Appendix F. Aquatic Habitat Technical Team Report

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Executive Summary

The 2015 revision of Georgia's State Wildlife Action Plan provided an opportunity to update and improve the existing high priority waters dataset. We chose United States Geological Survey Hydrologic Unit Code 10 digit watersheds (hereafter HUC 10) for the identification of high priority watersheds, because it provides a consistent and practical scale for watershed-level conservation. Based on species occurrence data, land cover, and expert knowledge, the Fishes and Aquatic Invertebrates Species Technical Team identified 165 high priority watersheds to protect the best known populations of 168 high priority aquatic species. These watersheds were then prioritized by calculating a Global Significance Score (GSS), which was based upon the number of species identified in each watershed as well as the global rarity of each species. Watersheds with the highest GSS clustered in the Coosa and Tennessee drainages of northwest Georgia, but also occurred in the Tallapoosa, Chattahoochee, Flint, and Savannah drainages. Watersheds with high and moderate GSS occurred in all of Georgia's five ecological regions and 14 major drainages, except the Satilla. An additional 56 watersheds were designated as "significant" high priority watersheds, but were not further prioritized. Significant watersheds contained important coastal habitats, migratory corridors for anadromous species, recent occurrences or critical habitat for federally listed species, or occurred in a region of the state where high priority watersheds were poorly represented.

We carried out a GIS assessment of all of Georgia's HUC 10 watersheds (n = 366) to characterize their degree of protection, existing condition, recent land cover trends, and future threats. Existing conservation lands are concentrated in the Blue Ridge of northeast Georgia, but there are

significant parcels of protected land scattered throughout the state. Important patterns affecting watershed condition include high forest in northeast Georgia, high cultivated crop agriculture in southwest Georgia, and extensive development within and fringing the Metro Atlanta area and along the I-75 corridor. The density of dams varies across watersheds, but impacts aquatic connectivity in almost every watershed in the state. Trends in land cover between 2001-2011 include significant declines in forest cover in the Piedmont and Southeastern Plains, little change in row crop agriculture, and increases in developed land cover in urban areas throughout the state. Urban growth models predict that extensive urbanization will occur throughout the Piedmont and Blue Ridge provinces and at scattered locations throughout the state between now and 2050.

To provide examples of how the assessment data can be used, we have identified conservation actions for three high priority watersheds: Armuchee Creek, Upper Nottely River, and Spring Creek. Some key conservation actions for these watersheds include the protection of connectivity in free-flowing streams, technical assistance to farmers and local governments, and targeted outreach. While we acknowledge the limitations of our data and the existence of additional data sets that should be considered, the information provided in this report can help guide conservation of Georgia's high priority watersheds. Conserving high priority watersheds is important to the conservation of Georgia's high priority aquatic species as well as southeastern aquatic species diversity overall. In addition, efforts to protect and restore these watersheds may also improve water quality and recreational opportunities for humans.

Introduction

As part of the development of a State Wildlife Action Plan (SWAP) in 2005, Georgia identified 212 waterbodies (i.e, rivers, streams, and creeks) as a high priority for conservation efforts. High priority waters were selected to protect important populations of high priority species and also to protect or restore representative aquatic systems throughout the state. High priority waters and their surrounding watersheds are considered a high priority for a broad array of conservation activities, including watershed-level protection efforts, riparian restoration, protection or restoration of natural flow regimes, and other conservation activities. Since the action plan was completed, the protection of high priority waters has been promoted through GADNR's high priority waters webpage, and in Georgia's SWAP plan. In addition, high priority streams are listed along with rare species occurrences when GADNR comments on projects that could potentially impact rare species or habitats.

Changes to the list of high priority species made as part of the current SWAP revision necessitate an update of the high priority waters dataset and also provide an opportunity to make the data more useful for conservation. One of the limitations of the initial data set was the lack of prioritization: streams were designated as high priority or not. With such a large number of high priority waterbodies and watersheds in the state, it is difficult to know where limited conservation resources should be invested. Another limitation was the lack of a GIS assessment of watershed characteristics, which can help identify the most prudent conservation strategies needed in each watershed. For example, an urbanizing watershed with no protected lands would face different threats than one that is dominated by agricultural land uses.

The objective of this report was to identify high priority watersheds for the conservation of SWAP high priority aquatic species and aquatic systems in general. In addition, we have summarized

GIS characteristics that will help identify the most appropriate conservation actions for high priority watersheds.

Assessment Methods

Selecting High Priority Watersheds for Rare Aquatic Species

We chose United States Geological Survey Hydrologic Unit Code 10 digit watersheds (hereafter HUC 10) as the spatial scale for the identification of high priority watersheds. Georgia has 366 HUC 10 watersheds that occur within or straddle our state boundaries, with an average size of 454 km^2. While the smaller and more numerous HUC 12 watersheds (mean = 91 km^2, n =1964) also provide a standard and widely used spatial scale, many have not been adequately surveyed for rare aquatic species in Georgia. In addition, HUC 10 watersheds are typically large enough to include the variety of habitat types (e.g., small streams to large rivers) required by most species for survival and reproduction (Schlosser and Angermeier 1999). In contrast to larger HUC 8 watersheds, HUC 10 watersheds provide a spatial scale in which watershed groups and other stakeholders can work effectively to conserve aquatic species populations (McGurrin and Forsgren 1997). Overall, we believe that the HUC10 scale provides an appropriate framework for the management of aquatic species populations, but note that no single spatial scale will be appropriate for all species. For example, protecting an individual HUC 10 watershed would not protect a population of a highly migratory species.

Species experts selected high priority watersheds during SWAP technical team meetings held in January and February 2014. Watersheds were selected to protect the best occurrences of 165 high priority aquatic species, which are listed in the SWAP Fishes and Aquatic Invertebrates Assessment Report (Albanese et al. 2015). Factors considered included date of species occurrences, watershed condition based on personal knowledge or reference to a 2008 land cover map, and existing watershed protection based on the Conservation Lands Database. Conservation status assessment maps, which show watersheds with the most recent documented occurrences of a species, were used to help guide selection of high priority watersheds. Technical team members attempted to select 4 HUC 10 watersheds for each high priority species. However, for many species it was not possible to identify all four watersheds because: 1) the species occurred in fewer than 4 watersheds in the state (common issue), 2) the species did occur in 4 or more watersheds, but some watersheds were not considered significant to the conservation of the species for a variety of reasons (e.g., the watershed was considered severely degraded, the occurrence was not indicative of an important population or life history function, or old occurrence dates suggest that the species may be extirpated from the watershed). In a few cases, the technical team selected unoccupied watersheds that might be important for reintroduction of a species with few or no extant occurrences in the state.

To focus conservation efforts in watersheds protecting multiple species, we attempted to eliminate watersheds only protecting a single species from the data set. In most cases, we used an alternate high priority watershed selected to protect other high priority species, as long as the new watershed contained recent occurrences of the species and the old watershed was not considered critical for conserving the species. If we could not identify an alternate high priority watershed for a species with an apparently secure (G4) or secure (G5) NatureServe global rarity rank (i.e. G Rank), we

eliminated it from the data set as long as the species was represented in three other high priority watersheds. If we could not identify an alternate watershed for a G1-G3 species (Critically Imperiled to Vulnerable), we retained the single species watershed in the dataset. Through this editing process, we eliminated 16 watersheds.

The species and aquatic habitat technical teams were given an opportunity to review a draft map of high priority watersheds during May 2014, which resulted in the selection of additional high priority watersheds. Based upon the suggestion of one technical team member, we asked John Jensen (Reptile and Amphibian technical team leader) to designate watersheds for nine high priority reptile and amphibian species that occur in rivers and streams: Apalachicola Alligator Snapping Turtle (*Macrochelys apalachicolae*), Alabama Map Turtle (*Graptemys pulchra*), Barbour's Map Turtle (*Graptemys barbouri*), Brown-Back Salamander (*Eurycea aquatic*a), Dwarf Waterdog (*Necturus punctatus*), Eastern Hellbender (*Cryptobranchus alleganiensis*), One-Toed Amphiuma (*Amphiuma pholeter*), Patch-nosed Salamander (*Urspelerpes brucei*), *and* Suwannee Alligator Snapping Turtle *(Macrochelys suwanniensis)*. We also identified additional watersheds for Robust Redhorse (*Moxostoma robustum*) to ensure that important habitats for both Evolutionarily Significant Units (Altamaha and Savannah; see Wirgin et al. 1991) of the species were represented.

Prioritizing High Priority Watersheds

Given the large number of high priority watersheds identified by the technical team, it was important to further prioritize them for conservation efforts. For example, a watershed with several globally imperiled species might require substantial investments, such as species monitoring, targeted land acquisition, restoration, and finer scale conservation planning. On the other hand, a high priority watershed may not be significant globally, but might still be significant for proactive conservation of species that have a limited range in the state.

We assigned a global significance score (GSS) for all high priority watersheds in the state, calculated as:

$$\text{GSS} = \sum_{i=1}^{s} SI$$

Where SI = individual species importance score, which is summed across all (s) high priority species in the watershed. The species importance score was based on NatureServe Global Rarity Ranks (lower number means greater imperilment), to place greater emphasis on species that are imperiled globally. We used the following weighting: G1=5 points, G2= 4 points, G3= 3 points, G4 = 2 points, G5 = 1 point. Thus, watersheds with the highest global significance scores will protect many globally rare species. For example, a watershed with five G5 species would have a GSS of 5, whereas a watershed with five G1 species would have a GSS of 25.

Selection of Additional High Priority Watersheds

After reviewing the initial map of high priority watersheds, technical team members suggested selection of additional high priority watersheds that did not meet our initial criteria based on rare species occurrences. These additional watersheds were selected because they met at least one of five criteria: 1) they contained critical habitat for a species listed under the U.S. Endangered Species Act (ESA), 2) they contained important coastal habitats, such as estuaries and marshes, 3) they were part of a migratory corridor for a high priority diadromous species (Alabama Shad *Alosa alabamae*, American Shad *Alosa sapidissima*, Atlantic Sturgeon *Acipenser oxyrinchus*, and Shortnose Sturgeon *Acipenser brevirostrum*), 4) they contained an extant population of an ESA listed species, or 5) they occurred in an ecological region of the state where high priority watersheds were poorly represented. These criteria were only evaluated for watersheds that had not already been designated as high priority because they contained an important population (s) of a high priority species. These additional watersheds were not prioritized as described above and are hereafter designated as "significant" high priority watersheds, regardless of which criterion or criteria they met.

Watersheds with critical habitat for ESA listed aquatic species were identified using a GIS coverage of critical habitat units obtained from the U.S. Fish and Wildlife Service (Athens Ecological Services) in September 2014. All watersheds intersecting the EPA Level 4 ecoregion 75j "Sea Islands/Coastal Marsh" were considered important coastal habitat (Griffith et al. 2001). Migratory corridors included the mainstem Chattahoochee, Flint, Little, Withlacoochee, St. Marys, Satilla, Altamaha, Ocmulgee, Oconee, Ogeechee, and Savannah Rivers up to the first point where passage is blocked by a dam or the most upstream record of the diadromous species in un-impounded systems. Watersheds with extant populations of ESA listed species were identified using GADNR's Rare Species Database (aka, NatureServe Biotics Database). This database includes records from research projects carried out by GADNR or its contractors, publications, consultant reports, and scientific collection permit reports. It also includes records from the Georgia Museum of Natural History and GADNR's Stream Survey Team.

To identify watersheds occurring in an ecological region of the state where high priority watersheds were poorly represented, we identified ecological drainage units by intersecting six Level 3 ecoregions (Griffith et al. 2001) with the 14 major river drainages occurring in the state. This resulted in the identification of 32 ecological drainage units. For example, the Savannah drainage would include separate units for the Blue Ridge, Piedmont, Southeastern Plains, and Southern Coastal Plain. Ecological drainage units serve as a coarse filter to represent aquatic community diversity (see Sowa et al. 2007). We assessed the effectiveness of our species-based approach in capturing aquatic community diversity by overlaying high priority watersheds on a map of ecological drainage units. We then identified additional high priority watersheds for poorly represented ecological drainage units as necessary. Our minimum goal was at least one high priority watershed in each ecological drainage unit.

Watershed Assessment

The purpose of the watershed assessment was to assess watershed scale protection, existing condition, and recent trends and threats for all Georgia watersheds at the HUC 10 scale. This information will be used to help identify the most appropriate conservation actions for high priority watersheds. For example, additional land acquisition or easements might be appropriate in

watersheds with existing but insufficient protected areas. Similarly, growth management policies might be the most important conservation action in watersheds threatened by future urbanization.

The aquatic habitat committee met in February 2014 to discuss the merits of different GIS data layers to include in the assessment, which are listed in Appendix I. Individual data layers are categorized to indicate the degree to which they protect aquatic resources, reflect the existing condition of aquatic habitats, or represent a recent trend or future threat to water quality or habitat. Layers were also designated with a + or − to indicate their potential relationship with aquatic species and habitats. Many of the data layers were selected from the most currently available version (2011) of the National Land Cover Dataset (NLCD; Jin et al. 2013; Figure 1). Descriptions of land cover classes can be found at http://www.mrlc.gov/nlcd06_leg.php. We considered a subset of current land cover classes (e.g., % Forest, % Developed, etc.) to be an indicator of the current condition of aquatic habitats within watersheds. We used changes in the proportion of different land cover classes between 2001-2011 to reflect recent watershed trends, with the expectation that similar changes would likely affect aquatic resources in the future.

In addition, each layer was identified as a **potential predictor** or as **exploratory**. Potential predictors could be used in future analyses relating condition variables to attributes of aquatic species. For example, the number of high priority aquatic species in a watershed or reach could be modeled as a function of forest land cover. To be included in our list of potential predictor variables, the data layer had to be available in GIS format for the entire state of Georgia and known to influence aquatic species and habitats in other studies. Exploratory data layers may also impact aquatic species and habitats, but may be difficult to include in analyses for a variety of reasons (e.g., variable not assessed for entire state). Nonetheless, the technical team felt that exploratory data layers were useful for visually representing watershed condition and threats and could also help identify conservation actions within portions of the state. Some additional data layers could not be included in the assessment due to time constraints or because they are not yet available in a GIS format and are listed in Appendix II.
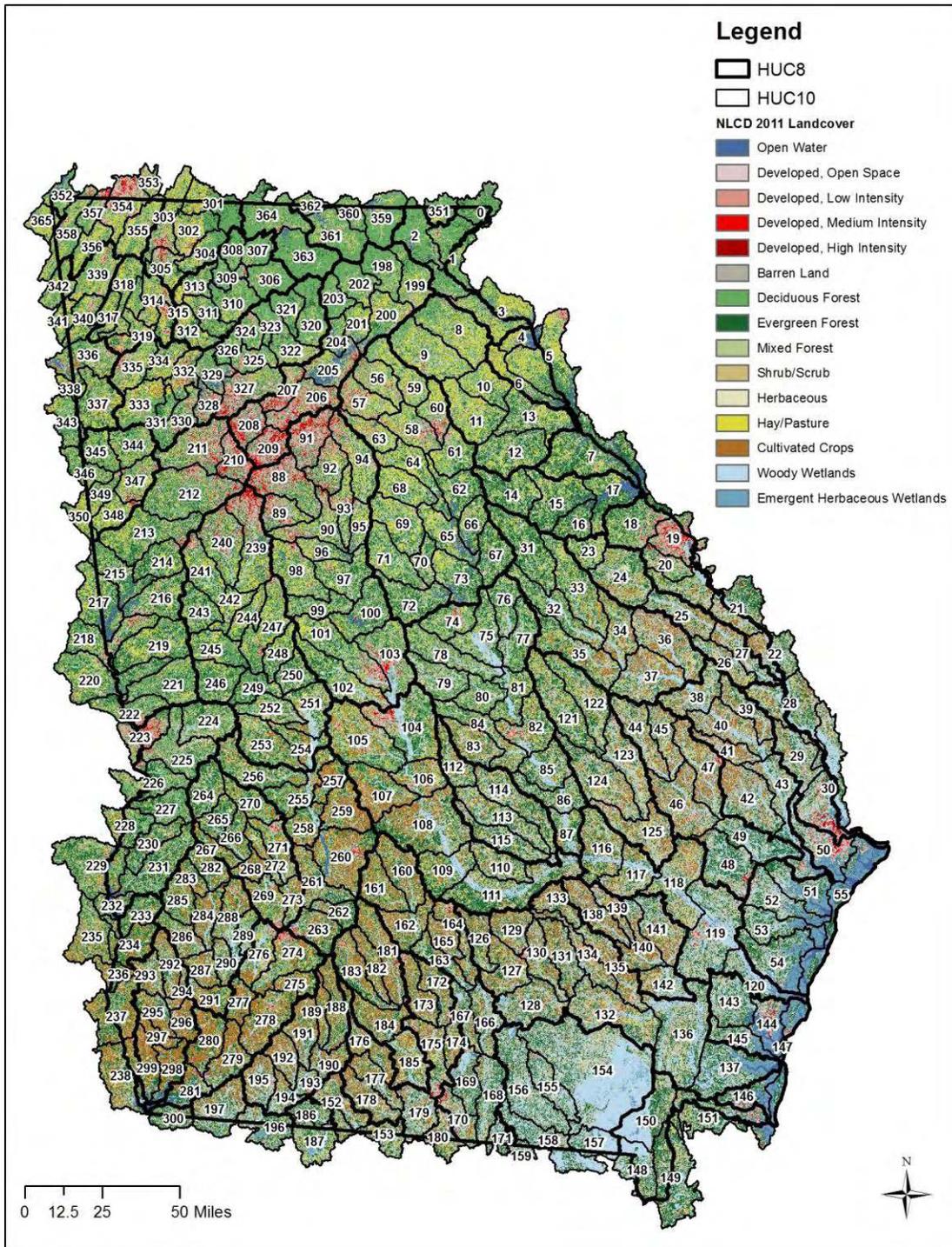
Figure 1. National Land Cover Classification (NLCD 2011), with HUC 8 and HUC 10 watershed boundaries. Map numbers correspond to watersheds listed in Tables 1 and 2.

Assessment Results

High Priority Watersheds

The technical team identified 165 high priority watersheds (45% of watersheds in the state; Figure 2), which were designated for 168 of 174 high priority aquatic species (including 9 reptile and amphibian species). Lack of distributional data prevented designation of watersheds for the remaining 6 aquatic species.

The number of watersheds selected for each species varied, with one watershed designated for 30 species, two watersheds designated for 20 species, three watersheds designated for 30 species, four watersheds designated for 87 species, and eight watersheds designated for Robust Redhorse. The number of high priority species designated within a single watershed ranged widely, from one species in 58 watersheds to 24 and 26 species in two upper Conasauga River watersheds (units 301 and 302). It is important to realize that the number of high priority species listed for each watershed reflects the number of species that were selected by the technical team as having an important population in the watershed, not necessarily the number of species that may occur or historically occurred within the watershed.

Global significance scores ranged from 95 to 1 for watersheds. For visual representation, we grouped GSS into three categories: moderate 1-10, high 11-19, and highest 20-95 (Figure 2). Because this represents a somewhat arbitrary categorization of continuous data, we also present actual GSS for each watershed (Table 1). Watersheds with the highest GSS clustered in the Coosa and Tennessee drainages of northwest Georgia, but also occurred in the Tallapoosa, Chattahoochee, Flint, and Savannah drainages. Watersheds categorized as high GSS were concentrated in the Coosa, lower Flint and Savannah drainages, but also occurred in every other major drainage except the Suwannee, St. Marys, and Satilla. Watersheds with moderate GSS were present in all drainages but the Satilla.

We selected an additional 56 watersheds because they met at least one of our five criteria, increasing the number of high priority watersheds to 221 (60% of watersheds in the state; Figure 2). This included 15 watersheds that met multiple criteria, 9 with important coastal habitats, 20 containing critical habitat or a recent occurrence of an ESA listed species, 10 that were part of a migratory corridor, and 2 watersheds that were added from ecological drainage units that were poorly represented in the dataset.

The two watersheds added from poorly represented units were both in the Satilla River system. Watershed 128 (Satilla-Southeastern Plains) was added because no watersheds were represented in this ecological drainage unit. We selected this individual watershed because of its relatively low urban cover. Watershed 126 (Satilla-Southern Coastal Plain) was added because of the designation of few high priority watersheds relative to the size of this ecological drainage unit and their clustering along the edge of the coast. This particular watershed was selected based on low urban cover and fish sampling data indicating relatively diverse communities in Guest Mill Pond (a Carolina Bay) and the upper Satilla River. Otherwise, high priority watersheds were well represented in all ecological drainage units (Figure 3).
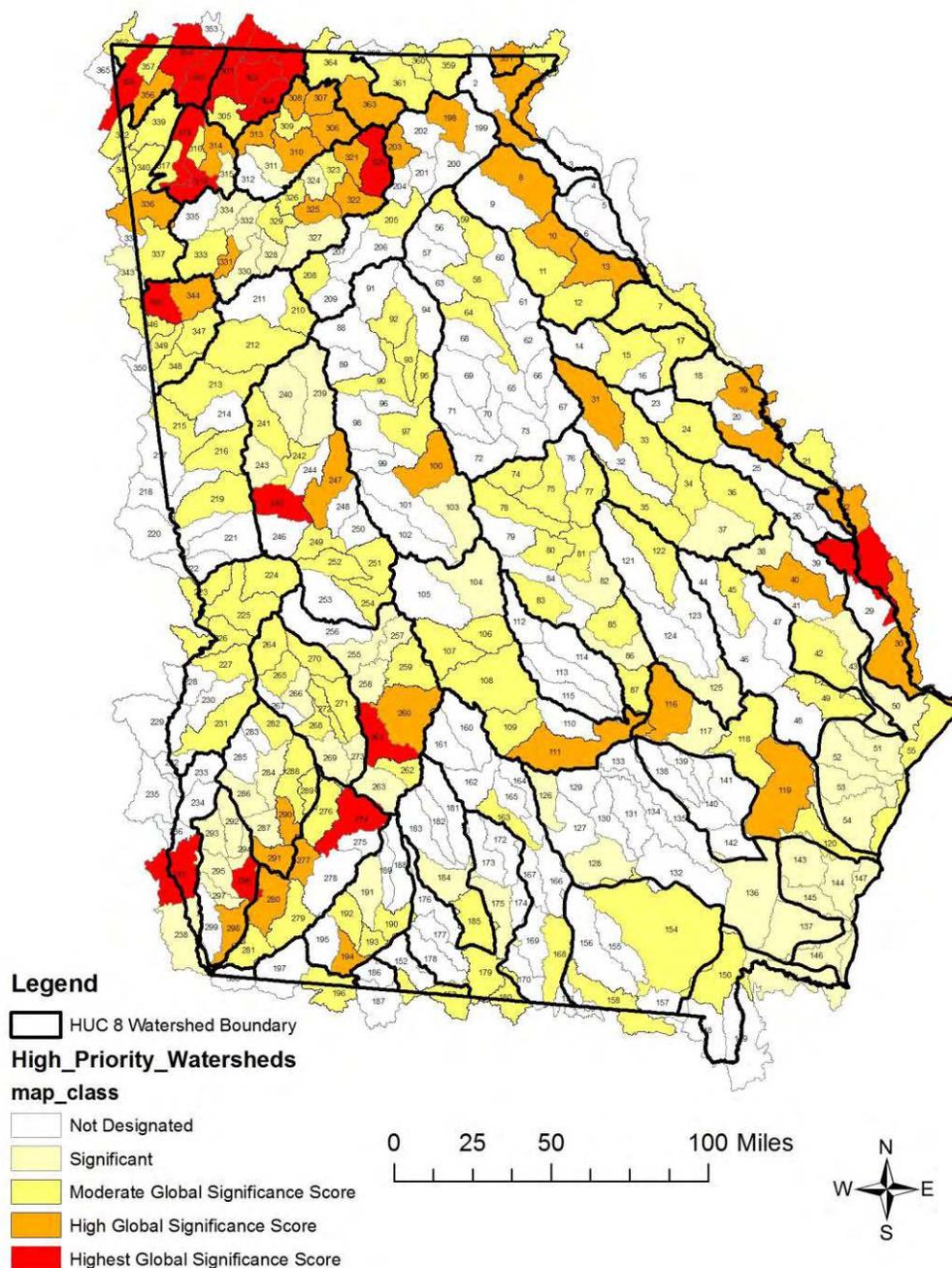
Figure 2. High priority watersheds identified during the 2015 revision of Georgia's State Wildlife Action Plan. Watersheds categorized by global significance score were selected because they contain important populations of a high priority aquatic species. Watersheds categorized as "significant" contained one or more of the following: important coastal habitat, a migratory corridor for a high priority diadromous species, critical habitat or a recent occurrence of an ESA listed species, or an aquatic community from an ecological region of the state where high priority watersheds are poorly represented. Map numbers correspond to the watersheds listed in Tables 1 and 2. Zoom in to view map numbers.

Table 1. High priority watersheds designated during the 2015 revision of Georgia's State Wildlife Action Plan. The global significance score (GSS; higher score indicates greater significance) is based upon the number of high priority aquatic species (No. Species) with important populations occurring in the watershed and the global rarity of those species. Additional watersheds were designated as high priority because they contain important coastal habitat (C), a migratory corridor (MC) for a high priority diadromous species, critical habitat (CH) or a recent occurrence of an ESA listed species (LS) or are representative of an aquatic community (AC) from an ecological region of the state where high priority watersheds are poorly represented. Watersheds are sorted by descending global significance score and then by map number.

Map Number	HUC 10 Watershed Name	GSS	No. Species	Criteria
302	Conasauga River 2	95	26	GSS
301	Conasauga River 3	94	24	GSS
304	Holly Creek	56	14	GSS
354	Chickamauga Creek	41	13	GSS
274	Flint River Lower 4	35	8	GSS
319	Oostanaula River 1	29	8	GSS
355	Little Chickamauga Creek	29	10	GSS
320	Etowah River 7	28	8	GSS
318	Armuchee Creek	27	10	GSS
245	Flint River Upper 4	24	6	GSS
303	Coahulla Creek	24	7	GSS
296	Spring Creek 3, Spring Creek	22	7	GSS
358	Lookout Creek	22	8	GSS
28	Savannah River Lower 2	20	5	GSS
237	Chattahoochee River Lower South 2	20	5	GSS
261	Flint River Middle 2	20	5	GSS
345	Tallapoosa River 2	20	7	GSS
198	Chattahoochee Upper North 5	19	5	GSS
313	Coosawatee River 1	19	6	GSS
325	Etowah River 5	19	6	GSS
13	Broad River 1, Clark Hill	18	5	GSS
277	Flint River Lower 3	18	4	GSS
280	Flint River Lower 2	18	4	GSS
307	Ellijay River	18	5	GSS
356	West Chickamauga Creek	18	6	GSS
290	Chickasawhatchee Creek 1	17	4	GSS
322	Etowah River 6	17	6	GSS
344	Tallapoosa River 3	17	6	GSS
8	Broad River 3	16	5	GSS
10	Broad River 2	16	5	GSS
31	Ogeechee River Upper 4	16	5	GSS

Map Number	HUC 10 Watershed Name	GSS	No. Species	Criteria
351	Little Tennessee River	16	6	GSS
194	Ochlockonee River Upper 1	15	4	GSS
291	Ichawaynochaway Creek 1	15	4	GSS
314	Oostanaula River 2	15	5	GSS
331	Raccoon Creek, Etowah River	15	4	GSS
100	Ocmulgee River Upper 2	14	5	GSS
203	Chestatee River 2	14	4	GSS
310	Talking Rock Creek	14	4	GSS
363	Toccoa River	14	6	GSS
1	Panther Creek	13	3	GSS
119	Altamaha River 2	13	3	GSS
247	Potato Creek	13	3	GSS
260	Flint River Middle 3, Lake Blackshear	13	3	GSS
111	Ocmulgee River Lower 1	12	4	GSS
298	Spring Creek 1, Spring Creek, Lake Seminole	12	4	GSS
306	Cartecay River	12	3	GSS
308	Mountaintown Creek	12	3	GSS
321	Amicalola Creek	12	3	GSS
19	Savannah River Middle 3	11	3	GSS
22	Savannah River Middle 1	11	3	GSS
30	Savannah River Lower 1	11	4	GSS
40	Ogeechee River Lower 2	11	3	GSS
116	Altamaha River 5	11	3	GSS
336	Coosa River, Wells Reservoir	11	4	GSS
75	Oconee River Lower 6	10	4	GSS
168	Alapaha River 1	10	3	GSS
179	Withlacoochee River 2	10	3	GSS
346	Tallapoosa River 1	10	4	GSS
349	Big Indian Creek, Tallapoosa River	10	4	GSS
12	Long Creek	9	2	GSS
81	Oconee River Lower 5	9	2	GSS
93	Yellow River 1, Jackson Lake	9	2	GSS
95	Alcovy River 1, Jackson Lake	9	2	GSS
118	Altamaha River 3	9	2	GSS
339	Teloga Creek	9	3	GSS
360	Brasstown Creek	9	4	GSS
21	Savannah River Middle 2	8	2	GSS
34	Ogeechee River Upper 2	8	2	GSS
180	Withlacoochee River 1	8	3	GSS
196	Ochlockonee River Lower	8	2	GSS

Map Number	HUC 10 Watershed Name	GSS	No. Species	Criteria
249	Flint River Upper 3	8	2	GSS
251	Flint River Upper 2	8	2	GSS
281	Flint River Lower 1, Lake Seminole	8	3	GSS
288	Chickasawhatchee Creek 2	8	2	GSS
305	Conasauga River 1	8	2	GSS
309	Coosawatee River 2, Carters Lake	8	2	GSS
317	Little Armuchee	8	3	GSS
326	Shoal Creek, Etowah River	8	3	GSS
11	South Fork Broad River	7	2	GSS
35	Williamson Swamp Creek	7	2	GSS
36	Buckhead Creek	7	2	GSS
64	Apalachee River 1, Lake Oconee	7	2	GSS
163	Alapaha River 3	7	2	GSS
224	Upatoi Creek 2	7	4	GSS
225	Upatoi Creek 1	7	4	GSS
231	Pataula Creek	7	3	GSS
259	Turkey Creek, Flint River Middle	7	2	GSS
289	Kiokee Creek	7	2	GSS
359	Hiawassee River, Chatuge Lake	7	2	GSS
120	Altamaha River 1	6	2	GSS
213	Chattahoochee River Lower North 6	6	2	GSS
254	Flint River Upper 1	6	2	GSS
333	Euharlee Creek	6	2	GSS
340	Chattooga River	6	2	GSS
0	West Fork	5	2	GSS
7	Savannah River Upper 1, Clark Hill	5	1	GSS
17	Little River 1, Little R, Clark Hill	5	1	GSS
24	Brier Creek 3	5	2	GSS
83	Rocky Creek	5	1	GSS
85	Oconee River Lower 3	5	1	GSS
97	Ocmulgee River Upper 3	5	1	GSS
106	Ocmulgee River Lower 4	5	1	GSS
107	Big Creek, Ocmulgee River Lower	5	1	GSS
108	Ocmulgee River Lower 3	5	1	GSS
109	Ocmulgee River Lower 2	5	1	GSS
153	Aucilla River 1	5	2	GSS
216	Yellowjacket Creek, West Point Lake	5	1	GSS
219	House Creek, Chattahoochee River Lower North	5	1	GSS
227	Hannahatchee Creek	5	2	GSS
241	White Oak Creek	5	1	GSS

Map Number	HUC 10 Watershed Name	GSS	No. Species	Criteria
252	Patsiliga Creek	5	1	GSS
323	Long Swamp Creek	5	1	GSS
352	Cole City Creek	5	2	GSS
357	Chattanooga Creek	5	2	GSS
361	Upper Nottely River	5	2	GSS
15	Little River 2, Little R	4	1	GSS
49	Canoochee River 1	4	1	GSS
58	Middle Oconee River 1	4	1	GSS
74	Oconee River Lower 7	4	2	GSS
77	Sandy Hill Creek	4	1	GSS
78	Commissioner Creek	4	1	GSS
80	Big Sandy Creek 1	4	1	GSS
87	Oconee River Lower 1	4	1	GSS
90	South River 1, Jackson Lake	4	1	GSS
92	Yellow River 2	4	1	GSS
122	Little Ohoopee River	4	1	GSS
190	Ochlockonee River Upper 3	4	1	GSS
192	Barretts Creek	4	1	GSS
223	Chattahoochee River Upper South 5	4	2	GSS
262	Abrams Creek	4	1	GSS
268	Kinchafoonee Creek 2	4	1	GSS
279	Big Slough 1	4	1	GSS
329	Etowah River 4, Allatoona Lake	4	2	GSS
342	Middle Fork Little River	4	1	GSS
347	Little Tallapoosa River 2	4	1	GSS
364	Fightingtown Creek/Lower Toccoa	4	2	GSS
33	Rocky Comfort Creek	3	1	GSS
59	North Oconee River 2	3	1	GSS
150	St. Marys River 2	3	1	GSS
154	Suwannee River 3	3	1	GSS
158	Suwannee River 2	3	1	GSS
185	Little River 1, Little River	3	1	GSS
193	Ochlockonee River Upper 2	3	1	GSS
205	Chattahoochee Upper North 3, Lake Lanier	3	1	GSS
208	Chattahoochee Upper North 1	3	1	GSS
210	Chattahoochee River Lower North 8	3	1	GSS
212	Chattahoochee River Lower North 7	3	1	GSS
215	Chattahoochee River Lower North 5, West Point Lake	3	1	GSS
226	Chattahoochee River Upper South 4, Eufaula Lake	3	2	GSS
242	Flint River Upper 5	3	1	GSS

Map Number	HUC 10 Watershed Name	GSS	No. Species	Criteria
264	Kinchafoonee Creek 5	3	1	GSS
265	Kinchafoonee Creek 4	3	1	GSS
270	Muckalee Creek 3	3	1	GSS
271	Muckalee Creek 2	3	1	GSS
272	Muckaloochee Creek	3	1	GSS
276	Cooleewahee Creek	3	1	GSS
282	Ichawaynochaway Creek 4	3	1	GSS
316	Johns Creek	3	1	GSS
341	Alpine Creek	3	1	GSS
348	Little Tallapoosa River 1	3	1	GSS
337	Cedar Creek	2	1	GSS
42	Black Creek	1	1	GSS
45	Fifteenmile Creek	1	1	GSS
55	Ogeechee River, Coast	1	1	GSS
18	Savannah River Middle 4	0	0	MC
37	Ogeechee River Upper 1	0	0	MC
38	Ogeechee River Lower 3	0	0	MC
43	Ogeechee River Lower 1	0	0	C, LS, MC
50	Little Ogeechee River	0	0	C
51	Medway River	0	0	C, LS
52	North Newport River	0	0	C
53	South Newport River	0	0	C
54	Sapelo River	0	0	C
82	Oconee River Lower 4	0	0	MC
86	Oconee River Lower 2	0	0	MC
103	Ocmulgee River Upper 1	0	0	MC, LS
104	Ocmulgee River Lower 5	0	0	MC
117	Altamaha River 4	0	0	CH, LS, MC
125	Ohoopee River 1	0	0	CH
126	Satilla River 6	0	0	AC
128	Satilla River 4	0	0	AC
136	Satilla River 2	0	0	MC
137	Satilla River 1	0	0	C, LS, MC
143	Turtle River	0	0	C
144	Brunswick River	0	0	C
145	Satilla River Coast 2	0	0	C
146	Crooked River	0	0	C
147	Satilla River Coast 1	0	0	C
151	St. Marys River 1	0	0	C, LS
175	Withlacoochee River 3	0	0	MC

Map Number	HUC 10 Watershed Name	GSS	No. Species	Criteria
184	Little River 2, Little River	0	0	MC
191	Little Ochlockonee River	0	0	CH
238	Chattahoochee River Lower South 1, Lake Seminole	0	0	MC
239	Flint River Upper 6	0	0	CH
240	Line Creek	0	0	CH, LS
243	Red Oak Creek	0	0	CH
255	Flint River Middle 5	0	0	CH, LS
257	Hogcrawl Creek	0	0	CH
258	Flint River Middle 4	0	0	CH
263	Flint River Middle 1	0	0	CH, LS
266	Kinchafoonee Creek 3	0	0	CH, LS
269	Kinchafoonee Creek 1	0	0	CH, LS
273	Muckalee Creek 1	0	0	CH, LS
284	Ichawaynochaway Creek 3	0	0	CH
286	Pachitla Creek 1	0	0	CH
287	Ichawaynochaway Creek 2	0	0	CH, LS
292	Spring Creek 5, Spring Creek	0	0	CH
293	Dry Creek	0	0	CH
294	Spring Creek 4, Spring Creek	0	0	CH, LS
295	Aycocks Creek	0	0	CH
297	Spring Creek 2, Spring Creek	0	0	CH, LS
311	Salacoa Creek	0	0	LS
315	Oothkalooga Creek	0	0	LS
324	Sharp Mountain Creek	0	0	LS
327	Little River, Etowah River, Allatoona Lake	0	0	LS
328	Allatoona Creek, Allatoona Lake	0	0	LS
330	Pumpkinvine Creek	0	0	LS
332	Etowah River 3	0	0	LS
334	Etowah River 2	0	0	LS
343	Terrapin Creek	0	0	CH
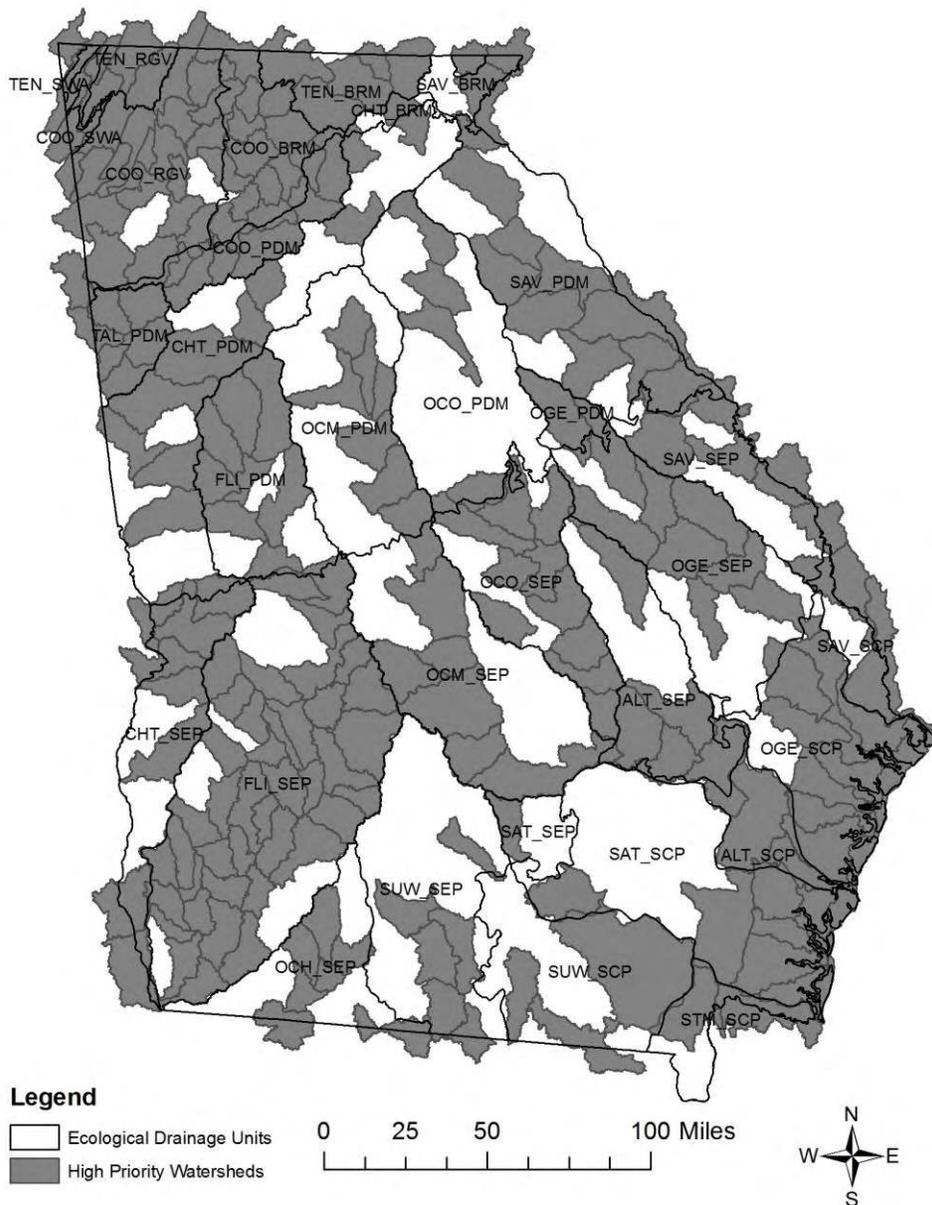
Figure 3. High priority watersheds designated within each of 32 ecological drainage units. Ecological drainage units (EDU) were formed by intersecting Georgia's 14 major river drainages with six ecoregions. Each EDU unit is labeled as drainage_ecoregion abbreviations: CHT = Chattahoochee, FLI = Flint, OCH = Ochlockonee, SUW = Suwannee, STM = St. Marys, SAT = Satilla, ALT = Altamaha, OCM = Ocmulgee, OCO = Oconee, OGE = Ogeechee, SAV = Savannah, COO = Coosa, TAL = Tallapoosa, TEN = Tennessee, SWA = Southwestern Appalachians, RGV = Ridge and Valley, BRM = Blue Ridge Mountains, PDM = Piedmont, SEP = Southeastern Plains, and SCP = Southern Coastal Plain.

Watershed Assessment

Maps were created to summarize the degree of protection, existing condition, and recent trends and future threats to all of Georgia's HUC 10 watersheds. Here we briefly summarize major patterns across the state. Detailed information for all watersheds is provided in Table 2, which is available as a separate excel file that should always accompany this report.

Degree of Protection and Existing Condition

Existing conservation lands are concentrated in the Blue Ridge of northeast Georgia (Figure 4), but there are significant parcels of protected land scattered throughout the state. Similarly, the proportion of watersheds classified as forest is highest in northeast Georgia, exceeding 70% in most watersheds (Figure 5) and providing important headwater protection for several high priority watersheds. The lowest forest cover (<30%) occurs in watersheds in the Metro Atlanta area and within the Southeastern Plains and Southern Coastal Plain ecoregions. Cultivated crop agriculture is present throughout the state, but reaches its highest coverage (>30%) in southwest Georgia (Figure 6). Developed land (Figure 7) exhibits peak levels (> 50%) in the metro Atlanta area and in the I-75 corridor north into Tennessee. In addition, watersheds throughout the upper Piedmont and Ridge and Valley have levels ranging from 10-50% developed. A similar pattern is exhibited when Developed Open Space (e.g., parks, golf courses, athletic fields) is included in the classification (Figure 8) and when examining the proportion of individual 30 m landscape cells that are impervious (e.g., paved surfaces that promote runoff as opposed to infiltration of precipitation; Figure 9). Relatively high numbers of dams per kilometer of stream occur in watersheds scattered throughout the state, with the highest levels in watersheds within and fringing the Metro Atlanta area (Figure 10). To put these levels in perspective, the two highest categories mapped represent one dam for every 6 to 25 km of stream or river. Road crossing densities are greatest in Metro Atlanta and relatively high throughout north Georgia (Figure 11). Clean Water Act impairment designations, based on Index of Biotic Integrity fish community sampling in 1094 stream reaches sampled between 1998-2011, show a large proportion of impaired streams (42.8%) scattered throughout the state (Figure 12). The proportion of stream length listed as impaired under the Clean Water Act (i.e., 303d listed streams) is relatively high in Metro Atlanta, north Georgia in general, and in southeast Georgia (Figure 13). Habitat condition index values indicate a very high risk of habitat degradation in the Metro Atlanta area, in the I-75 corridor near Tennessee, and in other urban areas around the state. Stream reaches with a moderate to high risk of degradation are concentrated in the upper Piedmont and throughout the Southeastern Plains (Figure 14).
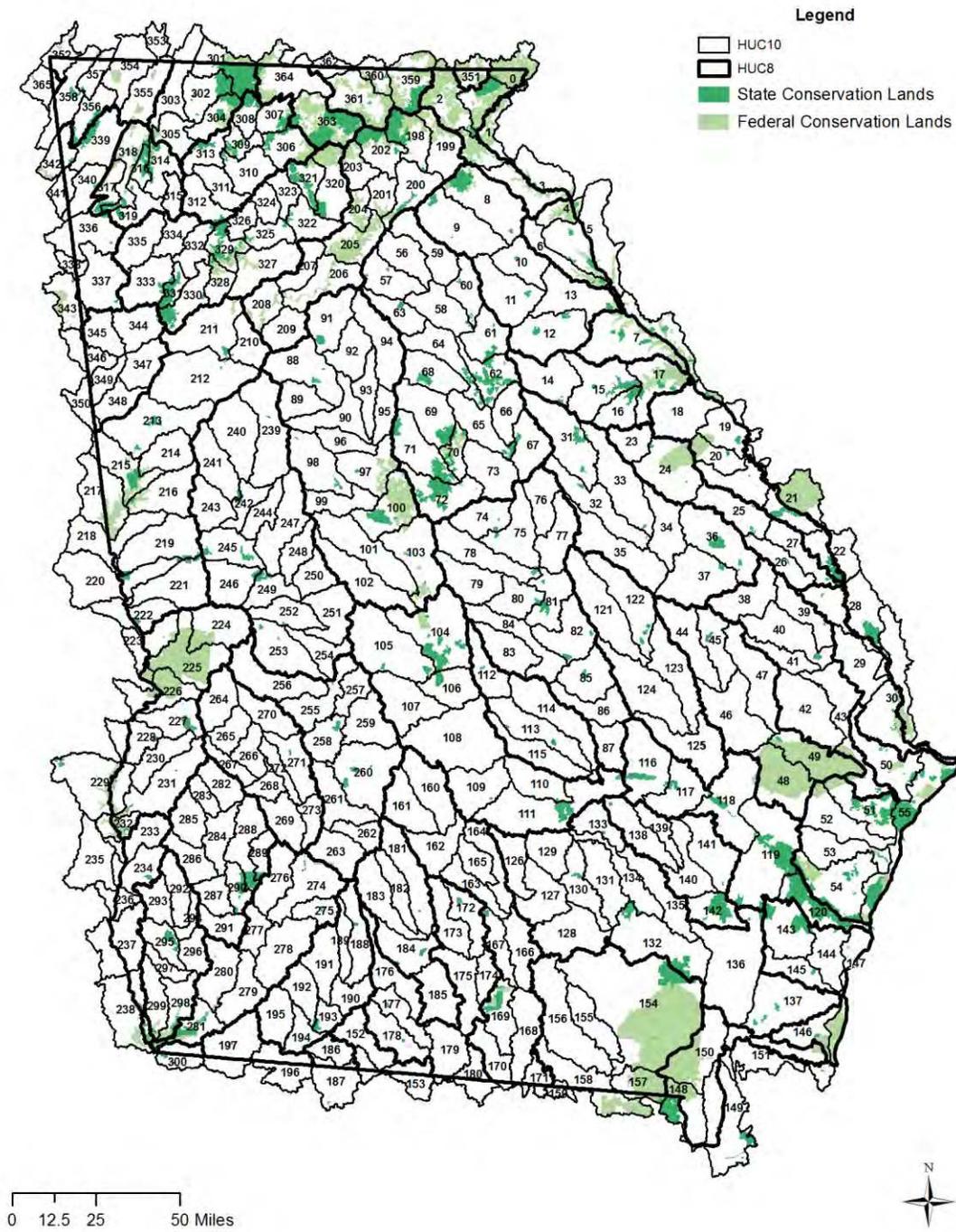
Figure 4. State and federal conservation lands, with HUC 8 and HUC 10 boundaries. Map numbers correspond to watersheds listed in Tables 1 and 2.
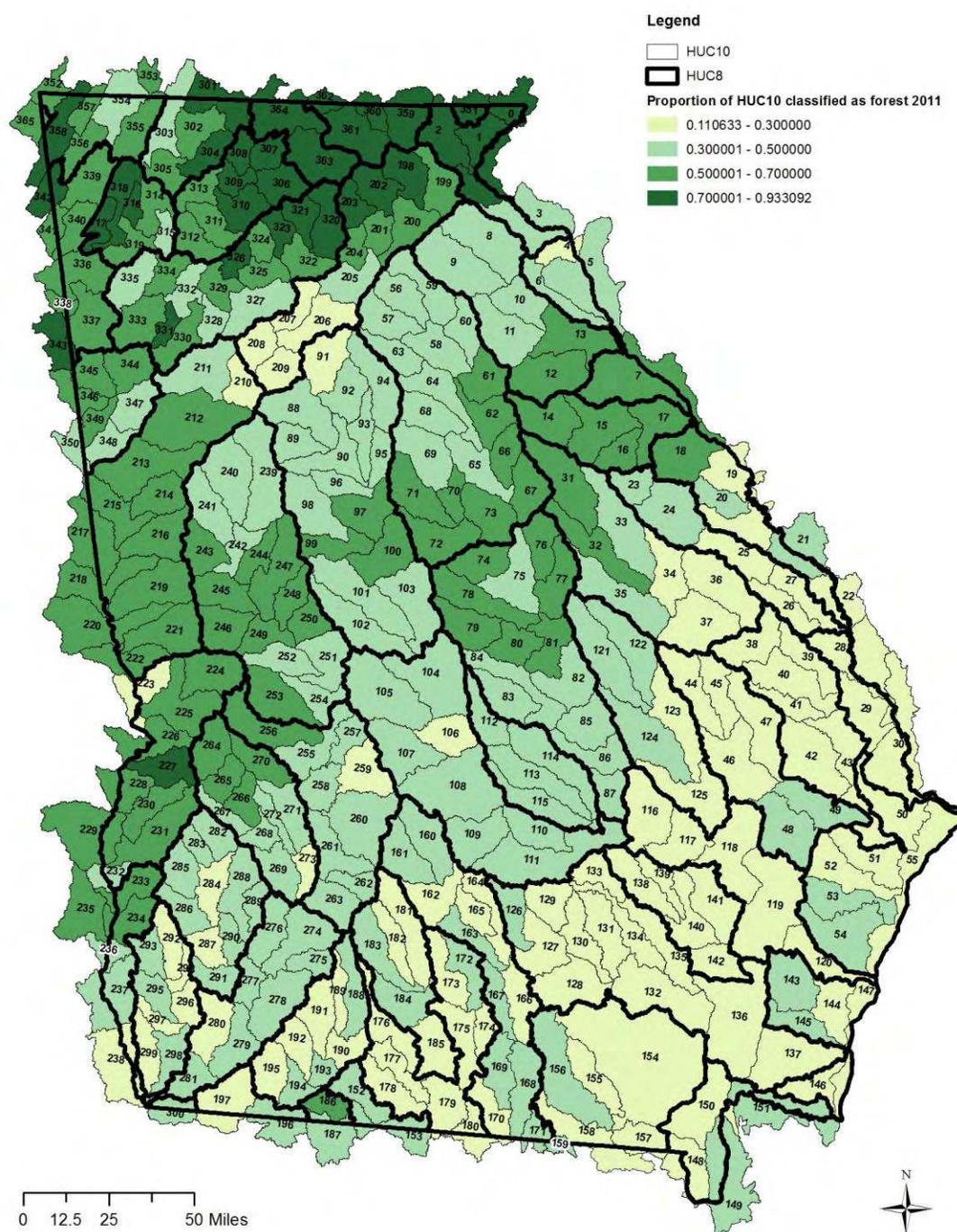
Figure 5. Proportion of HUC 10 watersheds classified as forest in 2011, based on the National Land Cover Classification Dataset. Forest cover includes deciduous, evergreen, and mixed forest classes. HUC 8 watershed boundaries are also shown.
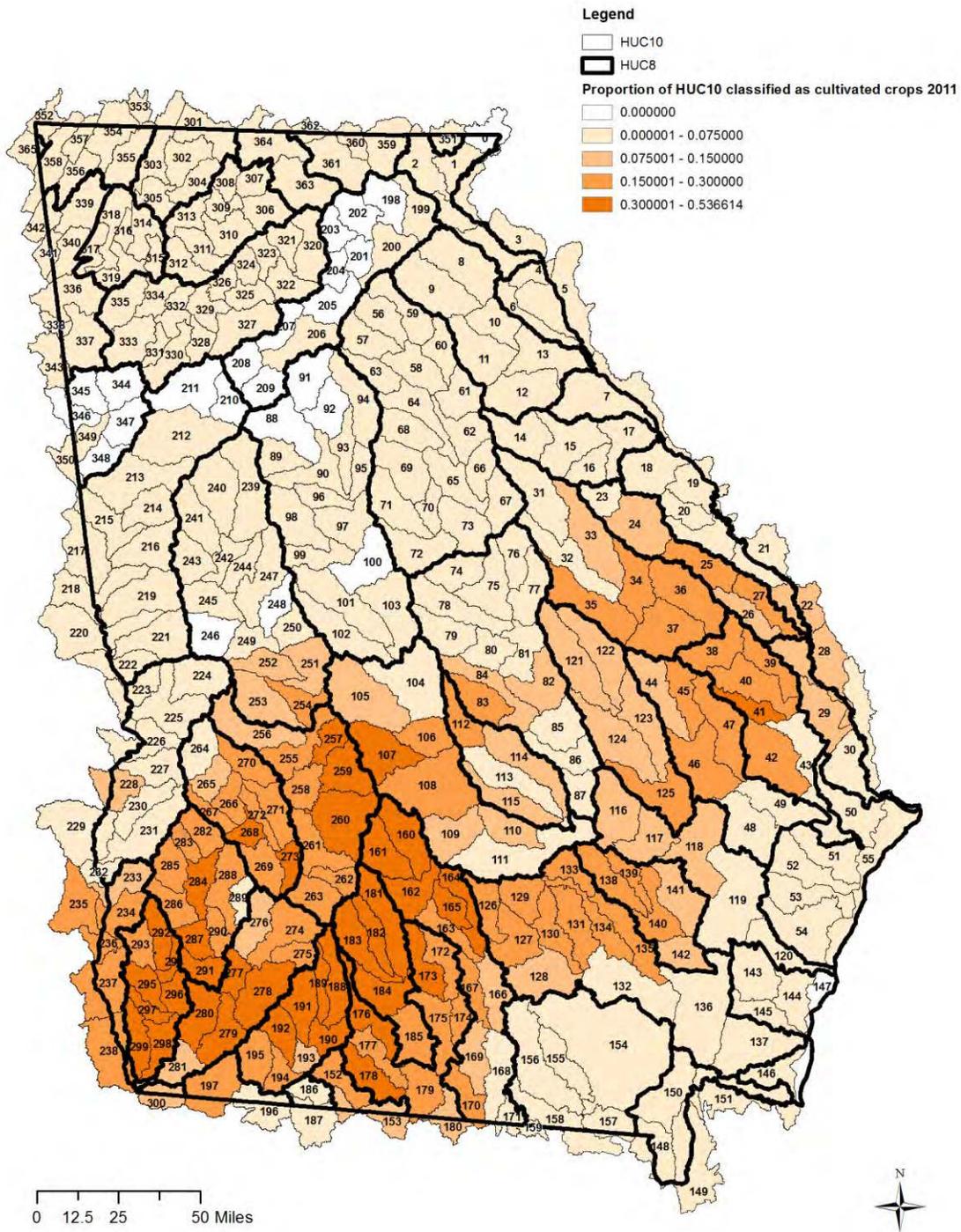
Figure 6. Proportion of HUC 10 watersheds classified as cultivated crops in 2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
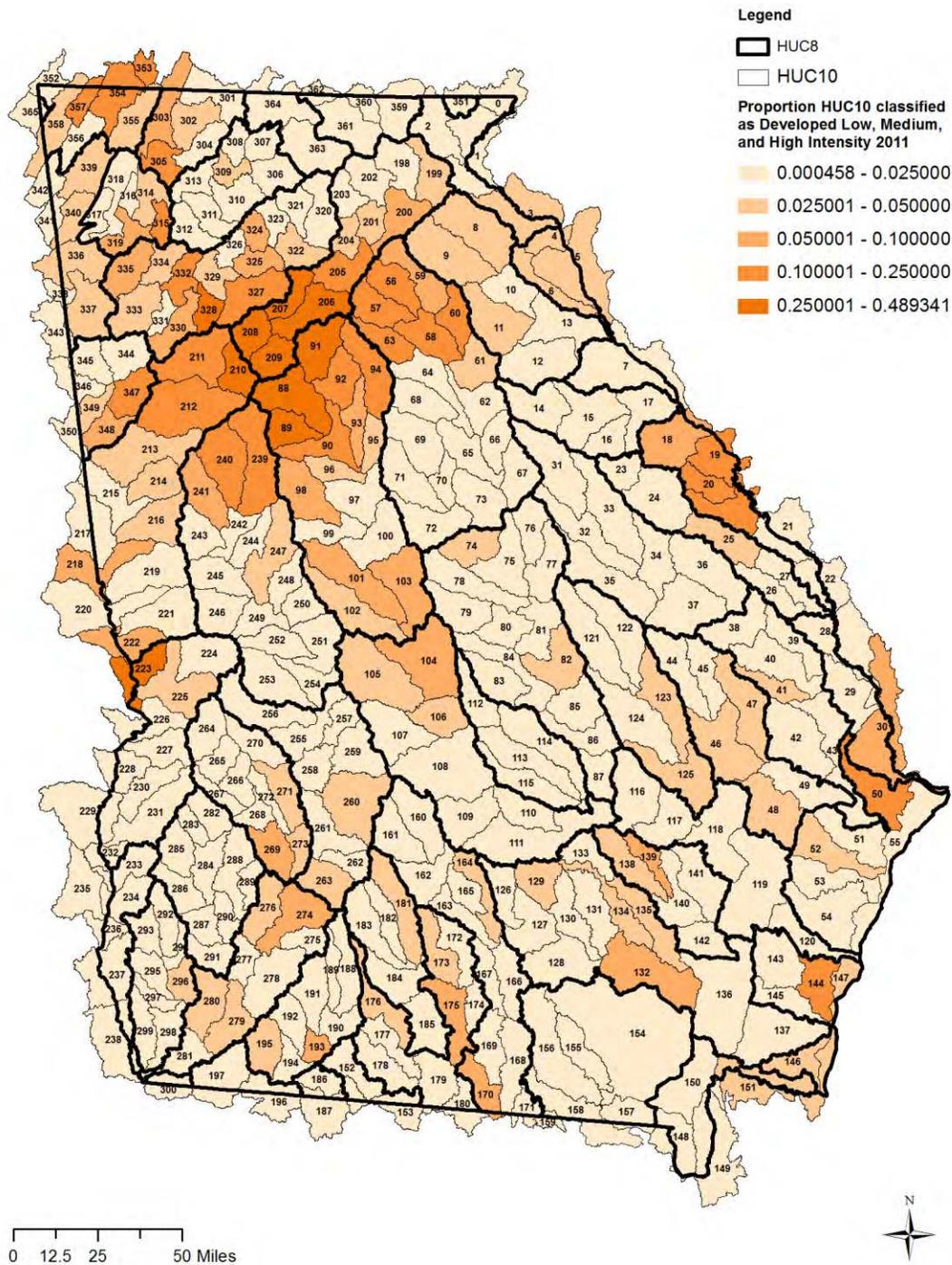
Figure 7. Proportion of HUC 10 watersheds classified as low, medium, or high intensity development in 2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
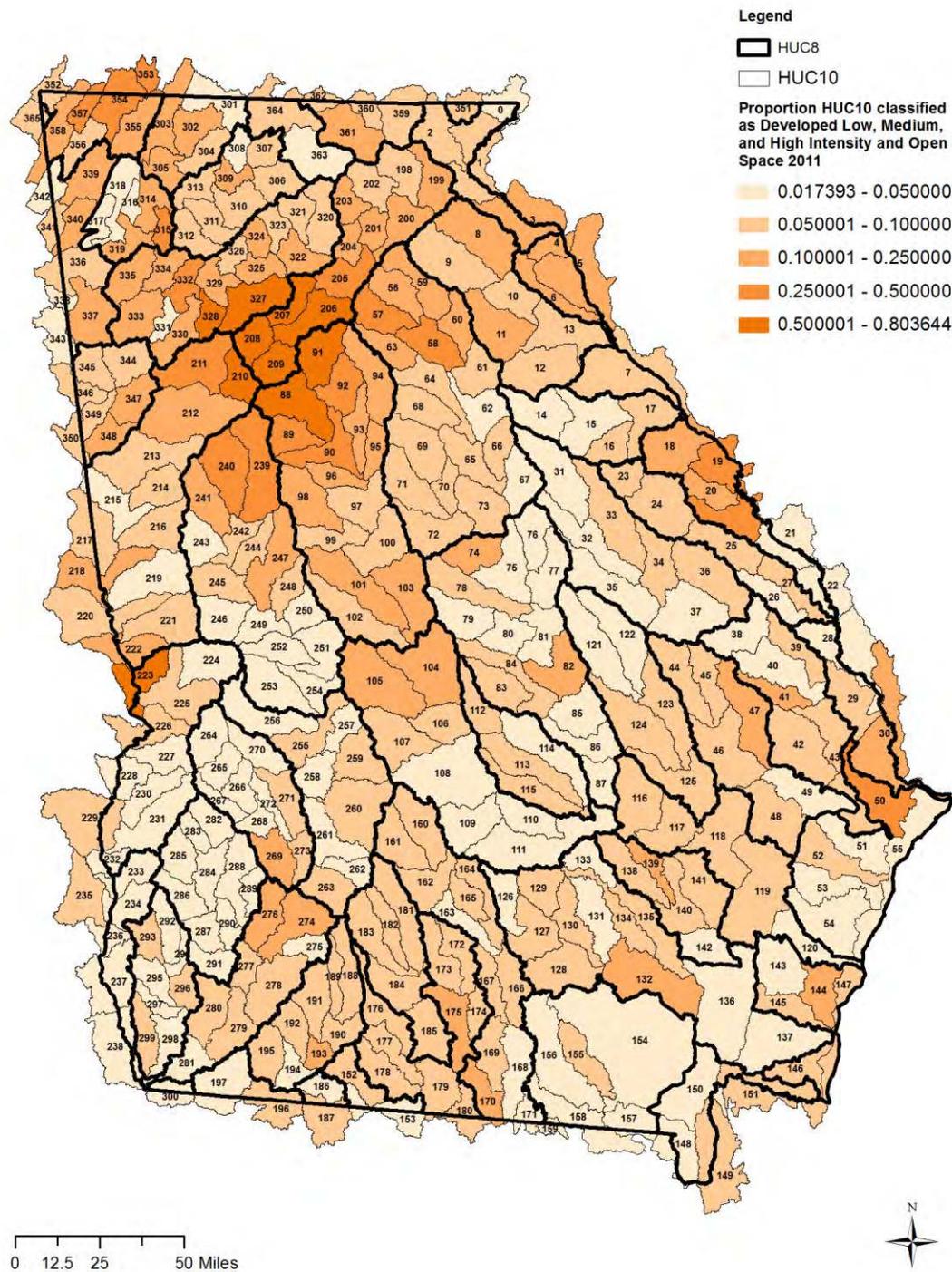
Figure 8. Proportion of HUC 10 watershed classified as low, medium, or high intensity development or developed open space in 2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
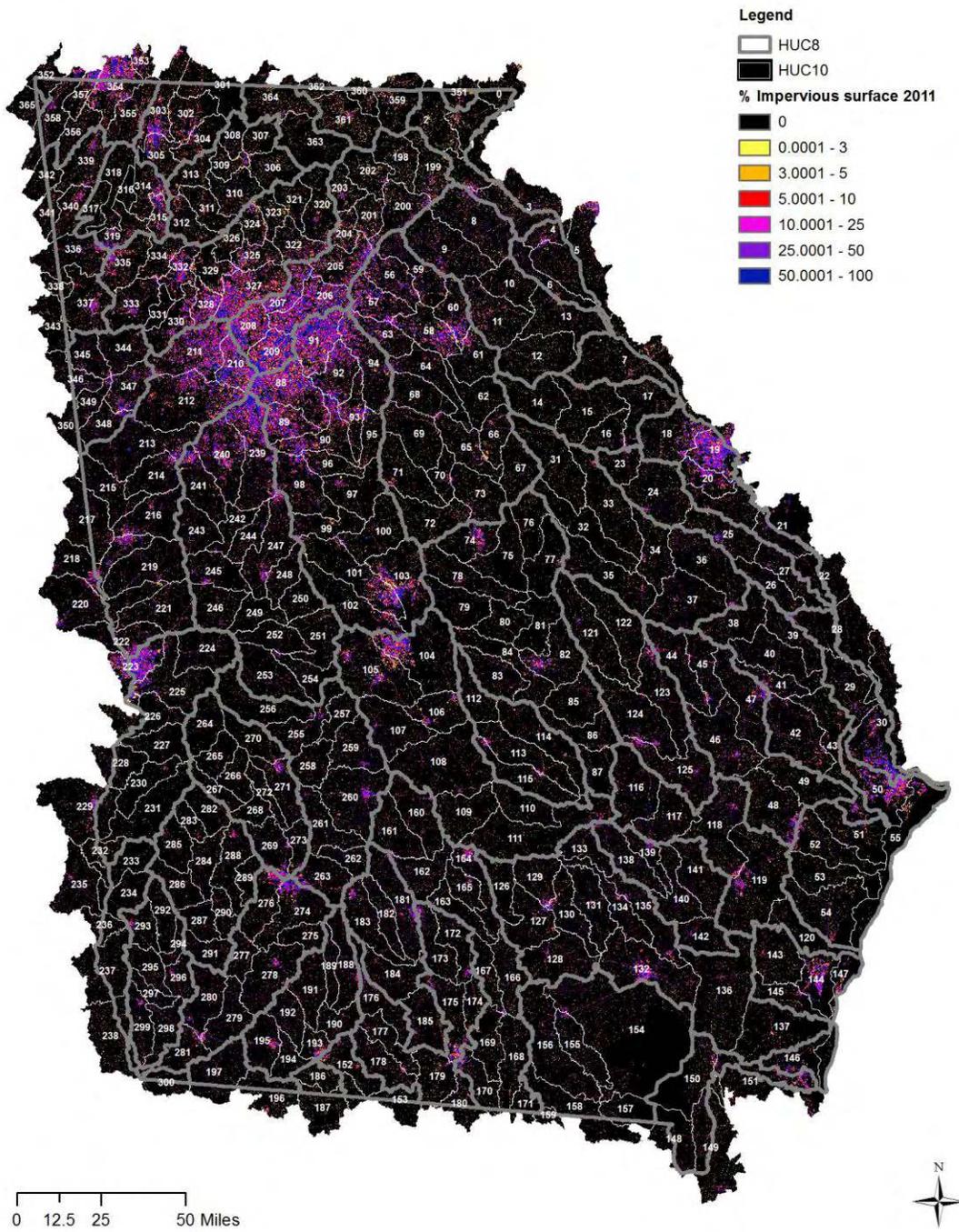
Figure 9. Percent imperviousness of 30 m landscape cells within HUC 10 watersheds in 2011, based on the National Land Cover Classification Dataset. Additional impervious cells are visible as you zoom into the figure. HUC 8 watershed boundaries are also shown.
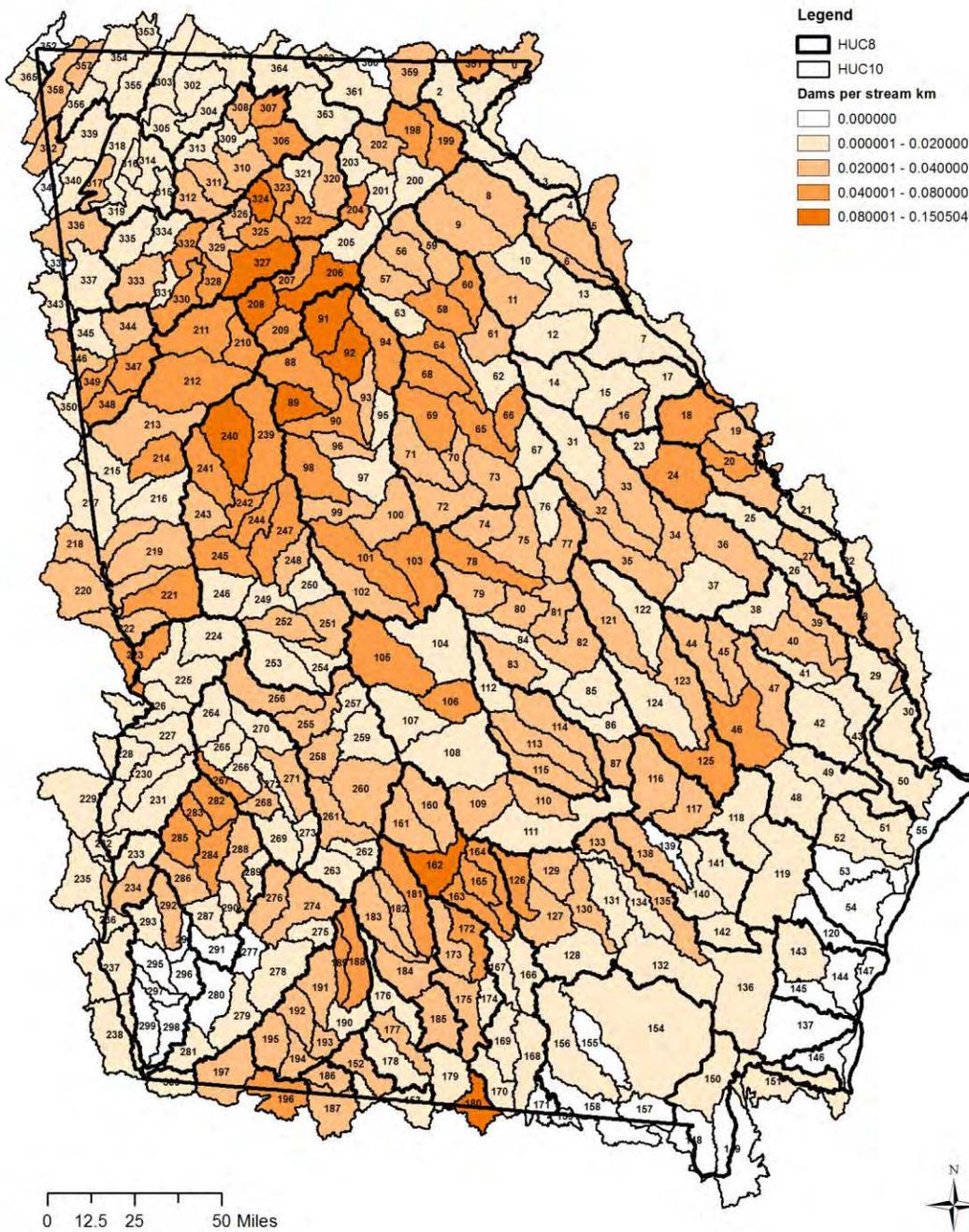
Figure 10. Number of dams per kilometer of stream in HUC 10 watersheds, based on the 2013 National Inventory of Dams and the National Hydrography Dataset (fine resolution hydroline). HUC 8 watershed boundaries are also shown.
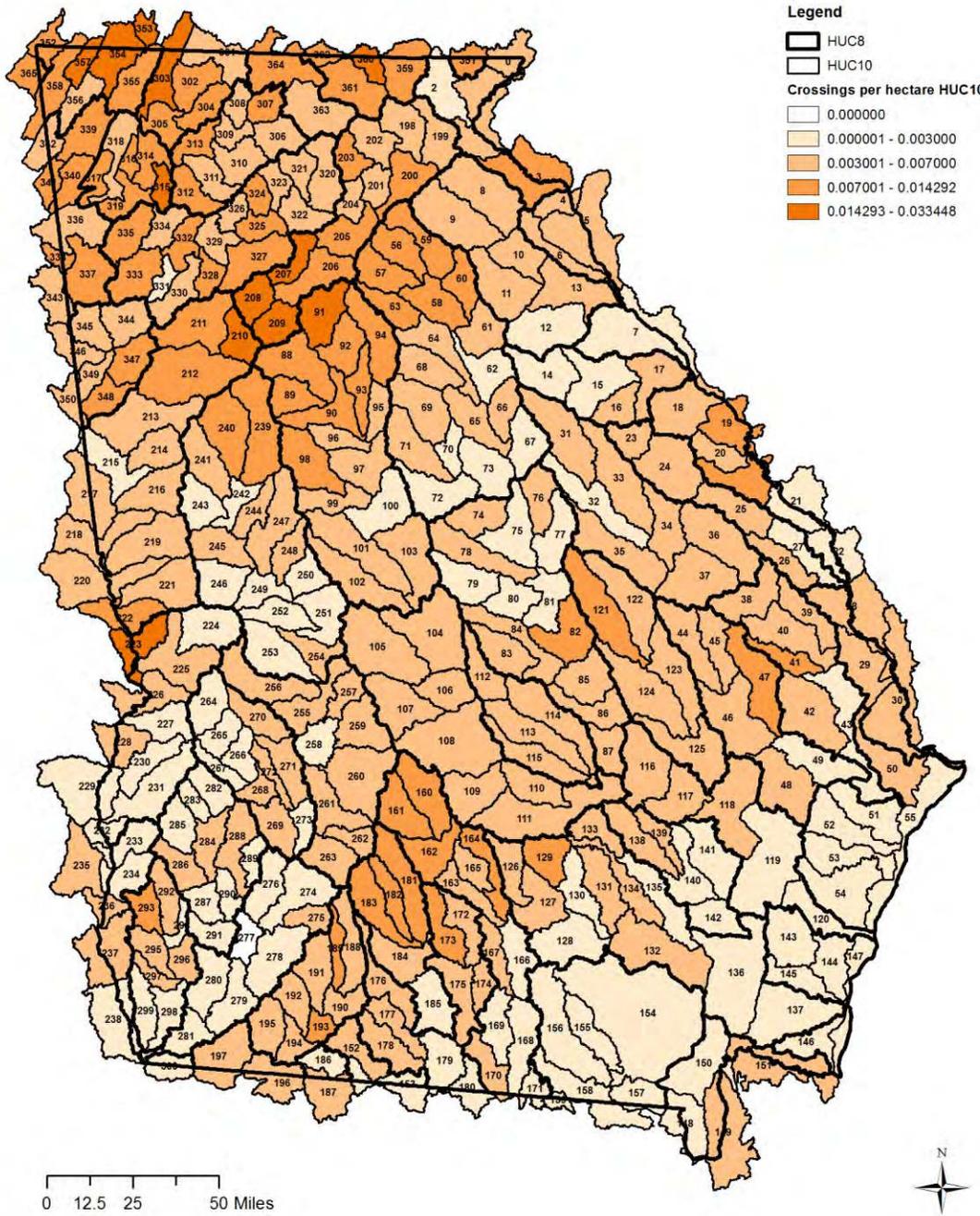
Figure 11. Number of road crossings per hectare of HUC 10 watershed area, based on Georgia Department of Transportation Road coverages in Georgia and the U.S and Canada Detailed Streets dataset (TomTom North America, Inc.) for portions of watersheds outside of Georgia. HUC 8 watershed boundaries are also shown.
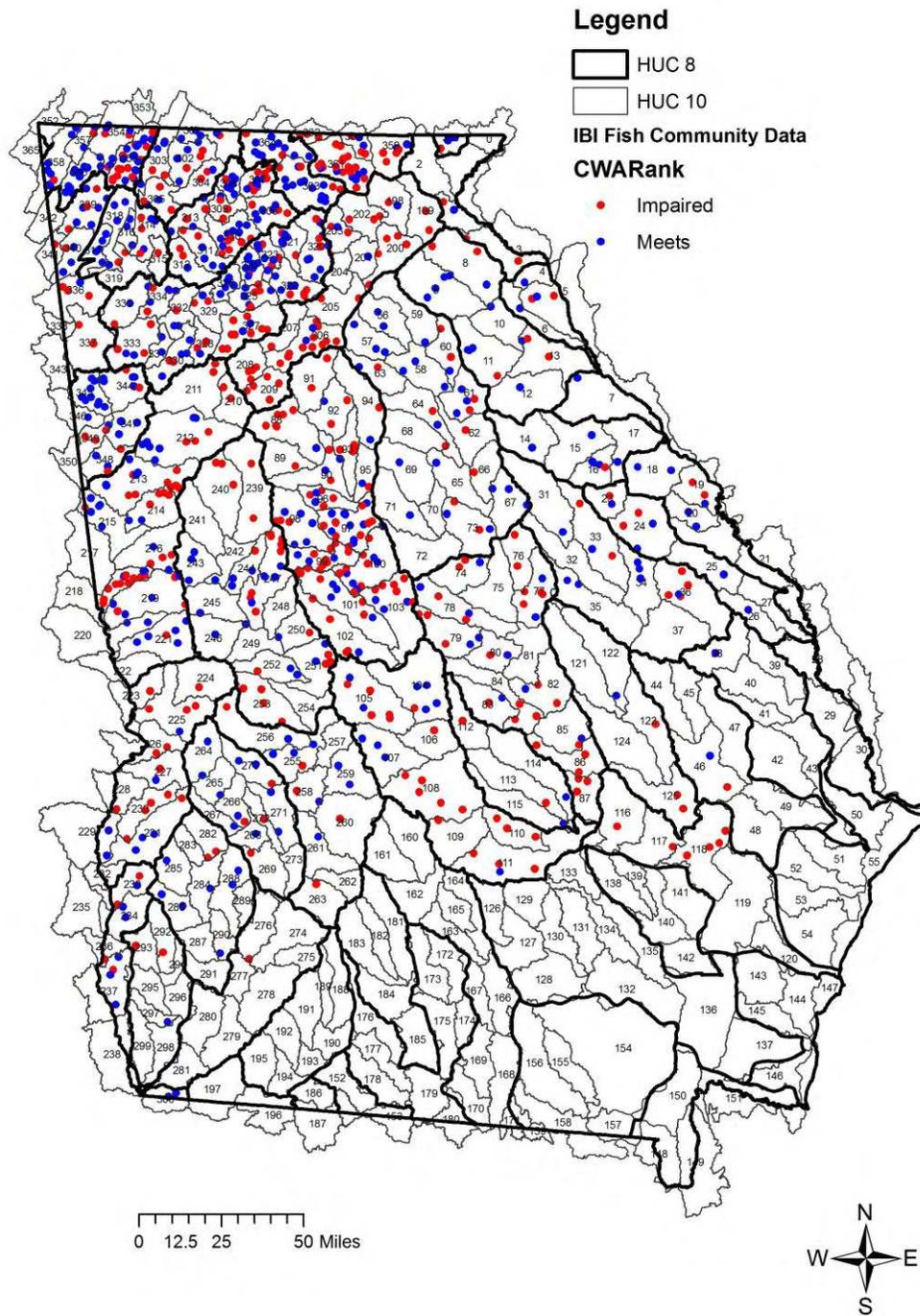
Figure 12. Sites that meet their designated use under the Clean Water Act or are considered impaired (i.e., not meeting their designated use) based on Index of Biological Integrity (IBI) fish community sampling. Sites were sampled between 1998-2011 by the Georgia DNR Stream Survey Team.
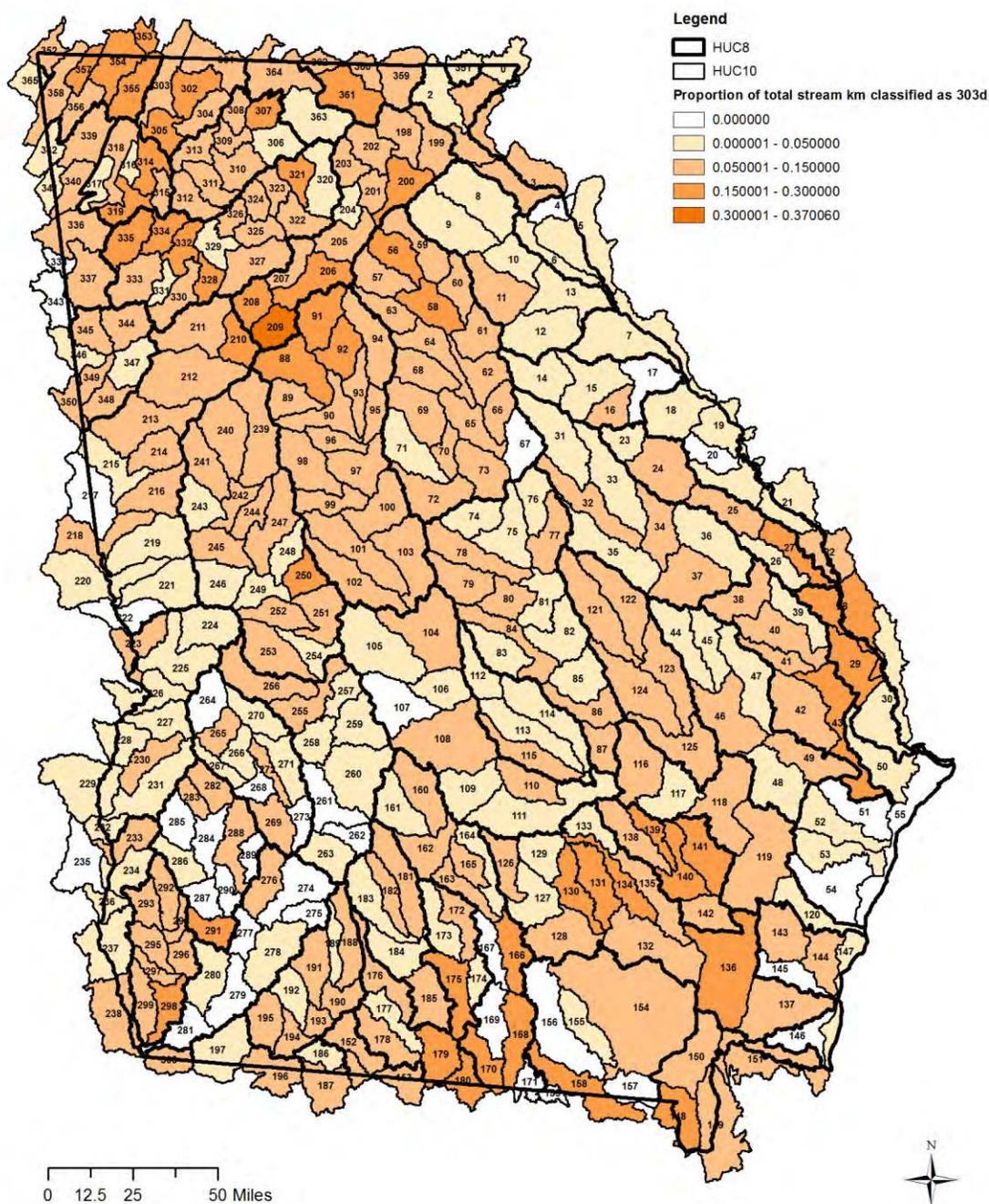
Figure 13. Proportion of stream length in HUC 10 watersheds on the the U.S. Environmental Protection Agency's list of impaired waters (i.e., the 303d list), as updated through 2012. Streams are listed for violating a variety of water quality critera, including criteria based on biological sampling, heavy metals, temperature, fecal coliform bacteria, dissolved oxygen, and other factors. HUC 8 watershed boundaries are also shown.
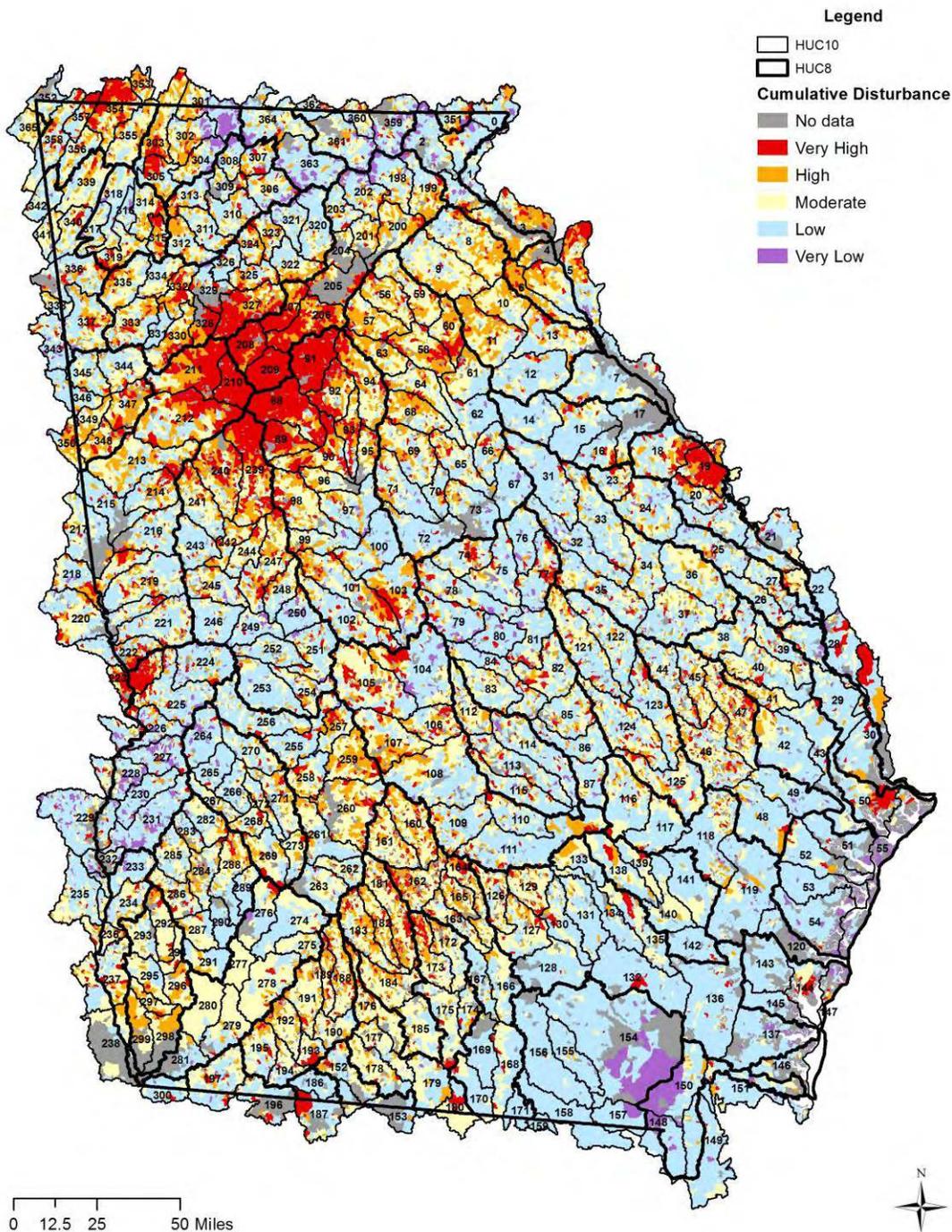
Figure 14. Risk of stream habitat degradation based on the cumulative influence of landscape variables such as land use, population density, roads, dams, mines, and point-source pollution. This dataset was created in support of a National Fish Habitat Action Plan and was released in 2010.

Recent Trends and Future Threats

Significant loss in the proportion of forested land cover (up to 13.5%) has occurred in many watersheds between 2001-2011, particularly in Metro Atlanta, the western Piedmont, and in the central portion of the Southeastern Plains (Figure 15). Forest cover has increased in most watersheds in southwest Georgia and exhibited stability or more modest declines in other parts of the state.   Overall, cultivated crop agriculture has changed little over the last decade (Figure 16). The proportion of developed land cover has increased in a large number of watersheds within the Metro Atlanta area and within a few other urbanizing areas around the state (Figure 17) and Figure 18). Similarly, there is a clustering of pixels with large increases in percent imperviousness in a wide area around Metro Atlanta (Figure 19). Projected urban growth is expected to increase modestly in these same areas in 2020 (Figure 20). By 2050, however, extensive urbanization is expected to occur throughout the Piedmont and Blue Ridge provinces and at scattered locations throughout the state (Figure 21).
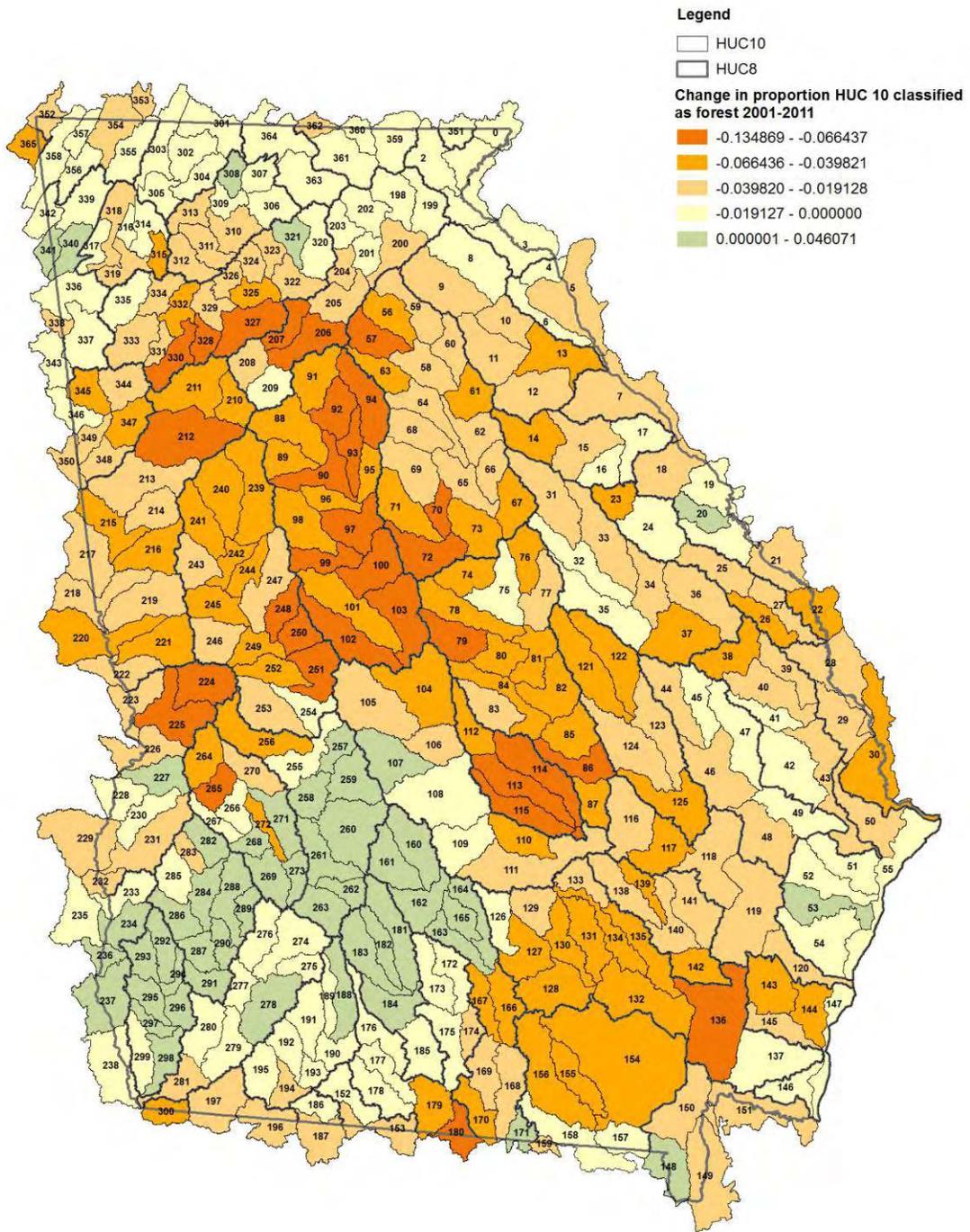
Figure 15. Change in the proportion of HUC 10 watersheds classified as forest between 2001-2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
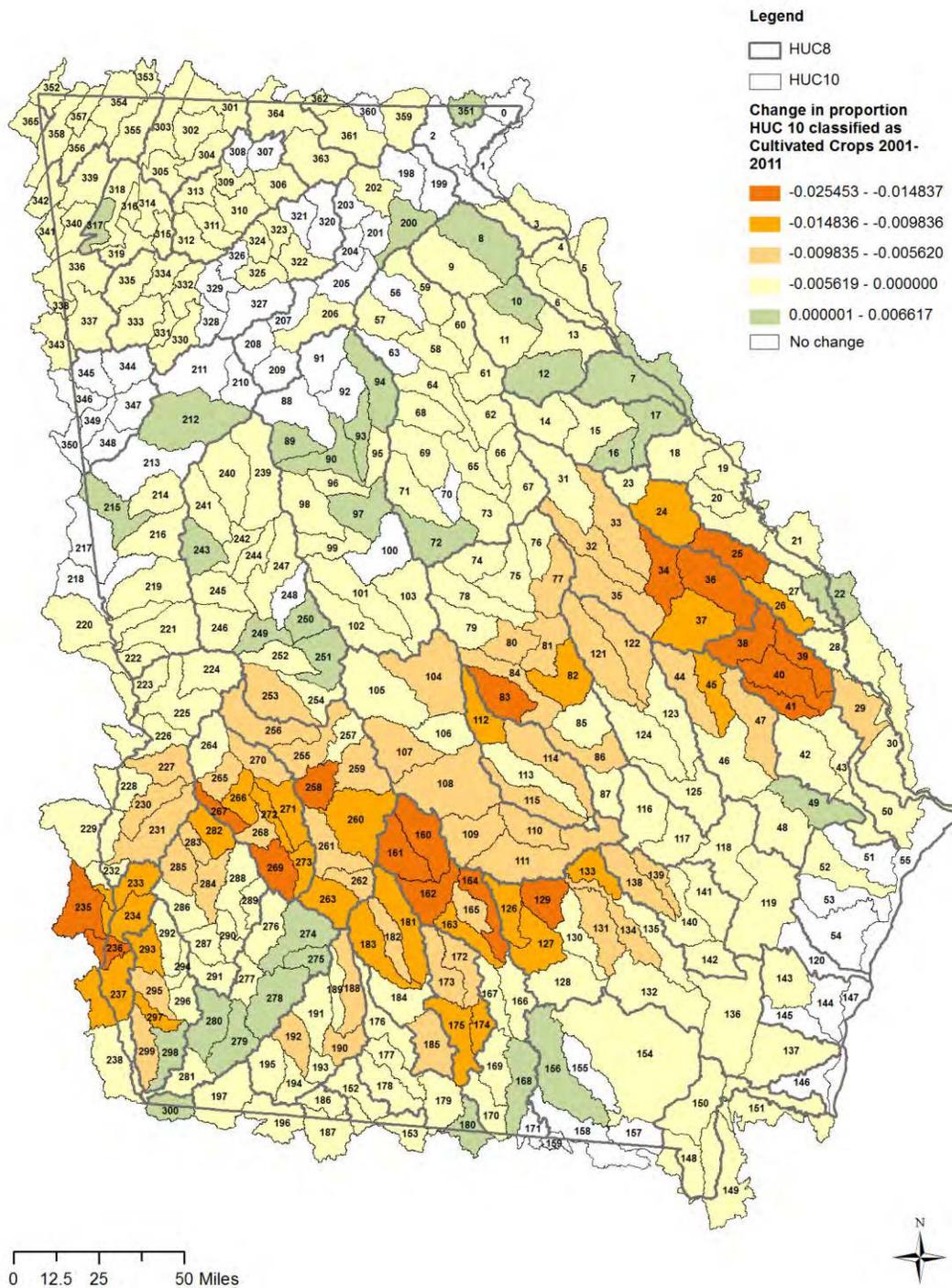
Figure 16. Change in the proportion of HUC 10 watersheds classified as cultivated crops between 2001-2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
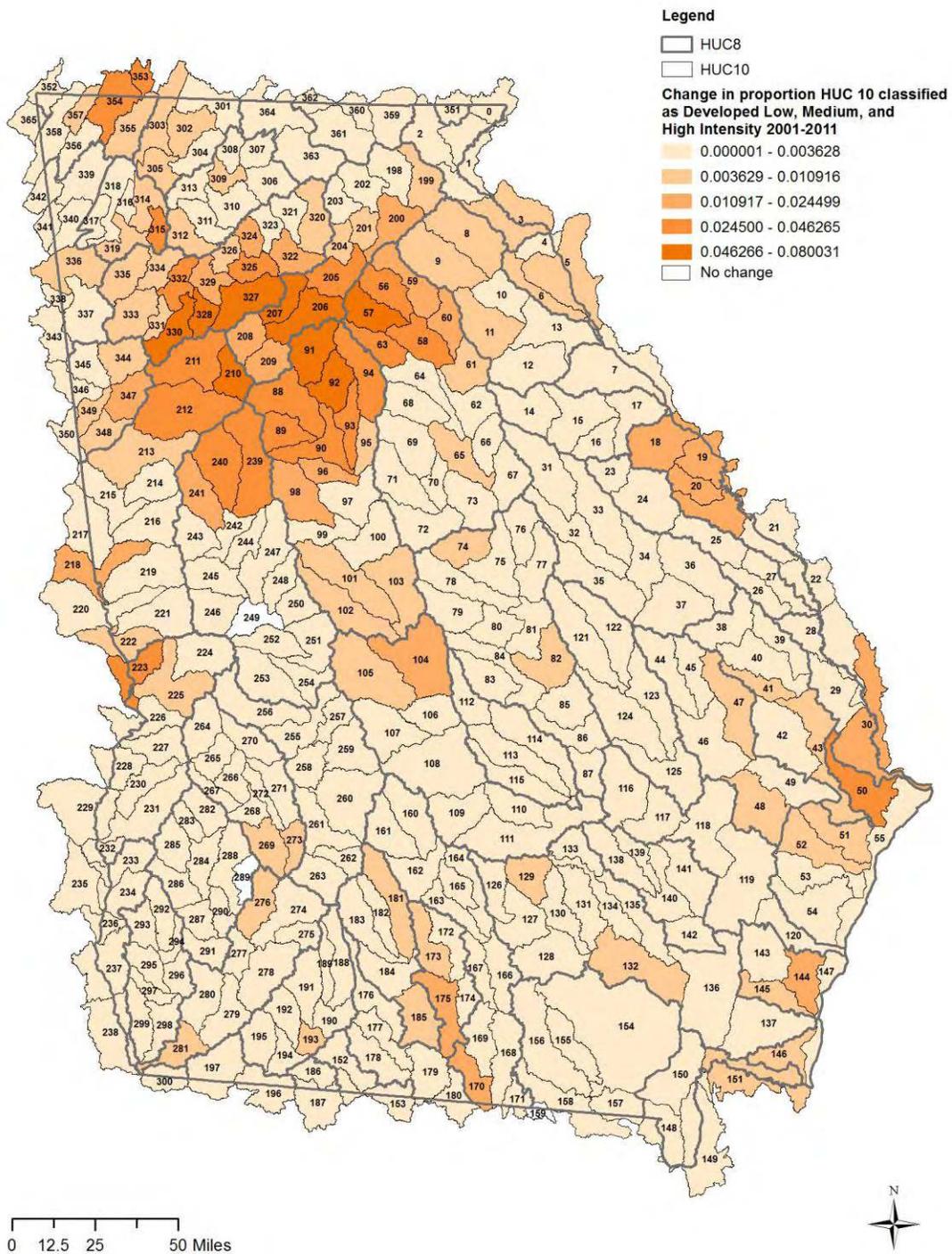
Figure 17. Change in the proportion of HUC 10 watersheds classified as low, medium, or high intensity development between 2001- 2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
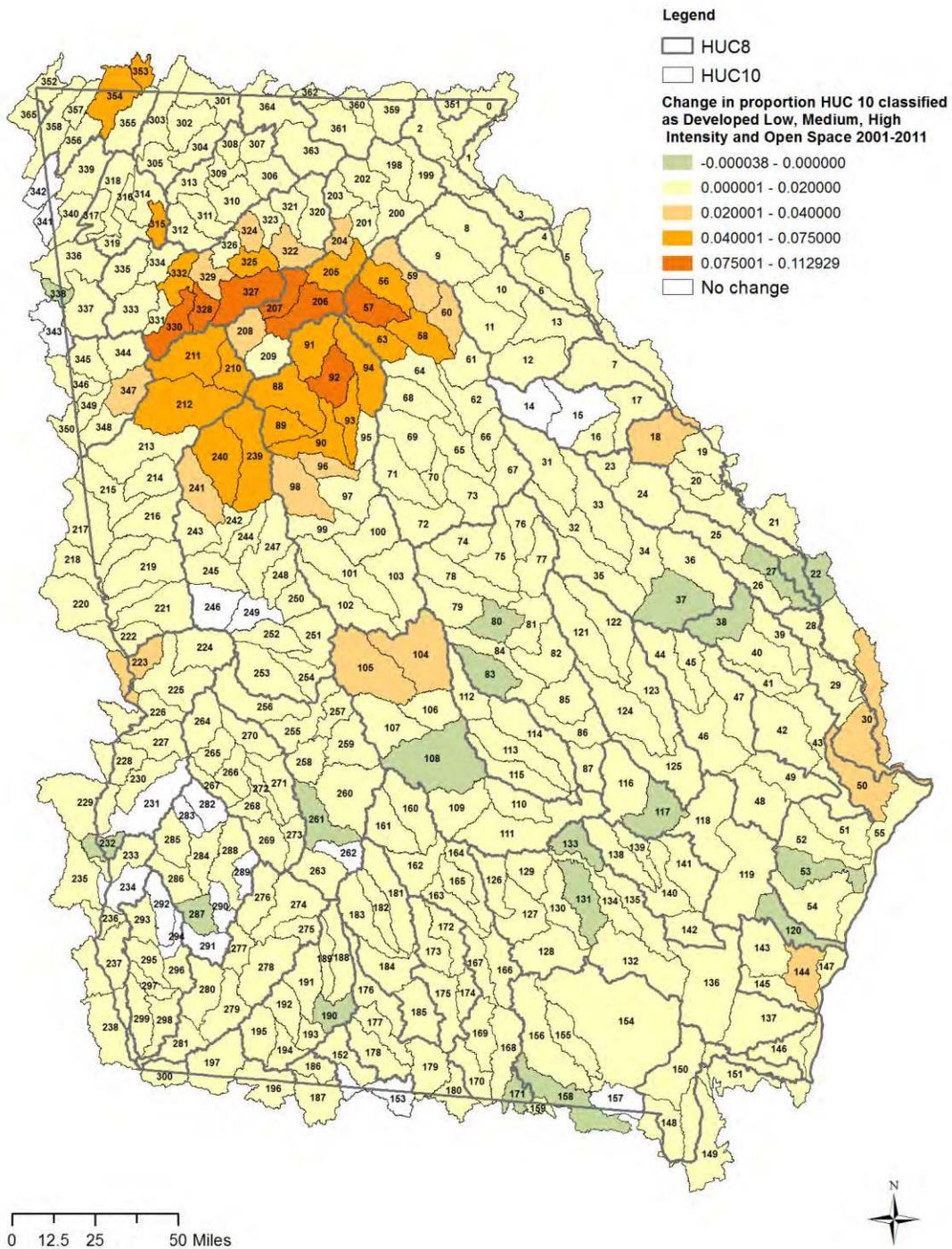
Figure 18. Change in the proportion of HUC 10 watersheds classified as low, medium, or high intensity development or developed open space between 2001-2011, based on the National Land Cover Classification Dataset. HUC 8 watershed boundaries are also shown.
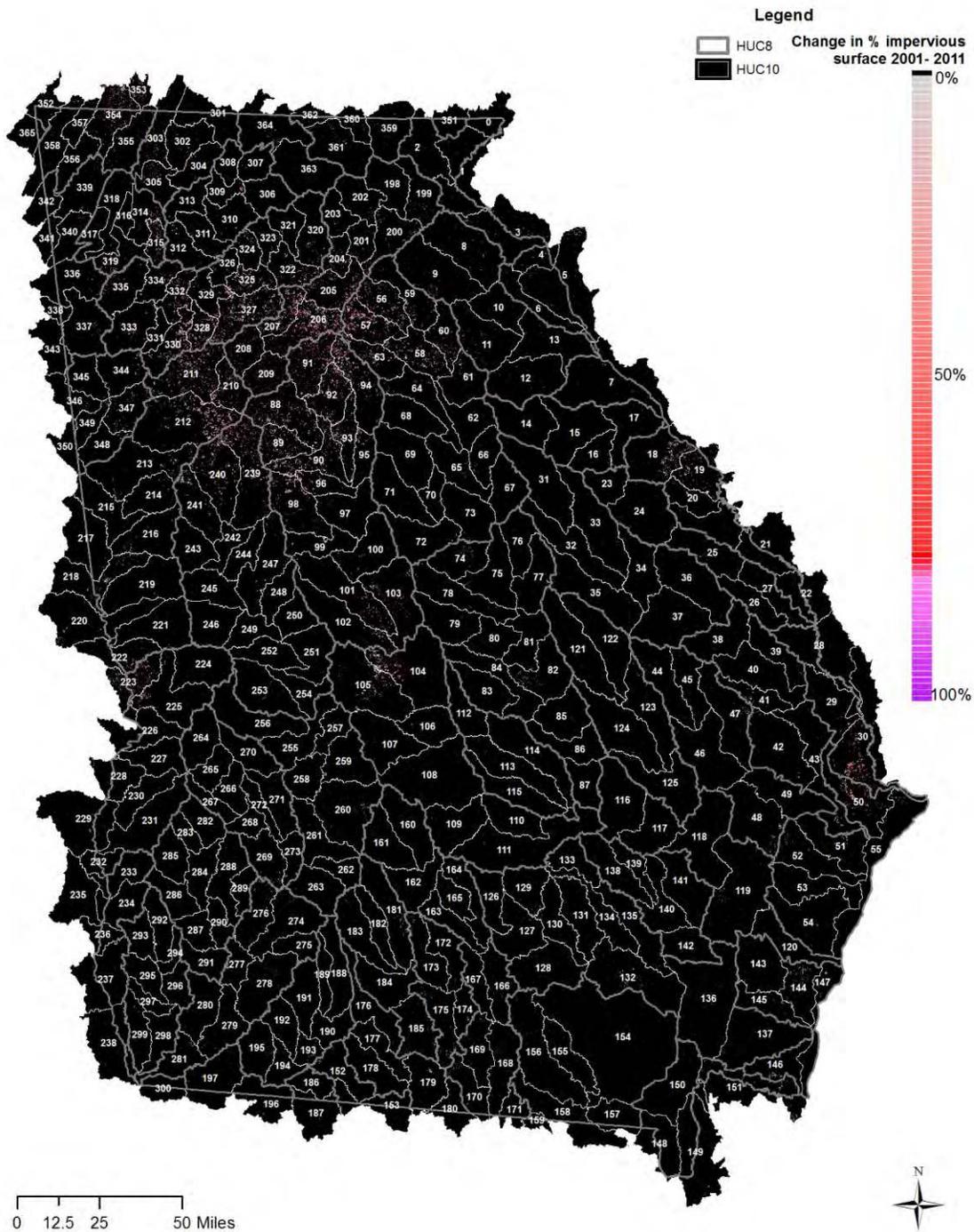
Figure 19. Change in the percent imperviousness of 30 m landscape cells within HUC 10 watersheds between 2001-2011, based on the National Land Cover Classification Dataset. Additional impervious cells are visible as you zoom into the figure. HUC 8 watershed boundaries are also shown.
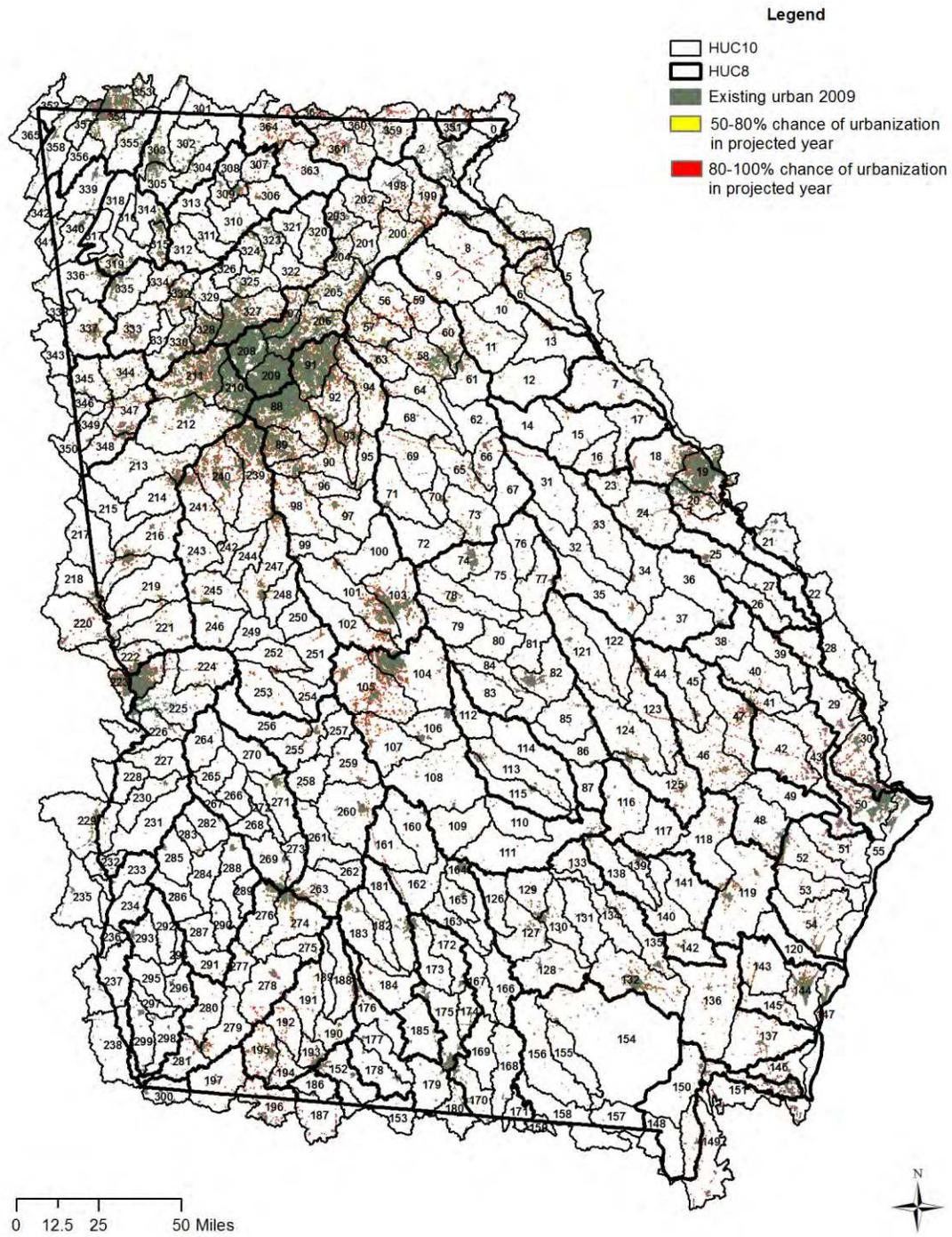
Figure 20. Predicted urbanization in HUC 10 watersheds based on SLEUTH model predictions for the year 2020. The model uses five datasets (slope, land use, excluded areas (i.e., conservation lands), existing urban, and transportation) to predict the probability of future urbanization. HUC 8 watershed boundaries are also shown.
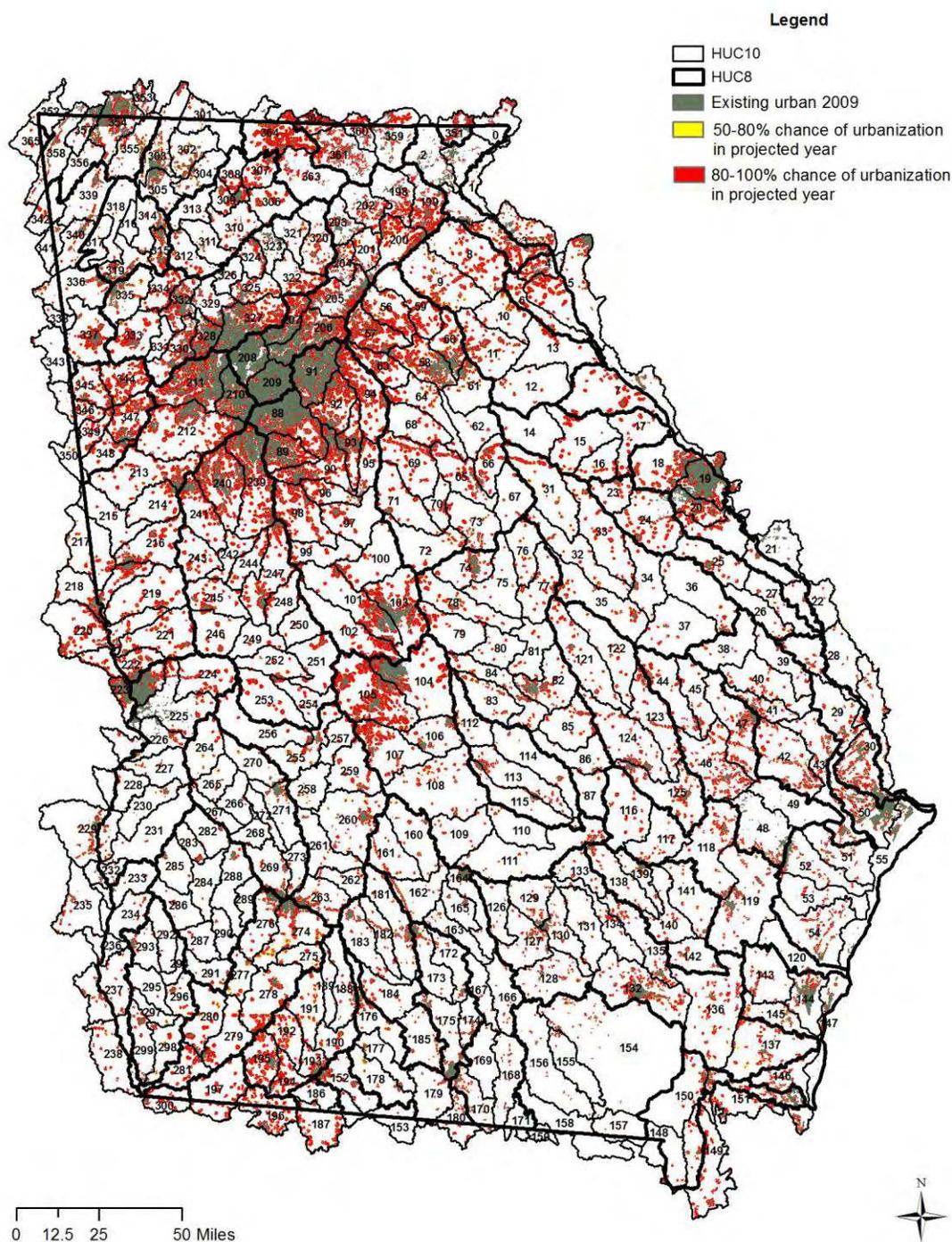
Figure 21.   Predicted urbanization in HUC 10 watersheds based on SLEUTH model predictions for the year 2050 (Belyea 2012). The model uses five datasets (slope, current land use, excluded areas (i.e., conservation lands), existing urban, and transportation) to predict the probability of future urbanization. HUC 8 watershed boundaries are also shown.

Discussion

As part of the 2015 revision of Georgia's State Wildlife Action Plan, we identified 221 high priority watersheds for conservation. Collectively, these watersheds are important for conserving the best known populations of high priority aquatic species, all extant occurrences and critical habitat units of ESA listed aquatic species, migratory corridors for high priority diadromous species, important coastal habitats, and representative aquatic communities from around the state. The majority of these watersheds (165) were designated because they contained at least one important population of a high priority aquatic species. These 165 watersheds were further prioritized based upon the number and global rarity of high priority species.

We also carried out a corresponding GIS assessment of the degree of protection, existing condition, as well as trends and future threats to all Georgia watersheds. Below we provide examples of how the assessment data can be used to help identify specific conservation actions in three high priority watersheds. We chose these specific watersheds because they help illustrate a wide range of threats and conservation actions that are relevant to watersheds throughout the state. Where appropriate, we have referenced some of the specific conservation actions identified by The Fishes and Aquatic Invertebrates Assessment Team (Albanese et al. 2015). More information about these conservation actions can be found in an excel file that should always accompany this report.

Example 1, Armuchee Creek

Armuchee Creek (#318; Figure 2) is a high priority watershed in the Ridge and Valley portion of the Coosa River drainage in northwest Georgia. It supports important populations of 10 high priority aquatic species (3 mussels, 3 fishes, 2 snails, a crayfish and a dragonfly), placing it among watersheds with the highest global significance scores in the state. It has a high percentage of forest cover (71.1%) and a relatively high percentage of protected lands (32.9%; Table 2). Outside of forest areas, pasture (12.6%) and cultivated crops (2.6%) are the dominant land cover types, with low total urban cover (0.7%), and a moderate amount of developed open space (3.5%; Figure 22). Index of Biotic Integrity (IBI) fish community sampling has been conducted at 5 sites in the watershed, with most recent scores including poor (unnamed trib), fair (Lavender Creek), good (1 site each in East and West Armuchee Creeks), and excellent (a different site in West Armuchee Creek). Armuchee Creek still contains high quality aquatic habitat (Figure 23) and most reaches are predicted to be at low to moderate risk for habitat degradation (Figure 14). However, sampling in 2012 did document extensive mats of filamentous algae, which could indicate nutrient pollution (Figure 24). The density of dams is relatively low (1 per 166 Km of stream length; Table 2; Figure 10) and the density of stream crossings is moderate (Figure 11).

In contrast to many other north Georgia watersheds, recent landuse changes and urban growth models do not evince dramatic changes for the Armuchee Creek watershed in the future. The largest change between 2001-2011 was the loss of 3.7% forest cover, but developed land (+0.2%) and cultivated crops (-0.1%) changed little. Only a small number of pixels increased in imperviousness between 2001-2011 (Figure 19). Similarly, urban growth is not predicted to be extensive in the watershed in either 2020 or 2050 (Figure 20 and Figure 21). While Armuchee Creek has exhibited little recent development and is not predicted to urbanize, the neighboring watershed to the south is (#319). In addition, the current pattern of public ownership and roads in

the watershed suggest that any additional development would be concentrated near rivers and streams.

Several SWAP conservation actions may be appropriate for the Armuchee Creek watershed. High resource quality and the low density of existing dams demonstrates the need for protection of aquatic connectivity in free-flowing systems (action #3). This action can be implemented by avoiding construction of new dams and improving aquatic organism passage through poorly designed stream culverts (see Georgia's Stream Crossing Handbook).   The importance of pasture as a land cover type and the potential nutrient issue mentioned above suggest the value of technical assistance to farmers to protect streams in high priority watersheds (action #8). Targeted aquatic species outreach (action #32) would help generate local interest and support for conserving the watershed and could be completed in conjunction with additional surveys and monitoring (action #47).
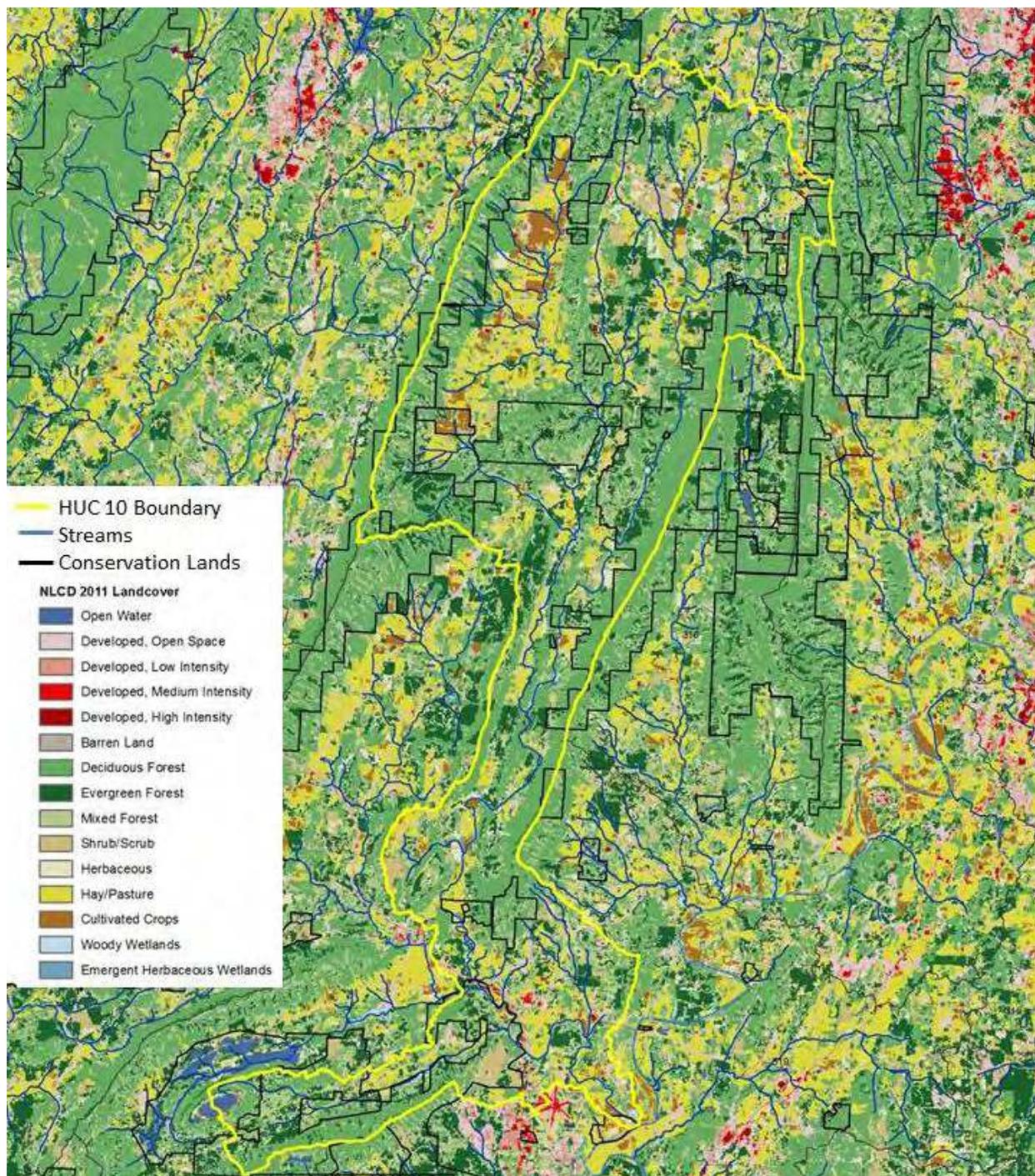
Figure 22. National Land Cover Classification (NLCD 2011) for the Armuchee Creek HUC 10 watershed, with streams and conservation land boundaries also shown.

Figure 23. High quality aquatic habitat in Armuchee Creek, including a patch of native emergent vegetation, a shallow backwater habitat, a rocky riffle with moderate to swift current, and an intact and mature riparian forest.
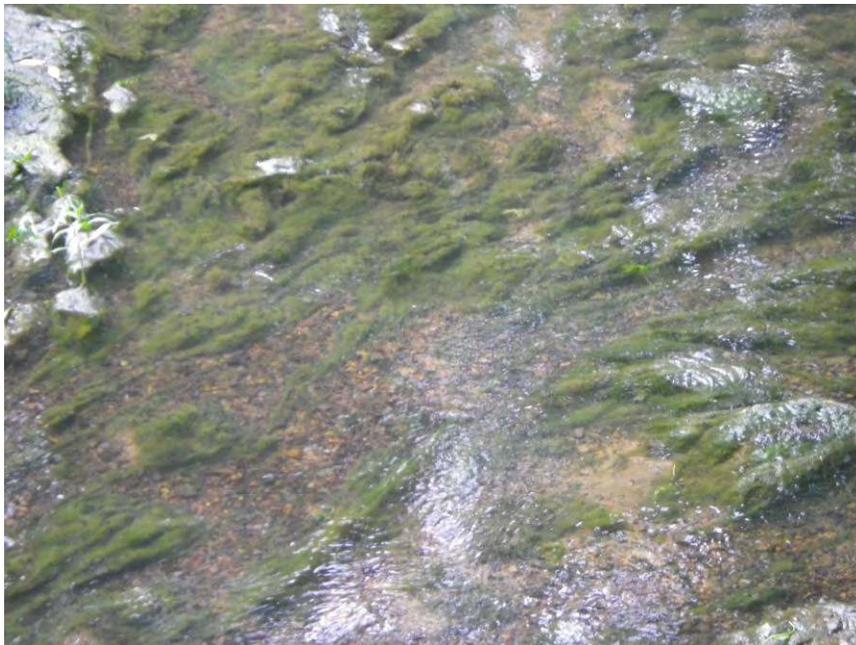
Figure 24. Patch of filamentous algae in Armuchee Creek. Extensive beds of filamentous algae can be an indicator of nutrient enrichment problems and may degrade habitat conditions for aquatic species.

Example 2, Upper Nottely River

The upper Nottely River (#361; Figure 2) is in the Blue Ridge ecoregion of north Georgia near the North Carolina border. It is categorized as having moderate global significance because of important populations of Blotched Chub (*Erimystax insignis*) and Eastern Hellbender (*Cryptobranchus alleganiensis*). It is also a potential reintroduction site for the undescribed Sicklefin Redhorse (*Moxostoma* sp.), which likely occurred in the watershed before Lake Nottely was created. Like Armuchee Creek, the Upper Nottely River has a high percentage of forest cover (76.5%) and protected lands (36.4%) and low total urban cover (1.2%) (Table 2; Figure 25). Outside of forested areas, the only land cover types representing more than 2% of watershed area are developed open space (9.2%) and pasture/hay (7.4%; Table 2). There is relatively low dam density (1 per 63 km of stream length; Figure 10; Table 2), but the density of road crossings is relatively high (Figure 11). Index of Biotic Integrity scores indicate widespread impairment of fish communities, with 15 of 21 sites scoring fair, poor, or very poor (Figure 12). The risk of habitat degradation is generally low and moderate, but there is a high to very high risk of degradation in the city of Blairsville and along U.S Highway 76 (Figure 14). Overall land cover has changed little between 2001-2011. However, additional urbanization is expected at scattered locations throughout the watershed by 2020 (Figure 20) and extensive urbanization is expected by 2050 (Figure 21).

While there is relatively high forest cover and a significant amount of protected land, the Nottely River watershed exhibits some signs of stress that will likely be exacerbated as urbanization continues. Because of steep mountainous terrain in the Blue Ridge ecoregion, most development and agricultural activities are limited to small floodplain areas near rivers and streams (Figure 25). Thus, the spatial pattern of land use may contribute to the widespread degradation suggested by the IBI scores. Another important factor is the impact of both small dams and Lake Nottely on aquatic connectivity, which can decrease the resilience of aquatic species populations by blocking colonization and other movements required for life-cycle completion. The large number of road crossings in the watershed also suggests that culverts may further restrict aquatic organism passage. Other sources of habitat degradation include bank erosion and nutrient enrichment associated with cattle grazing, development in riparian areas associated with vacation homes and tourism, and sedimentation from unpaved roads (personal observations). These impacts are not restricted to the Nottely River system, but are representative of impacts to streams throughout the Blue Ridge in Georgia (Owers et al. 2012).

As in Armuchee Creek, our assessment results suggest the importance of several SWAP conservation actions. Technical assistance to farmers (#8) could involve the development of alternative watering sites and fencing in reaches where cattle are currently accessing streams. There are also opportunities for riparian zone restoration (#12) in both agricultural and residential areas. The greatest challenge, though, will be protecting aquatic habitats from projected urbanization. Technical assistance to local governments (#6) could help identify and implement innovative policies to minimize the myriad of impacts associated with new development (e.g., impervious surfaces, stream crossings, water supply development, sewage treatment, etc.). The policies developed for the Etowah Habitat Conservation Plan would be a good starting point for consideration.
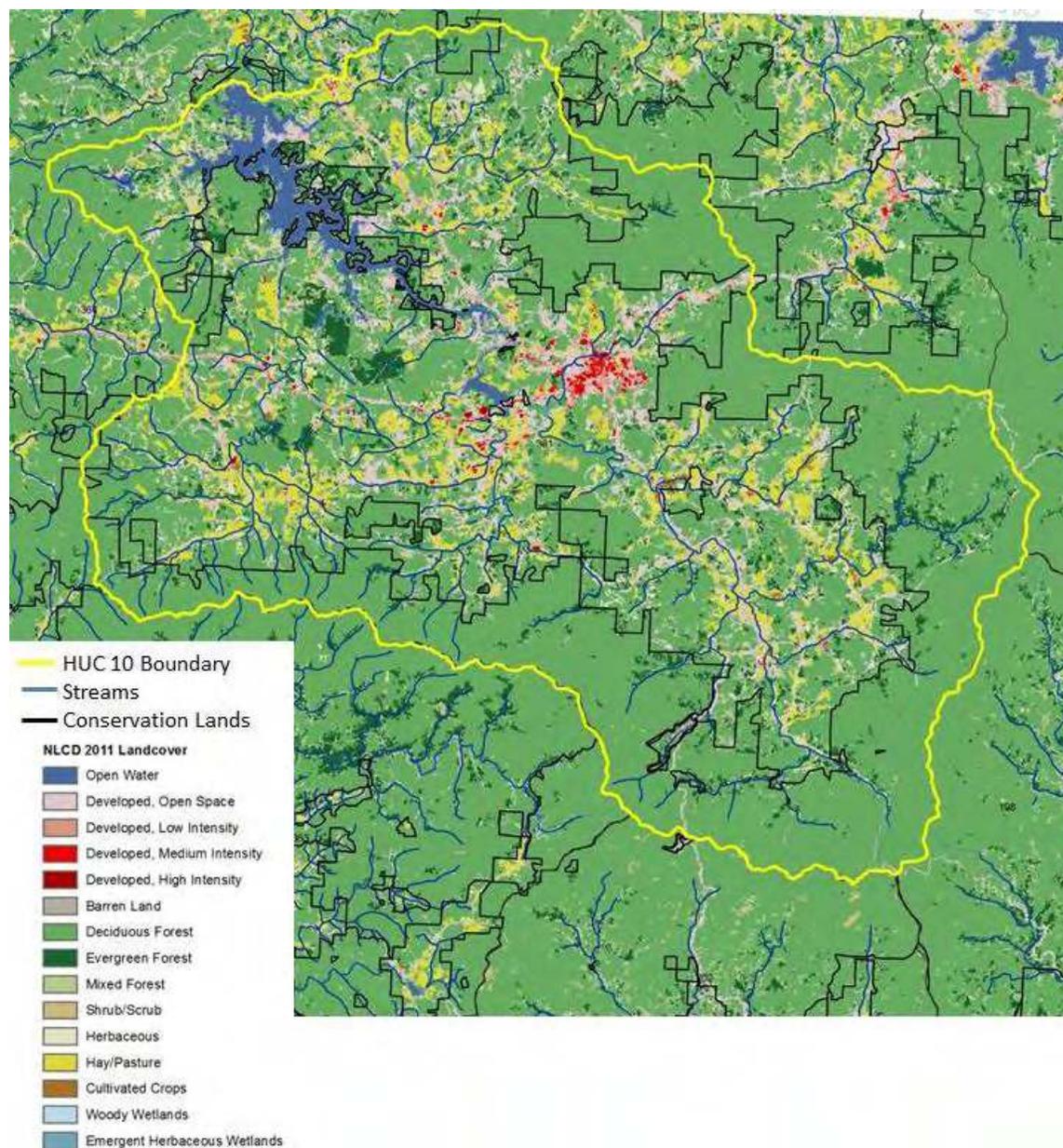
Figure 25. National Land Cover Classification (NLCD 2011) for the Upper Nottely River HUC 10 watershed, with streams and conservation land boundaries also shown.

Example 3, Spring Creek

Spring Creek (#296) is a high priority watershed in the Southeastern Plains portion of the Flint River drainage in southwest Georgia (Figure 2). It supports important populations of 7 high priority aquatic species (5 mussels, 1 fish, and 1 reptile), placing it among watersheds with the highest global significance scores in the state (Table 1). Predominant land cover types are cultivated crops (48.6%), forest (21.4%), woody wetlands (10.2%), and pasture/hay (6.0%; Table 2; Figure 26). Total urban (3.1%) and developed open space (3.6%) represent a small portion of

the watershed. There are no dams ([Figure 10](#)) and the density of road crossings is moderate ([Figure 11](#)). Index of Biotic Integrity fish community sampling has not been conducted in the watershed, but 12.7% of stream length is impaired due to other water quality criteria (Table 2). The risk of habitat degradation is primarily moderate and high ([Figure 14](#)). Overall, land cover was stable between 2001-2011 and only modest increases in urbanization are predicted for 2050.

Despite the dominance of cultivated crops in the watershed, Spring Creek still provides high quality habitat for aquatic species ([Figure 27](#)). We attribute this to the occurrence of woody wetlands and forested habitat along the mainstem of Spring Creek as well as the supply of high quality water from underlying aquifers. The most significant threat to the persistence of species is the impact of severe and persistent drought coupled with agricultural water use. These two factors have resulted in record low stream flows in 9 of the past 15 years, with extensive portions of Spring Creek stagnating or going completely dry for extended time periods ([Figure 28](#)).   In addition, the high density of cultivated crop agriculture appears to contribute substantial sediment loads into the creek, which degrades habitat quality and reduces the availability of deeper refuge pools during droughts. Despite these threats, this watershed contains perhaps the best remaining populations of two federally endangered mussel species. In addition, it supports 47% of all the freshwater mussel species known in the Apalachicola-Chattahoochee-Flint River Basin.

The most important conservation action for the Spring Creek watershed is the development of environmental flow recommendations (action #4), which involves identification of the timing and magnitude of stream flows needed to sustain ecosystems and provide for human use. It is an understatement to say that this issue has received considerable attention from the general public, researchers, the agricultural community, and various state and federal agencies. Nonetheless, providing adequate streamflows in Spring Creek will require continued focus, investment, and cooperation. Working with stakeholders through the statewide water planning process (action #9) and through other mechanisms is necessary to develop solutions to environmental flow issues in Spring Creek and other southwest Georgia streams. Continued monitoring of mussels (action #33) will help ensure that species are persisting and help measure their response to different management actions which protect stream flows during droughts (i.e. adaptive management). Targeted aquatic species outreach should help generate local interest and support for conservation efforts (action #32).
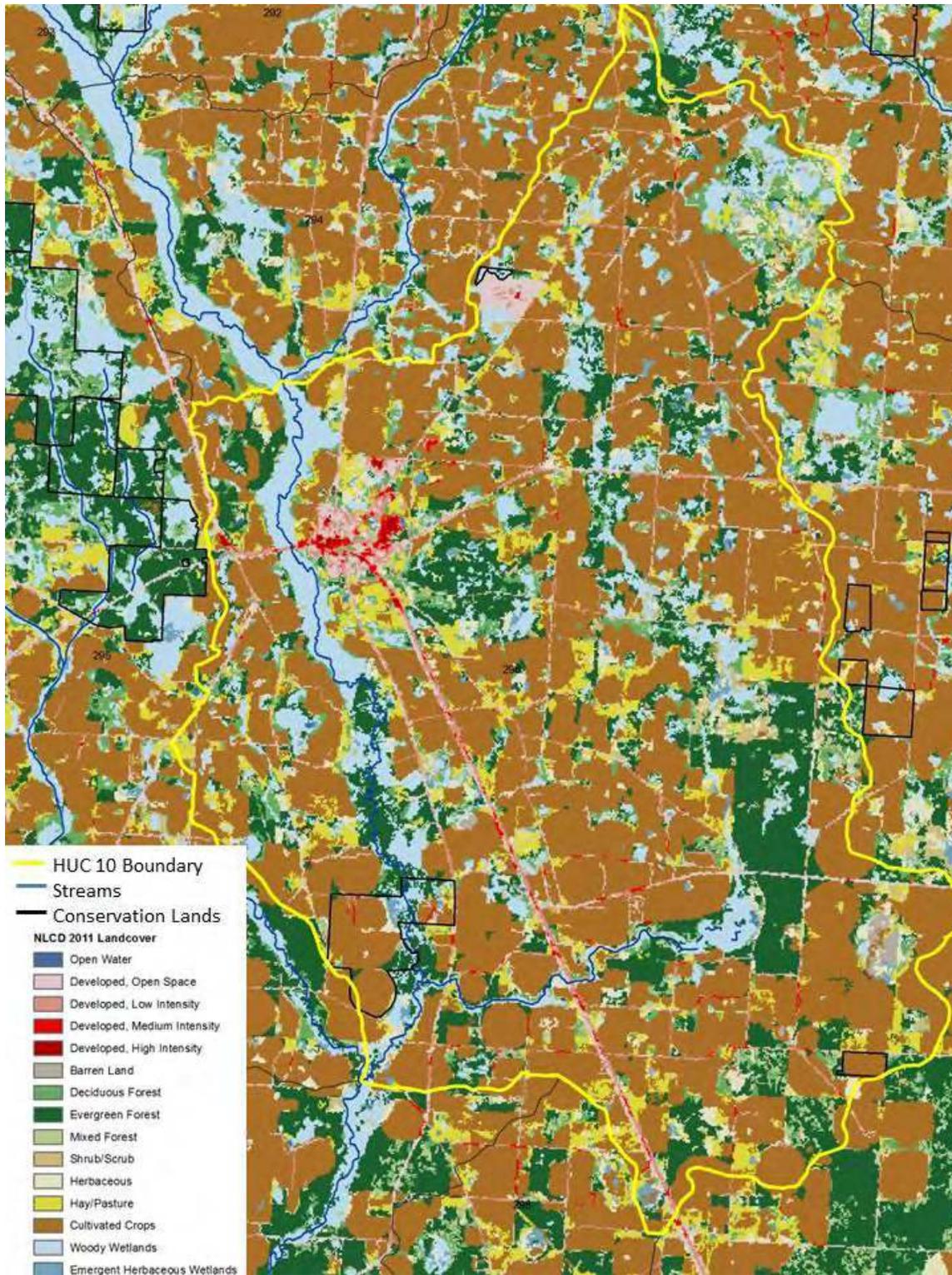
Figure 26. National Land Cover Classification (NLCD 2011) for the Spring Creek watershed, with streams and conservation land boundaries also shown.

Figure 27. High quality habitat in Spring Creek, which includes extensive woody debris and undercut banks, clear water with deep runs and pools, and an extensive and mature riparian forest. Photo by Jason Wisniewski.

Figure 28. Reach of Spring Creek impacted by low stream flows associated with drought and agricultural water use. Photo by Jason Wisniewski.

Additional Recommendations for Conservation of High Priority Watersheds

We acknowledge that there are some limitations and caveats to consider when utilizing this report to guide conservation. First, there is underlying error in the process of classifying land cover types using satellite data (Wickham et al. 2013). Thus, while these data may identify a **potential** threat to water quality, it is important to verify actual impacts to water quality before investing resources into a project. Similarly, data sets such as the National Inventory of Dams are known to underestimate the true number of dams and are biased towards larger dams with more storage. There are many additional data sets that can help support more detailed conservation planning in high priority watersheds. For example, the Southeastern Aquatic Connectivity Assessment Project (SEACAP) has developed an online tool to help identify the most ecologically significant barriers to the movement of aquatic species. This tool could be used to identify where to improve organism passage (e.g., a dam or culvert site) to provide the greatest overall benefit to aquatic ecosystems within a high priority watershed. Another example would be the use of aerial photography and other remote sensing imagery (Klemas 2014) to identify specific areas for the protection and restoration of riparian zones.

With these considerations in mind, we still believe that the information contained in this report provides a useful starting point for watershed-level conservation in Georgia. It is our hope that this information will help support:

1. Efforts by conservation groups and government agencies to protect and restore southeastern aquatic species diversity, which is considered globally significant (Abell et al. 2000; Jelks et al. 2008). Watersheds with the highest global significance scores are a priority for implementing conservation projects carried out by groups such as American Rivers, The Nature Conservancy, Southeastern Aquatic Resources Partnership, The Tennessee Aquarium Conservation Institute, and The U.S. Fish and Wildlife Service.
2. Efforts by Georgia and its conservation partners to protect and recover Georgia's high priority aquatic species. The SWAP Fishes and Aquatic Invertebrates Team identified altered water quality, incompatible agricultural practices, altered hydrology, residential development, and dam and impoundment construction as significant threats to a large number of high priority aquatic species. Addressing these threats on a statewide basis may be unrealistic, but they can be addressed by focusing efforts in individual high priority watersheds.
3. Efforts to protect water quality and provide compatible recreational opportunities, such as angling, boating, or hiking. While the goal of a group or agency may not be to protect aquatic species *per se*, there are numerous opportunities to protect natural resources to the benefit of species, habitats, and local citizens. An example would be the establishment of a community natural area in a high priority watershed.

Acknowledgments

We thank members of the SWAP Aquatic Habitat Technical Team, Fishes and Freshwater Invertebrates Team, and Advisory Committee for guidance and feedback throughout this process. Jason Wisniewski contributed to the section on Spring Creek. Sara Gottlieb and Deb Weiler provided additional editorial review. Greg Krakow developed the necessary GIS scripts to

aggregate species importance scores across watersheds. Chris Canalos helped with the interpretation of the National Land Cover Data.

Appendix I: Data Layers Used in Watershed Assessment

1. Degree of Protection

    a. **Proportion Conservation Land** (+): Percent of watershed owned or under permanent conservation easement and managed for natural resource protection Source: <u>Conservation Lands Database</u> and <u>Protected Areas Database</u> for portions of HUC10 watersheds outside the state of Georgia.
    Data Type: Exploratory

2. Existing Condition

    a. **Proportion Forest** (+): Proportion of the HUC10 that is classified as Deciduous Forest, Evergreen Forest or Mixed Forest.
    Source: National Land Cover Dataset (NLCD 2011)
    Data Type: Potential Predictor

    b. **Proportion of Cultivated Crops (-):** Proportion of the HUC10 that is classified as Cultivated Crops.
    Source: National Land Cover Dataset (NLCD 2011)
    Data Type: Potential Predictor

    c. **Proportion Developed 1 (-):** Proportion of the HUC10 that is classified as Developed Low, Developed Medium, or Developed High Intensity.
    Source: National Land Cover Dataset (NLCD 2011)
    Data Type: Potential Predictor

    d. **Proportion Developed 2 (-):** Proportion of the HUC10 that is classified as Developed Low, Developed Medium, Developed High Intensity or Open Space. Calculated using 2011 version of 2001 and 2011 NLCD Land cover data.
    Source: National Land Cover Dataset (NLCD 2011)
    Data Type: Potential Predictor

e. **Percent Impervious (-):** To assess the potential impact of urban development and infrastructure on aquatic environments, we used the NLCD impervious surface coverage for 2011. Percent impervious represents the fraction of impervious surface within a 30 x 30m cell.
Source: NLCD 2011 impervious surface coverage
Data Type: Potential Predictor

f. **Dam Density (-):** These data are summarized in two ways: as the number of dams divided by watershed area (hectares) and the number of dams divided by stream length (km). Stream length was based upon NHD hydroline (fine resolution).
Source: 2013 National Inventory of Dams
Data Type: Exploratory, since it does not include many small dams

g. **Road Crossing Density (-):** number of crossings divided by watershed area, developed by placing a point at the intersection of stream and road crossing data sets. This is a general indicator of the potential for aquatic habitat fragmentation associated with poorly designed culverts and other impacts associated with roads. All underground conduit, pipelines, and artificial paths were removed from the stream data set to minimize crossings that would likely be bridges or have limited aquatic habitat
Source: 2007 and 2012 GDOT Road geodatabase (inside GA), U.S. and Canada Detailed Streets, (TomTom North America, Inc.; outside GA)
Data Type: Exploratory

h. **Index of Biotic Integrity Scores (IBI) (+):** IBI fish community sampling in 1094 stream reaches sampled between 1998-2011 was used to determine if stream reaches are impaired or meet their designated uses under the Clean Water Act. Streams with no fish, a very poor, or a poor IBI category are designated as "impaired", whereas streams rated fair, good, or excellent are designated as "meet". Additional analyses could average IBI score by watershed.
Source: Georgia DNR Stream Survey Team
Data Type: Potential Predictor

i. **Proportion Impaired (-):** Proportion of total stream length in watershed not supporting their designated uses (i.e., 303d listed streams). Calculated total m of impaired waters divided by total m of waters in the watershed. Streams can be listed for violating a variety of water quality criteria, including biotic integrity (based fish or macroinvertebrate community), temperature, dissolved oxygen, heavy metals, algae, fecal coliform and other factors. Thus, this data set is more inclusive than the

information provided by Index of Biotic Integrity scores alone. More information on Georgia's 303d list can be found here.
Source: 2012 303d Stream Data.
Data Type: Exploratory

j. **Habitat Condition Index (-):** This index was developed to reflect the cumulative influence of landscape variables on aquatic habitat and is based upon land use, population density, roads, dams, mines, and point-source pollution sites. The index is based on landscape variables and predicts the risk of habitat degradation at the scale of an individual stream reach or local catchment. Scores range from 1 (highest risk of habitat degradation) to 5 (lowest risk of habitat degradation). Risk of Current Habitat Degradation is classified as very low = 4.34-5.0, low = 3.5-4.33, moderate = 2.51-3.49, high = 1.51-2.5, very high =1.0-1.5, and unscored reach = 0.
Esselman et al. (2011) describe the approach in more detail.
Source: National Fish Habitat Plan 2010 Habitat Condition Scores
Data Type: Potential Predictor

3. Recent Trends and Future Threats

   a. **Forest Change** (+/-): Forest change was expressed in two ways. First, as the change in the proportion of each watershed classified as any of the forest types between 2001 and 2011 (negative indicates loss of forest). Second, as a loss/gain map for each cell (30 x 30m block of area) in the landscape. Forest loss was attributed to cells that were classified as Deciduous forest, Evergreen forest or Mixed forest in 2001 and classified as a non-forest type in 2011. Forest gain was defined as any cells classified as a non-forest type in 2001 and classified as one of the forest types in 2011.
   Source: NLCD 2001 to 2011 Land Cover from to Change Index
   Type: Potential predictor

   b. **Cultivated Crop Change** (+/-): Change in the proportion of watershed classified as cultivated crops between 2001 and 2011. Also presented as a loss/gain map and calculated as described for forest change.
   Source: NLCD 2001 to 2011 Land Cover from to Change Index
   Type: Potential predictor

   c. **Change in Proportion Developed I:** Change in proportion of each watershed classified as Developed Low, Medium, and High Intensity between 2001-2011 (negative indicates loss of landuse type).
   Source: 2011 versions of 2001 and 2011 NLCD.
   Type: Potential Predictor

d. **Change in Proportion Developed II:** Change in proportion of each watershed that is classified as Developed Low, Developed Medium, Developed High Intensity, or Open Space between 2001-2011 (negative indicates loss of landuse type).
Source: 2011 versions of 2001 and 2011 NLCD.
Type: Potential Predictor

e. **Change in Percent Impervious (+/-):** Contains the difference in percent developed imperviousness of pixels that changed between NLCD 2001 percent developed imperviousness (2011 Edition), and NLCD 2011 (2011 Edition) percent developed imperviousness. " - http://www.mrlc.gov/nlcd06_data.php
Source: 2001 Percent Developed Imperviousness (2011 Edition) and 2011 Percent Developed Imperviousness.
Type: Exploratory

f. **Predicted Urbanization (SLEUTH):** The SLEUTH-3r model was used to simulate the extent of urban growth throughout the southeastern United States as part of the Southeast Regional Assessment Project for the USGS National Climate Change and Wildlife Science Center. The model uses five datasets (slope, land use, exclusion (i.e. conservation areas), urban, and transportation) to predict the probability of future urbanization at various time intervals. We selected model outputs for 2020 and 2050 and overlayed watershed boundaries.
Source: SLEUTH Models for DSL-SERAP, Decadal Predictions 2000 – 2100
Type: Exploratory

Appendix II: Other Important Data Layers Considered but Not Included in the Watershed Assessment

a. 2001 Riparian Condition Assessment (-): Percent agricultrual and urban land cover within 30 m of stream (-)
This data set identifies the percent of agricultural and urban land cover within 100 feet of stream banks (30 m). This data set has some limitations that preclude its use as a predictor variable. For example, a few canopy trees on the stream bank would result in classification as forest even though houses, pavement, or lawns could be underneath the canopy trees. In addition, large sections of rivers were excluded from the data set due to mapping errors. Nonetheless, it may be useful for looking at coarse temporal trends in stream buffers and identifying management actions for individual HUC 10s. The model can be re-run with 2011 NLCD data, but that has not yet been completed.
Source: SALCC Conservation Planning Atlas
Data Type: Exploratory

b. SARP SE Connectivity Assessment Data (SEACAP) : The goal of this project is to assess stream connectivity throughout the southeast, based on locations of dams and other barriers to aquatic organism passage. The data set was released in early 2015 and will be important for determining the ecological benefit of dam removal and culvert improvement projects.
Source: Southeast Aquatic Resource Partnership
Data Type: Exploratory

c. Chemical Spill Data (-): Data documenting toxic spills and fish kills into waterways. This was identified as a data need during discussion.
Source: Unknown

d. Concentrated Animal Feeding Operations (-): This was identified as a data need during discussion. This data would show the locations of concentrated animal feeding operations (CAFO) and help identify areas where conservation actions could help reduce water quality impacts.
Source: Unknown

e. SparrowWater Quality Dataset. The U.S. Geological Survey Sparrow dataset provides models and water quality data for streams and watersheds. Models for Georgia include suspended sediment, carbon, phosphorus, and nitrogen.
Source: USGS SPARROW Project

f. Invasive Species Data. This provides a list of non-native aquatic species at the HUC 8 scale. Although this dataset is at a different scale than the HUC 10 used in this assessment, knowledge of invasive species could provide insight to potential threats to aquatic species identified in the SWAP.
Source: USGS Nonindigenous Aquatic Species Page

g. Risk of Flow Alteration (-): This dataset reflects the combined effects of water consumption, evapotranspiration, and impervious cover. Data can be viewed online in map viewer.
Source: Data Basin Webpage

h. Permitted Groundwater and Surface Water withdrawals (-): This data set would help estimate risk to streamflow from water withdrawals. One important caveat is that actual water use may not be well characterized from the number of permits in each watershed. Of these two withdrawal types, surface water withdrawal data would be more meaningful, as influence of groundwater withdrawals is much more variable depending on local geology. USGS conducts a national water census every 5 years, which might be a better way to assess threat of water use.
Source: EPD or USGS

i. Predicted Stream Temperatures: A data set that shows predicted stream temperature and precipitation changes associated with climate change at the stream reach scale. This would help understand potential impacts to species in high priority watersheds.
    Source: Unknown