

Interim Core Map Documentation for the Bunched Arrowhead

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Interim Core Map Developer: Compliance Services International (CSI) on behalf of Bayer CropScience.

Species Summary

The bunched arrowhead (*Sagittaria fasciculata*; Entity ID 818) is a dicotyledonous endangered plant found in North Carolina and South Carolina. The U.S. Fish and Wildlife Service (FWS) has not assigned designated critical habitat for the bunched arrowhead. This species inhabits seepages in gently sloping bogs with a slow, continuous flow of cool, clean water. Additional habitat information is provided in **Appendix 1**.

Description of Core Map

The core map for the bunched arrowhead is biological information type, based on the species range refined to include only the species' habitat. The species' ECOS page (FWS 2025) includes textual descriptions of habitats where the species is known to occur. Known location information from the iNaturalist and the Global Biodiversity Information Facility (GBIF) databases, and NatureServe, provided corroboration for using the range as the core map outer extent, but were not otherwise used in core map development.

Habitat within these areas was represented using different state-level datasets for North Carolina and South Carolina. In North Carolina, habitat was primarily represented using a species-specific model developed by the North Carolina Department of Transportation (NCDOT) in 2020. In South Carolina and a small portion of North Carolina, habitat areas were represented using the National Wetlands Inventory (NWI) water bodies with attributes matching descriptions of species habitat.

The core map developed in this document for the bunched arrowhead spans 11,155 acres (**Figure 1**). A summary of acreage by National Landcover Database (NLCD 2021) land use type is provided in

Table 1.

Based on the U.S. Environmental Protection Agency’s (EPA) “best professional judgment classification” system, CSI has graded this core map as “moderate” (4) because assumptions were made when connecting species life history and/or biological needs (i.e. habitat preferences) to a Geographical Information System (GIS) dataset, in this case the NWI dataset (FWS 2023). These assumptions involved associating the species’ habitat—gently sloping bogs with continuous water flow—with corresponding NWI classifications, in this case, select palustrine and riverine wetlands listed in **Appendix 2** Section 3. The NCDOT dataset was developed independently of this core mapping effort; however, its underlying data sources and subsequent vetting by FWS render it suitable for use in this analysis. More information about the best professional judgment classification system and its definitions can be found in the core map process document (EPA 2024).

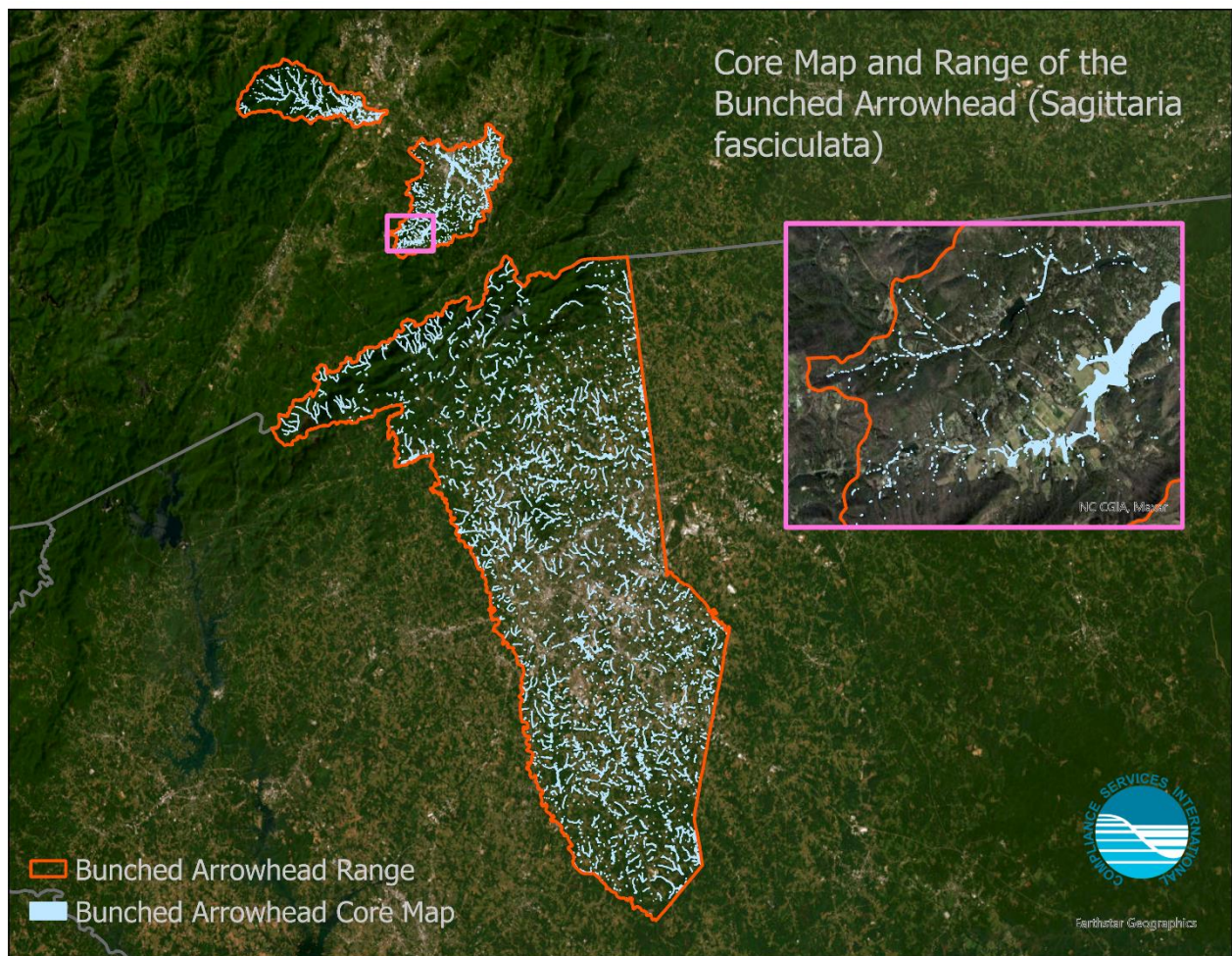


Figure 1. Interim core map for the bunched arrowhead (Sagittaria fasciculata; Entity ID 818). The core map spans 11,155 acres, while the range is 563,044 acres.

Table 1. Acres by National Land cover Database (NLCD 2021) class within the core map of the bunched arrowhead. Total core map area (based on NLCD pixel count): 11,153 acres¹.

NLCD_Land_Cover_Class	Acres
Woody Wetlands	4,232
Deciduous Forest	2,276
Open Water	1,142
Hay/Pasture	927
Mixed Forest	835
Developed, Open Space	592
Developed, Low Intensity	241
Emergent Herbaceous Wetlands	221
Herbaceous	164
Developed, Medium Intensity	153
Evergreen Forest	137
Cultivated Crops	129
Developed, High Intensity	48
Shrub/Scrub	36
Barren Land	20

Evaluation of Known Location Information

There were four evaluated datasets with known location information:

- Textual descriptions of sites in the most recent 5-Year Review (FWS 2020)
- Occurrence locations in iNaturalist;
- Occurrence locations in GBIF; and
- Occurrence locations in NatureServe.

Compliance Services International evaluated publicly available occurrence data before developing the core map. Overall, there were forty-seven usable research-grade observations found in iNaturalist². The GBIF dataset comprised 51 georeferenced observations, 41 of which were considered usable based on the criteria described below. The iNaturalist dataset was useful to corroborate the interim core map for the bunched arrowhead, but not precise enough to be used as a meaningful refinement of range in core map development. The GBIF dataset was entirely a subset of the iNaturalist data and was not used.

Approach Used to Create Core Map

The core map was developed using EPA’s process for developing core maps for species listed by the FWS and their designated critical habitat (referred to as “the process”). This core map was developed by CSI

¹ This acreage is slightly different from the core map acreage (11,155) due to the pixelation of NLCD land cover. The core map is not developed from raster data.

² According to iNaturalist, an observation is designated as “research grade” if it 1) is verifiable with date, coordinates, photos/sounds, and not captive; 2) achieves community agreement defined as “more than 2/3 of identifiers needs to agree on the species level ID or lower;” and 3) “must pass a data quality assessment, which includes checks for accurate date and location, evidence of a wild organism, and clear evidence of the organism itself” (<https://help.inaturalist.org/en/support/solutions/articles/151000169936-what-is-the-data-quality-assessment-and-how-do-observations-qualify-to-become-research-grade->).

using the four steps described in the process document:

1. Compile available information for a species;
2. Identify core map type from among the following defined types: critical habitat, range, and biological information. From EPA, summaries of each core map type are provided below (EPA 2024).
3. Develop the core map for the species; and
4. Document the core map.

For step 1, CSI compiled available information for the bunched Arrowhead (*Sagittaria fasciculata*) from FWS, as well as observation information available from various publicly available sources including iNaturalist, GBIF, and NatureServe. The information compiled for Bunched Arrowhead is included in **Appendix 1**. Influential information that impacted the development of the core map includes a description of the species habitat from the species' ECOS page:

- '*Sagittaria fasciculata* occupies seepages in gently sloping bogs with a slow, continuous flow of cool, clean water (Rayner, 1981). Wooten (1973) reports that these bogs are underlain by a clay layer. Studies by Douglass (1981) mention that the seepages may be related to a long, linear fault which occurs in the four northwestern South Carolina counties. Additional data (Douglass, 1981) show variable water temperatures, soil and water pHs between 4.8 and 6.6, and constant water depths... They need clean, slow flowing water on gently sloped landscapes or in deciduous forests' (FWS 2025).

For step 2, CSI used the compiled information including the species range, known locations, and habitat location information to determine the core map type. Compliance Services International compared the known location data to the range and found that known locations from iNaturalist, GBIF and NatureServe were not used as the basis for this core map either because the data were not precise enough (iNaturalist and NatureServe) or because they were redundant datasets (GBIF).

Review of the available data also suggested including/excluding specific habitats for this species would provide a meaningful refinement. To represent the species' habitat, in South Carolina the NWI dataset was used to identify habitat classes associated with the species habitat description above; using the "ATTRIBUTE" field. In North Carolina, habitat was primarily represented by areas of "High" potential habitat according to a species-specific model developed by the NCDOT, and a small portion outside of this layer's scope was developed using the same general approach that was used in South Carolina. The state-level habitat areas were merged and then had contiguous cultivated areas > 25 acres (EPA 2025) removed to develop the core map.

For step 3, CSI used the best-available data sources to generate the core map. Data sources are discussed in EPA's core map process document. For this interim core map, CSI followed EPA's decision framework to arrive at a core map type of biological information. Designated critical habitat was quickly eliminated as a core map type because the bunched arrowhead does not have critical habitat. The range core map type was considered because it was recently refined and appears to be based primarily on watershed (HUC-12) boundaries, which is often appropriate for a wetland-dependent species. Ultimately, range was not chosen because it still contained a significant amount of area that is not consistent with descriptions of bunched arrowhead habitat. Rather, range was used to establish the outer boundary of the core map shape.

Appendix 2 provides more details on the GIS analysis and data used to generate the core map.

Discussion of Approaches and Data that were Considered but not Included in Core Map

Known Observation Datasets

Datasets such as iNaturalist and NatureServe were considered but not used directly to refine the core map. NatureServe public EOs are viewable in their mapper as hexagons corresponding to locations where the species may have been observed. Use of iNaturalist observations buffered by their uncertainty, or NatureServe EOs at a public resolution of 343 mi² hexagons, would not meaningfully limit the extent of this core map.

The most recent 5-Year review document from FWS identifies specific populations and colonies that could be used to further refine the core map. Some of these locations were identifiable based on their name; others were not identifiable from the documentation. Therefore, CSI decided not to rely on this known location information. However, if the known observation data from FWS were to be made public or otherwise available for use in core map development, this information could be used to further refine this interim core map.

Appendix 1. Information compiled for Bunched Arrowhead

1. Recent FWS documents

- 5-Year Review (2014) https://ecosphere-documents-production-public.s3.amazonaws.com/sams/public_docs/species_nonpublish/2167.pdf.
- 5-Year Review (2020) https://ecosphere-documents-production-public.s3.amazonaws.com/sams/public_docs/species_nonpublish/3046.pdf.
- ECOS Profile Page (2025) <https://ecos.fws.gov/ecp/species/1720>.
- Recovery Plan (1983) https://ecos.fws.gov/docs/recovery_plan/Bunched_Arrowhead_RP.pdf.

2. Background information

- Status: Federally listed as endangered in 1979.
- Resiliency, redundancy, and representation (the 3Rs) were not evaluated for this species.
- Habitat, Life History, and Ecology
 - Habitat: '*Sagittaria fasciculata* occupies seepages in gently sloping bogs with a slow, continuous flow of cool, clean water (Rayner, 1981). Wooten (1973) reports that these bogs are underlain by a clay layer. Studies by Douglass (1981) mention that the seepages may be related to a long, linear fault which occurs in the four northwestern South Carolina counties. Additional data (Douglass, 1981) show variable water temperatures, soil and water pHs between 4.8 and 6.6, and constant water depths. Observations of the populations in an extreme drought year by the author verified the constancy of the seeps.' (FWS 2025).
 - 'Snipes *et al* (1986). examined the hydrology and geology of the French Broad – Bat Fork, Enoree (mainstem), and Reedy River populations of *S. fasciculata*. They characterized occupied habitat as muck-filled seep areas on alluvial flood plains, with a few noteworthy exceptions where the species occurred in small sand bars in streams. Analyses of soil chemistry, particle size, and x-ray diffraction revealed that the species tends to occur in acidic (pH 5.3 to 6.8) soils in which the primary organic content is humus, which attributes both porosity and water holding to the soil. Ground water wells (piezometers) installed at one site revealed ground water levels close to the surface, a finding regarded as consistent with the observation that larger seeps occupied by *S. fasciculata* do not dry up even in hot, dry summers. These authors also attribute a consistent source of ground water to the greater volume (roughly 20 times) of residual soil beneath the alluvial and muck sediments. They also speculate that the residual soil beneath the alluvium and muck functions as an aquitard (bed of low permeability along an aquifer) slowing downward migration of ground water.

Baxter *et al.* (2007) examined the hydrogeologic, physical and chemical characteristics of 14 Greenville County locations supporting colonies of *S. fasciculata*. Sites were characterized by (1) visual characterization of land cover, topography and hydrologic setting, (2) measurements of pH, dissolved oxygen, conductivity, temperature and numerous chemical analyses of surface water, and (3) grain size and organic content analysis of the substrate. These authors reached similar conclusions as others familiar with the species, namely that *S. fasciculata* appears to require well shaded, hydrated soils fed by a constant source of freshwater. Baxter *et al.* (2007) found that plants tend

to occur in organic-rich (average 10% organic), shallow (less than 5cm) sandy mucks in shallow (< 5 cm), acidic (pH 4-5), sodium mixed cation-bicarbonate waters with moderate levels of dissolved oxygen (3-7 mg/L) and relatively low conductivities (20-50 μ S)' (FWS 2020).

- 'Newberry (1991b) conducted a series of transplant experiments during the fall of 1990. In her summary of these efforts, Newberry notes that all increases in cover and/or plant numbers were attributable to vegetative propagation from rhizomes. This finding has significant implications for the genetic structure within and among populations of this species.' (FWS 2020).
- Taxonomy
 - 'E. O. Beal described *Sagittaria fasciculata* as a new species in 1960 (Beal, 1960). Previous to his treatment, specimens of *S. fasciculata* collected in Henderson and Buncombe Counties, North Carolina, were included with *S. macrocarpa* by J. G. Smith (1894) and by Small (1909), and in *S. graminea* var. *macrocarpa* by Bogin (1955). Both of these names were misapplied, with Smith's *S. macrocarpa* a direct synonym of *S. graminea* var. *graminea*. However, even with the confusion of names most authors recognized the morphologically distinct and geographically isolated plants in southwestern North Carolina.' (FWS 1983).
- Relevant Potential Pesticide Use Sites
 - 'Across the range of the species, several colonies of *S. fasciculata* occur in managed road, railroad, or utility rights-of-way (ROW) where overspray or drift from herbicides poses a threat to *S. fasciculata* (Bunch, M., SCDNR, pers. comm. 2010; Geosyntec, 2009; Newberry, 2000). Overspray or drift has been implicated in at least temporary reductions in the number of *S. fasciculata* plants in a given area, however in some instances these declines may have been offset by a reduction in the density of encroaching vegetation (primarily woody), which also poses a threat to *S. fasciculata* (Bunch, M., SCDNR, pers. comm. 2010; Worton, A., Geosyntec, pers. comm. 2010; Geosyntec, 2009). Despite attempts by SCDNR to inform utility companies about consistent, appropriate management practices to benefit *S. fasciculata*, managed rights-of-way continue to be an impediment to conservation efforts for this species (Bunch, M., SCDNR, pers. comm. 2010)' (FWS 2020).
- Relevant Recovery Criteria and Actions (FWS 2020)
 - Delisting Criteria:

'The recovery plan does not contain itemized or enumerated recovery criteria, but consists of a narrative with statements which are interpreted as such. These are presented here following the sequence in which they are presented in the recovery plan narrative:

 1. *Criterion 1: At least three colonies in each of four of the five populations should be protected.*

There are 11 extant populations of *S. fasciculata* (Appendix B, Table B.1); seven of these populations contain at least one colony in protective ownership (Table B.2). However, only one population (the Enoree River – mainstem in South Carolina) contains more than a single protected colony. Thus the number of protected populations, and colonies within populations, is less than specified in the recovery plan and this criterion has not been met.

2. *Criterion 2: ...the following colonies should be protected: the two North Carolina colonies in the East Flat Rock population, the single colony in the Beaverdam Creek – Enoree River population, the single colony in the Beaverdam Creek – Tyger River population, all three colonies in the Reedy River population, and eight colonies in the Enoree River population.*

Not met. The North Carolina East Flat Rock population does not contain any protected colonies. The Beaverdam Creek – Enoree River population is extirpated, and there are no protected colonies within the Beaverdam Creek – Tyger River populations. The Reedy River population contains one colony subject to a voluntary landowner agreement with Furman University; three colonies within the Enoree River (mainstem) population are protected as South Carolina Department of Natural Resources (SCDNR) Heritage Preserves.

3. *Criterion 3: Within each of the populations, sufficient colonies must be protected and located near enough to one another to ensure that there is normal gene flow between the colonies*

Not met. The number of protected colonies within all populations is lower than the minimum numbers called for in the recovery criteria. The recovery plan calls for multiple protected colonies within each protected population; as of this review only one population (the Enoree River - mainstem) contains more than a single protected colony.'

- Recommendations for Future Actions

1. *Obtain the most appropriate and highest protection for each population or colony (Recovery Task 12, Priority 1).*

Once updated information on the size and vigor of extant colonies is obtained, protection efforts should be undertaken immediately. The current number of protected colonies/populations is far less than that specified in the current set of recovery criteria.

2. *Estimate current colony and population size and vigor (Recovery Task 111, Priority 2).*

Updated information on the size and vigor of extant colonies/populations is critically needed to assess and refine protection priorities. It would be particularly useful to include detailed mapping of the spatial extent of occupied habitat.

3. *Monitor colonies, populations, permanent plots, transplants and propagation facilities (Recovery Task 4, Priority 3).*

The lack of monitoring data hinders objective assessments of colony/population trends. Anecdotal observation suggests that this species exhibits considerable fluctuation in response to drought and heavy rainfall events; monitoring would help to determine the range of acceptable fluctuations in colony/population size, and critical thresholds for management intervention.

3. Range

- Historical Range (FWS 1983)
 - 'The historical North Carolina range of the bunched arrowhead includes only Henderson and Buncombe Counties, North Carolina. All records are from the French Broad River Valley from south of East Flat Rock north to Asheville. There are seven historical localities known other than the single extant population. The single Buncombe County location, from which the type specimen was collected, actually may not have been collected in Buncombe County (Wooten, personal communication). There is a possibility that it was collected from the vicinity of East Flat Rock.'
- Current Range (FWS 2020)
 - The recovery plan describes the current range as consisting of Henderson County, North Carolina and Greenville County, South Carolina (Figure 2). The recovery plan identifies a single herbarium specimen from Buncombe County, North Carolina, while acknowledging concerns (citing Wooten, pers. comm.) that this specimen may have been collected in Henderson County. Thus, the recovery plan describes the current range as consisting of Henderson County, NC and Greenville County, SC. Within these counties, the recovery plan identifies a total of five extant populations (one in NC and four in SC).

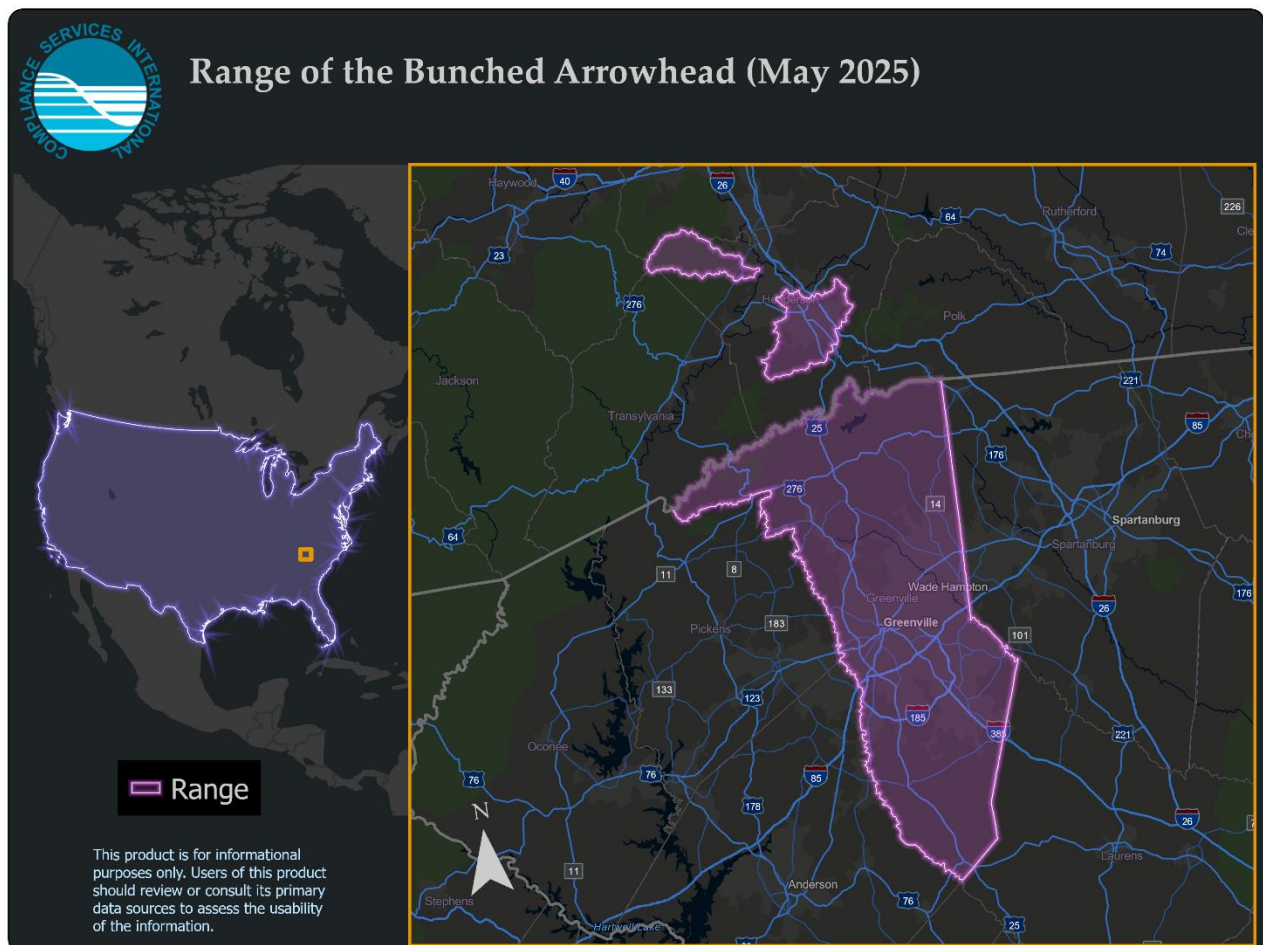


Figure 2. Range of the Bunched Arrowhead (FWS 2025).

4. Description of Critical Habitat

- Critical habitat has not been designated for this species.

5. Known Locations

- FWS (2020)
 - ‘The county-level distribution of the species has not changed since the final recovery plan. The number of known populations has increased from five to 11, with new populations discovered in the Mills River and Mud Creek watersheds of the French Broad basin (both in Henderson County, NC); North Enoree River watershed (Greenville County, SC); and Clear Creek watershed of the South Tyger River basin (Greenville County, SC). As noted elsewhere, this review adopts the same definition of population used in the recovery plan, with groups of colonies related by drainage and in relatively close physical proximity (generally within 2 km of each other as measured in river or stream miles). There are no other necessary corrections to the historical or current range.’

Table 2. Sagittaria fasciculata populations and the number of colonies they are estimated to contain. Also noted are the corresponding Natural Heritage Program (NHP) element occurrence records (EORs) located within the boundary of each population recognized by FWS. Copied from Table B.1 of the most recent 5-Year Review (FWS 2020).

Extant/ Extirpated	State	County	Population name	Colonies (total)	Colonies extant (presumed)	Protected colonies	NHP EORs
Extant	NC	Henderson	French Broad - East Flat Rock	2	2	0	NC*001
Extant	NC	Henderson	French Broad – Highland Lake Inn	1	1	1	NC*008
Extant	NC	Henderson	French Broad – Mud Creek	2	2	1	NC*002, 003
Extant	NC	Henderson	French Broad - Bat Fork Creek	1	1	1	NC*004
Extant	NC	Henderson	French Broad - Mills River	1	1	0	NC*007
Extant	SC	Greenville	Enoree River - mainstem	15	15	3	SC*001, 003, 004, 005, 006, 008, 009, 018, 019, 020, 022, 023, 024
Extant	SC	Greenville	North Enoree River	3	2	1	SC*016, 023
Extant	SC	Greenville	South Tyger – Beaverdam Creek	3	2	0	SC*014, 025
Extant	SC	Greenville	South Tyger – Clear Creek	1	1	1	SC*015
Extant	SC	Greenville	Reedy River	9	8	1	SC*002, 010, 011, 012, 013, 021, 027, 028
Extant	SC	Greenville	Enoree River – below Cane Creek	2	2	0	SC*007
Extirpated	NC	Henderson	French Broad – Memminger Creek	1	0		NC*006
Extirpated	SC	Greenville	Enoree River – Beaverdam Creek	2	0	0	SC*007

Table 3. Protected colonies of *Sagittaria fasciculata*. Copied from Table B.2 of the most recent 5-Year Review (FWS 2020).

Population name	Colony name	Landowner	Protection type	NHP EORs
French Broad River – Highland Lake Inn (NC, Henderson County)	Highland Lake Inn/CMLC easement	Highland Lake Inn	Conservation easement	NC*008
French Broad River – Bat Fork Creek (NC, Henderson County)	Bat Fork Bog	NCPCP	Fee title by a state natural resource agency; also a Dedicated Nature Preserve [¶]	NC*004
French Broad River – Mud Creek (NC, Henderson County)	Ochlawaha Bog	NCPCP, CMLC	Fee title by a state natural resource agency; also a Dedicated Nature Preserve [¶] and a Registered Heritage Area ^λ	NC*003
Enoree River – mainstem (SC, Greenville County)	Bunched Arrowhead Heritage Preserve	SCDNR	Fee title by a state natural resource agency	SC*005, 006, 019
Enoree River – mainstem (SC, Greenville County)	Blackwell Heritage Preserve - West	SCDNR	Fee title by a state natural resource agency	SC*018
Enoree River – mainstem (SC, Greenville County)	Blackwell Heritage Preserve - East	SCDNR	Fee title by a state natural resource agency	SC*022
North Enoree River (SC, Greenville County)	Bellvue Springs Heritage Preserve	SCDNR	Fee title by a state natural resource agency	SC*016
South Tyger River – Clear Creek (SC, Greenville County)	Clear Creek Heritage Preserve	SCDNR	Fee title by a state natural resource agency	SC*015
Reedy River (SC, Greenville County)	Furman University	Furman University	Voluntary registry	SC*010

[¶]Dedicated Nature Preserves represent a permanent land allocation agreement approved by the NC Council of State, signed by the Department of Administration and the Department which administers the state agency's lands, which provides standards for management and restoration of the lands.

^λRegistered Heritage Areas represent voluntary agreements between the landowner and the NC Department of Environment and Natural Resources (NCDENR) which express the intentions of the owner not to permit changes damaging to the natural values of the site and recommending a management prescription specific to the area. Unlike Dedicated Nature Preserves, this form of protection is not legally binding and non-regulatory.

- GBIF: <https://www.gbif.org/species/5328953>
 - GBIF includes 189 occurrence records; fifty-one of which are georeferenced. Forty-one of these had usable coordinate data based on these criteria:
 - U.S. only (excludes Canada)
 - Latitude and longitude precision were both 3+ decimal places.
 - Coordinate uncertainty values no greater than 30 km.
 - Relative recency (2010-present)
 - Must include date information.
 - No “preserved specimen” observations; only “human observation.”
 - The 41 usable coordinates were mapped against the species range to evaluate their utility in representing species extent (Figure 4). It was observed that all the usable GBIF coordinates are originally sourced from iNaturalist, which also had more records. Therefore, the GBIF dataset was not used for core map development.

51 GEOREFERENCED RECORDS



Figure 3. GBIF occurrences for the bunched arrowhead (GBIF 2025).

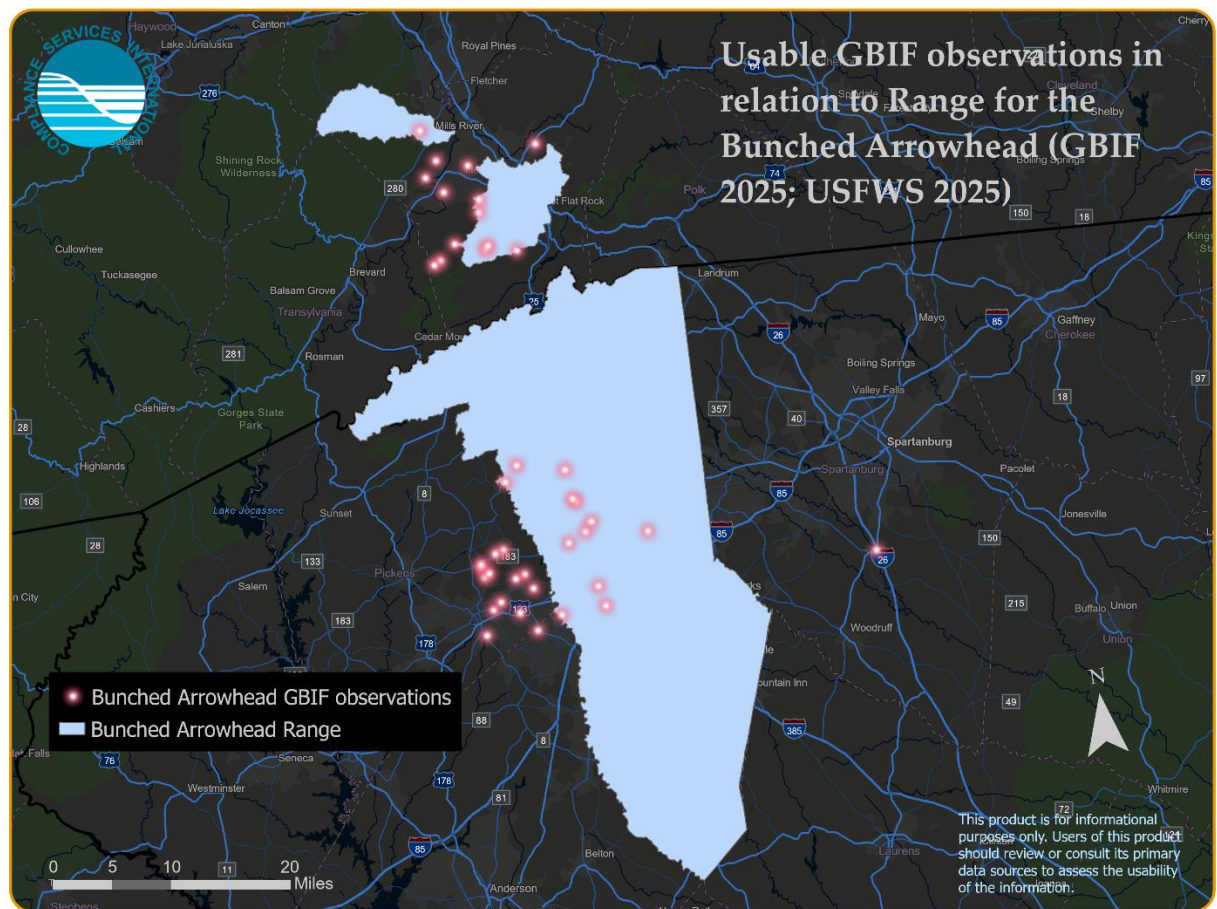


Figure 4. Usable GBIF occurrences (pink) in relation to the range of the bunched arrowhead (GBIF 2025; FWS 2025).

- iNaturalist: https://www.inaturalist.org/observations?taxon_id=129697
 - iNaturalist includes 52 total observations, 47 of which are research-grade with usable coordinate data based on these criteria (Figure 5 and Figure 6):
 - U.S. only (excludes Canada)
 - Latitude and longitude precision were both 3+ decimal places.
 - Relative recency (2010-present)
 - Observation description did not include the text “intentionally incorrect.”
 - Public positional accuracy (PPA) value no greater than 30 km³.
 - This resulted in the exclusion of three records.
 - The PPA value represents the positional uncertainty of the coordinate. This value was used as the buffer distance for iNaturalist points, to ensure that the actual position of the observation is captured. This is shown in Figure 6, but did not factor into core map development.
 - Twenty-nine iNaturalist records are outside of the FWS species range; however, all of these intersect the range when accounting for the PPA uncertainty value.
 - The iNaturalist data are plentiful and their distribution provides support for the general extent of the current range. However, these data are not usable as a meaningful refinement of an already-refined range. Therefore, these data were not used in core map development.

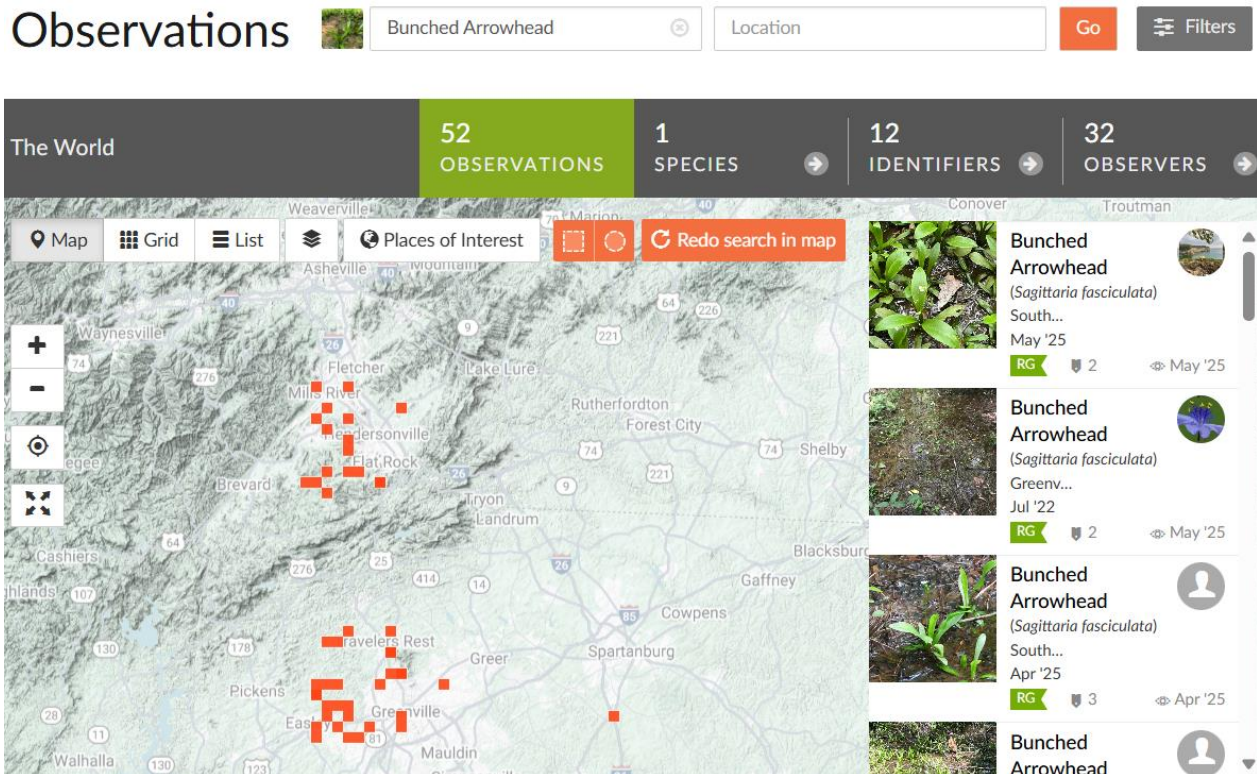


Figure 5. iNaturalist occurrences for the bunched arrowhead (iNaturalist 2025).

³ For “obscured” observations, public positional accuracy (PPA) represents the diagonal of a 0.2 x 0.2 arc cell. See the iNaturalist geoprivacy page for more details on this and related terms [What is geoprivacy? What does it mean for an observation to be obscured? : iNaturalist Help](#).

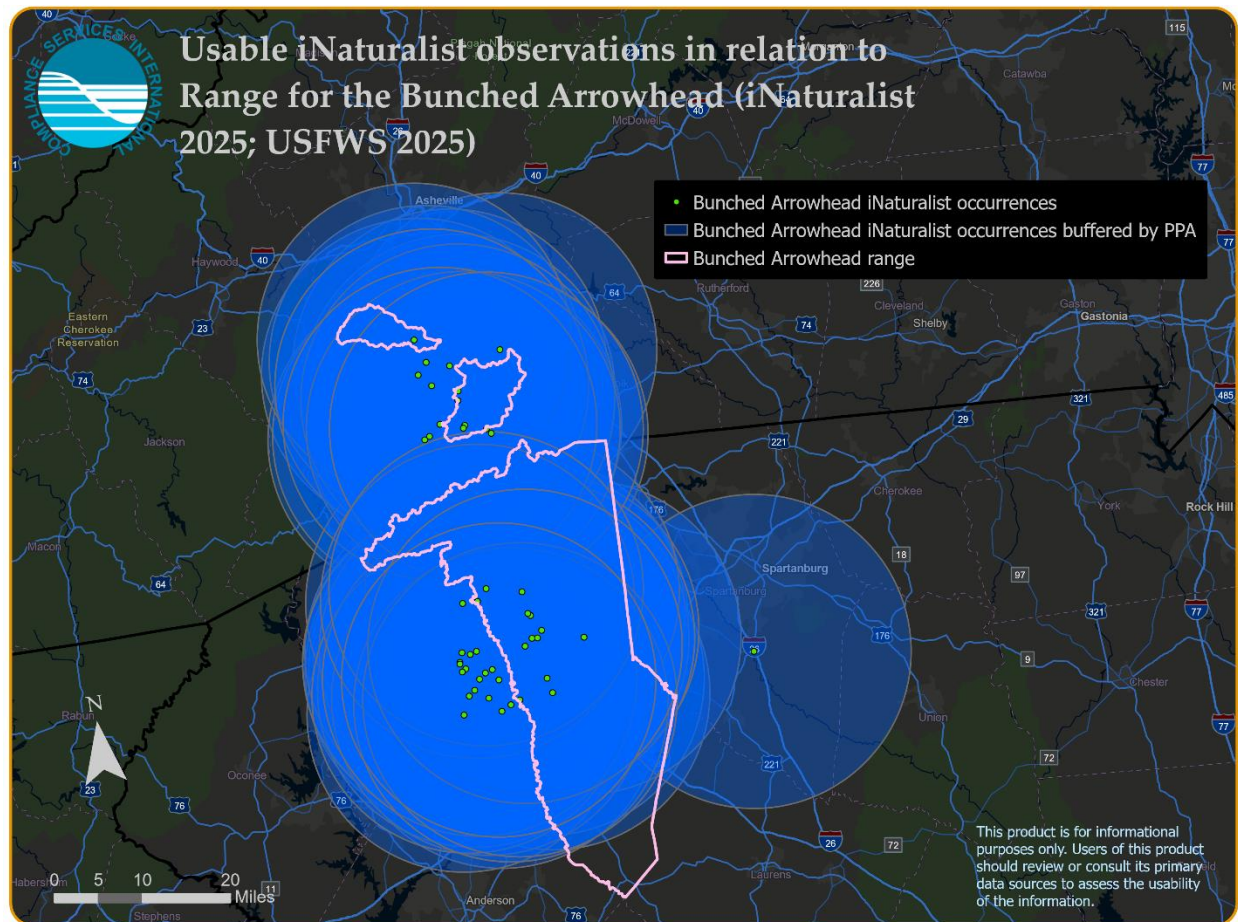


Figure 6. Usable iNaturalist observations, buffered by PPA, for the bunched arrowhead in relation to species range (iNaturalist 2025; FWS 2025).

- NatureServe Explorer: <https://explorer.natureserve.org/>
 - Available public occurrence information from NatureServe Explorer aligns with the information from iNaturalist.
 - EOs were generally consistent with the range and did not support expanding the core map outside of its range.

Appendix 2. GIS Data Review and Method to Develop Core Map

The core map for this species is based on biological information, which includes the habitat used by this species found within a spatial extent of species range. The core map identifies all areas within the extent matching the species' habitat description from **Appendix 1**. In North Carolina, potential habitat areas were primarily represented using a species-specific model developed by the NCDOT. In South Carolina, professional judgment was used to match "ATTRIBUTE" classes in the National Wetland Inventory (NWI) dataset as described below (FWS 2023). NWI is regarded as a high quality national-level dataset that is appropriate to identify habitat for aquatic species such as the Bunched Arrowhead.

1. References and Software

- National Wetlands Inventory (FWS 2023): <https://www.fws.gov/program/national-wetlands-inventory>.
- North Carolina Department of Transportation: "Bunched Arrowhead - Potential Habitat, March 2020." <https://xfer.services.ncdot.gov/gisdot/AtlasData/AtlasSpeciesModels/ATLASGISPlantAndAnimalModels/>.
- Software used: ArcGIS Pro version 3.2.
- EPA Modified Cultivated Layer: <https://cdn.arcgis.com/home/item.html?id=159e70ce4c284f5b972c687037f8a668>.
- FWS Species Range (FWS 2025): <https://ecos.fws.gov/ecp/species/1720>.

2. Datasets Used in Core Map Development

2.1. Range

The range for this species was last updated by FWS on Feb. 19, 2025. A shapefile including species range for all listed species was downloaded from the USFWS ECOS website on May 5, 2025. The shapefile was converted to a feature class stored in a file geodatabase and reprojected to WKID #102008 ("North America Albers Equal Area Conic").

1. Using an ArcGIS Web Map the species was queried based on the ECOS listed "Entity ID" of 818 and exported as a feature class to a temporary file geodatabase as a standalone Entity ID-specific layer.
2. The area of the range was calculated automatically by loading it into the software (ArcGIS Pro version 3.2) and reading its area from the attribute table ("Shape_Area"), then converting its units (square meters) into acres with a conversion factor of 0.000247105.

This shapefile was added to an ArcGIS Pro map and compared against the known observation datasets and state-level habitat information (described below). The range was used to establish the outer boundary of the core map.

2.2. North Carolina Department of Transportation (NCDOT) Dataset

Regions of suitable habitat were used to refine the core map based on biological information. The NCDOT completed a project named "ATLAS" in 2021 that categorized land within the range as low or high suitability for species habitat for the bunched arrowhead. Ultimately, regions of Low suitability were excluded from the core map, while High suitability were included. Categories of "low" and "high" for this species are defined as follows:

- Low: Regions and sites where biologists would be very surprised to find this species and its habitat (occurrence here should be extremely rare).
- High: Biologists expect to frequently encounter areas that look like potential habitat based on visible environmental and vegetation community characteristics (Figure 7, NCDOT 2020).

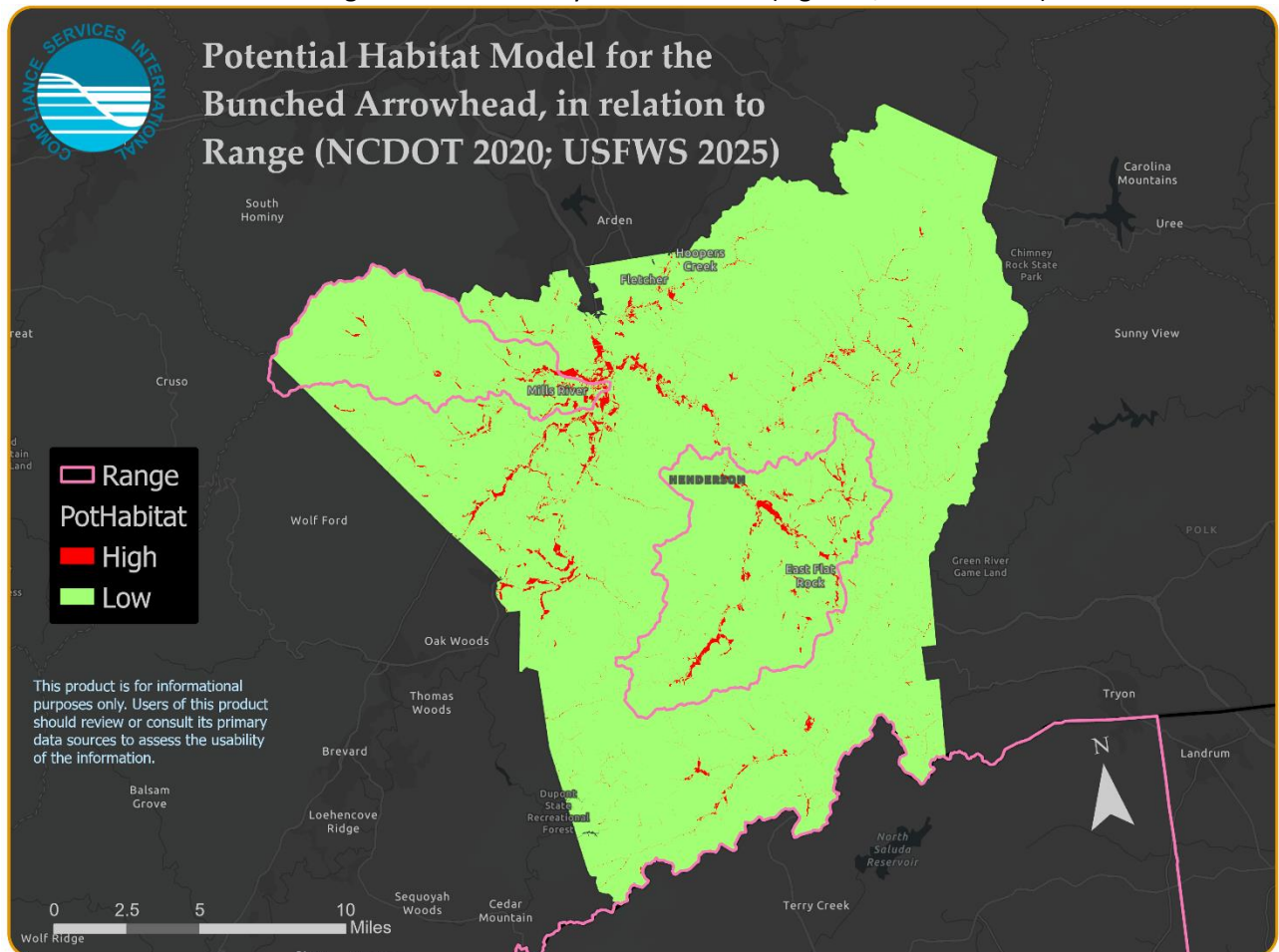


Figure 7. Areas of low and high habitat suitability for the bunched arrowhead in North Carolina in relation to a section of the species' range (NCDOT 2020; FWS 2025).

2.3. National Wetlands Inventory (NWI) dataset

The NWI dataset was preliminarily vetted to determine its appropriateness in representing aquatic areas matching descriptions of the bunched arrowhead habitat, for areas not already represented by the species-specific model developed by the NCDOT (mostly South Carolina, but also a small portion of the North Carolina range without modeled information). As indicated previously, the species inhabits seepages in gently sloping bogs with a slow, continuous flow of cool, clean water. CSI reviewed NWI attribute classes in relation to this description and determined that the species' potential habitat is best represented by a combination of riverine and palustrine systems:

- Riverine (NWI code = R)
 - Subsystems: Intermittent (4), Streambed (5)
 - Classes: Unconsolidated Bottom (UB)
- Palustrine (code = P)
 - Classes: Unconsolidated Bottom (UB), Moss-Lichen (ML), Emergent (EM), Scrub-Shrub, and

Forested (FO)

These possible site location types were selected in the merged NWI wetlands dataset using the following SQL query:

- `ATTRIBUTE LIKE '%R4UB%' OR ATTRIBUTE LIKE '%R5UB%' OR ATTRIBUTE LIKE '%PUB%' OR ATTRIBUTE LIKE '%PML%' OR ATTRIBUTE LIKE '%PEM%' OR ATTRIBUTE LIKE '%PSS%' OR ATTRIBUTE LIKE '%PFO%'`

The selected water body features were dissolved into a single shape to represent potential habitat of the bunched arrowhead in South Carolina (and a small portion in North Carolina, processed separately), then merged with the separately-developed dataset for North Carolina developed by the NCDOT.

2.4. EPA Cultivated Lands > 25 acres

EPA has developed and published its own cultivated layer for use in core map development as a potential refinement of habitat and/or extent (EPA 2025). For the Bunched Arrowhead, habitat was refined by this layer using the Pairwise Erase tool to remove significant areas of agriculture because the species habitat is not consistent with cultivated land and is therefore considered by CSI to be an “off-field” species. This removed 282 acres (2.5% of area) and is considered a reasonable refinement for core map development for off-field species.

3. Creating the Core Map

3.1. Species potential habitats from NCDOT

The core map for the bunched arrowhead in North Carolina was developed primarily using a specific-specific model produced by the NCDOT; there was a small portion of the range extending beyond the NCDOT layer’s extent, which was processed according to the procedure given “Non-NCDOT Areas” section below. The NCDOT data downloaded contained only areas of “low” probability; areas of high probability were inferred to be the inverse of this shape, which was confirmed by a map in the model’s metadata (**Figure 8**). Finally, this portion of the core map was clipped to species range, which has decreased in North Carolina since the time the NCDOT data were developed (2020).

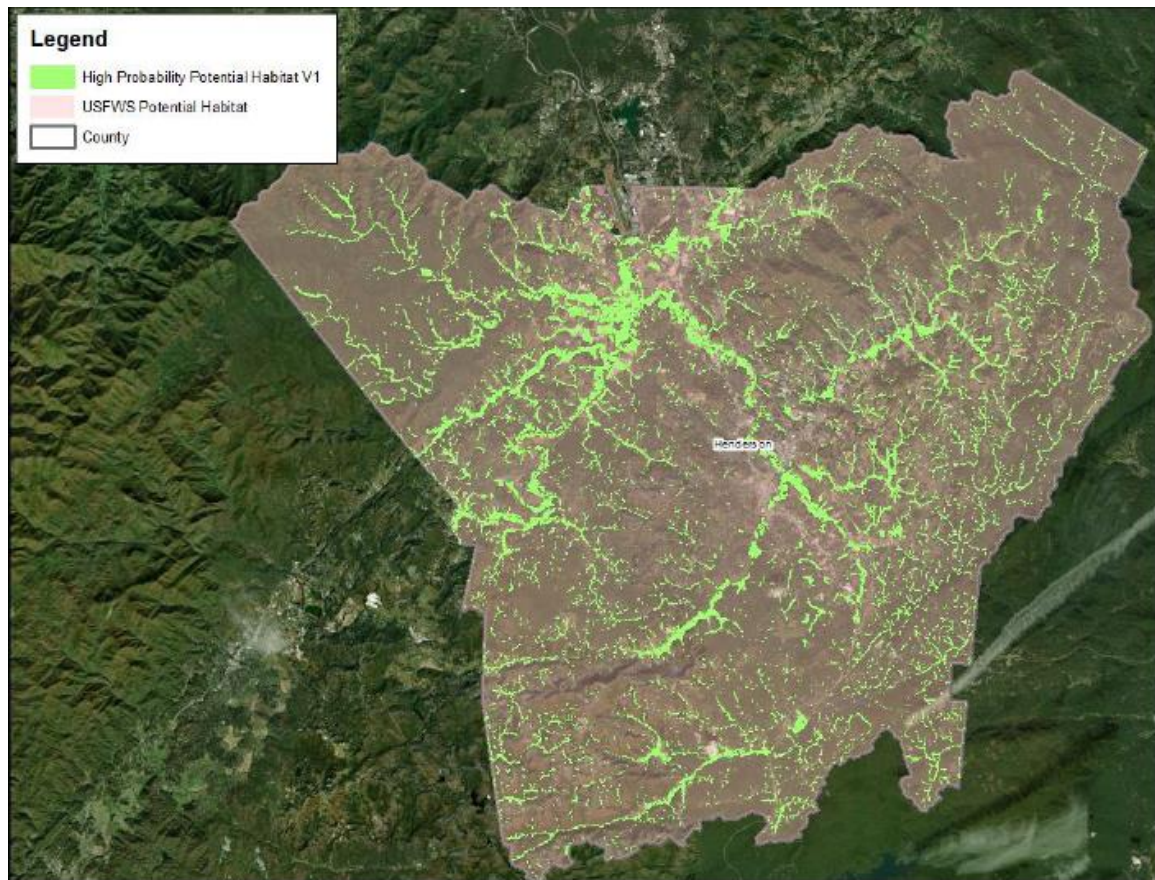


Figure 8. NCDOT areas of high probability (green) for the bunched arrowhead. Copied from Figure 1 of the model metadata (NCDOT 2020).

Areas of high probability were extracted as the inverse of the downloaded data and dissolved into a single shape as follows:

1. Download the species habitat model shapefile for the bunched arrowhead. Import this layer into a geodatabase, saved as "NCDOT". Choose to output this layer and subsequent ones using the preferred projection of WKID #102008.
2. Use the Feature to Polygon tool to fill in "holes" in the previous layer ("NCDOT"). Save output as a new layer, "NCDOT_f2p".
3. Use the Pairwise Erase tool to remove areas of low probability ("NCDOT") from the overall extent of the NCDOT data ("NCDOT_f2p") and save as a new layer named to indicate its representation of high-probability habitat, "NCDOT_high".
4. Use the Pairwise Dissolve tool to dissolve the previous layer "NCDOT_high" into a feature class with a single shape, saved as "NCDOT_high_pd".
5. Use the Pairwise Clip tool to clip the previous layer ("NCDOT_high_pd") by the species range ("BA_range"), and save as a new layer, "NCDOT_high_pd_pcRange".

3.2. Species Potential habitats for areas outside of NCDOT Areas (primarily South Carolina)

In South Carolina, the core map for the bunched arrowhead was developed from NWI data. Specifically, the state-level South Carolina and North Carolina datasets were clipped to species range and a state boundary layer, queried for habitat land cover types consistent with FWS descriptions of species habitat, and dissolved

into a single shape as follows:

South Carolina

1. Import bunched arrowhead range ("BA_range") and a state boundaries layer into a GIS.
2. Use the Select tool to select South Carolina from the state boundaries layer. This is done to facilitate the next step.
3. Use the Pairwise Clip tool to clip the species range ("BA_range") by the selected state boundaries layer, to extract just the portion of the range in South Carolina ("BA_range_pcSC").
4. Download the state-level NWI layer of water bodies for South Carolina.
5. Use the Pairwise Clip tool to clip NWI water bodies in South Carolina by the portion of the species range that occurs in South Carolina ("BA_range_pcSC") and save as a new layer, "NWI_SCwetlands_pcRangeSC".
6. Use the Select by Attributes tool to select only features from the previous layer ("NWI_SCwetlands_pcRangeSC") with "ATTRIBUTE" field values consistent with the species habitat description for the Bunched Arrowhead according to the classes listed in **Appendix 2** Section 3, using the following SQL query. Save as a new layer, "NWI_SCwetlands_pcRangeSC_sel".
 - ATTRIBUTE LIKE '%R4UB%' OR ATTRIBUTE LIKE '%R5UB%' OR ATTRIBUTE LIKE '%PUB%' OR ATTRIBUTE LIKE '%PML%' OR ATTRIBUTE LIKE '%PEM%' OR ATTRIBUTE LIKE '%PSS%' OR ATTRIBUTE LIKE '%PFO%'
7. Use the Pairwise Dissolve tool to dissolve the previous layer "NWI_SCwetlands_pcRangeSC_sel" into a feature class with a single shape, saved as "NWI_SCwetlands_pcRangeSC_sel_pd".

North Carolina

1. Use the Select tool to select North Carolina from the state boundaries layer. This is done to facilitate the next step.
2. Use the Pairwise Clip tool to clip the species range ("BA_range") by the selected state boundaries layer, to extract just the portion of the range in North Carolina ("BA_range_pcNC").
3. Use the Pairwise Erase tool to remove areas covered by the NCDOT dataset ("NCDOT_f2p") from the portion of the range occurring in North Carolina ("BA_range_pcNC"), and save output as a new layer, "BA_range_pcNC_peNCDOTf2p".
4. Download the state-level NWI layer of water bodies for North Carolina.
5. Use the Pairwise Clip tool to clip NWI water bodies in North Carolina by the portion of the species range that occurs in North Carolina that is not covered by the NCDOT layer ("BA_range_pcNC_peNCDOTf2p") and save as a new layer, "NWI_NCwetlands_pcRangeNC_peNCDOTf2p".
6. Use the Select by Attributes tool to select only features from the previous layer ("NWI_NCwetlands_pcRangeNC_peNCDOTf2p") with "ATTRIBUTE" field values consistent with the species habitat description for the Bunched Arrowhead according to the classes listed in **Appendix 2** Section 3, using the following SQL query. Save as a new layer, "NWI_NCwetlands_pcRangeNC_peNCDOTf2p_sel".
 - ATTRIBUTE LIKE '%R4UB%' OR ATTRIBUTE LIKE '%R5UB%' OR ATTRIBUTE LIKE '%PUB%' OR ATTRIBUTE LIKE '%PML%' OR ATTRIBUTE LIKE '%PEM%' OR ATTRIBUTE LIKE '%PSS%' OR ATTRIBUTE LIKE '%PFO%'
7. Use the Pairwise Dissolve tool to dissolve the previous layer "NWI_NCwetlands_pcRangeNC_peNCDOTf2p_sel" into a feature class with a single shape, saved as "NWI_NCwetlands_pcRangeNC_peNCDOTf2p_pd".

3.3. Merging North Carolina and South Carolina Core Map Elements

The NCDOT for portions of North Carolina and NWI shapes for North Carolina and South Carolina are mutually exclusive datasets that were merged and dissolved to form the core map habitat as follows:

8. Use the Merge tool to merge the core map elements from North Carolina (“NCDOT_high_pd_pcRange” and “NWI_NCwetlands_pcRangeNC_peNCDOTf2p_pd”) and South Carolina (“NWI_SCwetlands_pcRangeSC_sel_pd”) into a single layer representing species habitat in these two states. Save as a new layer, “BA_habitat”.
9. Use the Pairwise Dissolve tool to dissolve the previous layer (“BA_habitat”) into a feature class with a single shape, saved as “BA_habitat_pd”.

3.4. Cultivated Lands-based Refinement

The bunched arrowhead is not expected to be found in agricultural areas, so a refinement to exclude areas of agriculture was applied. Here agricultural areas are represented by EPA’s modified cultivated layer, which includes areas spanning at least 25 acres. This was done as follows:

1. Use the Pairwise Erase tool to exclude cultivated areas > 25 acres from the previous layer (“BA_habitat_pd”) according to a layer developed by EPA (“CultivatedAreas_Over25acres”). Save as a new layer (“BA_habitat_pd_peCultivated25ac”).
2. (Optional) Export features from the previous layer (“MSPP_habitat_pd_peCultivated25ac”) into a new layer recognizable as the bunched arrowhead core map, “BA_CoreMap”.

References

Documents

- U.S. Environmental Protection Agency. 2024. Process EPA Uses to Develop Core Maps for Pesticide Use Limitation Areas. Accessed June 18, 2025. <https://www.epa.gov/endangered-species/process-epa-uses-develop-core-maps-pesticide-use-limitation-areas>.
- U.S. Fish and Wildlife Service. 1983. "Bunched Arrowhead (*Sagittaria fasciculata*) Recovery Plan." North Carolina Department of Agriculture; Plant Industry Division. Accessed June 18, 2025. https://ecos.fws.gov/docs/recovery_plan/Bunched_Arrowhead_RP.pdf.
- U.S. Fish and Wildlife Service. 2014. "Bunched Arrowhead (*Sagittaria fasciculata*) 5-Year Review: Summary and Evaluation." Asheville, NC. Accessed June 18, 2025. https://ecosphere-documents-production-public.s3.amazonaws.com/sams/public_docs/species_nonpublish/2167.pdf.
- U.S. Fish and Wildlife Service. 2020. "Bunched Arrowhead (*Sagittaria fasciculata*) 5-Year Review: Summary and Evaluation." Asheville, NC. Accessed June 18, 2025. https://ecosphere-documents-production-public.s3.amazonaws.com/sams/public_docs/species_nonpublish/3046.pdf.

Spatial Data & Software

- GBIF Secretariat. "Sagittaria fasciculata (Bunched Arrowhead)." *GBIF Backbone Taxonomy*. Accessed June 18, 2025. <https://www.gbif.org/species/5328953>.
- iNaturalist. "Bunched Arrowhead (*Sagittaria fasciculata*)." Accessed June 18, 2025. https://www.inaturalist.org/observations?taxon_id=129697.
- NatureServe. 2025. NatureServe Network Biodiversity Location Data accessed through NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Available <https://explorer.natureserve.org/>. Accessed June 18, 2025.
- North Carolina Department of Transportation (NCDOT). 2020. "Bunched Arrowhead - Potential Habitat." Accessed June 16, 2025. [xfer.services.ncdot.gov - /gisdot/AtlasData/AtlasSpeciesModels/ATLASGISPlantAndAnimalModels/](https://xfer.services.ncdot.gov-/gisdot/AtlasData/AtlasSpeciesModels/ATLASGISPlantAndAnimalModels/).
- Software used: ArcGIS Pro version 3.2.
- U.S. Environmental Protection Agency. 2025. Modified Cultivated Layer. Accessed June 18, 2025. <https://cdn.arcgis.com/home/item.html?id=159e70ce4c284f5b972c687037f8a668>.
- U.S. Fish and Wildlife Service. 2025. "Bunched Arrowhead (*Sagittaria fasciculata*)." Environmental Conservation Online System (ECOS). Accessed June 18, 2025: <https://ecos.fws.gov/ecp/species/1720>.
- U.S. Fish and Wildlife Service. 2023. *National Wetlands Inventory*. Accessed June 18, 2025. <https://www.fws.gov/program/national-wetlands-inventory>.