Upland Streams and Rivers of the Ozark Highlands

Introduction

"High gradient streams and rivers of the Ozark Highlands" were selected by the Gulf Coastal Plains and Ozarks (GCPO) Adaptation Science Management Team (ASMT) as a priority habitat system. The goal of this document discover and apply geospatial data and analysis to estimate the amount, configuration and condition of key habitat features of this priority habitat in the GCPO.

The desired ecological state for priority habitat systems should characterize the least impacted condition – systems in this condition should be targets for maintenance/protection and the goal of restoration activities in degraded systems. In the GCPO Integrated Science Agenda (ISA), a general description of the desired ecological state for this habitat is: "*Small springs, runs, and headwaters characterized by clear, clean, and relatively cold water in largely undisturbed forest settings*". Landscape endpoints for this habitat are listed as:

Amount: Maintain current river miles

Configuration:

- Landscape context: watersheds should be >75% forested, with <10% impervious cover
- Intact riparian corridors consisting primarily of hardwoods within 30 m buffer of stream
- Interconnected stream systems

Condition:

Water Quality

- High water quality – minimal contaminants and nutrients
- Temperatures – low
- DO – high
- Sediment – minimal

Water Quantity

Natural flow regimes maintained

- Groundwater flow regime: low flow variability, low peak flows, low frequency of low flows
- Runoff Flow regime: moderate flow variability, moderate peak flows, moderate frequency of low flows
- Intermittent flow regime: high flow variability high peak flows, high frequency of lows flows

Structure

- Abundant leaf litter
- Variety of substrates – gravel to boulders

The GCPO ecological assessment (version 1) for medium-low gradient streams used a 2% slope threshold to differentiate medium-low gradient streams from high gradient streams. This gradient threshold was chosen to align with categories of “high” and “very high” established by the Southeast Aquatic Resources Partnership (SARP). These classification categories were based on fish distribution patterns across the southeast including both the Appalachian and Ozark mountains. Climatic conditions in the Ozark mountains are, however, significantly drier during the summer compared with the more humid Appalachians to the east. The natural flow regimes (Leasure et al. 2014) for streams in the Ozarks having slope > 2% were overwhelmingly classified as “intermittent flashy” or “intermittent runoff”. These flow regimes are characterized by 1-3 months of zero flow days and do not appear to align well with the desired ecological condition description of the ISA. For this reason, we adopted a modified definition of **“upland streams and rivers”** based on elevation greater than 130m for the current assessment. This elevation threshold was suggested by the GCPO SARP project to refine the ISA for aquatic systems. As a result, the revised definition of this broadly defined habitat includes rivers and streams having a wide range of slope/gradient classes (Figure 1).

Data from the EPA StreamCat database (Hill et al. 2016) was used extensively throughout this assessment.

Hill, Ryan A., Marc H. Weber, Scott G. Leibowitz, Anthony R. Olsen, and Darren J. Thornbrugh, 2016. The Stream-Catchment (StreamCat) Dataset: A Database of Watershed Metrics for the Conterminous United States. Journal of the American Water Resources Association (JAWRA) 1-9. DOI: 10.1111/1752-1688.12372

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint: Maintain current river miles

Landscape Attribute: Amount

Data Sources and Processing Methods:

We used NHD Plus v2 flowlines to define the location of upland streams and rivers in the GCPO. NHD 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 by subgeography 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 the smallest 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.”

Upland streams and rivers were defined as having an elevation of > 130m (MINELEVSMO> 13000). We chose this threshold to align with river the ongoing SARP project to revise the aquatics endpoints for the ISA. The extent of upland streams and rivers satisfying this elevation is shown in Fig XX. This definition includes rivers and streams in the Ouachita Mountains of the West Gulf Coastal Plain (WGCP) and also in the Tennessee Valley of the East Gulf Coastal Plains (EGCP). A slightly higher elevation threshold of 150m would eliminate most of the rivers and streams included in the EGCP. By using the elevation thresholds, a wide range of slope categories are included in the analysis.

Summary of Findings:

The distribution of upland streams and rivers in each subgeography based on elevation is shown in Fig XX and Table XX. The OZH subgeography has the most streams and rivers >130m (46,220km; 62% of total for the GCPO). The WGCP has 19,448 km (26% of total for the GCPO) and the EGCP has the smallest (8,910; 12% of total for the GCPO) and most of those (69% of total for the EGCP) is at elevations below 150m.

Throughout all the subgeographies, most upland rivers and streams fell into moderate (0.5-2%) or low-moderate (0.1-0.5%) gradient categories (Table XX). Upland rivers and streams (> 130m) falling into the highest gradient category (> 2%) captured a much smaller fraction (8-15%) of the total abundance of streams regardless of subgeography.

Future Directions and Limitations:

The lack of updates to NHD data will limit the ability of these data to detect changes in amount of upland streams and rivers.

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 upland streams and rivers within each slope and elevation class in the GCPO LCC by subgeography. Estimates are based on NHDPlus v2 using specific selection criteria and definitions described in the text. Important figures related to the distribution of habitats are highlighted in bold.

Subgeog	Length (km)	% of total within the GCPO	Elevation	Length (km)	% of total in each elevation class within each subgeography	Slope Class	Slope	Length (km)	% of total within each slope and elevation class within each subgeography
OZH	**46,220**	**62%**							
			130-150 m	2,605	6%				
						High	>2%	282	11%
						Mod	0.5-2%	857	33%
						Low-Mod	0.1-0.5 %	1,296	**50%**
						Low	<0.1%	169	6%
			>150 m	43,615	**94%**				
						High	>2%	5,421	12%
						Mod	0.5-2%	12,542	29%
						Low-Mod	0.1-0.5 %	21,654	**50%**
						Low	<0.1%	3,999	9%
			>130 m	46,220	100%				
						High	>2%	5,703	12%
						Mod	0.5-2%	13,399	29%
						Low-Mod	0.1-0.5 %	22,950	**50%**
						Low	<0.1%	4,168	9%

Subgeog	Length (km)	% of total within the GCPO	Elevation	Length (km)	% of total in each elevation class within each subgeography	Slope Class	Slope	Length (km)	% of total within each slope and elevation class within each subgeography
WGCP	**19,448**	**26%**							
			130-150 m	4,505	23%				
						High	>2%	944	21%
						Mod	0.5-2%	1,871	**42%**
						Low-Mod	0.1-0.5 %	1,492	33%
						Low	<0.1%	199	4%
			>150 m	14,943	**77%**				
						High	>2%	1,920	13%
						Mod	0.5-2%	4,212	28%
						Low-Mod	0.1-0.5 %	7,002	**47%**
						Low	<0.1%	1,808	12%
			>130 m	19,448	100%				
						High	>2%	2,864	15%
						Mod	0.5-2%	6,083	31%
						Low-Mod	0.1-0.5 %	8,495	**44%**
						Low	<0.1%	2,006	10%

Subgeog	**Length (km)**	**% of total within the GCPO**	**Elevation**	**Length (km)**	**% of total in each elevation class within each subgeography**	**Slope Class**	**Slope**	**Length (km)**	**% of total within each slope and elevation class within each subgeography**
EGCP	**8,910**	**12%**							
			130-150 m	6,108	**69%**	High	>2%	556	9%
						Mod	0.5-2%	2,753	**45%**
						Low-Mod	0.1-0.5 %	2,676	44%
						Low	<0.1%	122	2%
			>150 m	2,803	31%				
						High	>2%	163	6%
						Mod	0.5-2%	687	25%
						Low-Mod	0.1-0.5 %	1,622	**58%**
						Low	<0.1%	330	12%
			>130 m	8,910	100%				
						High	>2%	720	8%
						Mod	0.5-2%	3,441	39%
						Low-Mod	0.1-0.5 %	4,299	**48%**
						Low	<0.1%	451	5%
Total	**74,579**	**100%**							

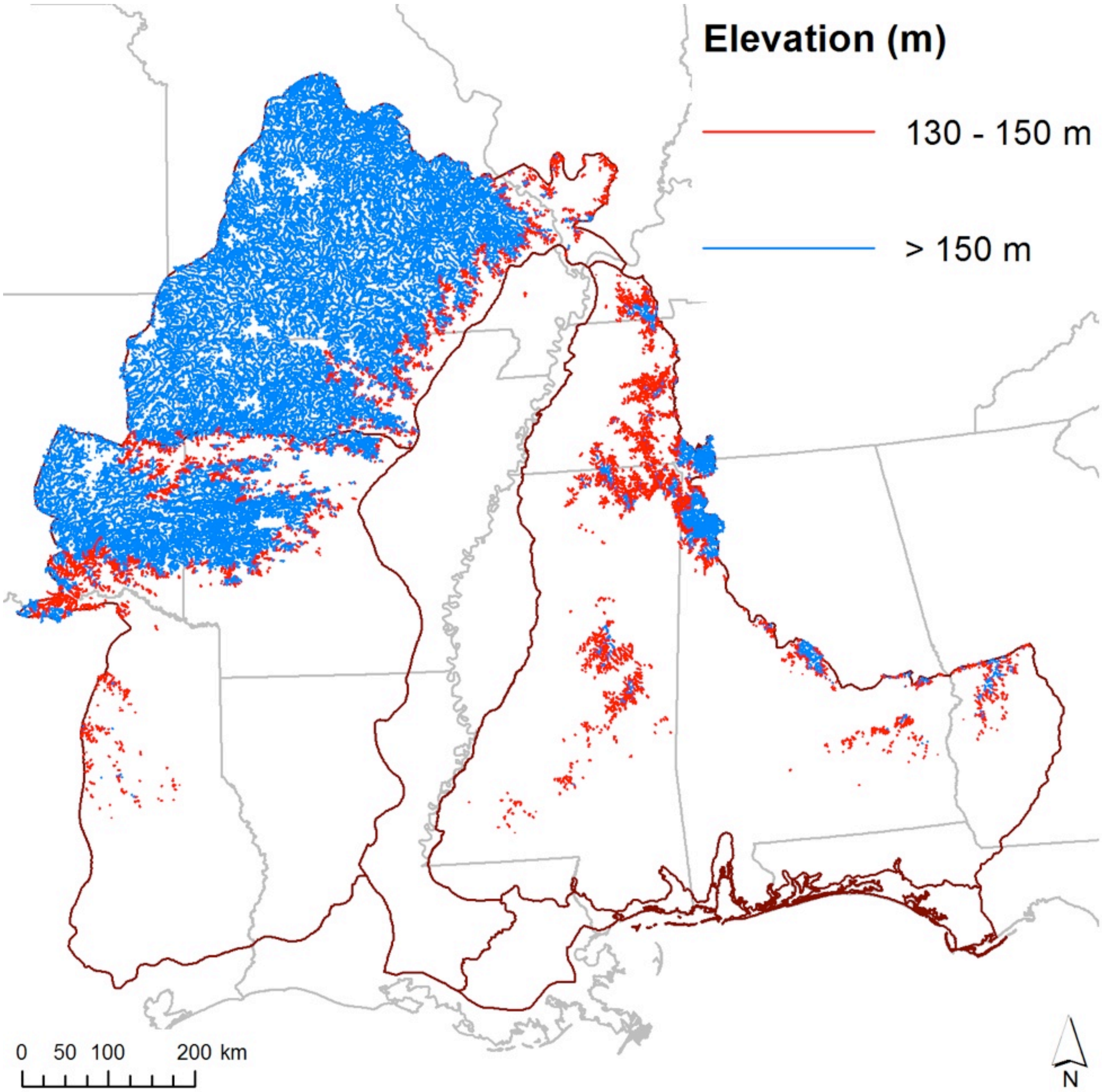

Figure 1. Distribution of upland streams and rivers using the >130m and >150m thresholds and satisfying the other selection conditions indicated in the text.

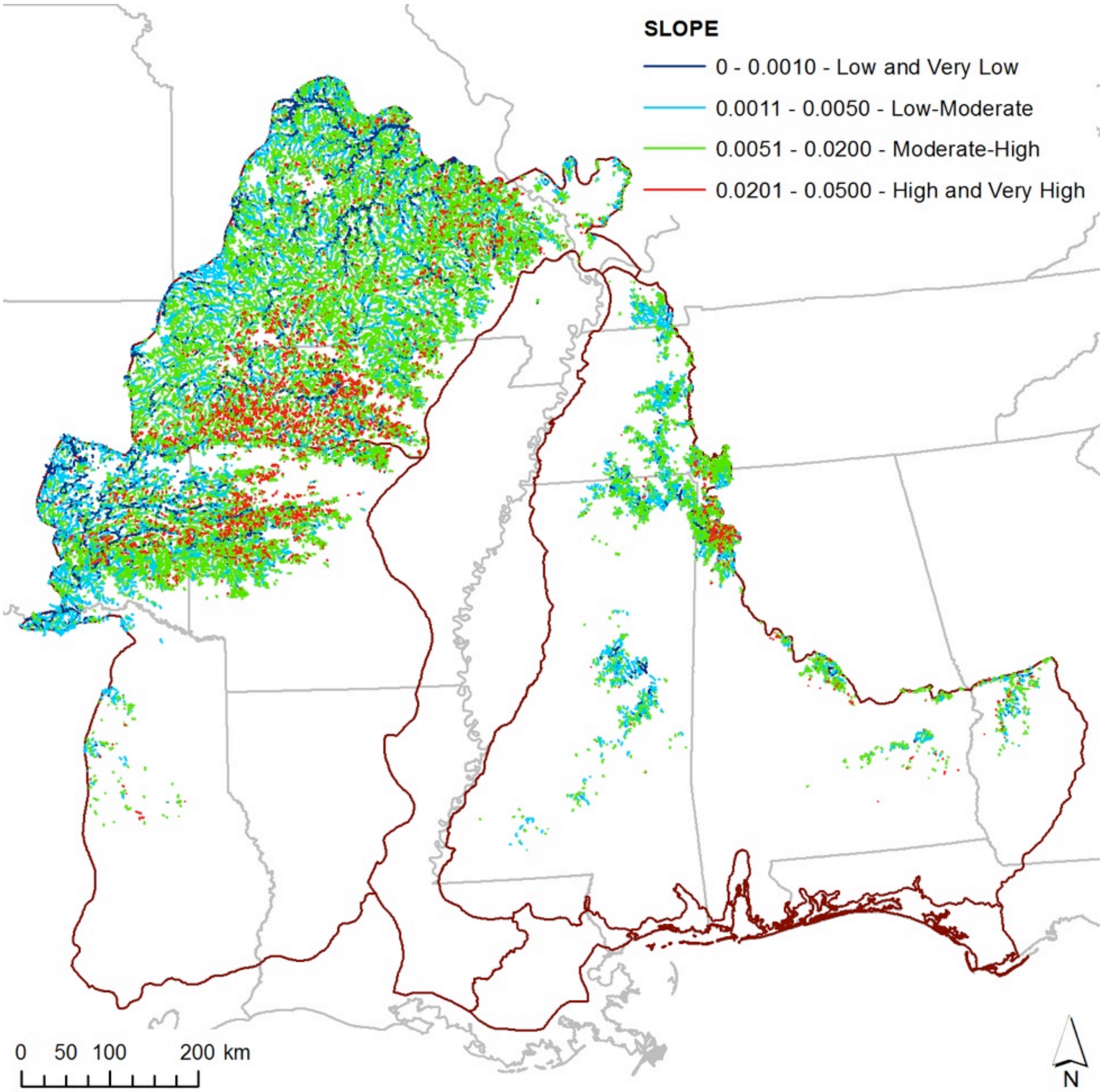

Figure 2. Slope classification of upland streams and rivers having elevation > 130m (MINELEVSMO >13000).

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Configuration - watersheds should be >75% forested, with <10% impervious cover

Data Sources and Processing Methods:

We used NHD Plus v2 flowlines satisfying the basic definitions outlined in the amount chapter above to define the location of upland streams and rivers in the GCPO. The EPA StreamCat database definitions (Table XX) were used to identify variables associated with upstream watershed configuration.

The ASMT identified the landscape endpoint thresholds described above. The impervious cover threshold is reasonable, but the impervious cover model is based on the assumption that the stream is a *headwater* stream having an upstream watershed of **5-50km^2** (Scheuler et al. (2009). Larger watersheds lie beyond the predictive power of the impervious cover model. The headwater definition applies to 69%, 75% and 91% of upland streams and rivers in the OZH, WGCP and EGCP respectively. For this reason, the analysis presented here is modified to apply both criteria of > 75% forested watershed condition and < 10% impervious cover only to headwater upland streams and rivers with watersheds < 50km^2. For upland streams and rivers having watersheds greater than 50km^2, we only applied the criterion of > 75% forested watershed configuration.

Summary of Findings:

Headwater upland streams and rivers (< 50 km^2) make up the majority (54,497 km; 73%; Table XX) of total upland streams and rivers length for the entire GCPO. Within the headwaters class most (58%), lie within the OZH subgeography and the amount of upstream forested watershed, provides a major separation in these streams. Only 33% of headwaters upland streams and rivers in the OZH have > 75% forested watershed area. This percentage is slightly higher for the WGCP (43%) but the WGCP has fewer upland streams and rivers so the overall percentage of upland streams and rivers across the GCPO in the best forested condition class is still highest in the OZH (59%). Far fewer upland streams and rivers in the EGCP (15%) meet this landscape endpoint.

The application of % impervious cover in the upstream watershed does little to alter these patterns in headwaters (< 50km^2) upland streams and rivers. For all of the subgeographies, the overwhelming majority (97-100%) of upland streams and rivers meeting the forested cover criterion also met or exceeded the impervious cover threshold (Table XX).

Non-headwater upland streams and rivers make up 27% (20,082km, Table XX, Figure XX) of total upland streams and rivers length for the entire GCPO. Again, the majority of these are found in the OZH. As is true for headwaters streams, the amount of upstream forested watershed provides a major separation in these streams, but the percentage falling into the best condition classes is somewhat lower compared with headwaters streams. Only 21% of non-headwaters upland streams and rivers in the OZH have > 75% forested watershed area. As is true for headwaters streams, this percentage is slightly higher for the WGCP (29%) but the WGCP has fewer upland streams and rivers so the overall percentage of upland streams and rivers across the GCPO in the best forested condition class is still highest in the OZH (68%). Again, as is true for headwaters streams in EGCP, far fewer upland streams and rivers (only 8km or 0%) of non-headwater upland streams and rivers meet this landscape endpoint.

Upland streams and rivers satisfying the criteria for both river classes are primarily found in the Ouachita, Boston and Ozark mountains (Figure XX).

Future Directions and Limitations:

Future versions of the ISA may wish to consider a different application of “impervious area in the watershed” to this analysis since results from the impervious cover model are not accurate for watersheds larger than 50km^2. One variation may be to use the approach defined here and include an impervious cover threshold for small watersheds, but only use % forested cover for larger watersheds.

The EPA StreamCat database will provide new NLCD landcover as those data become available. We also expect that the EPA StreamCat database will soon be updated to include 2011 impervious surface definitions.

Note that the EPA StreamCat database does not provide attributes for NHD segments that are not in the NHD flow network (e.g. side branches of braided streams). The total stream lengths will therefore differ between those attributed using only NHD attributes (e.g. slope and elevation) vs. those attributed using the EPA StreamCat database. Total river kilometers Included in the upland streams and rivers definition, but omitted from the EPA StreamCat database are: OZH: 23 km, WGCP: 17 km and EGCP: 4 km.

References:

Schueler, T., Fraley-McNeal, L., and Cappiella, K. (2009). "Is Impervious Cover Still Important? Review of Recent Research." J. Hydrol. Eng., 10.1061/(ASCE)1084-0699(2009)14:4(309), 309-315.

Tables and Figures:

Table 2. EPA StreamCat variables and definitions used in the analysis of landscape configuration.

EPA Stream Cat Variable Name	Definition
PctMxFst2011Ws	% of watershed area classified as deciduous forest land cover (NLCD 2011 class 41)
PctConif2011Ws	% of watershed area classified as evergreen forest land cover (NLCD 2011 class 42)
PctDecid2011Ws	% of watershed area classified as mixed deciduous/ evergreen forest land cover (NLCD 2011 class 43)
PctWdWet2011Ws	% of watershed area classified as woody wetland land cover (NLCD 2011 class 90)
PctImp2006Ws	Mean imperviousness of anthropogenic surfaces within watershed (2006)

Table 4. Report by subgeography for headwaters (watershed < 50km²) configuration of upstream forested area and impervious cover.

Headwaters Category	Length (km)	% of total for GCPO	Subgeog	Length (km)	% of total for headwaters in the GCPO	Watershed Forested Area Class	Length (km)	% in each forested class within each subgeography	% in best forested class within GCPO	Impervious Class	Length (km)	% in each impervious class within each subgeography
< 50 km²	54,479	**73%**	OZH	31,872	58%							
						>75%	10,534	33%	59%			
										<5%	10,532	100%
										5-10%	2	0%
										>10%	-	0%
						< 75%	21,337	67%				
										<5%	20,305	95%
										5-10%	473	2%
										>10%	560	3%
			WGCP	14,544	27%							
						>75%	6,206	43%	35%			
										<5%	6,205	100%
										5-10%	2	0%
										>10%	-	0%
						< 75%	8,337	57%				
										<5%	8,189	98%
										5-10%	77	1%
										>10%	71	1%
			EGCP	8,064	15%							
						>75%	1,198	15%	7%			
										<5%	1,198	100%
										5-10%	-	0%
										>10%	-	0%
						< 75%	6,866	85%				
										<5%	6,674	97%
										5-10%	124	2%
										>10%	67	1%

Table 3. Report by subgeography for non-headwaters (watershed > 50km²) configuration of upstream forested area.

Headwaters Category	Length (km)	% of total for GCPO	Subgeog	Length (km)	% of total for non-headwaters in the GCPO	Watershed Forested Area Class	Length (km)	% in each condition class within each subgeography	% in best forested class within GCPO
> 50 km²	20,055	**27%**							
			OZH	14,325	71%				
						>75%	2,992	21%	68%
						< 75%	11,333	79%	
			WGCP	4,887	24%				
						>75%	1,409	29%	32%
						< 75%	3,478	71%	
			EGCP	843	4%				
						>75%	8	1%	0%
						< 75%	834	99%	

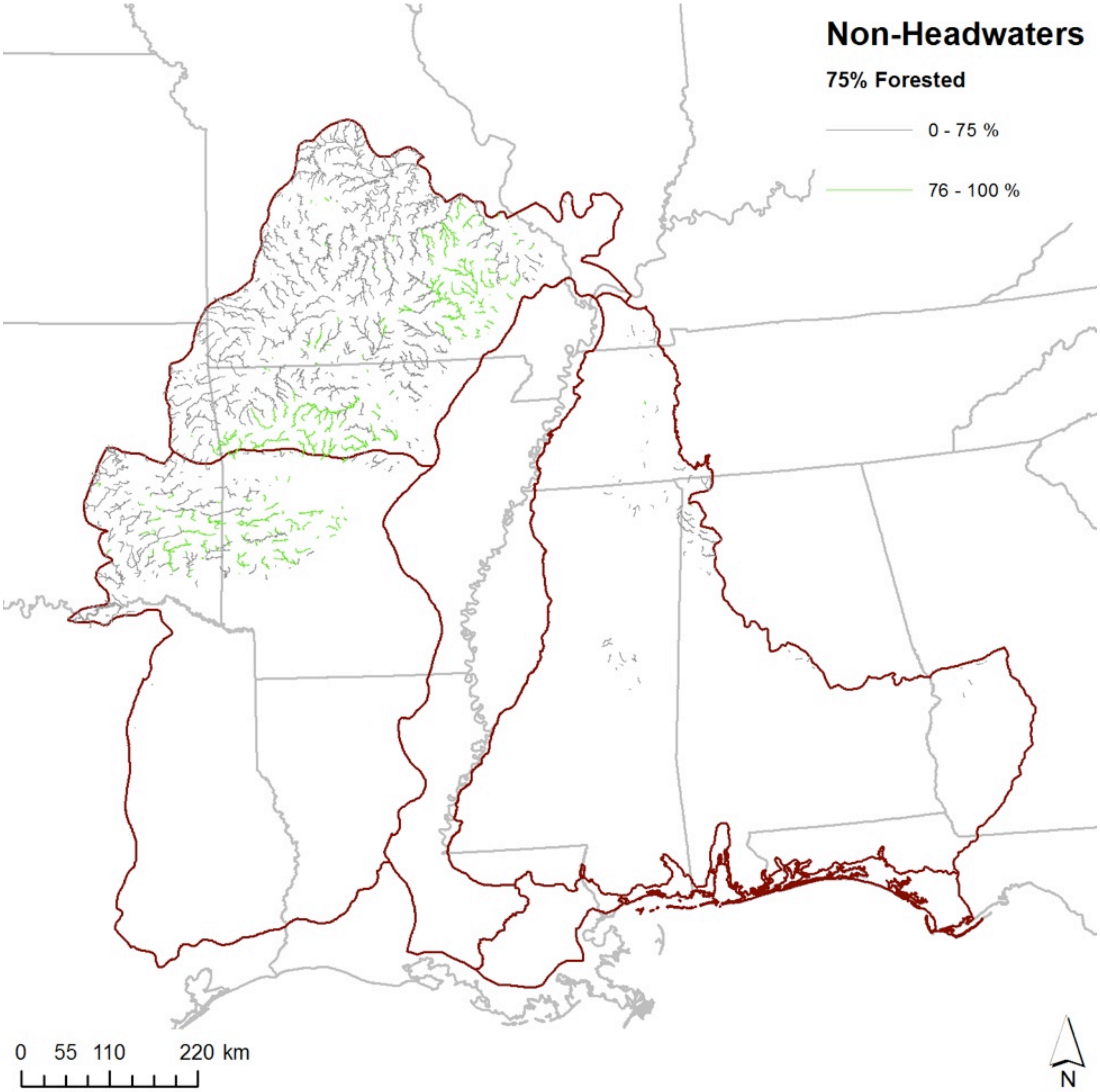

Figure 3. Upland streams and rivers in non-headwaters (watershed >50km²) category. Figure highlights non-headwaters reaches that have > 75% upstream forested watershed area. Upstream watershed metrics are based EPA StreamCat database variables.

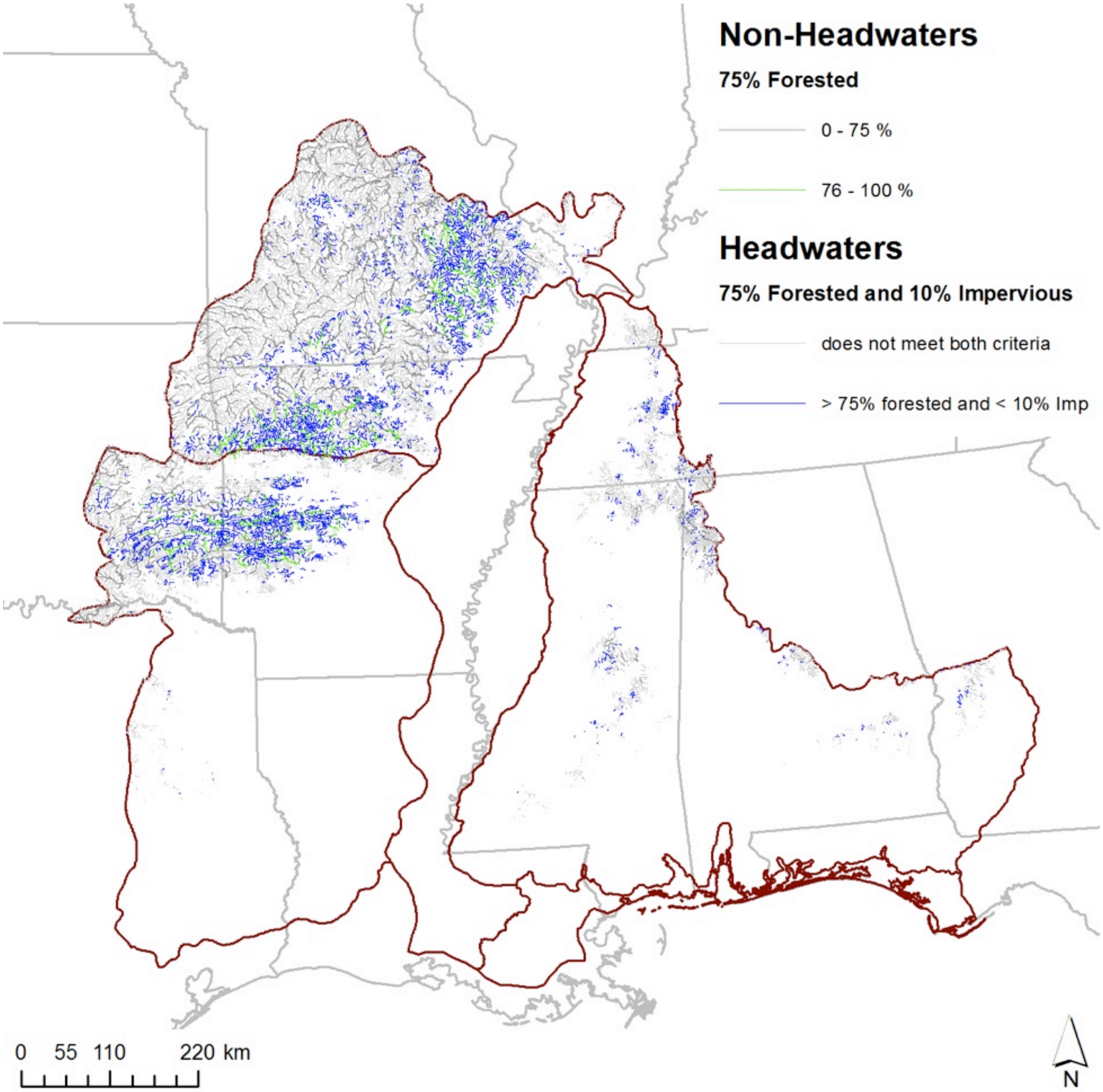

Figure 4. Upland streams and rivers in both headwaters (watershed >50km²) and non-headwaters (watershed <50km²) categories. Headwaters reaches must satisfy both criteria of >75% upstream forested watershed area and < 10% upstream impervious area. Non-headwaters reaches satisfy only the criterion of having upstream watershed area that is >75% forested. All metrics are based EPA StreamCat database variables.

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Configuration - Intact riparian corridors consisting primarily of hardwoods within 30 m buffer of stream

Data Sources and Processing Methods:

We used NHD Plus v2 flowlines satisfying the basic definitions outlined in the amount chapter above to define the location of upland streams and rivers in the GCPO. The EPA StreamCat variables listed in Table XX were used to identify the total forested area in the riparian buffer. The EPA StreamCat process used a 100m riparian buffer instead of the 30m identified in the ISA. We feel that this larger buffer should be more robust to variation in landcover classification. EPA StreamCat calculated riparian buffer for smaller rivers using a 100m buffer on NHD lines. For larger rivers and waterbodies, the buffer was generated around the border of all open water that is in direct contact with on network flowlines (see EPA StreamCat documentation). All forested classes (Table XX) were summed to determine the percent of catchment area classified as forested within a 100m buffer of each NHD stream segment.

Summary of Findings:

Riparian conditions for upland streams and rivers are slightly better overall in the WGCP where 50% of stream buffers are >75% forested and 24% are > 90% forested. In the OZH and EGCP, 34-35% of stream buffers are > 75% forested and only 14-17% are > 90% forested. However, because the OZH has the highest stream density it holds the highest proportion of streams in the best condition. 58% of all upland streams and rivers having >90% forested riparian buffer across the GCPO geography lie within the OZH subgeography. The highest density of upland streams and rivers in the highest riparian condition class lies in the Ouachita mountains of the WGCP and in the Boston Mountains of the OZH.

Future Directions and Limitations:

The EPA StreamCat database will be updated as new NLCD landcover become available. Future refinements could use improved landcover products to specifically target hardwood composition if necessary.

Note that the EPA StreamCat database does not provide attributes for NHD segments that are not in the NHD flow network. The total stream lengths will therefore differ between those attributed using only NHD attributes (e.g. slope and elevation) vs. those attributed using the EPA StreamCat database. Total river kilometers Included in the upland streams and rivers definition, but omitted from the EPA StreamCat database are: OZH: 23 km, WGCP: 17 km and EGCP: 4 km.

Tables and Figures:

Table 5. EPA StreamCat variables and definitions used in the analysis of riparian configuration.

EPA Stream Cat Variable Name	Definition
PctDecid2011CatRp100	% of catchment area classified as deciduous forest land cover (NLCD 2011 class 41) within a 100-m buffer of NHD streams
PctConif2011CatRp100	% of catchment area classified as evergreen forest land cover (NLCD 2011 class 42) within a 100-m buffer of NHD streams
PctMxFst2011CatRp100	% of catchment area classified as mixed deciduous/evergreen forest land cover (NLCD 2011 class 43) within a 100-m buffer of NHD streams
PctWdWet2011CatRp100	% of catchment area classified as woody wetland land cover (NLCD 2011 class 90) within a 100-m buffer of NHD streams

Table 6. Report by subgeography for riparian configuration endpoints as described in the text.

Subgeog	Length (km)	Riparian Condition Class	Length (km)	% in each condition class within each subgeography	% in best condition across the GCPO
OZH	46,194				
		riparian > 90%	7,954	17%	34%
		riparian 75- 90%	7,814	17%	
		riparian < 75%	30,426	66%	
WGCP	19,420				
		riparian > 90%	4,615	24%	50%
		riparian 75- 90%	5,136	26%	
		riparian < 75%	9,668	50%	
EGCP	8,906				
		riparian > 90%	1,210	14%	35%
		riparian 75- 90%	1,911	21%	
		riparian < 75%	5,785	65%	
Grand Total	74,520				

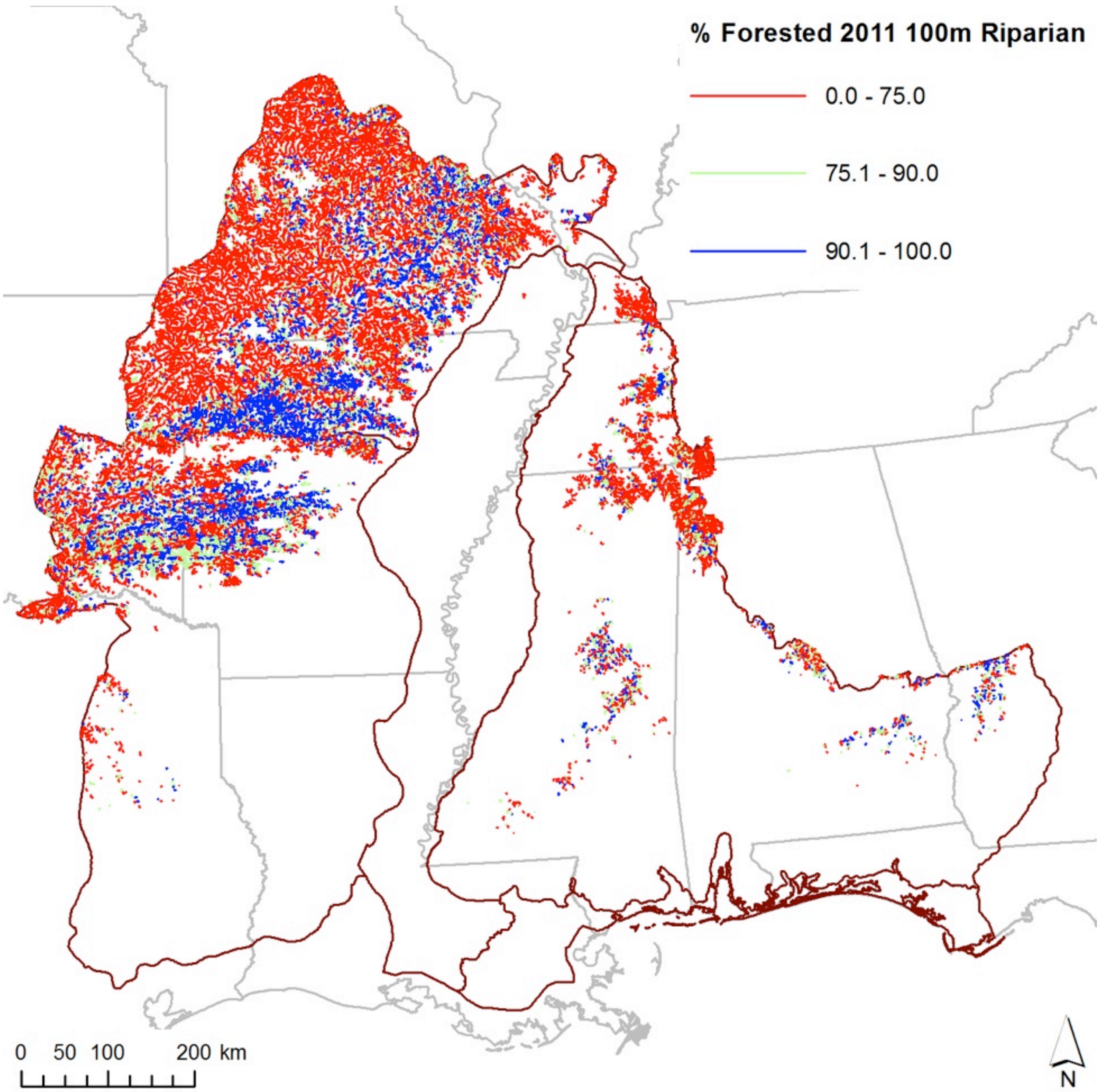

Figure 5. Locations of upland streams and rivers and the associated percent of forested riparian corridor condition within the local catchment.

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Configuration - Interconnected stream systems

Data Sources and Processing Methods:

We used NHD Plus v2 flowlines satisfying the basic definitions outlined in the amount chapter above to define the location of upland streams and rivers in the GCPO. The EPA StreamCat variable "DamDensWs" was used to evaluate the connectivity of upland streams and rivers in the GCPO. This variable uses the National Inventory of Dams (NID) to assess the density of georeferenced dams within upstream watershed of each stream reach (dams/ square km). Any stream segment having zero upstream (watershed) dams was considered to be in the best condition.

Summary of Findings:

Within each of the subgeographies, the proportion of upland streams and rivers having not upstream network dams was roughly equal at 71-72% (Table XX). Within the entire GCPO geography, the OZH has the greatest amount of upland streams and rivers, so it also has the greatest proportion of streams having no upstream dams. Across the GCPO, upland streams and rivers having the zero upstream dams were typically located at higher elevations compared with streams having upstream dams (Table XX).

Future Directions and Limitations:

Further development of the Southeast Aquatic Connectivity Assessment Project (SEACAP) into the GCPO will greatly increase the accuracy and relevance of this metric. The database of dams generated from this project is intended to be the input dataset for the SEACAP Tool, which prioritizes dams for removal or fish passage based on suite of ecologically-relevant metrics which assess the potential ecological benefit of conducting a removal or other passage project.

Note that the EPA StreamCat database does not provide attributes for NHD segments that are not in the NHD flow network. The total stream lengths will therefore differ between those attributed using only NHD attributes (e.g. slope and elevation) vs. those attributed using the EPA StreamCat database. Total river kilometers Included in the upland streams and rivers definition, but omitted from the EPA StreamCat database are: OZH: 23 km, WGCP: 17 km and EGCP: 4 km.

Tables and Figures:

Table 7. Report by subgeography for upstream watershed dam density as described in the text.

Subgeography	Length (km)	Watershed Dam Density Classes	Length (km)	% in each dam density class within each subgeography	% in best condition across the GCPO	Average Elevation (m)
OZH	46,197					
		zero	32,813	71%	44%	265
		>zero	13,384	29%		234
WGCP	19,431					
		zero	14,593	75%	20%	208
		>zero	4,838	25%		180
EGCP	8,906					
		zero	7,325	82%	10%	151
		>zero	1,581	18%		143
Grand Total	74,534					

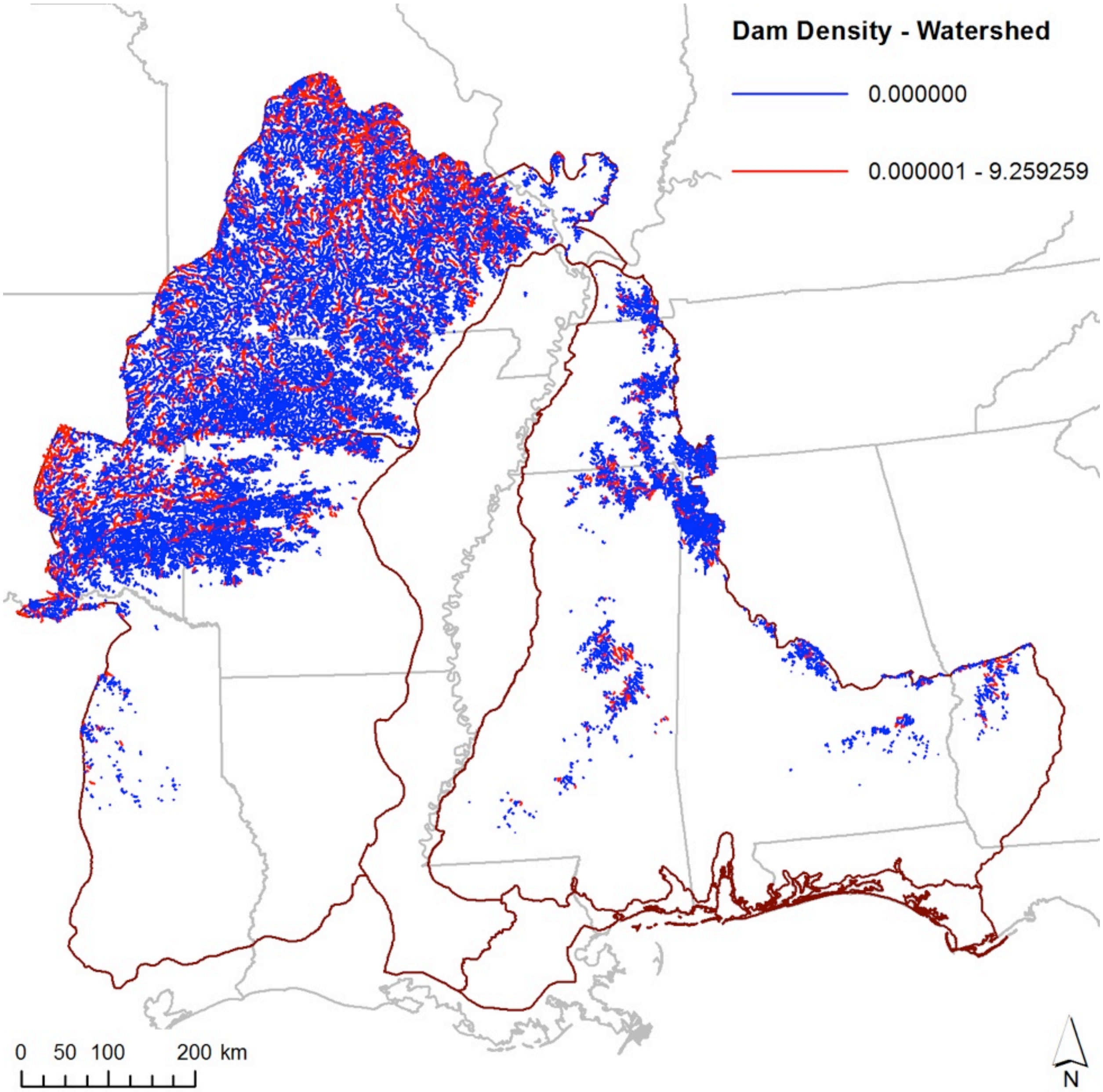

Figure 6. Locations of upland streams and rivers and the associated density of any upstream dams based on the National Inventory of Dams database.

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Condition - High water quality – minimal contaminants and nutrients

Data Sources and Processing Methods:

The specific intent of this analysis was interpreted to be: find locations that have a low risk for contamination from sources of septic system discharge. For that reason, we used data sources related to housing density and land cover to find combinations of low housing density and natural landcover.

2010 US census data by block for individual states of the GCPO (shapefiles, housing unit counts – blocks) was downloaded from the US Census. The individual state shapefiles were merged into a single file in a geodatabase. That merged vector file was converted to a 30m raster snapped to the GCPO 2011 NLCD. The resulting raster file was then compared with NLCD 2011 to determine locations that have natural landcover. Natural land cover was defined by any pixels that were not: urban, developed or agricultural. Census pixels that intersected any urban, developed and agricultural landcover categories were recoded to zero. Areas of open water were recoded to "nodata". All census data for the remaining pixels was retained. This new raster was intersected with upland streams and rivers NHD flowlines using the isectlinerst function in Geospatial Modelling Environment – housing density was calculated for each segment using the "length weighted mean" of raster values along the line. % of natural area that also has housing density < 1 house/km^2 was calculated based on the total non-water area in the catchment.

Arbitrary thresholds for this landscape endpoint were chosen based on the geographic distribution of the data.

Summary of Findings:

Even though the OZH have a greater amount of upland streams and rivers, a greater amount of streams satisfying this condition were found in the WGCP (52% of total for the GCPO). Across all subgeographies, only 15% of all upland streams and rivers fell into the best condition class (natural cover and < 1 house sq $^{km-2}$). As with other metrics, most of these upland streams and rivers are located in the Ouachita, Boston and Ozark mountains.

Future Directions and Limitations:

Increased specificity of the endpoint will help to refine the most appropriate target data source to characterize this metric. Other data sources that may address this endpoint include:

Pesticides, SPARROW nitrogen and phosphorus loading, % upstream cropland, % upstream urban. Results from other landscape endpoints (e.g. % upstream forested area) may also accurately describe the intent of this metric. Future versions should use species reference data to determine the most appropriate data sources and thresholds that support landscapes in good condition.

Note that the EPA StreamCat database does not provide attributes for NHD segments that are not in the NHD flow network. The total stream lengths will therefore differ between those attributed using only NHD attributes (e.g. slope and elevation) vs. those attributed using the

EPA StreamCat database. Total river kilometers Included in the upland streams and rivers definition, but omitted from the current analysis are: OZH: 26 km, WGCP: 22 km and EGCP: 4 km.

Tables and Figures:

Subgeography	Length (km)	% of natural area and housing < 1 km^2	Length (km)	% of total in each condition class within each subgeography	% in best (>75%) condition class across the GCPO
OZH	46,194				
		>75%	4,921	11%	44%
		50-75%	2,757	6%	
		<50%	38,515	83%	
WGCP	19,426				
		>75%	5,791	30%	52%
		50-75%	2,531	13%	
		<50%	11,104	57%	
EGCP	8,906				
		>75%	465	5%	4%
		50-75%	519	6%	
		<50%	7,922	89%	
Grand Total	74,526				

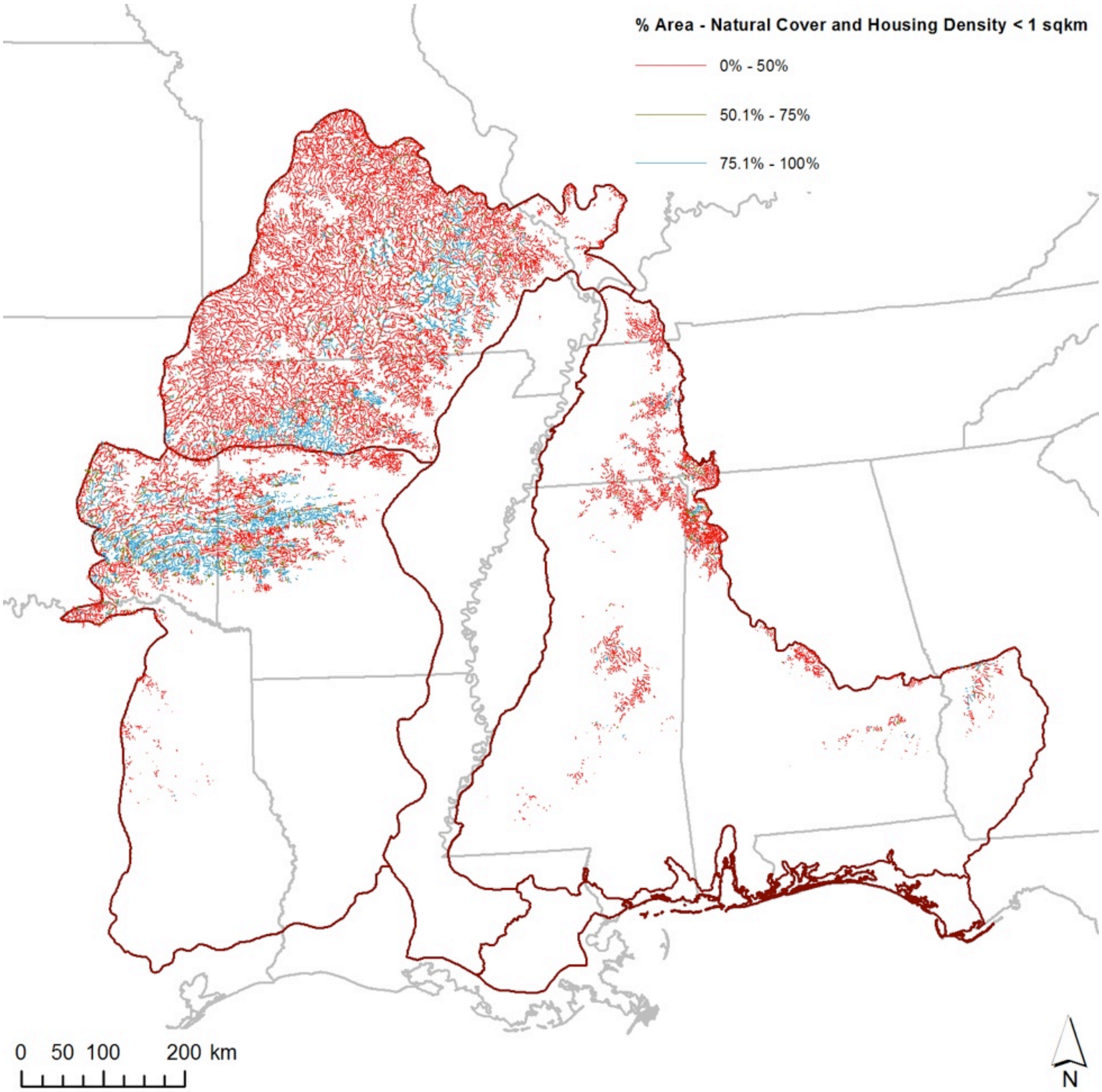

Figure 7. Percent of local catchment area satisfying the combined criteria of < 1 house / km^2 based on 2010 US Census block data and natural landcover based on 2011 NLCD.

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Condition - Temperatures – low

Data Sources and Processing Methods:

We used NHD Plus v2 flowlines satisfying the basic definitions outlined in the amount chapter above to define the location of upland streams and rivers in the GCPO. The 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). In an effort to better characterize the potential distribution temperature during the peak of summer in the GCPO, the most recent long-term (1981-2010) mean and maximum August temperature grids were downloaded from PRISM. These grids were intersected with NHDPlus using isectlinerst function in Geospatial Modelling Environment – data was mapped using calculated values of: length weighted mean of raster values along the line.

Summary of Findings:

The range of thermal conditions for upland streams and rivers is largely driven by latitude and elevation (Table XX, Figure XX). Average August air temperatures are below 26 degrees C throughout most (89%) of the OZH subgeography. By contrast, 99% of average August air temperatures are greater than 26 degrees C in the WGCP. Temperatures in the EGCP fall in between these two extremes with 98% having average August air temperatures in the range of 25-27 degrees C.

Future Directions and Limitations:

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.

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 would be more meaningful to analysis of cumulative degree-day growth rates, cumulative maximum degree-days, or the establishment of seasonal thermal boundaries that may critical to aquatic species survival and growth.

Tables and Figures:

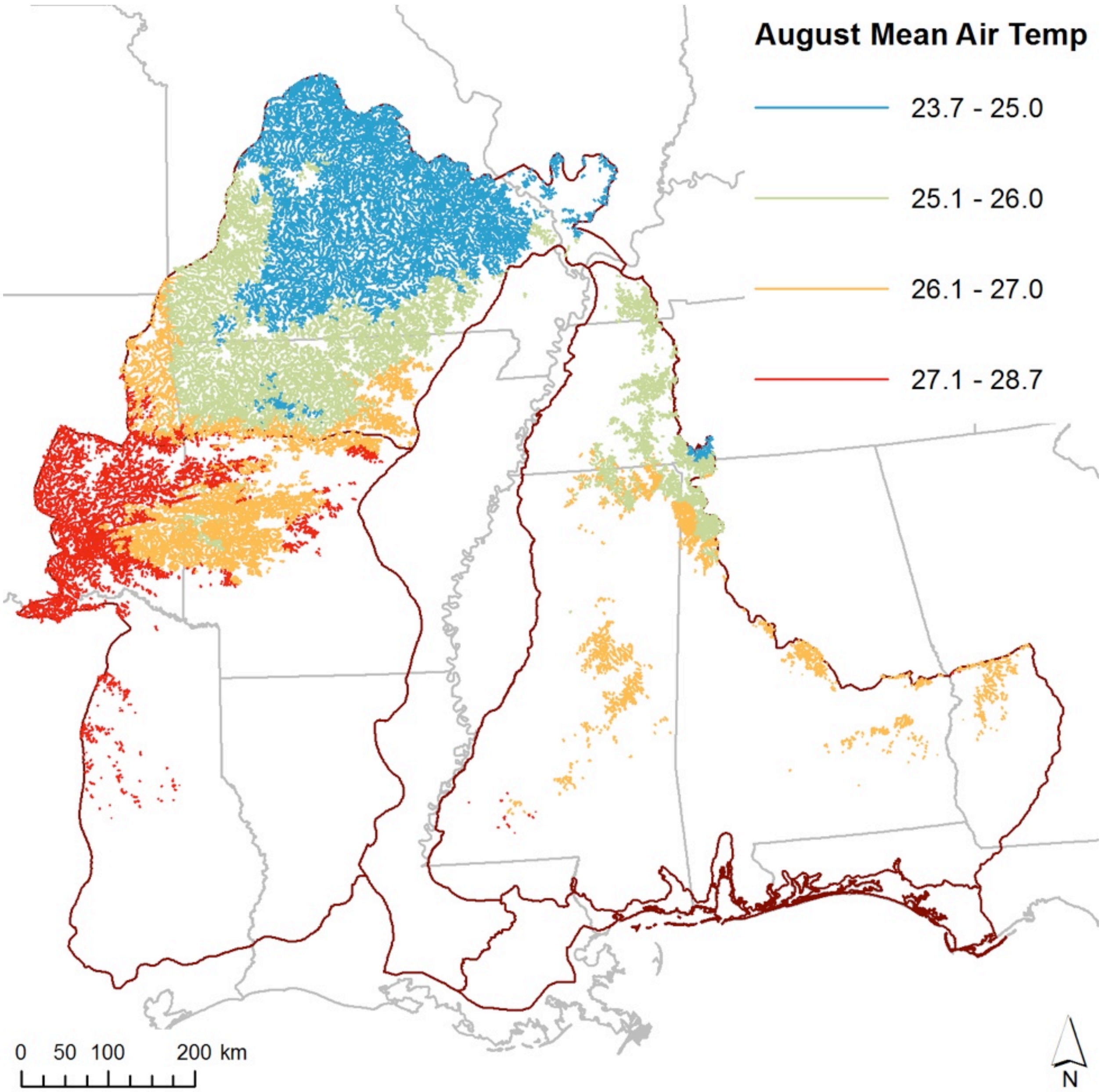

Figure 8. August mean air temperatures based on long-term (1980-2010) PRISM climate data.

Table 8. Report by subgeography for long-term average August air temperature as described in the text.

Subgeography	Length (km)	Mean August Temp Bin	Length (km)	% in each thermal class within each subgeography
OZH	46,220			
		23 - 24	251	1%
		24 - 25	24,177	**52%**
		25 - 26	16,725	**36%**
		26 - 27	4,478	10%
		27 - 28	589	1%
		28 - 29	-	0%
WGCP	19,448			
		23 - 24	-	0%
		24 - 25	-	0%
		25 - 26	242	1%
		26 - 27	8,162	**42%**
		27 - 28	10,239	**53%**
		28 - 29	805	4%
EGCP	8,910			
		23 - 24	-	0%
		24 - 25	163	2%
		25 - 26	4,528	**51%**
		26 - 27	4,193	**47%**
		27 - 28	27	0%
		28 - 29	-	0%
Grand Total	74,579			

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Condition – sediment - minimal

Data Sources and Processing Methods:

We used NHD Plus v2 flowlines satisfying the basic definitions outlined in the amount chapter above to define the location of upland streams and rivers in the GCPO. We used the EPA StreamCat database definition “RdCrsCat” (Density of roads-stream intersections based on Census 2000 roads and NHD 100k streams, Carlisle et al. 2009, (crossings/km^2)) within the stream catchment. We set arbitrary thresholds for “best”, “acceptable” and “poor” density of road crossings: < 0.5, 0.5-1 and > 1 crossings/km^2 within the local catchment.

Summary of Findings:

All of the subgeographies have roughly equivalent percentages of road-stream crossing densities in the “best” condition (71-77% of total within the subgeography; Table XX, Figure XX) as defined by the arbitrary thresholds set in this analysis. Because the OZH has the greatest amount of upland streams and rivers therefore, it also contains the greatest amount of streams in the “best” condition for this landscape endpoint.

Future Directions and Limitations:

This variable is not included in any previous assessments and it may be important in assessing the potential for excessive sediment contribution but it has not been tested against reference data. There are, however, many other potential datasets that may contribute to or explain sediment disturbance and the value of competing datasets should be rigorously evaluated in future iterations. For example, the total density of roads may also describe accelerated sediment contributions and this variable is also available through the EPA StreamCat database. Increased road density can also alter flows to deliver more high flashy flows which may in turn increase stream sediment delivery.

Unpaved roads are typically a major contributor to sediment in streams – especially during high water periods (Trombulak and Frissell 2000). Other types of watershed anthropogenic land disturbances may also deliver sediment to a stream including timber harvest, aggressive agricultural practices and conversion to developed land. If warranted, new analyses could be developed to assess these conditions or to update variables using more current (e.g. Census 2010) data.

Natural factors including stream or watershed slope and surface soil erodibility (“kfact” from STATSGO via EPA StreamCat) may also influence sediment delivery to upland streams and rivers. Values for these natural factors are readily available data which can be incorporated into a revised metric to assess sediment delivery.

Additionally, riparian conditions will interact with all of the above listed variables to impact sediment delivery.

We set thresholds for “best”, “acceptable” and “poor” percentages of road-stream crossings based on the geographic distribution of the data and not on thresholds based on species or habitat requirements. Future versions should test these thresholds against reference or species data to determine if they are suitable.

Note that the EPA StreamCat database does not provide attributes for NHD segments that are not in the NHD flow network. The total stream lengths will therefore differ between those attributed using only NHD attributes (e.g. slope and elevation) vs. those attributed using the EPA StreamCat database. Total river kilometers Included in the upland streams and rivers definition, but omitted from the EPA StreamCat database are: OZH: 23 km, WGCP: 17 km and EGCP: 4 km.

References:

Carlisle, Daren M., James Falcone, and Michael R. Meador. 2009. Predicting the biological condition of streams: use of geospatial indicators of natural and anthropogenic characteristics of watersheds. Environmental Monitoring and Assessment 151: 143–160. doi:10.1007/s10661-008-0256-z.

Trombulak, Stephen C., and Christopher A. Frissell. 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14: 18–30. doi:10.1046/j.1523-1739.2000.99084.x.

Tables and Figures:

Table 10. Report by subgeography for density of road-stream crossings (#/km^2)within the local catchment as described in the text.

Subgeography	Length (km)	Road – Stream Crossing Class	Density of road-stream crossings in catchment (#/km2)	Length (km)	% in each condition class within each subgeography	% in best condition class within GCPO
OZH	46,197					
		Best	< 0.5	33,381	**72%**	**61%**
		Acceptable	0.5 - 1	7,517	16%	
		Poor	>1	5,299	11%	
WGCP	19,431					
		Best	< 0.5	15,001	**77%**	27%
		Acceptable	0.5 - 1	2,577	13%	
		Poor	>1	1,854	10%	
EGCP	8,906					
		Best	< 0.5	6,285	**71%**	11%
		Acceptable	0.5 - 1	1,758	20%	
		Poor	>1	863	10%	
Grand Total	74,534					

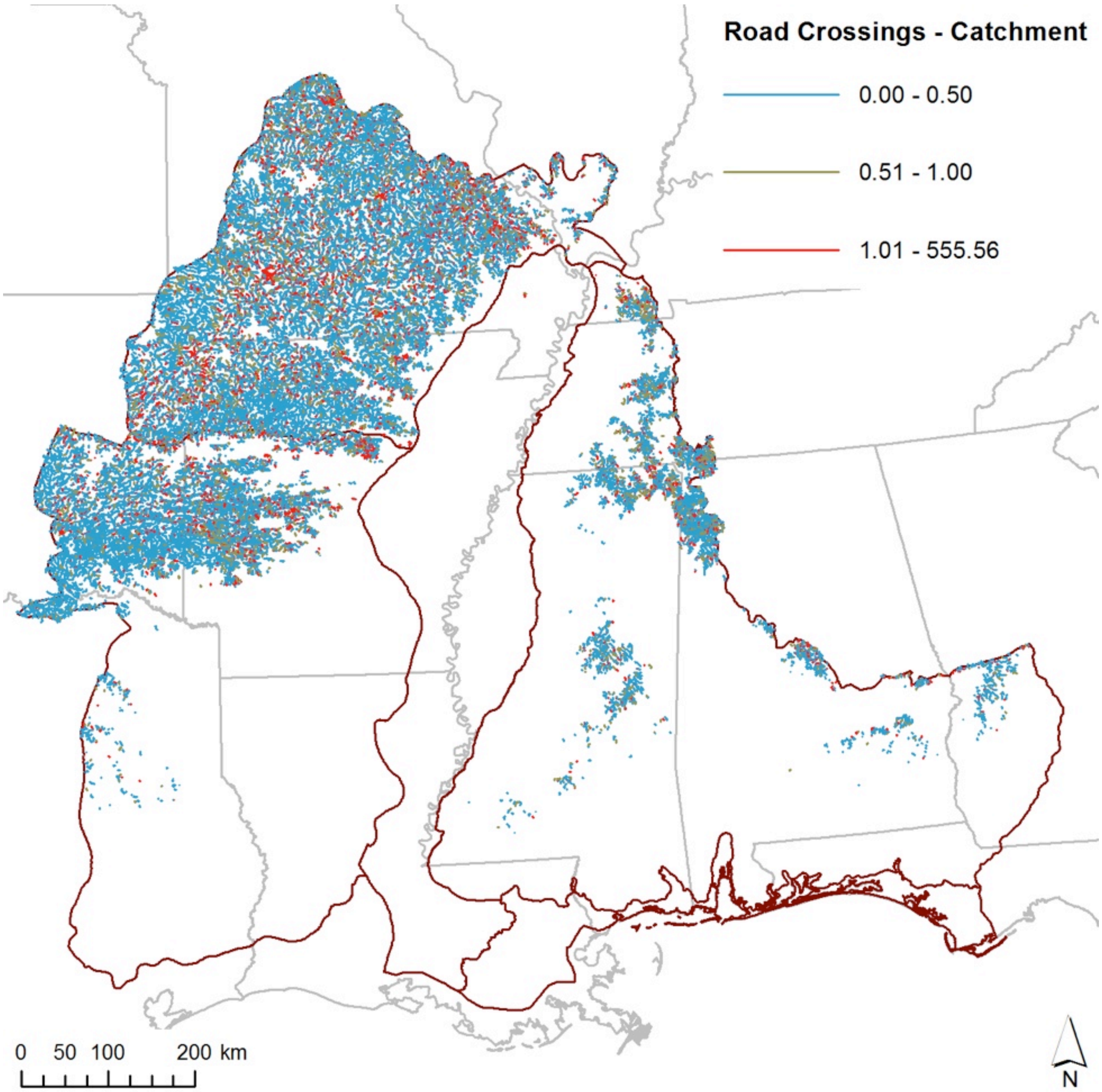

Figure 10. Locations of upland streams and rivers and the density of road-stream intersections within the local catchment of each stream reach (crossings/km^2).

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Desired Landscape Endpoint:

Landscape Attribute: Condition – natural flow regimes maintained

- Groundwater flow regime: low flow variability, low peak flows, low frequency of low flows
- Runoff Flow regime: moderate flow variability, moderate peak flows, moderate frequency of low flows
- Intermittent flow regime: high flow variability high peak flows, high frequency of low flows

Data Sources and Processing Methods:

This endpoint seeks to identify locations where natural flow regimes are maintained. There are two aspects of this endpoint: what are the natural flow regimes are and where are they likely to remain in natural condition.

Leasure et al. (2014) recently published predicted natural flow regimes for streams and rivers of the Interior Highlands. This dataset forms the basis of information to address the location and description of natural flow regimes. The geographic extent they used and some key definitions differ between that study and the current analysis (Figure XX). Leasure et al. flowlines include some lowland rivers (< 130m) and they exclude upland streams and rivers at the northernmost extent of the GCPO as well as all upland streams and rivers in the EGCP and some in Texas in the WGCP. In addition, the definitions of drainage area thresholds differ – Leasure et al. included streams draining greater than 5 km^2 and less than 10,000 km^2. By contrast, upland streams and rivers as defined here exclude flowlines having < 10km^2 upstream watershed and also exclude flowlines going through reservoirs. The flowlines for Leasure et al. were derived independently of NHDPlus flowlines so Leasure et al. flowlines located within 1km of upland streams and rivers were selected for analysis (Figure XX).

The Leasure et al. data do not, however address the second question of where streams flows are likely to remain in natural condition. Natural streamflows may be altered by a variety of factors including: significant impoundment, direct surface water withdrawl or diversion, or groundwater withdrawl that significantly lowers the water table. Locations where significant upstream impoundment is absent was addressed in a previous landscape endpoint. Similarly, locations having largely unimpacted upstream watersheds identified in previous landscape endpoints are also unlikely to be experiencing significant surface or groundwater withdrawls. Results from the analysis of those endpoints may also be applied here as surrogates for flow modification.

Summary of Findings:

62% all stream segments from the Leasure et al. “natural flowlines” fell within 1km of upland streams and rivers based on the definition used here (Table XX and Figure XX). Of those selected streams, the majority (60%) fell into the “intermittent flashy” class. This natural flow class is typified by small drainage areas (< 22km^2) and streams in this class run dry 1-3 months out of the year.

The distribution of **all** Leasure et al. predicted natural flow classes is only slightly different from those intersecting upland streams and rivers of the GCPO - the “runoff flashy” natural flow class tends to occur more commonly in streams of south central plains of Arkansas which lies outside of the upland streams and rivers geographic definition.

Intermittent streams are clearly an important feature of this landscape and aquatic organisms native to these streams are adapted to these seasonal extremes (Magoulick and Kobza 2003). During times of drought, fish clearly have to find locations have to maintain water, but beyond the presence of water, it is not clear that deeper, more persistent pools are preferred for all species. Hodges and Magoulick (2011) report higher abundance and survival for creek chub in pools during times of drought. However, survival and abundance of highland stoneroller and bigeye shiner were equivalent or higher in riffle habitats which may offer reduced competition during drought periods compared with pools. Maintaining a high local diversity of habitats may therefore be important in allowing an array of native species to survive variable drought severity.

Future Directions and Limitations:

Leasure et al. provides predicted natural flow regimes, but these predictions should be compared with current conditions to evaluate flow departure from natural conditions.

Also, the impact of climate change – especially changes in patterns timing and intensity of precipitation may impact these streams. Currently, climate projections for precipitation have a high degree of uncertainty but recent precipitation trends show an increasing frequency of very heavy precipitation.

References:

Hodges, Shawn W., and Daniel D. Magoulick. 2011. Refuge habitats for fishes during seasonal drying in an intermittent stream: movement, survival and abundance of three minnow species. Aquatic Sciences 73: 513–522. doi:10.1007/s00027-011-0206-7.

Leasure, D. R., D. D. Magoulick, and S. D. Longing. 2016. Natural Flow Regimes of the Ozark–Ouachita Interior Highlands Region. River Research and Applications 32: 18–35. doi:10.1002/rra.2838.

Magoulick, Daniel D., and Robert M. Kobza. 2003. The role of refugia for fishes during drought: a review and synthesis. Freshwater Biology 48: 1186–1198. doi:10.1046/j.1365-2427.2003.01089.x.

Tables and Figures:

	All Leasure et al. flowlines			Leasure et al. flowlines within 1km of upland streams and rivers	
Flow Category	Length (km)	% of total for all Leasure et al. flowlines		Length (km)	% of total for Leasure et al. flowlines within 1km of upland streams and rivers
Groundwater	891	1%		676	1%
Groundwater Flashy	9,175	11%		8,377	16%
Groundwater Stable	1,295	2%		736	1%
Intermittent Flashy	48,077	**58%**		30,980	**60%**
Intermittent Runoff	7,246	9%		3,041	6%
Perennial Runoff	5,348	6%		3,614	7%
Runoff Flashy	8,816	11%		3,812	7%
Blank	2,632	3%		541	1%
Grand Total	83,480	100%		51,776	100%
				Percent of upland streams and rivers flowlines within 1km of Leasure et al. flowlines	
				62%	

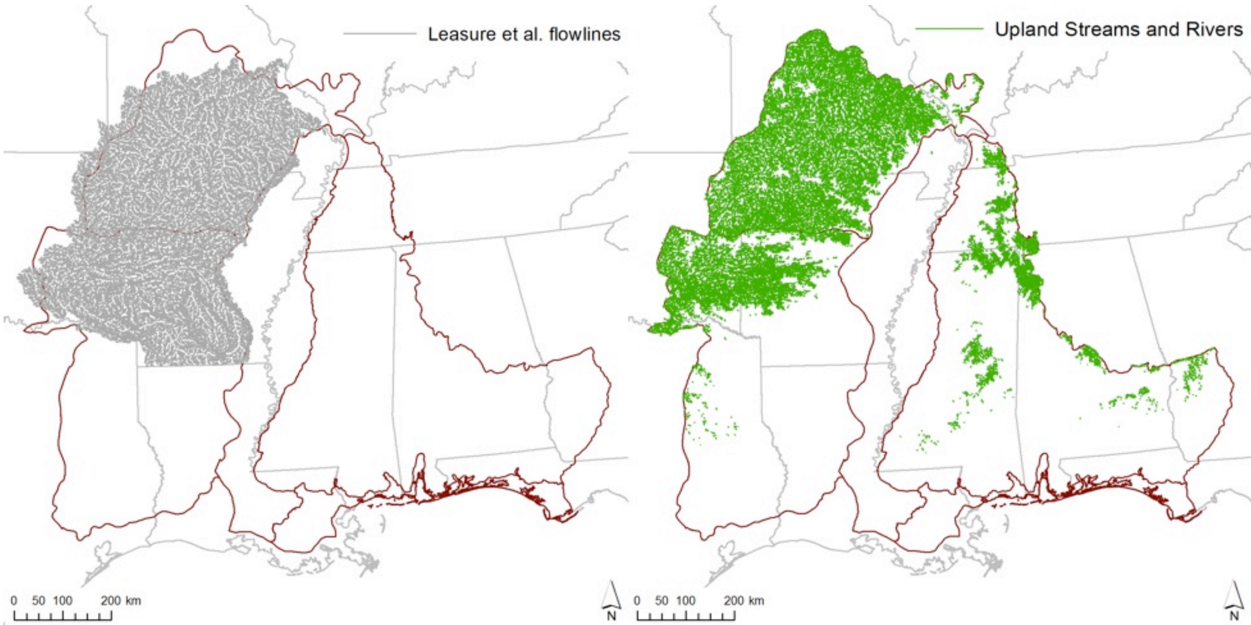

Figure 11. Comparison of the geographic distribution of Leasure et al. flowlines (left) and upland streams and rivers (right).

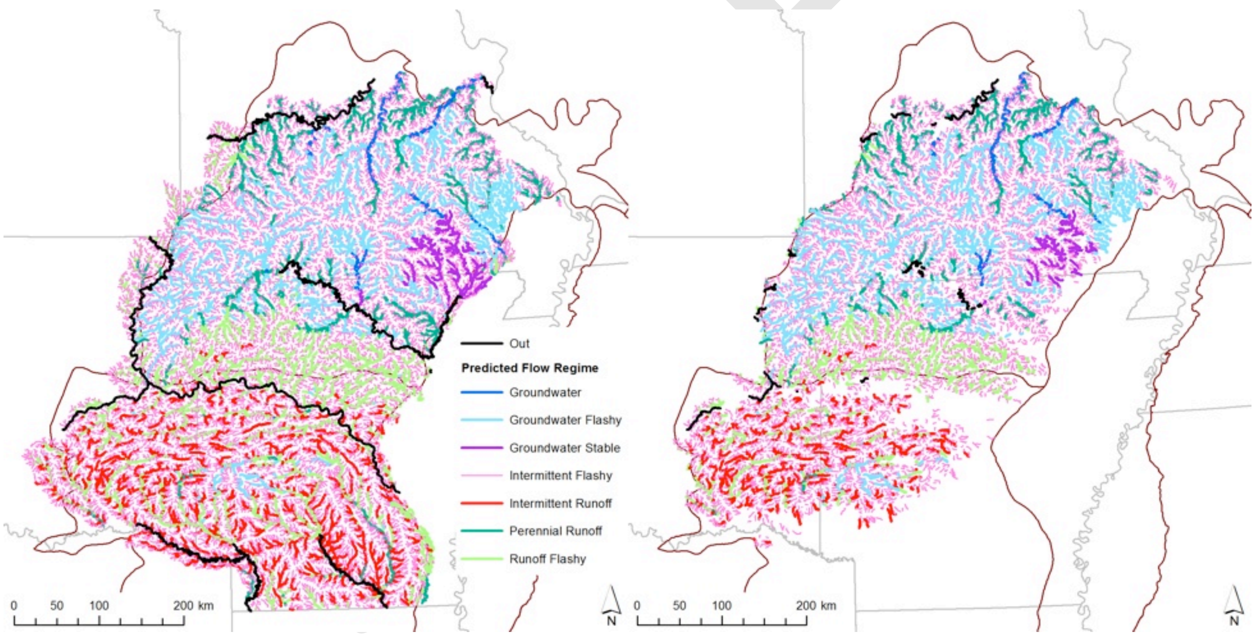

Figure 12. Comparison predicted natural flow regime for all Leasure et al. flowlines (left) and for selected Leasure et al. flowlines that fall within 1km of upland streams and rivers.

Subgeography: **Ozark Highlands**

Ecological System: **Upland Streams and Rivers**

Landscape endpoints lacking suitable geospatial data sources:

1) Desired Landscape Endpoint: Condition

Landscape Attribute: DO – high

Rapidly moving water interacts extensively with the atmosphere, so small, turbulent streams having limited pollution can maintain oxygen concentrations near saturation with seasonal and diurnal changes driven by temperature (Allan and Castillo 2007). Smoothly flowing rivers having less turbulence have reduced interaction with the atmosphere and may have lower oxygen levels. High natural organic and anthropogenic nutrient loadings can lead to higher biological activity and higher biological oxygen demand (BOD). The impacts of high BOD may be acutely felt in summer when high water temperatures reduce oxygen solubility. Intact watersheds and riparian zones composed of natural vegetation can however help to temper nutrient delivery from anthropogenic sources. Factors affecting dissolved oxygen content therefore include: stream size, flow velocity, nutrient loading, temperature and watershed condition.

Of the non-seasonal variables, flow velocity may be the most important and stream gradient strongly influences flow velocity. In upland streams and rivers of the Ozark Highlands, however, high gradient streams having a slope of greater than 2% are strongly associated with “intermittent flashy” stream classes that tend to dry up for extended periods during the summer. A suitable combination of stream size, slope and/or stream velocity that is able to maintain high quality DO and flow throughout the summer months is yet to be determined.

When summer low stream flow and high temperature are most likely to impact stream DO conditions, streams having intact watersheds and riparian corridors with low risk for anthropogenic or organic nutrient loading may be most likely to maintain suitable DO conditions. High quality streams for DO may therefore also be captured by assessments of high quality landscape endpoints detailed above including: watershed, riparian, contaminant and sediment characteristics.

2) Desired Landscape Endpoint: Structure

- Variety of substrates: gravel to boulder
- Abundant leaf litter

Suitable geospatial data to capture these two landscape endpoints could not be found and are therefore not mapped.

Substrate quality is similarly not captured in the assessment because this variable lacks adequately detailed supporting landscape level data. EPA lithology data from StreamCat are based on the USGS Surface lithology layer, but these data may be too coarse (scale 1:5,000,000) to support estimation of this landscape endpoint.

Abundant leaf litter may be partially determined by local riparian condition (estimated above) but this endpoint is also driven by flows which are not currently captured or quantified.

Future Directions and Limitations:

We could investigate the relationship between species reference data and potential indirect measures to determine if any landscape level data exist that suitable capture the intent of these endpoints.