

Australian Water-clover (*Marsilea mutica*)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, December 2022

Revised, March 2023

Web Version, 4/30/2024

Organism Type: Fern

Overall Risk Assessment Category: Uncertain



Photo: Duane Chapman. Public domain. Available:
<https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2615> (December 2022).

1 Native Range and Status in the United States

Native Range

From Jacono and Johnson (2006):

“Native to Australia and New Caledonia.”

Status in the United States

According to Pfingsten (2023), observations of *Marsilea mutica* have been reported in the following States (years of reports and hydrologic unit code names given after State name):

- Alabama (2001-2021; Buttahatchee; Cahaba; Chipola)
- Arkansas (2004-2006; Lower Arkansas-Maumelle)
- Florida (2002; Tampa Bay)
- Georgia (2001-2022; Middle Chattahoochee-Lake Harding; Upper Flint; Upper Oconee; Upper Ocmulgee)
- Illinois (2019-2022; Lower Ohio-Bay)
- Maryland (2006-2022; Gunpowder-Patapsco; Lower Potomac)
- Mississippi (2001-2006; Bogue Chitto; Lower Big Black)
- Missouri (2011; Lower Missouri-Moreau)
- North Carolina (2019; Rocky)
- Oklahoma (2000; Lower North Canadian; Lower Salt Fork Arkansas)
- Oregon (2014; Upper Willamette)
- South Carolina (1995-1997; Middle Savannah; Seneca)
- Texas (2017-2021; Austin-Travis Lakes; Lower Brazos)
- Virginia (1997-2013; Albemarle; Middle James-Willis; Middle Potomac-Anacostia-Occoquan; Pamunkey; Rapidan-Upper Rappahannock; Upper Dan; Upper Roanoke)
- Washington (2008-2016; Lake Washington; Willapa Bay)

According to Pfingsten (2023), established populations of *Marsilea mutica* have been confirmed in Washington, Maryland, North Carolina, Georgia, Alabama, and Texas.

From Knepper et al. (2002):

“A small but vigorous population was discovered [in Virginia] on 20 October 2001 growing in shallow water (<1.0 m depth) and adjacent muddy shores for 10 m along Cooper’s Ditch, a canal dug through non-tidal forested wetlands in the early 1980’s as a stormwater in the city of Chesapeake.”

This species is in trade in the United States (e.g., Arizona Aquatic Gardens 2022; The Pond Megastore 2022).

From Jacono and Johnson (2006):

“[...] popular items in the water-garden industry.”

Regulations

Marsilea mutica is listed as a prohibited invasive noxious plant in Louisiana (Louisiana Department of Wildlife and Fisheries 2022) and a noxious aquatic plant in Oklahoma (Oklahoma Department of Wildlife Conservation 2022). It is on the Washington State Noxious Weed Control Board’s (2022) quarantine list.

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

Means of Introductions within the United States

From Jacono and Johnson (2006):

“[...] popular items in the water-garden industry.”

“Their recent influx to North America [...] is more likely through escape from horticultural cultivation than waterfowl dispersal as has been previously suggested (Burkhalter 1995).”

Remarks

From Oklahoma Department of Wildlife Conservation (2022):

“[Also known as:] Variegated Water-clover, Nardoo”

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2022):

Kingdom Plantae
Subkingdom Viridiplantae
Infrakingdom Streptophyta
Superdivision Embryophyta
Division Tracheophyta
Subdivision Polypodiophytina
Class Polypodiopsida
Subclass Polypodiidae
Order Salviniaceae
Family Marsileaceae
Genus *Marsilea*
Species *Marsilea mutica* Mett.

According to World Flora Online (2022), *Marsilea mutica* is the current valid name for this species.

Size, Weight, and Age Range

From Jacono and Johnson (2006):

“Petioles 9-18 cm (to 1 m in aquatic forms), fleshy, glabrous. Leaflets to 11-18 mm long x 9-17 mm wide (26-40 mm long x 23-42 mm wide in aquatic forms) [...] the four leaflets together 2.1-3.3 cm in diam (to 8 cm in diam in aquatic forms). Peduncles erect, singular or branched, attached at base of petiole or 1 mm above its base, 6-21 mm long, glabrous. Sporocarps horizontal to strongly ascending, 4-6 mm long x 2-4.5 mm wide (height).”

Environment

From Jacono and Johnson (2006):

“[...] locally abundant at lakes and ponds, rooted in sandy soils to heavy clays, fringing shorelines and extending into water 1 m deep”

From Pfingsten (2023):

“Sediment samples from a *Marsilea mutica* stand in Bushells Lagoon, near Sydney, Australia had a pH of 4.7 and sand/silt/clay percentages of 5/40/55% (Yen and Myerscough 1989a). Also in Bushells Lagoon, *M. mutica* had the highest growth rates and dry weights between 10 and 40°C after eight weeks (Yen and Myerscough 1989b).”

Climate

From Jacono and Johnson (2006):

“[...] appear better suited to the warmer climate of the Southeast [United States]”

“Excepting requirements for full sun and wet periods [...] *M. mutica* demonstrate little preference for habitat and readily adjust to environmental change [...] effective colonizers and extensive growers, often depending on dormant vegetative propagules, rather than sporocarps, to persist through interludes of water recession and low temperature.”

From Pfingsten (2023):

“*Marsilea mutica* prefers warm climates of eastern Australia and southeastern United States (Jacono and Johnson 2006), but may be able to endure colder winters in higher latitudes of the northern hemisphere due to the depth of rhizomes in sediment (Redman 2008).”

Distribution Outside the United States

Native

From Jacono and Johnson (2006):

“Native to Australia and New Caledonia.”

Introduced

Champion and Hofstra (2022) report *Marsilea mutica* as naturalized in New Zealand as of 1988.

Means of Introduction Outside the United States

Champion and Hofstra (2022) report that *M. mutica* was introduced to New Zealand as an ornamental pond plant.

Short Description

From Pfingsten (2023):

“**Rhizomes:** rooting at nodes and sometimes internodes; adventitious and creeping; glabrous [hairless], sometimes with scattered pubescence

Leaves: quadrifoliate compound leaves, with two pairs of leaflets; obdeltoid [flipped triangle] shaped; margins entire [smooth]; glabrous, with pubescence occasionally at the base; variegated leaflets appear two-toned with the lighter color at the base; petioles [leaf stems] are slightly inflated at the apex in aquatic forms (Senn 1909)

Sporocarps: arising near the base of the petioles on single or branched peduncles [sporocarp stems]; peduncles glabrous; sporocarps glabrous to slightly pubescent; lacking distal and proximal teeth and a rathe [peduncle joined along the sporocarp]”

Biology

From Pfingsten (2023):

“In the United States populations, *Marsilea mutica* spreads vegetatively via rhizomes more than sexually via sporocarps (Jacono and Johnson 2006).”

Human Uses

From Jacono and Johnson (2006):

“[...] popular items in the water-garden industry.”

This species is in trade in the United States (e.g., Arizona Aquatic Gardens 2022; The Pond Megastore 2022).

Diseases

No information was found on diseases associated with *Marsilea mutica*.

Threat to Humans

No information was found on threats to humans from *Marsilea mutica*.

3 Impacts of Introductions

From Moorhead (2021):

“Little is known about the invasive potential of *M. mutica* specifically, though Johnson (1986) notes several life-history characteristics of the genus *Marsilea* common to invasive seed plants, including rapid growth, occurrence in early successional habitats, and long viability of propagules.”

Oklahoma, Washington, and Louisiana regulate the trade and possession of *M. mutica*.

Review of the biology, distribution, and impact of introductions for Australian Water-clover (*Marsilea mutica*) indicates that the species has become established outside of its native range and has been documented in at least 15 U.S. States. There is some level of commercial trade ongoing in the United States via the aquarium and ornamental pond industry with websites found from multiple States offering this species for sale, although volume and duration of these sales is unknown. Several States regulate trade of this species. Despite this classification, there was no evidence of documented negative impacts from this species, or evidence documenting a lack of negative impacts. For this reason, the History of Invasiveness for *Marsilea mutica* is classified as “Data Deficient.”

A world map showing the distribution of sampling locations. Red dots represent the locations, with a high density in the Pacific Ocean (especially around the Philippines and Indonesia), the Indian Ocean (around the Seychelles and East Africa), and the Southern Ocean (around Australia and New Zealand). Smaller clusters are visible in the Atlantic Ocean (around the Caribbean and off the coast of South America) and the Mediterranean Sea.

Figure 1. Known global distribution of *Marsilea mutica*. Map from GBIF Secretariat (2022). Locations are in its native range of Australia and New Caledonia, and non-native occurrences in the United States and New Zealand. The locations in Arkansas, Florida, Illinois, Mississippi, Missouri, Oklahoma, Oregon, South Carolina, Virginia, and southern Argentina were not used to select source points for the climate match, as they do not represent wild, established populations.

6 Distribution Within the United States

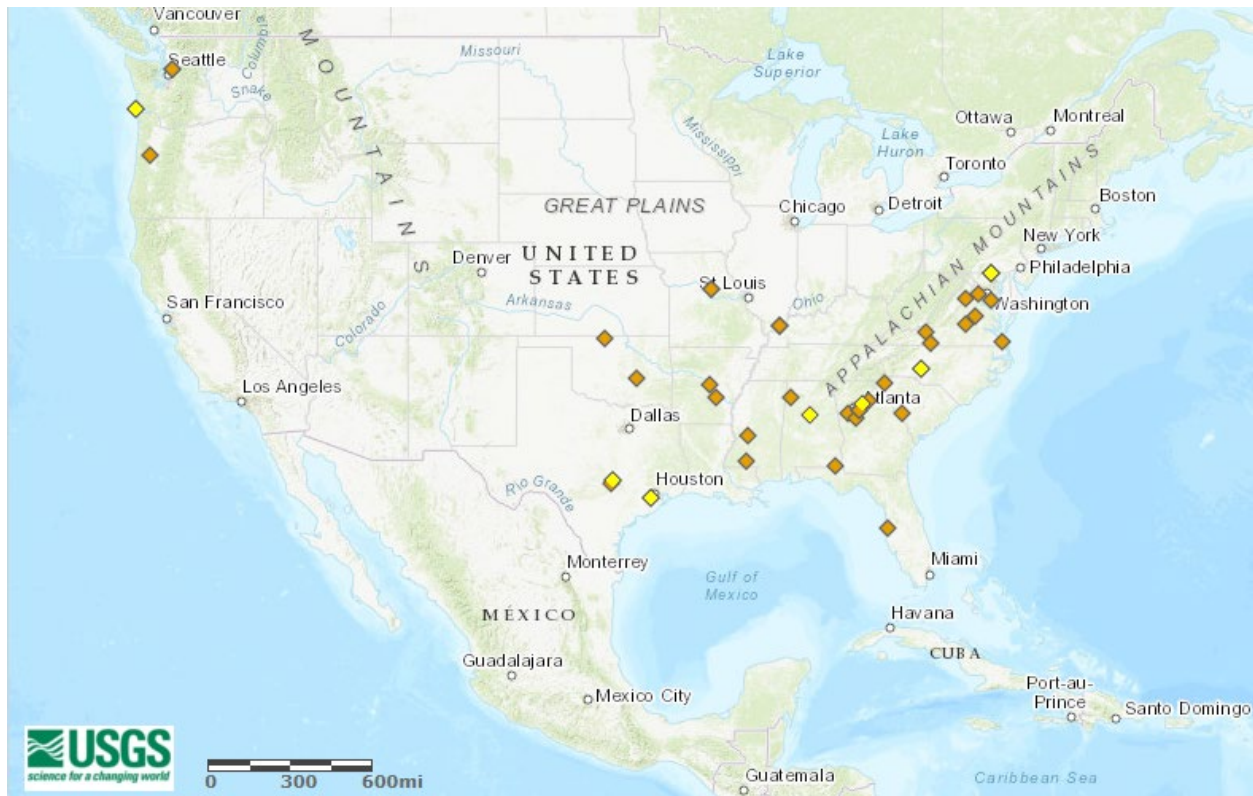


Figure 2. Reported distribution of *Marsilea mutica* in the United States. Map from Pfingsten (2023). Established populations are identified with a yellow diamond and other observations are marked with an orange diamond. Only established populations were included as source points for climate matching.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Marsilea mutica* was high in areas within the United States where established populations exist, particularly in the Southeast. The climate match was also medium to high in most other parts of the contiguous United States, except for the northern Great Plains, the Pacific Coast north of San Francisco Bay, and the Sierra Nevada range, where the climate match was low. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.647, indicating that Yes, there is establishment concern for this species. The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). Establishment concern is warranted for Climate 6 scores greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024).

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

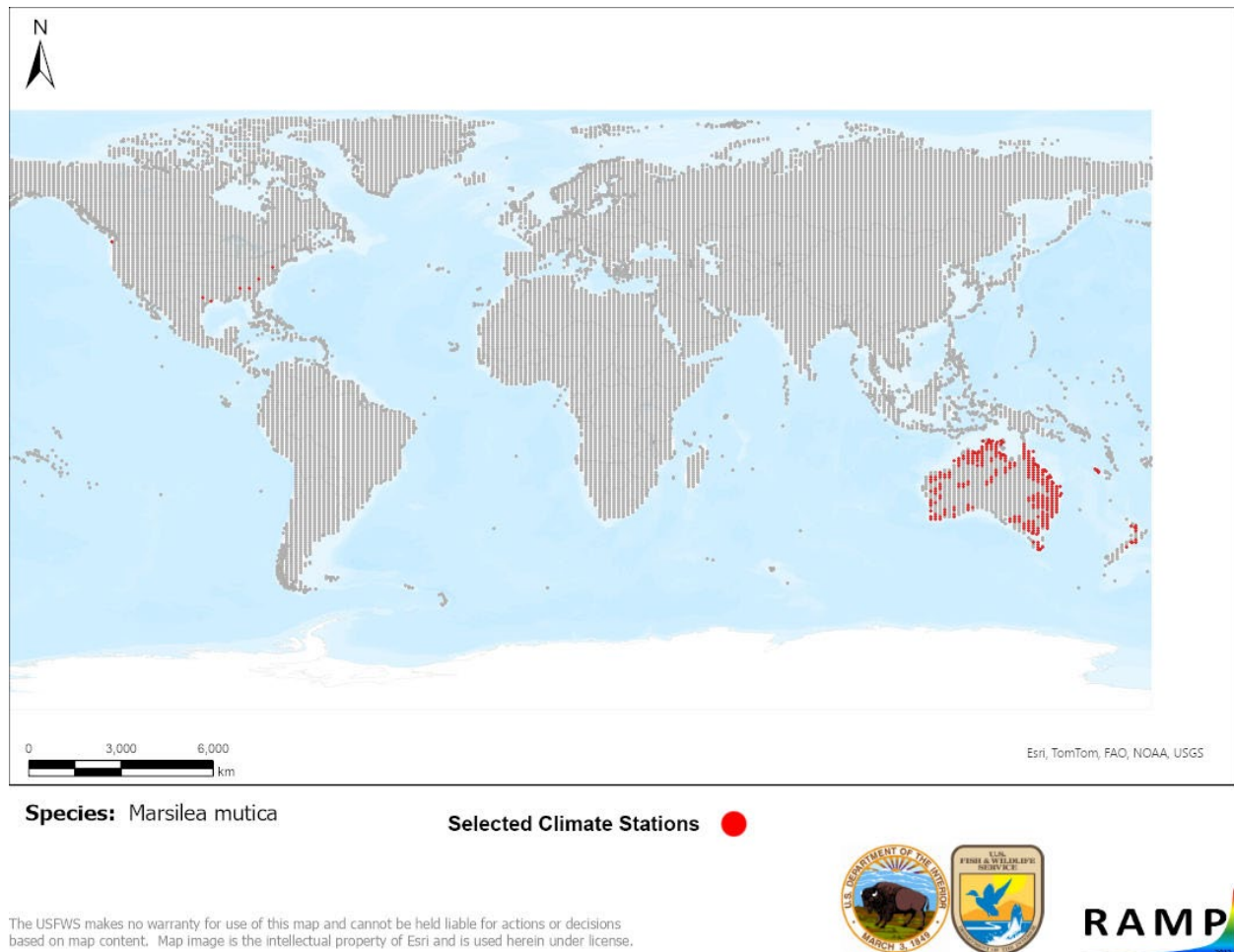


Figure 3. RAMP (Sanders et al. 2023) global source map showing weather stations selected as source locations (red; Australia, New Caledonia, New Zealand, and the United States) and non-source locations (gray) for *Marsilea mutica* climate matching. Source locations from GBIF Secretariat (2022) and Pfingsten (2023). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

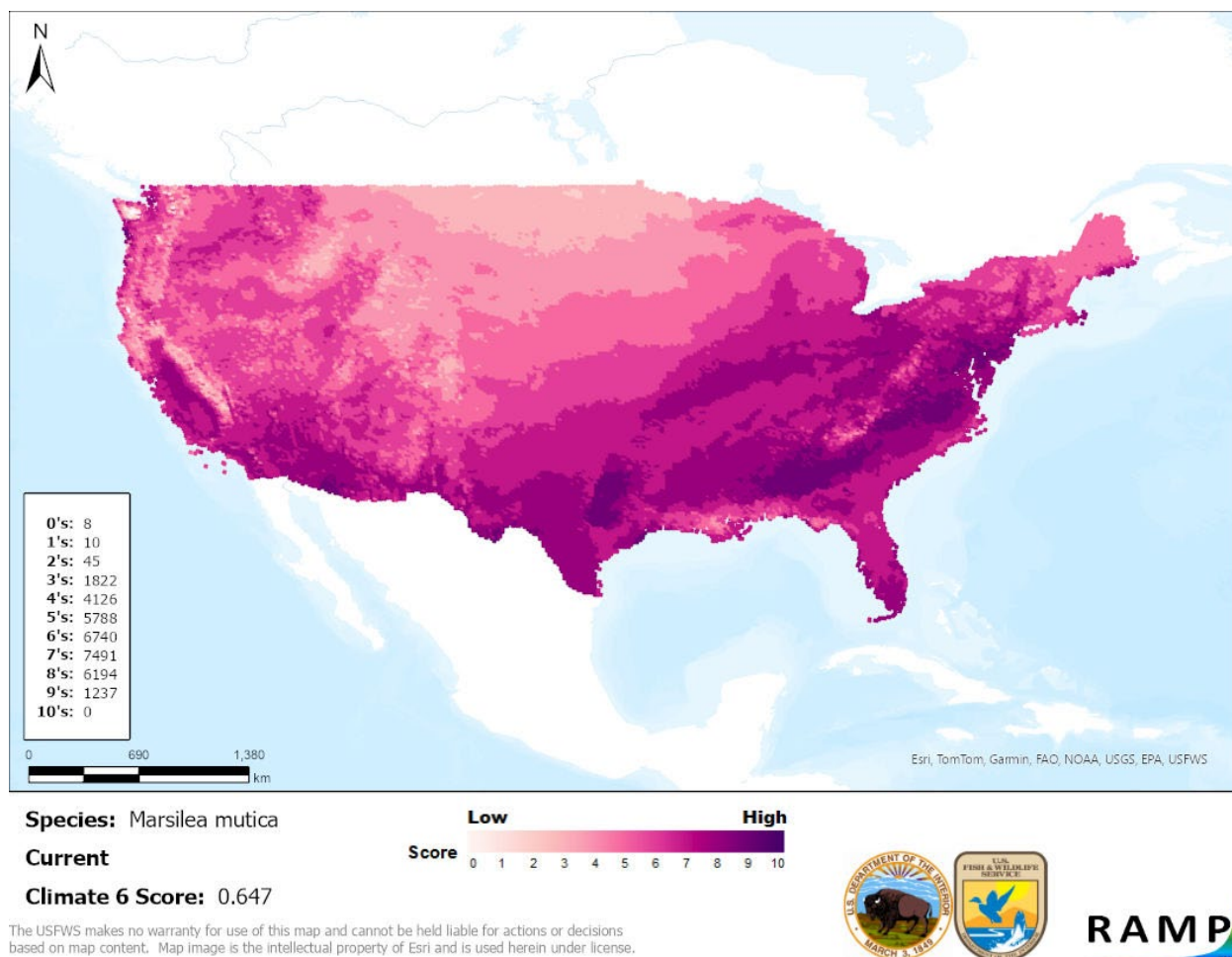


Figure 4. Map of RAMP (Sanders et al. 2023) climate matches for *Marsilea mutica* in the contiguous United States based on source locations reported by GBIF Secretariat (2022) and Pfingsten (2023). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple =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

8 Certainty of Assessment

The Certainty of Assessment for *Marsilea mutica* is classified as Low. While there is reasonably complete information regarding the species distribution, and evidence that introductions have resulted in established populations, there is no information available about the impacts of introduction of this species or lack thereof.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Marsilea mutica, Australian Water-clover, is a perennial aquatic fern that is native to Australia and New Caledonia. Appearance is like that of a four-leaf clover, with the overall diameter being up to 8 cm. It lives in lakes, ponds, and along waterways, rooting in sandy to heavy clay soils in water depths of 1 m or less. *Marsilea mutica* more often spreads vegetatively via rhizomes than sexually via sporocarps. The first wild observation of *Marsilea mutica* in the United States was

in Virginia in 2001. Since then, observations have been reported in a total of fifteen states but established wild populations have only been recorded for Washington, Maryland, North Carolina, Georgia, Alabama, and Texas. Exact estimates on trade volume could not be located, but several websites in the United States sell this species commercially as a decorative plant for use in ponds and water features. Oklahoma, Louisiana, and Washington regulate possession and trade of *Marsilea mutica*. No information could be found on impacts associated with established populations of *Marsilea mutica* in the wild. The History of Invasiveness for *Marsilea mutica* is classified as Data Deficient due to a lack of documentation of impacts or lack of impacts from species introductions and establishment. The climate matching analysis for the contiguous United States indicates establishment concern for this species. Most of the contiguous United States was predicted to be a high climate match for this species, with only portions of the northern Great Plains predicted to be a low match. The Certainty of Assessment for this ERSS is classified as Low due to the lack of information regarding the impacts of introduction and establishment. The Overall Risk Assessment Category for *Marsilea mutica* 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:** This species is sold in the United States although overall trade volumes are unknown.
- **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.

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- [USFWS] U.S. Fish and Wildlife Service. 2024. Standard operating procedure: how to prepare an “Ecological Risk Screening Summary.” Version 3.
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- [WFO] World Flora Online. 2022. World Flora Online – a project of the World Flora Online Consortium. Available: <http://www.worldfloraonline.org> (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.

- Burkhalter JR. 1995. *Marsilea mutica* (Marsileaceae): new to Florida and North America. *SIDA, Contributions to Botany* 16:545–549.
- Redman DE. 2008. *Marsilea mutica* in Maryland. *American Fern Journal* 98(3):176–177.

Senn G. 1909. Schwimmblase und Intercostalstreifen einer neukaledonischen Wasserform von Marsilea. *Berichte der Deutschen Botanischen Gesellschaft* 27:111–119.

Yen S, Myerscough PJ. 1989a. Co-existence of three species of amphibious plants in relation to spatial and temporal variation: field evidence. *Austral Ecology* 14(3):291–303.

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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 (2022) and Pfingsten (2023).

Under the future climate scenarios (figure A1), on average, high climate match for *Marsilea mutica* was projected to occur in the northern Appalachian Range into the eastern Midwest, Mid-Atlantic, and Southwest regions of the contiguous United States. There was also an area of high match near Seattle. Low matches were found along the Pacific coast, similar to current conditions, but also in the northeastern Rocky Mountains and along parts of the Gulf Coast. Areas of high climate match contracted and areas of low climate match expanded from the 2055 time step to 2085 time step. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.64 (model: MPI-ESM1-2-HR, SSP5, 2085) to a high of 0.82 (model: GFDL-ESM4, SSP5, 2085). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species under future climate scenarios. The Climate 6 score for the current climate match (0.647, figure 4) falls within the range of scores for future projections. Under one or more time step and climate scenarios, areas within the Colorado Plateau, Great Lakes, Northeast, Northern Plains, Southern Plains, and New Mexico saw a moderate increase in the climate match relative to current conditions (figure A3). No large increases were observed regardless of time step and climate scenarios. At the 2085 time step, areas within the southern Appalachian Range and Southeast saw a large decrease in the climate match relative to current conditions. Additionally, areas within California, the Gulf Coast, Mid-Atlantic, Northern Pacific Coast, Southern Atlantic Coast, Southern Florida, Southern Plains, southwestern Arizona, and Western Mountains saw a moderate decrease in the climate match relative to current conditions. The change relative to current conditions was more extreme for SSP5 than for SSP3, and more extreme for the 2085 time step than the 2055 time step.

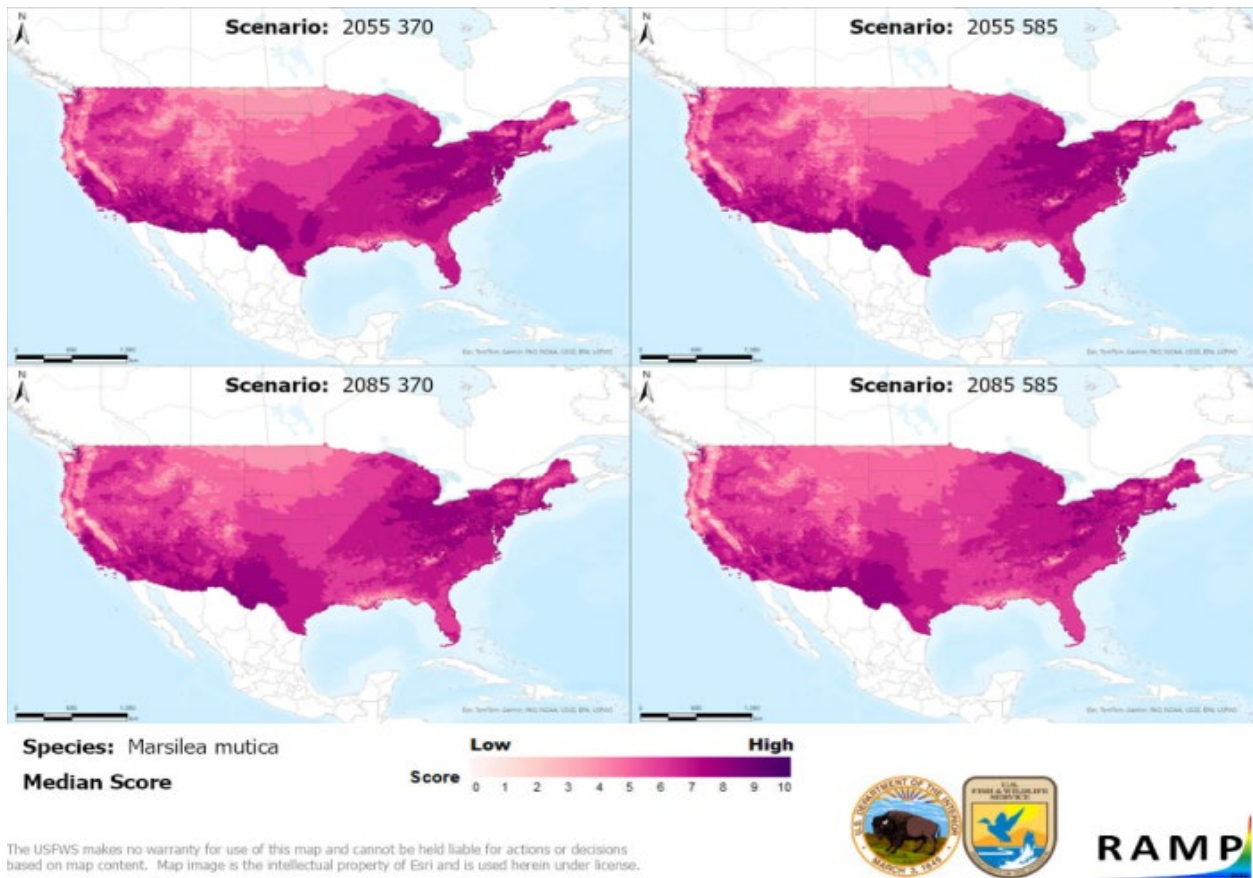


Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Marsilea mutica* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2022) and Pfingsten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

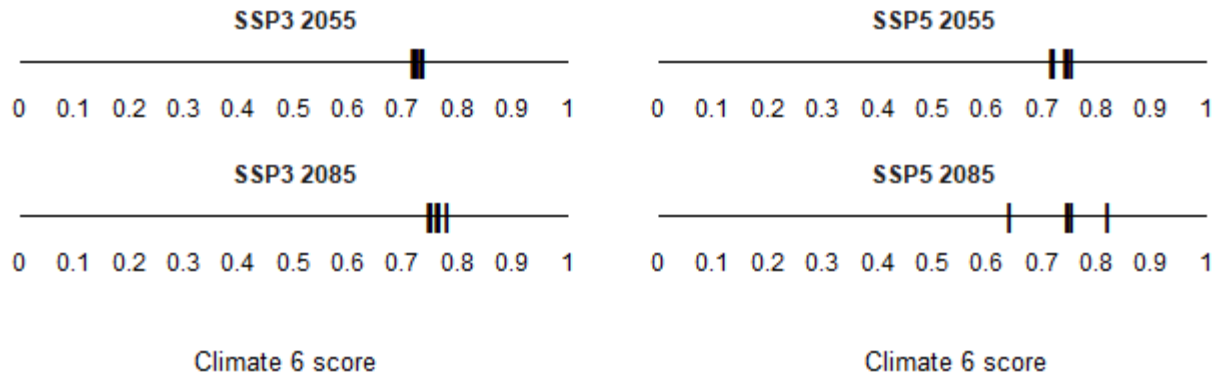
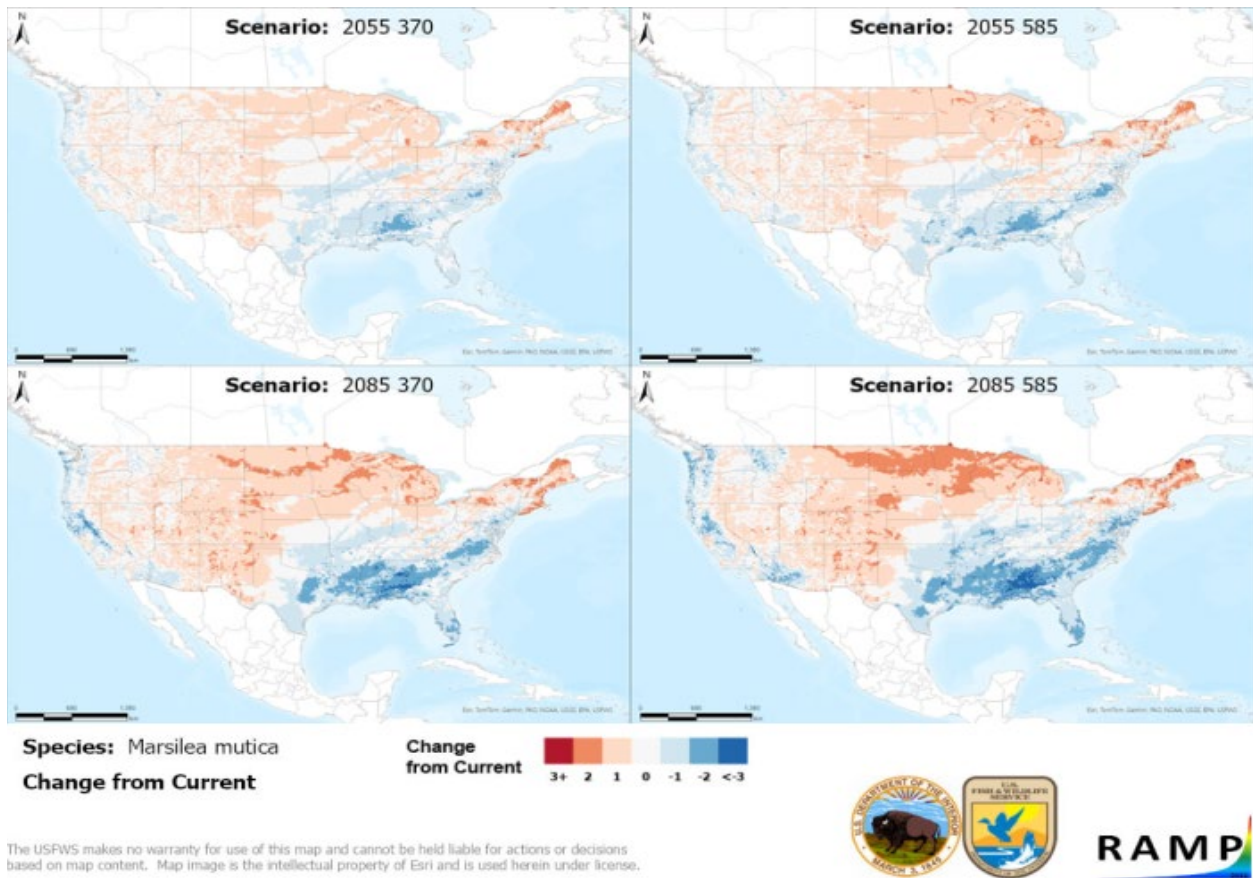


Figure A2. Comparison of projected future Climate 6 scores for *Marsilea mutica* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; IPCC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



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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 *Marsilea mutica* based on source locations reported by GBIF Secretariat (2022) and Pfingsten (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.

Literature Cited

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