Using GIS and a Multi-Criteria Decision Tool to Identify and Prioritize Freshwater Resources for Management Actions

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Abstract: Florida freshwater habitats provide many essential functions including flood control and nutrient sequestration. While serving as habitat for many fish and wildlife species, wetlands also contribute significantly to the outdoor recreation industry. Despite these services, aquatic habitats continue to face threats, such as urban encroachment, water withdrawals, water-level stabilization, sedimentation, non-native species introduction, cultural eutrophication, and climate change. With Florida's increasing human population, encroachment and development continues into natural areas, stressing aquatic habitats and the fish and wildlife that depend on healthy wetlands. This paper summarizes a GIS process for identifying publicly accessible freshwater resources and presents a multi-criteria decision analysis tool for prioritizing those resources to guide management considerations. Publicly accessible lakes, streams, and freshwater forested and non-forested wetlands were identified, mapped, and quantified based on a suite of parameters representing their socioeconomic value, fish and wildlife value, and management emphasis (i.e., the need and opportunity for habitat restoration). We used a simple additive approach rather than a weighted overlay approach because no one parameter was deemed more important than another. Results prioritized 1235 sub-watersheds, 1835 conservation areas containing forested and/or non-forested wetlands, and 324 lakes ≥20.2 ha. Freshwater resources identified as high priority tended to have high values for most or all parameters measuring socioeconomic values, with more variation in values for parameters measuring value to fish and wildlife and management emphasis. Prior to development of this prioritization tool, selection of aquatic resources for enhancement and restoration projects was very subjective. This prioritization provides a quantitative, science-based decision framework to reduce that subjectivity and maintain the continuity of the prioritization and selection process. Further, the tool accounts for regional variations in aquatic resources and allows effective allocation of resources to provide the greatest sociological and ecological benefits resulting from restoration, enhancement, and management activities.

Key words: restoration, natural resources, GIS, wetlands, lakes, rivers

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Freshwater aquatic resources are among the most dynamic and ecologically unique habitats in Florida. Wetlands serve as a critical interface between terrestrial habitats and many of the state's lakes and rivers; further, wetlands intercept runoff and serve as natural water treatment facilities for the assimilation of nutrients and the entrapment of heavy metals and other toxins (Kautz et al. 1998). Freshwater habitats provide nesting, foraging, wintering, and migrating habitat for many avian species as well as spawning grounds, nurseries, and food resources for fish, amphibians, and invertebrates. Many freshwater habitats nationwide are identified as critical habitat under the provisions of the Endangered Species Act due to the fact that 26% of listed plants and 45% of listed animals rely on these resources for survival (Niering 1988, Hammer 1992, Flynn 1996). Wetlands, along with streams and lakes, contribute significantly to Florida's US$38.3 billion outdoor recreation industry (Outdoor Industry Association 2011) by providing opportunities for camping, hunting, boating/paddling, fishing, birding, and photography. Accordingly, these activities support over 329,000 jobs and contribute $2.5 billion through state and local taxes.

Since 1845, when Florida became the 27th state, approximately 45% (3.6 million ha) of Florida's wetlands, streams, and lakes have been converted, altered, or destroyed, the largest total area of any state (Estevez et al. 1984, Dahl 2005). The majority of the net losses (72%) are attributed to urban and rural development, with the remaining 28% from agricultural activities (Dahl 2005). Many of the remaining aquatic resources have been impacted by changes in hydrology, including canals cut to facilitate drainage and navigation, engineering works to hold back floodwaters, untreated waste discharge, and fragmentation of systems leading to disconnected floodplains. Furthermore, water-management activities have reduced the surface area of lakes, and water-level regulation schedules prevent natural fluctuations that otherwise maintain the health of these ecosystems (Kautz et al. 1998).

As of 2010, wetlands covered approximately 31% of Florida, a greater percentage of the land surface than any other state in the conterminous United States (Dahl 2005, USDA 2015). Significant threats to these wetlands, as well as to freshwater lakes and streams, include human population growth, water withdrawals, water-level stabilization in natural lakes, sedimentation, non-native species introduction and expansion, cultural eutrophication, and climate change (Purdum 2002). Florida's burgeoning population exceeded 20.2 million in 2015 (U.S. Census Bureau 2015) and is expected to increase 22% to 24.6 million by 2030 (University of Florida-Bureau of Economic and Business Research 2015). Conserving, protecting, and restoring natural systems, while ensuring an adequate water supply for human uses, remains one of Florida's greatest challenges (Purdum 2002).

Various restoration projects have been implemented to address freshwater degradation, and natural resource managers face the task of identifying suitable sites for restoration projects. Many restoration projects show poor cost to benefit ratios due to inadequate planning, improper placement or a failure to incorporate the values of local citizens (Roni 2005). A restoration priority system that can be implemented across broad scales is needed to maximize ecological, sociological and fish and wildlife benefits while minimizing restoration costs (Darwiche-Criado et al. 2017, Lovette et al. 2018). In 2009, the Florida Fish and Wildlife Conservation Commission (FWC) began utilizing a lake prioritization decision support tool known as the Aquatic Restoration Prioritization and Evaluation Tool (ARPET). The ARPET synthesizes existing socio-economic, ecological, and environmental data in a GIS platform for the purposes of identifying and prioritizing public lakes for potential restoration and represents an expedient and cost-effective decision framework for aquatic habitat restoration (FWC 2012a). The effectiveness of the ARPET has demonstrated the need to expand the tool to include streams, freshwater forested wetlands, and freshwater non-forested wetlands. Starting in 2015, the FWC began to synthesize existing socio-economic, ecological, and environmental data relevant to streams, freshwater forested wetlands, and freshwater non-forested wetlands in a GIS platform, with the objective of applying a uniform method of identifying and prioritizing public aquatic resource sites for restoration across Florida. This resulted in Florida's Freshwater Priority Resources: A Guide for Future Management (FFPR), a tool intended to provide an expedient and cost-effective decision framework for aquatic habitat restoration, as well as removing the subjectivity of individual bias from the process of selecting aquatic resources for restoration. The tool provides priority rankings for each of four types of freshwater aquatic resources, independent of the others, for each of the five Florida Fish and Wildlife management regions. In other words, freshwater forested wetlands are prioritized independently of freshwater non-forested wetlands, lakes and streams. Here we present the methodology behind the tool and a representative set of results to demonstrate the use of the tool for the purpose of restoration prioritization planning.

Methods

All geospatial analyses were conducted in ArcGIS 10.3.3. Data sources for the GIS data layers used in the analysis can be found in Table 1. Additionally, a more detailed description of data sources and methodology used in the GIS analysis can be found in the FFPR (FWC 2017) and in the ARPET descriptions (FWC 2012a).

Identification of Publicly Accessible Freshwater Resources

The focus of the FFPR was on publicly accessible resources because statutory authorization and funding language restricted state expenditures of funding dollars to habitat restoration and enhancement projects in freshwater habitats that are public held resources. Florida's freshwater aquatic habitat types were grouped into four major categories: 1) rivers and streams, 2) freshwater non-forested wetlands, 3) freshwater forested wetlands, and 4) lakes. Lake data were obtained directly from the ARPET (FWC 2012a), with minor revisions (the final values for lakes were ranked by region rather than by the entire state). Although lakes were prioritized in the ARPET, results were included in the FFPR to avoid users having to seek out two separate tools. The variables considered for streams, lakes and wetlands addressed similar concerns, but differed in order to accommodate difference among habitat types (Table 2).

The process of prioritizing the four major aquatic habitat types began by partitioning out publicly owned lands from those held in private ownership. Lakes were determined to be publicly accessible if they could be reached from a public boat ramp. Due to the large number of lakes resulting from this step (32,000), only lakes greater than 20.2 ha were included in the analysis. Stream reaches from the National Hydrography Dataset (NHD) were considered public if they were reachable from any public freshwater boat ramp. To reduce the number of stream reaches included the analyses, these resources were consolidated by sub-watershed (NHD Hydrologic Unit Code 12) boundaries. Sub-watersheds, which ranged in size from 4047 to 16,187 ha, provided the best available resolution of

Table 1. Data sources used during the creation of the parameters used to prioritize publicly accessible streams, freshwater wetlands and lakes in Florida. FDEP = Florida Department of Environmental Protection.

Category	Data	Source	Agency
Units	Conservation areas	Florida Natural Areas Inventory (FNAI). Florida Conservation Lands, March 2016 http://www.fnai.org/gisdata.cfm	FNAI
	HUC-12 (sub-watersheds)	National Hydrography Dataset 1:100,000 resolution, August 2016 https://nhd.usgs.gov/	USGS
	Streams	National Hydrography Dataset https://nhd.usgs.gov/	USGS
	Wetland areas	Florida Cooperative Land Cover Map (CLC) http://myfwc.com/research/gis/applications/articles/Cooperative-Land-Cover	FWC, FNAI
	Lakes	Florida National Hydrography Dataset (2010)	FDEP
Socioeconomic importance	Boat ramps	FWC Florida Boat Ramp Inventory http://geodata.myfwc.com/datasets/fwc-florida-boat-ramp-inventory	FWC
	Recreational trails	Florida Greenways and Trails System—Existing Trails http://geodata.dep.state.fl.us/datasets/florida-greenways-and-trails-system-existing-trails	FDEP
	Population	2010 U.S. Census Blocks in Florida https://www.census.gov/geo/maps-data/	U.S. Census Bureau
	Hunting areas	Hunting Areas in Florida, 2015–2016 Contact FWC data librarian: GISLibrarian@MyFWC.com	FWC
	Great Florida Birding Trail	Great Florida Birding and Wildlife Trail FWC, Office of Public Access and Wildlife Viewing Services	FWC
Fish and wildlife populations	Stream size	Stream Size (Strahler Order) http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php	USGS
	Avian focal areas	Avian Focal Areas (North American Bird Conservation Joint Ventures http://acjv.org/	USFWS
	Species occurrences	2017 freshwater obligate Threatened, Endangered and Species of Greatest Conservation Need Multiple species occurrence layers Contact FWC data librarian: GISLibrarian@MyFWC.com	FNAI, FWC, USGS
	Invasive plants	NAS—Nonindigeneous Aquatic Species https://nas.er.usgs.gov/ iMapInvasives http://www.fnai.org/invasivespecies.cfm	USGS, FNAI
Management emphasis	Roads	TIGER Roads 2015 https://www.census.gov/geo/maps-data/data/tiger-line.html Florida Department of Transportation (FDOT) "surface width" data and "number of lanes" data, August 2016 http://www.fdot.gov/statistics/gis/	U.S. Census Bureau, FDOT
	Impaired waterbodies	Verified Impaired Waterbodies, Run 49, DEP—October 2014 http://geodata.dep.state.fl.us/	FDEP

priority stream locations. The ARPET used the Florida National Hydrography Dataset to determine the geographical location of lakes (Table 1).

Freshwater non-forested and forested wetlands were mapped by aggregating the appropriate sub-classes for each habitat type from the 10-m resolution Cooperative Land Cover Map and clipping them to boundaries of conservation lands (Table 1). More than 2500 federal, state, local, and private managed conservation areas exist in Florida, and properties considered conservation land must have a significant portion of undeveloped property and retain most of the attributes expected in a natural condition. In addition, the managing agency or organization must demonstrate a formal commitment to the conservation of the land in its natural condition (Florida Natural Areas Inventory 2016). Henceforth, the term conservation area refers to a managed area containing freshwater forested and/or non-forested wetlands.

Collectively, this information was used to create four new "base" geospatial data layers, one for each of the four publicly owned/accessible aquatic habitat types. In other words, sub-watersheds were used to prioritize stream reaches based on the characteristics of the stream reaches within an individual sub-watershed; conservation areas were prioritized based on the characteristics of the freshwater forested and non-forested wetlands occurring within their boundaries; lakes were prioritized as individual units (Figure 1).

Table 2. Summary of variables used to prioritize publicly accessible streams, freshwater wetlands and lakes in Florida.

Category	Resource type	Variable
Socioeconomic	Streams, wetlands and lakes	Accessibility
	Streams, wetlands and lakes	Recreational trail length
	Streams, wetlands and lakes	Great Florida birding trail sites
	Streams, wetlands and lakes	Population within 80.5 km
	Streams and wetlands	Hunting and fishing opportunities
	Lakes	Fish management areas
	Lakes	FWC permitted bass tournaments
	Lakes	Alligator egg collection areas
Fish and wildlife	Streams, wetlands and lakes	Threatened, endangered, and species of greatest conservation need
	Streams, wetlands and lakes	Avian focus areas
	Streams, wetlands and lakes	Size
	Wetlands	Conservation area size
	Lakes	Division of freshwater fisheries management prioritized lakes
	Lakes	Snail kite priority nesting areas
	Lakes	Wetland connectivity
	Lakes	Alligator management units
Management emphasis	Streams and wetlands	Impaired waters
	Streams and wetlands	Road density
	Streams and wetlands	Invasive aquatic plants
	Streams and wetlands	Land use\landcover within a buffer
	Lakes	Outstanding Florida waters
	Lakes	Conservation lands
	Lakes	Trophic state index
	Lakes	Managed water control structures
	Lakes	Aquatic habitat restoration/enhancement subsection funded projects
	Lakes	Invasive plant management funded projects
	Lakes	Water quality restoration

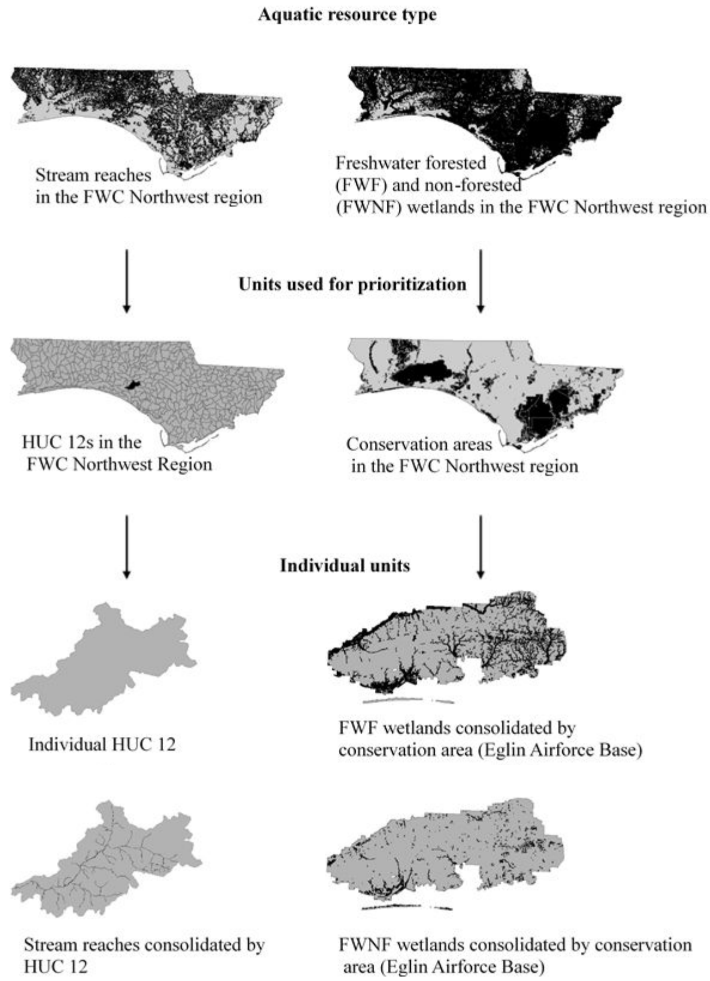

Figure 1. An example of how aquatic resources were consolidated by sub-watersheds (for streams) or conservation area (freshwater forested and non-forested wetlands).

Resource Valuation

Parameters (i.e., data layers; Table 2) quantifying physical and biological data relevant to socioeconomic value, fish and wildlife value, and management emphasis were developed at a statewide level and an iterative, analytical process was then used to overlay these parameters on top of the four base layers to evaluate their presence (or absence) and importance to the resource.

Socioeconomic Importance Analysis.—We selected variables for the socioeconomic category to measure the outdoor recreational opportunities offered by each freshwater aquatic resource: accessibility, recreational trails, population within a 50-mile radius, fishing and hunting opportunities, and presence or absence of Great Florida Birding Trail sites (Table 2).

Accessibility for streams was measured by Euclidian (straight line) distance to a public boat ramp (either on the stream or from a lake connected to the stream) (Table 1), with a shorter distance resulting in a higher value. This was done to account for sections of stream that flowed through privately held lands. For forested and non-forested wetlands, accessibility was assessed by the number of unique roads (Table 1) occurring in the conservation area, based on the idea that a higher number of roads equals a higher number of entry points, and therefore greater accessibility. Conservation areas with a higher number of roads had higher values.

Recreational trails included public paved or unpaved trails intended for hiking, biking, equestrian, multiple use, paddling, or motorized vehicle use (Table 1). Values for trail length were calculated by summing the length of recreational trails within a 1.6-km buffer surrounding streams and conservation areas. Therefore, greater length of trails resulted in higher values. Human population values were calculated based on the March 2010 census blocks (Table 1) that fell within 80.5-km buffers around sub-watersheds and conservation areas, so higher populations resulted in higher values.

Fishing and hunting opportunities were determined for each sub-watershed and conservation area with values ranging from zero (no fishing or hunting opportunities) to two (opportunities for both hunting and fishing). Fishing was presumed to occur in all publicly-accessible streams (i.e., all streams occurring in this prioritization). Therefore, all streams were considered to have fishing opportunities. Any conservation area containing a publicly accessible stream was also considered to have fishing opportunities. Additionally, conservation areas that did not contain streams were manually inspected in Google Earth for the presence of fishing piers and an internet search was performed to check for fishing opportunities. Any conservation area or sub-watershed containing a stream intersecting the 2015–2016 "Hunting Areas in Florida" layer (Table 1) was considered to have hunting opportunities.

The Great Florida Birding and Wildlife Trail is a statewide network of 515 sites spread throughout the state over a 3218-km trail, created to develop wildlife viewing opportunities and encourage local communities to utilize their natural resources to stimulate the local economy (FWC 2012a). Value was based on presence (one) or absence (zero) of the trail within the conservation area or sub-watershed.

Fish and Wildlife Importance Analysis.—The variables included in the fish and wildlife category measure the ecological significance of each aquatic resource. These variables include: conservation area size (for freshwater forested and non-forested wetlands only), stream/wetland size, presence of species (threatened, endangered, and species of greatest conservation need (SGCNs), and avian focal areas (Table 2). Conservation area size values were calculated in GIS, with freshwater forested and non-forested wetlands within a conservation area receiving individual values. In general, larger size enhances habitat stability, increases the number of species that can potentially use the site, and increases potential for habitat complexity (FWC 2012b).

Strahler order, the hierarchy of streams from the source (or headwaters) downstream (Strahler 1957), is often used as a surrogate for stream size and is arguably a fundamental determinant of lotic ecosystem structure and function (Vannote et al. 1980, Hughes et al. 2010). Publicly accessible streams were assigned Strahler Order based on the NHD Plus (Table 1); however, the NHD Plus is at a lower resolution than the NHD, meaning that many smaller streams are not delineated. Therefore, any streams not included in the NHD Plus were assumed to have a Strahler Order of 1. Values were calculated by multiplying the length of each stream reach by its Strahler Order, and summing the weighted lengths by sub-watershed.

Avian focus areas (AFA) within Florida were digitized from georectified maps provided by the North American Bird Conservation Joint Ventures for wading birds, waterfowl, shorebirds, seabirds, and land-birds. Values were determined by summing the number of AFAs occurring at least partially within each conservation area or sub-watershed, such that units containing a higher number of AFAs received a higher value.

Species occurrence data for state threatened and endangered species as well as SGCNs, were obtained from a variety of sources (see FWC 2017 for a complete list). Each species was assigned a value of 1 for presence, or 0 for absence, and the values for all species found within a 1-km buffer around forested wetlands and non-forested wetlands (assessed individually for this variable) or publicly-accessible stream were summed, thus conservation areas or sub-watersheds with the highest number of species had the highest values.

Management Emphasis Analysis.—We selected variables in the management emphasis category to measure the need and opportunity for aquatic habitat restoration, including impaired waters, weighted roads density, invasive aquatic plants, and land use/landcover within a riparian/freshwater buffer (Table 2). An impaired waters layer representing impairment parameters grouped as nutrients, conductivity, turbidity, pesticides/dioxin, un-ionized NH_3, bacteria, metals, biological oxygen demand/dissolved oxygen, and coliforms (Table 1) was intersected with each of the aquatic resource data layers. Values were calculated by summing the percentages of each resource type contaminated by each of the nine parameters for each sub-watershed or conservation area for a maximum total of 900%. Thus, higher percentages of contaminated areas resulted in higher values. Road density values were calculated by weighting road length within 1.6 km of streams/conservation areas by number of lanes (Table 1) and dividing this number by the area of the sub-watershed or conservation area. Therefore, higher weighted road densities received higher values.

The coordinates of category I invasive aquatic plants (Florida Exotic Pest Plant Council's 2017 List of Invasive Plant Species) were obtained from the USGS Nonindigenous Aquatic Species Program and from the Florida iMapInvasives, an online mapping tool for invasive species (iMapinvasives 2017) (Table 1). Data were included from the past 25 years (1991 through 2016) with the rationale that, if the plant was present in the past, then the possibility existed that the plant could re-colonize the same area. Each sub-watershed and conservation area was assigned values based on the number of invasive species present.

Values for human-altered uses types (excluding agriculture) within riparian buffer zones were calculated by buffering streams and freshwater forested and non-forested areas by 90 m and then intersecting the buffers with the Cooperative Land Cover v3.2 to determine the percentage of human-altered uses types within the buffer zones. Resource areas containing a higher percent of altered land uses therefore received a higher value.

Final Ranking

After creating the individual prioritization parameters, values for each parameter were normalized to fall between 0 and 1 for all sub-watersheds and conservation areas (Ouyang et. al. 2011). This same process was applied for lakes using the ARPET data (FWC 2012a). The unweighted normalized values were then summed for all parameters and categories similar to the example shown in Table 3 and grouped into one of FWC's five regions (administrative boundaries determined by county lines). Each resource unit (conservation area or sub-watershed) was binned into five classes using the Jenks (1967) natural breaks method by their parameter values and summed values for both the three categories and overall totals for each resource. The Jenks natural breaks optimization method identifies breakpoints that minimize the sum of variance within classes and maximize the variance between classes (Jenks 1967, Jenks and Caspall 1971). Each freshwater resource unit was ranked such that the bin containing the lowest summed values for that region and resource type (e.g. streams in the Northwest region) received a ranking of low priority for restoration (rank value = 1). The bin with the second lowest summed value was ranked as medium-low priority (rank value = 2), and so on, until the highest summed value was ranked high (rank value = 5). Parameter, category, and overall values were compared relative to other values within that region and resource type, so there was no "minimum value" or value range that a resource unit had to achieve to be placed within a ranking class. Ranking freshwater aquatic resource areas by parameter, category, and FWC region allowed managers in each region to not only identify high priority resources within their areas of responsibility, but also to identify specific issues within those resources (such as resources that were especially valuable from threatened and endangered species or Fish and Wildlife perspective).

Table 3. An example of how normalized values for variables in the three categories (socioeconomic value, fish and wildlife value, and management emphasis) were summed for forested wetlands in two conservation areas prior to running a Jenks (1967) natural break optimization classification.

	Wetland	
Category and associated variable	**Nayfield Acres Conservation Easement**	**Teneroc Fish Management Area**
Socio-Economics		
Accessibility	0.00022	0.00154
Recreational trail length	0.00000	0.06373
Great Florida Birding Trail	0.00000	1.00000
Population	0.05187	0.79648
Hunting/fishing opportunities	0.50000	0.50000
Subtotal	0.55209	2.36175
Fish and Wildlife Populations		
Threatened/endangered/SGCN	0.09375	0.12500
Avian focus area	0.20000	0.60000
Size of wetland	0.00003	0.00680
Conservation area size	0.00009	0.00555
Subtotal	0.29387	0.73735
Management Emphasis		
Impaired Waters	0.00000	0.59822
Road density	0.00212	0.00079
Invasive aquatic plants	0.00000	0.47368
Land use/land cover	0.00000	0.28151
Subtotal	0.00212	1.35419
Total resource values	0.84808	4.45329

Results and Discussion

Identification of Publicly Accessible Freshwater Resources

Based on the NHD flowlines, 1295 sub-watersheds were identified of which 1235 (95%) contained publicly accessible streams. Over 2500 public conservation areas were identified of which 1835 (~73%) contained either forested or non-forested wetlands or both. Three hundred and twenty-four (324) public lakes greater than or equal to 20.2 ha were identified for prioritization (FWC 2012a). These aquatic areas contained 89,750 stream km (56% of total stream km occurring in Florida), 1,098,997 ha of freshwater non-forested wetlands (50% of total ha of freshwater non-forested wetland ha occurring in Florida), 880,294 ha of freshwater forested wetlands (52% of total ha of freshwater forested wetlands occurring in Florida) and 405,720 ha of lake surface area (80% of total ha of lake surface area occurring in Florida) (Table 4).

Table 4. Total number of resources and number of high priority (HP) resources assessed by habitat type in each Florida Fish and Wildlife Conservation Commission (FWC) region.

		Aquatic habitat type							
		Rivers and streams		Non-forested wetlands		Forested wetlands		Lakes	
FWC region		**Sub-watersheds**	**Stream km**	**Conserv. areas**	**Wetland ha**	**Conserv. areas**	**Wetland ha**	***n*** **>50 ha**	**Total ha**
Northwest	Assessed	340	26,355	201	65,606	230	286,656	35	21,780
	HP	42	3875	12	50,295	11	202,551	4	8763
North central	Assessed	231	13,700	247	47,776	340	177,368	30	21,701
	HP	42	4060	28	28,576	35	96,629	5	14,356
Northeast	Assessed	259	16,011	380	142,958	407	19,683	137	133,927
	HP	39	4545	26	89,732	30	107,451	11	47,294
Southwest	Assessed	270	16,921	361	59,930	414	99,638	117	46,091
	HP	29	2799	43	31,175	65	54,478	1	11,207
South	Assessed	136	15,437	242	842,656	243	219,443	5	182,221
	HP	16	3932	29	759,084	20	168,353	1	181,299

Category type and separation by region are important in the prioritization process to allow a greater number of different resources to be identified for management. The socioeconomic category provided higher summed normalized values than the other two categories (fish and wildlife value and management emphasis) for all resource types, except lakes (Figure 2). Socioeconomic values also tended to be higher as the regions progressed south with the Northeast, Southwest, and South regions having higher values for all categories. Socioeconomic values were higher in these three regions likely because the further south resources are found in Florida, the higher human population and more developed are the surrounding areas. For the lakes assessment, category values were similar for each region, except the South region, where there were only five public lakes greater than 20.2 ha, one of which was Lake Okeechobee (the only high priority lake), the second largest lake in the contiguous United States and ten times larger than any other lake in Florida. There were also higher numbers of invasive species, poorer water quality, and other threats to aquatic resources in the more developed areas. In developing future assessments of resources in other states, it would be prudent to separate those areas of the state or region where differences in resources and development may exist.

Analyses also indicated that special consideration should be given to parameters identified for assessment and the valuation used. Parameters with values based on a presence/absence basis (e.g., normalized values of either 0 or 1 for the presence of Great Florida Birding Trail sites; 0, 0.5, or 1 for hunting and fishing opportunities) and a defined-scale basis (e.g., normalized values on a 0, 0.2, 0.4, 0.6, 0.8, and 1 scale for AFAs) had much higher values and thus had

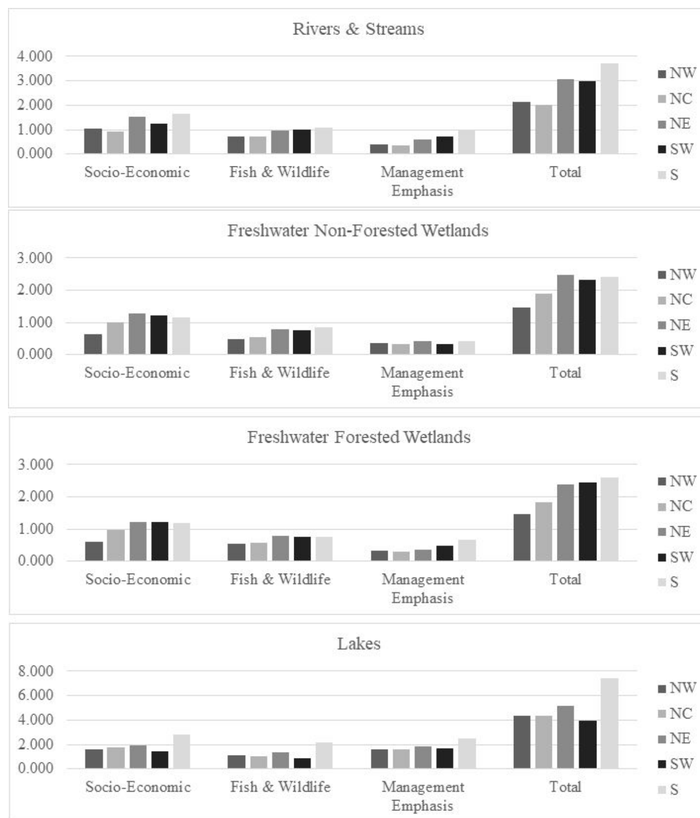

Figure 2. Mean normalized value sums by category and total value for each resource type by FWC region (NW = Northwest; NC = North Central; NE = Northeast; SW = Southwest; S = South).

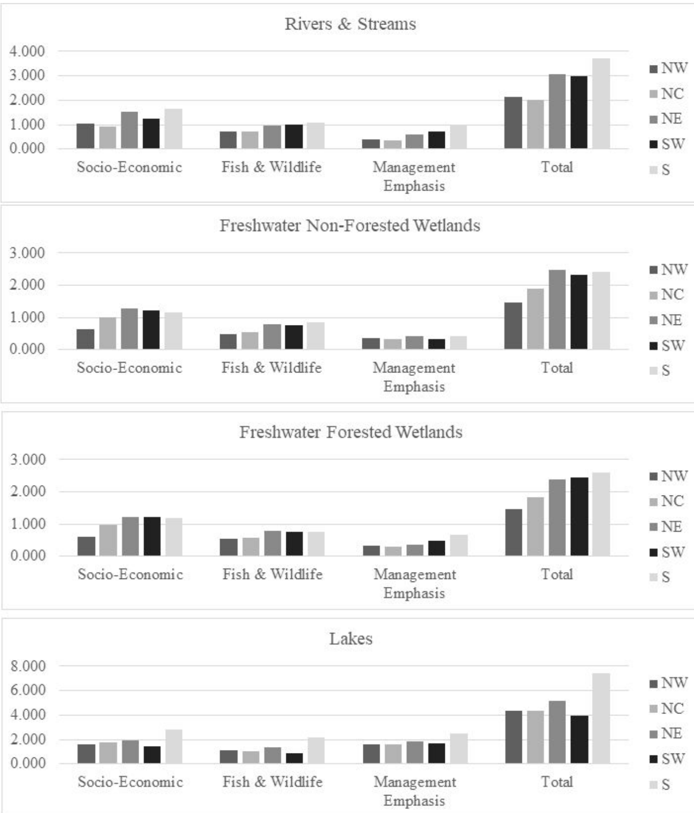

Figure 3. Mean normalized value by parameter (all FWC regions combined) for each resource type (HUC = Rivers and Streams; FWNF = Freshwater Non-forested Wetlands; FWF = Freshwater Forested Wetlands).

Table 5. Mean ranking values for each category for the high priority resources for each habitat type by Florida Fish and Wildlife Conservation Commission (FWC) region.

FWC region	Aquatic resource type	Socio economic	Fish and wildlife	Management emphasis
		Mean	Mean	Mean
Northwest	Rivers and Streams	4.8	3.6	3.4
	Freshwater non-forested wetlands	4.5	4.9	4.0
	Freshwater forested wetlands	5	4.6	3.9
	Lakes	4.3	5	4.3
North Central	Rivers and Streams	4.7	4.1	3.2
	Freshwater non-forested wetlands	5	3.9	3.4
	Freshwater forested wetlands	5	4.0	3.2
	Lakes	4.6	4.6	4.6
Northeast	Rivers and Streams	5	4.1	3.7
	Freshwater non-forested wetlands	4.4	3.8	3.6
	Freshwater forested wetlands	4.8	4.4	4.1
	Lakes	4.4	4.7	4.5
Southwest	Rivers and Streams	4.4	4.1	3.9
	Freshwater non-forested wetlands	4.7	4.1	4.3
	Freshwater forested wetlands	4.7	3.8	3.7
	Lakes	5	5	5
South	Rivers and Streams	4.6	3.8	4.1
	Freshwater non-forested wetlands	4.8	3.8	4.5
	Freshwater forested wetlands	4.9	4.5	3.8
	Lakes	4.0	5	5

a greater influence on the category and overall values for resources within a region (Figure 3). Parameter values based on continuous variables (e.g., percent wetland acreage within the conservation area, length of recreation trails) had the potential for much lower values and had a lower contribution to the category and overall values. Also, because parameter raw values were normalized against all other resources within the same resource type throughout the state, versus within the region they occupied, normalized values for those "percentage basis" parameters tended to be even lower when compared to the "presence/absence" parameters. However, because the values were relative to other values for those resources within a defined region, comparison within each region is still valid for those parameters. The benefit of normalizing across all resources of the same type throughout the area of assessment (statewide) versus only specific areas within the entire assessment area (i.e., regional) is that statewide data normalization allows evaluation of all resources of that type against one another statewide, while normalization within a section of the assessment area limits comparison to within that region. When developing other assessments, it is necessary to consider the influence of valuation methodology and normalization on prioritization of those resources.

For the high priority resources, mean ranked values tended to have higher socioeconomic values when compared to the fish and wildlife and management emphasis mean rank values (Table 5). The management emphasis mean rank values tended to be the lowest of the three categories for several of the resource types, especially for the northern regions. These higher rank values suggested that those resources ranked higher from a socioeconomic and fish and wildlife perspective were more important in determining the rank of a resource than the resource's management emphasis. In other words, resources that were valued by stakeholders (socioeconomic) and provided greater potential or actual fish and wildlife value may be considered more viable management targets if they have only moderate management issues. Those resources with low management emphasis values need to be preserved, and those resources with the highest management emphasis values either have low fish and wildlife value or may be too difficult (too far gone) to reasonably restore.

Management Implications

Prior to development of this prioritization tool, the procedure for evaluating and selecting aquatic resources for enhancement and restoration projects was very subjective. A statewide team was developed to solicit projects from agency staff and others working with guilds in their areas of expertise. Projects were selected through a submitted application process, with project applications from throughout the state pooled prior to the evaluation and selection process and team members serving as subject matter experts to review applications and evaluate the biological merit of proposed projects using a standardized scoring system. Changes in team membership through attrition and job classification changes resulted in variations in how projects were selected on an annual basis.

The current wetland prioritization employs a quantification process that reduces the dynamic of individual bias and maintains continuity of the prioritization and selection process on an annual basis, while accounting for regional variations in aquatic resources. It correctly identified and ordered aquatic resources based on their relative abundance and importance within each administrative region.The prioritization process was able to identify several key resources from each region, demonstrating its usefulness as a decision support tool. The resources identified in each region were often both extremely valuable socioeconomic resources and threatened by their past use or proximity to urban areas.

The prioritization of aquatic resources within each FWC region provided a science-based decision framework for identifying those resources that will likely produce the greatest ecological benefits. Accordingly, an increased focus will be placed on those resources with the greatest conservation, restoration and enhancement needs within each FWC Region. This will be accomplished by establishing five regional teams to assess priority sites and, based on those assessments, develop specific restoration and enhancement proposals. Regional teams will consist of FWC staff from various offices, divisions, and institutes who are familiar with and have local knowledge pertinent to the priority aquatic resources within the region. Because many of the priority aquatic resources are owned and managed by governmental entities other than the FWC, representatives from appropriate external governmental partners and conservation organizations will be asked to participate on the regional teams. Coordinating with internal and external partners will build stronger synergistic relationships with stakeholders, increase scientific and technical knowledge of these resources, and provide opportunities to leverage or cost-share restoration and enhancement funds.

Regional teams will be provided with detailed maps and access to digital tools and resources utilized in the analysis of aquatic resources and identified during the development of this guide. This tool will allow regional team members to query the databases and various GIS layers to further investigate and aid in the development of project proposals for submittal for funding consideration. Regional teams will be directed to give greater consideration and emphasis in developing project proposals that address high-priority aquatic resources within their respective FWC Region, with the goal of increasing comprehensive management of these aquatic resources. All project proposals generated by the five regional teams will be submitted for review by the FWC Aquatic Habitat Restoration and Enhancement Standing Team. This team will have the responsibility to score and rank the regional teams' high-priority proposals and develop a recommended slate of statewide prioritized projects for funding consideration.

In summary, the analyses detailed in this manuscript provided a consistent, defensible methodology to prioritize the allocation of limited management and restoration funding to aquatic resources and will help guide future decisions to provide the greatest conservation benefit from management, restoration, and enhancement. This decision framework strengthened management accountability in making informed, science-based decisions when expending legislatively appropriated funds towards public trust resources, benefiting not only fish and wildlife, but the citizens of Florida as well. The process of building upon previous effective conservation measures and applying new, innovative science-based techniques represents a continued evolution to improve and refine methodologies to restore, enhance and manage Florida's aquatic resources in a comprehensive manner. Support for these measures is paramount and FWC will continue to engage directly with our stakeholders, expand participation with our partners, and communicate our actions and decisions with those connected to the public trust resources managed by FWC.

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