FISH PASSAGE AND AQUATIC CONNECTIVITY IN GEORGIA: CONTINUED PLANNING AND ACTION

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Abstract. A session at the 2013 Georgia Water Resources Conference set the stage for large-scale fish passage projects in the state by highlighting several methods for prioritizing barriers for removal, and comparing methods of improving fish passage at existing barriers. Since that time, a great deal of progress has been made in Georgia and across the southeast develop comprehensive databases of dams and culverts and to prioritize these barriers for removal or further assessment.

We present some examples of recent advances in prioritization modeling and mapping. At the same time, several fish passage projects have been underway long enough to have measurable outcomes and several case studies provide insight for future projects.

Several case studies are presented, focused on the impact of barrier removals and alternative passage methods on key fish populations as a conservation strategy. At the state, regional, and national levels, changes in the regulatory framework and progress in overseeing dam safety provide opportunities to engage land owners through more streamlined processes.

We address the potential of these efforts to potentially speed the pace of barrier removals, while improving public safety. We conclude by highlighting continuing challenges and opportunities for continuing to increase the scale of barrier removal and improved aquatic connectivity to benefit fish populations and human communities in Georgia and across the Southeast.

REGULATORY ISSUES RELATED TO DAM REMOVAL, *Ben Emanuel, American Rivers*

Not unlike prospective dam removal practitioners, regulators in Georgia have relatively little experience permitting dam removal projects that have aquatic habitat restoration as a chief goal and that are representative of the variety of structure types present on the equally wide variety of streams and rivers across the state. Although the Eagle & Phenix and City Mills dam removals on the Chattahoochee River at Columbus, Georgia provide an exciting model for large-scale dam removal with multiple benefits on main stem rivers, collective experience removing (and permitting the removal of) dams on a wider variety of stream types in Georgia is generally lacking. While the Georgia Safe Dams Program (a unit of the Georgia Environmental Protection Division [EPD]) reports permitting the removal of approximately 15 dams over the past 20 years, the Safe Dams Program only regulates dams 25 feet or greater in height or those with 100 acre-feet or more of water storage - criteria that fail to encompass thousands of dams across Georgia—and is chiefly focused on public safety, rather than aquatic habitat restoration, as a dam removal goal, in accordance with its mission.

At present, dam removals in Georgia require individual permits administered by the U.S. Army Corps of Engineers (Corps), Savannah District, under Section 404 of the federal Clean Water Act; the Section 404 permitting process covers such topics as Endangered Species Act compliance, National Environmental Policy Act compliance, National Historic Preservation Act compliance, and so on. Concomitant to the Section 404 permit is the Section 401 Water Quality Certification, administered by Georgia EPD. Additionally, many projects will require stream buffer variances from Georgia EPD, and some may require local (county or municipal) stream buffer variances or other permits.

As more dam removal proposals are developed on a wider variety of stream types and for a wider variety of structure types in Georgia, establishing processes for greater interagency coordination between both state and federal agencies will enhance permit applicants' ability to develop and manage dam removal projects that accomplish aquatic habitat restoration goals while minimizing the potential negative (typically short-term) ecosystem impacts of dam removal on rivers and streams.

Indeed, as regards low-head dams in particular, the Corps "recognize[s] that the removal of low-head dams will have both positive and negative adverse impacts, generally with short-term adverse environmental effects and long-term beneficial environmental effects" (Federal Register, 2017). Thus, the Corps' Nationwide Permit (NWP) 53, authorizing removal of low-head dams, was codified in rule in January, 2017. NWP 53, which streamlines low-head dam removal permitting to some extent, has not been adopted by the Corps Savannah District, meaning that the Savannah District will continue to require individual permits for the foreseeable future. In part, this decision reflects concerns over sediment management challenges and other potential negative impacts of dam removals.

However, there may be opportunities for stakeholders to discuss potential approaches that could lead to effective application of NWP 53 in Georgia in future years. A review of both the available literature and forthcoming resources would inform such efforts. In particular, state and federal regulators and other stakeholders in Georgia may benefit from a review of sediment assessment and management guidance for dam removal projects developed by other states (e.g., Massachusetts and New Hampshire) that possess more extensive experience with restoration techniques.

The forthcoming Dam Removal Analysis Guidelines for Sediment from the Federal Subcommittee on Sedimentation, led by the U.S. Bureau of Reclamation, should also prove helpful. These guidelines have been developed to provide engineers, scientists, and resource managers an approach for evaluating the data collection, analysis, and modeling needs of a dam removal project, as well as the sediment management techniques that may be most appropriate. Multi-stakeholder collaboration on the topic of dam removal permitting going forward will inform and support Georgia's growing community of practice around dam removal.

CULVERT PRIORITIZATION MODELING

How to avoid death by 10,000 culverts: spatially-explicit tools for multi-scale prioritization to restore aquatic connectivity, *by Nathan P. Nibbelink), Evan Collins, Thomas Prebyl (UGA Warnell School of Forestry and Natural Resources), and Duncan Elkins (UGA River Basin Center).*

Problem

Culverts far outnumber large dams on the landscape, yet a culvert can also be a barrier to aquatic organism movement, depending on type and condition (Januchowski-Hartly 2014, Anderson 2012, Coffman 2005). Because they are so numerous, aggregate effects of these small structures on aquatic connectivity within or across large regions are largely unquantified, and thus pose a significant challenge for prioritizing efforts to remediate these potential barriers to improve passability. In partnership with the US Fish & Wildlife Service, the Federal Highways Administration, and the South Atlantic Landscape Conservation Cooperative, the University of Georgia completed a study resulting in a hierarchical modeling approach for the prioritization of remediation efforts at the watershed and individual culvert scales.

Coffman (2005) identified measurable traits of culverts that most influence fish movement, including substrate within the culvert, outlet drop, slope, and length; all factors which are based on conceptual and empirical models of fish swimming ability. Using Coffman's culvert classification model, passability can be classified as "passable," "impassable," or "indeterminate" for three taxonomic groups of fish. The problem is that with literally thousands of culverts per 8-digit hydrologic unit, exhaustive surveys are lacking. Thus, it is desirable to estimate passability using models relating readily available landscape variables to local culvert conditions in order to prioritize areas likely to have passability problems.

Once we have passability estimates for all culverts (whether field- or model-based), there are still several hurdles to determining which culverts should be considered high priority for remediation. Questions such as "How much connected habitat is enough?", "How many culverts need to be remediated to have a positive effect?" and "If I can only remove three culverts, which three are best?" are important questions for which the answer is often, "It depends." Nonetheless, at a fundamental level, it is generally agreed that culverts whose remediation results in the largest improvement in the length of contiguous habitat should be dealt with first.

The dendritic connectivity index (DCI) provides a means to quantify longitudinal connectivity between points in a network (Cote et al. 2009), thus prioritization of culverts for remediation can be done by simulating the iterative removal of one or more barriers and prioritizing those that result in the largest improvement to the DCI value. While conceptually simple, the challenge is substantial when dealing with thousands of potential barriers.

For example, when considering removing the top 3 barriers out of 10,000, there are $1.7 * 10^{10}$ combinations. It would take years to find an exhaustive solution with current computer processors. Thus, alternative methods are needed to guide prioritization efforts at the individual culvert scale. We present a hierarchical approach that guides both regional and local prioritization efforts using a combination of empirical and heuristic models in a geospatial framework.

Approach - Watershed scale prioritization

We used data from 542 culverts from six 8-digit HUCs representing a gradient of landscape conditions throughout the southeast as training data for a landscape-level passability model. For each culvert we estimated passability using a binary classification of "passable" or "impassable" (Coffman 2005). We used eleven landscape predictor variables which were included or easily derived from NHDPlusV2 attributes associated with each culvert. Land cover variables included percent cover measures for seven land cover classes in the upstream catchment area based on the 2011 National Land Cover Dataset (NLCD), as well as the mean percent impervious surface in the upstream catchment. Terrain variables consisted of: stream slope, estimated flow, and stream power (stream slope * estimated flow).

We used random forest (RF) models in R (Breiman 2001, Liaw and Wiener 2002) and a parameter selection method by Murphy et al. (2010) to predict culvert passability as a function of landscape variables. RF models perform well when non-parametric relationships are expected (e.g., different combinations of conditions can lead to impassability). As we wished to develop models capable of predicting passability in un-sampled watersheds, we used a spatial cross validation approach which iteratively fit RF models, withholding one of the six watersheds in each iteration, then predicting the passability in the withheld watershed. We then compared observed vs. predicted % impassable culverts.

Results – Watershed scale prioritization

Although results varied by taxonomic group, RF models were successful at predicting the percentage of impassable culverts with mean absolute error of ~8% (probability of impassability). The most important variable in predicting culvert passability was stream slope. Mean square error increased by ~109% when stream slope was excluded as a covariate. Stream power and estimated flow were also important variables in the model (Figure 1).

While predictions for individual culverts were understandably variable (likely due to local conditions such as culvert age, installation, and other factors), we are able to identify key factors such as stream slope that can lead to a higher likelihood of impassability. Thus regional or watershed level prioritization based on estimated passability rates is feasible (Figures 2 & 3).

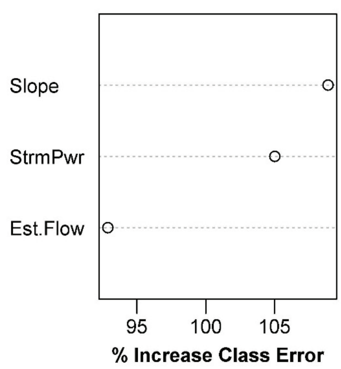

Figure 1. Variable importance as measured by increase in error when each variable was withheld from the RF model fitting.

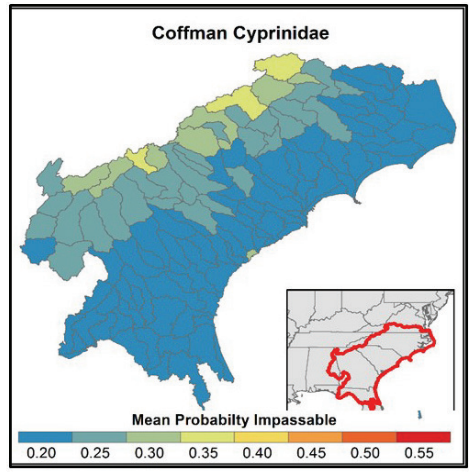

Figure 2. Predicted probability of impassable culverts for South Atlantic watersheds. Results are average probability impassable across all culverts in each HUC8 watershed.

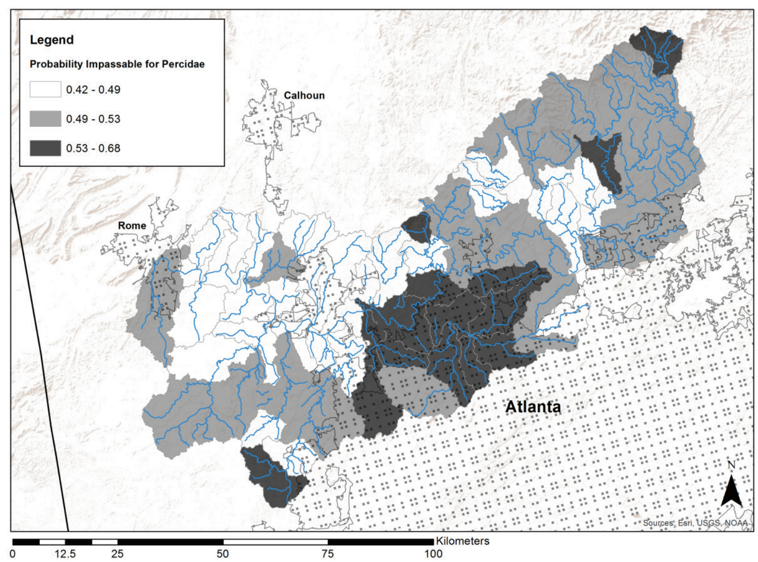

Figure 3. Visualization of mean passability for each HUC 12 in the Etowah watershed. The map reflects mean passability estimates for fishes in the Percidae family, with darker colors representing a higher number of impassable structures.

Approach – Culvert scale prioritization

We used the Dendritic Connectivity Index (DCI) as a method to prioritize culverts for removal or remediation in our three study watersheds. The DCI provides a means to quantify longitudinal connectivity based on an organism's probability to move between points in a network (Cote et al. 2009). The equation to calculate the DCI for potamodromous fishes is presented below.

$$= \sum_{=1} \sum_{=1} \quad —— * 100$$

The DCI_p evaluates connectivity based on the length of sub-reach i and j (represented by and in the equation) in relation to the total length of the network (represented by). Passability of barriers between reaches i and j is represented by . This value is calculated by finding the product of the upstream ( ) and downstream ( ) passability for M number of barriers between reaches i and j.

$$= \prod_{=1}$$

The DCI_P is capable of incorporating environmental parameters by weighting the sub-reach length based on habitat suitability, presence of target species, or water quality. However, we simply use segment length as the weight for our analysis. To calculate DCI_P we assigned the predicted passability from the RF model to the DCI_P equation (c_{ij} = predicted passability). Prioritizations were evaluated based on passability estimates for the three focal families (Percidae, Cyprinidae, and Salmonidae). Then, through iterative removal of potential barriers, we can find the one (or combination) resulting in the largest increase in DCI score, thus finding the top priority for remediation.

To overcome the computational limitations of calculating DCI for thousands of potential combinations of barriers, we developed a heuristic algorithm using a graph-theoretic framework in Python, which we have packaged in an ArcGIS toolbox and distributed to project partners and beyond. As inputs, the tool requires: Stream data from the National Hydrology Dataset (USGS), NHDPlus Version 2 (Horizon Systems); Dams resulting from combining data from the National Inventory of Dams (NID), US Army Corps of Engineers National Anthropogenic Barrier Dataset (NABD), GeoFIN (USFWS), NHD Dam Events (USGS), and various regional and state datasets (e.g. SARP); Roads from the TIGER/Line data (US Census); and Bridges from the National Bridge Inventory (NBI, FHWA). Before running the tools the user must intersect roads and streams to identify likely culverts, snap dams to the stream network, and remove known bridges.

The toolbox can then be used to condition the input data, and then run the prioritization scheme based on desired number of culverts to remove and number of combinations to test. While the prioritization algorithm can be run exhaustively on small watersheds with relatively few culverts (hundreds), the heuristic model must be used for large problems (thousands). The heuristic approach prioritizes the reconnection of high-weight streams (longest length for our simulation), identifies paths resulting in cumulative improvement to DCI, and then progressively expands this search from a path to the whole network.

Results – Culvert scale prioritization

The DCI method for prioritization worked well for finding one or more combinations of culverts whose remediation would lead to the best improvement in overall network connectivity. We found that the overall influence of any one culvert on the watershed is relatively low, which can be expected in any highly fragmented system with numerous potential barriers. Further, we found an asymptotic relationship between barrier priority and total connectivity improvement (Figure 4). This result highlights the importance of prioritizing barriers for remediation because very little improvement to connectivity can be made by addressing a barrier ranking lower than the top ~3% for remediation.

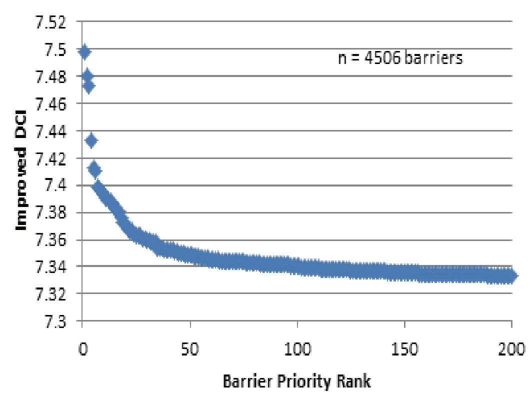

Figure 4. DCI_P improvement for the Etowah River drainage. DCI_P scores are based on Cyprinidae passability for this example.

Furthermore, within a hydrologic unit, our heuristic prioritization algorithm improves computation times by several orders of magnitude, and exactly matches the exhaustive solution for the prioritization of more than 350 barrier removal options (Figure 5).

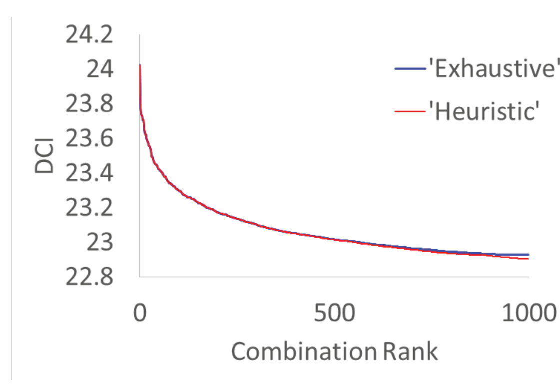

Figure 5. Compared to exhaustive searches, 300 node network, Removing 3 barriers > 4 million possible combinations

Our results indicate that a predictive modelling approach can provide enough information to adequately inform decision makers and lead to actionable results. Ultimately, these models estimate the tendency to become impassable based on landscape characteristics, and are limited in their ability to definitively predict culvert passability at a specific point. Thus, we recommend looking at predictions of impassabilty at a regional scale to help identify areas for monitoring or further attention.

Summary

Our study reinforces others in demonstrating that culverts at road-stream intersections can have large cumulative effects on aquatic connectivity. Further we provide a hierarchical modeling approach to assess and prioritize connectivity problems for remediation by 1) modeling the potential for connectivity problems at watershed scales using broadly available landscape variables and 2) providing a robust algorithm for the prioritization of one or more individual culverts for remediation to achieve the largest improvement in connectivity for an area of interest.

DAM SAFETY AND FLOOD MAPPING

Shoring Up Dam Safety: Assessing the Future Threat Level of Georgia's Dams and Reviewing the Applicability of Simplified Inundation Maps for Emergency Planning, *by Robert Hines, UGA Carl Vinson Institute of Government*

Adequate strategic and emergency planning is essential to protect Georgia's expanding communities from aging dam infrastructure. Emergency action plans (EAP) based on simplified inundation maps (SIM) may be able to inform emergency service delivery when formal maps are unavailable.

Small, private, and aging earthen dams increasingly threaten communities that continue to expand into dam break floodplains. The National Inventory of Dams contains 5,420 dams in Georgia (U.S. Army Corps of Engineers 2017), of which 99 percent are earthen and 86 percent are privately owned (missing values omitted). Large dams heavily right skew the size distribution of Georgia's dams.

While the median dam stores a maximum of 138 acre feet of water, Georgia's dams store 3,678 acre feet of water on average. Georgia's dams are aging. Due to a building boom that occurred between 1950 and 1970, the average dam is now 54 years old (Army Corps of Engineers, 2017).

In the event of a dam break, an EAP can prepare local emergency responders to quickly issue warnings, plan for efficient emergency service delivery, and identify at-risk infrastructure (Federal Emergency Management Agency, 2013). While the high cost of complex dam break inundation mapping studies has prevented EAP development across the United States, new Environmental Protection Division rules now require all category one dams that, by definition, may cause a loss of life upon breaking to have an EAP by July 1, 2017 (National Dam Safety Review Board Emergency Action Plan Workgroup, 2009) (Environmental Protection Division, 2017). However, given a situation in which full dam break studies are unavailable, SIM may be able to fill the gap in dam break emergency action planning.

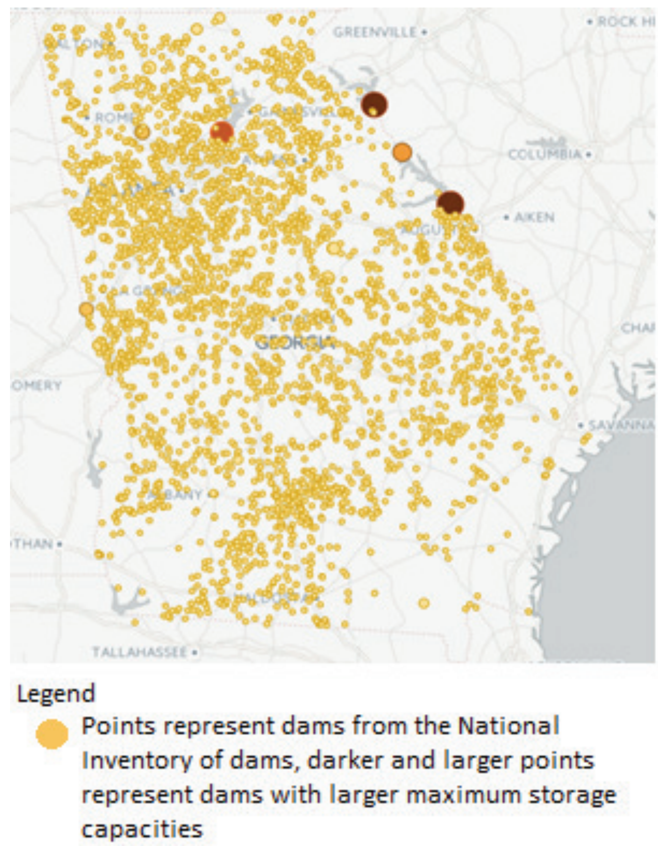

Figure 6. Georgia's Dams Shaded and Sized by Storage Capacity

This project reviewed engineering recommendations and created a mapping methodology based on engineering recommendations produced for the Indiana Department of Natural Resources. The methodology assumes a sunny day, earthen dam failure at full reservoir volume with no inflow and a nonfunctioning spillway. The method recommends modeling the flowpath, banks, overbanks, and cross sections in ArcGIS using HEC GeoRAS. Under the method, the delineation should be carried out until the end of the expected flood section zone with cross sections cut perpendicular to the flood flow path at significant channel geometry changes.

Once the geometry file is exported into HEC RAS, each cross section is assigned a Manning n value via table analysis of aerial topography. Each reach is assigned a peak flow as determined by the Froehlich equation for earthen dam breaches attenuated via Washington Department of Ecology generalized attenuation curves and upstream/downstream normal boundary conditions with a friction slope equal to the two most downstream/upstream cross-sections' bed slope. Finally, HEC RAS is run in the steady state model and the SIM is viewable within HEC RAS (Christopher B Burke Engineering, 2009).

Federal Emergency Management Agency (FEMA) recommendations for EAP development were assessed to identify road closings and threatened structures as the most relevant and practical points of comparison between simplified and formal maps because both inform the distribution of emergency response services. Two qualitative case studies compared simplified maps against formal, unsteady state maps provided by the Georgia Soil and Water Commission. Little Sandy Creek Structures 2 and 14 were selected because full dam break inundation studies and 1-meter National Oceanic and Atmospheric Administration digital elevation maps of the surrounding topography were available for both structures.

The Little Sandy Creek Structure 14 SIM predicted 23 more flooded homes and 11 more closed roads than the official map, and the Little Sandy Creek Structure 2 SIM predicted 5 fewer flooded buildings and 1 fewer closed road than the official map. While both SIM were created by the admittedly inexperienced author, selected via a convenience sample, and suffered from known modeling errors, the majority of the error in both cases was traced back to the failure of the modeling methodology to provide an adequate ad hoc method for determining the probable extent of the flooding. Despite its flaws, an improved version of this methodology may be useful in emergency situations in which higher quality maps are simply unavailable. Further research is required to improve and evaluate this methodology.

NRCS Dam Maintenance and Rehabilitation, *by George Skovran and Eric Harris, Georgia Natural Resources Conservation Service*

Across the nation, Natural Resources Conservation Service (NRCS), watershed projects provide an estimated annual benefit of $2.2 billion in reduced flooding and erosion damages, and improved wildlife habitat, recreation, and water supply for an estimated 47 million people. These projects provide additional benefits, such as improved water quality through sediment and erosion control. Watershed rehabilitation projects also can create rural economic growth and job opportunities.

Local communities in Georgia, with USDA Natural Resources Conservation Service (NRCS) assistance, have constructed 357 dams since 1953. Many of these dams are nearing the end of their 50-year design life. Maintenance and rehabilitation of these dams is needed to address critical public health and safety issues in these communities.

Prior to rehabilitation, a supplemental watershed plan is developed for each project that addresses environmental impacts, costs, and benefits, planned conservation practices, and the responsibilities of involved parties. A variety of agencies and organizations can assist sponsors with developing a plan.

Watershed project sponsors represent interests of the local community in federally assisted watershed projects. Sponsors request assistance from NRCS. When funding is allocated, the sponsor and NRCS enter an agreement that defines the roles and responsibilities of each party to complete the rehabilitation.

NRCS provides technical and financial assistance to sponsors and assists them with the planning, design, and construction of the projects.

Fish Passage and Conservation Locking at Jim Woodruff Lock and Dam, *by Douglas L. Peterson (UGA Warnell School of Forestry and Natural Resources)*

The lack of effective fish passage at hydroelectric dams is one of the most serious impediments to the conservation and sustainable management of anadromous fish populations throughout North America. In addition to the direct impacts of impeding spawning migrations, impoundments also have many indirect adverse effects on migratory fishes including altered flows regimes, altered temperature regimes, and sediment starvation in downstream reaches. On the Apalachicola River, Florida, the completion of the Jim Woodruff Lock and Dam (JWLD) in 1957 eliminated approximately 78% of historic riverine habitat available to migratory fishes (USFWS and GSMFC 1995) within the Apalachicola-Chattahoochee-Flint River Basin.

The Gulf Sturgeon, *Acipenser oxyrinchus desotoi*, is large benthic fish native to the Apalachicola River. Despite nearly 30 years of protections as a federally threatened species, the population has recovered only marginally compared to levels prior to construction of JWLD. Although some Gulf Sturgeon spawning below the dam has been documented, Flowers et. al (2009) suggest these down river spawning areas are highly susceptible to environmental fluctuations that may negatively affect spawning success, and that the tributaries above JWLD likely constituted the vast majority of population's historical spawning habitat.

Although recent attempts to manipulate the navigational locks at JWLD to facilitate upstream passage of Alabama Shad have proven quite successful (Ely et al. 2008; Young et al. 2012; Sammons and Young 2012); similar attempts with Gulf Sturgeon have not been effective (Weller 2002) and passage at JWLD has been identified as a key impediment to restoring the population. Consequently, the objective of this study was to evaluate the potential effectiveness of passing adult Gulf Sturgeon at JWLD with an experimental "trap and transfer" approach. Specific objectives of the study were to, (1) determine if adult Gulf Sturgeon released above JWLD could successfully navigate the reservoir in their search for suitable spawning habitats in Flint and Chattahoochee tributaries; and (2) determine if these same fish could subsequently pass downstream through the locks or spillways at the end of the spawning season.

During April 2015, we used anchored gill nets to capture 10 adult Gulf Sturgeon from known spawning areas below JWLD. The captured fish were loaded into a customized hauling truck, and individually transported to a release site in lower Lake Seminole, located approximately 1.5 km above the dam. All fish were carefully evaluated to ensure they were in spawning condition, after which they were tagged with internal sonic transmitters and released. The seasonal movements of the tagged fish were monitored using a series of stationary acoustic receivers distributed throughout Lake Seminole, and the lower Flint and Chattahoochee tributaries. Telemetry data on the tagged fish collected though July, 2015, revealed that 20% of the translocated individuals moved at least 60 km upstream of their release site into potential spawning habitats located in the lower Flint River. The data also showed that that 60% of tagged fish were able to pass back downstream through the JWLD spillway. Although these results were encouraging, 40% of the transported fish were lost from the study before passing back downstream, suggesting that trap and transfer is not likely an effective long-term recovery strategy for passing adult Gulf Sturgeon at JWLD. Despite recent successes with passage of other migratory fish species through the locks at JWLD, we suggest that future studies consider other potential fish passage methods for Gulf Sturgeon.

Southeast Native Black Bass Initiative. Southeast Aquatic Resources Partnership: Connectivity and its Relationship with the Native Black Bass Initiative, *by Vance Crain (Southeast Aquatic Resources Partnership)*

The Southeast Aquatic Resources Partnership (SARP) was formed in 2001 by the Southeast Association of Fish and Wildlife Agencies (SEAFWA) as a joint party committee to address the myriad of issues relating to the management of aquatic resources in the southeastern United States. In 2008, SARP published the Southeast Aquatic Habitat Plan (SAHP) with the mission to protect, conserve and restore aquatic resources throughout the southeast for the benefit of the American people (SARP, 2008).

Improving or maintaining aquatic connectivity is a specific objective within the plan, with program goals of creating a GIS-based fish barrier inventory and assessments, facilitating on the ground restoration and creating aquatic connectivity teams throughout the Southeast (SARP, 2014). In October of 2016, SARP and American Rivers hosted a dam removal workshop in Athens, Georgia and from that event, the Aquatic Connectivity Team in Georgia was founded (SARP, 2017). This group, with coordination provided by SARP and The Nature Conservancy (TNC), is utilizing a regional online database of barriers developed by SARP and the USFWS, as well as the Southeast Aquatic Connectivity Assessment Project (SEACAP) tool to identify, assess and prioritize barriers for removal or bypass within the state of Georgia (Martin et al. 2014).

This tool allows regional managers to identify potential barriers to fish passage through a host of metrics based on species or environmental needs in the area. One such species is the shoal bass, and is a focal species of the Native Black Bass Initiative (NBBI). Given shoal bass life history, the construction of impoundments across the ACF has altered their natural range (Williams and Burgess 1999; Taylor In Review).

The NBBI was started by SARP through significant support from the National Fish and Wildlife Foundation and black bass researchers in the southeast as a 10-year, $30 million-dollar business plan focusing on the preservation of endemic black bass species (Long, et al. 2015). In this plan, endemic riverine black bass species are used as keystone species, where benefits to the species provide benefits to other aquatic organisms and the watershed as a whole (Birdsong et al. 2010).

This plan provides guidance and target metrics for recovery of the species and their native watersheds. This plan provides common ground for various natural resource partners to facilitate research needs to aid in management and recovery decisions, along with promoting water conservation within the ACF. Shoal bass, *Micropterus cataractae*, are one of the major focal species under this plan, where connectivity is a major threat.

The shoal bass is native to the Apalachicola-Chattahoochee-Flint (ACF) River basin and was first described by Williams and Burgess (1999). These fluvial specialists prefer large to medium size rivers of moderate to fast current, are generally associated with rock habitats, and intolerant of reservoir conditions (Ramsey 1975; Wheeler and Allen 2003).

Dams serve as barriers to movement resulting in isolated populations, coupled with the lentic systems created that further eliminate shoal bass habitat. Fragmented populations lower effective population size and put genetic diversity at risk, increasing the likelihood of extinction (Sammons and Maceina 2009). In addition, an evaluation of shoal bass in the upper Flint River showed this species can travel up to 200-km to reach spawning shoals, especially in the coastal plain where spawning habitat is limited (Sammons 2015). Potadromy amongst centrarchid species is a novel concept that is important in understanding the relationship connectivity plays on shoal bass populations. Addressing these threats to shoal bass (*Micropterus cataractae*) involves working with the Southeast Aquatic Resources Partnership through the Native Black Bass Initiative and the Georgia Aquatic Connectivity Team.

The coordination allows regional biologists to not only identify and assess barriers for removal, but also provide further guidance on shoal bass life history and prioritized restoration needs throughout the ACF basin. It provides potential funding opportunities, staff to facilitate and manage projects, as well as promote and highlight aquatic connectivity for shoal bass in the ACF basin and the entirety of Georgia.

Dam Removal and Culvert Replacement Case Study: Raccoon Creek, *by Kathleen Owens and Sara Gottlieb (The Nature Conservancy), Ashley Monroe, (U.S. EPA)*

The Raccoon Creek Watershed is one of several high priority Etowah River tributaries that The Nature Conservancy (TNC), Georgia Department of Natural Resources (DNR), and the U.S. Fish and Wildlife Service (USFWS) have identified for aquatic and terrestrial habitat restoration, management, and protection. Raccoon Creek provides the only known habitat for the federally endangered Etowah darter (*Etheostama etowahae*) downstream of Lake Allatoona and it supports the largest known population of the Federally Threatened Cherokee darter's (*Etheostoma scotti*) genetically distinct lower evolutionary species unit.

In addition to listed species, the current Raccoon Creek aquatic community is comprised of 43 native fishes, 13 of which are endemic to the Mobile Basin or a smaller geographic area. The watershed has been impacted by stream channel alterations, fish passage barriers including poorly designed road crossings and several dams, and land use alterations. Here, we focus on stream restoration and fish passage projects that have been prioritized and implemented to improve and expand habitat for aquatic species in Raccoon Creek watershed.

The total population size is unknown for both federally listed darters, as well as their complete life histories. The Etowah River HCP identified guidelines, aimed at minimizing the risk of extinction by setting population thresholds for both Cherokee and Etowah darters: (1) Maintain the major existing populations; (2)Maintain high habitat quality within existing populations; (3) Maintain existing levels of connectivity among populations by minimizing impact of road crossings, dams, and other man-made instream structures on fish passage; (4)Maintain populations across species ranges within the Raccoon Creek project area. TNC's project partners identified five biodiversity goals for Raccoon Creek:

- Match density of Etowah darter and Cherokee darter in Amicalola Creek.
- Extend range of Etowah darter to include reach above Silver Comet Trail and in Pegamore Branch.
- Restore natural population genetics and connect gene flow throughout the watershed.
- Maintain fish biodiversity in the Raccoon Creek watershed.
- Provide a permanent refuge for the furthest downstream Evolutionary Significant Unit (ESU) of Cherokee darter.

RESTORATION PROJECTS

Since 2008 TNC and partners have restored a 6,441 linear foot reach of Raccoon Creek impaired by a power line right-of-way just downstream from the Paulding County Wildlife Management Area. TNC established a 25-year encroachment agreement with Georgia Power to ensure the long-term success of the Georgia Power restoration site project. Poorly designed road crossings, stream channelization, livestock access and associated grazing, and power line management practices have degraded riparian and floodplain buffers, destabilized streambanks, and created an unstable stream channel. Identified instability issues include down valley migration of meanders, reach wide erosion, stream incision, and lack of a stable riparian woody buffer. The Georgia Power restoration reach restored over a mile of stream buffer, stabilized six mass wasting banks, removed one seasonal fish passage barrier, and created a riffle/pool/run ratio within the restoration reach that is characteristic of the greater Raccoon Creek Watershed.

FISH PASSAGE

TNC partnered with DNR and USFWS to identify and prioritize major stream crossings that are inhibiting natural fish passage in Paulding and Bartow Counties (Figure 7). The removal of small barriers in Raccoon Creek will allow for expansion and colonization of Cherokee and Etowah darters into areas of suitable habitat and refugia (headwaters), and enables species movement as the thermal isoline shifts.

Pegamore Creek Fish Passage Project

In 2015, TNC collaborated with USFWS, DNR, Paulding County, and local landowners to install a 32' free span steel bridge over Pegamore Creek and Lee Road in Paulding County (Site 'a' in Figure 7; site photos in Figure 8). Pegamore Creek is a major tributary of Raccoon Creek, with the confluence located within a mile downstream of TNC's previous restoration work in the Raccoon Creek mainstem.

The original Pegamore Creek/Lee Road crossing was comprised of six undersized metal culverts with a poured concrete top. The undersized culverts resulted in a significant perch on the downstream side, preventing fish passage except during high flow events, and creating a deep scour pool with active erosion on both sides of the creek.

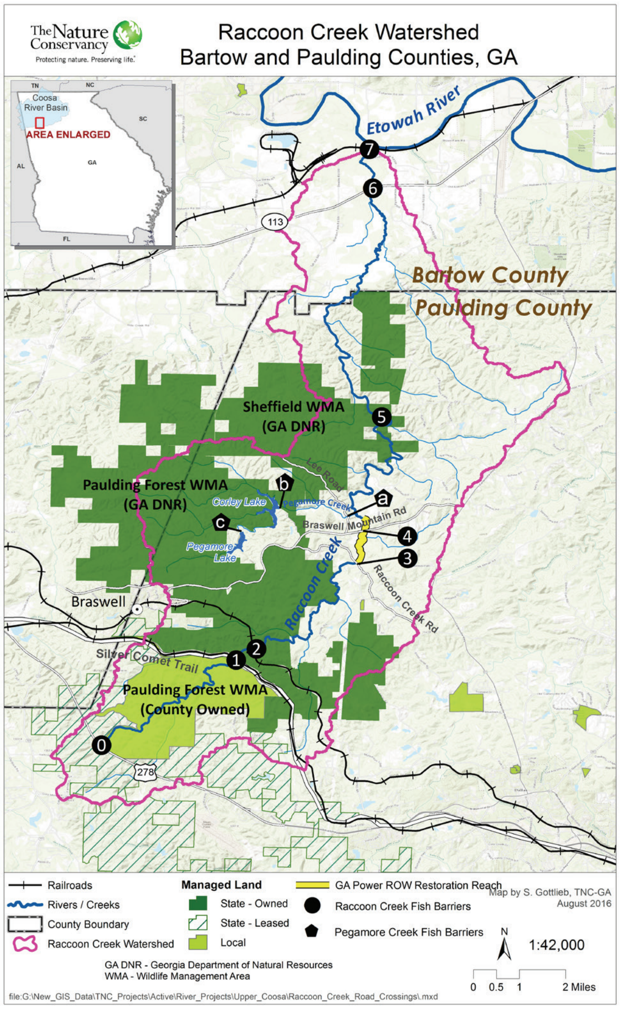

Figure 7. Road Crossings and Fish Passage Barriers Raccoon Creek Watershed

The upstream side of the crossing had widened over time due to the inability of the culverts to pass adequate flows and woody debris.In May 2014 TNC and DNR sampled Pegamore upstream and downstream of the current crossing and discovered populations of Cherokee darters, a federally threatened species, as well as several fresh dead *Villosa vibex* shells, a common river mussel to the Upper Coosa, but rare find in the Etowah.

TNC hired Erudite Engineering Inc. to design bridge abutments and a new road approach to meet the bridge. In June 2014 TNC signed a 10-year landowner agreement with Keith Lee, the local landowner who owns the property just upstream of the current crossing who agreed to have the free span bridge installed on his property. The bridge was installed during the fall of 2015 (Figure 8). Removing the six undersized culverts at this site and replacing them with a free span bridge has reconnected Cherokee darter populations and decreased sediment loading, improving habitat within the Raccoon Creek watershed.

Figure 8. (Top) Culverts Forming Fish Passage Barrier at Pegamore Creek/Lee Road Crossing and (Bottom) Free-Span Bridge Installed at Pegamore Creek/Lee Road Crossing.

Braswell Mountain Road Fish Passage - Lip Removal

The culverts under Braswell Mountain Road crossing of Raccoon Creek (site 4 on Figure 7) presented a partial barrier to fish passage due to an 18-inch 'lip' on the downstream apron originally designed to prevent scour, but never functioned as designed, and which at low flows created a cascade that was impassible by small-bodied fish. This barrier was removed in 2014 during the stream restoration by notching out 10-foot section of the center of the lip to enable fish to pass under all flow conditions.

Raccoon Creek Road Fish Passage Barrier

TNC is currently working in partnership with Paulding County to replace the Raccoon Creek Road crossing (site 3 on Figure 7) with a free-standing bridge. An analysis by Anderson et al. (2012) determined that the culvert is completely dry, but the stream is not. The stream runs completely under culvert and culvert apron; upstream apron is perched 0.39 m above water and 0.62 m above the streambed; downstream apron is perched 0.75m above the water and 1.0 m above the streambed (Anderson et al., 2012).

They estimated that the probability that the culvert was a barrier to passage by small fishes equaled 93.5% regardless of passage criteria used.They estimated that removing the culvert as a barrier could restore access to 5,784 m for the Etowah darter (*E. etowhae*), 43,700 m for the Cherokee darter (*E. scotti)* and 7951 m for the undescribed Etowah chub (*Hybopsis* sp. sc H. winchelli). This culvert on Raccoon Creek ranked #1 or #2 among all 256 culverts assessed, because of high probability that the culvert was a barrier and relatively large amounts of habitat that could be reconnected for target species.

Pegamore Lake Dam Removal

Pegamore Lake is an approximately 23-acre impoundment created by one of two earthen dams on Pegamore Creek ('c' on Figure 7) upstream from the Lee Road crossing, which was opened up to fish passage in 2015. The dam, which was constructed in the 1950's for recreation, has been tagged by the GA Safe Dams Program as not meeting safety standards as a Category I dam (O.C.G.A. Code Section 12-5-372A, 12-5-375(a) and 391-3-8-.03): "Category I dams are those for which improper operation or dam failure would result in probable loss of human life. Situations constituting 'probable loss of life' are those situations involving frequently occupied structures or facilities, including but not limited to, residences, commercial and manufacturing facilities, schools, and churches."

TNC is currently pursuing removal of Pegamore Lake Dam in a way that will restore the natural stream channel, stabilize restored stream banks, minimize the release of sediment into the system, and restore fish passage between the headwaters of Pegamore Creek and the reach above Corley Lake. Cherokee darter have been documented above Pegamore Lake and below Corley Dam. Eventually, TNC hopes to remove Corley Lake Dam, which would complete the reconnection of the entire reach of Pegamore Creek from headwaters to confluence with Raccoon Creek.

WHITE DAM REMOVAL UPDATE

Considerations for Improved Aquatic Connectivity at White Dam on the Middle Oconee River, by *James Shelton and Justin Vining (UGA Warnell School of Forestry and Natural Resources), Duncan Elkins (UGA Odum School of Ecology, River Basin Center), Derek Little and Lisa Perras Gordon (U.S. EPA)*

White Dam is a historic stone and masonry structure which spans the Middle Oconee River just upstream from its confluence with the North Oconee River south of Athens, GA. Records of the structure are scarce, but hydropower generation and transmission is thought to have begun at the site in the late 1800s or early 1900s in support of a textile mill known first as the Georgia Factory and later as the Athens Manufacturing Company (Mooney, 2012). The entire property is now owned by the University of Georgia, and is managed as a working forest by the Warnell School of Forestry and Natural Resources (WSFNR). The dam has not been operational for decades but has been identified as a potential impediment to native fish movement and aquatic connectivity (Georgia Department of Natural Resources et al. 2013). Since the cessation of power generation, the old dam serves no economic or flood-control purpose, but remains an in-channel obstruction. During high-flow periods, woody debris collects in one or both of its openings and must be removed periodically by WSFNR staff. Boaters have occasionally been unable to navigate the dam and their boats have become impinged on the structure.

UGA Faculty, staff and students have investigated the feasibility of modifying White Dam to improve aquatic connectivity and fish passage, and have sought comment on the merit of this project from a number of interested stakeholders including the US Fish and Wildlife Service, US Environmental Protection Agency, GA Department of Natural Resources, American Rivers and others. Our preliminary investigations suggest that the dam can be modified to improve aquatic connectivity, and that the most practical project alternative identified to address fish passage would also substantially ameliorate any potential risk of injury to boaters passing through this section of the Oconee River.

The initial processes of scoping and pre-permitting investigation indicate that improved aquatic connectivity can be achieved at relatively low cost and with significant external support. This support includes assistance from the US Fish and Wildlife Service (USFWS) - Southeast Region Fisheries - Fish Habitat, Fish Passage, Maintenance and Construction team. This highly experienced team has examined the site and, pending successful planning and permitting, offered to assist as part of their voluntary cost-match program. Other stakeholders including US Environmental Protection Agency, US Geological Survey and USDA Natural Resources Conservation Service have offered to assist by providing services required during the planning, permitting and monitoring phases of the project.

Beyond the substantial environmental benefits of this project, we feel it offers extraordinary teaching, research and outreach opportunities as improvements to aquatic connectivity become a national priority. This work may ultimately benefit important native fish species of conservation concern such as the Altamaha shiner (*Cyprinella xaenura)*, the robust redhorse (*Moxostoma robustum*) and the American shad (*Alosa sapidissima*).

In January of 2017 we initiated pre-application agency consultation for this through the US Army Corps of Engineers (USACE) Savannah District, Piedmont Branch Office. Subsequent to this meeting the project was assigned an official USACE project number: SAS-2017-00086 and USACE Project Manager. This meeting provided us with specific information needed to navigate the permitting phase of this project. With the help of our various agency partners we have initiated a number of investigations designed to provide the information required for planning and permitting. In addition, we have consulted engineering and archeological firms to obtain procedural information and associated costs for completion of planning and permitting prior to construction.

SUMMARY AND EMERGING CHALLENGES

Increasing the pace of removing barriers to fish passage in Georgia is a priority for a variety of stakeholders across the state, and the work described in this section provides a promising view of progress being made. Advances in methods to prioritize barrier removal projects have helped to focus statewide and watershed-wide efforts on those projects that are likely to have the greatest benefits. The permitting process is becoming somewhat more streamlined, and the regulatory agencies involved in the management of dam operations, maintenance, safety, and removal are working together with the conservation community to take advantage of opportunities to improve aquatic connectivity through a variety of creative solutions.

As several case studies have shown, the process of culvert replacement and dam removals remains complex and expensive, even while the benefits to biodiversity and society are proving to be significant. Challenges remain in terms of scaling up from individual projects to the widespread adoption of a culture of barrier removal: (1) Limited experience among the stakeholders resulting in significant time spent learning how to enable each individual project; (2) Regulatory agencies' narrow focus on their specific authority and limited ability to work with fellow agencies at various levels of government; (3) Lack of local project management capacity to shepherd a project through the lengthy process of landowner and stakeholder outreach, fund raising, permitting, engineering design, and project implementation; (4) Funding; (5) Public perception of the value of old dams as a familiar part of the landscape, and uncertainty about the benefits of their removal.

The Georgia Aquatic Connectivity Team has recognized these challenges and has organized itself around finding ways to overcome them. Nevertheless, a key to our success is the completion of more projects in the state, providing case studies and lessons that can be shared among all those involved in aquatic connectivity.

Top-down (streamlining the permitting process and identifying major new sources of funding) as well as a bottom-up (developing case studies both strategically and opportunistically) approaches being pursued simultaneously will help achieve our shared goals of improving the health and resilience of our waterways and to conserve our natural heritage.

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