

Orangespotted Sunfish (*Lepomis humilis*)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, December 2022
Revised, December 2022
Web Version, 3/5/2025

Organism Type: Fish
Overall Risk Assessment Category: Uncertain



Photo: Koaw Nature. Licensed under Creative Commons Attribution-NonCommercial 4.0 International. Available: <https://www.inaturalist.org/photos/142674249> (December 2022).

1 Native Range and Status in the United States

Native Range

From NatureServe (2022):

“Mostly in Mississippi basin (Ohio to southern North Dakota, south to Louisiana) and Gulf Slope drainages (Mobile Bay, Alabama, to Colorado River, Texas), and north to southern Great Lakes region.”

According to Fuller et al. (2022a), *Lepomis humilis* is native to the following U.S. States: Alabama, Arkansas, Colorado, Georgia, Iowa, Illinois, Indiana, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Missouri, Mississippi, North Dakota, Nebraska, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Wisconsin, and West Virginia.

Status in the United States

From NatureServe (2022):

“Mostly in Mississippi basin (Ohio to southern North Dakota, south to Louisiana) and Gulf Slope drainages (Mobile Bay, Alabama, to Colorado River, Texas), and north to southern Great Lakes region.”

“[...] Introduced to west and east of native range, though rarely intentionally. Page and Burr (1991) included the Hudson Bay (Red River) basin in their range description, but did not include this area on their range map; presumably it has been introduced there.”

From Fuller et al. (2022a):

“Established where recorded.”

Fuller et al. (2022a) reports nonindigenous occurrences of *Lepomis humilis* from the following States: Alabama, Colorado, Florida, Georgia, Idaho, Indiana, Kentucky, Michigan, Minnesota, Mississippi, Missouri, North Dakota, Ohio, Pennsylvania, South Dakota, Texas, West Virginia, and Wisconsin.

Wallace and Zaroban (2013) list *Lepomis humilis* as likely extirpated in Idaho. Courtenay et al. (1987) states that the recorded specimens in Idaho were collected from thermally regulated waters.

Lepomis humilis may be for sale in the United States. For example, aquatics wholesaler The Fish Warehouse, based in Charlotte, North Carolina, lists *L. humilis* as “sold out” on its website (The Fish Warehouse 2025).

Regulations

Lepomis humilis is regulated in Arkansas (AGFC 2022) and Hawaii (HDOA 2019). It is regulated at the family level (Centrarchidae) in Arizona (Arizona Game and Fish Commission 2022), New Hampshire (NHFG 2022), and New Mexico (NMDGF 2023). Please refer back to state agency regulatory documents for details on the regulations, including restrictions on activities involving this species. While effort was made to find all applicable regulations, this list may not be comprehensive. Notably, it does not include regulations that do not explicitly name this species or its genus or family, for example, when omitted from a list of authorized species with blanket regulation for all unnamed species.

Means of Introductions within the United States

From Fuller et al. (2022a):

“Usually unintentional stocking as stock contaminant with other centrarchids. [...] Orangespotted Sunfish expanded its range eastward across Ohio aided by introductions into farm ponds and reservoirs (Trautman 1981). It gained access to the Lake Erie drainage when it overcame a spillway (probably aided by humans) dividing the Wabash (Ohio basin) from the St. Marys system (Great Lakes basin). It then invaded the Maumee River and progressed downriver to Lake Erie (Trautman 1981).”

From Warren (2009):

“In historical times, the species expanded its range into southeastern Michigan and adjacent Ontario, northward in Wisconsin, and eastward across Indiana and Ohio, as agricultural activities converted formerly clear prairie-type streams into turbid plains-type streams (Trautman 1981; Holm and Coker 1981; Becker 1983; Noltie 1990; Bailey et al. 2004).”

Remarks

From Fuller et al. (2022b):

“Originally thought to be native to Lake St. Clair and Lake Erie and expanding into Canadian Waters (Cudmore-Volkey and Crossman, 2000). More recent research has found that *L. humilis* is not native to the Great Lakes (COSEWIC, 2008; Roth et al., in prep)”

“*L. humilis* was originally listed in Canada under the Species at Risk Act (SARA), but it was removed once its native status was revised (COSEWIC, 2008) [...]”

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2022):

Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Deuterostomia
Phylum Chordata
Subphylum Vertebrata
Infraphylum Gnathostomata
Superclass Actinopterygii
Class Teleostei
Superorder Acanthopterygii
Order Perciformes
Suborder Percoidei
Family Centrarchidae
Genus *Lepomis*

Species *Lepomis humilis* (Girard, 1858)

According to Fricke et al. (2022), *Lepomis humilis* is the current valid name for this species.

Size, Weight, and Age Range

From Froese and Pauly (2022):

“Max length : 15.0 cm TL [total length] male/unsexed; [Page and Burr, 1991]; common length : 7.4 cm TL male/unsexed; [Hugg, 1996]; max. reported age: 4 years [Altman and Dittmer, 1962]”

From Fuller et al. (2022a):

“3-15 cm at sexual maturity”

Environment

From NatureServe (2022):

“Sloughs, lakes, ponds, rivers, and creeks; in quiet pools in streams [...] (Becker 1983)”

From Froese and Pauly (2022):

“Inhabits quiet pools of creeks and small to large, often turbid, rivers; usually near brush [Page and Burr, 1991; Etnier and Starnes, 1993]”

“Freshwater; benthopelagic [...] 10°C - 28°C [Baensch and Riehl 1995; assumed to be recommended aquarium water temperature]”

From Hegrenes (2001):

“Orangespotted sunfish often inhabit small, turbid streams that may lack vegetation [...] (Noltie 1990)”

From Fuller et al. (2022a):

“They have a higher tolerance to turbidity and pollution compared to other sunfishes (Hegrenes, 2000).”

Climate

From Froese and Pauly (2022):

“Temperate”

Distribution Outside the United States

Native

The native range of *Lepomis humilis* is entirely within the United States, see Native Range in section 1.

Introduced

From Eakins et al. (2022):

“Ontario [Canada] Origin [...] introduced”

“[In Canada:] Cedar Creek (Lake Erie tributary), Canard River (Detroit River tributary), Lake Erie (Pelee Island), Big Creek (Lake Erie tributary); first reported from Ontario in 1980”

GBIF Secretariat (2022) lists six records of preserved specimens that were caught in Morocco (Oum Er-Ribia, Oued Ziz, Oued Ouerrha, and Oued Grou rivers). No information was found on whether these captures were from established populations.

Means of Introduction Outside the United States

From Fuller et al. (2022a):

“It gained access to the Lake Erie drainage when it overcame a spillway (probably aided by humans) dividing the Wabash (Ohio basin) from the St. Marys system (Great Lakes basin). It then invaded the Maumee River and progressed downriver to Lake Erie (Trautman 1981).”

Short Description

From Fuller et al. (2022a):

“Spawning males carry orange-red lines of the cheeks and gill covers. Their bellies and lower fins are reddish. Ear lobes are dark with a pale border. Large mouth that extends to front of eye when closed; spiny dorsal fin with 10 spines, directly connected to soft part of fin; long gill flap with vivid orange spots on the side; medium gill raker length; sides olive colored with fine golden or emerald dots. Becker (1983); Hubbs et al. (1991); Page and Burr (1991); Etnier and Starnes (1993).”

“They are morphologically similar to other members of the *Lepomis* genus, but significantly smaller.”

Biology

From NatureServe (2022):

“Eggs laid on gravel in nest (often in colonies) made by male on bottom in shallow water (Becker 1983).”

From Froese and Pauly (2022):

“Feeds on microcrustaceans and aquatic insect larvae, principally chironomid dipterans [Etnier and Starnes, 1993].”

From NatureServe (2022):

“Spawns May to August in north, April to September in south. Eggs hatch in 5 days at 18-21 C. Male guards eggs. Sexually mature usually at age II. [...] (Becker 1983, Lee et al. 1980).”

From Fuller et al. (2022a):

“Like other centrarchids, *L. humilis* are generalist predators feeding on zooplankton, insect larvae, and smaller fish (Barney and Anson, 1923). Similar to Bluegill (*L. macrochirus*) *L. humilis* display morphological plasticity based on their diet; fish feeding on small planktonic prey develop a more elongate fusiform body shape while those feeding on larger prey form a taller body and blunt snout (Hegrenes, 2000).”

Human Uses

From Warren (2009):

“The orangespotted sunfish does not reach a size of interest to most anglers. The species is reportedly a good bioassay animal and aquarium fish (Becker 1983; Schleser 1998), and ecologically, is suggested as a natural biological control for mosquitoes (Barney and Anson 1923).”

From Froese and Pauly (2022):

“Aquarium: public aquariums”

Lepomis humilis may be for sale in the United States. For example, aquatics wholesaler The Fish Warehouse, based in Charlotte, North Carolina, lists *L. humilis* as “sold out” on its website (The Fish Warehouse 2025).

Diseases

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

According to Poelen et al. (2014), *Lepomis humilis* hosts the following parasites: *Acanthocephalus dirus*, *Actinocleidus* sp., *Actinocleidus fergusonii*, *Allocreadium lobatum*, *Anchoradiscus* sp., *Anchoradiscus anchoradiscus*, *Bothriocephalus claviceps*, *Camallanus* sp., *Cleidodiscus* sp., *Cleidodiscus nematocirrus*, *Clinostomum complanatum*, *Crepidostomum cooperi*, *Crepidostomum cornutum*, *Diplostomum* sp., *Echinochasmus donaldsoni*, *Eocollis arcanus*, *Gyrodactylus* sp., *Haplobothrium golbuliforme*, *Homalometron armatum*, *Leptorhynchoides thecatus*, *Lyrodiscus seminolensis*, *Neascus* sp., *Neoechinorhynchus cylindratus*, *Odhneriotrema incommodum*, *Onchocleidus* sp., *Onchocleidus cyanellus*,

Onchocleidus ferox, *Ornithodiplostomum ptychocheilus*, *Philometra* sp., *Philometroides wellborni*, *Phyllodistomum pearsei*, *Pomphorhynchus* sp., *Posthodiplostomum minimum*, *Postodiplostomum minimum*, *Proteocephalus ambloplitis*, *Pterocleidus* sp., *Spinitectus* sp., *Spinitectus carolini*, *Spinitectus micracanthus*, *Spinitectus microcephalus*, *Urocleidus* sp., *Urocleidus chaenobryttus*, *Urocleidus dispar*, and *Uvulifer* sp.

Threat to Humans

From Froese and Pauly (2022):

“Harmless”

3 Impacts of Introductions

Although *Lepomis humilis* has been reported as introduced beyond its native range, information on documented impacts from those introductions was not found. The following quotation refers to potential impacts only.

From Fuller et al. (2022a):

“Orangespotted Sunfish probably competes for food with young bass, bluegill, and crappies (Cross 1967).”

The importation, possession, and/or trade of *Lepomis humilis* is regulated in the following States (see section 1): Arkansas (AGFC 2022), Arizona (Arizona Game and Fish Commission 2022), Hawaii (HDOA 2019), New Hampshire (NHFG 2022), and New Mexico (NMDGF 2010).

4 History of Invasiveness

The History of Invasiveness for *Lepomis humilis* is classified as Data Deficient. Although established populations of *L. humilis* have been found outside of its native range, there was no information found regarding actual impacts of introduction. *L. humilis* also appears to be available for sale in the United States. However, there were no records found quantifying the duration or number of individuals in trade.

5 Global Distribution

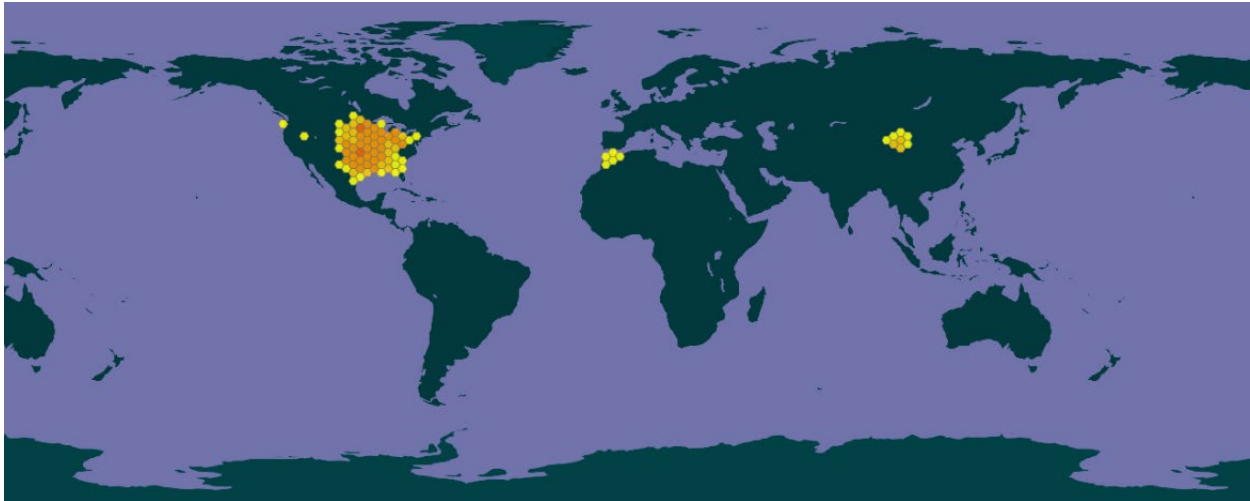


Figure 1. Known global distribution of *Lepomis humilis*. Observations are reported from the United States, Canada, China, and Morocco. Map from GBIF Secretariat (2022). Points in China and from the Pacific Ocean near Oregon were excluded from the climate matching analysis because of incorrect coordinates. Points in Morocco and a few in the United States (Idaho, eastern West Virginia, central New York) were also excluded as they were not found to represent established populations.

6 Distribution Within the United States

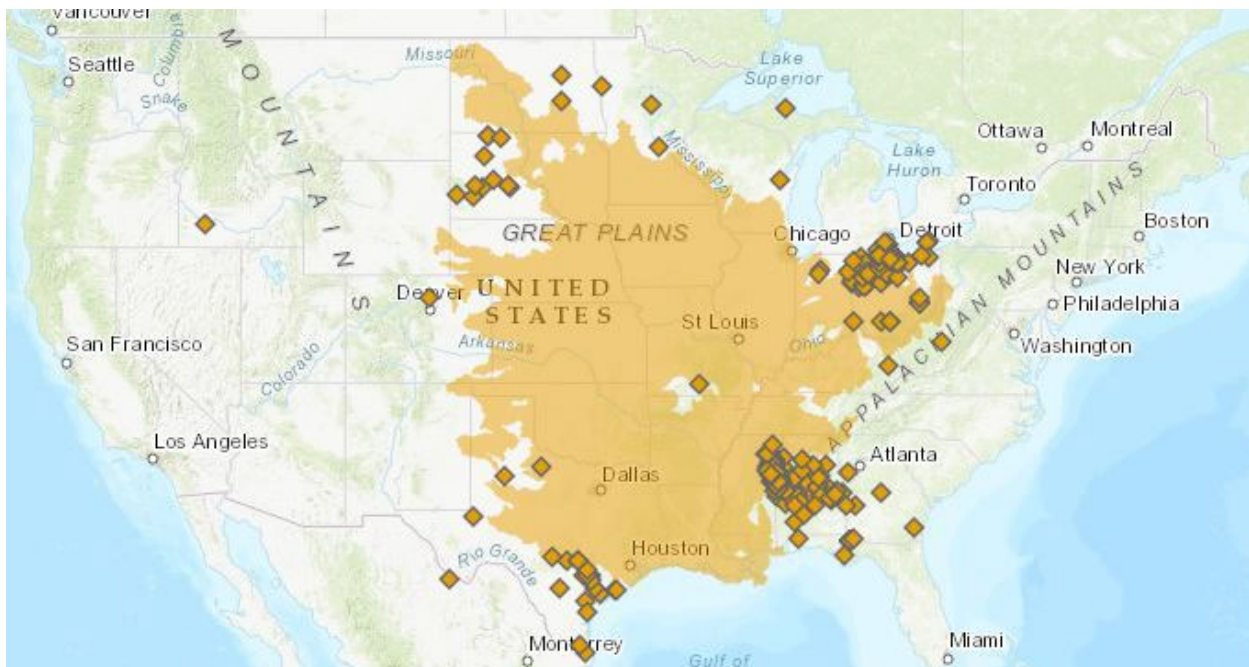


Figure 2. Map of the contiguous United States showing the native range and nonnative occurrences of *Lepomis humilis*. The orange shading represents the native range of the species;

orange diamonds represent nonnative occurrences. Map from Fuller et al. (2022a). The point in Idaho is not indicative of an established population and was excluded from the climate matching analysis.

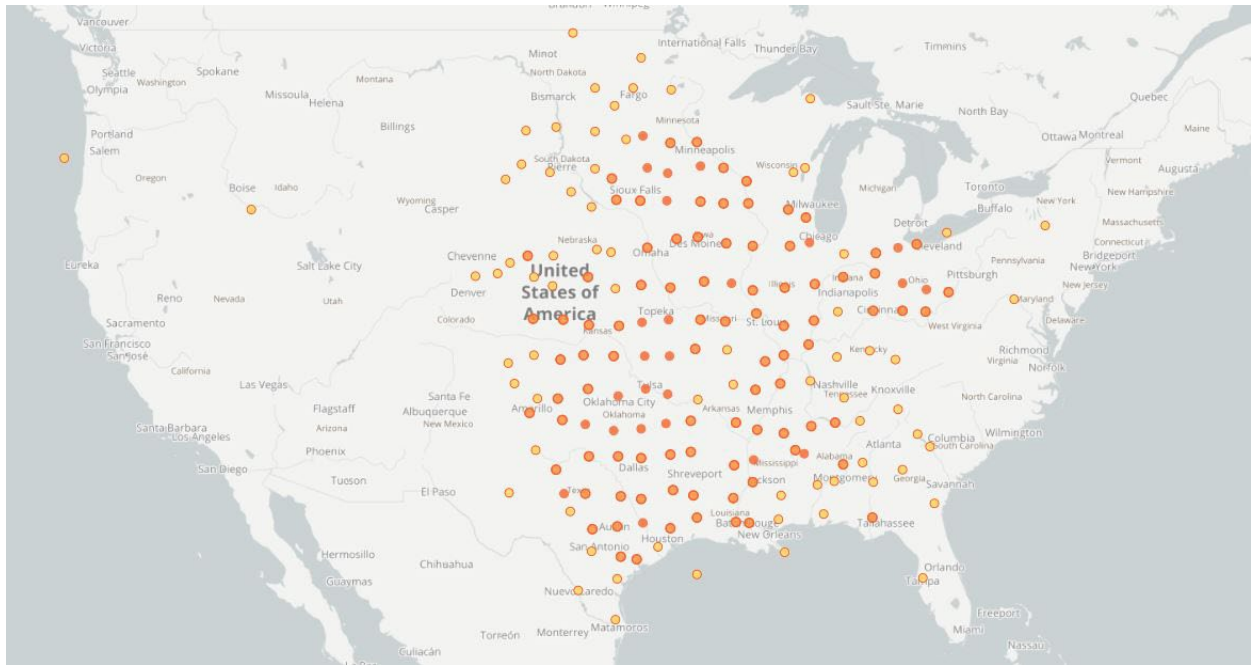


Figure 3. Reported distribution of *Lepomis humilis* in the United States. Map from GBIF-US (2022). Observations are primarily reported from states in the Midwest and southern regions of the contiguous United States. Points in Idaho, eastern West Virginia, New York, off the coast of Oregon, and in the Gulf of America are not indicative of established populations and were excluded from the climate matching analysis.

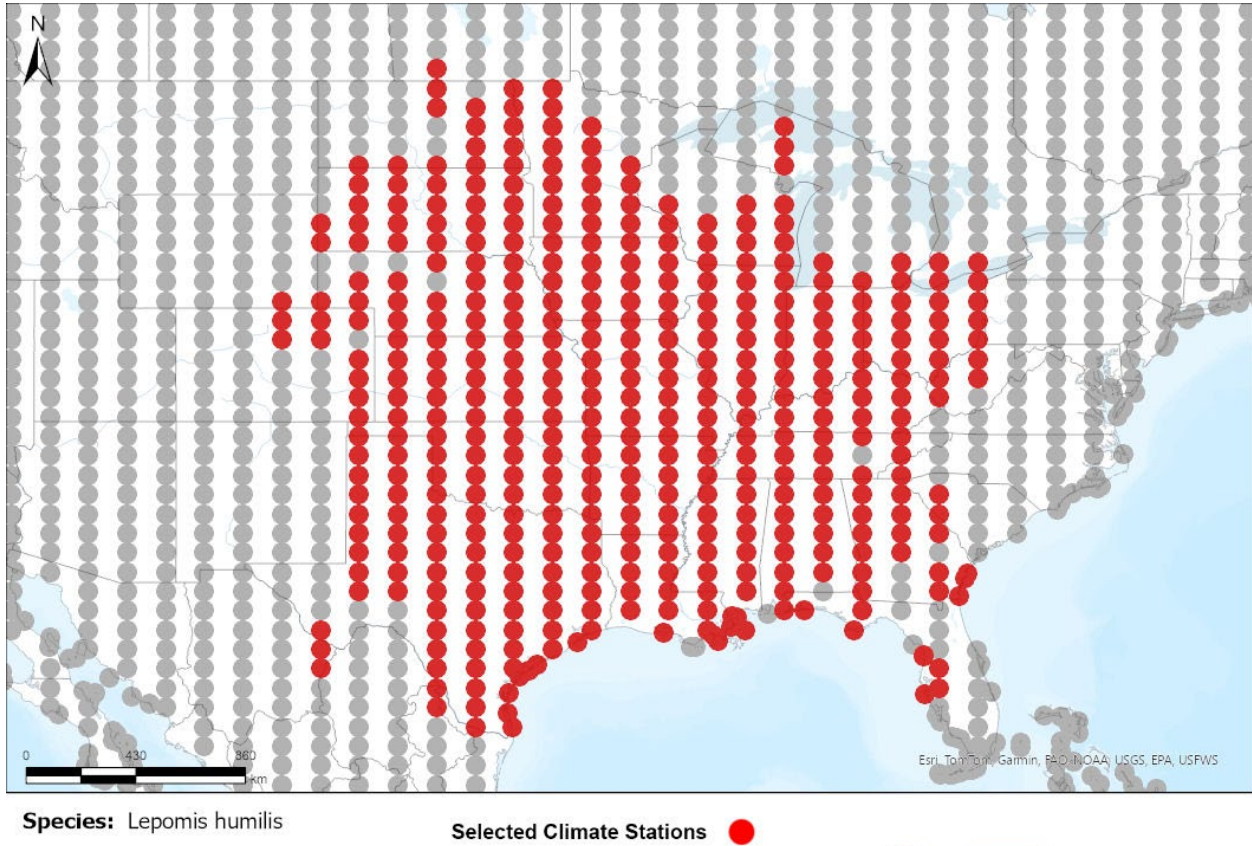
7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Lepomis humilis* in the contiguous United States was generally high from the Atlantic Coast to the Rocky Mountains, including within the species' native range. Medium matches were found in the western Rocky Mountains, Great Basin, Southwest, and in isolated portions of the Northeast. Areas of low match were restricted to the coastal Pacific Northwest, Cascade Mountains, and Sierra Nevada. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.856, 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 *Lepomis humilis* (see Appendix). These projected climate matches are provided as

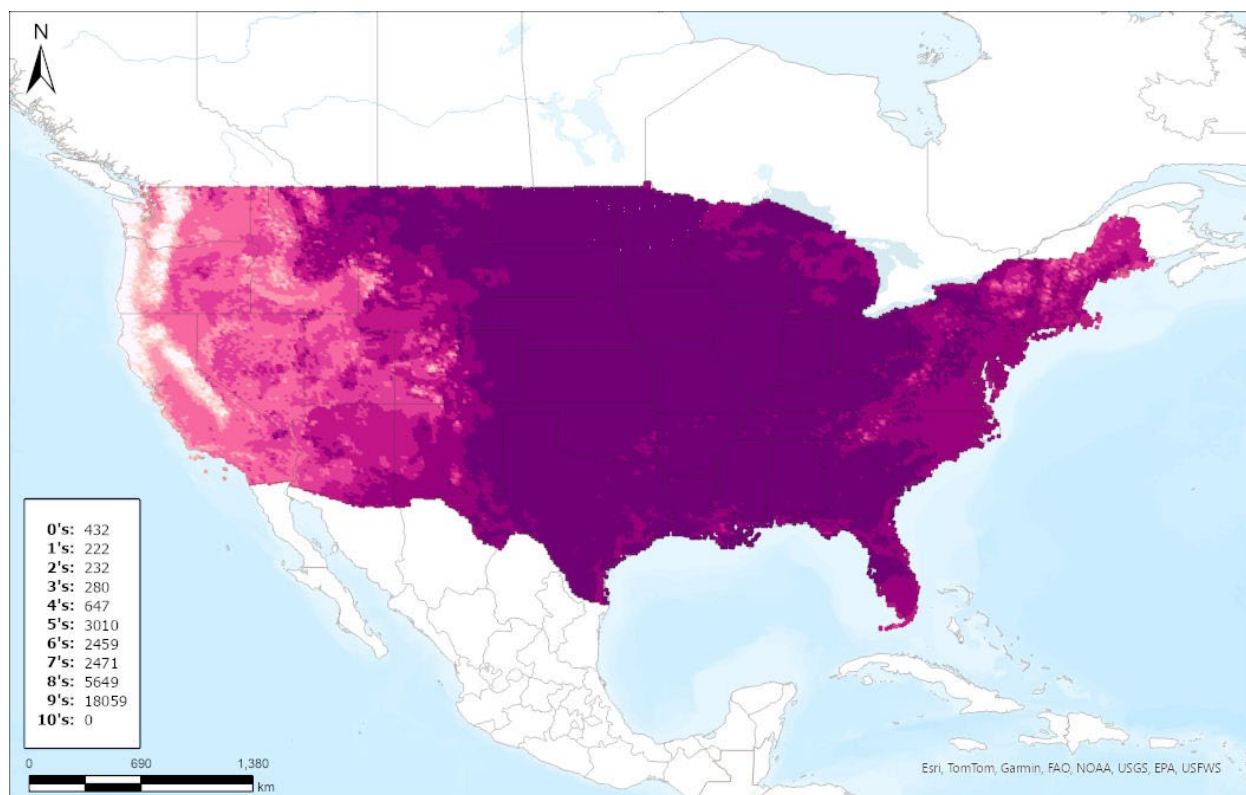
additional context for the reader; future climate scenarios are not factored into the Overall Risk Assessment Category.



The USFWS makes no warranty for use of this map and cannot be held liable for actions or decisions based on map content. Map image is the intellectual property of Esri and is used herein under license.



Figure 4. RAMP (Sanders et al. 2023) source map showing weather stations in North America selected as source locations (red; United States, Canada, Mexico) and non-source locations (gray) for *Lepomis humilis* 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.



Species: *Lepomis humilis*

Current

Climate 6 Score: 0.856



The USFWS makes no warranty for use of this map and cannot be held liable for actions or decisions based on map content. Map image is the intellectual property of Esri and is used herein under license.



Figure 5. Map of RAMP (Sanders et al. 2023) climate matches for *Lepomis humilis* 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 *Lepomis humilis* is classified as Low. Information is available on the biology, ecology, and distribution of *L. humilis*. However, no information is available on actual impacts of introduction, and minimal information is available on the use of *L. humilis* in trade.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Lepomis humilis, Orangespotted Sunfish, is a freshwater fish that is native to the Midwest and southern regions of the contiguous United States. *L. humilis* is one of the smallest species of sunfish, found in small turbid streams. They have a higher tolerance for turbidity and pollution compared to other sunfish species. They are not often targeted by anglers but may be of interest to aquarium hobbyists. *L. humilis* has been introduced to locations in North America, particularly to watersheds adjacent to its native range. Some introductions have resulted in established

nonnative populations. The History of Invasiveness for *L. humilis* is classified as Data Deficient due to a lack of information regarding impacts of introduction. The climate matching analysis for the contiguous United States indicates establishment concern for this species outside its native range. Areas of high match were found from the Atlantic Coast to the Rocky Mountains, which includes the native range of the species. The Certainty of Assessment is classified as Low due to the lack of information regarding impacts of introduction and trade. The Overall Risk Assessment Category for *Lepomis humilis* 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.

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

Arizona Game and Fish Commission. 2022. Restricted live wildlife. Arizona Administrative Code R12-4-406.

Courtenay WR Jr, Robins CR, Bailey RM, Deacon JE. 1987. Records of exotic fishes from Idaho and Wyoming. *The Great Basin Naturalist* 47(4):523–526.

Eakins RJ. 2022. Ontario freshwater fishes life history database. Available: <https://www.ontariofishes.ca/home.htm> (December 2022).

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

Froese R, Pauly D, editors. 2022. *Lepomis humilis* (Girard, 1858). FishBase. Available: <http://www.fishbase.org/summary/SpeciesSummary.php?ID=3374&AT=orangespotted+sunfish> (December 2022).

Fuller P, Jacobs G, Cannister M, Larson J, Makled TH, Fusaro A. 2022a. *Lepomis humilis* (Girard, 1858). Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: <https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=383> (December 2022).

- Fuller P, Jacobs G, Cannister M, Larson J, Makled TH, Fusaro A. 2022b. *Lepomis humilis* (Girard, 1858). Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database, and Ann Arbor, Michigan: NOAA Great Lakes Aquatic Nonindigenous Species Information System. Available: https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?Species_ID=383 (December 2022).
- GBIF Secretariat. 2022. GBIF backbone taxonomy: *Lepomis humilis*. Copenhagen: Global Biodiversity Information Facility. Available: <https://www.gbif.org/species/2394483> (December 2022).
- GBIF-US. 2022. Species occurrences: *Lepomis humilis*. Available: <https://doi.org/10.15468/dl.597yf2> (December 2022).
- [HDOA] Hawaii Department of Agriculture. 2019. Non-domestic animal import rules. Hawaii Administrative Rules Chapter 4-71.
- Hegrenes S. 2001. Diet-induced phenotypic plasticity of feeding morphology in the orangespotted sunfish, *Lepomis humilis*. *Ecology of Freshwater Fish* 10:35–42.
- [ITIS] Integrated Taxonomic Information System. 2022. *Lepomis humilis* (Girard, 1858). Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=168151#null (December 2022).
- Jonah's Aquarium. 2022. *Lepomis humilis*. Jonah's Aquarium. Available: <http://www.jonahsaquarium.com/jonahsite/piclhumilis06.htm> (December 2022).
- NatureServe. 2013. *Lepomis humilis*. The IUCN Red List of Threatened Species 2013. Available: <https://www.iucnredlist.org/species/202556/18228862> (December 2022).
- NatureServe. 2022. NatureServe Explorer: an online encyclopedia of life. Arlington, Virginia: NatureServe. Available: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.103679/Lepomis_humilis (December 2022).
- [NHFG] New Hampshire Fish and Game Department. 2022. The importation, possession and use of all wildlife. New Hampshire Code of Administrative Rules Fis 800.
- [NMDGF] New Mexico Department of Game and Fish. 2023. Director's species importation list. Santa Fe: New Mexico Department of Game and Fish. Available: <https://www.wildlife.state.nm.us/download/enforcement/importation/information/Importation-Info-Directors-Species-Importation-List-1-3-2023.pdf> (October 2023).
- Poelen JH, Simons JD, Mungall CJ. 2014. Global Biotic Interactions: an open infrastructure to share and analyze species-interaction datasets. *Ecological Informatics* 24:148–159.

- Rasmus RA, Phelps QE, Duehr JP, Berry CR. 2008. Population characteristics of lotic orangespotted sunfish. *Journal of Freshwater Biology* 23:459.
- Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.
- The Fish Warehouse. 2025. Orangespotted sunfish (*Lepomis humilis*). Available: <https://thefishwarehouse.com/products/orangespotted-sunfish-lepomis-humilis> (March 2025).
- [USFWS] U.S. Fish and Wildlife Service. 2024. Standard operating procedure: how to prepare an “Ecological Risk Screening Summary.” Version 3. Available: <https://www.fws.gov/media/standard-operating-procedures-how-prepare-ecological-risk-screening-summary-2024> (January 2025).
- Wallace RL, Zaroban DW. 2013. Native fishes of Idaho. Bethesda, Maryland: American Fisheries Society.
- Warren ML. 2009. Centrarchid identification and natural history. Page 566 in Cooke SJ, Philipp DP, editors. Centrarchid fishes: diversity, biology, and conservation. West Sussex, England: Wiley-Blackwell.
- 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.

- Altman PL, Dittmer DS. 1962. Growth, including reproduction and morphological development. Bethesda, Maryland: Federation of American Societies for Experimental Biology.
- Baensch HA, Riehl R. 1995. Aquarien Atlas. Band 4. Melle, Germany: Mergus Verlag GmbH, Verlag für Natur-und Heimtierkunde.
- Bailey RM, Latta WC, Smith GR. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Ann Arbor: University of Michigan Museum of Zoology.
- Barney RL, Anson BJ. 1923. Life history and ecology of the orange spotted sunfish (*Lepomis humilis*). Report of the U.S. Commissioner of Fisheries for 1922.
- Becker GC. 1983. Fishes of Wisconsin. Madison: University of Wisconsin Press.

- Cudmore-Volkey, Crossman. 2000. [Source material did not provide complete citation]
- COSEWIC. 2008. [Source material did not provide complete citation]
- Cross FB. 1967. Handbook of fishes of Kansas. Topeka: University of Kansas Museum of Natural History. Miscellaneous Publication 45.
- Etnier DA, Starnes WC. 1993. The fishes of Tennessee. Knoxville: The University of Tennessee Press.
- Fuller PL, Nico LG, Williams JD. 1999. Nonindigenous fishes introduced into inland waters of the United States. Bethesda, Maryland: American Fisheries Society. Special Publication 27.
- Holm E, Coker GA. 1981. First Canadian records of the ghost shiner (*Notropis buchanani*) and the orangespotted sunfish (*Lepomis humilis*). Canadian Field-Naturalist 95:210–211.
- Hubbs C, Edwards RJ, Garrett GP. 1991. An annotated checklist of freshwater fishes of Texas, with key to identification of species. Texas Journal of Science 43(4):1–56.
- Hugg DO, Hugg S. 1996. MAPFISH georeferenced mapping database. Freshwater and estuarine fishes of North America. Edgewater, Maryland: Life Science Software.
- 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.
- Noltie DB. 1990. Status of the orangespotted sunfish, *Lepomis humilis*, in Canada. Canadian Field-Naturalist 104:69–86.
- Page LM, Burr BM. 1991. A field guide of freshwater fishes of North America north of Mexico. Boston: Houghton Mifflin Company.
- Schleser DM. 1998. North American fishes for the home aquarium. Hauppauge, New York: Barron's Educational Series Publishing.
- Trautman MB. 1981. The fishes of Ohio. Columbus: Ohio State University Press.

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 *Lepomis humilis* was projected to occur in the Appalachian Range, Colorado Plateau, Great Lakes, Gulf Coast, Mid-Atlantic, Northeast, Northern Plains, Southeast, Southern Atlantic Coast, and Southern Plains regions of the contiguous United States. The extent of the areas of high match contracted between 2055 and 2085 for both SSPs. Low climate match was projected to occur in the Northern Pacific Coast region. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.814 (model: MPI-ESM1-2-HR, SSP5, 2085) to a high of 0.857 (model: UKESM1-0-LL, SSP3, 2055). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species under future scenarios. The Climate 6 score for the current climate match (0.856, figure 5) falls within 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 one or more time step and climate scenarios, areas within the Northeast and Western Mountains saw a moderate increase in the climate match relative to current conditions. No large increases were observed regardless of time step and climate scenarios. Under one or more time step and climate scenarios, areas within the Northern Plains saw a large decrease in the climate match relative to current conditions. Additionally, areas within the Appalachian Range, Great Basin, Gulf Coast, Mid-Atlantic, 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). The magnitude of change increased with time and between SSP3 and SSP5, particularly at time step 2085.

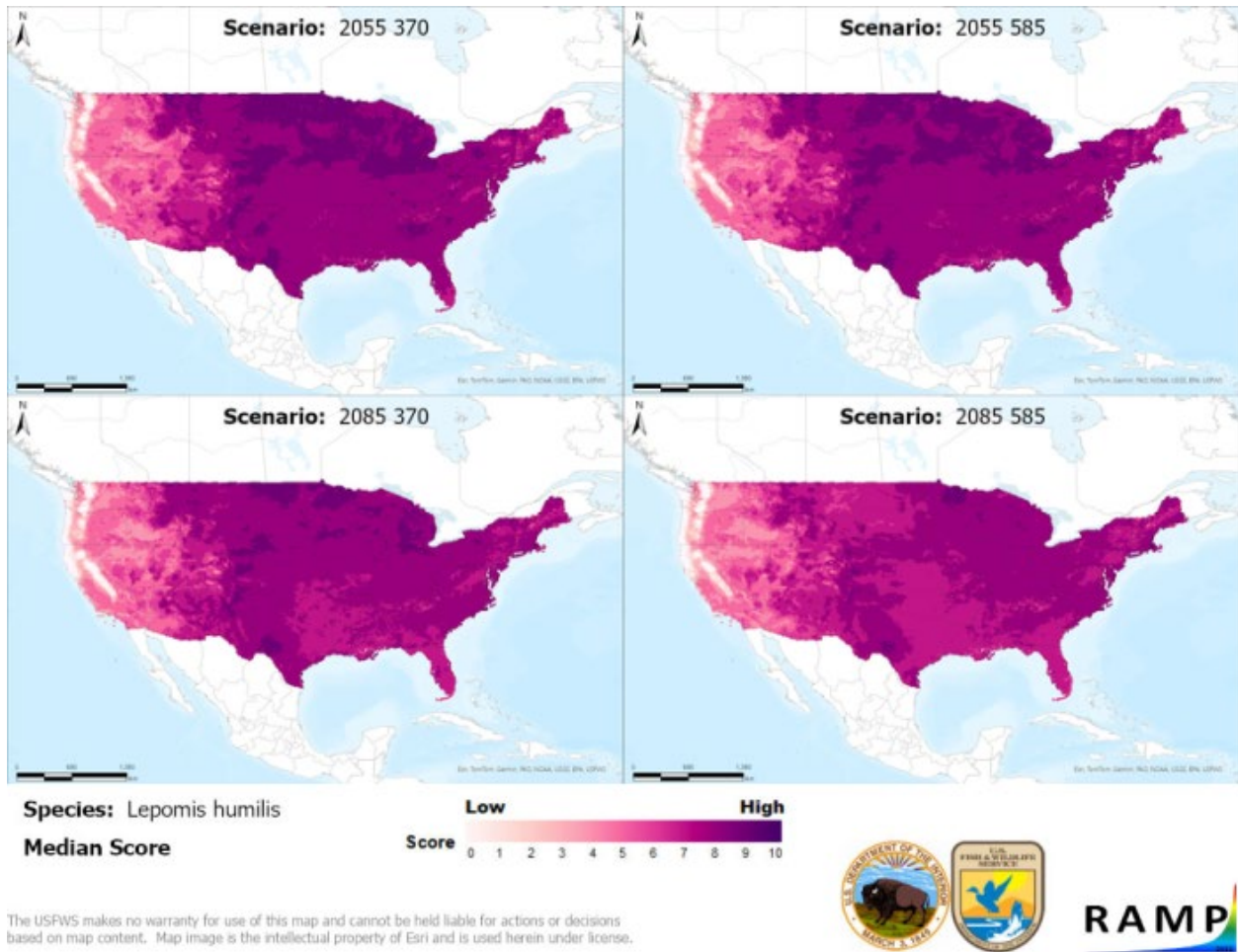


Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Lepomis humilis* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2022). Shared Socioeconomic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

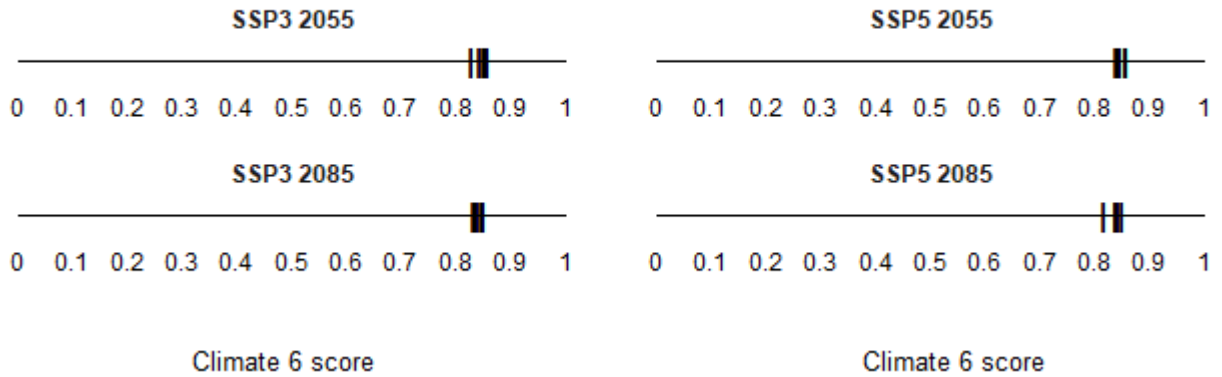


Figure A2. Comparison of projected future Climate 6 scores for *Lepomis humilis* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; IPCC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

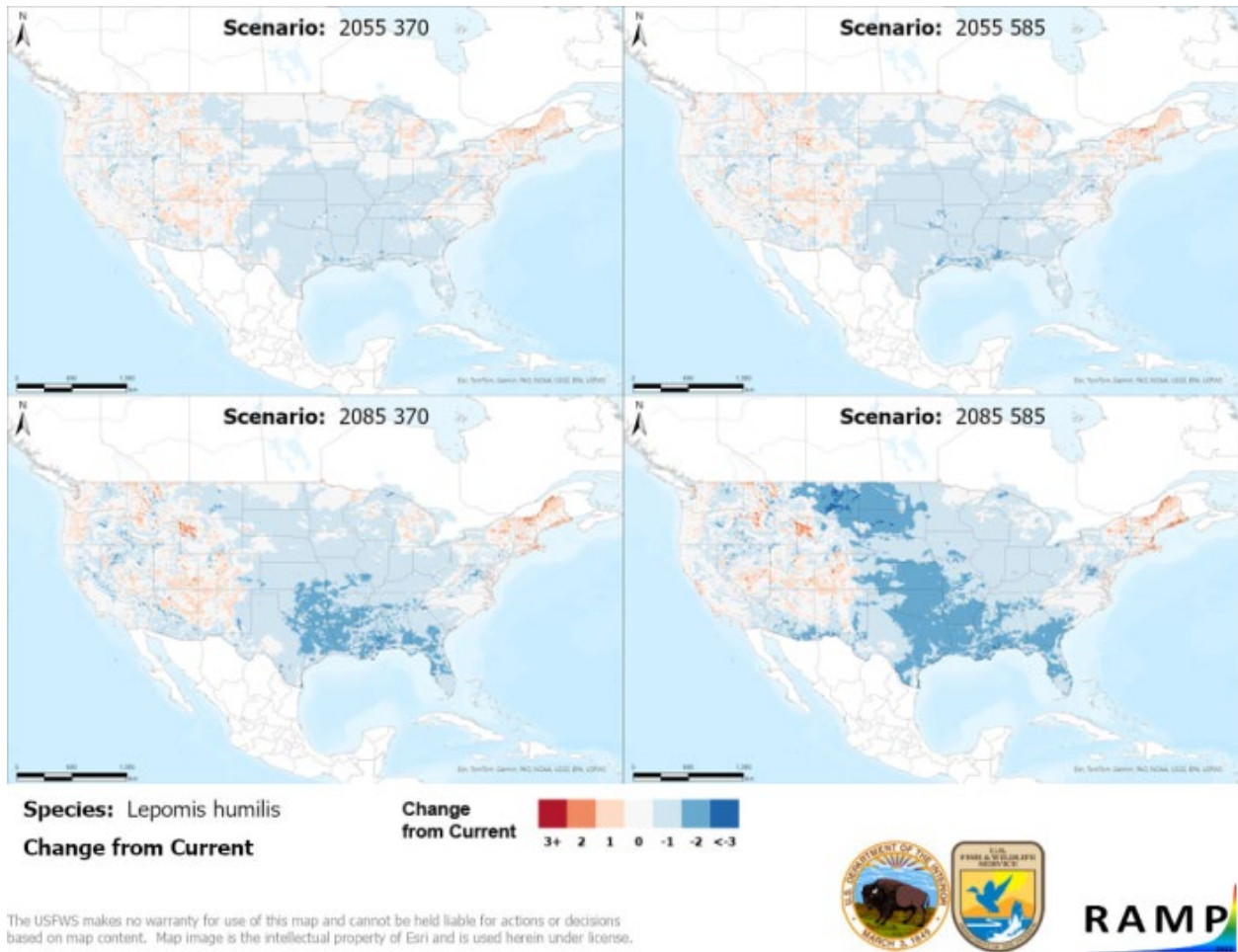


Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 5) and the median target point score for future climate scenarios (figure A1) for *Lepomis humilis* based on source locations reported by GBIF 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: *Lepomis humilis* (Jezerinac, 1993). Copenhagen: Global Biodiversity Information Facility. Available: <https://www.gbif.org/species/2394483> (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.