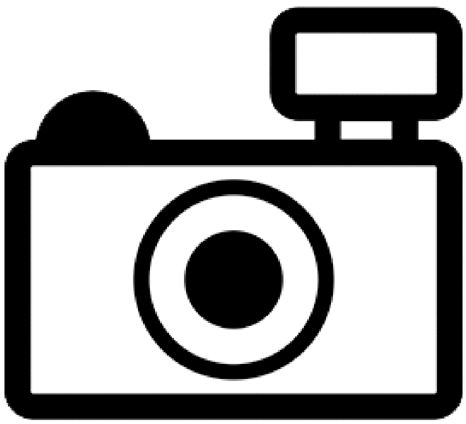
Lyngbya (*Microseira wollei*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, December 2022
Revised, September 2023
Web Version, 3/24/2025

Organism Type: Algae
Overall Risk Assessment Category: High



No Photo Available

1 Native Range and Status in the United States

Native Range

From Kasinak et al. (2015):

"*Lyngbya wollei* (Farlow ex Gomont) comb. nov. (hereafter *Lyngbya*) is a benthic, filamentous cyanobacterium that is native to Asia, Africa, and Australia."

From McGregor and Sendall (2015):

"Three populations of the freshwater filamentous cyanobacterium *Lyngbya wollei* (Farlow ex Gomont) Speziale and Dyck have been putatively identified from north-eastern Australia […]"

Status in the United States

From Bridgeman and Penamon (2010):

"*L. wollei* is commonly found from North Carolina to northern Florida where it is usually described as growing in mats along the bottom of ponds and reservoirs or, in larger water bodies, in shallow, protected embayments (Speziale and Dyck, 1992, Cowell and Botts, 1994, Stevenson et al., 2004)."

From Lévesque et al. (2012):

"Proliferations of *L. wollei* have been reported with increasing frequency in the last 30 years in rivers, lakes, reservoirs, and springs in southeastern USA (Speziale et al. 1991; Cowell and Botts 1994; Stevenson et al. 2007). Recently, *L. wollei* has been observed also at higher latitudes […] in the Great Lakes (Bridgeman and Penamon 2010), and in the St. Lawrence River (hereafter designated as SLR) (Vis et al. 2008)."

From Vijayavel et al. (2013):

"Here we report on large deposits of *L. wollei* washing onshore at a popular recreational beach in Lake Saint Clair, part of the Great Lakes system."

From Bridgeman and Penaman (2010):

"We report on the emergence of the potentially toxic filamentous cyanobacterium, *Lyngbya wollei* as a nuisance species in western Lake Erie. The first indication of heavy *L. wollei* growth along the lake bottom occurred in September 2006, when a storm deposited large mats of *L. wollei* in coves along the south shore of Maumee Bay."

"Descriptions of floating *Lyngbya* mats (probably *L. wollei*) in New England ponds date to the nineteenth century (Speziale and Dyck, 1992)."

From Macbeth (2004):

"At the time of this writing Lake Itasca in Minnesota is the most northern known location of *L. wollei* in the United States."

From Smith et al. (2019):

"Microseira wollei (basionym *Lyngbya wollei*) was found at two of 15 sites in Butterfield Lake [New York] […]"

From Onodera et al. (1998):

"*Lyngbya wollei* collected from Guntersville Reservoir on the Tennessee River in Alabama."

Cowell and Botts (1994) report *Microseira wollei* (as *Lyngbya wollei*) from the Kings Bay/Crystal River estuarine system in central Florida.

No records of *Microseira wollei* in trade in the United States were found.

Regulations

No species-specific regulations on possession or trade were found within the United States.

Means of Introductions within the United States

No information regarding the means of introduction to the United States was found.

Remarks

According to Guiry (2018), *Microseira wollei* is the current valid scientific name for this species. However, most information in this ERSS was found from sources still using the former valid scientific name, *Lyngbya wollei*. This assessment follows World Register of Marine Species (Guiry 2018) in treating *Microseira wollei* as the accepted name. Literature searches to inform this report were completed for both the synonym, *Lyngbya wollei*, and the valid name, *Microseira wollei*.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From Guiry (2018):

"Bacteria (Kingdom) > Gracilicutes (Subkingdom) > Cyanobacteria (Phylum) > Cyanophyceae (Class) > Oscillatoriophycidae (Subclass) > Oscillatoriales (Order) > Aerosakkonemataceae (Family) > *Microseira* (Genus) > *Microseira wollei* (Species)"

According to Guiry (2018), *Microseira wollei* is the current valid scientific name for this species.

The following synonyms of *Microseira wollei* were used to search for information for this report: *Lyngbya wollei* and *Plectonema wollei*.

Size, Weight, and Age Range

From Macbeth (2004):

"L. wollei cells are defined as discoid in shape having a diameter of 24-65 mm. Cells vary in length from 2-12 mm. The cells are arranged into uniseriate filaments, which are encased by a hyaline, lamellate sheath up to 12 mm thick. The filaments are indeterminate in length and can exceed 40 cm in length."

Environment

From McGregor and Sendall (2015):

"[...] inhabits the benthos of freshwater riverine habitats (Komárek and Anagnostidis 2005)."

From Macbeth (2004):

"Water conductivity and alkalinity were found to account for 55% of the variability in *L. wollei* biomass (Cowell and Botts 1994). Limited halotolerance suggests that *L. wollei* is a freshwater species. *L. wollei* is a stenohaline species with a strong preference for freshwater, showing negative growth at all salinities between 0 and 35 ppt by the loss of cells. At salinities of l7.5ppt and above, rapid death of the organism occurs (Cowell and Botts 1994). Optimal growth of *L. wollei* occurs in water of pH 8 (Cowell and Botts 1994). It may be concluded that *L. wollei* is sensitive to acidity and grows optimally in an alkaline environment. In contrast, at pH 4 there was negligible growth (Tubea et al. 1981). *L. wollei* has been identified most commonly in the southwestern [sic] United States in freshwater lentic ecosystems with these characteristics. Lakes, ponds and reservoirs may all be affected."

From McGregor and Sendall (2015):

"These proliferations have been attributed to the ability of *L. wollei* to grow under low light conditions (<50 µmol photons m^{-2} s^{-1}; Speziale et al. 1991, Pinowska et al. 2007, Bridgeman and Penamon 2010), and low nutrient conditions due to its diazatrophic (Philips et al. 1991, Joyner et al. 2008) and heterotrophic capabilities (Lévesque et al. 2012)."

Climate

No information was found on climate requirements for *Microseira wollei*.

Distribution Outside the United States

Native

From Kasinak et al. (2015):

"Lyngbya wollei (Farlow ex Gomont) comb. nov. (hereafter *Lyngbya*) is a benthic, filamentous cyanobacterium that is native to Asia, Africa, and Australia."

From McGregor and Sendall (2015):

"Three populations of the freshwater filamentous cyanobacterium *Lyngbya wollei* (Farlow ex Gomont) Speziale and Dyck have been putatively identified from north-eastern Australia […]"

Introduced

From McGregor and Sendall (2015):

"It [*Microseira wollei*] has a wide distribution, which includes […] Canada, southern Europe […]."

From MacBeth (2004):

"[…] *Lyngbya wollei*, was studied in lakes of Whiteshell Provincial Park in eastern Manitoba."

Means of Introduction Outside the United States

From Bridgeman and Penaman (2010):

"Recently, *L. wollei* infestations have been reported in two shallow lakes in Whiteshell Provincial Park near Winnipeg, Manitoba (Winnipeg Free Press 2003) where it is believed that the cyanobacterium was accidentally introduced by boats and trailers that are transported to southern states [of the United States] during winter."

Short Description

From University of Florida, IFAS (2022):

"Lyngbya wollei (Lyngbya) is a large-celled, filamentous, mat-forming cyanobacterium (blue-green alga). […] An individual *Lyngbya* filament is usually unbranched. It is composed of large, discoid cells that are stacked within a firm, polysaccharide sheath; much as pennies are stacked within a roll of coins. […] Benthic *Lyngbya* mats are usually dark blue to black. Benthic mats may float to the surface due to trapped gases. When they float to the surface, the mats oxidize and turn yellow-orange (Hoyer and Canfield, 1996)."

From Virginia Department of Health (2021):

"The mats are a dark green to black color. They are fibrous and dense, like wet wool or cotton, and have an unpleasant musty smell."

Biology

From Virginia Department of Health (2021):

"Lyngbya wollei is a type of blue-green algae, or cyanobacteria, that grows in freshwater lakes and rivers. It normally grows on the lake or riverbed and forms thick mats that slowly spread. When conditions are right the mats can cover large areas and crowd out other vegetation. Mats can sometimes detach from the bottom and float to the surface and can wash up on shore. Mats may wash up along the surface or in coves where water is shallow where they may dry out […]."

From Macbeth (2004)

"L. wollei is a perennial species, which overwinters as a benthic mat. *L. wollei* has no specialized reproductive or overwintering structures such as akinetes. All biomass produced throughout the water column accumulates as a benthic mat which functions as a base stock for re-infestation in the following growth season."

From Kasinak et al. (2015):

"One important cyanobacterium, *Lyngbya wollei* (Farlow ex Gomont) comb. nov., is a nuisance species in North America that forms benthic mats and surface scums and can produce multiple intracellular toxins and off-flavor compounds."

Human Uses

No information was found on human uses of *Microseira wollei*.

Diseases

No information was found on diseases associated with *Microseira wollei*.

Threat to Humans

From Anderson et al. (2019):

"*L. wollei* has been documented to produce numerous toxins that can negatively impact irrigated crops, livestock, wildlife and humans (Foss et al. 2012; Bhadha et al. 2014; Paerl et al. 2016)."

From MacBeth (2004):

"*L. wollei* produces toxins. These may confound [sic] the problem of aesthetically unpleasant infestations in the lakes, ponds and reservoirs where they are found. Paralytic shellfish poisoning (PSP) is a human poisoning syndrome which is caused by the potent neurotoxin saxitoxin (STD) and its analogues. Two species *Anabaena circinalis* and, *Aphanizomenon flos-aquae* are known to produce PSPs. Carmichael et at. (1997) report that *L. wollei* is a third PSP producer."

From McGregor and Sendall (2015):

"Notably, it [*Microseira wollei*] has been implicated through anecdotal reports of adverse skin reactions such as rashes, hives and blisters, gastrointestinal disorders, respiratory illness, and temporary loss of consciousness following recreational exposure (Foss et al. 2012)."

3 Impacts of Introductions

From University of Florida, IFAS (2022):

"Mats composed of entangled *Lyngbya* filaments may cover entire coves and small ponds and be several feet deep. Mats can impede navigation and recreation, cover and smother submersed plants, and clog water intakes. In addition, they emit a strong and unpleasant earthy or musk-like odor (Speziale, Turner and Dyck, 1988)."

From Anderson et al. (2019):

"Large-scale *Lyngbya wollei* (Cyanobacteria, Oscillatoriales) infestations are increasing throughout the USA and globally and causing significant obstruction of water resource uses."

"Growth forms include benthic, suspended, and floating mats which impede critical water resource uses (e.g., power generation, wildlife habitat, recreation, property values) and can harbor pathogenic fecal bacteria (Vijayavel et al. 2013). *L. wollei* has been documented to produce numerous toxins that can negatively impact irrigated crops, livestock, wildlife and humans (Foss et al. 2012; Bhadha et al. 2014; Paerl et al. 2016)."

From MacBeth (2004):

"*L. wollei* produces toxins. These may confound the problem of aesthetically unpleasant infestations in the lakes, ponds and reservoirs where they are found. Paralytic shellfish poisoning (PSP) is a human poisoning syndrome which is caused by the potent neurotoxin saxitoxin (STD) and its analogues. Two species *Anabaena circinalis* and, *Aphanizomenon flos-aquae* are known to produce PSPs. Carmichael et at. (1997) report that *L. wollei* is a third PSP producer."

From Kasinak et al. (2015):

"Due to the nuisance and potential negative economic impacts caused by this taxon, recreational fisheries and water resource managers are interested in controlling *Lyngbya*."

From Vijayavel et al. (2013):

"In the southeastern United States, *L. wollei* is becoming increasingly common and considered as a nuisance species due to its 1) prolific nature, 2) clogging water intakes, and 3) unaesthetic appearance and offensive odor associated with the decaying shoreline mats (Speziale and Dyck, 1992)."

4 History of Invasiveness

The History of Invasiveness for *Microseira wollei* is classified as High. There are records of nonnative introductions which have resulted in established populations. There is information available on the impacts of introductions, both potential and realized, of this species outside of its native range. There are known human health risks associated with infestations of *M. wollei*.

5 Global Distribution

Figure 1. Reported global distribution of *Microseira wollei*. Map from GBIF Secretariat (2023). Observations are reported from the United States, Australia, Jamacia, Mexico, the Democratic Republic of the Congo, Japan, and South Korea. There was no evidence that the point in Jamacia represented an established population, therefore it was not included in the climate matching analysis.

The description of the native range of *Microseira wollei* found in researching this report was very general and broad (Kasinak et al. 2015; see section 1). The limited georeferenced observations within that described range may underrepresent the actual range of the species.

MacBeth (2004) gave an additional observation location of *Microseira wollei* in Manitoba, Canada.

There were no observations available to represent the range of the species in southern Europe (McGregor and Sendall 2015).

6 Distribution Within the United States

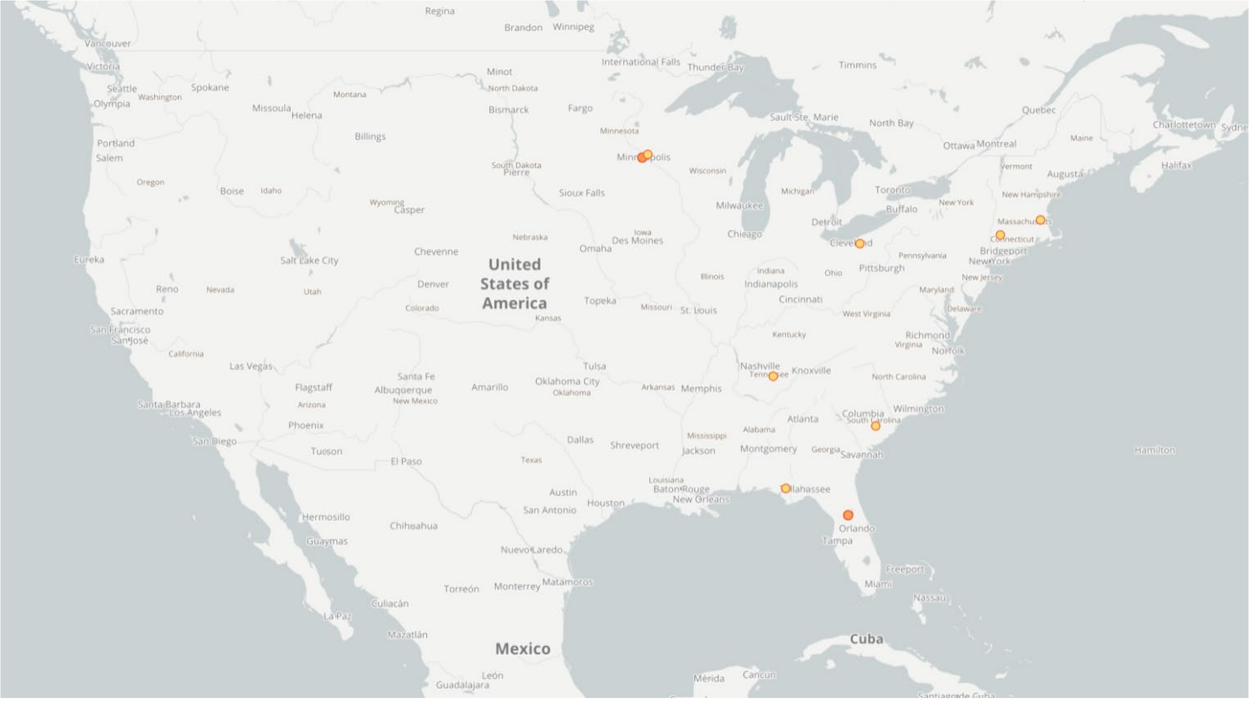


Figure 2. Reported distribution of *Microseira wollei* in the United States. Map from GBIF-US (2023). Observations are reported from Florida, Massachusetts, Tennessee, South Carolina, and Minnesota.

Additional observation locations were available in the literature for Lake Itasca, Minnesota (MacBeth 2004), Butterfield Lake, New York (Smith et al. 2019), Guntersville Reservoir in Tennessee (Onodera et al. 1998), and south shore of Maumee Bay, Lake Erie, Ohio (Bridgeman and Penaman 2010).

7 Climate Matching

Summary of Climate Matching Analysis

The climate matching analysis to the contiguous United States for *Microseira wollei* found high match in much of the eastern and Midwest parts of the United States. Specifically, parts of New England, the Great Lakes region, the southeastern United States, and peninsular Florida had areas of high match. Most of the contiguous United States west of the Colorado Plateau had a low climate match. Due to the potential underrepresentation of the species' native range in the source points for the climate matching analysis, the results may underestimate the climate match to the contiguous United States. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.754, 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 *Microseira wollei* (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.

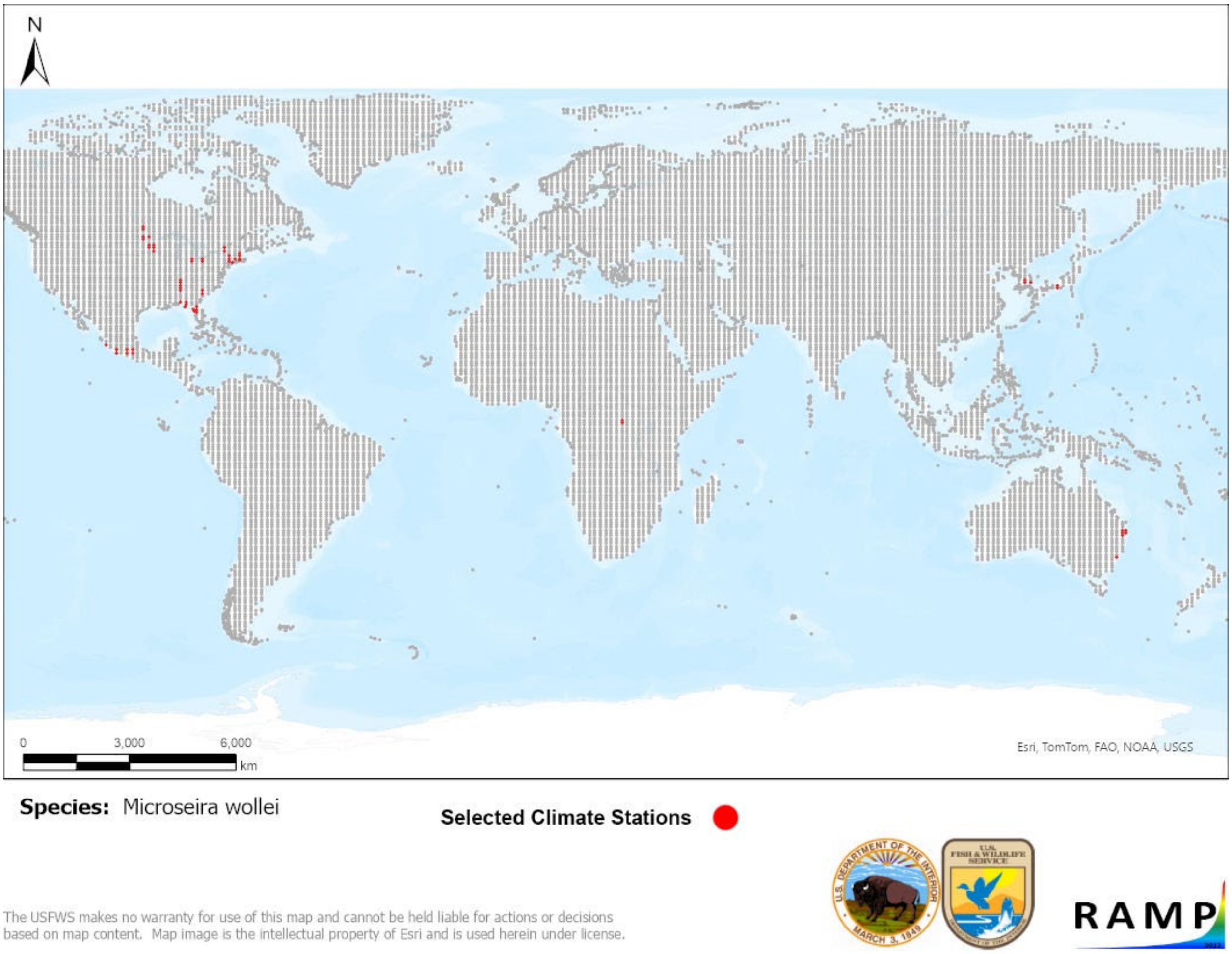


Figure 3. RAMP (Sanders et al. 2023) source map showing weather stations in the North America, Asia, Africa, and Australia (red; United States, Canada, Mexico, Democratic Republic of the Congo, Australia, Japan, and South Korea) and non-source locations (gray) for *Mircoseira wollei* climate matching. 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.

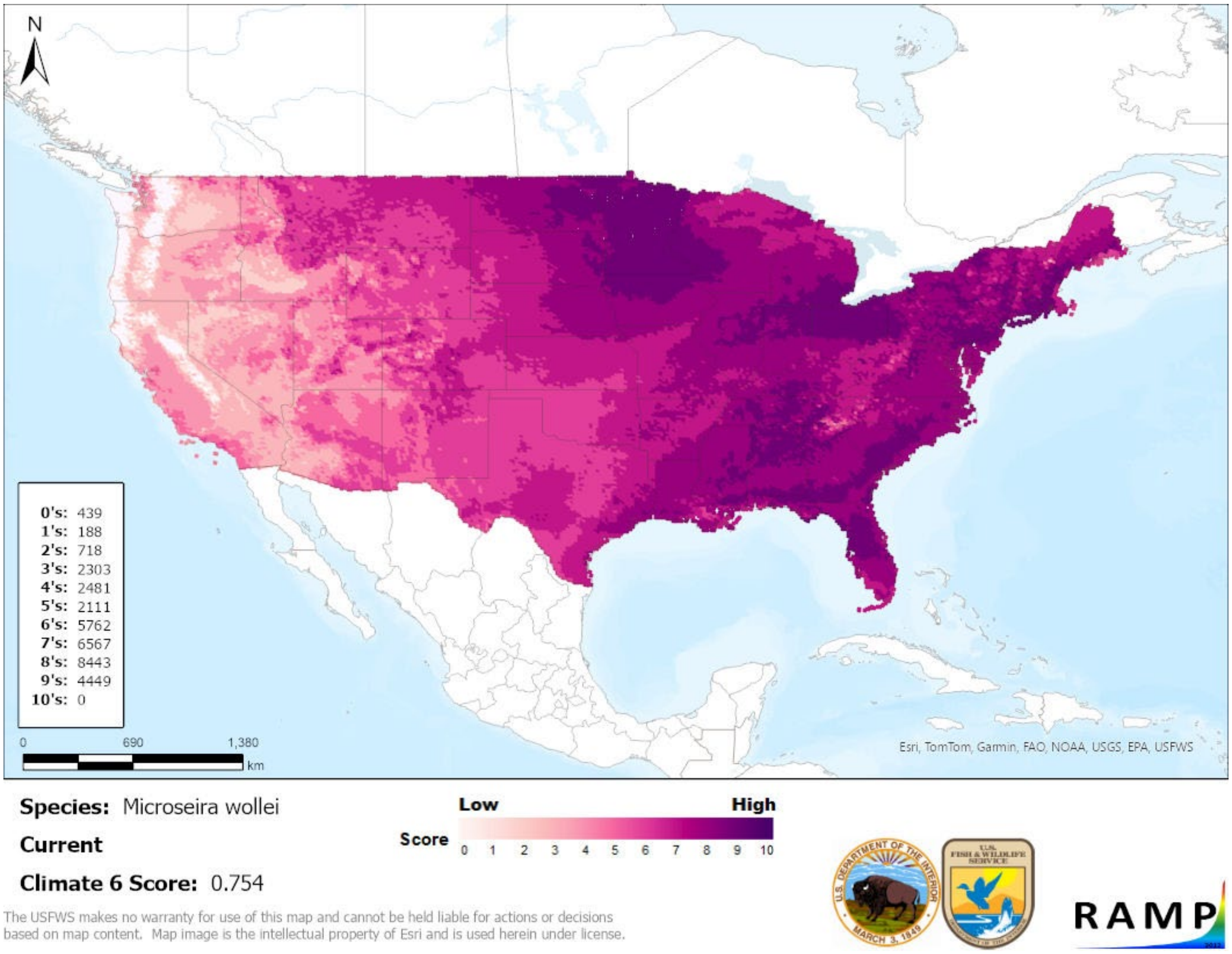


Figure 4. Map of RAMP (Sanders et al. 2023) climate matches for *Microseira wollei* in the contiguous United States based on source locations reported by GBIF Secretariat (2023). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment for *Microseira wollei* is classified as Medium. Although *Microseira wollei* has recently changed names, there is information available on this species biology and ecology under the previous valid name. Information on introductions and negative impacts were available. However, the description of the species' native range was very broad and there were significant gaps in georeferenced observations to use in the climate matching analysis when compared to the described range.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Microseira wollei, Lyngbya, is an algal species that is native to Australia, Asia, and Africa. It is a blue-green alga that grows in the benthos of freshwater rivers and lakes. It is known to produce toxins that may be harmful to crops, livestock, and humans. The History of Invasiveness for

Microseira wollei is classified as High. This species has been introduced and has become established outside of its native range, including within the United States, and there was information available regarding negative impacts of introductions. In addition to the toxin produced by *Microseira wollei*, mats of algae can impede water resource uses, smother submersed plants, and reduce aesthetic value of water bodies through its appearance and odor. The climate matching analysis for the contiguous United States indicates establishment concern for this species. Areas with high match were found in the Northeast, northern Midwest, Southeast, Great Lakes region, and peninsular Florida. The Certainty of Assessment is classified as Medium due to large gaps in representation of the native range in the climate matching analysis. The Overall Risk Assessment Category for *Microseira wollei* is High.

Assessment Elements

- **History of Invasiveness (see section 4): High**
- **Establishment Concern (see section 7): Yes**
- **Certainty of Assessment (see section 8): Medium**
- **Remarks, Important additional information: Known to produce toxins that can be harmful to humans.**
- **Overall Risk Assessment Category: High**

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.

Anderson WT, Yerby JN, Carlee J, Bishop WM, Willis BE, Horton CT. 2019. Controlling *Lyngbya wollei* in three Alabama, USA reservoirs: summary of a long-term management program. Applied Water Science 9:178.

Bridgeman TB, Penamon WA. 2010. *Lyngbya wollei* in Western Lake Erie. Journal of Great Lakes Restoration 36:167–171.

Cowell BC, Botts PS. 1994. Factors influencing the distribution, abundance and growth of *Lyngbya wollei* in Central Florida. Aquatic Botany 49:1–17.

GBIF Secretariat. 2023. GBIF backbone taxonomy: *Microseira wollei* (Farlow ex Gomont) G.B.McGregor & Sendall ex Kenins, 2017. Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/10603679 (March 2025).

GBIF-US. 2023. Species occurrences: *Microseira wollei*. Available: https://doi.org/10.15468/dl.8zy4gg (September 2023).

Guiry MD. 2018. *Microseira wollei* (Farlow ex Gomont) G.B.McGregor & Sendall ex Kenins, 2017. World Register of Marine Species. Available: https://www.marinespecies.org/aphia.php?p=taxdetails&id=1310067 (September 2023).

Kasinak JE, Bishop CJ, Wright RA, Wilson AE. 2015. Grass carp do not consume the nuisance benthic cyanobacterium, *Lyngbya wollei*. Journal of Aquatic Plant Management 53:74–80.

Lévesque L, Cattaneo A, Hudon C, Gagnon P. 2012. Predicting the risk of proliferation of the benthic cyanobacterium *Lyngbya wollei* in the St. Lawrence River. Canadian Journal of Fish and Aquatic Sciences 69:1585–1595.

Macbeth A. 2004. Investigation of an introduced subtropical alga (*Lyngbya wollei*) in Whiteshell Provincial Park, Manitoba. Masters thesis. Winnipeg: University of Manitoba.

McGregor GB, Sendall B. 2015. Phylogeny and toxicology of *Lyngbya wollei* (Cyanobacteria, Oscillatoriales) from north-eastern Australia, with a description of *Microseira* gen. nov. Journal of Phycology 51:109–119.

Onodera O, Satake M, Oshima Y, Yasumoto T, Carmichael W. 1997. New saxitoxin analogues from the freshwater filamentous cyanobacterium *Lyngbya wollei*. Chemistry-Natural toxins 5(4):146–151.

Smith ZJ, Martin RM, Wei B, Wilhelm SW, Boyer GL. 2019. Spatial and temporal variation in paralytic shellfish toxin production by benthic *Microseira (Lyngbya) wollei* in a freshwater New York lake. Toxins 11:44.

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

[UF IFAS] University of Florida Center for Aquatic and Invasive Plants. 2022. *Lyngbya* species. Available: https://plants.ifas.ufl.edu/plant-directory/lyngbya-species/ (September 2023).

[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 (Month Year of review or finalization).

Vijayavel K, Sadowsky MJ, Ferguson JA, Kashian DR. 2013. The establishment of the nuisance cyanobacteria *Lyngbya wollei* in Lake St. Clair and its potential to harbor fecal indicator bacteria. Journal of Great Lakes Research 39:560–568.

[VDH] Virginia Department of Health. 2021. Lake Gaston and *Lyngbya wollei*. Available: https://www.vdh.virginia.gov/content/uploads/sites/178/2021/04/Lake-Gaston-and-Lyngbya-wollei-Factsheet-210222.pdf (September 2023).

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.

Bhadha JH, Lang TA, Alvarez OM, Giurcanu MC, Johnson JV, Odero DC, Daroub SH. 2014. Allelopathic effects of *Pistia stratiotes* (Araceae) and *Lyngbya wollei* Farlow ex Gomont (Oscillariaceae) on seed germination and root growth. Sustain Agricultural Research 3:121–130.

Carmichael W, Evans WR, Yin QQ, Bell P. 1997. Evidence for paralytic shellfish poisons in the freshwater cyanobacterium *Lyngbya wollei* (Farlow ex Gomont) comb. nov. Applied and Environmental Microbiology 63(8):310–410.

Foss AJ, Phlips EJ, Yilmaz M, Chapman A. 2012. Characterization of paralytic shellfsh toxins from *Lyngbya wollei* dominated mats collected from two Florida springs. Harmful Algae 16:98–107.

Hoyer MV, Canfield DE. 1996. Proc. Rainbow River *Lyngbya* workshop. Gainesville: Southwest Florida Water Management District, SWIM Department.

Joyner JJ, Litaker RW, Paerl HW. 2008. Morphological and genetic evidence that the cyanobacterium *Lyngbya wollei* (Farlow ex Gomont) Speziale and Dyck encompasses at least two species. Applied Environmental Microbiology 74:3710–3717.

Komárek J, Anagnostidis K. 2005. Cyanoprokaryota. 2. Teil: Oscillatoriales. In Büdel B, Gärtner G, Krienitz L, Schagerl M, editors. Süßwasserflora von Mitteleuropa, Bd. 19 (2). München, Germany: Elsevier GmbH.

Paerl HW, Gardner WS, Havens KE, Joyner AR, McCarthy MJJ, Newell SE, Qin B, Scott JT. 2016. Mitigating cyanobacterial harmful algal blooms in aquatic ecosystems impacted by climate change and anthropogenic nutrients. Harmful Algae 54:213–222.

Pinowska A, Stevenson RJ, Sickman JO, Albertin A, Anderson M. 2007. Integrated interpretation of survey for determining nutrient thresholds for macroalgae in Florida Springs. Tallahassee: Florida Department of Environmental Protection.

Philips EJ, Ihnat J, Conroy M. 1991. Nitrogen fixation by the benthic freshwater cyanobacterium *Lyngbya wollei*. Hydrobiologia 234:59–64.

Speziale BJ, Turner EG, Dyck LA. 1991. Physiological characteristics of vertically-stratified *Lyngbya wollei* mats. Lake Reservoir Management 7:107–114.

Speziale BJ, Dyck LA. 1992. *Lyngbya* infestations: comparative taxonomy of *Lyngbya Wollei* comb. nov. (cyanobacteria). Journal of Phycology 28:693–706.

Stevenson et al. 2004. [Source material did not provide full reference]

Stevenson RJ, Pinowska A, Albertin A, Sickman JO. 2007. Ecological condition of algae and nutrients in Florida springs: the synthesis report. Tallahassee: Florida Department of Environmental Protection.

Tubea B, Hawxby K., Mehta R. 1981. The effects of nutrient, pH and herbicide levels on algal growth. Hydrobiologia 79:221–227.

Vis C, Cattaneo A, Hudon C. 2008. Shift from chlorophytes to cyanobacteria in benthic macroalgae along a gradient of nitrate depletion. Journal of Phycology 44:38–44.

Winnipeg Free Press. 2003. [Source material did not provide full reference]

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 *Microseira wollei* was projected to occur in the Appalachian Range, Great Lakes, Mid-Atlantic, Northeast, and Southern Atlantic Coast regions of the contiguous United States. Areas of low climate match were projected to occur in the Northern Pacific Coast region. Areas of low match were also found in western areas of the Western Mountains, Great Basin, and Southwest. Areas of low match expanded under time step 2085 compared to time step 2055 under both SSP3 and SSP5. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.380 (model: UKESM1-0-LL, SSP5, 2085) to a high of 0.732 (model: IPSL-CM6A-LR, 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 (0.754, figure 4) 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 one or more time step and climate scenarios, areas within the Colorado Plateau 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 and Southern Plains saw a large decrease in the climate match relative to current conditions. Additionally, areas within the Appalachian Range, Great Basin, Great Lakes, Gulf Coast, Mid-Atlantic, Northeast, Southeast, Southern Atlantic Coast, Southern Florida, and Southwest 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).

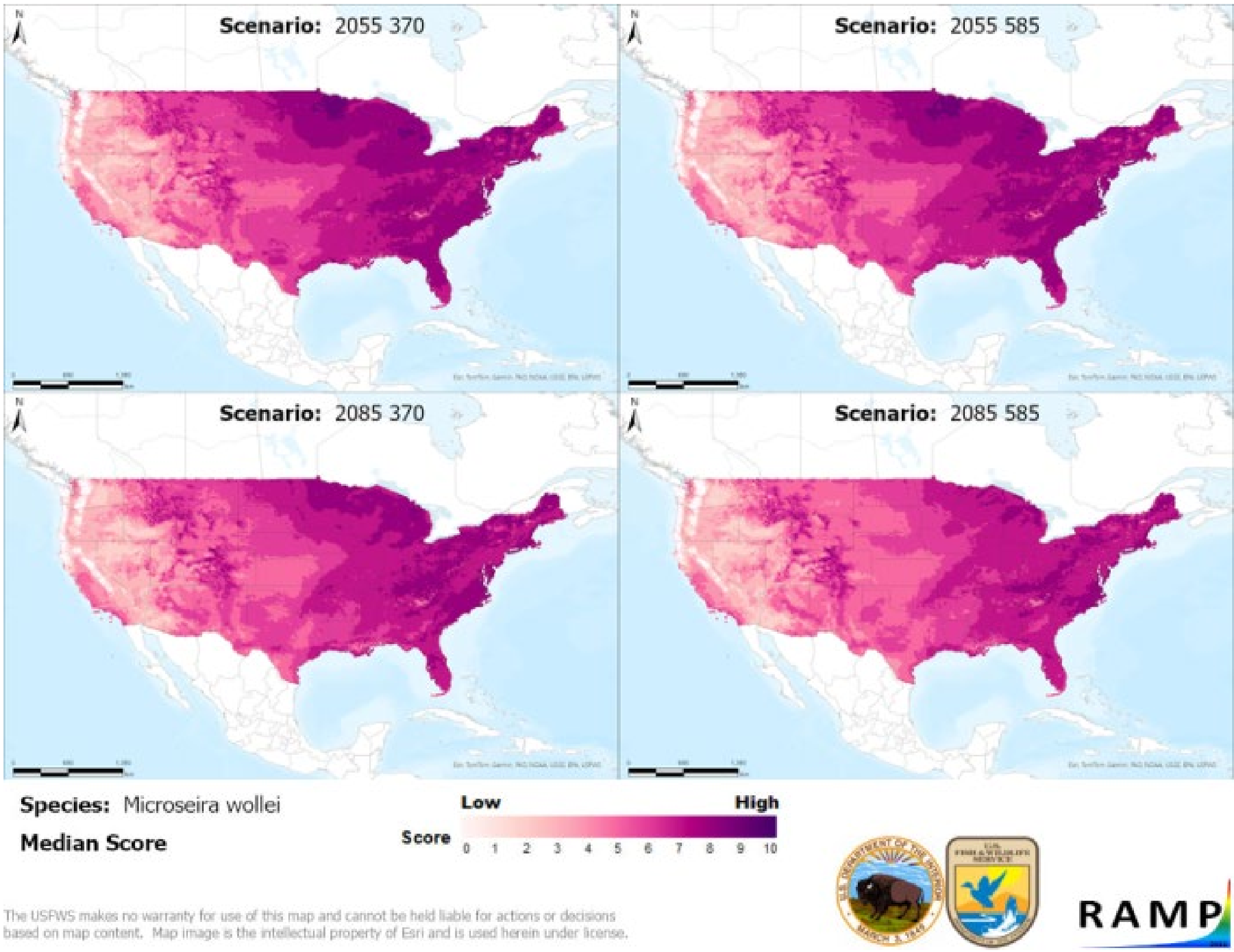


Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Microseira wollei* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2023). Shared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

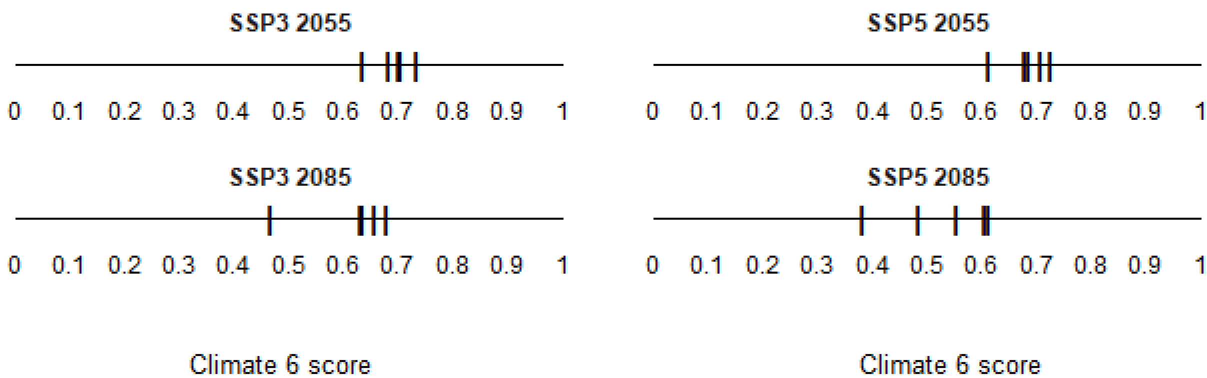


Figure A2. Comparison of projected future Climate 6 scores for *Microseira wollei* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018;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

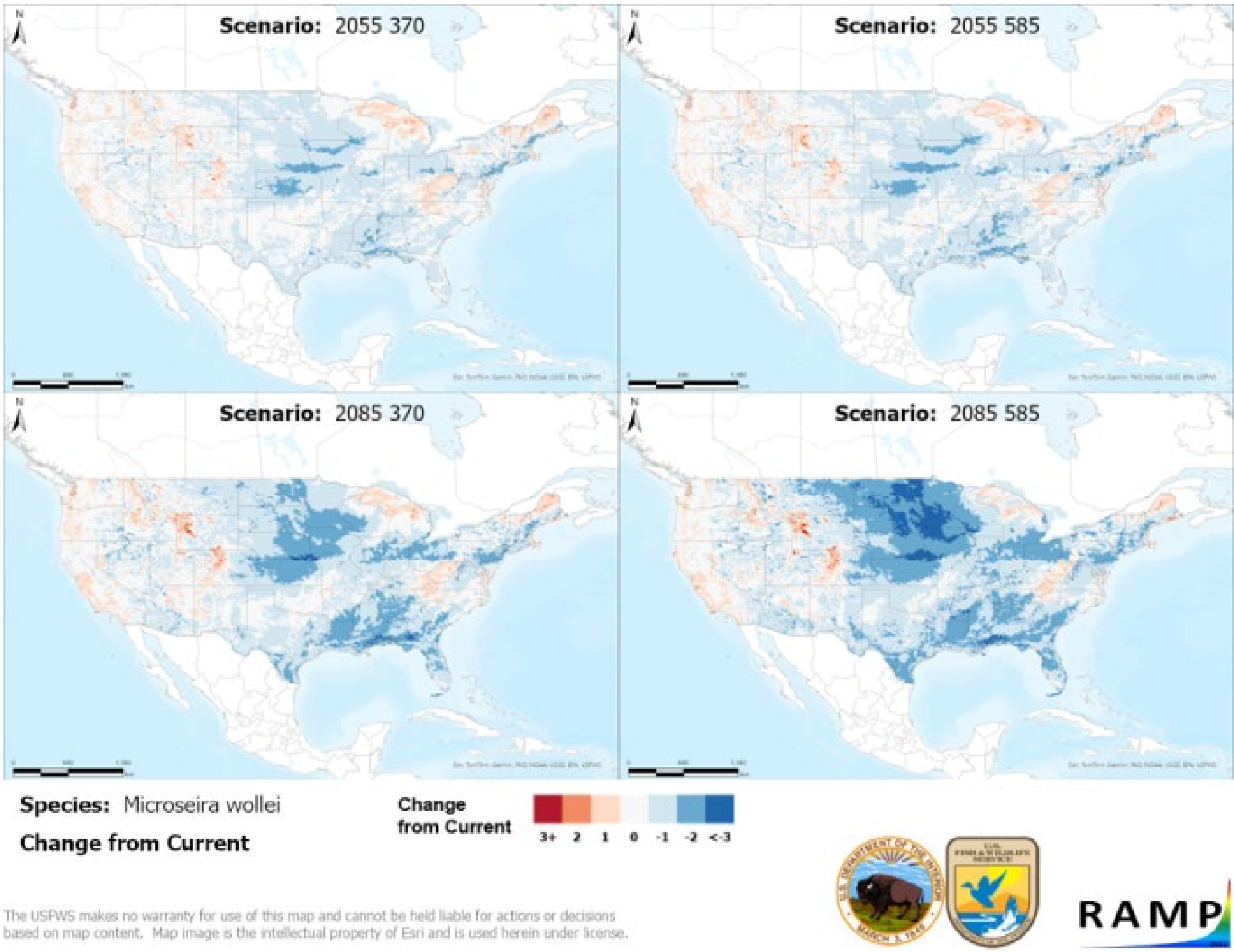


Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 4) and the median target point score for future climate scenarios (figure A1) for *Microseira wollei* based on source locations reported by GBIF 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.

Literature Cited

GBIF Secretariat. 2023. GBIF backbone taxonomy: *Microseira wollei* (Farlow ex Gomont) G.B.McGregor & Sendall ex Kenins, 2017. Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/10603679 (March 2025).

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.