnej Volgi [Annotated checklist of cyclostomata and fishes of the Upper Volga basin water bodies]. Pages 52–69 *in* A. I. Kopylov, editor. Ekologicheskie problem Verkhnej Volgi [Ecological problems of the Upper Volga]. Yaroslavl Technical University, Yaroslavl, Russia. (In Russian.)

Yemtyl, M. Kh. 1997. Ryby Krasnodarskogo kraja i respubliki Adygeja [Fishes from the Krasnodar Kray and Adygeya Republic]. Kuban State University, Krasnodar, Russia. (In Russian.)

Zhulidov, A. V., D. A. Zhulidov, D. F. Pavlov, T. Nalepa, and T. Yu. Gurtovaya. 2005. Expansion of the invasive bivalve mollusk *Dreissena bugensis* (quagga mussel) in the Don and Volga River Basins: revisions based on archived specimens. Ecohydrology and Hydrobiology 5(2):127–133.