Golden Topminnow (*Fundulus chrysotus*)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, December 2022
Revised, January 2023
Web Version, 3/18/2024

Organism Type: Fish
Overall Risk Assessment Category: Uncertain

Photo: Fredlyfish4. Licensed under Creative Commons Attribution-Share Alike 4.0 International. Available: https://commons.wikimedia.org/wiki/File:Fundulus_chrysotus_UMFS_2.jpg (December 2022).

1 Native Range and Status in the United States

Native Range

From Fuller (2019):

"Atlantic and Gulf Coastal Plain from Santee River drainage, South Carolina, to Trinity River drainage, Texas; Former Mississippi Embayment north to Kentucky and Missouri. East of Mississippi River, mostly restricted to lower Coastal Plain (Page and Burr 1991)."

Status in the United States

From McAllister et al. (2006):

"The golden topminnow, *Fundulus chrysotus* (Günther), is a small killifish that is distributed in the Coastal Plain from the Santee River drainage of South Carolina through Georgia, Florida, Alabama, Mississippi, and Louisiana, and northeastward from the Trinity River drainage of Texas and Oklahoma through eastern Arkansas up the Mississippi River Embayment to Tennessee, Kentucky and Missouri (Shute 1980, Etnier and Starnes 1993)."

"During the period from 1960 to 1987, Robinson and Buchanan (1988) reported 33 localities in the state [of Arkansas] for the species; however, prior to 1960, only 3 localities were known. In addition, Buchanan et al. (2003), Buchanan (2005), and Robinson (2005) reported this fish from the Red River drainage (rarely), 11 of 66 Arkansas reservoirs (1,380 specimens), and the Pine Bluff Arsenal (Jefferson County, 7 specimens), respectively. Additional fieldwork in Arkansas has revealed further distributional records in 27 counties for *F. chrysotus,* and we document 98 new locales herein."

"Between August 1996 and September 2005, golden topminnows were collected […] We document the collection of 3,619 *F. chrysotus* from 27 of 75 counties (36%) of Arkansas (Ashley, Bradley, Calhoun, Clark, Columbia, Crawford, Crittenden, Dallas, Desha, Drew, Hempstead, Hot Spring, Howard, Jackson, Jefferson, Lafayette, Lincoln, Little River, Lonoke, Miller, Ouachita, Poinsett, Prairie, Sebastian, Sevier, St. Francis, Union)."

From NatureServe (2022):

"Also occurs in North Carolina (Wayne Starnes, pers. comm., 2006)."

From Edwards et al. (2021):

"Collections of Golden Topminnow were notable in that these collections are the first report of the Golden Topminnow in the upper San Marcos River, which is 230 river km upstream from the nearest known population in Bird's Creek in the lower reach of the Guadalupe River [Texas]."

Fuller (2019) report nonindigenous occurrences of *F. chrysotus* from two States: Arkansas (L'Anguille and Little Missouri basins) in 2019, and Texas (San Marcos basin) in 2020.

From Fuller (2019):

"Status: Probably established in Texas."

From Wills et al (1998):

"The golden topminnow, *Fundulus chrysotus* (Günther), is historically known in Missouri from only five specimens collected from two localities in Dunklin and Pemiscot counties, both in the 'bootheel' region. No other *F. chrysotus* have been found in Missouri since 1944 and 1946, when

these specimens were collected. The species has been considered extirpated in Missouri (Anon. 1997, Pflieger 1997). However, we recently collected six specimens of *F. chrysotus* during a survey of the fishes of the Saint John's drainage and the New Madrid floodway in New Madrid and Mississippi counties in the southwestern region of Missouri."

Fundulus chrysotus is available in the pet trade in the United States (e.g., Wild Fish Tanks 2022), though no estimates of trade volume were found.

Regulations

Hawaii lists *Fundulus chrysotus* on the list of conditionally approved animals (Hawaii Department of Agriculture 2019).

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

Means of Introductions within the United States

From Edwards et al. (2021):

"It is unclear if the 2 Golden Topminnows collected in the upper San Marcos River represent a natural population expansion or resulted from human-mediated transport."

From Fuller (2019):

"Means of Introduction: Unknown."

Remarks

No additional remarks.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

According to Fricke et al. (2022), *Fundulus chrysotus* is the current valid name for this species. Synonyms of this species include: *F. kompi, F. scartes, Gambusia arlingtonia, Haplochilus chrysotus,* and *Zygonectes henshalli.*

From ITIS (2022):

Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Deuterostomia
Phylum Chordata
Subphylum Vertebrata
Infraphylum Gnathostomata
Superclass Actinopterygii
Class Teleostei
Superorder Acanthopterygii

Order Cyprinodontiformes
Suborder Cyprinodontoidei
Family Fundulidae
Genus *Fundulus*
Species *Fundulus chrysotus* (Günther, 1866)

Size, Weight, and Age Range

From Froese and Pauly (2022):

"Max length: 8.5 cm TL [total length] male/unsexed [Huber 1996] common length: 4.0 cm TL male/unsexed; [Hugg 1996]"

From Edwards et al. (2021):

"Age-0 fish grow rapidly, reaching 30 mm (SL [standard length]) within 3 months, and can become sexually mature within 10 months (Foster 1967). Lifespan of the Golden Topminnow is 2 years (Foster 1967)."

Environment

From NatureServe (2022):

"Habitat includes swamps, sloughs, backwaters, and pools of ditches and slow-moving creeks and small to medium rivers; […] (Lee et al. 1980, Page and Burr 2011); occasionally they occurs [sic] in brackish water along the coast."

From Edwards et al. (2021):

"Baseflow of the upper San Marcos River [where *F. chrysotus* was collected] is primarily from spring outflows of the Edwards Aquifer, which provide year-round 20 – 24 °C water temperatures (Groeger et al. 1997)."

Climate

From Froese and Pauly (2022):

"Subtropical […]"

Distribution Outside the United States

Native

The native range of *Fundulus chrysotus* is not known to extend outside of the United States. See section 1 for a description of the native range.

Introduced

No records were found for introductions of *Fundulus chrysotus* in the wild outside the United States.

Means of Introduction Outside the United States

No records were found for introductions of *Fundulus chrysotus* in the wild outside the United States.

Short Description

From Hendrickson and Cohen (2022):

"Life colors: Dark spots on body absent or small and not in rows; body mottled, barred or irregularly spotted; body barred or not but never with a dark spot on dorsal part of caudal peduncle (Hubbs et al.1991). The back is olive and has dark, narrow, predorsal stripe. There are considerable color differences between the sexes. Males have 7-11 vertical bars (often faint) and a scattering of red dots on the sides; both are best developed posteriorly. Males also have flecks of iridescent blue or gold along the sides of the head and body. The undersides of the head and body are white or silver. The caudal fin has four or five rows of red spots, and there are spots on both the dorsal and anal fins. Fins are yellow to white. The pectoral and pelvic fins are generally unpigmented, except for small melanophores along the fins rays. Females and juveniles lack the vertical bar, gold flecks, and red spots, but may have smaller bluish spots on the sides. Both sexes lack a suborbital bar and horizontal lateral band (Ross 2001)."

"Counts: Usually 10 anal fin rays; fewer than 15 scale rows from pelvic fin origin to isthmus; 30-40 longitudinal scale rows (Hubbs et al., 1991)."

"Body shape: Slender (Ross 2001). Eye contained fewer than one and one half times in snout (Hubbs et al. 1991)."

"Mouth position: Supraterminal (Goldstein and Simon 1999)."

Biology

From NatureServe (2022):

"**Immature Food Habits:** Invertivore
Adult Food Habits: Invertivore
Food Comments: Eats mainly insects and other aquatic invertebrates near or at the surface."

"[…]; these topminnows usually are associated with heavy submergent aquatic vegetation (Lee et al. 1980, Page and Burr 2011); […]"

From Edwards et al. (2021):

"[…] feeding primarily on surface invertebrates (e.g., water beetles [Haliplidae], midges [Chironomidae]; Goldstein and Simon 1999, Hunt 1953). Its [*F. chrysotus*] reproductive season is April through September (De Vlaming et al. 1978, Foster 1967, Hellier 1967), with Golden Topminnow depositing multiple batches of eggs with adhesive threads on plants and substrates (Foster 1967, Leitholf 1917, Pflieger 1975)."

Human Uses

From Froese and Pauly (2022):

"Aquarium: commercial."

Fundulus chrysotus is available in the pet trade in the United States (e.g., Wild Fish Tanks 2022), though no estimates of trade volume were found.

Diseases

No information was found associating *Fundulus chrysotus* with any diseases listed by the World Organisation of Animal Health (2022).

According to Poelen et al. (2014), *Fundulus chrysotus* hosts the following parasites: *Eustrongylides ignotus* and *Neoechinorhynchus* sp.

From McAllister et al. (2019):

"Between March 2016 and March 2018, 52 golden topminnows, *Fundulus chrysotus*, were collected in the Arkansas […] Twenty-three (44%) were infected/infested, including 1 (2%) with *Calyptospora funduli*, 4 (8%) with *Myxobolus* sp., 9 (18%) with *Salsuginus* sp., 2 (4%) with *Homalometron* sp., 2 (4%) with metacercaria of *Clinostomum marginatum*, 4 (8%) with *Posthodiplostomum minimum*, 5 (10%) with immature *Proteocephalus* sp., 4 (8%) with larval *Eustrongylides* sp., 5 (10%) with acanthocephalan cystacanths, 2 (4%) with *Leptorhynchoides* sp., 1 (2%) with *Neoechinorhynchus* sp., and 1 (2%) with *Lernaea cyprinacea*."

Threat to Humans

From Froese and Pauly (2022):

"Harmless"

3 Impacts of Introductions

From Fuller (2019):

"The impacts of this species are currently unknown, as no studies have been done to determine how it has affected ecosystems in the invaded range. The absence of data does not equate a lack of effects. It does, however, mean that research is required to evaluate effects before conclusions can be made."

Hawaii lists *Fundulus chrysotus* on the list of conditionally approved animals (Hawaii Department of Agriculture 2019).

4 History of Invasiveness

The History of Invasiveness for *Fundulus chrysotus* is classified as Data Deficient. There are records of occurrences outside of the native range (i.e., Texas and Arkansas) and the species is most likely established in Texas. It is uncertain if these occurrences represent natural expansion or anthropogenic introductions, and no information was found regarding the negative impacts *F. chrysotus* may or may not have outside of its native range.

5 Global Distribution

Figure 1. Reported global distribution of *Fundulus chrysotus.* Map from GBIF Secretariat (2022). Observations are primarily reported from the southeastern United States. The occurrence in Michigan was excluded from the climate matching analysis as the record information indicates that the specimens may represent a different species and no evidence suggests that there is an established population of *F. chrysotus* in Michigan. The point in the Gulf of Mexico was also excluded due to coordinate error.

6 Distribution Within the United States

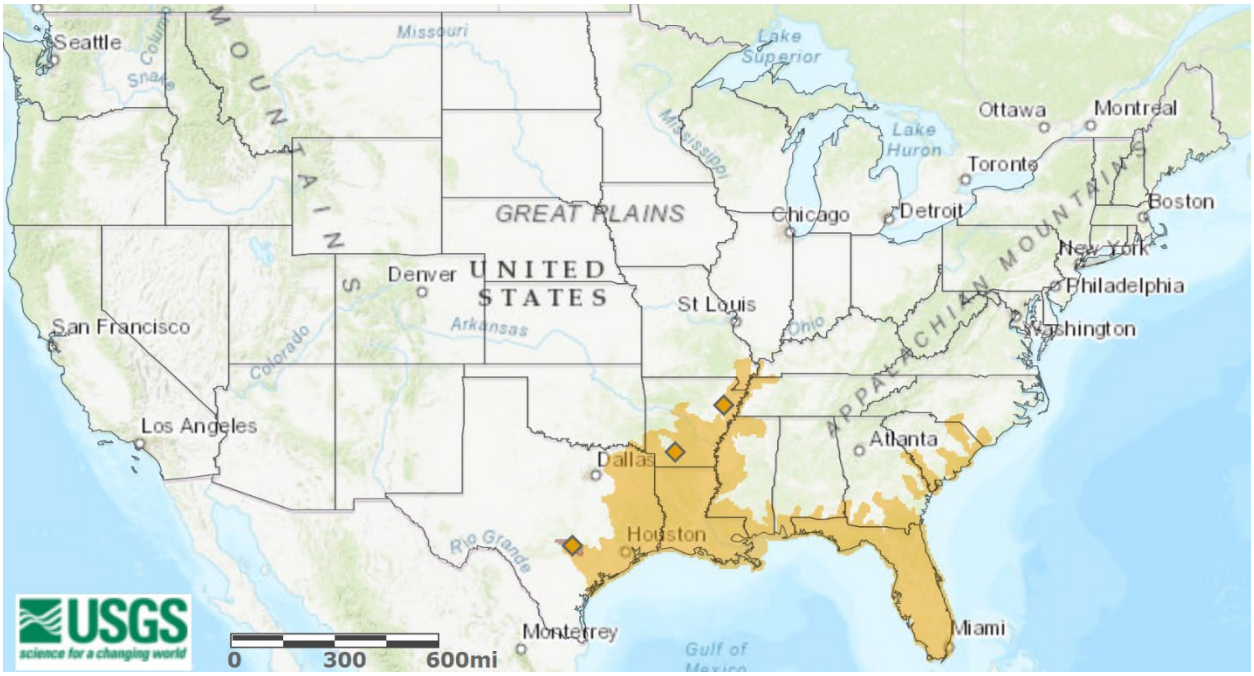

Figure 2. Reported distribution of *Fundulus chrysotus* in the United States. Map from Fuller (2019). Observations outside the native range are reported from Texas and Arkansas (orange diamonds); orange shading indicates the native range of this species.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Fundulus chrysotus* was variable for the contiguous United States with large areas of high match in the Southeast where the species is native, areas of medium match in the Midwest and Northeast, and generally low matches in western and the northernmost States. The areas of highest match were found in coastal drainages from Texas to North Carolina and in the lower Mississippi River basin, where this species is native. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.463, indicating that Yes, there is establishment concern for this species outside its native range. The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). Establishment concern is warranted for Climate 6 scores greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024).

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

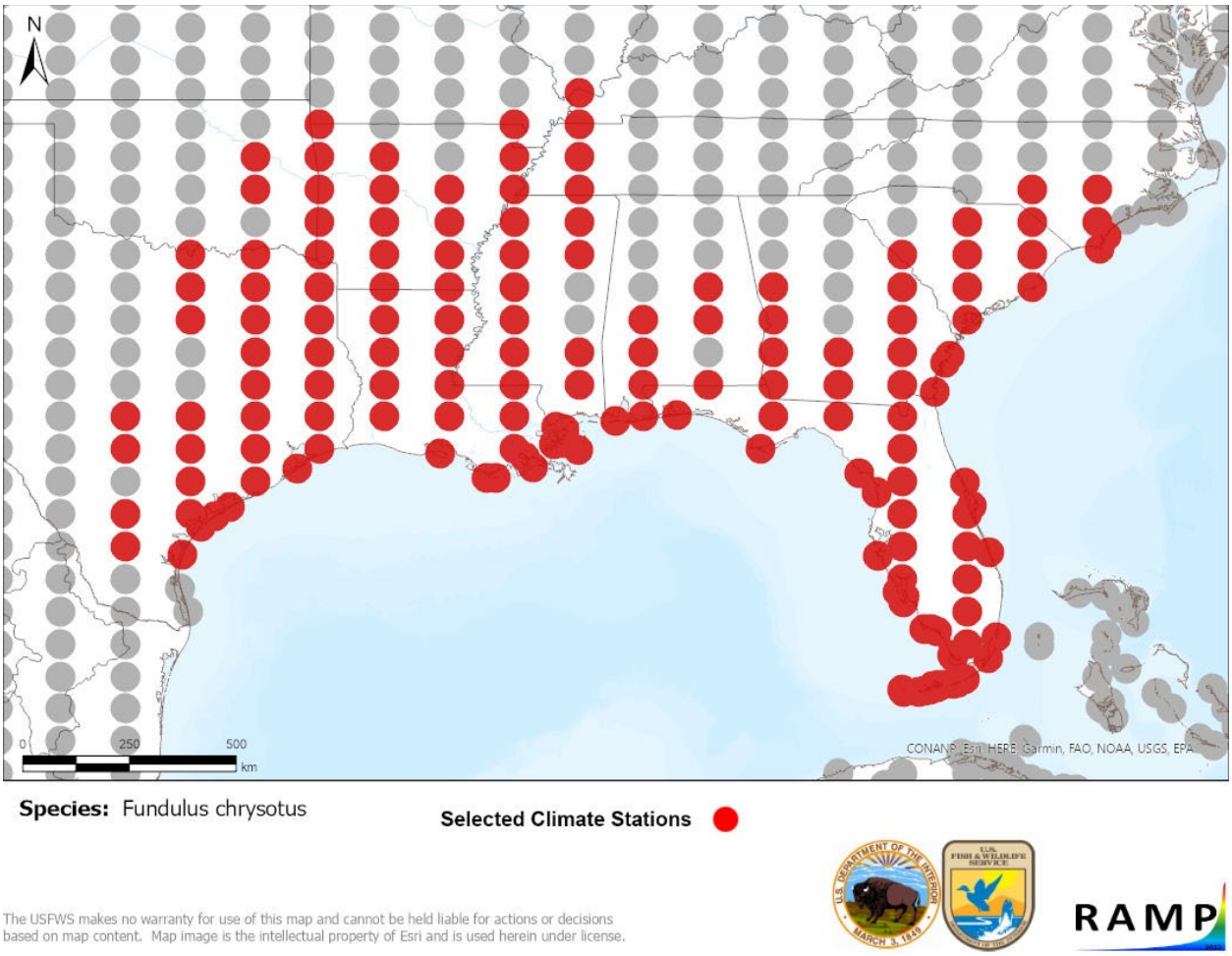

Figure 3. RAMP (Sanders et al. 2023) source map showing weather stations in the southeastern and central United States selected as source locations (red) and non-source locations (gray) for *Fundulus chrysotus* climate matching. Source locations from GBIF Secretariat (2022). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

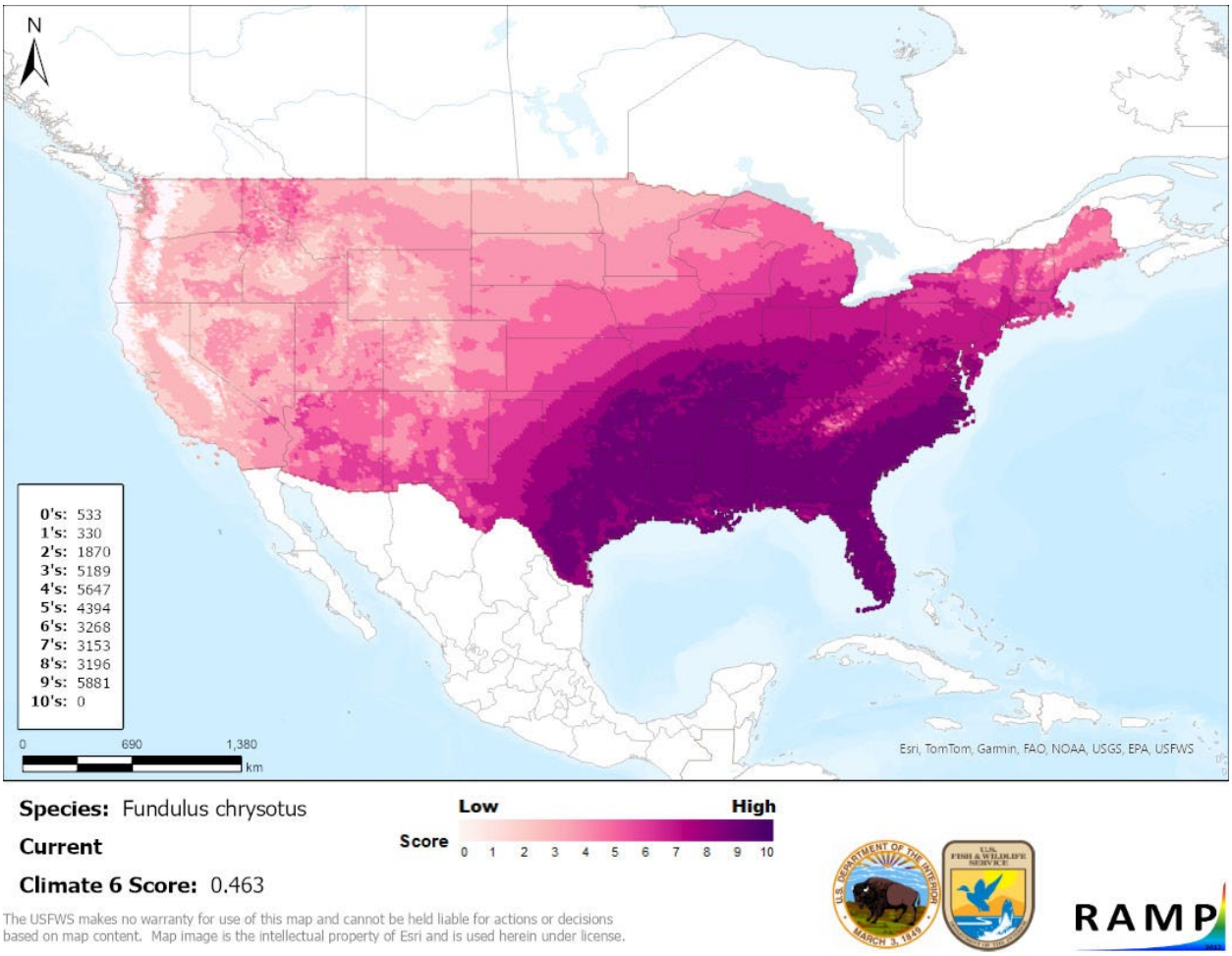

Figure 4. Map of RAMP (Sanders et al. 2023) climate matches for *Fundulus chrysotus* in the contiguous United States based on source locations reported by GBIF Secretariat (2022). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment for *Fundulus chrysotus* is classified as Low. There is reasonably complete information regarding the species biology and distribution. Records of introduction were found but there was no information regarding any impacts of introduction. Therefore, the overall certainty of this assessment is Low.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Fundulus chrysotus, the Golden Topminnow, is a small freshwater fish that is native to the Atlantic and Gulf Coastal Plain in the southeastern United States, although it is mostly restricted to the lower Coastal Plain. There have been limited introductions in Arkansas and Texas, and it is thought to be established in Texas. No information on impacts of introductions was found. *F. chrysotus* is available via the pet trade but no estimates were found regarding quantity or

duration of trade. Hawaii lists *F. chrysotus* as a conditionally approved species; no other State regulations were found during this assessment. The History of Invasiveness for *F. chrysotus* is classified as Data Deficient due to the lack of information on impacts of non-native populations. The climate matching analysis for the contiguous United States indicates establishment concern for this species outside its native range. The highest matches were found in the Southeast centered around where this species is native. The Certainty of Assessment for this ERSS is classified as Low due to the lack of impact information. The Overall Risk Assessment Category for *F. chrysotus* in the contiguous United States is Uncertain.

Assessment Elements

- **History of Invasiveness (see section 4): Data Deficient**
- **Establishment Concern (see section 7): Yes**
- **Certainty of Assessment (see section 8): Low**
- **Remarks, Important additional information: None**
- **Overall Risk Assessment Category: Uncertain**

10 Literature Cited

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

Edwards CR, Thiels SE, Sullivan KT, Guajardo J, Littrell BM, Bonner TH. 2021. Occurrence of golden topminnow, *Fundulus chrysotus*, in the San Marcos River, Texas. Southeastern Naturalist Notes 20(3):N83–N87.

Fricke R, Eschmeyer WN, van der Laan R, editors. 2022. Eschmeyer's catalog of fishes: genera, species, references. California Academy of Science. Available: https://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp (December 2022).

Froese R, Pauly D, editors. 2022. *Fundulus chrysotus* (Günther, 1866). FishBase. Available: http://www.fishbase.us/summary/SpeciesSummary.php?ID=3187&genusname=Fundulus&speciesname=chrysotus&AT=Fundulus+chrysotus&lang=English (December 2022).

Fuller P. 2019. *Fundulus chrysotus* (Günther, 1866). Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=684 (December 2022).

GBIF Secretariat. 2022. GBIF backbone taxonomy: *Fundulus chrysotus* (Günther, 1866). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5203617 (December 2022).

Hawaii Department of Agriculture. 2019. Non-domestic animal import rules. Hawaii Administrative Rules Chapter 4 –71.

Hendrickson DA, Cohen AE. 2022. Fishes of Texas Project Database. Version 3.0. Austin: Texas Advanced Computing Center, University of Texas. Available: http://doi.org/10.17603/C3WC70 (January 2023).

[ITIS] Integrated Taxonomic Information System. 2022. *Fundulus chrysotus* (Günther, 1866). Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=165652 (December 2022).

McAllister CT, Fayton TJ, Cloutman DG, Bursey CR, Robison HW, Trauth SE, Whipps CM. 2019. Parasites of the golden topminnow, *Fundulus chrysotus* (Cyprinodontiformes: Fundulidae), from Arkansas, U.S.A. Comparative Parasitology 87:19–32.

McAllister CT, Robison HW, Buchanan TM. 2006. Noteworthy geographic distribution records for the golden topminnow, *Fundulus chrysotus* (Cyprinodontiformes: Fundulidae), from Arkansas. Journal of the Arkansas Academy of Science 60(32):185–188.

NatureServe. 2022. NatureServe Explorer: an online encyclopedia of life. Arlington, Virginia: NatureServe. Available: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.100956/Fundulus_chrysotus (December 2022).

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

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

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

Wild Fish Tanks. 2022. Golden topminnow (*Fundulus chrysotus* Killifish). Available: https://www.wildfishtanks.com/product/goldentopminnow/34 (December 2022).

Wills PS, Sheehan RJ, Heidinger RC, Burr BM, Alarcón MN. 1998. Range expansion for the golden topminnow, *Fundulus chrysotus* (Günther), and its rediscovery in Missouri. Journal of Freshwater Ecology 13(2):253–254.

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

11 Literature Cited in Quoted Material

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

Anonymous. 1997. Rare and endangered species checklist of Missouri. Jefferson City: Missouri Department of Conservation.

Buchanan TM. 2005. Small fish species of Arkansas reservoirs. Journal of the Arkansas Academy of Science 59:26–42.

Buchanan TM, Wilson D, Claybrook LG, Layher WG. 2003. Fishes of the Red River in Arkansas. Journal of the Arkansas Academy of Science 57:18–26.

De Vlaming VL, Kuris A, Parker Jr FR. 1978. Seasonal variation of reproduction and lipid reserves in some subtropical cyprinodontids. Transactions of the American Fisheries Society 107(3):464–472.

Etnier DA, Starnes WC. 1993. The fishes of Tennessee. Knoxville: University of Tennessee Press.

Foster NR. 1967. Comparative studies on the biology of killifishes (Pisces: Cyprinodontidae). Doctoral dissertation. Ithaca, New York: Cornell University.

Goldstein RM, Simon TP. 1999. Toward a united definition of guild structure for feeding ecology of North American freshwater fishes. Pages 123–202 in Simon TP, editor. Assessing the sustainability and biological integrity of water resources using fish communities. Boca Raton, Florida: CRC Press.

Groeger AW, Brown PF, Tietjen TE, Kelsey TC. 1997. Water quality of the San Marcos River. Texas Journal of Science 49(4):279–294.

Günther A. 1866. Catalogue of the Physostomi, containing the families Salmonidae, Percopsidae, Galaxidae, Mormyridae, Gymnarchidae, Esocidae, Umbridae, Scombresocidae, Cyprinodontidae, in the collection of the British Museum. Catalogue of fishes in the British Museum 6:i –xv, 1–368.

Hellier TR. 1967. The fishes of the Santa Fe river system. Bulletin of Florida State Museum, Biological Sciences Series 2:1–46.

Hubbs C, Edwards RJ, Garret GP. 1991. An annotated checklist of freshwater fishes of Texas, with key to identification of species. Texas Journal of Science, Supplement 43(4):1–56.

Huber JH. 1996. Killi-data 1996. Updated checklist of taxonomic names, collecting localities and bibliographic references of oviparous Cyprinodont fishes (Atherinomorpha, Pisces). Paris: Société Française d'Ichtyologie, Muséum National d'Histoire Naturelle.

Hugg DO, Hugg S. 1996. MAPFISH georeferenced mapping database. Freshwater and estuarine fishes of North America. Edgewater, Maryland: Life Science Software.

Hunt BP. 1953. Food relationships between Florida spotted gar and other organisms in the Tamiami Canal, Dade County, Florida. Transactions of the American Fisheries Society 82:13–33.

Lee DS, Gilbert CR, Hocutt CH, Jenkins RE, McAllister DE, Stauffer Jr JR. 1980. Atlas of North American freshwater fishes. Raleigh: North Carolina State Museum of Natural History.

Leitholf E. 1917. *Fundulus chrysotus*. Aquatic Life 2(11):141–142.

Page LM, Burr BM. 1991. A field guide to freshwater fishes of North America north of Mexico. The Peterson Field Guide Series. Volume 42. Boston: Houghton Mifflin Company.

Page LM, Burr BM. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Second edition. Boston: Houghton Mifflin Harcourt.

Pflieger WL. 1975. The fishes of Missouri. Columbia: Missouri Department of Conservation.

Pflieger WL. 1997. The fishes of Missouri. Revised edition. Jefferson City: Missouri Department of Conservation.

Robinson HW. 2005. Fishes of the Pine Bluff Arsenal, Jefferson County, Arkansas. Journal of the Arkansas Academy of Science 59:148–157.

Robinson HW, Buchanan TM. 1988. Fishes of Arkansas. Fayetteville: University of Arkansas Press.

Ross ST. 2001. Inland fishes of Mississippi. Jackson: University Press of Mississippi.

Shute JR. 1980. *Fundulus chrysotus*. Page 510 in Lee DS et al., editors. Atlas of North American freshwater fishes. Raleigh: North Carolina State Museum of Natural History.

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 (2022).

Under the future climate scenarios (figure A1), on average, high climate match for *Fundulus chrysotus* was projected to occur in the Appalachian Range, Great Lakes, Gulf Coast, Mid-Atlantic, and Southeast regions of the contiguous United States. Extent of areas of high match decreased over time. Areas of low climate match were projected to occur in California and the Northern Pacific Coast regions. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.521 (model: MPI-ESM1-2-HR, SSP5, 2085) to a high of 0.685 (model: UKESM1-0-LL, SSP5, 2085). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species outside its native range. The Climate 6 score for the current climate match (0.463, figure 4) falls below 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 (figure A3). Under one or more time step and climate scenarios, areas within the Colorado Plateau, Great Lakes, Northeast, and Northern Plains saw a large increase in the climate match relative to current conditions. Additionally, areas within the Great Basin, Northern Pacific Coast, Southern Plains, and Western Mountains saw a moderate increase in the climate match relative to current conditions. Under one or more time step and climate scenarios, areas within the Gulf Coast, Southeast, Southern Plains, and Southwest regions saw a moderate decrease in the climate match relative to current conditions. No large decreases were observed regardless of time step and climate scenarios. The degree of change increased with time and from SSP3 to SSP5.

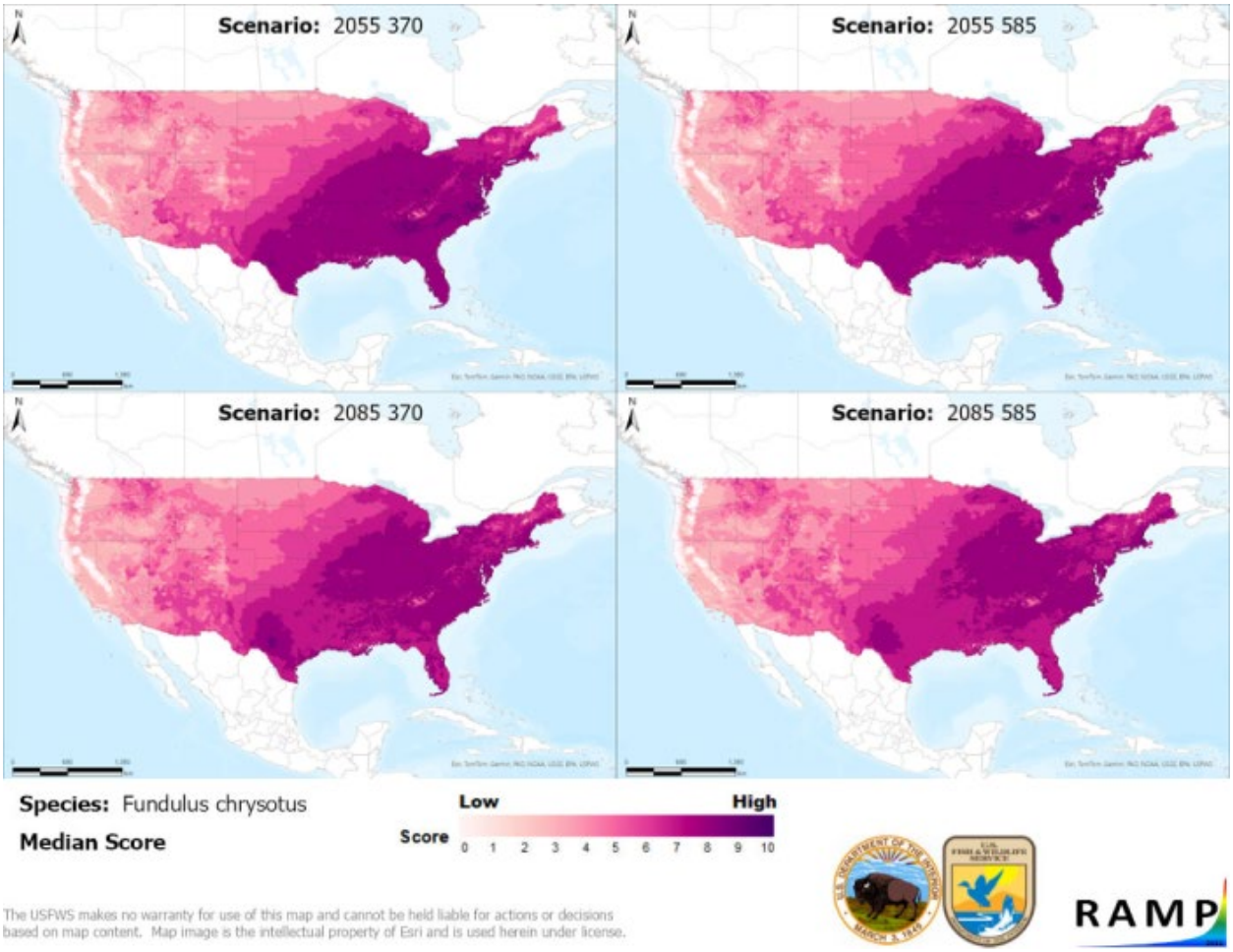

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Fundulus chrysotus* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2022). Shared 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.

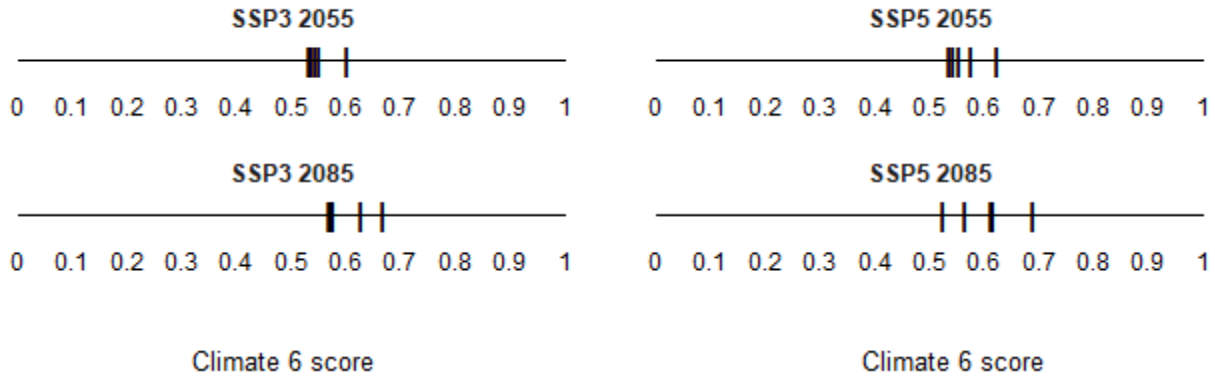

Figure A2. Comparison of projected future Climate 6 scores for *Fundulus chrysotus* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018;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

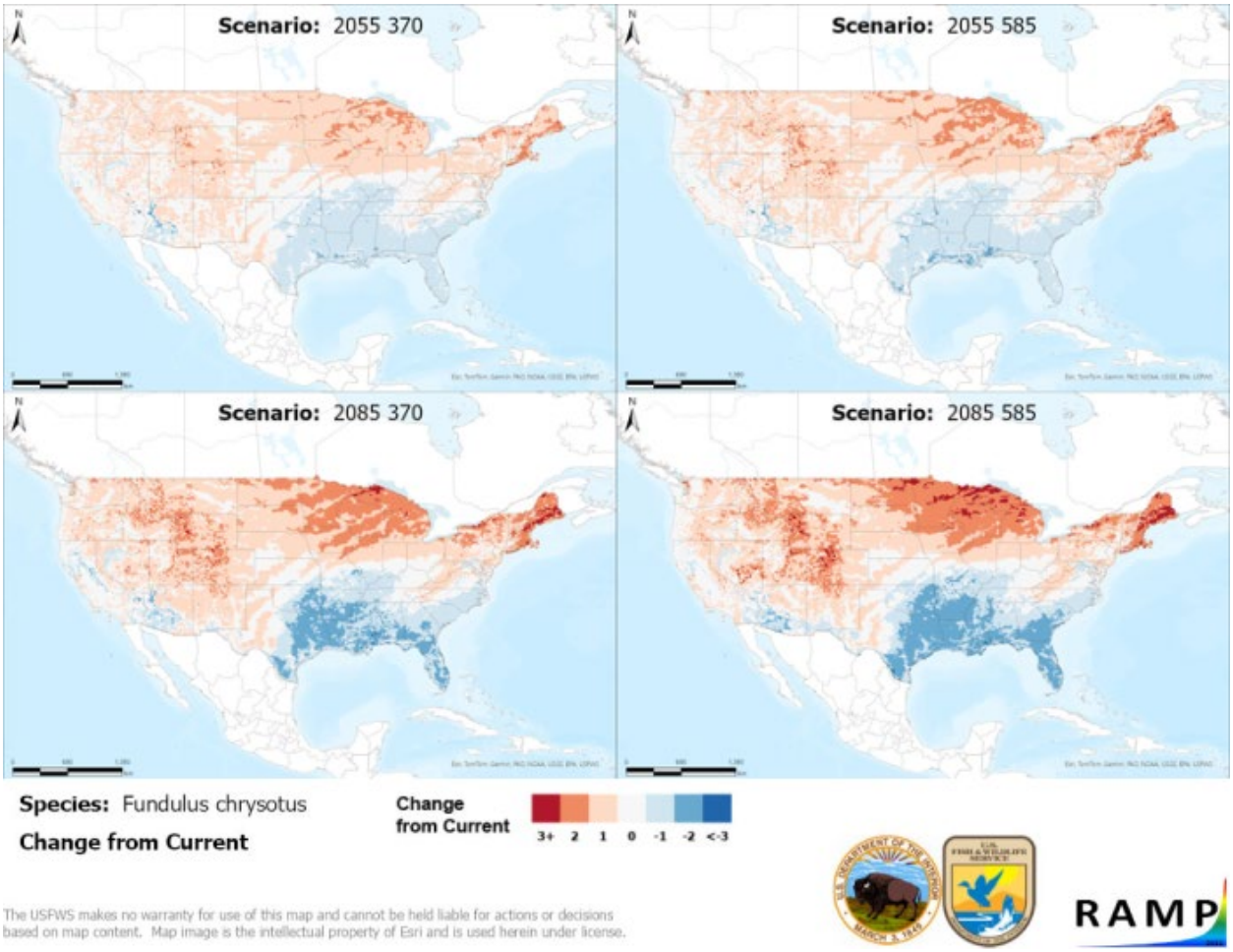

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 4) and the median target point score for future climate scenarios (figure A1) for *Fundulus chrysotus* based on source locations reported by GBIF Secretariat (2022). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. Shades of blue indicate a lower target point score under future scenarios than under current conditions. Shades of red indicate a higher target point score under future scenarios than under current conditions. Darker shades indicate greater change.

Literature Cited

GBIF Secretariat. 2022. GBIF backbone taxonomy: *Fundulus chrysotus* (Günther, 1866). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5203617 (December 2022).

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

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

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

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