Medium-low gradient streams and rivers in the East and West Gulf Coastal Plains (EWGCP)

The designation of “medium-low gradient streams and rivers” was adopted for use by the USFWS Region 4 as a “broadly defined habitat” at the 2009 USFWS Bioconference. This term was based on southeastern aquatic community types described by Felley (1992 in: Hackney et al. eds). This habitat type is very broad in that it includes only the most minimal physical habitat description – gradient - and relies on the ecoregional distinctions of the GCPO subgeography to further define community associations (although future refinements of habitat types as defined by the Integrated Science Agenda, or ISA, may wish to consider distinct major drainages which structure patterns and pathways of aquatic species dispersal). Gradient is also included in other classification systems as a primary structuring variable (Rosgen 1994, Higgins et al. 2005, Anderson et al. 2014). The Southeast Aquatic Resources Partnership, or SARP, has established thresholds for stream classification based on size, gradient, elevation, ecoregion, seasonal flow and impoundment. These thresholds are intended to be applied as needed within other regional classification frameworks. Within the East and West Gulf Coastal Plains subgeographies and the broadly defined habitat type of “medium-low gradient streams and rivers,” landscape endpoints specified in the ISA are intended to more narrowly describe localized stream amount, configuration and condition.

The desired landscape endpoint for these rivers and streams should characterize a natural system in a least impacted condition – systems in this condition should be targets for protection and the goal of restoration activities in degraded systems. In the ISA, a general description of desired landscape endpoints for medium-low gradient streams and rivers include intact channel morphologies that support riffles and pools and a complex of physical structure (woody debris, leaf litter, and substrate types). Flows should be relatively steady, with infrequent periods of low water quantity. Hydrology for a given reach should be closest to the most natural hydrology given its landscape position. Many of these waters will be primarily composed of organisms adapted to warmwater conditions, but water quality should not lead to lethal conditions for warm water communities.

Gradient threshold definitions were adapted from those established by SARP. For the current analysis, medium-low gradient stream includes all streams having a gradient (slope) of less than 0.02 (meters/meters) based on the “SLOPE” attribute for each stream segment reported in the NHDPlus v2 attribute table. (NHDPlus v2 is a geo-spatial, hydrologic framework dataset developed by the Environmental Protection Agency and the US Geological Survey). This definition includes a large proportion of rivers and streams throughout the EWGCP but excludes low order, high-gradient streams that are most abundant across the Ozark Highlands, in the Ouachita Mountains of the WGCP, and in higher elevations of the EWGCP.

Within the East and West Gulf Coastal Plains the designation of “medium-low gradient streams and rivers” will include rivers from a variety of drainage basins including the South Atlantic Gulf drainages, the Texas Gulf drainages and rivers draining ultimately into the Mississippi or the Atchafalaya through the Yazoo and Red rivers. Because of physical barriers to dispersal between drainage basins, the species endpoints are likely to vary within a subgeography across basins. On the other hand, the landscape variables described here that relate to targets for physical habitat condition are more likely to be shared in common across subgeographies.

Throughout this analysis, the medium resolution NHD plus v2 was adopted for direct and indirect estimates of many landscape endpoints. These data were relied upon because they provide complete publicly available coverage throughout the GCPO geography. The data are, however, only as good as the USGS topographic data sheets upon which they are based. Inaccuracies arise due to a variety of factors including actual change in stream configuration since the data were created or overgeneralization due to the scale at which the data were created. Inaccuracies may also be the result of inconsistency in flowline delineation between topographic data sheets or misinterpretation of flow pathways, particularly in areas having low relief and abundant barriers to flow.

Results in the following chapters focus on the EWGCP but, where available, landscape level data and more limited results for the entire GCPO are also presented to provide the reader with a broader landscape level perspective.

References

Anderson, M.G. M. Clark, C.E. Ferree, A. Jospe, A. Olivero Sheldon and K.J. Weaver. 2013. Northeast Habitat Guides: A companion to the terrestrial and aquatic habitat maps. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA. http://nature.ly/HabitatGuide.

Hackney, C. T., S. M. Adams, and W. E. Martin. 1992. Biodiversity of the Southeastern United States, Aquatic Communities. 1st edition. Wiley, New York.

Higgins, J. V., M. T. Bryer, M. L. Khoury, and T. W. Fitzhugh. 2005. A Freshwater Classification Approach for Biodiversity Conservation Planning. Conservation Biology 19:432–445.

Rosgen, D. L. 1994. A classification of natural rivers. CATENA 22:169–199.

Below is the relevant section from Appendix 1 of the GCPO LCC Integrated Science Agenda outlining the desired conditions for medium-low gradient streams and rivers in the EWGCP.

EAST AND WEST GULF COASTAL PLAINS

Freshwater Aquatic: Medium-low gradient streams and rivers

General description of desired ecological state: Medium-sized streams and rivers characterized by intact channel morphologies that support riffles and pools and a complex of physical structure (woody debris, leaf litter, and substrate types). Flows are relatively steady, with infrequent periods of low water quantity and high water temperatures.

Amount: Maintain current river miles

Configuration: Connectedness that ensures accessibility of habitats and resources within a watershed

- Lateral connectedness: functional connectivity to floodplain habitats
- Linear connectedness: functional connectivity of a stream network

Condition:

- Quality
  - Temperature – below critical threshold
- Quantity
  - Adequate magnitude with limited frequency of low flows conditions
- Structure
  - Intact channel morphologies
    - Natural riffle-pool sequences
    - Meandering channels with natural sinuosity
  - High physical structure complexity
    - High amounts of small woody debris
    - Adequate amounts of large woody debris
    - Diversity of substrates, including numerous gravel beds and sandbars

Chapter 1: Amount, current river miles

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Amount

Desired Landscape Endpoint: Maintain current river miles

Data Sources and Processing Methods

We used NHD Plus v2 flowlines to define the location of rivers in the GCPO and selected all line segments that intersect the EWGCP subgeographies. Line densities differ across the entire GCPO depending on location specific methodologies that were used to generate the NHD flowlines. Similar cartographic inconsistencies were encountered by Kaeser and Watson (2011). An assessment of total river miles would therefore not be valid using all data. To reduce problems associated with differing line densities we selected only line segments that satisfy criteria of: “flow greater than 10 cfs (Q1000A>10) or cumulative drainage area > 10 km^2 (TotDASqKM>10) or the stream segment has a specific name (GNIS_Name=TRUE).” Application of these criteria eliminates headwaters, but also greatly reduces problems of differing NHD line density. Application of “intermittent” vs. “perennial” designations appeared to be different across the GCPO geography and was therefore not used. We also excluded NHD flowlines that intersect NHD waterbody categories of “LakePond,” “Estuary” and “Reservoir.” From these lines we applied an additional criterion of “slope < 0.02” to identify only medium to low gradient streams and rivers. This threshold was chosen to align with river classification thresholds established by SARP. Slope is a unitless value of m/m based on maximum and minimum elevations along a line segment. Reported total river miles include only segments that touch the boundaries of the GCPO. **This geospatial definition of medium-low gradient streams and rivers provides the frame of reference for analyses reported in subsequent chapters.**

We also summarized river amount by HUC12. Total Length (Sum of LENGTHKM) was summarized by each HUC12 using “Tabulate Intersection” in ArcMap. Total length in each HUC was normalized by dividing by the total area (square kilometers) of each HUC.

Summary of Findings

The amount of medium-low gradient streams and rivers are shown by SARP slope class in Figure 1. There are no distinct geographic patterns in the distribution of medium to low gradient streams within the East and West GCP subgeographies. Areas having low density of streams were frequently associated with the presence of a large reservoir. In the extreme southeast EGCP there is a lower density of streams in the vicinity of the

Dougherty Plains where karst topography creates many sinkholes and subterranean streams. The total kilometers of medium to low gradient streams in the EWGCP is 205,812 km; EGCP=111,727 km and WGCP=94,085 km. Estimates normalized to area within each subgeography are approximately the same for both subgeographies with East and West GCP having approximately 0.44 km/km^2.

Future Directions and Limitations

The selection criteria used in this analysis create a more unbiased distribution of streams across the GCPO geography but exclude the smallest headwater streams. Also, depending on the methodologies used in NHD creation, some sections of braided rivers may over-represent the amount of streams present. These instances of braided flowlines will probably not greatly affect final assessment of stream length on the subgeography scale. Further detailed work could be done to reduce or eliminate the influence of braided flowlines.

References

Kaeser, A. J., and E. Watson. 2011. A GIS–based Assessment of Land Cover within Stream and River Riparian Buffers of the Southeastern United States. A publication of the Science and Data Committee, Southeast Aquatic Resources Partnership.

Tables and Figures

Table 1. Amount of medium-low gradient streams and rivers within the GCPO LCC by subgeography. Estimates are based on NHDPlus v2 using specific selection criteria described in the text.

Geographic extent	**Med-Low Gradient Streams and Rivers**	
	km	**km/km^2**
Mississippi Alluvial Valley	46,426	0.45
East Gulf Coastal Plain	111,727	0.44
West Gulf Coastal Plain	94,085	0.44
Ozark Highlands	50,405	0.37
Gulf Coast	9,186	0.37
Gulf Coastal Plains and Ozarks (full extent)*	309,064*	0.42

* Note that the total length of high gradient streams in each subgeography is based on stream segments touching the boundaries of the subgeography. A single segment that bridges two HUCS may be counted in each subgeography. The total length of streams

for the entire GCPO is therefore less than estimates based on a sum of all subgeographies.

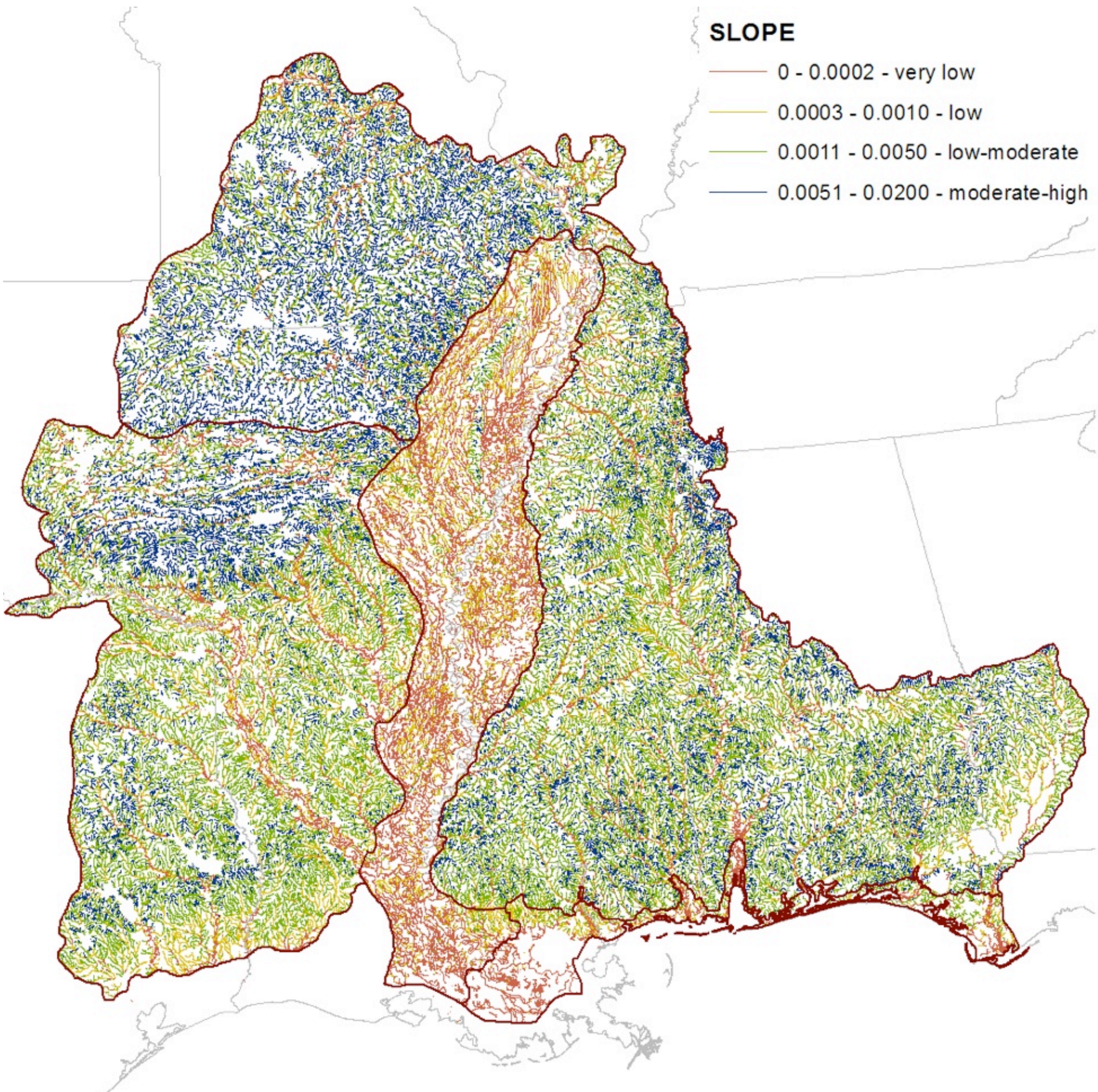


Figure 1. Distribution of medium to low gradient streams and rivers within the subgeographies of the GCPO LCC. Categories of slope correspond with SARP gradient thresholds. Note that high gradient streams (>0.02) and flowlines through open waterbodies are excluded from this analysis.

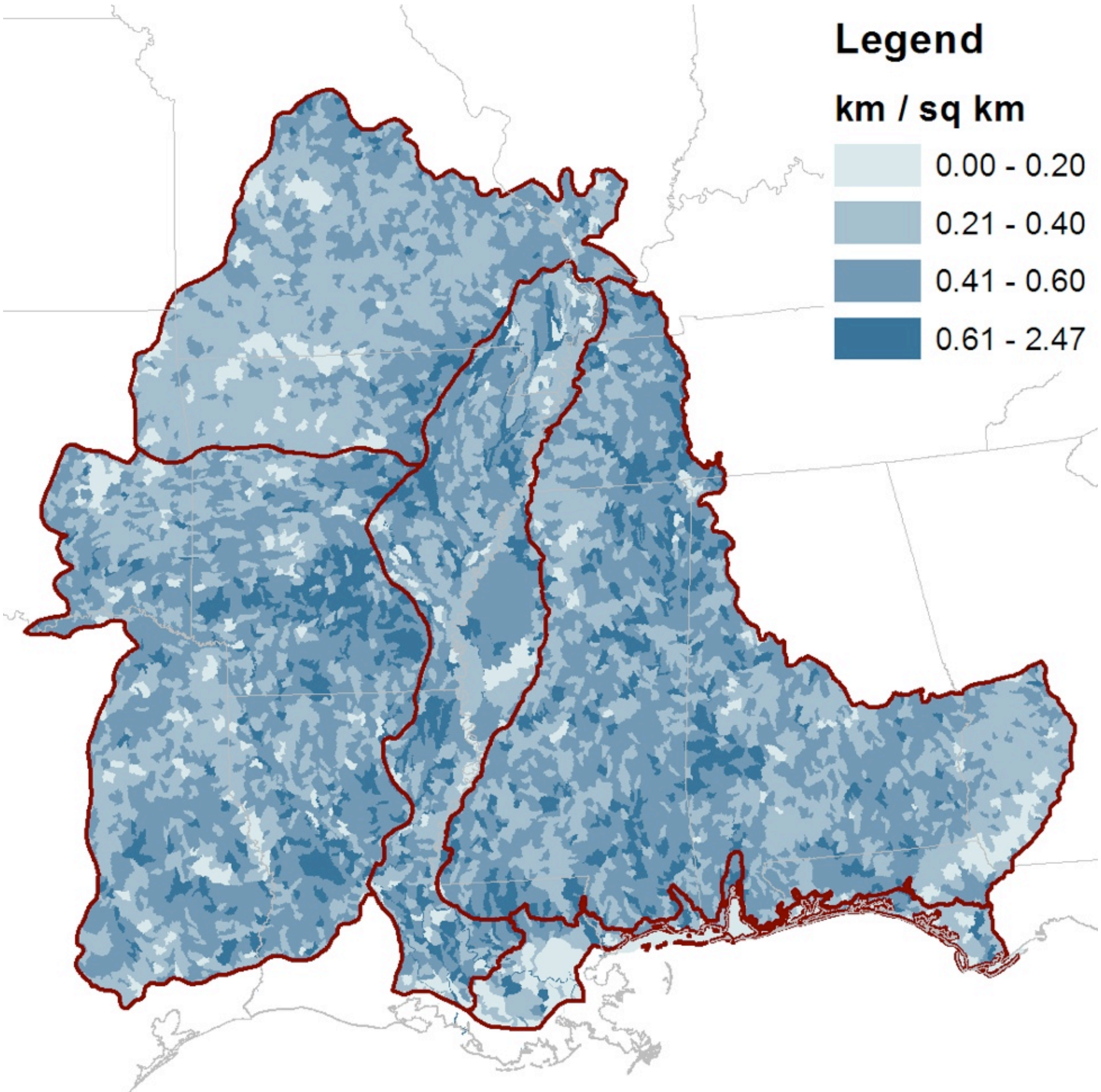


Figure 2. Distribution of medium to low gradient streams and rivers by HUC 12 within the subgeographies of the GCPO LCC.

Conservation Planning Atlas Links to Available Geospatial Data Outputs (in process)

- Medium-Low Gradient Streams and Rivers (based on NHDPlus v2)
    - GCPO geography (vector – line)
    - GCPO geography (vector – polygon)

Chapter 2: Configuration, floodplain connectivity

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Configuration

Desired Landscape Endpoint: Lateral Connectedness: functional connectivity to floodplain habitats

Data Sources and Processing Methods

We used a draft version of floodplain inundation frequency developed by Allen (in prep) as a basis for estimating floodplain availability in the EWGCP. This product is based on multiple observations of inundation extent including open water and flooded vegetation using landsat imagery from 1983-2011 during leaf-off conditions (Dec-Mar). For this assessment, we defined "lateral connectedness" by locations that are intermittently inundated and have inundation frequency of 10-90% (Figure 1). "Permanent inundation" was defined as locations having > 90% inundation frequency. This data source includes all inundated areas including flooded fields that may or may not be associated with a riverine floodplain. To account for this potential misinterpretation, we intersected the 2012 Cropland data layer with the inundation frequency dataset, and we reported results for each subgeography as intermittent and agriculture or intermittent and non-agriculture.

Lateral connectedness was also summarized by HUC12 (Figure 2). Total area having intermittent inundation (10-90%) in each HUC was normalized by dividing by the total area (square kilometers) of each HUC.

Summary of Findings

In contrast with the MAV, far more areas of intermittent inundation in the EWGCP are associated with riverine systems (Table 1). The largest of these is the upper Mobile river basin (Figure 1 and Figure 2). In west Tennessee, extensive floodplains are associated with the Hatchie, Obion, and North and South Forked Deer Rivers. Coastal rivers including the Pearl, Pascagoula, Escambia, Choctawhatchee and Apalachicola Rivers also have significant floodplain systems. In the WGCP extensive floodplain areas are associated with the Ouachita River especially on the Felsenthal National Wildlife Refuge and on the Sulphur River in Arkansas and Texas.

Future Directions and Limitations

The floodplain inundation data used in this analysis have some inherent limitations primarily based on the ability of the optical sensor to determine the extent of inundation. Inundated locations that also have dense ground, understory, or emergent marsh vegetation that persists throughout December through March will be underestimated using this approach.

The assessment provided here can and should be improved with a more specific definition and target of "functional connectivity."

References

Allen Y.C., in prep. Landscape scale assessment of floodplain inundation frequency in the south central US using Landsat imagery

Tables and Figures:

Table 1. Lateral connectedness – area of intermittently inundated floodplains within the GCPO LCC by subgeography. Estimates are based on draft inundation frequency dataset (Allen in prep).

Geographic extent	Med-Low Gradient Streams and Rivers			
	Total Intermittent (km^2)	Intermittent non-Ag (km^2)	Intermittent non-Ag %	Intermittent + Ag (km^2)
Mississippi Alluvial Valley	28,281	17,042	60	11,239
East Gulf Coastal Plain	9,886	9,656	98	229
West Gulf Coastal Plain	9,412	9,149	97	262
Ozark Highlands	3,985	3,808	96	177
Gulf Coast	3,342	3,340	100	2
Gulf Coastal Plains and Ozarks (full extent)	54,905	42,995	78	11,910

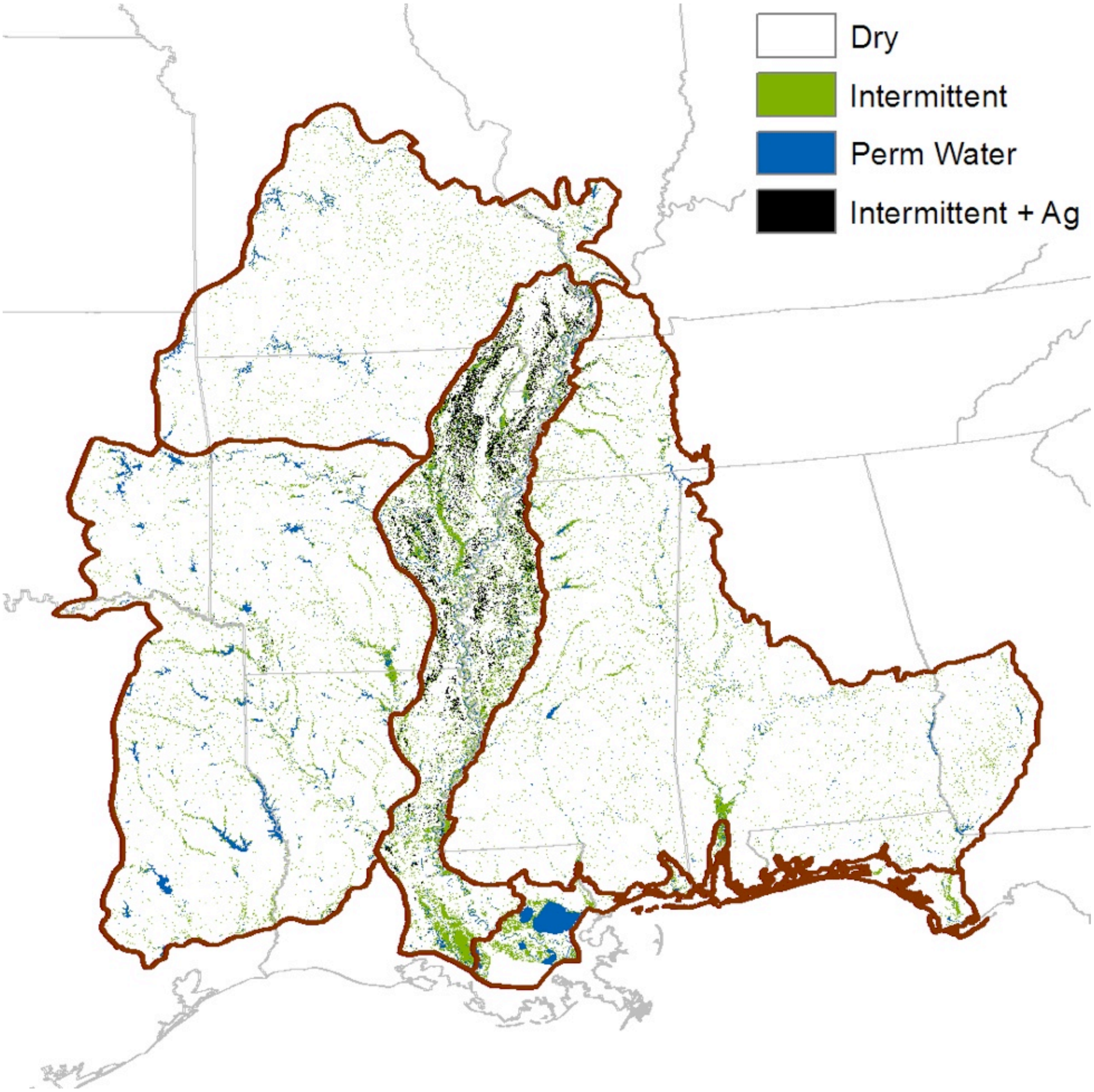


Figure 1. Areas having permanent (>90%) inundation and intermittent inundation (10-90%) in the GCPO. Areas having intermittent inundation were further described as locations associated with agriculture production and locations not associated with agricultural production using the 2012 Cropland data layer.

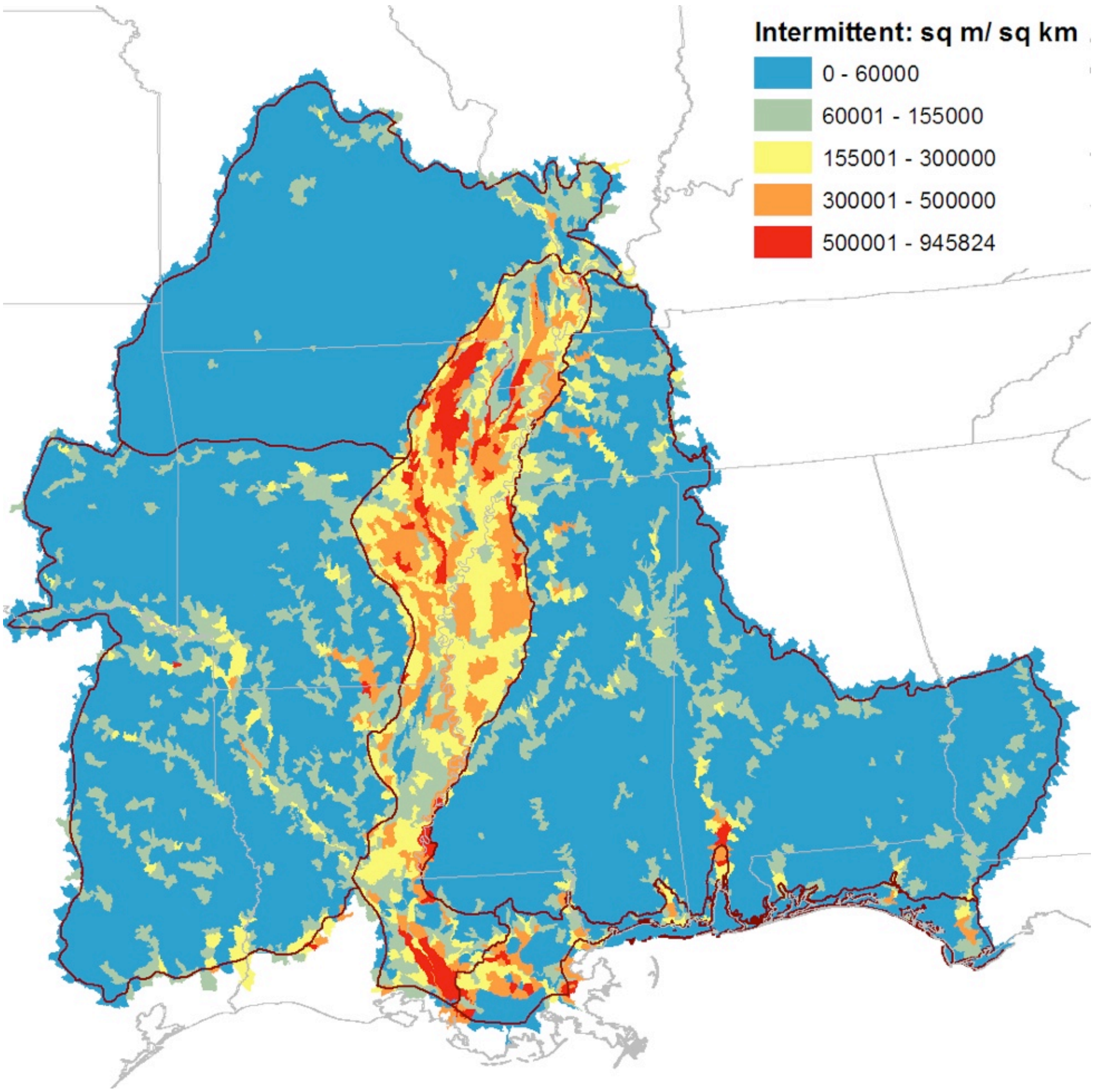


Figure 2. Amount of intermittent inundation (10-90%) normalized by the total area in a given HUC.

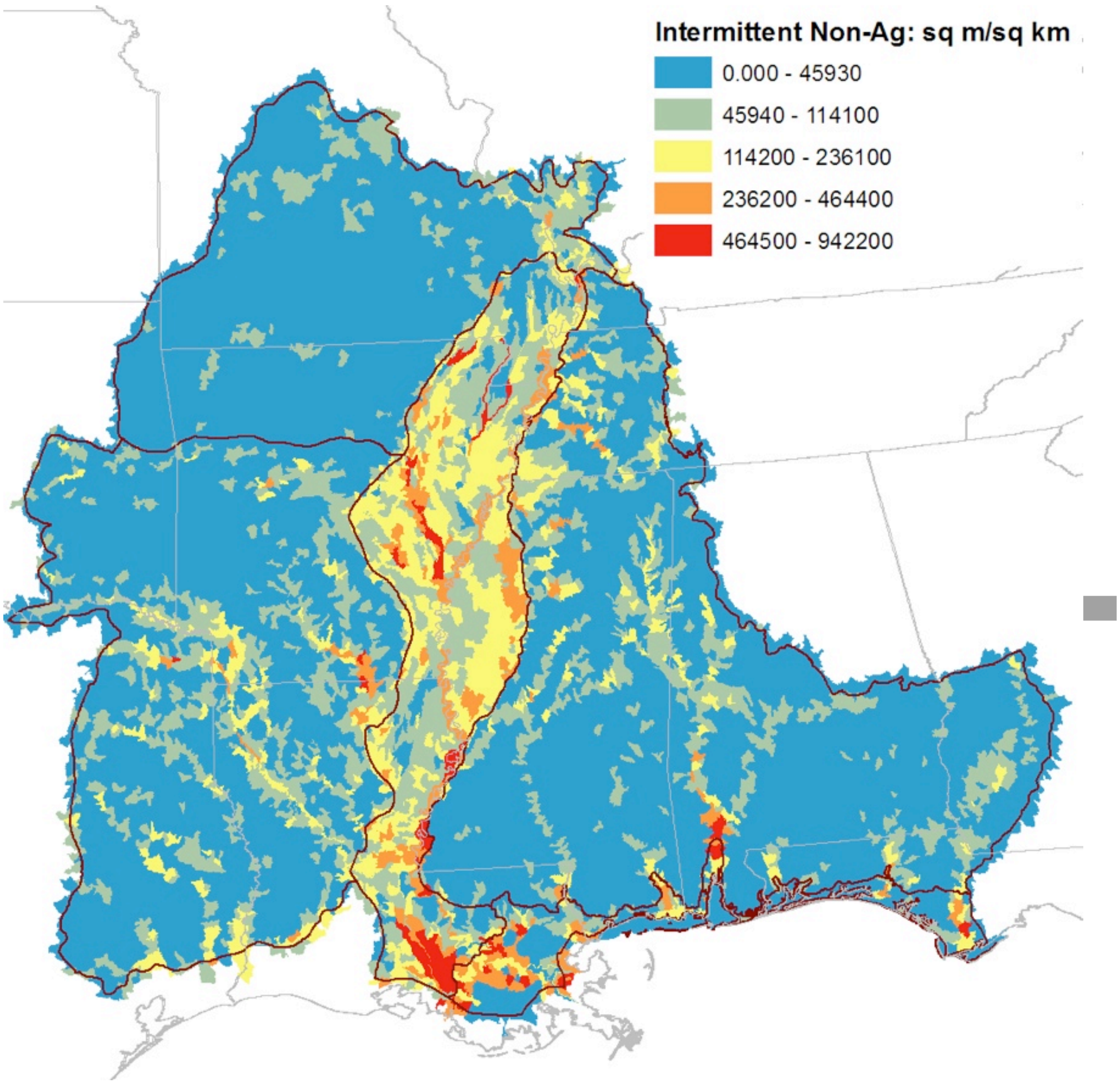


Figure 3. Amount of non-ag intermittent inundation (10-90%) normalized by the total area in a given HUC.

Conservation Planning Atlas Links to Available Geospatial Data Outputs (in process)

- Medium-Low Gradient Streams and Rivers – Lateral Connectedness
  - GCPO geography (raster)
  - GCPO geography (vector – polygon)

Chapter 3: Configuration, functional connectivity

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Configuration

Desired Landscape Endpoint:

Linear Connectedness – functional connectivity of a stream network

Data Sources and Processing Methods

The 2012 National Anthropogenic Barriers Database (NABD) was used to evaluate the abundance of barriers in the East and West Gulf Coastal Plains. The NABD represents an improved version of the National Inventory of Dams (NID) that is linked to NHDPlus flowlines. The accuracy of the data is improved in the NABD, but there are still many inaccuracies and inconsistencies in both geography and attributes. For the current assessment, all NABD locations were selected that fell within 10 meters of a medium-low gradient stream. Summaries are presented for the total number of dams within each HUC, the total number of dams per km^2 and the mean dam height based on the NABD attribute table.

Summary of Findings

The total reported number of dams intersecting medium-low gradient streams is highest in the EGCP (1,031). The reported mean height of dams is, however, higher in the WGCP (32 feet compared with 20 feet in the EGCP). Estimates of inundation frequency (see lateral connectedness chapter) also show more than twice the area of permanent open water in the WGCP (5,002 km^2, 2.30%) compared with the EGCP (2,262 km^2, 0.89%) and this is largely attributable to the greater abundance of large reservoirs in the WGCP.

Future Directions and Limitations

The accuracy of the assessment reported here is only as good as the accuracy of the NABD. There are readily apparent differences in density of dams reported, particularly for small dams, and these differences appear to fall along state lines. We alleviated the potential for inconsistent data somewhat by requiring that dams fall within 10m of flowlines designating medium-low gradient streams as defined in this Assessment (i.e. not headwaters). Even so, examination of the locations of these data compared with current aerial photography reveals many instances of errors of omission (dam location is not present in the inventory) or commission (reported dam location that is not present in reality). The degree of inaccuracy is currently not possible to evaluate since there is no reference of “truth.” Even for some of the larger mainstem river dams there are duplicates and inaccuracies in locations. An update or reevaluation of these data is needed.

This analysis would be improved by a network analysis showing sections of medium-low gradient streams and river that are free flowing, but such an analysis would be more meaningful if it were based on a barriers dataset that is more reliable. There are other existing efforts such as USFWS GeoFIN that use available data such as the NABD to evaluate potential changes in connectivity based on dam removal. The South Atlantic LCC (SALCC) recently funded the Southeast Aquatic Connectivity Assessment Program. This assessment will provide a more comprehensive inventory of barriers to linear aquatic connectivity (excluding road crossings) and their potential impacts on species of concern within the SALCC. Preliminary results from this assessment found almost four times the number of barriers indicated in the NABD. Visual inspection of the floodplain inundation frequency dataset used in lateral connectedness chapter also clearly shows the underestimate of dams reported by the NABD.

Tables and Figures

Table 1. Linear connectedness – number of dams and mean dam height in each subgeography of the GCPO based on the 2012 NABD. Note that these estimates only include dams within 10m of all medium-low gradient streams and rivers. Note also the caveats of data accuracy reported in the text.

Geographic extent	Medium- Low Gradient Streams and Rivers		
	Count of dams	Dams/km^2	Mean dam height (ft)
Mississippi Alluvial Valley	743	0.00349	19
East Gulf Coastal Plain	984	0.00956	21
West Gulf Coastal Plain	812	0.00320	33
Ozark Highlands	337	0.00247	42
Gulf Coast	14	0.00057	10
Gulf Coastal Plains and Ozarks (full extent)	2890	0.00395	28

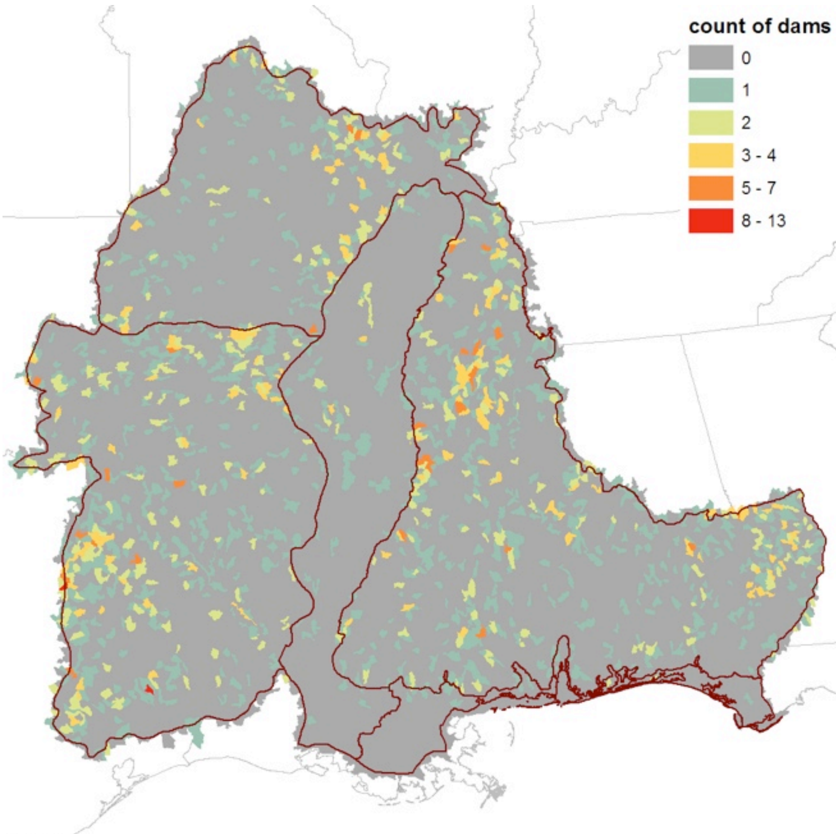
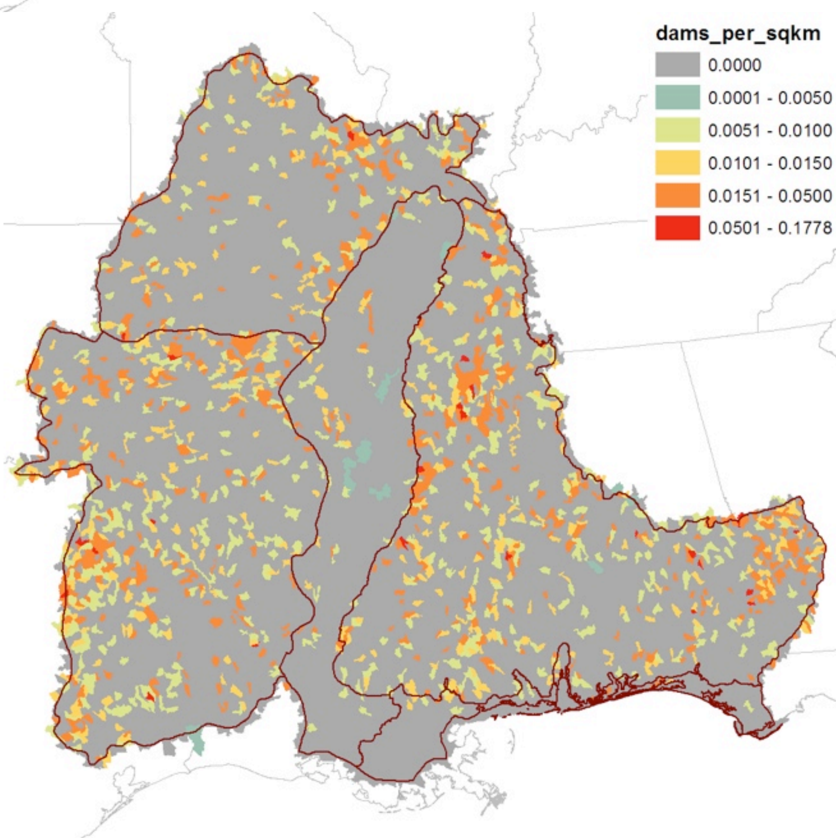


Figure 1. Number of dams in a single HUC (top) and abundance of dams normalized by area within HUCs of the GCPO based on the 2012 National Anthropogenic Barriers Dataset (NABD).



Conservation Planning Atlas Links to Available Geospatial Data Outputs (in process)

- Medium-Low Gradient Streams and Rivers – Linear Connectedness
    - GCPO geography (vector – polygon)
    - GCPO geography (vector – point)

Chapter 4: Condition, temperature

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Condition

Desired Landscape Endpoint: Temperature – below critical threshold

Data Sources and Processing Methods

The USGS National Water Information System (NWIS) and US Forest Service have real time temperature monitoring stations at locations given in Figure 1. We also evaluated several geospatial datasets: The National Hydrographic Dataset (NHDPlus v2) provides mean annual and mean monthly temperature estimates for most stream segments and catchments based on long-term annual averages (1971-2000) from Parameter-elevation Regressions on Independent Slopes Model data (PRISM). Thermal tolerance limits for aquatic organisms may be alternatively characterized in mean monthly or maximum temperatures. To better characterize the potential distribution of temperature during the peak of summer in the GCPO, we downloaded the most recent long-term (1981-2010) mean and maximum August temperature grids from PRISM. We then intersected these grids with NHDPlus using isectlinerst function in Geospatial Modelling Environment (This tool creates a summary for a line (polyline) based on a raster layer.) Data were mapped using calculated values of length weighted mean of raster values along the line. Selection of lines that represent medium-low gradient streams and rivers is based on the parameters described in the Amount chapter

Summary of Findings

Actual temperature reports from NWIS or USFS vary by station in length and detail of record, but individual stations may be queried for data to be used in validation of spatial datasets or in conservation decisions. The mean annual temperature range listed in NHD (TEMP0001) reflects broad patterns of thermal gradients that are mostly driven by latitude, but mean annual temperature does not provide suitable information to evaluate periods of thermal stress which typically occur in late summer.

The maximum August temperature ranges observed in the EWGCP correspond with thermal tolerance limits for the most heat-tolerant cool water species and all warm water species. Pockets of cooler water exist in some medium-low gradient rivers and streams of the Ouachita Mountains in the WGCP (Mean August range: 26-27 degrees C), but most of the coolest water is associated with high-gradient streams. Mean August temperatures were highest in east Texas and the Red River Valley (28-29 degrees C). In the EGCP mean August temperatures are somewhat lower (26-27 degrees C) throughout most of the geography with slightly lower temperatures (25-26 degrees C) in parts of Tennessee and Kentucky. State water quality limits for temperature vary, but most describe a maximum temperature that is not to exceed a temperature at an upstream reference location. The observed variable distribution of mean and maximum August temperature across the geography certainly lend support to this approach versus establishing a fixed upper temperature.

Specific thresholds or targets were not provided in the Integrated Science Agenda, so we designated temperature ranges that generally appear to describe how conditions differ across the subgeographies (see Table 1).

Preliminary climate change analysis (Tsang et al. in prep) suggests that most of the GCPO aquatic habitats may not be negatively impacted by projected increases in temperature due to climate change.

Future Directions and Limitations

The current distribution of real time and daily temperature monitoring across the GCPO is relatively sparse. Concerns about the impacts of increasing temperatures associated with climate change have increased actions to establish more monitoring, and there is certainly room for improved distribution of water temperature monitoring throughout this geography. For example, because of the challenges of establishing fixed monitoring stations on the Mississippi River, there are only two stations – at Baton Rouge, LA and Cape Girardeau, MO – that currently report real time river temperature.

Results from this assessment may be best interpreted as a relative measure of summer high temperature patterns over a large landscape. Air temperature is at best a coarse correlate of water temperature. This is particularly true for streams that are largely spring-fed or streams that lie immediately downstream from a dam that releases outflow from a cooler hypolimnion. Riparian conditions will also strongly affect temperatures in narrow streams.   The method of using PRISM grid as a surrogate for instream temperatures is also used by NHDPlus, and an informal comparison of a few selected long-term gaging records with results reported in this assessment indicate good agreement. However, a more rigorous comparison using representative gaging stations across subgeographies and stream sizes may be useful.

P2S provides capacity to couple the USGS PRMS flow model currently being developed for the GCPO with Stream Temperature Network Models (SNTEMP) for a more detailed prediction of daily in-stream temperatures. Such an analysis may be more meaningful than air temperature models to analysis of cumulative maximum degree-days, cumulative degree-day growth rates (sensu Venturelli et al. 2010), or the establishment of seasonal thermal boundaries that may be critical to aquatic species survival and growth.

References:

Tsang, Y-P., D. M. Infante, L. Wang, D. Krueger, and D. Wieferich, in prep "A framework for a climate-driven stream ecological classification: Assessing stream habitat vulnerability to changing climate." In preparation).

Venturelli, P. A., N. P. Lester, T. R. Marshall, and B. J. Shuter. 2010. Consistent patterns of maturity and density-dependent growth among populations of walleye (Sander vitreus): application of the growing degree-day metric. Canadian Journal of Fisheries and Aquatic Sciences 67:1057–1067.

Tables and Figures:

Table 1. Estimated temperature in medium-low gradient streams and rivers based on August mean air temperatures from PRISM.

Geographic extent	**Medium-low Gradient Streams and Rivers**		
	km in August mean temperature range		
	< 26	**26-28**	**>28**
Mississippi Alluvial Valley	3,817	42,185	422
East Gulf Coastal Plain	11,467	100,253	6
West Gulf Coastal Plain	139	70,076	23,842
Ozark Highlands	43,579	6,826	0
Gulf Coast	0	8451	734
Gulf Coastal Plains and Ozarks (full extent)*	58,690	225,396	24,978

* Note that the total length of streams in each subgeography is based on stream segments touching the boundaries of the subgeography. A single segment that bridges two HUCs may be counted in each subgeography. The total length of streams for the entire GCPO is therefore less than estimates based on a sum of all subgeographies.

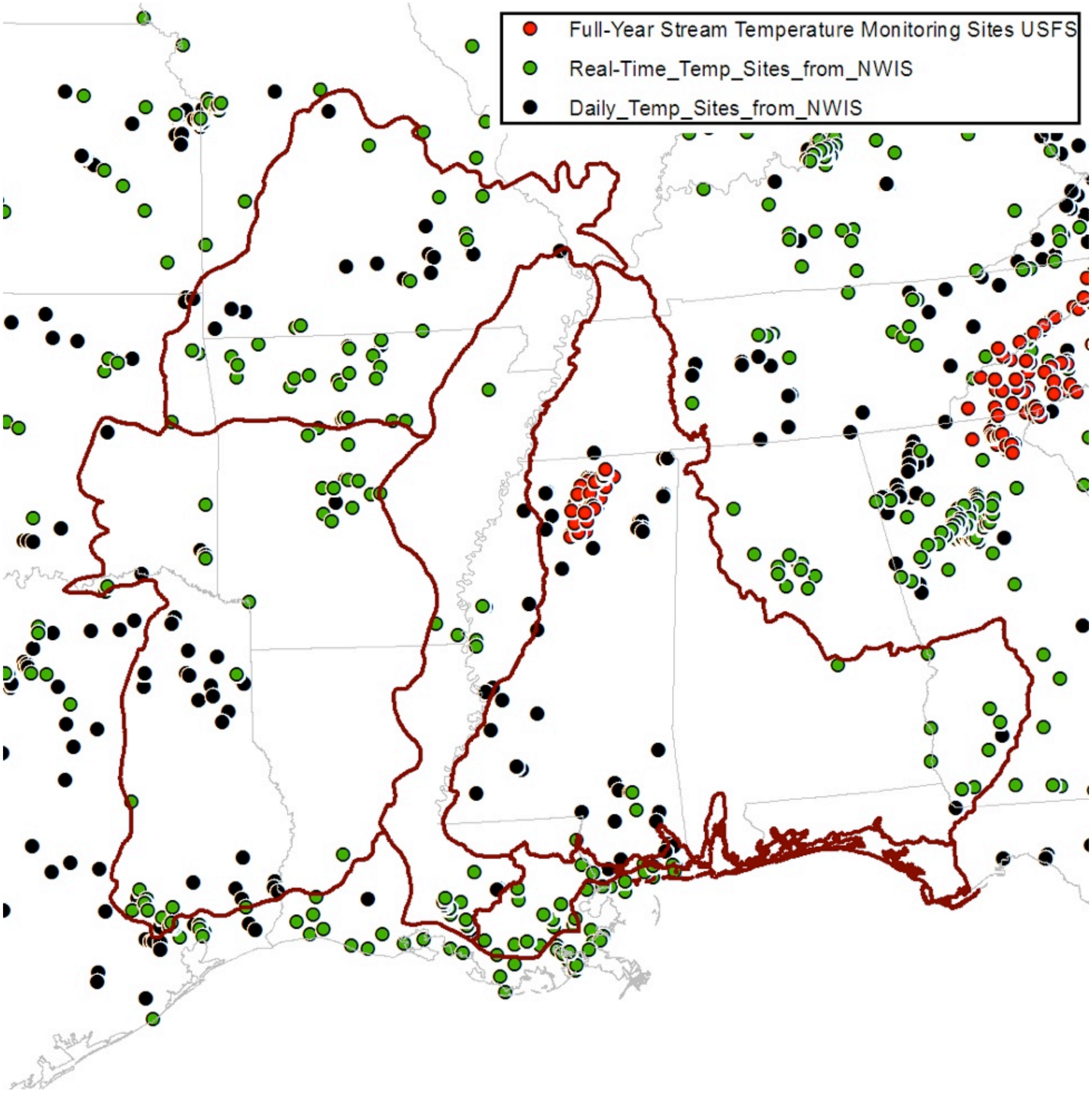


Figure 1. Temperature monitoring locations from USFS and USGS (NWIS)

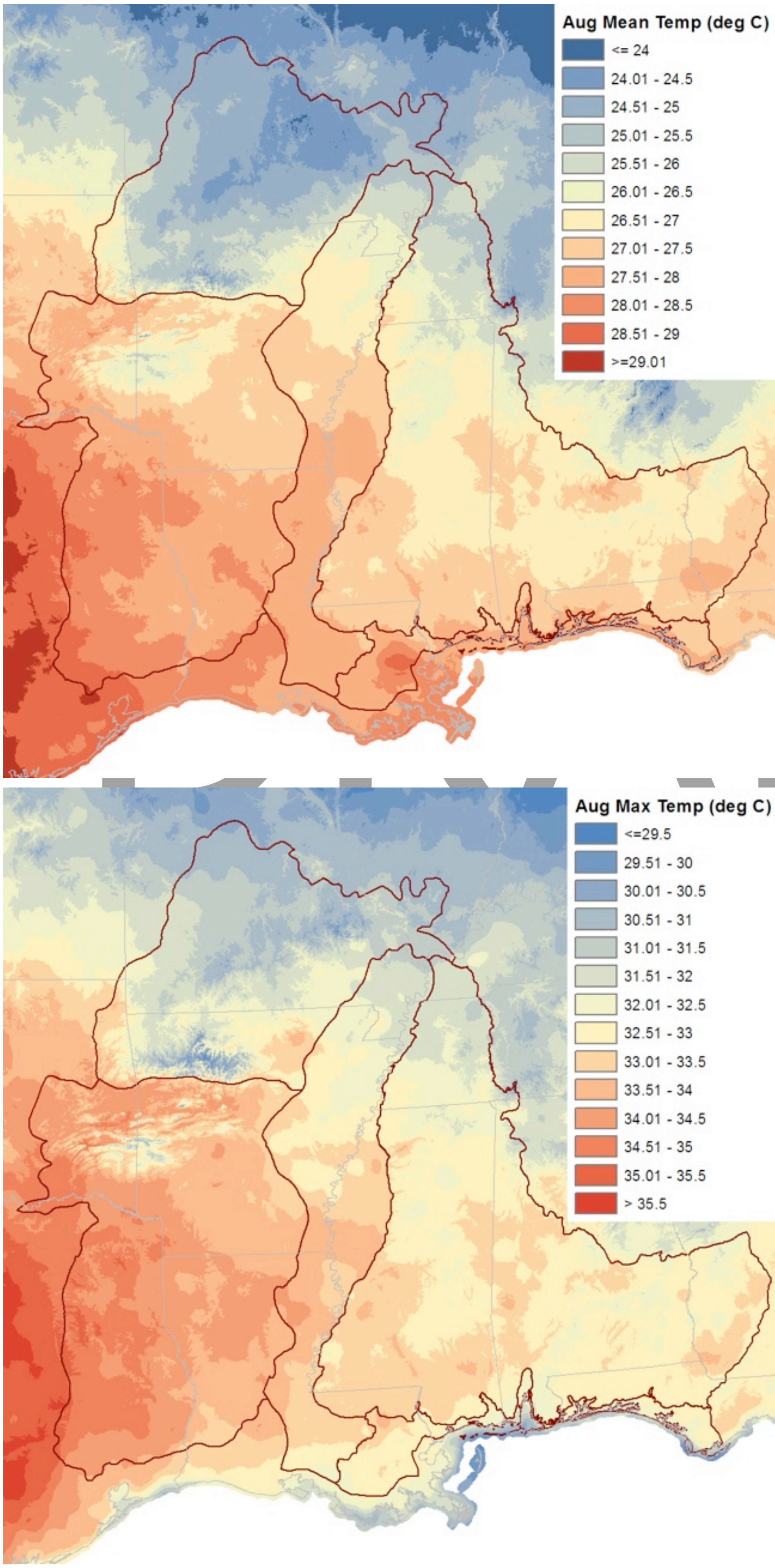


Figure 2. Long-term (1981-2000) August mean air temperature (top) and August maximum temperature (bottom) from PRISM grids.

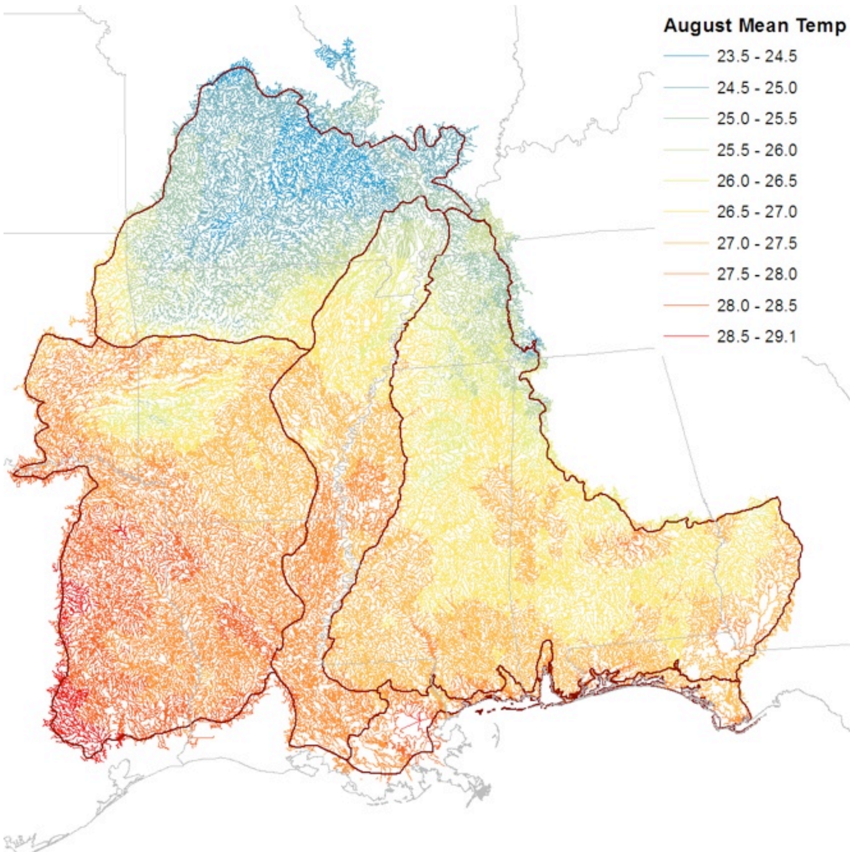
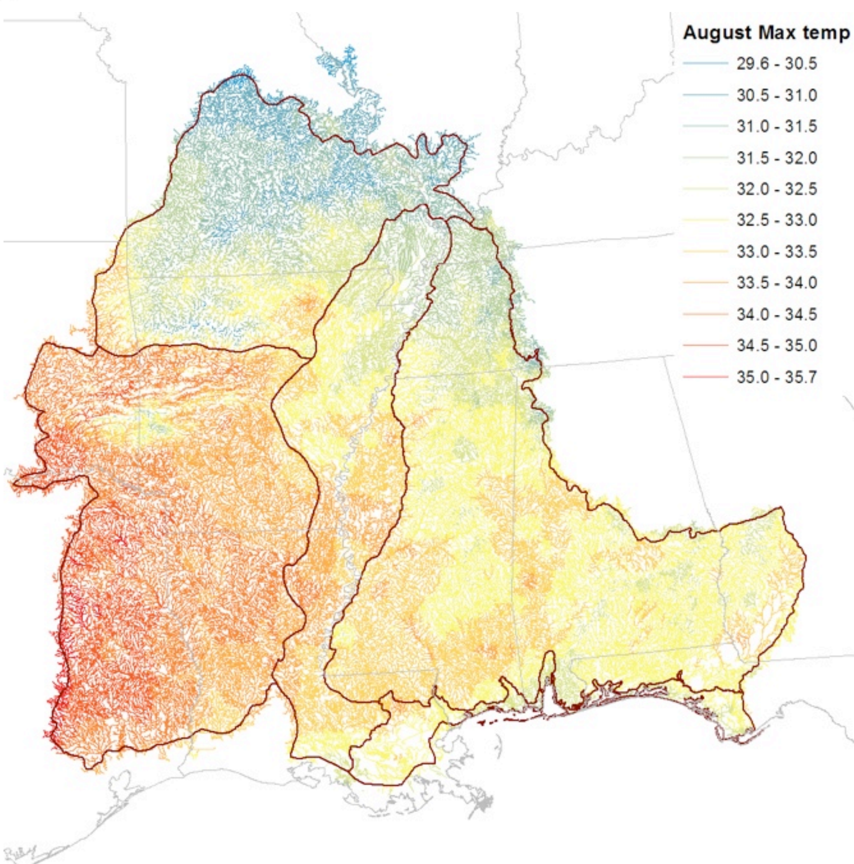


Figure 3. Long-term (1981-2000) August mean air temperature (top) and August maximum temperature (bottom) from PRISM grids intersected with NHDflowlines for medium-low gradient streams and rivers.



Conservation Planning Atlas Links to Available Geospatial Data Outputs (in process)

- Medium-low Gradient Streams and Rivers – Temperature
    - GCPO geography (vector – polygon)
    - GCPO geography (raster)

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Quantity – adequate magnitude with limited frequency of low flow conditions.

<u>Data Sources and Processing Methods</u>

Adequate variability in river flow is a very important variable within the larger suite of factors that describe desired landscape conditions for medium-low gradient streams and rivers. Adequate flow is critical not only to maintain the physical habitat availability and integrity within the stream, it is also inextricably linked to stream water quality. Due to the range of hydrologic conditions across the GCPO LCC region, it was assumed for this exercise that adequate variability is determined by the natural state of the stream or river. Currently, appropriate geospatial data within the GCPO are lacking to *directly* establish natural levels of hydrologic variability to address the desired landscape endpoint. Flow magnitude may, however, be reduced and low flow frequency increased through water diversions such as impoundment and consumptive water withdrawal associated with agricultural irrigation. These factors were used to indirectly identify locations that may be largely unaffected by these stressors to flow.

<u>Other factors that may influence magnitude and frequency of low flows not considered in the current analysis</u>.

Urbanization can cause reduced low flow conditions by direct consumption of surface and ground water for industry and municipal uses. Baseflows and infiltration are also decreased in urbanized areas as a consequence of increased impervious surface (Smakhtin 2001). This effect may, however, be counteracted by leakage of water supply or sewerage infrastructure, return flows and imports of water from outside the catchment (Walsh et al. 2005). Because these effects are mixed, urbanization was not included in this analysis. In addition, silviculture is a major industry in the EWGCP, and deforestation has been shown to have significant impact on low flow conditions (Smakhtin 2001). Brown et al. (2013), however, indicate that changes in the magnitude and timing of this impact can vary by catchment. Future revisions to this landscape endpoint may also wish to consider the potential impact of industrial forest harvest on hydrology.

Production of cultivated crops frequently relies on significant quantities of ground or surface water withdrawals for irrigation. This water is lost from the watershed through increased evapotranspiration and harvesting of the plant material. To identify locations that are potentially at risk for low flows due to agriculture, the NLCD 2011 “Cultivated Crops” category was summarized by HUC12 using the Tabulate Area in ArcMap. For this analysis, we assumed that all crops have equal potential to demand significant water for irrigation. HUCs having greater than 5% of total land area under crop were considered as having potential vulnerability to flow modifications as a result of irrigation.

We used NHDPlus v2 to identify locations that may be at risk for low flows due to abundant or large impoundments. Within the NHDPlus dataset, impoundments are variably attributed as: “Lake/Pond” or “Reservoir”. Open waterbodies within the EWGCP are largely artificial impoundments (however this is not true for many waterbodies in the Florida Panhandle or southwest Georgia). The total area of waterbodies with attributes of “LakePond” or “Reservoir” was calculated for each HUC12 using Tabulate Intersection in ArcMap and normalized using the total area in each HUC. HUCs having less than 1 ha open waterbodies/km^2 were defined as having minimal impact from impoundment. HUCs having greater than 1 ha open waterbodies/km^2 were defined as having potential impact from impoundment.

The above two factors only represent potential threats to flow alteration on a local basis. Ideally, we want to quantify the actual threat to flow alteration by identifying the location, quantity and timing of water withdrawals. The SALCC used currently available state and county level USGS water withdrawal data to quantify water withdrawals associated with individual stream segments (SARP 2012). They encountered significant difficulties associated with input source data accuracy, relating county level data with watershed phenomena, and incorporating patterns of daily variability and seasonality in both withdrawals and flows. The GCP LCC was able to eliminate these problems and improve on the SALCC flow alteration assessment by using state water withdrawal permit data (SARP 2014). However, these data are not available for the GCPO LCC region. Currently, the USGS is in the process of developing a national Site-Specific Water-Use Database (SWUDS). These data should provide improved specific accounting for the type, location, timing and amounts of water withdrawal and should improve our understanding of the risks and opportunities for instream resources.

Summary of Findings

Within the EGCP, areas of widespread cultivated cropland are located in southeast Georgia, southwest Alabama, northern Mississippi, western Tennessee and western Kentucky. Within the WGCP, although there is abundant agricultural activity throughout the geography, most is in pasture and hay, which were assumed to not require irrigation. Cultivated crops are largely located in former floodplain areas along the Arkansas and red River valleys.

Impoundments are abundant throughout the EWGCP and interrupt the flow of many medium-low gradient streams and rivers and their tributaries. While an analysis of the abundance of impoundments is important, the results presented here may overestimate the abundance and potential impact of impoundments as many floodplain, oxbow and other natural lakes and ponds are included. Conversely, many small impoundments in the WGCP are not accurately represented in the medium resolution NHDPlus used in this analysis. Additionally, while the local presence of an artificial waterbody has direct impact on flow, downstream conditions will also be variably affected depending on the size and purpose of the impoundment. An improved analysis of the location and characteristics of barriers to flow (see linear connectedness chapter) would improve the reliability and utility of these results.

Note also that the thresholds established here of <1 ha / km^2 open water bodies and < 5% of total area in agricultural production are based solely on the spatial distribution of the data. Future analysis should consider thresholds that relate directly to species requirements.

<u>Future Directions and Limitations</u>

The analysis presented here depicts only a limited and indirect method for assessing the potential low flow threats attributable to the presence of impoundments and agricultural irrigation in a watershed. This analysis does not quantitatively address the intention of the desired landscape endpoint which is to apply some practical measure or standard to achieve or maintain a natural level of environmental flows.   Richter (2010) states that "the maintenance of environmental flows capable of sustaining healthy river ecosystems should be viewed as both a goal and a primary measure of sustainability in water resources management."

Arthington et al. (2006) and Poff et al. (2010) proposed the Ecological Limits of Hydrologic Alteration (ELOHA) framework that details information needed to define and quantify scientifically defensible environmental flow standards. The process includes: 1) determine robust hydrologic classifications for rivers that have been minimally impact by anthropogenic sources (reference rivers), 2) find the natural range of variability within each river class for specific hydrologic measures, 3) compare the range of variability of reference systems with similar hydrologic measures in impacted systems and determine the level of alteration that falls outside of the natural range of variability for that river class and, 4) establish the relationship between a species or species group and the hydrologic threshold(s) that may be critical to ensure sustainability for that species.

For systems that currently lack a detailed and species driven application of ELOHA, Richter et al. (2012) used an examination of existing standards and personal experience to formulate a presumptive allowable standard of not greater than 20% withdrawal or augmentation of daily natural flow conditions to maintain good ecological conditions. This approach still relies on comparison of existing daily flow conditions with reference conditions.

The GCPO-funded USGS flow modeling project (Lafontaine et al 2013) takes a first significant step in establishing any environmental flow standard by providing critical baseline data: the magnitude and variability of natural hydrology for reference systems. Results from this project may be used to establish a more robust hydrologic classification methodology and expected variability within each class. Many hydrologic classification methods have been developed using an ever increasing variety of hydrologic alteration variables (Henriksen et al. 2006, Olden et al. 2011) related to magnitude, frequency, duration, timing, and rate of change (Poff and Zimmerman 2010). In a recent national study, however, Archfield et al. (2013) found that seven fundamental properties of daily streamflow categorized river classes more reliably compared with statistical analysis of typical hydrologic metrics. SARP has also established a framework of ecologically significant factors to classify rivers. We used the SARP definition of size and gradient in the current analysis and other factors in the SARP's classification framework may be used to help inform an ecological river classification.

As a complementary part of the ELOHA process, species habitat relationships including requirements for flow are being developed as part of another GCPO-funded project, the Freshwater Aquatic Landscape Condition (Davis et al.). This project will explicitly define the hydrologic patterns and variables that may be most important to securing sustainability for the species or species groups that represent intact, functional medium-low gradient streams and rivers within the EWGCP. Natural levels of variation around those key flow variables within a river class may then be determined using results from the flow modeling project.

Results provided by the USGS flow modeling project will only provide flow hydrographs for reference flow conditions. We expect these modeled conditions will be valid for watersheds that have remained largely unaltered by changes to land use or flow diversion. It would be useful to conduct a geospatial analysis similar to the one presented above to identify watersheds that face probability of any type of flow alteration. Comparison with species flow requirements should then be made to evaluate whether the observed level of hydrologic alteration is within acceptable limits that may be tolerated for long term sustainability of that species.

Climate change may also affect low flow conditions, and the USGS flow modeling project will use downscaled climate projections to estimate the amount of variation that may be expected for natural systems in reference condition. Changes may also be expected in the stressors affecting minimum flow requirements (urbanization, population growth, aging infrastructure, mining, crop production, silviculture, etc.) and these factors may affect the ability of a stream to remain within acceptable limits of hydrologic variability.

At the end of the day, all of the above discussion must revisit whether guidelines developed for sustainability of environmental flows fit within prescribed or perceived societal needs for flow (including cultural, recreational and withdrawal needs). Planning tools such as the Water Evaluation and Planning System (WEAP) should be explored for their potential utility in engaging stakeholders to optimize delivery of ecosystem services within a watershed (see Vogel et al. 2007).

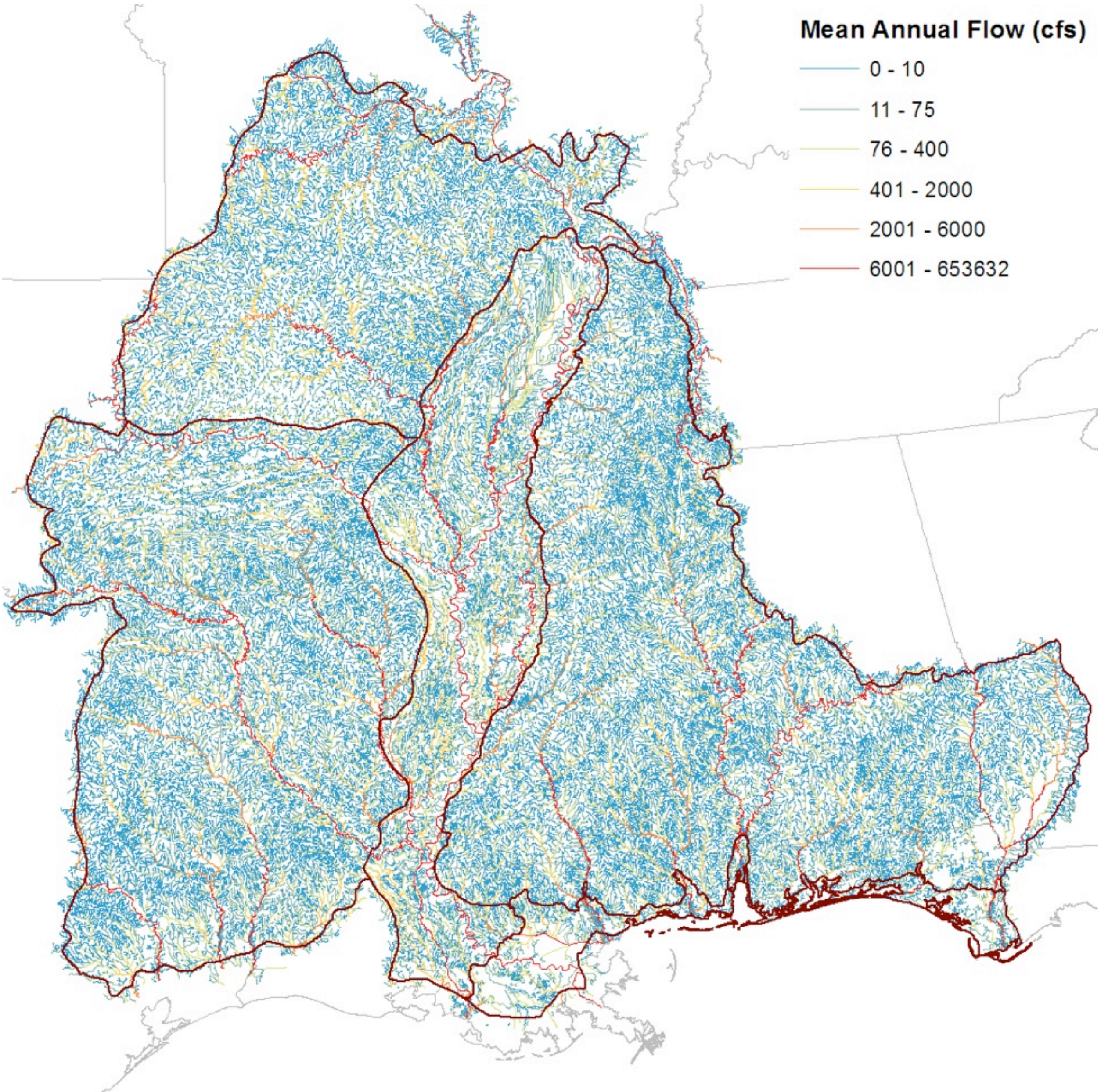


Figure 1. Mean annual flow based on NHDPlusv2 for medium-low gradient streams and rivers in the GCPO.

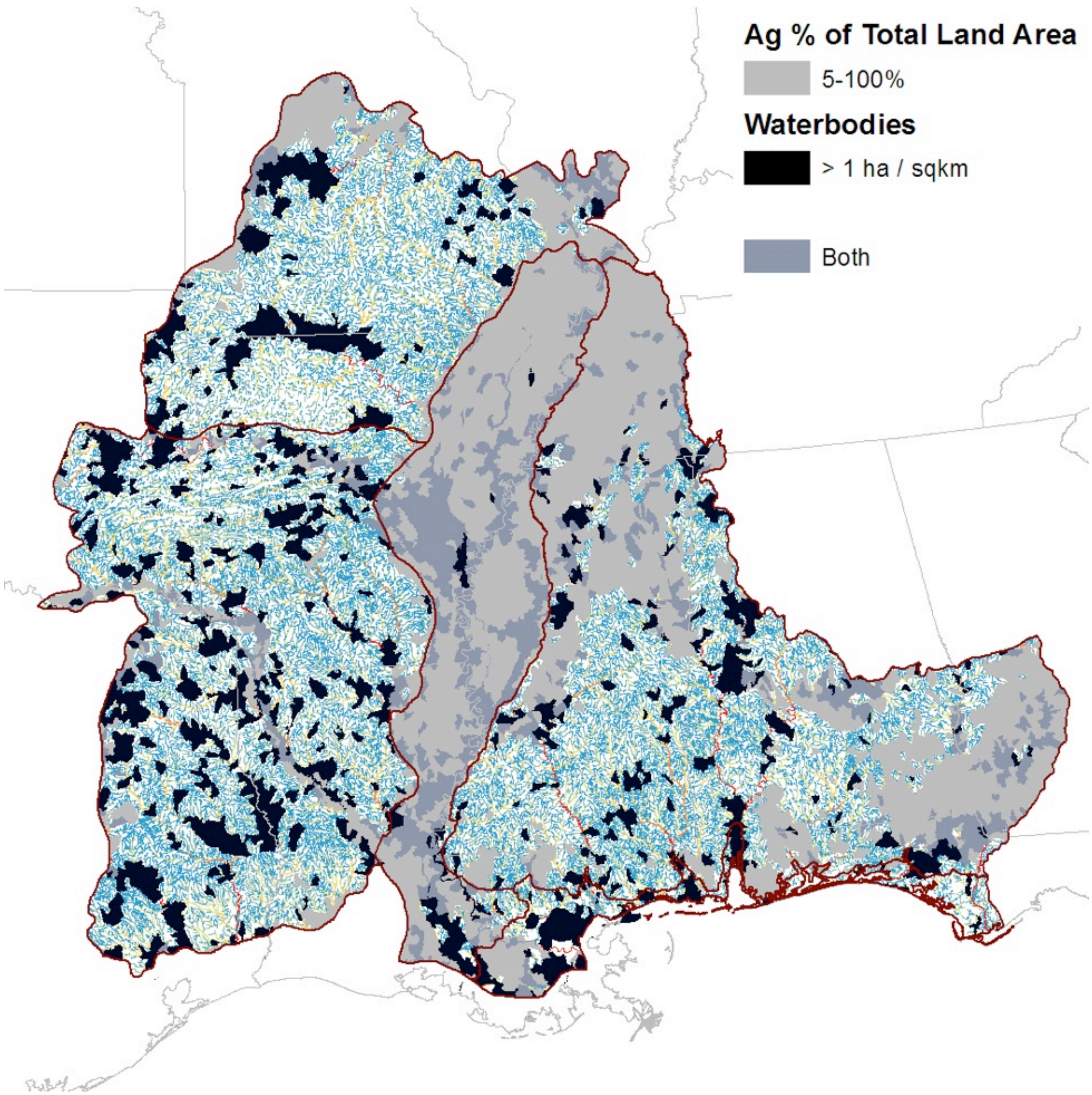


Figure 2. Areas with potential of local alteration of low flows due to human activites. Areas having greater 1 ha open water bodies per square kilometer is overlaid with areas having greater than 5% cultivated cropland within HUC12 watersheds. The remaining stream network is the same as shown in Figure 1.

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Links to Available Geospatial Data Outputs

- Medium-low Gradient Streams and Rivers – Flow
    - GCPO geography (vector – line)
    - GCPO geography (vector – polygon)

Chapter 6: Condition, riffle/pool

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Condition

Desired Landscape Endpoint: Structure – Natural riffle pool sequences.

Data Sources and Processing Methods

At this time, suitable landscape level data sources to characterize this landscape endpoint could not be identified.

Summary of Findings

Even the most basic identification of the location of riffles and pools requires some bathymetric data which is not available on a landscape scale. A qualitative description of a pool is “a topographically low area produced by scour which generally contains relatively fine-grained bed material, whereas a riffle is a topographically high area produced by the accumulation of relatively coarse-grained bed material” (Keller, 1971). However, identification of pools and riffles will depend to some extent on river stage and discharge (Gregory et al. 1994). At a minimum, depth variation along a channel thalweg has been used to identify riffle-pool sequences (Milne 1982), but this technique may overlook significant riffles that do not reach across the entire cross-sectional area of the channel (Hauer et al. 2011). Hauer et al. (2011) included measures of water depth, velocity and bed shear stress to objectively classify pools, riffles and runs (mesohabitats) in rivers.

The target endpoint is also not well defined, but literature suggests some patterns of pool development in natural unobstructed rivers that may be included in consideration of final landscape endpoints. Stream hydraulics along with patterns of flow convergence and meander development, result in so called ‘freely’ formed pools. Leopold et al. (1964) identified an average spacing between pools of five to seven times the channel width. Spacing between pools may, however, be considerably lower in environments having an abundance of obstructions such as boulders, bedrock outcrops or large woody debris (Lisle, 1986; Montgomery and Buffington, 1997, Montgomery et al., 1995) resulting in ‘forced pools’.

Future Directions and Limitations

If suitable landscape scale data are not available, the costs to acquire and effectively incorporate data of sufficient detail into conservation design becomes important. Consideration should be given to species-specific needs to detect the abundance, extent and character of riffle-pool sequences. Is it sufficient just to determine the presence of riffles, or is it critical to also know the nature of the substrate or even grain size distribution? The definition of these limits will determine the survey methods and survey extent that may be most appropriate and cost effective.

Current options for bathymetric collection include low water transect surveys using a “Total Station” and mobile acoustic RTK (real-time kinematic) surveys in high water. Low water digital photogrammetric or terrestrial lidar surveys may adequately characterize the distribution of shallow riffle features. Airborne green beam lidar surveys may be able to detect some subsurface features, given appropriate conditions of depth, water clarity and bottom reflectivity.

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Chapter 7: Condition, sinuosity

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Condition

Desired Landscape Endpoint: Structure – Meandering channels with natural sinuosity.

Data Sources and Processing Methods

The National Hydrographic Dataset (NHDPlus v2) stream segments presented here follow the selection criteria for medium-low gradient streams and rivers: "flow greater than 10 cubic feet per second (Q1000A>10) or cumulative drainage area > 10 square kilometers (TotDASqKM>10) or the stream segment has a specific name (GNIS_Name=TRUE)" and "slope < 0.02." NHD flowlines that intersect NHD waterbody categories of "LakePond," "Estuary" and "Reservoir" were excluded.

We calculated sinuosity on all segments using an ArcGIS sinuosity calculator. Using this toolbox, straight line segments will have a sinuosity value of 1 while more indirect paths will have a value closer to zero. Based on sinuosity values, line segments were classified into four categories: "good", "intermediate", "poor" and "too short". "Good" has sinuosity values less than 0.9; "intermediate" has values greater than or equal to 0.9 and less than 0.99, "poor" has values greater than or equal to 0.99; "too short" represents line segments having lengths of less than 0.5 kilometers. These segments were deemed too short to evaluate for sinuosity.

We also summarized sinuosity by HUC12. Total length of stream segments by category was summarized by each HUC12 using "Tabulate Intersection" in ArcMap. Total length in "good" and "poor" categories in each HUC was normalized by dividing by the total length of non-lake flowlines in each HUC. Missing or empty values occur in HUCs that are wholly encompassed by lakes or reservoirs.

Summary of Findings

In medium-low gradient streams and rivers, high sinuosity may be seen as a measure of increased available habitat diversity. Streams are frequently straightened to reduce localized flooding and increase navigability. This habitat alteration can reduce riffles, pools, and flow refugia and replace these habitats with more constant flow and homogenous depths – in turn leading to shifts in aquatic community composition and species abundance.

In the EGCP there is an elevated abundance of flowlines having very low sinuosity in western Tennessee and north Mississippi where the percent of streams categorized as "poor" range from 10-40% of all non-lake flowlines (Figure 1). This high channelization appears to be associated with extensive agricultural production in these areas. The remainder of the EGCP and the entire WGCP both have a far lower percentage of streams having very low sinuosity. The MAV by comparison has a very high degree of channelization, particularly in north east Arkansas and the boot heel of Missouri.

Future Directions and Limitations

There are many limitations using this approach, so the values reported here should be seen as a first attempt to identify locations having natural versus altered channel configurations. The approach may be more informative by comparing relative results among HUCs, but it is less reliable when viewed by line segment. The analysis is limited by the resolution of the NHD. Compared with higher resolution data sources, the medium resolution NHD will underestimate sinuosity. The analysis is also highly dependent on segment length. This approach will misclassify channelized segments that are mostly straight but have a significant bend or multiple angular bends. Such segments were usually misclassified as "intermediate," but in extreme cases may be misclassified as "good."

The measurements and determination of sinuosity could be further improved by aggregating stream reaches to an appropriate stream length to be determined by species or ecosystem requirements. The appropriate summary reach length will also likely vary by stream power since larger streams may be expected to have reduced sinuosity compared with smaller streams.

The thresholds for sinuosity established here were determined based solely on visual inspection of stream and river spatial configurations and do not relate to species requirements. Further determination of species-specific requirements and the applicability of these data to describing those relationships accurately should be further investigated.

Tables and Figures

Table 1. Amount (km) of streams in each sinuosity category by subgeography.

Geographic extent	Medium-low Gradient Streams and Rivers Sinuosity Categories				
	Good	**Intermediate**	**Poor**	**Too short**	**Total**
Mississippi Alluvial Valley	26,090	14,140	490	1,571	42,291
East Gulf Coastal Plain	65,296	38,399	4,623	4,396	112,714
West Gulf Coastal Plain	75,672	14,937	3,634	2,985	97,228
Ozark Highlands	29,976	17,482	676	2,269	50,403
Gulf Coast	5,713	2,607	401	465	9,186
Gulf Coastal Plains and Ozarks (full extent)*	200,552	87,060	9,777	11,675	309,064

* Note that the total length of streams in each subgeography is based on stream segments touching the boundaries of the subgeography. A single segment that bridges two HUCs may be counted in each subgeography. The total length of streams for the entire GCPO is therefore less than estimates based on a sum of all subgeographies.

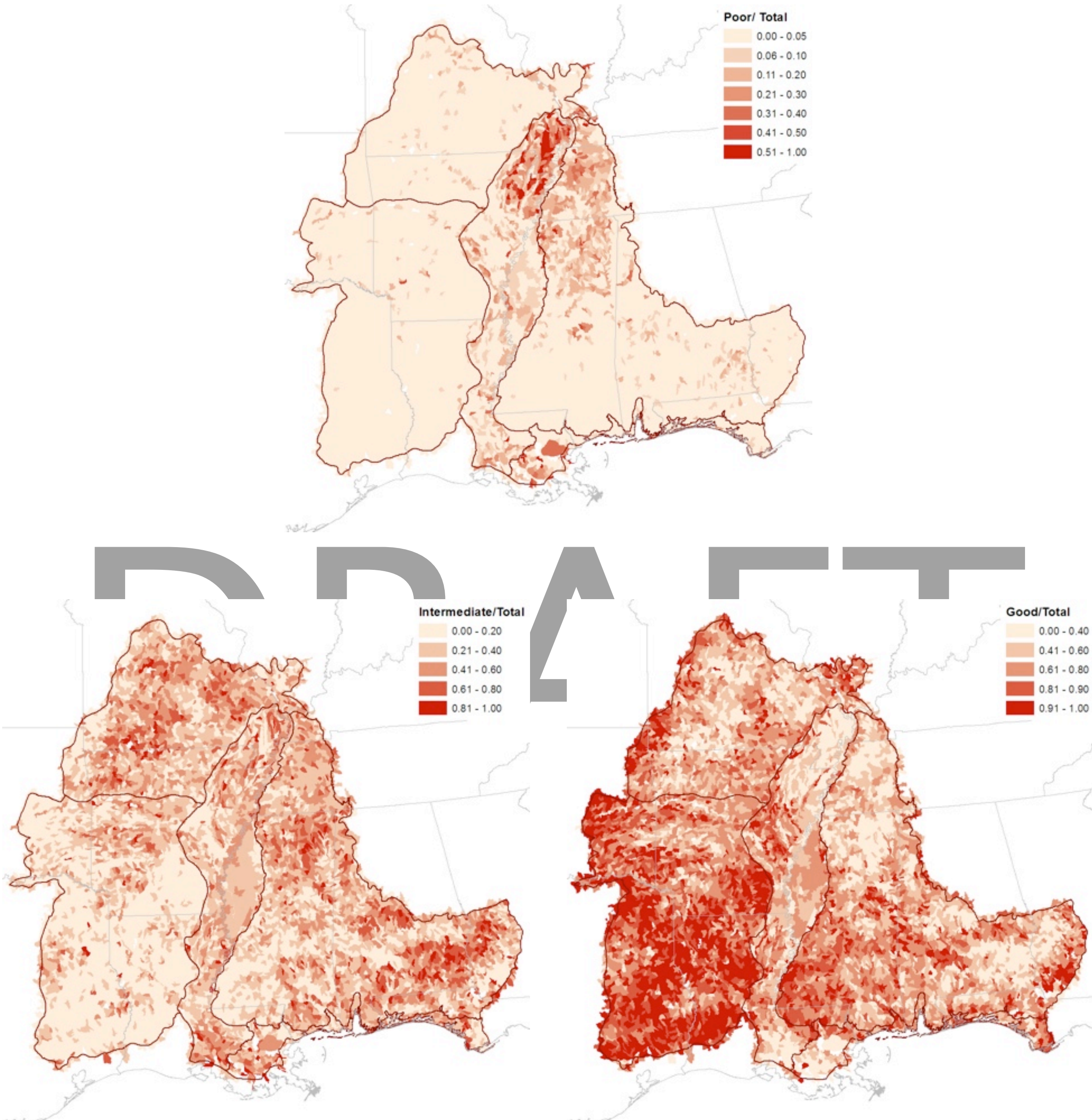

Figure 1. Percentage of medium-low gradient streams and rivers classified as having “poor”, “intermediate” or “good” sinuosity based on thresholds and methods described in the text.

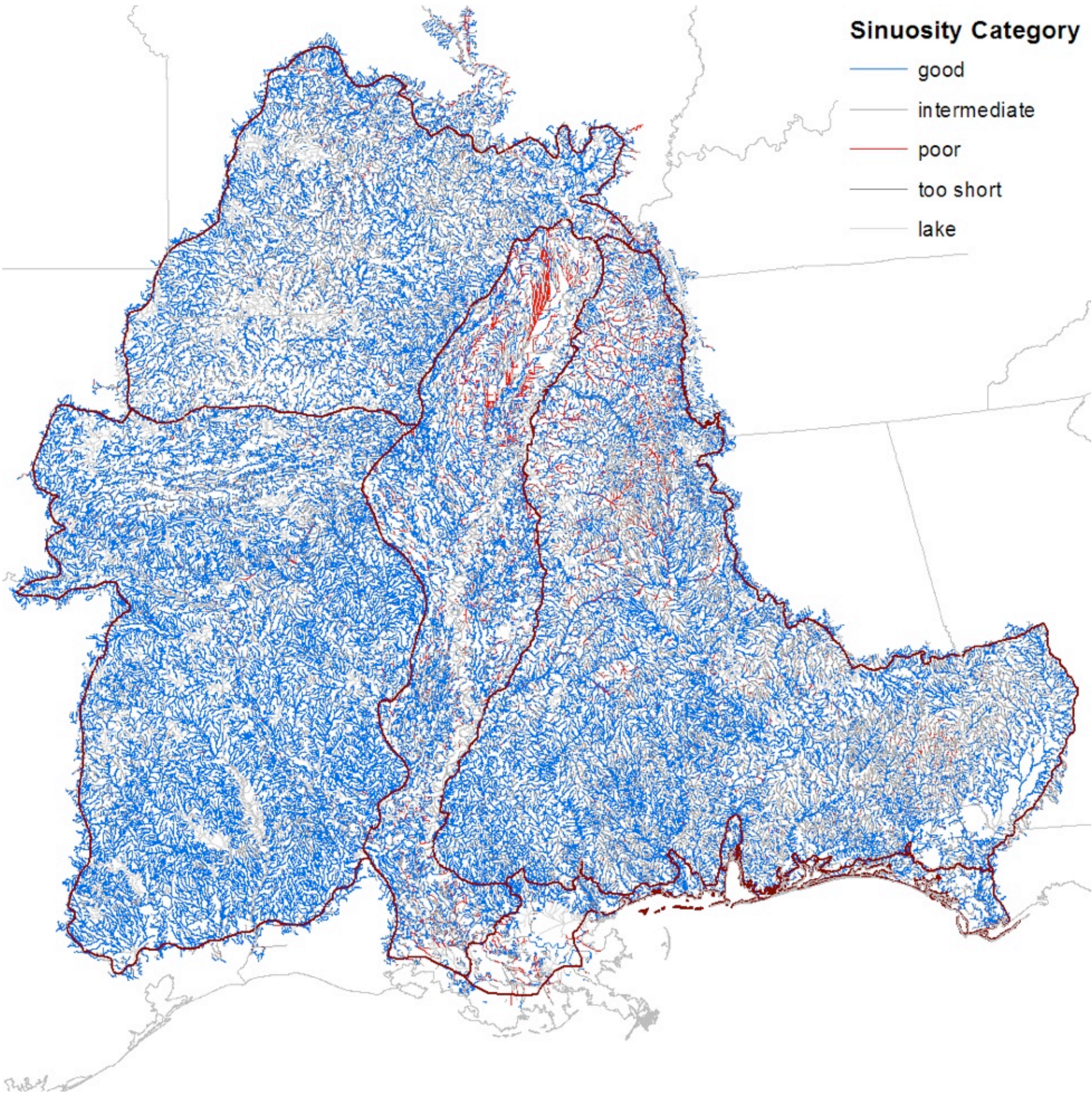

Figure 2. Category of sinuosity for medium-low gradient streams and rivers in the GCPO based on thresholds and methods described in the text.

<u>Conservation Planning Atlas Links to Available Geospatial Data Outputs (in process)</u>

- Medium-low Gradient Streams and Rivers – sinuosity
  - GCPO geography (vector – line)
  - GCPO geography (vector – polygon)

Chapter 8: Condition, small woody debris

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Condition

Desired Landscape Endpoint: Structure – High amounts of small woody debris.

Data Sources and Processing Methods

At this time, suitable landscape level data sources to characterize this landscape endpoint could not be identified.

Summary of Findings

Literature relating landscape variables specifically to the amount of in stream small woody debris (SWD) are sparse.

Culp et al. (1996) found that SWD provided structurally complex habitat that provided refuge from predators and increased carrying capacity for trout fry. At a coarse level, the analysis of SWD may be similar to that of large woody debris, but SWD is less likely to be retained locally. Retention is likely to be influenced more by seasonal variation in flow and site-specific characteristics related to local flow conditions and the amount of obstacles in the stream (Young et al. 1978, Speaker et al. 1984).

Future Directions and Limitations

Results from the ongoing daily flow model in development for the GCPO LCC may be able to provide coarse estimates of particulate transport.

If suitable landscape scale data are not available, the costs to acquire and effectively incorporate data of sufficient detail into conservation design becomes important. Consideration should be given to species-specific needs to detect the appropriate abundance, extent and character of SWD. The definition of these limits will determine the survey methods and survey extent that may be most appropriate and cost effective.

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Chapter 9: Condition, large woody debris

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Condition

Desired Landscape Endpoint: Structure – Adequate amounts of large woody debris

Data Sources and Processing Methods

Two data sources were used to estimate the availability of large woody debris (LWD) for medium-low gradient streams and rivers in the EWGCP. The SARP Riparian Assessment (SRA) uses the high resolution NHD (NHDH) and is based on the 2001 NLCD. We developed a new assessment using the subset of medium-low gradient streams and rivers as defined and used throughout this document as well as the 2011 NLCD.

Data in the SRA consists of flowline and polygon features, which includes attributes containing the total riparian area and riparian area in each NLCD class for each feature (polygon or line segment). Polygon features generally denote larger streams and rivers (>10m width) while line features are generally associated with smaller stream and rivers. LWD has a greater local impact on smaller streams having lower widths and lower peak and lower mean annual flow rates (Keller and Swanson 1979, Bilby and Ward 1989), so only line features were used in the current analysis.

The density of lines included in the SARP riparian assessment varied across the GCPO based on available NHDH flowline density (see Kaeser and Watson 2011). The NHDH flowlines also do not necessarily intersect the NHDPlus medium resolution flowlines used throughout this document. To reduce both of these problems and isolate only medium-low gradient streams and rivers, only line segments from the SARP riparian assessment located within 10 meters of defined medium-low gradient streams and rivers were selected. For each selected segment, forested riparian area fields (NLCD categories 41, 42, 43 and 90) in the SARP attribute table were summarized as shown below.

$$Proportion\ Forested\ Riparian\ SARP = \frac{(VALUE41 + VALUE42 + VALUE43 + VALUE90)}{total\ riparian\ land}$$

Results from this analysis are shown in Figure 1. We also summarized forested riparian area by HUC12 using “Tabulate Intersection” in ArcMap. For each HUC, the proportion of forested riparian area was calculated as the sum of all forested riparian area normalized by the total riparian land in the HUC. HUCs having less than 2 hectares of total riparian land were not included in the analysis and appear as missing or empty HUCs (Figure 2). Missing or empty values also occur in HUCs that are wholly encompassed by lakes or reservoirs.

We also completed analysis based on NLCD 2011 using the same medium-low gradient streams and rivers NHDPlus flowlines employed throughout this document. As in the SARP assessment, only line segments were used and not polygon features because the local impact of LWD is likely to be greatest for smaller streams. The average mean annual (non-zero) flow for the smaller stream segments used in this analysis (for the entire GCPO) was 106 cubic feet per second and mean stream segment length was 1.7 kilometers. By contrast, the average mean annual (non-zero) flow for larger stream segments not used in this analysis was 26,718 cfs and mean stream segment length was 1.6 km.

Each flowline segment was buffered to produce polygons having 30m on each side. We evaluated each polygon to determine the proportion of each NLCD category in the polygon using Geospatial Modelling Environment (isectpolyrst). Using this function, very small segments (0-28m) could not be classified and were deleted. We created a new field to determine the total proportion of “forested” in each polygon (NLCD categories, 41,42,43 and 90). We then adjusted this estimate to exclude that proportion of the polygon categorized as “open water” (NLDC=11) as shown below.

$$Proportion\ Forested\ 2011\ (nonwater) = \frac{(NLCD\ 41 + NLCD\ 42 + NLCD\ 43 + NLCD\ 90)}{(1 - NLCD\ 11)}$$

Polygons having 100% water were assumed to represent problems associated with channel migration or large channel width. These polygons were assigned a value of -99 and were excluded from subsequent analysis. The proportion of forested non-water attribute was joined back to each flowline using its common ID(COMID). Results from these lines can be seen in Figure 3.

The average proportion of 2011 forested riparian area for smaller streams was also evaluated by HUC12 (Figure 2). For this analysis, we summed the total length of smaller streams for each HUC using “Tabulate Intersection” in ArcMap. We then calculated a length-weighted proportion of forested riparian area as shown below.

$$Total\ km\ forested\ nonwater\ in\ a\ HUC = \sum proportion\ forested\ nonwater * lengthkm$$

Total length of forested non-water was normalized by dividing by the total length of assessed segments in the HUC. HUCs having less than 2 km of assessed waterway were not included in the analysis and appear as missing or empty HUCs. Missing or empty values also occur in HUCs that are wholly encompassed by lakes or reservoirs.

Summary of Findings

The 2011 assessment includes more stream length (290,029 km) compared with the SRA (244,712km). The mean line segment is, however, longer for the 2011 assessment (1.7 km), compared with 0.8 km for the SRA. This detail shows greater precision using the SRA, but greater currentness and coverage using the 2011 assessment.

Overall, the landscape level patterns of potential LWD availability were similar for both assessments (Table 1,Table 2). Both the EGCP and WGCP have high amounts of streams having greater than 80% forested riparian zone. The northern extent of the EGCP generally shows a lower abundance of forested riparian habitat with the expected consequence that the availability of large woody debris may be quite limited for stream segments in these regions compared with medium-low gradient streams and rivers in the south and eastern EGCP (Figure 1, Figure 2). The former areas are typically associated with agricultural production including row crops and hay/pasture. Similarly, low abundance of forested riparian habitat is found in the WGCP along the Arkansas and Red rivers in floodplain areas that have been converted to agricultural production.

Stream abundance is low in the karst area of the Dougherty Plain of Southwest Georgia and north central region of Florida where there is an abundance of sinkholes and losing streams.

Future Directions and Limitations

As in other assessments, definitions and target thresholds for the size and abundance of LWD are not specified. The presence of forested riparian vegetation alone is only the first step in determining the abundance of large woody debris. Once LWD targets are established, other factors related to frequency and intensity of overbank flow, channel width, floodplain extent, channel erodibility, and sinuosity may also be incorporated to assess LWD. Bragg et al. (2000) describe a relationship between mean bankfull widths (which may be estimated by mean annual flow) and LWD volume in small streams of the central Rocky Mountains. Moulin et al. (2011) and Schenk et al. (2014) found that bank roughness, channel geometry and flow dynamics influence LWD accumulation. The presence of locks and dams will also influence LWD. Sinuosity measures are already available in another chapter of this Assessment. Factors related to flow amount and duration may be evaluated in more detail as results from the GCPO daily flow modeling project become available.

The analysis presented here is limited to smaller streams because the impact of LWD is more likely to remain local in streams having lower flow and smaller widths. The same analysis could also be conducted for larger streams although the impact of LWD debris in these systems will be most concentrated along the immediate riparian zone. This analysis would be more complicated because the polygon representing the larger stream frequently encompasses a very long stream segment, and calculation of average conditions over this very large area is less useful. Parameters are also more uncertain because of the relatively greater potential for inaccuracies in channel delineation using the NHD and the likely transport of LWD to downstream locations at peak flow periods.

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Tables and Figures

Table 1. Amount (km) of streams by proportion of forested riparian based on SARP riparian assessment and 2011 NLCD classification by subgeography. Note that the SARP assessment covers a subset of the medium-low gradient streams as defined in this GCPO assessment .

	Geographic extent	Medium-low Gradient Streams and Rivers km forested by category				
		<0.2	0.2-0.4	0.4-0.6	0.6-0.8	>0.8
SARP Riparian Assessment	Mississippi Alluvial Valley	4,568	1,999	1,802	2,036	5,258
	East Gulf Coastal Plain	6,140	5,895	8,261	13,607	66,697
	West Gulf Coastal Plain	2,870	3,091	5,845	11,405	60,234
	Ozark Highlands	3,677	4,114	6,216	9,041	18,587
	Gulf Coast	442	155	227	400	3,094
	Gulf Coastal Plains and Ozarks (full extent)*	17,643	15,156	22,210	36,303	153,400
2011 Riparian Assessment	Mississippi Alluvial Valley	12,785	5,414	5,073	5,199	12,167
	East Gulf Coastal Plain	4,440	6,325	10,498	18,508	68,048
	West Gulf Coastal Plain	2,215	3,311	6,650	16,830	60,088
	Ozark Highlands	2,593	4,616	7,632	12,088	21,305
	Gulf Coast	912	287	445	858	4,215
	Gulf Coastal Plains and Ozarks (full extent)*	22,829	19,751	29,981	52,967	164,501

* Note that the total length of streams in each subgeography is based on stream segments touching the boundaries of the subgeography. A single segment that bridges two HUCs may be counted in each subgeography. The total length of streams for the entire GCPO is therefore less than estimates based on a sum of all subgeographies.

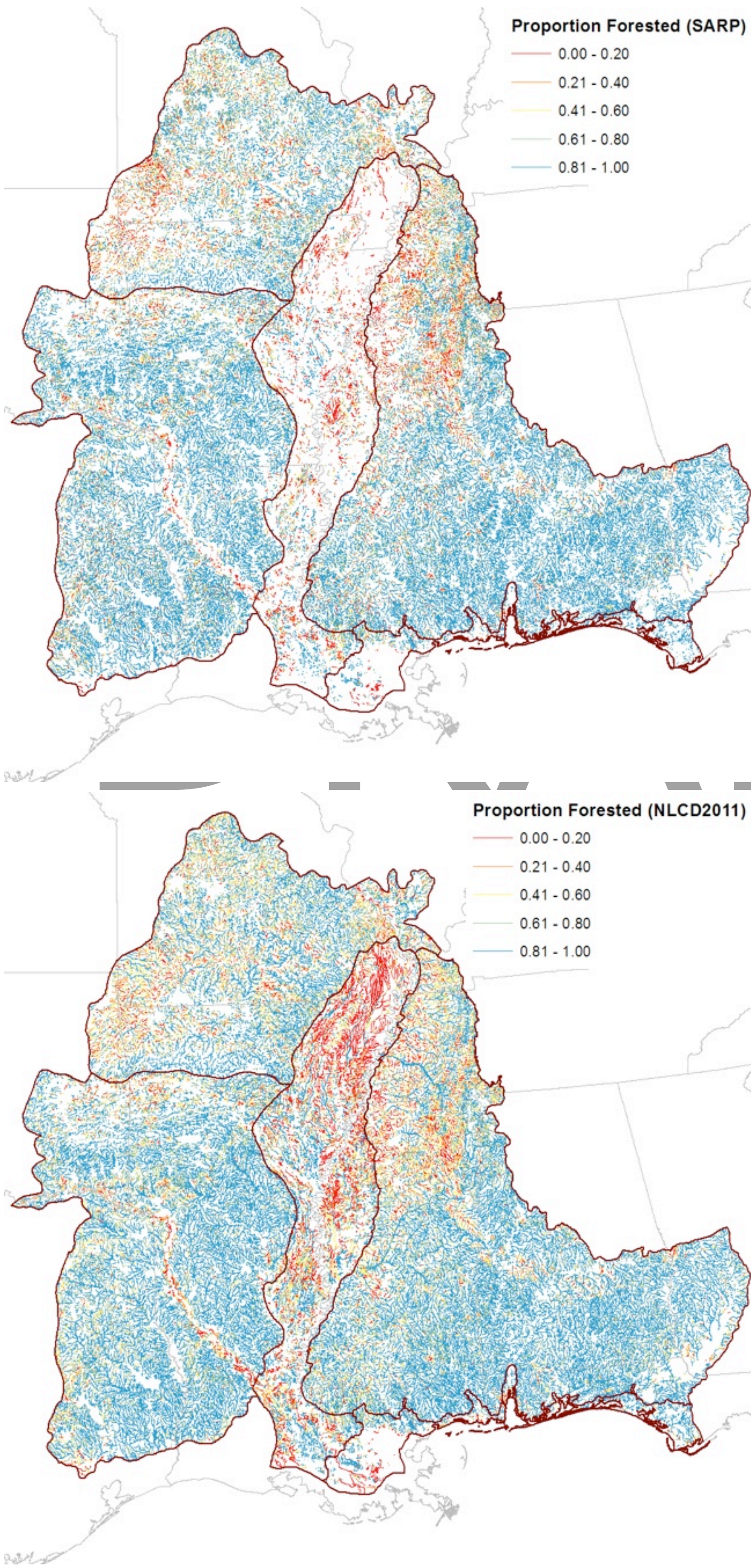

Figure 1. Proportion forested non-water area in the riparian zone for each NHDPlus v2 segment based on SARP riparian assessment (top) and NLCD 2011 (bottom). Note the varying stream selection and assessment criteria described in text.

Table 2. Percentage of streams by proportion forested riparian based on SARP riparian assessment and 2011 NLCD classification by subgeography. Note that the SARP assessment covers a subset of the medium-low gradient streams as defined in this full GCPO assessment.

	Geographic extent	Medium-low Gradient Streams and Rivers – % forested riparian zone by category				
		<0.2	0.2-0.4	0.4-0.6	0.6-0.8	>0.8
SARP Riparian Assessment	Mississippi Alluvial Valley	29%	13%	12%	13%	34%
	East Gulf Coastal Plain	6%	6%	8%	14%	66%
	West Gulf Coastal Plain	3%	4%	7%	14%	72%
	Ozark Highlands	9%	10%	15%	22%	45%
	Gulf Coast	10%	4%	5%	9%	72%
	Gulf Coastal Plains and Ozarks (full extent)	29%	13%	12%	13%	34%
2011 Riparian Assessment	Mississippi Alluvial Valley	31%	13%	12%	13%	30%
	East Gulf Coastal Plain	4%	6%	10%	17%	63%
	West Gulf Coastal Plain	2%	4%	7%	19%	67%
	Ozark Highlands	5%	10%	16%	25%	44%
	Gulf Coast	14%	4%	7%	13%	63%
	Gulf Coastal Plains and Ozarks (full extent)	31%	13%	12%	13%	30%

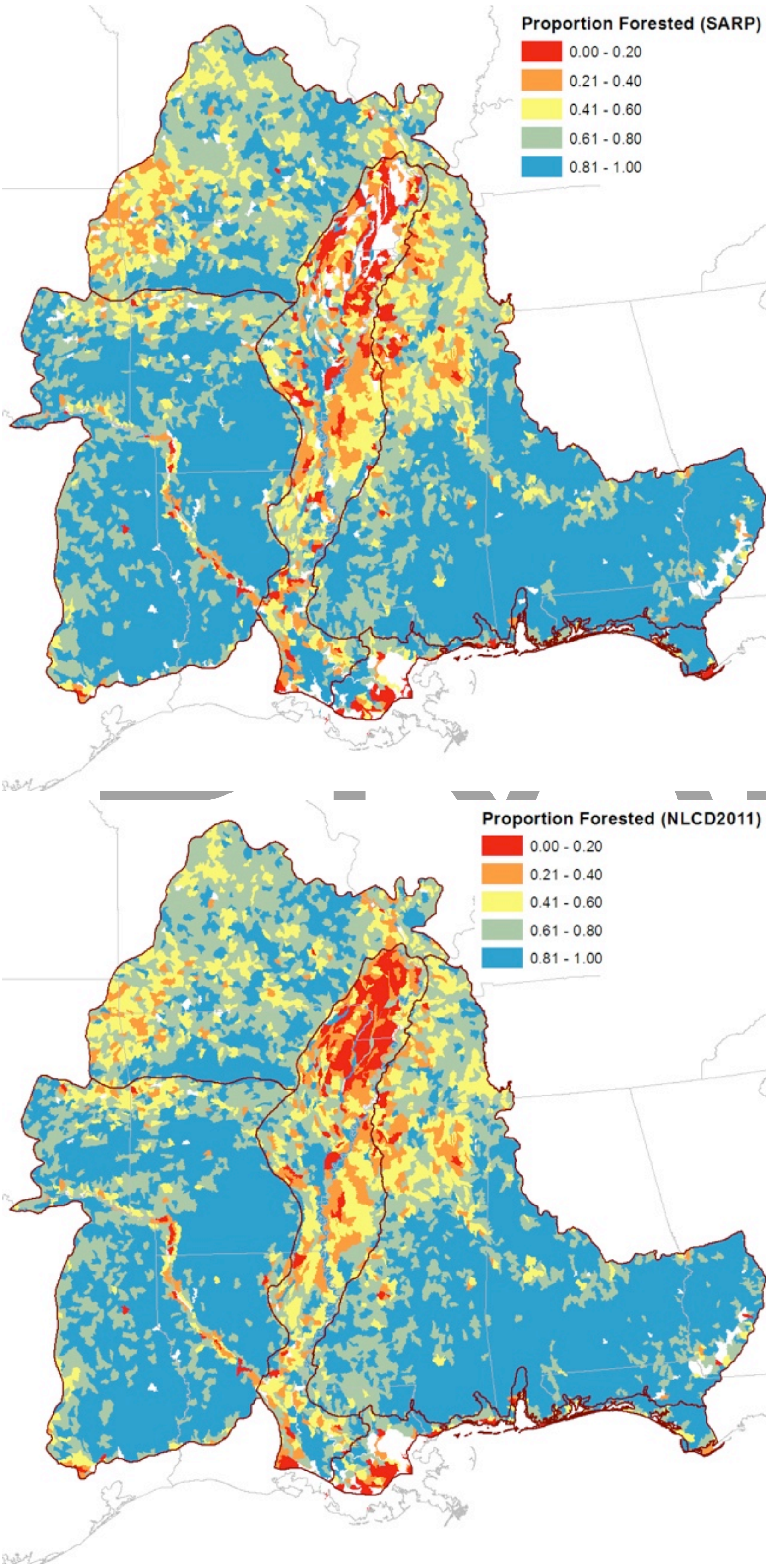

Figure 2. Proportion forested non-water area in the riparian zone of stream segments in each HUC based on SARP riparian assessment (top) and NLCD 2011 (bottom). Note that only smaller stream segments are included in this assessment and not larger streams and rivers (see text).

Conservation Planning Atlas Links to Available Geospatial Data Outputs (in process)

- Medium-low Gradient Streams and Rivers – LWD - SRA
  - GCPO geography (vector – line)
  - GCPO geography (vector – polygon)

- Medium-low Gradient Streams and Rivers – LWD – 2011 assessment
  - GCPO geography (vector – line)
  - GCPO geography (vector – polygon)

Chapter 10: Condition, structure - diversity of substrates

Subgeography: **EAST/WEST GULF COASTAL PLAIN**

Ecological System: **Medium-low Gradient Streams and Rivers**

Landscape Attribute: Condition

Desired Landscape Endpoint: Structure – Diversity of substrates including numerous gravel beds and sandbars.

Data Sources and Processing Methods

At this time, suitable landscape level data products to characterize this landscape endpoint could not be identified.

Summary of Findings

Instream substrate composition is important to a wide variety of aquatic organisms, and factors that influence instream substrate include: local and landscape geology, topography, land use configuration, riparian conditions, and stream power (a function of discharge and slope) (Allan and Castillo 2007). Site specific evaluations of the distribution and size of inorganic and organic particles can be made at the site or reach scale. A less quantitative, but still useful, approach may be to report the dominant and subdominant particle size. Larger scale in situ assessments can, however, become prohibitively labor-intensive, and site specific substrate measures may be difficult to transfer to a practical understanding of habitat configuration at the stream reach or watershed scale.

Riparian zone geology and land use both affect landscape scale predictions of instream substrate (Richards et al 1996). Wang et al. (2003) demonstrated 67% of variance in substrate could be explained by a combination of surficial geology, topography, watershed and riparian land use. Results from riparian land cover conditions would be similar to the analysis conducted for large woody debris in another chapter, but a comprehensive model that develops a quantitative linkage between geology, watershed and riparian landcover, on the one hand, with the presence and distribution of gravel beds and sandbars, on the other, would require further detailed analysis that is beyond the scope of this assessment.

In the absence of a well parameterized landscape model that is able to predict instream substrate to an accuracy sufficient to inform conservation actions, other methods to more quickly characterize subsurface aquatic habitats at a landscape scale are needed. Traditionally, sidescan sonar has been used to evaluate substrate composition on a broad scale. In recent years, several low-cost options using recreational grade sonar units have emerged that greatly improve the potential for developing more comprehensive aquatic habitat maps similar to what is commonly available for the terrestrial environment. These options can provide not only a more spatially complete characterization of inorganic substrate, but also the spatial distribution of organic substrates such as large woody debris and submerged aquatic vegetation.

Most commercial grade sidescan sonar processing deployments are prohibitively expensive for conservation applications. Kaeser and Litts (2008), however, developed a low-cost method for assessing subsurface characteristics using recreational grade sidescan sonar. SonarTRX also offers relatively low-cost sidescan sonar processing software. In both cases, results from sonar processing may be exported to traditional GIS applications for heads-up digitizing of instream habitats. Because of potentially large variability in environmental conditions and hardware settings used during the acquisition of acoustic data, classification should be related to some spot assessments of instream conditions using traditional habitat survey methods (such as Simonson et al. 1994).

As with other variables, the level of detail required versus the costs to acquire and effectively incorporate those data into conservation design is important. Consideration should be given to species-specific needs to detect the abundance, extent and character of substrate type. The definition of these limits will determine the survey methods and survey extent that may be most appropriate and cost effective to assist conservation delivery. Conversely, the results from any acoustic survey should be evaluated to determine whether they are at an appropriate scale and resolution to inform landscape scale conservation objectives.

Future Directions and Limitations

More specific habitat objectives will help to identify the best options for developing landscape scale data to characterize substrate composition. These objectives are perhaps best explored in conjunction with species-specific habitat requirements.

Because it is so labor-intensive, heads-up digitization of instream habitats conducted using acoustic techniques is a current bottleneck. Options for more automated bottom characterization will be explored in a current project to develop a watershed plan for Pearl River Basin.

A well-parameterized landscape model could also be developed to predict landscape scale patterns of substrate composition. GCPO-wide geology is currently being developed as part of the land cover database, and this dataset will be a crucial part of any model input.

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