Evaluating Fish Habitat in a South Carolina Watershed Using GIS

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Abstract: Fish habitat of the Edisto River Basin in South Carolina was evaluated using a geographic information system (GIS). A committee of fisheries biologists was formed to evaluate fish habitat within the Basin, and the GIS was used to compile and analyze data and generate maps to represent quality of fish habitat. United States Geological Survey (USGS) 1:24,000-scale digital line graph (DLG) hydrography data were assigned values for data on species composition, predesignated protected areas, riparian habitat, dams and impoundments, ditches and channelization, and water quality. Criteria were developed to evaluate fish habitat in the Basin. Each criteria was assigned a point value, and these values were totaled and subdivided into Value Classes 1, 2, and 3 representing high, moderate, and low quality fish habitat, respectively. Value Class 1 consisted of 92% of the main river reaches and the entire estuarine portion of the Basin. Value Class 2 included many tributaries of the northern upstream half of the Basin. The middle portion of the Basin contained most of the Value Class 3 reaches. Greater than 75% of the 11,000 km of Basin streams contained good fish habitat. Fish habitat was analyzed using a GIS over a larger area and with more comprehensive data sets than fisheries biologists traditionally use. Fisheries biologists could benefit from using GIS products in the prioritization of sampling efforts and in locating mitigation and restoration sites.

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The Edisto River Basin Project was designed as a state-of-the-art information management effort which involved citizens, businesses, and local government in the evaluation of basin resources and formulation of recommendations regarding future resource protection, management, and potential use (Hale et al. 1991). This project succeeded in demonstrating the benefits of cooperation between traditionally competing, isolated levels of government and the private sector (Natl. Acad. Sci. 1994). One goal of this project was to provide an interdisciplinary data base for more efficient and proactive decision making. This data base was stored and analyzed using a GIS. The GIS was used as a tool in the identification of potential conflict areas between economic development and management of natural resources. The Edisto River Basin Project serves as a model for other basins in the southeast to emulate this information management effort.

The Water Resources Division of the South Carolina Department of Natural Resources (SCDNR), funded by the U.S. National Oceanic and Atmospheric Administration, conducted the project in association with the South Carolina Department of Parks, Recreation and Tourism and the South Carolina Department of Commerce. Fifteen committees were organized to assess the natural, economic, and cultural resources of the nationally significant Edisto River Basin in South Carolina.

As part of the project, a fish habitat committee was organized to develop a methodology to assess the quality of fish habitat in the Edisto River Basin using GIS. The committee consisted of a private shrimper, a private fish dealer (retired federal hatchery manager), a University of South Carolina biological laboratory manager, 2 Westinghouse Savannah River Company freshwater fisheries biologists, a SCDNR freshwater fisheries biologist, 2 SCDNR marine fisheries biologists, 2 National Marine Fisheries Service biologists, a SCDNR environmental planner, and a SCDNR geographic information system design analyst.

The use of GIS provides access to a broader spatial data base than traditionally used for management purposes at the basin level (Brown et al. 1988, Brown et al. 1993). This data base consolidates separate levels of information often unavailable to fisheries biologists. Maps from the fish habitat evaluation are produced from results of the evaluation and data can be easily updated to analyze geographic trends. This evaluation is designed to serve as a prototype for fisheries management within other basins in the Southeast. Stream value assessments could be used to prioritize sampling efforts by locating gaps in data, mitigation sites, and habitat alteration problem areas (Angermeier and Bailey 1992, Angermeier et al. 1993, Brown et al. 1993, Scott et al. 1993). Future updates of data can be used to spatially represent and analyze conditions, trends, and predictions for species, communities, or water quality problems.

Methods

The Edisto River, one of the country's longest unimpounded blackwater rivers, is located in south-central South Carolina. This system drains 30 watersheds consisting of nearly 8,288 km^2 (S.C. Dep. Health and Environ. Control 1995). The river flows in a southeasterly direction for approximately 402 km from the headwaters in Edgefield County to the Atlantic Ocean. The Basin includes 4 sub-basins: the North Fork Edisto River, South Fork Edisto River, Four Hole Swamp, and Main Stem Edisto River.

The Basin transects 4 physiographic provinces which reflect variation in vegetation, geology, and topography including the Piedmont, Upper Coastal Plain, Middle Coastal Plain, and Lower Coastal Plain. The Edisto River and its tributaries meander across wetland, agricultural, and urban landscapes. The city of Orangeburg is the major urban area in a primarily rural basin (S.C. Water Resour. Comm. 1983). Land resource areas in the Basin include the Southern Piedmont, Carolina and Georgia Sandhills, Southern Coastal Plain, Atlantic Coast Flatwoods, and Tidewater Area. These resource areas are defined according to land use, climate, and soil conditions. The Edisto River flows over sand, loam, and clay sediments. Headwaters consist of narrow, canopied stream channels, but the river broadens and develops wide flood plains as it flows toward the coast. The Edisto River Basin provides habitat for 189 freshwater and saltwater fish species (Marcy and O'Brien-White 1995). These include important sportfish species such as redbreast sunfish (*Lepomis auritus*), striped bass (*Morone saxatilis*), and red drum (*Sciaenops ocellatus*). Shortnose sturgeon (*Acipenser brevirostrum*), a federally endangered species, is also located in the Edisto River Basin.

Criteria Development

The fish habitat committee began meeting monthly in January 1994 to develop a methodology for evaluating quality of fish habitat. First attempts evolved around individual species habitat preferences, habitat functions, and seasonal changes. It became apparent that data procurement involving microhabitat structure, spawning areas, migration corridors, and seasonal fluctuations would be too complicated to manage during the allotted time frame for all species at the basin level. General habitat characteristics were then addressed. After assessing the available data which could be utilized by the GIS (Table 1), work began on the classification of fish habitat quality in the Basin (Hale et al. 1991).

ARC/INFO, a GIS software package, was used to develop and analyze data bases. ARC/INFO is based on 3 major components: data base management, manipulation, and cartographic composition. More than 20 coverages were available to project committees. A coverage is spatial digital information of map features, such as streams, land use, roads, and political boundaries. Composites of these coverages can be spatially analyzed in a short period of time. USGS DLG hydrography (1:24,000 scale) data were used as the base map for the fish habitat committee. Selected data were attached to the hydrography coverage primarily by river reaches. A river reach is a section of a lotic system defined by the junction of an upstream and a downstream tributary. Some criteria required further division of river reaches into stream segments. Sectioning of stream segments was determined by abrupt physical changes in stream habitat or legal boundaries.

Available coverages included (1) domestic waste permits, (2) industrial waste permits, (3) hazardous waste sites, (4) mining and reclamation sites, (5) dams (reservoirs), (6) census data, (7) archaeological sites, (8) historic sites,

Table 1. Data sources used in a GIS fish habitat evaluation of the Edisto River Basin, South Carolina.

Coverage	Base map source	Map scale	Year
Digital line graph hydrography	U.S. Geological Survey (USGS)	1:24,000	varied
Basin boundaries	South Carolina Department of Natural Resources (SCDNR)	1:24,000	1992
Fisheries sampling locations	SCDNR	1:24,000	1991–1994
Protected areas (refuges, parks, and forests)	SCDNR	1:24,000	varied
Land use and land cover	SCDNR	1:24,000	1989
Wetlands	National Wetlands Inventory (NWI), U.S. Fish and Wildlife Service (USFWS)	1:24,000	1989
State Soil Geographic Data Base (STATSGO)	Natural Resources Conservation Service (NRCS)	1:24,000	1993
Water quality	South Carolina Department of Health and Environmental Control (SCDHEC)	1:100,000	1994

(9) threatened and endangered species sites, (10) heritage preserve sites, (11) timberlands, (12) mineral extraction locations, (13) fisheries sampling locations, (14) water quality, (15) water use, (16) rivers assessment, (17) shellfish grounds, (18) soils and State Soil Geographic Data Base (STATSGO), (19) National Wetlands Inventory (NWI), (20) land use (Anderson Level II), (21) hydrography DLGs, (22) transportation DLGs, (23) political boundaries and protected areas DLGs, (24) natural areas inventory, (25) boat ramps, and (26) navigable waters. After careful consideration by the fish habitat committee, many of these coverages were deemed not applicable to the evaluation.

Seven coverages were selected by the committee to serve as the basis for criteria development as follows: predesignated protected areas, freshwater and saltwater fish sampling efforts, water quality, riparian habitat, land use/land cover, impoundments, and ditches. Predesignated protected areas, such as state parks, were chosen for their protection status. Fish sampling data portrayed observed fish species composition at specific locations within the Basin. Water quality data summarized as the aquatic life use support were designated by the South Carolina Department of Health and Environmental Control (SCDHEC 1995). A riparian zone was addressed to determine potential flood plain habitat on the basis of land use activities and land cover. Impoundments, impairing native migratory fish populations, were identified on the hydrography coverage. Unimpounded streams from the main river upstream to the first order were considered essential to the aquatic system. Ditches and channelized reaches were located and regarded as a severe threat to fisheries habitat by draining wetlands, increasing water flow, and contributing to runoff.

The 7 coverages were compiled and assigned point scores. The fish habitat committee considered data quality and coverage importance to quantify the point scores. The scores were summed as the composite for each segment within a river reach and assigned to a value class (Table 2). Value Class 1 streams were those most habitable to fish, including predesignated protected areas. Value Class 2 streams contained minimal impacts, but were considered good fish habitat. Value Class 3 streams were those that had been altered and therefore caused potential fish habitat problems. Analyses began on prototype areas in the middle of the Basin, as well as the coast in November 1994 to test the capability of the system, criteria, and scoring methods.

Predesignated protected areas consisted of state or federal parks, refuges, or forests. Shellfish harvesting grounds and outstanding resource water (ORW), as designated by SCDHEC, also were considered protected areas. Stream segments that fell within the boundaries of predesignated protected areas were automatically assigned to Value Class 1.

Fish species composition was based on sampling collections from 1959 to 1994. Data were available on freshwater fish species composition from a statewide stream survey of all streams ≥4.8 km (SCDNR unpubl. data, Bulak 1991) and a main river channel survey (Thomason et al. 1993). Saltwater species composition data were compiled from trammel net, trawl, gill net, and larval fish surveys (Bearden 1961; Wenner et al. 1990, 1991; SCDNR, unpubl. data). Members of the committee evaluated sampling efforts conducted in the Basin for community composition. Levels of quality for the species composition were based on community structure and trophic diversity for the stream size and geographic location. High quality reaches were comprised of expected indigenous, pollution intolerant, or federally threatened or endangered species. Medium quality reaches contained exotics or were missing primary indigenous species. Low quality reaches were severely depleted of indigenous species or dominated by pollution tolerant species.

Stream survey sites were extrapolated to include the tributary system from

Table 2. Criteria and point scores used in a GIS fish habitat evaluation of the Edisto River Basin, South Carolina. A score of 8–11 or predesignated protected areas became Value Class 1, a score of 4–7 became Value Class 2, and a score of <4 became Value Class 3.

Point score	Species composition	Water quality	Riparian habitat	Dams	Ditches
3			>75% natural	Unimpounded	
2	High quality				Absent
1		Good	50–75% natural		
0	Medium quality			Reach below	
−1		Poor		Upstream from impoundment	
−2			<50% natural		
−3	Low quality				Present

which a sample was collected. River survey sites were extrapolated to include the main stem of each sub-basin. Reaches with high quality species composition received 2 points, medium quality species composition received 0 points, and a score of −3 was given to reaches with low quality species composition. High quality species composition received only 2 points due to extrapolation of data beyond the sample reach and lack of repetitive sampling.

Water quality data were collected and extrapolated from monitoring stations by SCDHEC (1995) into 4 classifications describing aquatic life use support as follows: fully supporting, fully supporting with trends, partially supporting, and not supporting. The fish habitat committee designated the first 2 classifications as good water quality with a point score of 1. The classifications of partially supporting and not supporting were combined as poor water quality with a point score of −1. The SCDHEC water quality data was collected to fulfill requirements of the Clean Water Act and not specifically for fish habitat requirements. The committee decided to lessen the impact of this coverage data in the evaluation and therefore the point range was minimal.

The riparian habitat criteria was formed by the combination of a riparian zone and a buffered area. The riparian zone was delineated from Natural Resources Conservation Service soils and USGS hydrography coverages. Categories of frequently flooded, occasionally flooded, or rarely flooded soils were selected from STATSGO (U.S. Dep. Agric. 1993). An arbitrary 30-m buffer was generated around these soils and all streams to include an area adjacent to the riparian zone.

The riparian habitat area was assessed for fish habitat using land use and land cover data from the NWI with additional delineated uplands. Wetland and upland data were delineated from 1989 National Aerial Photography Program (NAPP) at a 1:40,000 scale. The United States Fish and Wildlife Service Cowardin classification system was used to categorize the wetlands (Cowardin et al. 1979). The USGS Anderson Level II system was used for the upland classifications (Anderson et al. 1976). Land use/land cover data were collapsed into 2 categories. These were natural and unnatural riparian habitat. Natural habitat consisted of beaches, non-beach sandy areas, unconsolidated shores, deciduous forest, evergreen forest, mixed forest, palustrine, marine, riverine, estuarine, and lacustrine land uses. Unnatural riparian habitat consisted of residential, commercial, industrial, urban, mining, transitional, agricultural, rangeland, and planted pine areas. The riparian habitat areas within each of the 30 watersheds in the Basin were analyzed separately. A score of 3 was assigned to reaches within watersheds containing >75% natural habitat. Watersheds containing 50%–75% natural habitat received 1 point. A score of −2 was given to watersheds which had <50% natural habitat. Riparian habitat was assigned on the basis of the land use activities with each watershed evaluated separately.

Impoundments were identified manually on the hydrography coverage. While fish habitat upstream from impoundments may be of high quality to many species, these segments and reaches were assigned a score of −1 for presenting an obstruction to some species and changing natural stream morphology. The stream segment below an impoundment to the downstream confluence was assumed to be physically and chemically altered and therefore was given 0 points. A score of 3 was attached to unimpounded reaches from the main river.

The 1989 NAPP photography was used to identify ditches and/or channels. An attribute designating ditches or channels was attached to the hydrography coverage by stream segments. Segments with no ditches were given a score of 2. A score of −3 was attached to segments that had been altered by ditching or channelization.

Value classes were assigned to stream segments and reaches after all points had been calculated. Totaled points ranged from 8 to 11 for Value Class 1. Value Class 2 was composed of totaled points that ranged from 4 to 7. Totaled points <3 became Value Class 3. Predesignated protected areas were assigned to Value Class 1 regardless of the final total points; however, it was recognized that these areas may not represent the best fish habitat.

Results

Predesignated areas were located in 3 of the 4 sub-basins. The North Fork Edisto River Sub-Basin contained no predesignated protected areas. Aiken State Park was located within the South Fork Edisto River Sub-Basin. Four Hole Swamp Sub-Basin contained the Francis Beidler Forest owned by the National Audubon Society. Colleton State Park, Givhans Ferry State Park, Ashepoo-Combahee-Edisto (ACE) Basin Project area, ACE Basin National Wildlife Refuge, National Estuarine Research Reserve Core, Edisto Beach State Park, and shellfish harvesting grounds and ORW were located within the Main Stem Edisto River Sub-Basin.

Species composition in the freshwater portion of the Basin ranked primarily high quality. Seven tributaries systems were designated as medium quality species composition and 1 as low quality species composition. Four Hole Swamp Sub-Basin was comprised of only high quality species composition. The low quality tributary system was located within the Main Stem Edisto River Sub-Basin.

Water quality was predominantly good within the freshwater portion of the Basin; however, 2 watersheds and 1 tributary system of poor water quality were located within the North Fork Edisto River Sub-Basin. One watershed in the Main Stem Edisto River Sub-Basin and 1 tributary system in the Four Hole Swamp Sub-Basin also rated as poor water quality. The South Fork Edisto River Sub-Basin contained only good water quality watersheds.

Riparian habitat that consisted of >75% natural land use dominated 11 of the 30 watersheds in the Edisto River Basin. The other 19 watersheds were composed of 50%–75% natural riparian habitat. No watersheds contained <50% natural riparian habitat. In general, the riparian habitat in the Basin appeared to be in good condition.

The main river channels of all sub-basins were unimpounded. Tributaries of the Edisto River were heavily impounded. Most tributaries within the North and South Fork Edisto River Sub-Basins were impounded directly upstream of the main channel. Very few first-order streams remained unimpounded to the Edisto River. These unimpounded first-order streams were located predominantly within the Four Hole Swamp and Main Stem Edisto River Sub-Basins.

Tributaries in the Four Hole Swamp Sub-Basin and the upper portion of the Main Stem Edisto River Sub-Basin were heavily ditched and/or channeled. The primary land use in these regions was agriculture and pine plantations. The North and South Fork Edisto River Sub-Basins had minimal ditching.

The final map (Fig. 1) showed Value Class 1 covering approximately 47% of the rivers and streams in the entire Basin (Table 3). Main river channels

Figure 1. Value Class 1 streams in the Edisto River Basin, South Carolina. See Table 2 for explanation of Value Class 1.

Table 3. Value Class figures used in a GIS fish habitat evaluation of the Edisto River Basin and Sub-Basins, South Carolina

Mapping unit and Value Class	Length (km)	Value Class composition
	Edisto River Basin	
Value Class 1	5,204.9	47%
Value Class 2	3,497.0	31%
Value Class 3	2,392.9	22%
	North Fork Edisto River Sub-Basin	
Value Class 1	321.9	15%
Value Class 2	1,205.9	58%
Value Class 3	557.1	27%
	South Fork Edisto River Sub-Basin	
Value Class 1	728.3	27%
Value Class 2	1,625.7	61%
Value Class 3	323.0	12%
	Four Hole Swamp Sub-Basin	
Value Class 1	1,004.2	42%
Value Class 2	479.1	20%
Value Class 3	920.1	38%
	Main Stem Edisto River Sub-Basin	
Value Class 1	3,150.4	80%
Value Class 2	186.1	5%
Value Class 3	592.5	15%

within the Basin were 92% Value Class 1. Main river channels were unimpounded, had high quality species composition, and lacked ditching. The estuarine portion of the Basin was 100% Value Class 1. The remaining Value Class 1 reaches were a composite of primarily unimpounded streams with >75% natural riparian habitat, good water quality, high quality species composition, and predesignated protected areas.

Reaches in the estuary were assigned to Value Class 1 due to the status of predesignated protected areas. They were ORW and shellfish harvesting grounds according to SCDHEC standards. Most reaches in the estuary were of high quality species composition with few site-specific reaches of medium quality or low quality composition. Water quality of the estuary was rated good due to tidal influence. The estuary contained >75% natural riparian habitat. Dams and ditches were not considered a problem due to the tidal influence.

Value Class 2 comprised approximately 31% of the Basin (Fig. 2). The North Fork Edisto River Sub-Basin contained the only stretches of Value Class 2 main river channels (8%) in the Basin. Greater than 50% of the North and South Fork Edisto River Sub-Basins were Value Class 2. These reaches scored lower primarily as a result of "50%–75% natural" riparian habitat and their location upstream from impoundments.

Value Class 3 comprised 22% of the Basin (Fig. 3). The largest expanse of

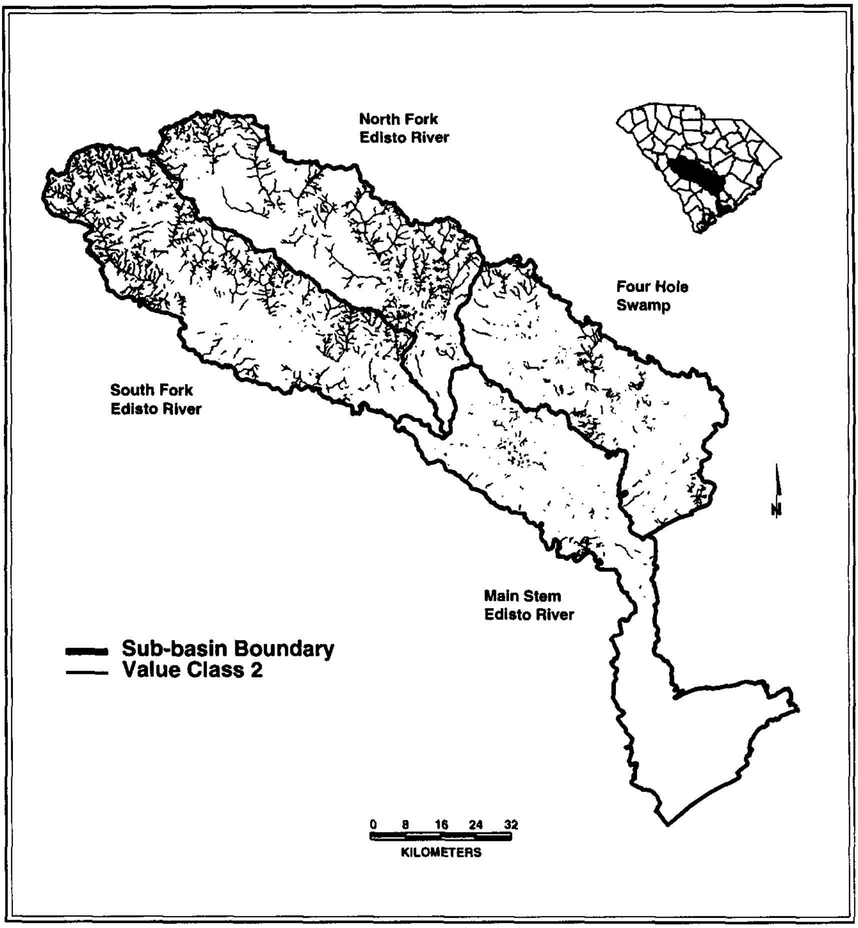

Figure 2. Value Class 2 streams in the Edisto River Basin, South Carolina. See Table 2 for explanation of Value Class 2.

Value Class 3 fell in the upper portions of Four Hole Swamp Sub-Basin and the Main Stem Edisto River Sub-Basin. Value Class 3 tributaries in these 2 sub-basins scored lower due to extensive ditching and 50%–75% natural riparian habitat. In addition, 27% of the North Fork Edisto River Sub-Basin tributaries were Value Class 3. These North Fork reaches contain 50%–75% natural riparian habitat, medium quality species composition or poor water quality, and are located upstream from impoundments.

Discussion

Results of the evaluation indicate the Edisto River Basin contained >75% of Value Class 1 and 2, where habitat alterations and impacts on fish communi-

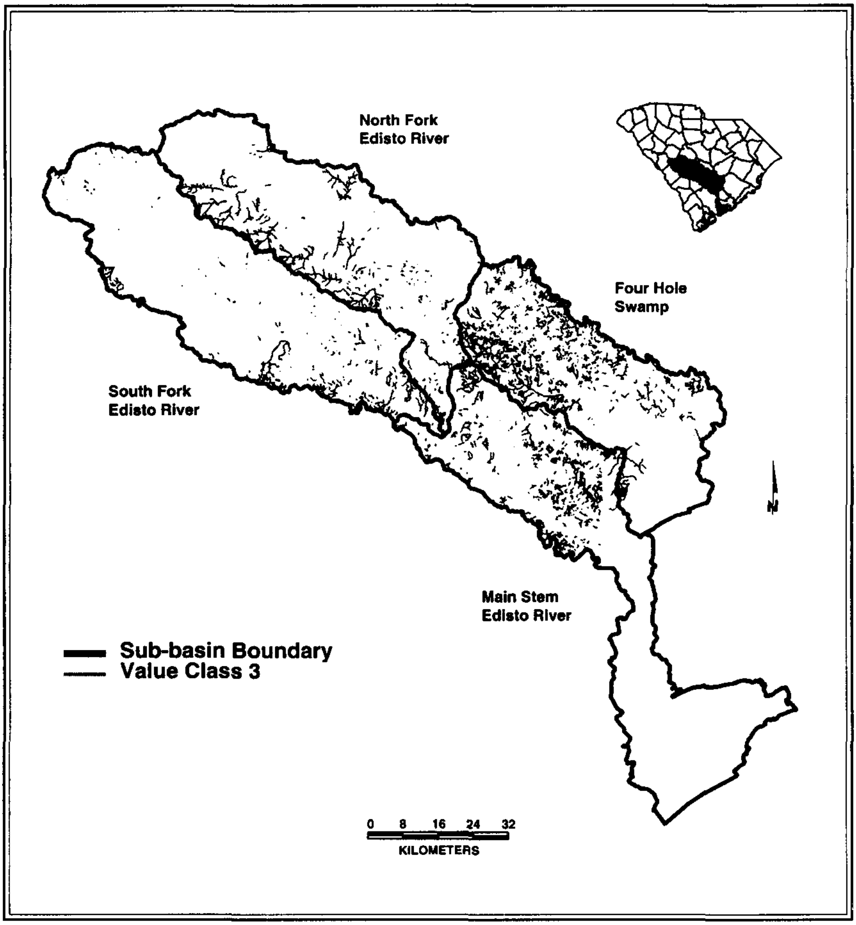

Figure 3. Value Class 3 streams in the Edisto River Basin, South Carolina. See Table 2 for explanation of Value Class 3.

ties were minimal (Table 3). The highest quality fish habitat was located in the unimpounded main river reaches and the estuary. Many tributaries in the upper half of the Basin also contained good fish habitat; however, impoundments prevented upstream movement of fish from inhabiting and spawning in these reaches. In addition, impoundments altered water conditions, which resulted in changes to indigenous fish communities. The majority of Value Class 3 tributaries in the middle portion of the Basin were altered and may cause potential problems for indigenous species due to the predominance of agricultural ditches.

In addition to the fish habitat evaluation, the committee developed recommendations on the basis of the mapped results. Tributaries of medium and low quality species composition need further investigation to determine the source of these lower rankings. Value Class 3 defined streams with problems that should have additional fish data collected to determine if the species composition is jeopardized. While portions of the North Fork Edisto River were Value Class 2, the results demonstrate that water quality and riparian habitat point score improvements to these reaches would result in their reclassification to Value Class 1.

The Edisto River Basin is currently less developed than most other basins in South Carolina. Watersheds containing the best riparian habitats should be maintained. It is realized that the land use data used in the evaluation is dated (1989), therefore, critical riparian habitat should be further investigated by ground truthing. Altered riparian habitat should be restored through public education and the use of best management practices, where possible.

First-order streams are a critical component of the aquatic system. They should remain free-flowing to the Edisto River and must be protected from impoundments. First encountered impoundments from the Edisto River should be evaluated to determine if the dams may be removed or fish ladders installed.

The committee was able to develop a methodology to analyze fish habitat quality with available spatial data. They felt confident with the results of the evaluation; however, they realized that more extensive fish species composition and water quality data would greatly increase the validity of the evaluation. Additional data requirements became apparent during the course of the criteria development. These were identified as repetitive fisheries sampling, systematic water quality collection, contours, and slope. Future data should be collected to reduce the amount of extrapolation required for GIS analysis. Long-term records of fish data would enable the results of this evaluation to be used to its full potential. Water quality data should be collected after storm events, more frequently, in additional locations, and with all fish sampling. Contour and slope data would help further identify riparian zones. Data should be collected at standard scales and in complementary formats.

Maps of fish habitat quality are only a prediction for fisheries habitat management and may not accurately reflect fish microhabitat. Base maps at a scale of 1:24,000 are the most detailed for basin-level evaluations and are widely available. However, base map source years vary and data must be matched to account for changes in stream channel location. GIS applications and modeling are coarse-filter approaches to ecological evaluations, therefore, the need for on-the-ground fish managers should never be diminished (Scott et al. 1993). As technology and cooperation between state and federal agencies increases, the use of GIS should become more widespread, cost effective, and accurate.

GIS can be used successfully to spatially model and identify management needs for fisheries habitat. This GIS evaluation addresses fish habitat with broader data sets over a larger area than traditionally used by fisheries biologists. Complex spatial and mathematical manipulation, computing speed, query ability, and ease of updating are benefits gained from using a GIS in such an analysis. Scott et al. (1993) developed Gap Analysis, an application for GIS locating gaps in the protection of biodiversity. The technique of Gap Analysis could be used on aquatic systems such as the Edisto River. Fisheries biologists using a GIS to evaluate fish habitat have an advantage over traditional approaches by combining additional data components from many sources to fisheries sampling data. By gaining a comprehensive depiction of factors influencing the fish resources, fisheries biologists could use the GIS data to visualize locations and clusters of habitat characteristics. The use of GIS products will assist on-the-ground fishery biologists in prioritization of sampling efforts and in locating mitigation and restoration sites.

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