U.S. Fish & Wildlife Service

Basket Clam (*Corbicula fluminea*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, November 2024
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Organism Type: Mollusk
Overall Risk Assessment Category: High

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1 Native Range and Status in the United States

Native Range

From Modesto et al. (2023):

"Originating from Southeast Asia (China, Japan, Korea, Thailand, and Russia), […]"

Allen (2019) lists the following locations as part of the native range of *C. fluminea*: [mainland] China, Hong Kong, Japan, Philippines, South Korea, Taiwan, Thailand, and Russia.

Status in the United States

From Benson et al. (2024a):

"*Corbicula fluminea* is established in river networks across many states as well as in Lake Erie, Lake Michigan, and Lake Superior (USEPA 2008)."

"The first collection of *C. fluminea* in the United States occurred in 1938 along the banks of the Columbia River near Knappton, Washington (Counts 1986). Since this first introduction, it is now found in 47 states, the District of Columbia, and Puerto Rico."

According to Benson et al. (2024a), nonindigenous occurrences of *Corbicula fluminea* have been reported in the following States, with the range of observation years, number of watersheds (8-digit hydrologic unit), and population status when reported following in parentheses:

- Alabama (1960-2023; 42; established)
- Arizona (1955-2020; 16; established)
- Arkansas (1964-2022; 48; established)
- California (1945-2024; 67; established)
- Colorado (1991-2022; 17; established)
- Connecticut (1990-2022; 8; established)
- Delaware (1981-2017; 4; established)
- District of Columbia (1978-2009; 1; established)
- Florida (1960-2024; 44; established)
- Georgia (1967-2021; 44; established)
- Hawaii (1982-2022; 4; established)
- Idaho (1955-2018; 9; established)
- Illinois (1960-2019; 49; established)
- Indiana (1964-2020; 28; established)
- Iowa (1974-2018; 13; established)
- Kansas (1983-2020; 51; established)
- Kentucky (1957-2016; 32; established)
- Louisiana (1961-2020; 32; established)
- Maryland (1975-2023; 19; established)
- Massachusetts (1999-2020; 11; established)
- Michigan (1980-2024; 23; established)
- Minnesota (1978-2021; 9; established)
- Mississippi (1963-2021; 44; established)
- Missouri (1961-2019; 48; established)
- Montana (2019; 1; unknown)
- Nebraska (1991-2019; 14; established)
- Nevada (1959-2022; 5; established)

- New Hampshire (2007-2022; 1; established)
- New Jersey (1963-2014; 7; established)
- New Mexico (1964-2012; 10; established)
- New York (1977-2020; 20; established)
- North Carolina (1969-2020; 45; established)
- Ohio (2962-2022; 29; established)
- Oklahoma (1969-2020; 42; established)
- Oregon (1943-2023; 25; established)
- Pennsylvania (1972-2024; 41; established)
- Puerto Rico (1998-2011; 3; established)
- Rhode Island (1999-2014; 4; established)
- South Carolina (1968-2019; 29; established)
- South Dakota (2004-2018; 3; established)
- Tennessee (1959-2019;41; established)
- Texas (1958-2012; 126; established)
- Utah (1978-2018; 12; established)
- Vermont (2016; 1; established)
- Virginia (1971-2023; 38; established)
- Washington (1937-2022; 47; established)
- West Virginia (1963-2017; 24; established)
- Wisconsin (1977-2019; 13; established)
- Wyoming (2011-2022; 6; established)

Live *Corbicula fluminea* are readily available for purchase online in the United States on websites such as Live Aquaponics (Live Aquaponics 2024) and Arizona Aquatic Gardens (AZGardens 2024). The species is advertised as an effective biofilter for aquariums.

Regulations

Corbicula fluminea is classified as a banned or prohibited invasive species in the following states: Alaska (ADFG 2023), Arizona (Arizona Game and Fish Commission 2022), Connecticut (Connecticut DEEP 2020), Hawaii (HDOI 2019), North Dakota (North Dakota Game and Fish Department (2023), New Hampshire (NHFG 2022), New York (New York DEC 2022), Tennessee (TWRA 2022), Vermont (The Vermont Statutes 2017), Wyoming (WGFD 2022), and Wisconsin (Wisconsin DNR 2022).

In Idaho, the transportation of *Corbicula fluminea* is prohibited outside the known established distribution area without a permit (IDDA 2022).

In Indiana, *Corbicula* spp. are prohibited mussels (Indiana DNR 2022).

In Rhode Island, live specimens of *Corbicula fluminea* are prohibited (Rhode Island DEM 2022).

While effort was made to find all applicable regulations, this list may not be comprehensive.

Means of Introductions within the United States

From Benson et al. (2024a):

"Current methods of introduction include bait bucket introductions (Counts 1986), accidental introductions associated with imported aquaculture species (Counts 1986), and intentional introductions by people who buy them as a food item in markets (Devick 1991). The only other significant dispersal agent is thought to be passive movement via water currents (Isom 1986); fish and birds are not considered to be significant distribution vectors (Counts 1986; Isom 1986). Migrating blue catfish (*Ictalurus furcatus*) had shown the potential to pass live adults through their gut when the clam was consumed and digested in cooler water (<21.1[°C]) (Gatlin et al. 2013)."

From Allen (2019):

"One of the dispersal mechanisms reported in the drainage systems in Texas of *C. fluminea* was via migratory birds (Britton and Murphy, 1977). The pediveliger larvae and juveniles can be transported on the feet or feathers of aquatic birds, spreading *Corbicula* up and downstream of rivers (McMahon, 1982)"

"Accidental propagation of *C. fluminea* in the USA occurs by transport with sand and gravel (Counts, 1986) and larval transportation in live minnow shipments (Britton and Murphy, 1977)."

"Considering the vast cultivation in aquaculture of this item in Japan and Taiwan, it was assumed that Asian immigrants possibly brought some specimens [to the United States] as a known source of food (Britton and Morton, 1979; McMahon, 2000)."

Remarks

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

Corbicula fluminea can survive in fresh, brackish, and marine waters. The conclusions of this ERSS are valid for only fresh and brackish water areas.

There is a history of taxonomic ambiguity and confusion and hybridization among *Corbicula* species, including *C. fluminea*. This screening follows the most current information available at the time the screening was conducted.

From Benson et al. (2024a):

"The taxonomy of *Corbicula* species needs further revision. Therefore until then, in this database [U.S. Geological Survey's Nonindigenous Aquatic Species Database] unless otherwise named, all unidentified species of the genus *Corbicula* collected in the United States are compiled under one name, *Corbicula fluminea*."

"Common name: basket clam
Synonyms and Other Names: Asiatic clam, golden clam, good luck clam"

From Modesto et al. (2023):

"*Corbicula* are a complex of species, and invasive lineages so far include the androgenetically reproducing and morphologically diverse *C. fluminea, C. fluminalis, C. leana, Corbicula largillierti* (R. A. Philippi, 1844), and potential hybrids with an ambiguous shell phenotype (Ituarte, 1994; Siripattrawan et al., 2000; Lee et al., 2005; Pigneur et al., 2011; López-Soriano et al., 2018; Morhun et al., 2022). Therefore, it is possible that many studies with these organisms might have been conducted with incorrect taxonomically identifed [sic] specimens, which further complicate any previous conclusions about the physiology, ecology, and general biology of these clams."

"The taxonomy of *Corbicula* clams has been difficult to decipher and remains largely equivocal. It turns out that many congeneric morphospecies have been described based on morphological features, of which up to 43 are now recognised as Latin synonyms of *C. fluminea* (Prashad, 1929, 1930). Interestingly many doubts and controversies have arisen since the discovery of the occurrence of at least two invasive taxa in Europe (Skuza et al., 2009; Morhun et al., 2022). Originally identified as *C. fluminea* and *Corbicula fluminalis* (O. F. Müller, 1774), these taxa are often found in sympatry (Swinnen et al., 1998; Renard et al., 2000; Pfenninger et al., 2002; Domagala et al., 2004; Labecka et al., 2005; Paunović et al., 2007; Ciutti & Cappelletti, 2009; Bódis et al., 2011). This was surprising, as it had previously been believed that sympatry did not occur among these *Corbicula* clams (Morton, 1986). Historically, *C. fluminea* was described as an 'Eastern' *Corbicula*; as originally this species was widespread in Asia, occurring in China, Japan, Korea, Thailand, and Russia (Morton,1986 and references herein; Glaubrecht et al., 2003; Korniushin, 2004). Moreover, *C. fluminea* was considered a freshwater species whereas typical of the Middle East 'Western' *C. fluminalis* a brackish species (Žadin, 1952; Kinzelbach, 1992 and references herein; Britton & Morton, 1986). Difficulties in species designation have repeatedly arisen, leading to the introduction of alternative nomenclature such as *Corbicula* sp., *Corbicula fluminea/fluminalis*, *Corbicula* cf. *fluminalis, Corbicula* cf. *fluminea* (Morton, 1982; Haesloop, 1992; Tittizer & Taxacher, 1997; Bodon et al., 2020)."

From Fofonoff et al. (2018):

"*Corbicula fluminalis*, described from the Euphrates River, is one of two living *Corbicula* species recognized by Morton (1986), who synonymized it with *C. japonica*, which inhabits freshwaters and estuaries, up to 30 PSU salinity. *Corbicula fluminalis* has been reported from European waters together with *C. fluminea*. However, the taxonomy of these forms is complex, and not completely resolved, despite recent genetic studies (Pigneur et al. 2011). *Corbicula fluminalis* has not been found in North America (McMahon, in Thorp and Covich 1991; Lee et al. 2005)."

From Allen (2019):

"In the Rhine River there exists evidence of cryptic hybridization between *C. fluminea* and *C. fluminalis*. The hybrid specimens were rare in abundance compared to the two major forms and they did not reach the adult stage (Pfenninger et al., 2002)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2024):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Protostomia
      Superphylum Spiralia
        Phylum Mollusca
          Class Bivalvia
            Subclass Autobranchia
              Infraclass Heteroconchia
                Order Venerida
                  Superfamily Cyrenoidea
                    Family Cyrenidae
                      Genus *Corbicula*
                        Species *Corbicula fluminea* (O. F. Müller, 1774)

According to MolluscaBase eds. (2024), *Corbicula fluminea* (O. F. Müller, 1774) is the current valid name for this species. The original name for this species was *Tellina fluminea* O.F. Müller, 1774.

Size, Weight, and Age Range

From Modesto et al. (2023):

"In general, it appears that *C. fluminea* has a shorter lifespan of 2 to 3 years in native areas but live for up to 5 years in the invaded range (McMahon, 2000; Ilarri & Sousa, 2012; Yan et al., 2013; Yanshan et al., 2017)."

"The greatest shell length reported for the species in its native range was 34 mm, which is considerably less than reported from its invaded areas where *C. fluminea* individuals have been shown to reach lengths of more than 50 mm (McMahon, 2000; Sousa et al., 2006a, b; Yan et al., 2013)."

From Allen (2019):

"The life span is about one to seven years, and it can grow to a shell length of 50-65 mm, although it is usually less than 25 mm."

Environment

From Modesto et al. (2023):

"The optimal habitats for *C. fluminea* are rivers with a sandy-bottom and intermediate flow (Neck, 1986; Cummings & Graf, 2009; Fig. 6A [in source material]). This species also occurs in ponds, lakes, and rivers of all sizes with variable flows and variable concentrations of suspended solids (Aldridge et al., 1987; McMahon, 2002; Cummings & Graf, 2009). *Corbicula fluminea* is also found in habitats with varying sediment composition, ranging from bedrock to silt (Hakenkamp et al., 2001; Sousa et al., 2006a, b; Vaughn & Spooner, 2006)."

From NatureServe (2024):

"In a study of the relationships of 12 environmental variables to density and biomass of *Corbicula fluminea*, higher density and biomass were found to be correlated to where substrate was > 40% fine sand, < 45% silt, and < 8% organic content (Cooper, 2007)."

From Benson et al. (2024a):

"*Corbicula fluminea* is a highly plastic and tolerant bivalve capable of surviving in a variety of habitats and environmental conditions. It prefers shallow waters (<3 m deep) of rivers and lakes but is also found in waters ~10 m deep (Mattice and Dye 1975, Patrick et al. 2017). It inhabits sandy or fine gravel substrate and individuals commonly bury themselves in sediment (Paganelli et al. 2018, McDowell and Byers 2019). Temperature is one of the leading factors in the distribution of *C. fluminea*. *Corbicula fluminea* can tolerate a wide range of temperatures, but are prone to mass mortality in events of prolonged extreme heat and cold. In both simulated and natural heat waves where water temperatures reach >34[°C], nearly entire populations of *C. fluminea* can die off (McDowell et al. 2017). Similarly, near freezing temperatures (<5[°C]) also can lead to mass mortality (Basen et al. 2016). In regions where freezing temperatures are common, *C. fluminea* typically is found in artificially heated waters such as where cooling water from power plants are released. These regions can act as thermal refugia for *C. fluminea* to survive winter and act as a steppingstone for future spread (Castenada et al. 2018, Penk and Williams 2019)."

"*Corbicula fluminea* lives in fresh and brackish water (0–20 ppt) (Ferreira-Rodríguez and Pardo 2016), with survivorship decreasing as salinity approaches 30 ppt (Crespo et al. 2017). […] As a bivalve with a large shell, *C. fluminea* is reliant on the concentration of calcium in the water. Calcium concentrations <12 mg/L may limit the establishment of *C. fluminea* (Bollens et al. 2021) as low calcium concentrations increase oxidative stress (Ferreira-Rodríguez et al. 2017)."

From Allen (2019):

"The *Corbiculidae* are burrowing bivalves. […] For *C. fluminea*, ideal sediments are sand mixed with silt and clay, while rocky and pure silt exclude this species especially if the concentration of oxygen is low (Leff et al., 1990; Karatayev et al., 2003). *C. fluminea* inhabits by decreasing order of preference: fine sand, organically-enriched fine sand, coarse sand. However, *C. fluminea* can inhabit a vast variety of substrata, from fine sand to gravel (Belanger et al., 1986)."

“Concerning water levels, when *Corbicula* is exposed to low water levels long migration is inhibited and population size decreases (White and White, 1977). On the other hand, spring floods in the Ohio River (USA) cause high mortality to *C. fluminea* in all age classes, directly related to the increase in suspended sediments in the water column (Bickel, 1966).”

“Even though there are no available data for pH limits for […] *C. fluminea*, mortality rates can be enhanced by lower pH values. Asian clams were reported to be dying over [a] 3 year period due to pH lower than 5.6 in Mosquito Creek in Florida (Kat, 1982; Karatayev et al., 2007).”

“[*C. fluminea*] is able to tolerate salinities of up to 13 ppt for short periods. If allowed to acclimate it is able to tolerate up to 24 ppt salinity. Although generally known to occur in freshwater bodies, it has been reported in brackish and estuarine habitats. In a survey of the Minho River, Portugal, the major abiotic agents that influenced the distribution of *C. fluminea* were redox potential, nutrient concentration, water hardness, organic matter and sediment characteristics, explaining almost 60% of the total variation (Sousa et al., 2008a). […] in *C. fluminea* low dissolved oxygen inhibits growth (Belanger, 1991), and high temperatures cause mass mortalities and declines in body mass (Sousa et al., 2005; Vohmann et al., 2010). Lower temperatures prevent populations from reaching higher abundances (French and Schloesser, 1991) and/or restrict their colonization in the invasive range (Bates, 1987). Mass mortality events are described in severe low water periods associated with low temperatures in Lake Constance (Switzerland) (Werner and Rothhaupt, 2008). A population surviving 0-2°C has been reported in Michigan (USA) (Janech and Hunter, 1995).”

“[*C. fluminea*] is thought to be able to tolerate polluted environments better than native species of bivalves.”

Climate

According to Allen (2019), *Corbicula fluminea* can be found in steppe, desert, and warm temperate climates.

From Palomares and Pauly (2024):

“Tropical”

Distribution Outside the United States

Native

From Modesto et al. (2023):

“[*Corbicula fluminea*] Originating from Southeast Asia (China, Japan, Korea, Thailand, and Russia), […]”

Allen (2019) lists the following locations as part of the native range of *C. fluminea*: [mainland] China, Hong Kong, Japan, Philippines, South Korea, Taiwan, Thailand, and Russia.

Introduced

From Modesto et al. (2023):

"It was first recorded outside its native range in North America during the 1920s in Vancouver Island, Canada; although, only empty shells were detected (Counts, 1981). From this first record, the species rapidly spread across North America (Crespo et al., 2015). It was documented in South America in the Rio de la Plata estuary (Argentina and Uruguay) during the 1970s (Ituarte, 1985, 1994). Between 1970 and 1980s, this species was simultaneously introduced to major European rivers, including Tagus River (Portugal) and Dordogne River (France) (Mouthon, 1981). *Corbicula fluminea* is now widespread across the European continent from Portugal (west) to Russia (east), while also occurring in the United Kingdom and Ireland (Ilarri & Sousa, 2012; Crespo et al., 2015). Since 2008, invasive *C. fluminea* is also present in several river basins in Morocco, North Africa (Clavero et al., 2012; Sousa et al., 2016; Gomes-dos-Santos et al., 2019)."

From EDDMapS (2024):

"In Canada, *C. fluminea* were found in the St. Lawrence River in Quebec in 2009 and in St. Clair River in Ontario in 2010."

From NatureServe (2024):

"Canada: BC [British Columbia], ON [Ontario], QC [Quebec]"

From Allen (2019):

"[…] it is now found in freshwater and salt water throughout northern Mexico, and much of Europe. The presence of *C. fluminea* in South America has also been documented (Ituarte, 1981, 1994)."

"In Europe, *C. fluminea* was reported from Portugal (Mouthon, 1981), France (Mouthon, 1981), the Netherlands (bij de Vaate and Greijdanus-Klaas, 1990), Germany (bij de Vaate, 1991), Spain (Araujo et al., 1993), Czech Republic (Beran, 2000), the UK (Aldridge and Muller, 2001), Belgium (Nguyen and Pauw, 2002) and Switzerland (Schmidlin and Baur, 2007). It was found in the River Garonne in France in 1980-1981, in Germany's River Weser in 1983, and the River Rhine in 1987. By 1991, it was common throughout the lower and middle Rhine system (Den Hartog et al., 1992). It was first recorded in Switzerland (Basel) in 1995. By 2003 it was found 22 km upstream of Basel […]."

"In Serbia, dense populations of *C. fluminea* were first recorded between 1980 and 1995 (Paunovic et al., 2007)."

From NatureServe (2024):

"Recently it has been found in a number of permanent water bodies at the central and western regions of Cuba (Pointier et al., 2005)."

From Hubenov et al. (2013):

"The first record of the Asian clam *Corbicula fluminea* in Bulgaria was from the Danube River at Vetren in 2001. In 11 years the species has established in the entire Bulgarian stretch of the Danube, from Vrav (rkm [river kilometer] 836) to Vetren (rkm 395), where it reached densities up to 16 560 ind./m^2. The species extended its range rapidly upstream of the Danube tributaries reaching 80 km upstream from the confluence with the Danube (Iskar River). Recently, the species also established in standing waters, two reservoirs and one sand-pit lake, located at altitudes of up to 525 m a.s.l. [above sea level]"

From Maćkiewicz (2013):

"The Asian bivalve *Corbicula fluminea* was first reported from Poland in 2003, from the Odra (Oder) River. It was found in the lower and later in the middle course of the river. In May 2011 this invasive species was found for the first time in the Vistula River, in Cracow, which indicates an extension of its distribution range in Europe."

From Sousa et al. (2007):

"This Asian clam [*C. fluminea*] was first reported in the River Minho estuary [Portugal] in 1989. After a short period of time, it became the major component of the local benthic fauna in terms of abundance and biomass."

From Munjiu and Shubernetski (2010):

"In R. Moldova [Republic of Moldova] the first empty *Corbicula* shells were found on the bank of river near the village of Cislita-Prut (the Lower Prut, R.Moldova). This was an evident indicator of *Corbicula* presence in the Prut River. Living individuals of Asian clam *Corbicula fluminea* (Müller, 1774) […] were found in the Prut River at the sampling site Cislita-Prut in November 2009 (45º53'13"N, 28º17'16"E) […]."

From Popa and Popa (2006):

"In North America, the first report of *Corbicula fluminea* was made by Buch, in 1938, according to Araujo et al. (1993). Counts (1981, 1985) mentioned *Corbicula fluminea* as present since 1924 and 1937 in Nanaimo, Vancuver Island, British Columbia, Canada, Washington."

"After 1980, *Corbicula fluminea* was introduced in South America and in Europe. It is reported by Mouthon from France and Portugal, in 1981. From Portugal, it was reported by Nagel, in 1989, from Duero River (Araujo et al., 1993). In Europe, *C. fluminea* distributed from West to East, and in the Danube it penetrated after the opening of the canal Rin – Main – Danube, which offers the possibility of mixing the faunas of the Rin and the Danube basins (Müller et al., 2002)."

"The first living specimens collected from the Romanian sector of the Danube were juveniles (3-4 mm), taken from the Iron Gates area, at Berzeasca, by Skolka and Gomoiu, in the winter of 1997 (Skolka & Gomoiu, 2001). Later, in 1999, living specimens were collected from the Danube, at Vadu Oii [Romania] (Bij De Vaate & Hulea, 2000)."

"*Corbicula fluminea* spread rapidly in the Danube. In 2002, Bãnãrescu & Sîrbu reported the species from the Danube, from the sector which runs through Banat [region that includes western Romania, northeastern Serbia, and southeastern Hungary], including it in the category of the ubiquitary eurybiont species, which populate any kind of water, mainly the eutrophic waters."

"Popa (2005) reported the species from the confluence of the Jiu River [Romania] with the Danube, then downstream, from four stations placed between km 510-480."

Allen (2019) lists the following additional countries as part of the introduced range of *C. fluminea*: Austria, Italy, Ukraine, Panama, Australia, and Venezuela. According to Pagad et al. (2018), occurrences of *Corbicula fluminea* have also been reported from the following countries: Bolivia, Croatia, Finland, and Israel.

Means of Introduction Outside the United States

From Modesto et al. (2023):

"Different human activities are considered to be the main transport vectors of this species, including global trade, fishing bait, use of clams as a food resource, ballast water discharges, aquarium releases, sport fisheries, and recreational activities (McMahon, 1982; Araujo et al., 1993; Karatayev et al., 2007; Ferreira-Rodríguez et al., 2019a). However, the introduction and dispersal of these clams is also associated with passive natural downstream transport by water currents, as well as passive dispersal following their ingestion by, or adherence to, natural vectors. This is primarily achieved through gut passage survival following ingestion by fish and birds or via adherence to the feet of waterbirds, with natural vectors potentially facilitating dispersal in both the upstream and downstream directions, as well as among unconnected water bodies (McMahon, 1982; Coughlan et al., 2017; Ferreira-Rodríguez et al., 2021)."

From Allen (2019):

"Clams were newly recorded in several Swiss lowland lakes whose interconnecting rivers have not yet been colonized during 2003-2010 indicating dispersal by human activites [sic] and/or waterfowl (Schmidlin et al., 2012)."

"Introduction of *C. fluminea* in Lake Garda, Italy, is reported to be due to stocking activities (Gherardi et al., 2008) […]."

"*Corbicula* sp. juveniles will spread passively in the water column, both in lotic or lentic ecosystems (Prezant and Chalermwat, 1984). In rivers, colonization in the downstream direction is easily achieved for the juveniles since they will be transported by the current flow or by byssal attachment to floating vegetation (Prezant and Chalermwat, 1984). However, upstream movement is thought to be via secondary transportations by animals or man (Britton and

Murphy, 1977; Rodgers et al., 1977; McMahon 1983). Another dispersal tactic in *C. fluminea* is the secretion of long mucous threads in smaller specimens and the exhalant siphons which act as a draglines to buoy the descendents into the water column (Prezant and Chalermwat, 1984)."

"Some reports seem to support dispersion via fish; however, this must be treated with caution, because it is questionable if *Corbicula* could survive the conditions inside fish guts (McMahon, 1982). Even so, in Brazil (Upper Paraná River) in the fish *Pterodora granulosus* a considerable amount of closed *C. fluminea* were found at the end of its intestine (Cantanhêde et al., 2007)."

"At a global level the common means of transportation, applied to most aquatic species, is ship ballast waters, which is the probable cause of *C. fluminea* introduction to the Rhine River in Europe (Gittenberger and Janssen, 1998; Bij de Vaate and Greijdanus-Klaas, 1990; Bij de Vaate, 1991; Karatayev et al., 2007). The Rhine-Meuse Delta in Rotterdam is the main continental port, and the largest port in Europe, accounting for 76.5% of the total trans-shipment in Dutch ports (Ministry of Transport, Public Works and Water Management, 2009). Therefore, at local and national levels, the commercial or recreational activities in rivers and connectivity of canals are responsible for a rapid upstream colonization (Brancotte and Vincent, 2002; Panov et al., 2009a)."

"In Europe (France), there are reports confirming the capture of *C. fluminea* to use as a decorative species in freshwater aquariums (Brancotte and Vincent, 2002). Tourist activities could be another potential vector of dispersal (McMahon, 1982)."

Short Description

From Benson et al. (2024a):

"A small light-colored bivalve with shell ornamented by distinct, concentric sulcations, anterior and posterior lateral teeth with many fine serrations. Dark shell morphs exist but are limited to the southwestern United States. The light-colored shell morph has a yellow-green to light brown periostracum and white to light blue or light purple nacre while the darker shell morph has a dark olive green to black periostracum and deep royal blue nacre (McMahon 1991). Qiu et al. (2001) reported yellow and brown shell color morphs among specimens collected from Sichuan Province in China. The shells of the yellow morphs were straw yellow on the outside and white on the inside, those of brown morphs were dark brown and purple, respectively. Further analyses revealed that the yellow and brown morphs are triploid and tetraploid, respectively."

"A separate clonal population of *Corbicula* has been reported for one location in the Illinois River (Tiemann et al. 2017). Tentatively named Form D, this newest form is pyramidal in shape with weakly elevated ridges; exterior is yellowish-brown with fine rust colored rays radiating out from the umbo; interior is creamy white but the lateral teeth are purple. Form D has a distinctive nuclear ribosomal DNA genotype, but the mtDNA COI haplotype is identical to Form A."

From Allen (2019):

"The most distinctive feature is the shell which bears numerous heavy concentric ridges. […] Internally there are three cardinal teeth in each valve and the lateral teeth are heavily serrated.

[…] Larvae are D-shaped and weakly calcified, the hinge edge does not present irregularities and no structures are observed."

Biology

From Benson et al. (2024a):

"This species is a filter feeder that removes particles from the water column, including diatoms, flagellates, cyanobacteria, and other microplankton. Using its pedal, or foot, it can also feed on soil microbes and periphyton (Bolam et al. 2019). *Corbicula fluminea* is consumed by fish, birds, mammals, crustaceans, and turtles but its thick wide shell makes it less palatable than other unionids (Castro et al. 2018a, Castro et al. 2018b, Bradshaw-Wilson et al. 2019, Sterrett et al. 2020)."

"*Corbicula fluminea* is a functional hermaphrodite, and incubates its larvae in gill chambers when waters are >15[°C]. It can also reproduce by self-fertilization at different ploidy levels, and is capable of androgenesis, a type of male quasi-sexual reproduction (Hsu et al. 2020). The reproduction of *C. flumina* [sic] is very plastic, and it can respond to the onset of ideal environmental conditions by having multiple consecutive spawning events (Cao et al. 2017). The high reproductive potential of this species has garnered estimates that it only takes one individual to start a new population."

"Factors that may affect population density and distribution of Asian clams include excessively high or low temperatures, salinity, drying, low pH, silt, hypoxia, pollution, bacterial, viral and parasitic infections, inter- and intraspecific competition, predators, and genetic changes (Evans et al. 1979, Sickel 1986). *Corbicula fluminea* has been found in the stomachs of black buffalo (*Ictiobus niger*) (Minckley 1973); carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), yellow bullhead (*Ameiurus natalis*), redear sunfish (*Lepomis microlophus*), largemouth bass (*Micropterus salmoides*), Mozambique tilapia (*Tilapia mossambica*) (Minckley 1982); blue catfish (*Ictalurus furcatus*) (M. Moser pers. comm. 1996; Gatlin et al. 2013); and spotted catfish (*Ameiurus serracanthus*) (A. Foster pers. comm. 1996). Other predators of *Corbicula* include birds, raccoons, crayfish, and flatworms (Sickel 1986). Densities of *C. fluminea* have also been documented to occur by the thousands per square meter, often dominating the benthic community (Sickel 1986)."

From Allen (2019):

"Spawning can occur throughout the year at water temperatures of 16°C or higher. Fertilization occurs inside the paleal cavity and larvae are incubated in the gills. Larvae can be densely packed in the interlamellar space or irregularly distributed (Korniushin, 2004)."

"[*C. fluminea*] releases the veligers of c. 250 µm length into the water column through the siphon (King et al., 1986; Kennedy et al., 1991). Larvae produced in late spring and early summer reach sexual maturity by the following autumn. A single individual can release 400 juveniles a day and up to 70,000 a year, with reproductive rates being highest in the autumn (Aguirre and Poss, 1999). Reproductive forms with androgenesis have been recorded in *C. fluminea* (Korniushin, 2004) […]."

Human Uses

From Allen (2019):

"In Tennessee, *Corbicula* was produced commercially for fish bait (Williams, 1969; Sickel and Heyn, 1980); in Sacramento, California, in 1974, 553,889 lbs of bait clams (*C. fluminea*) were sold for US $83,689 (McAllister, 1976)."

"[*C. fluminea*] has never been marketed for food in the US, except canned or smoked, with the canned form mostly commercialized to the Oriental market. Even so, Asians were found harvesting for the Asiatic clam in the Potomac River, above Washington, DC and selling it in large quantities in New York, because they prefer to consume this item fresh (Phelps, 1994b). *C. fluminea* has importance in polyculture; it may promote superior water quality in catfish-rearing ponds (Buttner, 1981)."

"In its native range, *C. fluminea* is marketed for human consumption and as feed for poultry and shrimp. In the USA, it is used as fish bait and sold through the aquarium trade where it is known as 'pygmy' or 'gold' clam. The meat of *C. fluminea* contains 6.21% protein and 1.55% fat. In Korea, where *C. fluminea* is known locally as jaecheop, it is used in a soup known as jaecheopguk. It is reportedly rich in taurine which is thought to aid in lowering blood pressure. It is also used to cure liver problems. As it is also rich in vitamin B12, regular consumption is believed to prevent anaemia (Koo, 2002)."

"In Taiwan, *C. fluminea* is raised in polyculture systems with bighead, grass and silver carps."

"According to Lovatelli (1988), production of *C. fluminea* in Taiwan reached 1000 mt in 1974 and 6354 mt in 1980. In 2000, production of *C. fluminea* in Taiwan totaled 10,180 tons (FAO, 2002)."

"The combination of quite easy maintenance in laboratory conditions, possible transplanted field experiments, dissection and separation of different organs, and also its ability to bioaccumulate and bioamplify several contaminants make *C. fluminea* a very convenient model in ecotoxicology (Way et al., 1990; Bassack et al., 1997; Baudrimont et al., 1997a,b; Inza et al., 1997; Narbonne et al., 1999; Tran et al., 2001; Cataldo et al., 2001a,b; Achard et al., 2004; Sousa et al., 2008b)."

Diseases

No information was found associating *Corbicula fluminea* with any diseases listed by the World Organisation of Animal Health (2024).

From Allen (2019):

"Although populations of *C. fluminea* in the wild have been found to be free from *Echinostoma revolutum* infection, Fried et al. (1987) were able to experimentally infect them in the laboratory. *C. fluminea* serves as a host for *Phyllodistomum mingensis* sp. nov. (Tang, 1985) and

Lophotaspis orientalis (Tang and Tang, 1980). Chung et al. (2001) discuss Korean populations of *C. fluminea* as a possible second intermediate host of *Echinostoma cinetorchis*."

According to Allen (2019), *C. fluminea* can carry infectious pancreatic necrosis virus.

MolluscaBase eds. (2024) list *Corbicula fluminea* as a host to the following additional endoparasites: *Aspidogaster ijimai*, *Cotylaspis sinensis*, *Lophotaspis corbiculae,* and *Phyllodistomum mingense*.

Threat to Humans

From Allen (2019):

"*Corbicula* is one of the hosts [of *Echinostoma revolutum*] and some parasite forms cause severe diseases in man, and are still a public health problem in endemic areas. Pathway transmission is by eating clams raw or barely cooked (Carney et al., 1980)."

3 Impacts of Introductions

The following information refers to ***actual*** impacts by *Corbicula flumina.*

From Modesto et al. (2023):

"At the abiotic level, several studies have indicated that the presence of *C. fluminea* is responsible for significant changes in biogeochemical cycles in the invaded range (Dame, 2011; Turek & Hoellein, 2015). Nutrients that are not incorporated into *C. fluminea* biomass are excreted as inorganic forms, a process which is largely linked to an increase in nutrient availability such as higher ammonium and phosphorus concentrations (Dame, 2011; Turek & Hoellein, 2015). For example, Turek & Hoellein (2015) observed that the ammonium fux from sediments with *C. fluminea* present in high densities (1608 ind. m^{-2}) was 2028 μg N m^{-2} h^{-1} greater than in sediments without the clam. Moreover, *C. fluminea* like other bivalves, acts as a bioturbator species through their burrowing and pedal feeding activities (Vaughn & Hakenkamp, 2001; Ilarri & Sousa, 2012). These activities have also been documented to increase nitrogen fluxes from sediments to the surrounding water, resulting in a release of 3397 μg N m^{-2} h^{-1} (Turek & Hoellein, 2015). Additionally, shell deposition of *C. fluminea* also enhances inorganic chemical compounds. Carbonate concentration in sediments were three times higher in invaded than in non-invaded systems, which positively influenced calcium carbonate content in the water column by shell dissolution (Ferreira-Rodríguez et al., 2019b). On the other hand, *C. fluminea* can contribute to deteriorating water and sediment quality (McDowell et al., 2017; McDowell & Sousa, 2019). *Corbicula* populations experience periodic mass mortality events during extreme climatic conditions (Ilarri et al., 2011; Sousa et al., 2012; Bódis et al., 2014a). High amounts of unionised ammonia are released during the decay of its soft tissues, which can lead to the presence of toxic concentrations in aquatic systems (Cherry et al., 2005; Cooper et al., 2005). This is especially valid for the interstitial zone of the sediments and in rivers with low flow in which the impacts of unionised ammonia can be more pronounced. In contrast, the impact of

C. fluminea die-offs is may be [sic] reduced in high flow conditions through the dilution of unionised ammonia (Modesto et al., 2023)."

"*Corbicula fluminea* have been reported to negatively and positively impact biotic assemblages. This includes changes in microbes (bacteria, fungi), phytoplankton, zooplankton, macrophytes, invertebrates, as well as vertebrates. However, it is important to note that biotic impacts will be context dependent (Vaughn & Hakenkamp, 2001; Spooner & Vaughn, 2006), which is usually underpinned by the abundance and density of the *C. fluminea* populations."

"Bioturbation activities and the large inputs of decaying biomass after *C. fluminea* die-offs have been observed to stimulate fungi biomass and bacteria diversity (Novais et al., 2015b, 2016, 2017a, b)."

"This species is also an intermediate consumer responsible for both bottom-up and top-down effects within food webs, altering biotic interactions mainly through filtration (Hakenkamp & Palmer, 1999; Ilarri & Sousa, 2012). *Corbicula fluminea* is an important filter feeder that has high filtration rates per individual (ranging from 29 to 3252 ml. h−1: Boltovskoy et al., 1995; Viergutz et al., 2012). Its filtration capacity is a potential regulator of phytoplankton and small zooplankton, while also driving shifts in organic matter flow (Cohen et al., 1984; Phelps, 1994; Sousa et al., 2008e; Rong et al., 2021). Cohen et al. (1984) reported that the phytoplankton reduction of 40–60% coincided with high abundances of *C. fluminea*. Further, Rong et al. (2021) demonstrated that the abundance of small zooplankton was reduced by *C. fluminea*; however, disparate effects were detected across different species of zooplankton. Another consequence of high *C. fluminea* filtration rates is the deposition of ingested particles to the sediments, in the form of faeces or pseudofaeces, increasing the amount of organic matter, which contributes to the transfer of primary production from the pelagic to the benthic food web (Hakenkamp & Palmer 1999; Hakenkamp et al., 2001; Vaughn & Hakenkamp, 2001). These high filtration rates and subsequent release of nutrients in inorganic forms can benefit macrophytes, while water turbidity also becomes reduced which facilitates deeper light penetration and, consequently, submerged plant growth (Phelps, 1994; Dame, 2011; Jiao et al., 2021)."

"Most freshwater bivalves, including *C. fluminea*, are usually classified as omnivorous, consuming phytoplankton, small zooplankton, bacteria, organic detritus, and other fine particles (McMahon, 1991; Vaughn & Hakenkamp, 2001; Vaughn et al., 2008; Dias et al., 2016). However, *C. fluminea* is considered a superior competitor for food resources when compared to the native mussels as in addition to its capacity for high filtration rates, it also has high assimilation rates and distinct feeding strategies (Modesto et al., 2021). Feeding strategies include pedal and suspension feeding on organic matter from the sediments and water column, respectively. This variable approach to feeding allows *C. fluminea* to compete with the native species for food through multiple trophic pathways (Hakenkamp & Palmer, 1999; Vaughn & Hakenkamp, 2001; Werner & Rothhaupt, 2008)."

"Competition for space between *C. fluminea* and native freshwater water mussels was also documented (Hakenkamp et al., 2001; Vaughn & Hakenkamp, 2001; Ferreira-Rodríguez et al., 2016). For example, *C. fluminea* bioturbation stimulate the vertical (burrowing) or horizontal movement of native mussel species, which can result in their displacement towards less favourable habitats (Vaughn & Hakenkamp, 2001; Schwalb & Pusch, 2007; Ferreira- Rodríguez, 2019)."

"*Corbicula fluminea* can significantly influence the density, biomass, and diversity of macroinvertebrates, thereby affecting habitat heterogeneity. For example, macroinvertebrates characterised as burrowers have been observed to exhibit negative correlations with increased *C. fluminea* density (Firmiano et al., 2021; Martins et al., 2021, Linares et al., 2022). Higher densities of *C. fluminea* can make the access of this taxa difficult to soft substrates, limiting their access to food resources and shelter from predators (Hakenkamp et al., 2001; Ward & Ricciardi, 2007). Other groups of macroinvertebrates such as sessile crustaceans, gastropods, and insects, have shown a positive response to increased densities of *C. fluminea* (Ilarri et al., 2012)."

"A recent study by Haubrock et al. (2022) reported a total economic cost of *C. fluminea* invasion around $12.4 billion over the past 40 years. Although *C. fluminea* is considered a global invader (Sousa et al., 2008a), these economic costs considered by Haubrock et al. (2022) were mainly incurred in North America, and suggest the total estimate provided is a considerable undervaluation, due to a lack of cost estimates in the other invaded continents."

From Benson et al. (2024a):

"[*C. fluminea*] is known mostly as a biofouler of many electrical and nuclear power plants across the country [United States]. As water is drawn from rivers, streams, and reservoirs for cooling purposes so are *Corbicula* larvae. Once inside the plant, this clam can clog condenser tubes, raw service water pipes, and firefighting equipment. Economic problems can result from the decreased efficiency of energy generation. Warm water effluents at these power plants make a hospitable environment for stabilizing populations."

"The most prominent effect of the introduction of the Asian clam into the United States has been biofouling, especially of complex power plant and industrial water systems (Isom et al. 1986; Williams and McMahon 1986). It has also been documented to cause problems in irrigation canals and pipes (Prokopovich and Hebert 1965; Devick 1991) and drinking water supplies (Smith et al. 1979). It also alters benthic substrates (Sickel 1986), and competes with native species for limited resources (Devick 1991)."

"In the USA, *C. fluminea* has caused millions of dollars worth of damage to intake pipes used in the power and water industries. Large numbers, either dead or alive, clog water intake pipes and the cost of removing them is estimated at about a billion US dollars each year (Anon., 2005). Juvenile *C. fluminea* get carried by water currents into condensers of electrical generating facilities where they attach themselves to the walls via byssus threads, growing and ultimately obstructing the flow of water. Several nuclear reactors have had to be closed down temporarily in the USA for the removal of *Corbicula* from the cooling systems (Isom, 1986). In Ohio and Tennessee where river beds are dredged for sand and gravel for use as aggregation material in cement, the high densities of *C. fluminea* have incorporated themselves in the cement, burrowing to the surface as the cement starts to set, weakening the structure (Sinclair and Isom, 1961). Isom (1986) has reviewed the invasion of *C. fluminea* of the Americas and the biofouling of its waters and industries."

"*C. fluminea* is consumed mainly by fish and crayfish. An account of the different species which prey on *C. fluminea* in the USA is given by McMahon (1983). Garcia and Protogino (2005) describe the diet of some native fishes from Argentina (Rio de la Plata) previously not known to feed on *C. fluminea*. Their results indicate that several local fish species have modified their diet to feed on invasive molluscan species such as *C. fluminea*. A study of sections of a New Hampshire River pre and post-invasion showed that *C. fluminea* did not have any impact on local invertebrate denisty [sic] or biodiversity (Richardson 2020)."

From Benson et al. (2024b):

"A number of experiments analyzing the impact of *C. fluminea* on native [North American] bivalves have documented conflicting results, from competitive exclusion to coexistence (see Strayer 1999; Sousa et al. 2005). *Corbicula fluminea* has a competitive advantage over a native mussel *Unio delphinus* resulting in a decline in its performance (Ferreira-Rodríguez and Pardo 2017). *Corbicula fluminea* outcompeted *U. delphinus* for food resources (Ferreira-Rodríguez et al. 2018a) and negatively impacted the growth, condition, and locomotion of *U. delphinus* (Ferreira-Rodríguez et al. 2018b). In a Kentucky river, native mussel abundance was also negatively impacted by the presence of *C. fluminea* (Haag et al. 2021). Experimental ponds infested with *Hydrilla verticillata* that were treated with *Ctenopharyngodon idella* (Grass carp) resulted in secondary infestations of *C. fluminea* likely due to its superior competitive abilities and the loss of habitat for native species (Holbrook et al. 2020)."

"Cohen et al. (1984) documented a reduction in phytoplankton abundance by 40-60% in a roughly 7 km stretch of the Potomac River, MD [Maryland], relative to upstream and downstream segments. This was likely due to the very high densities of *C. fluminea* in this stretch (an increase from 1.2 clams/m2 in 1977 to 1,467 clams/m2 in 1981) and the high filter feeding rates that were observed (Cohen et al. 1984). Following the introduction of *C. fluminea* to the Potomac River Estuary, a series of ecosystem-level changes appeared to occur, including increased water clarity followed by growth of fish, bird, and submerged aquatic plant populations, all of which evidently reversed with the decline of *C. fluminea* populations (Phelps 1994). These observations suggest that *C. fluminea* is capable of having far-reaching effects on invaded ecosystems. Alteration of substrate habitat by *C. fluminea* via sediment disturbance and slow shell decay rates may also shift benthic community structures (Ilarri et al. 2019). In four Brazilian reservoirs, sites invaded by *C. fluminea* where benthic communities were once dominated by soft sediment taxa were instead dominated by an invasive gastropod (Linares et al. 2017)."

"A population in Florida filters enough water to play a significant role in benthic/pelagic biogeochemical coupling by transporting nutrients and metals from pelagic to benthic environments (Patrick et al. 2017)."

"[…] *C. fluminea* proved to be an ecosystem engineer in a New Hampshire river and had either no effect or a slight positive effect on native benthic macroinvertebrate communities (Richardson 2020)."

From Allen (2019):

"García and Protogino (2005) show that *C. fluminea* is a source of food to fishes that might induce accumulation of heavy metals in higher trophic levels. […] However a clear relationship between feeding habits and bioaccumulation of Cd, Cu and Zn it is not clearly confirmed (Villar et al., 2001). The high resistance of *C. fluminea* to toxic substances compared to other species can enhance their probability to exclude endemic taxa in polluted disturbed ecosystems (Burress et al., 1976). Empty shells, left after the animal dies, persist in the benthos providing a suitable habitat for other species especially on soft bottoms (Gutiérrez et al., 2003). The most recent studies on positive effects on ecosystems by *Corbicula* sp. relies on ecosystem engineer pathways; Lake Constance, Switzerland (Werner and Rothhaupt, 2007) is one example. In Lake Constance recent *C. fluminea* colonization enhanced the proliferation of typical hard-substrate species on a soft-benthic surface (e.g. *Caenis* sp. enhanced their density) (Werner and Rothhaupt, 2007). In the Minho River, Portugal, *C. fluminea* was first registered in 1989, and nowadays dominates the benthic biomass with about 98% of total biomass in the freshwater tidal estuarine area (Sousa et al., 2008d). In the Tennessee River, USA, Isom (1971) reported that the loss of native mussel (Unionidae) diversity was due to impoundment and overharvesting or by fish-host association; however, it is mentioned that a new pest (*Corbicula* sp.) has successfully established and is considered by many authors to be responsible for the unionid decline (Parmalee, 1945; Cummings and Mayer, 1992; Williams et al., 1993). The invasion in Europe threatens native unionid species (Reis, 2003; Geist and Kuehn, 2005). Vaughn and Spooner (2006), in a scale-dependant survey, revealed that cushions of unionid mussels exclude *Corbicula* sp. from their patches. However, *Corbicula* in a prior study by Clarke (1986) is capable of competitive exclusion of *Canthyria* (Unionidae). Assuming the taxonomic and functional similarities, the addition of a *Corbicula* specimen into a mussel community might represent as much difference as an introduction of unionid species (Vaughn and Spooner, 2006). Nonetheless, *Corbicula* sp. preferentially invades sites where native mussel communities are already in decline by anthropogenic ecosystem disturbances (Strayer, 1999) and its impact on native mussels is much weaker than that of the zebra mussel *Dreissena polymorpha* (Strayer, 1999). […] The survival of larval stages of native mussels can be affected by larvae of *Corbicula* sp. through direct food competition, sediment disturbance and displacing species downstream (Strayer, 1999; Yeager et al., 2000)."

From Sampaio and Rodil (2014):

"In this work, we compared the benthic macroinvertebrate assemblages in the freshwater section of two river estuaries, Lima and Minho [Portugal], which were invaded with a 12-year gap by this non-indigenous bivalve. This study shows that *C. fluminea*'s presence can model other species' abundance in a strong fashion, especially in the later stages of invasion when it is fully settled. Although our results showed that the abundance of this invasive bivalve is linked to high values of biodiversity and to direct increases in the abundance of Gastropoda, an invasion by *C. fluminea* seems to prompt negative effects on specific crustacean species, such as the abundant amphipod species *Corophium multisetosum.*"

From Munjiu and Shubernetski (2010):

"These clams negatively influence the native bivalves as they are in competition for both nutrient resources (filter-feeding) and substrate [in Republic of Moldova]."

The following information refers to ***possible*** impacts by *Corbicula* species in general.

From Allen (2019):

"*C. fluminea* has one of the highest filtration rates per biomass, compared to sphaeriids and unionids (McMahon, 1991). Consequentially one of the major impacts will be on reduction of planktonic communities (Cohen et al., 1984; Lauritsen, 1986b; Leff et al., 1990). The feeding behaviour of *Corbicula* sp. can induce wide effects in the invaded ecosystem by enhancing light penetration that increases the macrophyte coverage (Phelps, 1994a; Karatayev et al., 2007). *Corbicula* can also increase sedimentation rates, at local scales, as they constantly remove the seston and deposit them as faeces and pseudofaeces (Prokopovich, 1969). It is an important coupler between benthic and pelagic process because it uses organic matter from both the water column and sediments (Leff et al., 1990; Hakenkamp and Palmer, 1999). *Corbicula* influence macrobenthos in the partitioning of nitrogen through their motion and excretion and play an important role on primary production by recycling nitrogenous material (Yamamuro and Koike, 1993). Bioturbation of sediments through bivalve movements increases water and oxygen content in the sediments, releasing nutrients and transferring metals from the sediment to the water column (Vaughn and Hakenkamp, 2001; Ciutat and Boudou, 2003). Faeces and pseudofaeces of [*Corbicula* sp.] increase the organic matter in sediments (Vaughn and Hakenkamp 2001) and this situation could theoretically provide additional food for deposit feeding species (Roditi et al., 1997). However, this relationship was not observed (Hakenkamp and Palmer, 1999; Karatayev et al., 2005)."

"[*Corbicula* sp.] as ecosystem engineers will have an impact on habitat structure, biomineralization, oxygenation and benthic planktonic community structure. It can alter the nutrient cycle and the food web structure interfering with the community stability (Mattice, 1979; Phelps, 1994a; Crooks, 2002; Karatayev et al., 2005; 2007; Sousa et al., 2009). The accumulation of dead shells increase the roughness the bottom enhancing heterogeneity to soft bottoms which can provide benthos protection against erosion, by decreasing velocity flow in formed reefs of empty shells and clams (Gutiérrez et al., 2003; Sousa et al., 2009)."

"Another situation to take into consideration involves the die-off of *C. fluminea* in warmer water events. Clam die-offs clearly have the potential to cause death in the juvenile stages of some species of unionid mussels. During decomposition, the ammonia concentration exceeds the acute levels of LC50 (Cherry et al., 2005; Cooper et al., 2005)."

From Benson et al. (2024b):

"A variety of studies have demonstrated the competitive ability and ecosystem impact of *C. fluminea*. *Corbicula fluminea* may filter a wider range of food sources at a faster rate than native freshwater mussels, which could decrease food availability for other benthic and pelagic species (Strayer et al. 1999; Vaughn and Hakencamp 2001; Atkinson et al. 2010). […] The high thermal tolerance of *C. fluminea* may allow it to benefit more than native mussels during heat wave mass mortality events due to higher reproductive potential and faster recovery (Ferreira-Rodríguez et al. 2018c)."

"*Corbicula fluminea* has the potential to alter nutrient cycles in invaded systems. Microcosm experiments suggest that *C. fluminea* can increase sediment oxygen uptake, as well as the release of soluble reactive phosphorus, ammonium, and nitrate (Zhang et al. 2011). Bioturbation as a result of its burrowing behavior releases phosphorus, dissolved inorganic nitrogen, and iron from the sediments into the water column (Chen et al. 2016; Coelho et al. 2018). Nutrient enrichment by *C. fluminea* favors primary production and increased calcium dissolution which can cause a positive feedback loop and increase its invasion success (Ferreira-Rodríguez et al. 2019). Due to its ability to both filter feed and pedal feed, it can alter the abundance of organic matter in the sediment depending on its primary source of food at a given time (Hakencamp and Palmer 1999). *Corbicula fluminea* may also bioaccumulate toxic substances and transfer them throughout the food web via its feces (Kuehr et al. 2021). It also has a relatively rapid growth and turnover rate, which can increase its influence on energy and nutrient flows in aquatic ecosystems (Sousa et al. 2008). […] Furthermore, higher levels of nitrogen, ammonia (NH3), and orthophosphate (PO4) in feces and pseudofeces, as well as the chemical releases following *C. fluminea* summer die-offs, could alter nutrient cycling in freshwater systems (Lauritsen and Mozley 1989; Atkinson et al. 2010) and impact water quality and ecosystem dynamics (Novais et al. 2017)."

"The presence of *C. fluminea* shells in otherwise soft substrate has been correlated with an increase in arthropod and mayfly (*Caenis* spp.) densities (Karatayev et al. 2005; Werner and Rothhaupt 2007, 2008). In one experiment, the effect of the presence of three types of *C. fluminea* (fed individuals, starved individuals, and shells) on ten other species of invertebrates was tested, and the authors found that no species avoided live individuals or shells of *C. fluminea* when choosing a substrate (Werner and Rothhaupt 2008). Most taxa preferred sand habitat with *C. fluminea* shells, supporting the hypothesis that these shells add structural heterogeneity that is conducive to macroinvertebrate biodiversity (Werner and Rothhaupt 2008). Those benthic invertebrates that showed a preference for substrate with living *C. fluminea*, particularly gastropods, appeared to take advantage of the pseudofeces produced by *C. fluminea* as a food source (Werner and Rothhaupt 2008)."

From Maćkiewicz (2013):

"The expansion of *C. fluminea* is predicted to have a negative impact on the biological diversity of surface waters in the Vistula basin [Poland]. STAÑCZYKOWSKA & KO£ODZIEJCZYK (2011) report that a single specimen releases from 320 to 387 larvae per day, i.e. approximately 35,000–70,000 larvae per season. Competition for food and the high fertility of the species pose a danger primarily to other bivalves, in particular those of the families Sphaeriidae and Unionidae (STAÑCZYKOWSKA & KOŁODZIEJCZYK 2011)."

Corbicula fluminea is regulated in the following States: Alaska (ADF&G 2023), Arizona (Arizona Game and Fish Commission 2022), Connecticut (Connecticut DEEP 2020), Hawaii

(HDOI 2019), Idaho (IDDA 2022), Indiana (Indiana DNR 2022), North Dakota (North Dakota Game and Fish Department (2023), New Hampshire (NHFG 2022), New York (New York DEC 2022), Rhode Island (Rhode Island DEM 2022), Tennessee (TWRA 2022), Vermont (The Vermont Statutes 2017), Wyoming (WGFD 2022), and Wisconsin (Wisconsin DNR 2022).

4 History of Invasiveness

The History of Invasiveness for *Corbicula fluminea* is classified as High. *C. fluminea* has been introduced widely to countries outside of its native range and many of these introductions resulted in nonnative establishment. There are numerous documented negative impacts of *C. fluminea* in areas of nonnative establishment including impacts to nutrient cycling, native invertebrate abundances, and biofouling of energy production and water transport facilities. *Corbicula fluminea* is also a prominent trade species. *C. fluminea* is consumed by humans, used as feed for domestic fowl, as a bait species, and as an aquarium species.

5 Global Distribution

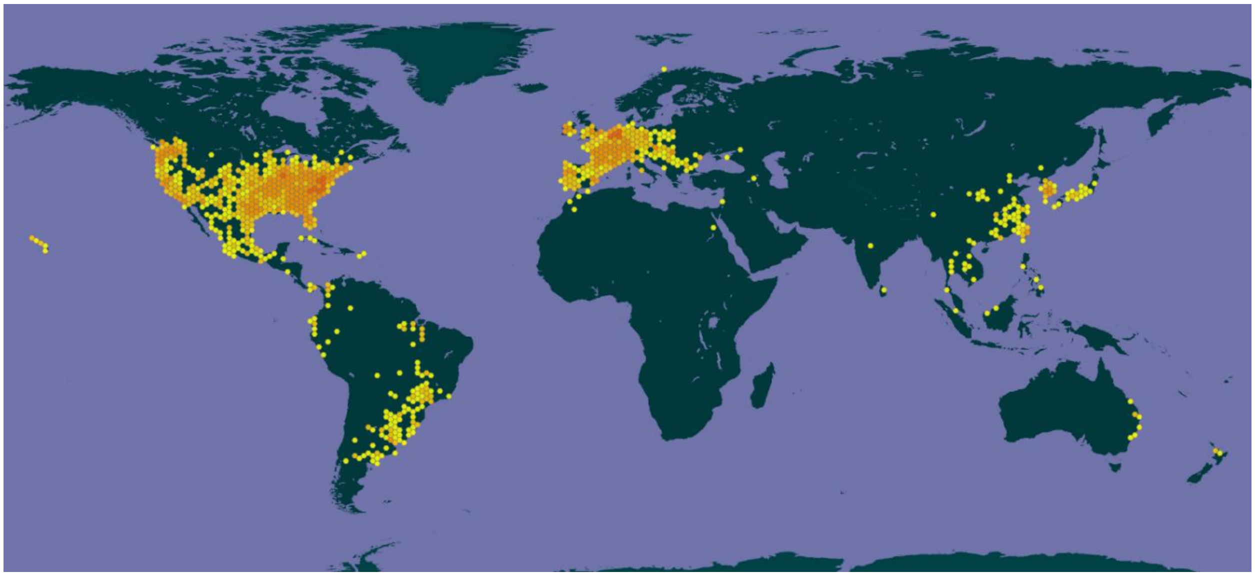

Figure 1. Reported global distribution of *Corbicula fluminea*. Map from GBIF Secretariat (2023). Observations are reported from the United States, Europe, India, Northern Africa, eastern and southeastern Asia, Australia, New Zealand, and throughout South America. Observations in Colombia, Ecuador, Peru, Norway, Armenia, Iran, and New Zealand are from preserved specimens and likely do not represent established populations. They were not used in the climate matching analysis.

Locations reported within the literature but without georeferenced observations include Austria, Finland, Moldova, and Venezuela.

6 Distribution Within the United States

Figure 2. Reported distribution of *Corbicula fluminea* in the contiguous United States. Map from Benson et al. (2024a). Observations are reported from the Southwest, Southern Plains, Southeast, Mid-Atlantic, Appalachian Range, Northeast, Great Lakes, California, Northern Pacific Coast, and Western Mountain regions. Observations are also shown for Cuba (not part of the United States) and Puerto Rico (U.S. territory).

Figure 3. Reported distribution of *Corbicula fluminea* in Hawaii. Map from Benson et al. (2024a). Observations occur throughout the state.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Corbicula fluminea* to the contiguous United States was uniformly high. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 1.0, 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). *Corbicula fluminea* can survive in fresh, brackish, and marine waters. The analysis of the climate matching is valid for only fresh and brackish water areas.

Projected climate matches in the contiguous United States under future climate scenarios are available for *Corbicula fluminea* (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.

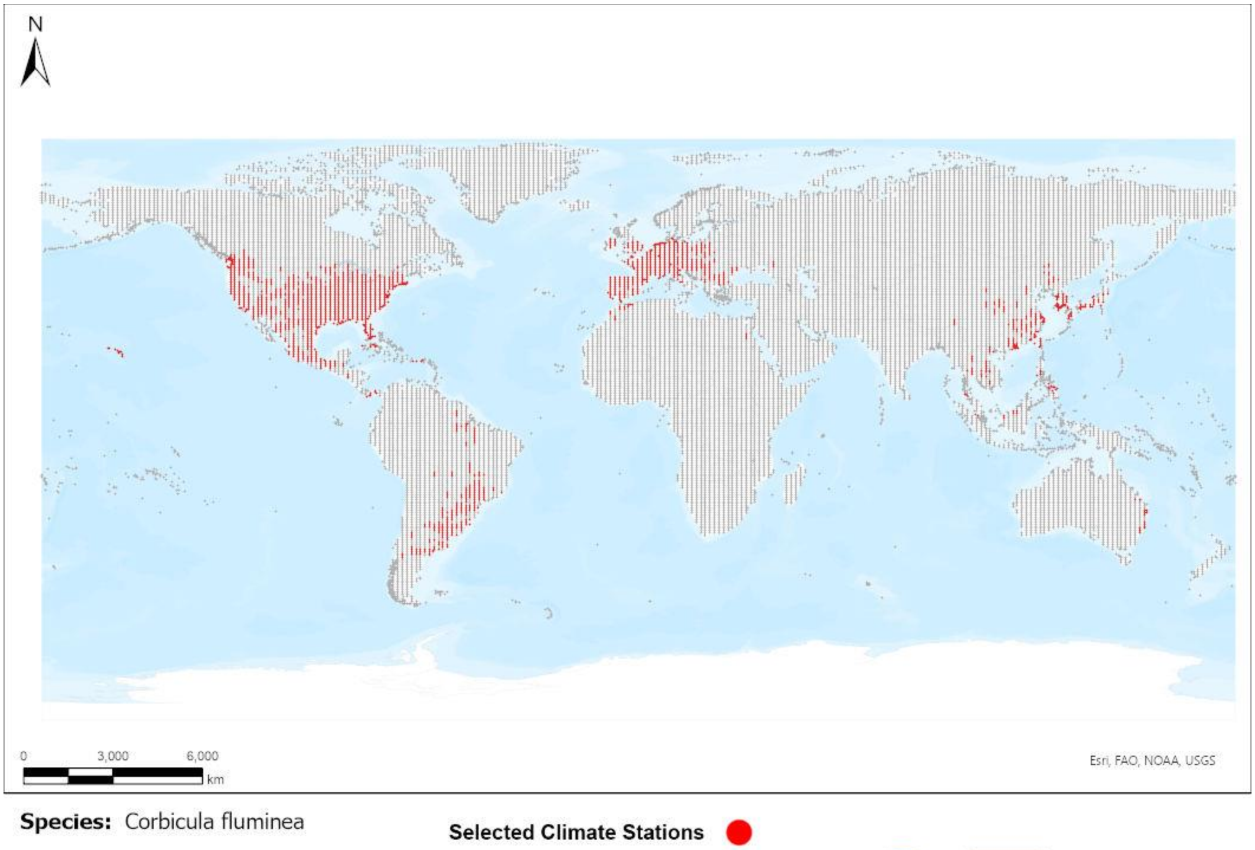

Figure 4. RAMP (Sanders et al. 2023) global source map showing weather stations selected as source locations (red; United States, Canada, South America, Europe, Asia, Australia, Africa) and non-source locations (gray) for *Corbicula fluminea* climate matching. Source locations from GBIF Secretariat (2023). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

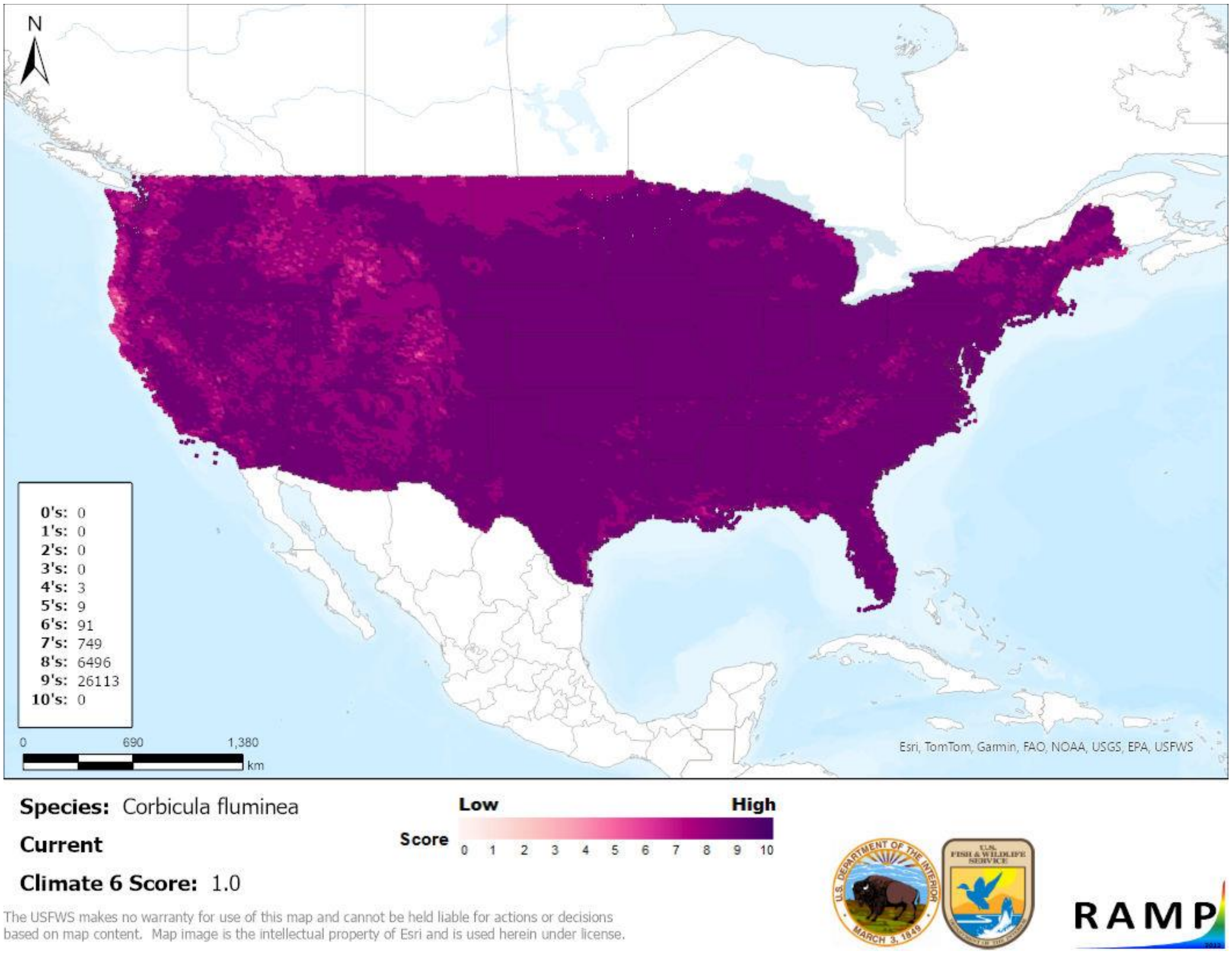

Figure 5. Map of RAMP (Sanders et al. 2023) climate matches for *Corbicula fluminea* in the contiguous United States based on source locations reported by GBIF Secretariat (2023). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment for *Corbicula fluminea* is classified as High. There is complete and scientifically defensible information available on the species distribution, nature of impacts in nonnative ranges, and prominence in trade. There is some uncertainty regarding the global distribution of *C. fluminea* due to difficulty distinguishing between *C. fluminalis* and other congeners, particularly in Europe (see Remarks). This uncertainty is not thought to be great enough to lower the Certainty of Assessment classification for this screening.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Corbicula fluminea, Basket Clam, is a mollusk that is native to southern and eastern Asia. The species can inhabit ponds, lakes, and rivers of all sizes with variable flows and sediment composition. *C. fluminea* can tolerate a wide range of temperatures and salinities. Aside from passive natural downstream transport, the main transport vector of this species is considered to be human activity, including global trade, fishing bait, human food source, ballast water discharges, aquarium releases, and recreational activities. *Corbicula fluminea* causes significant biofouling damage to water intake pipes, may carry parasites harmful to human, and impacts ecological systems in invaded areas. The species has high reproductive potential as it is a functional hermaphrodite, can reproduce by self-fertilization, and is capable of androgenesis. The History of Invasiveness for *C. fluminea* is classified as High due to its history of nonnative establishment and the documentation of numerous negative impacts from nonnative establishment. The climate matching analysis for the contiguous United States indicates establishment concern for this species. The climate match was high across the contiguous United States. The Certainty of Assessment for this ERSS is classified as High due to complete and scientifically defensible information available on the species distribution, history of introductions, and nature of impacts in the nonnative range. The Overall Risk Assessment Category for *Corbicula fluminea* in the contiguous United States is High.

Assessment Elements

- **History of Invasiveness (see section 4): High**
- **Establishment Concern (see section 7): Yes**
- **Certainty of Assessment (see section 8): High**
- **Remarks, Important additional information: Can self-fertilize.**
- **Overall Risk Assessment Category: High**

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Appendix

Summary of Future Climate Matching Analysis

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

Under the future climate scenarios (figure A1), on average, high climate match for *Corbicula fluminea* was projected to occur in the Appalachian Range, California, Colorado Plateau, Great Basin, Great Lakes, Gulf Coast, Mid-Atlantic, Northeast, Northern Plains, Southeast, Southern Plains, Southwest, and Western Mountains regions of the contiguous United States. The climate matches for *Corbicula fluminea* were lower in time step 2085 than in time step 2055, but still a high match at both time steps. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.978 (model: UKESM1-0-LL, SSP5, 2085) to a high of 1.0 (model: GFDL-ESM4, 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 (1.0, figure 5) falls above the range of scores for future projections. The time step and climate scenario with the most change relative to current conditions was SSP5, 2085, the most extreme climate change scenario. Under all time step and climate scenarios only minor or no increases in the climate match relative to the current match were observed. Under one or more time step and climate scenarios, areas within the Northern Pacific Coast region saw a large decrease in the climate match relative to current conditions. Additionally, areas within the Appalachian Range, California, Colorado Plateau, Great Basin, Gulf Coast, Mid-Atlantic, Northeast, Northern Plains, Southeast, Southern Atlantic Coast, Southern Florida, Southern Plains, Southwest, and Western Mountains saw a moderate decrease in the climate match relative to current conditions. Additional, very small areas of large or moderate change may be visible on the maps (figure A3).

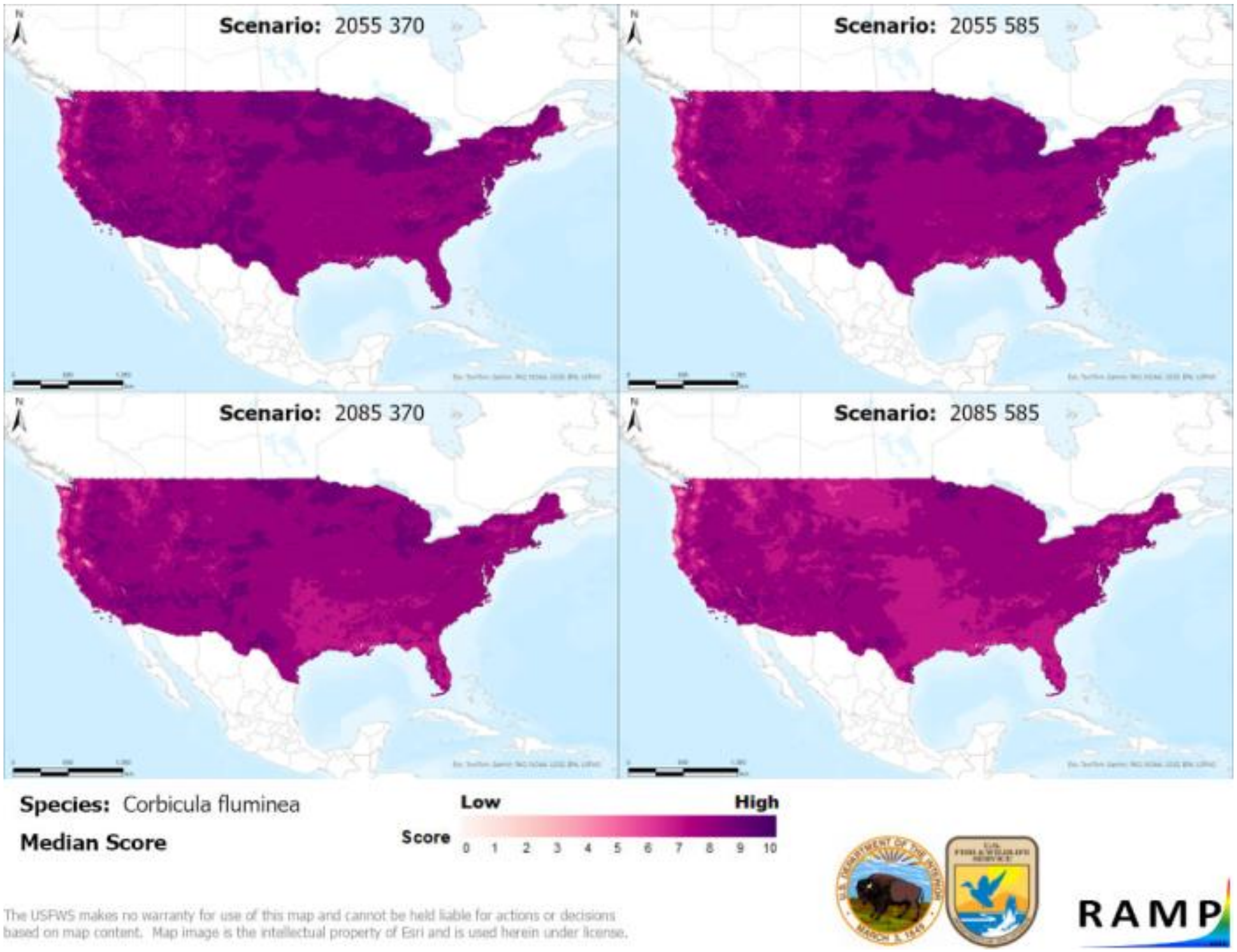

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Corbicula fluminea* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2023). Shared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

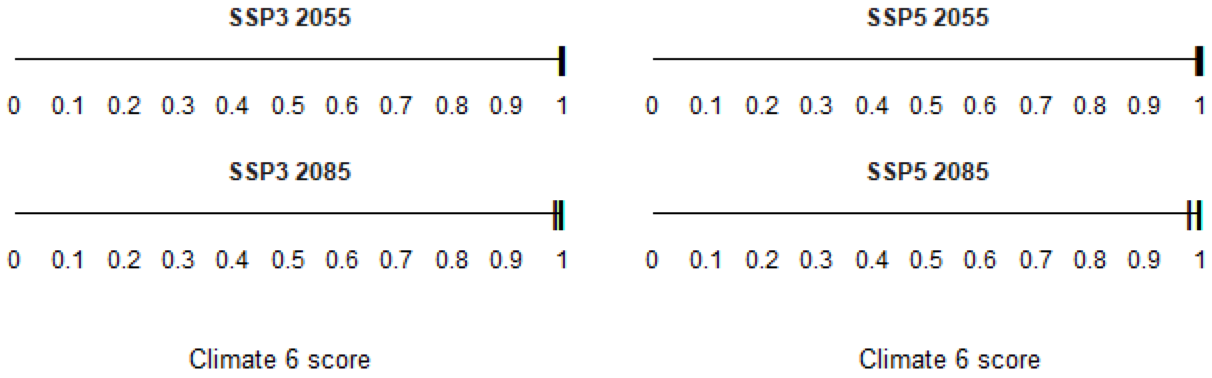

Figure A2. Comparison of projected future Climate 6 scores for *Corbicula fluminea* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; 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.

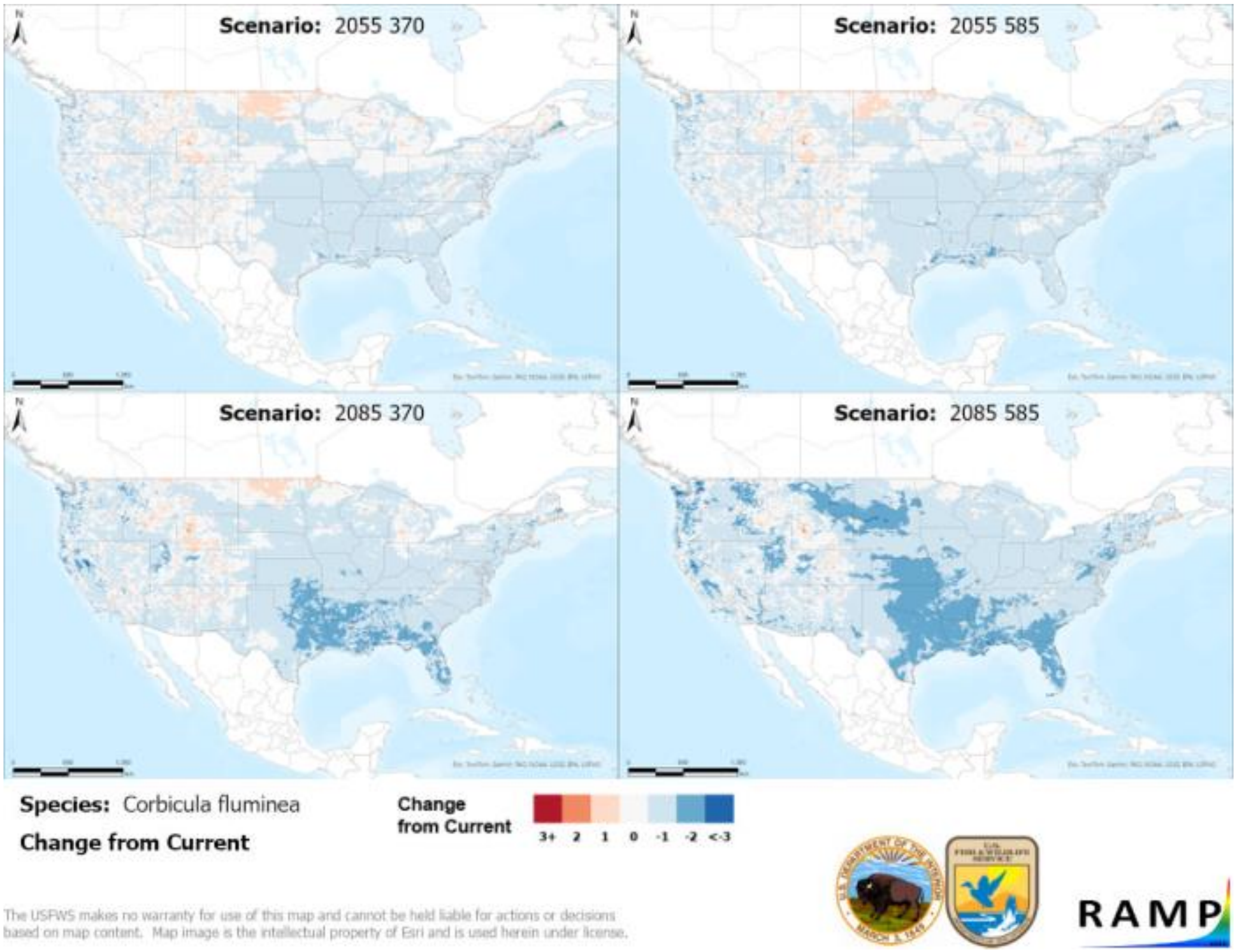

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 5) and the median target point score for future climate scenarios (figure A1) for *Corbicula fluminea* based on source locations reported by GBIF Secretariat (2023). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. Shades of blue indicate a lower target point score under future scenarios than under current conditions. Shades of red indicate a higher target point score under future scenarios than under current conditions. Darker shades indicate greater change.

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