Landscape level in-stream habitat mapping – side scan sonar

Introduction

Although the practice of landscape ecology has flourished using spatial technologies to reveal patterns and processes at broad scales in terrestrial habitats, the investigation of riverine landscapes has lagged behind (Wiens 2002), perhaps for want of analogous tools and techniques. Landscape level habitat data are extremely valuable in research, management and monitoring of aquatic systems. A multiscale landscape perspective is necessary to enable ecological investigations at scales relevant to the life history of stream fishes (Fausch et al. 2002; Lowe et al. 2006), and to identify, protect, restore and enhance fish and aquatic invertebrate habitat. In the past, the characterization of in-stream habitat at the landscape scale has been both difficult and costly. Side-scan sonar (SSS) offers an alternative to airborne remote sensing techniques, such as lidar and thermal infrared systems, which are costly and are significantly impacted by depth and turbidity (Kaeser and Litts 2010).

Side scan sonar has been used for decades to detect and map benthic features of marine and deep freshwater systems (Newton and Stefanon 1975; Fish and Carr 1990, 2001; Prada et al. 2008). Traditional SSS is, however, expensive and typically involves towing an underwater sensor (i.e., towfish), limiting its use in relatively shallow freshwater systems. In 2005 Humminbird® released the 900-series Side Imaging (SI) system, an inexpensive (~$2,000) side scan sonar device. The SI system employs a small, boat-mounted transducer, enabling surveys in shallow, rocky streams. This device is capable of producing very high resolution (<10 cm) imagery revealing substrate, large woody debris, and depth—all critical components of instream habitat. Sonar mapping provides a comparable and effective substitute for the labor intensive, traditional field assessment of several key habitat variables. Sonar mapping is not only more efficient, but the information generated is geospatially referenced at a level of detail that is difficult, if not impossible to achieve with traditional methods. By providing a means to visualize whole-channel, underwater features, sonar mapping overcomes limitations of traditional approaches in deep, turbid, and/or non-wadeable systems. From a practical standpoint, this technique can be performed using software readily available to researchers and managers with a limited amount of training and expertise. Within the GIS environment, information contained in these maps can be integrated with a wide variety of data layers providing new ways to examine patterns and processes occurring in aquatic landscapes. Applications of sonar habitat maps include studies of habitat-organism relationships, the identification or prediction of critical habitat, the association of land cover and instream habitat, and the monitoring of change over time (Kaeser and Litts 2010).

Side-scan sonar is currently being used to explore habitat selection of female Barbour's map turtle in a Southwest GA creek, locate spawning sites for the robust redhorse in the Ocmulgee River, study habitat relationships between three bass species in the upper Flint River, assess changes in substrate deposition following a 10-year flood event, model the distribution and abundance of mussels in the Apalachicola River, develop and evaluate a sonar-based approach to monitoring distribution and abundance of adult Gulf sturgeon, and evaluate alligator snapping turtle habitat use in the Suwannee River (Ga.DNR 2010 and Kaeser and Litts 2013).

The sub-basins selected for this project represent two FWLI priority Preservation sub-basins (Lower Choctawhatchee and Lower Ochlocknee), two FWLI priority Enhancement sub-basins (Withlacoochee and Peace) and a priority basin for partners/stakeholders (Lower Suwannee). The habitat maps produced will provide valuable information that can be used to identify critical habitat for numerous SGCN (Species monitoring goal). The benthic maps will provide the baseline data needed for instream habitat monitoring (Habitat monitoring goal). The physical habitat maps (substrate and large woody debris) will provide a measure of location and amount of various habitat types for aquatic species. Over-time changes in the location and amount can be tracked and provide a means of habitat monitoring. These maps will also identify potential areas for restoration (Freshwater goal). Additionally, mapping pre- and post-restoration efforts can aid in monitoring the outcomes of those efforts. For SWG funded restoration projects, these maps will aid in fulfilling the requirement of monitoring the effectiveness of how SWG funds are being allocated.

This project is being proposed jointly by two FWLI Goal teams (Monitoring and Freshwater). This single project addresses priority needs/goals from these two teams.

Objectives

The ultimate objective of this study is to expand current knowledge of in-stream habitat by creating benthic maps of all navigable river/stream waterways within 4- 5 HUC 8 sub-basins. There are three phases involved in the creation of substrate maps:

1. Collect sonar imagery during periods of high flow, when the streams are at bankfull width.
2. Process the sonar imagery. Raw imagery is imported into the GIS environment where it is georectified to reflect the shape and position of the stream channel. Errors in the automated rectification step will be manually corrected. The banks will be digitized. A minimum mapping unit will be established based on visual inspection of the sonar imagery. This step may require field visits. Areas of varying substrate will be manually identified and digitized via visual inspection.
3. Assess the accuracy of the maps. Random assessment points will be generated in a stratified random sampling scheme, and each point will be visited to verify the substrate type occurring at that point.

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Substrate types will be mapped (polygons) as well as locations of woody debris (points).
This research will produce substrate maps for all of the navigable river/stream waterways in the five selected basins, for a total of 1,140 river kilometers. It will also produce accurate and up to date location data for large woody debris within the rivers.

Methods

<u>Site Description</u>

Although the Florida Comprehensive Wildlife Conservation Strategy (FWC 2012) uses a habitat-based foundation to assess the status and conservation needs of Florida’s fish and wildlife populations, the complexity of mapping and quantifying freshwater systems by habitat type made determining where priority projects should take place and evaluating the project’s benefits difficult. Due to often limited funding and the vast array of threats to freshwater resources statewide, a basin approach was adopted in order to focus conservation efforts using the U.S. Geological Survey’s 8-digit Hydrologic Unit Codes (HUC 8 as the basin boundaries. The basins were ranked based on preservation and enhancement scores in their drainage basins, with preservation basins having relatively pristine and stable conditions and high value for fish and wildlife; and enhancement basins having poor and declining conditions but high value for fish and wildlife (FWC 2012). The five selected sub-basins include the Lower Choctawhatchee (265 km), Lower Ochlocknee (219 km), Withlacoochee (172 km), Peace (245 km) and Lower Suwannee (240 km) (Figure 1).

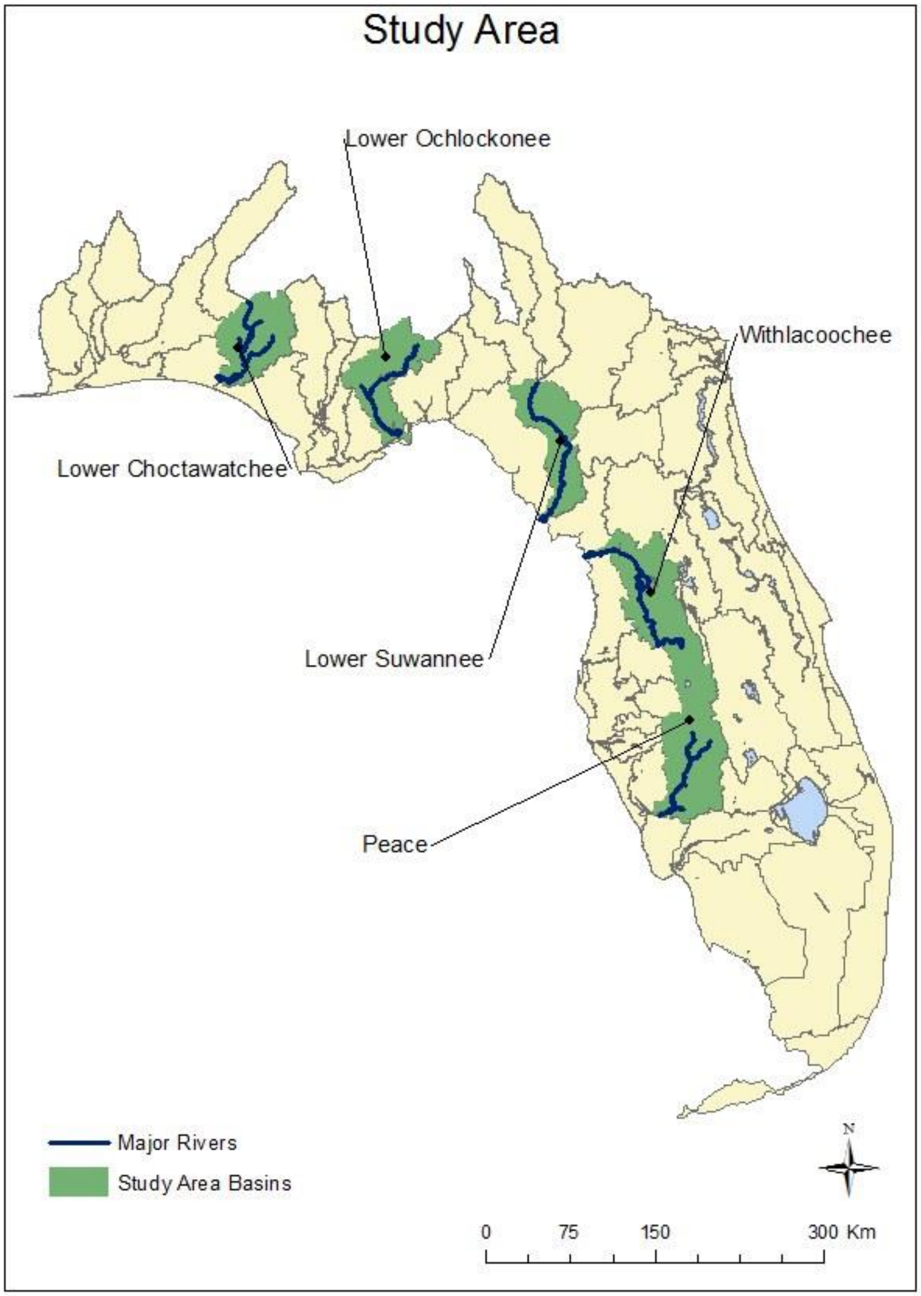

Figure 1. The proposed study area showing the five HUC 8 basins selected for side scan sonar mapping as well as the major rivers within the HUC 8s.

Activities

High resolution (<10 cm) side-scan sonar imagery will be obtained using Hummingbird Side Imaging system during periods of high water where the streams are at “bankfull level”. Additionally, depth along the survey route will be recorded continuously. Data will be collected via motorized boats (of appropriate size for navigability). Where possible, field work will be conducted in conjunction with other FWC and USFWS projects ongoing on the same waterways. The raw images, waypoints and track points will be transferred from the Hummingbird to a desktop computer. The imagery will be post-processed using ArcGIS and Irfanview software. During this phase the imagery will be rectified and mosaiced together to create a continuous image that correctly overlays the stream path. Stream banks will be identified and digitized. The physical habitat elements will be manually digitized via visual interpretation of sonar imagery within a GIS, according to a standardized classification system (to be developed with partners prior to project initiation, building upon existing systems). Woody debris will be identified and mapped, typically as a point. An accuracy assessment protocol will be developed and implemented. Error matrices and accuracy rates will be reported. Two OPS research assistants will be hired and trained to conduct all aspects of the project. Training will be provided in cooperation with USFWS.

Schedule

This project will begin in July 1 of 2014 and is expected to be completed in twenty months, by Feb 28. The timing of side-scan sonar imagery collection is dependent on streamflow conditions (streams must be running at bankfull width to allow for navigation and to allow mapping of the full extent of the stream channel). There is a pronounced difference in the seasonal cycle of river flows between peninsular Florida (where maximum flows occur in late summer (July to October) -- the so-called “SRP” or Southern River Pattern), and northern Florida (where maximum flows occur in late winter -- the “NRP” or Northern River Pattern) (Kelly 2004). Therefore, the first round of sonar image collection will likely occur in peninsular Florida during August or September after a brief training period to ensure that staff is competent in data collection techniques. Data processing and substrate classification will be performed as soon as the imagery is collected. It is important to perform the accuracy assessment as soon as possible after the sonar imagery maps are created; therefore this will be attempted for the peninsular data before data for the Panhandle basins is collected. Sonar image collection for the Panhandle will occur when stream conditions permit, likely during February or March. Data processing and substrate classification will be performed as soon as the imagery is collected. Reports will be submitted annually and at the end of the project period. This schedule is a tentative schedule and some phases may require additional time for completion. Additionally, two major portions of this project, image collection and accuracy assessment, are dependent on appropriate weather and streamflow conditions.

Schedule diagram

Year	Quarter	Processes
2014	Q1	Training/Southern Basin Data collection/Data Processing
	Q2	Data Processing/Classification/Report Due

2015	Q3	Classification/Panhandle Basin Data collection/Southern Basin Ground Truthing
	Q4	Processing /Classification/Panhandle Basin Data collection/Southern Basin Ground Truthing
	Q1	Processing /Classification/Panhandle Basin Ground Truthing
	Q2	Processing /Classification
	Q3	Report Due

Literature cited:

Fausch, K. D., C. E. Torgersen, C. V. Baxter, and H. W. Li.2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. BioScience 52:483-498.

Fish, J. P., and H. A. Carr. 1990. Sound underwater images. Lower Cape Publishing, Orleans, Massachusetts. 2001. Sound reflections. Lower Cape Publishing, Orleans, Massachusetts

Georgia Department of Natural Resources, 2010. DNR Researchers Use Low-cost Sonar to Map Stream Habitat [Press release]. Retrieved from http://www.georgiawildlife.com/node/2203

Kaeser, A. J. and T. L. Litts. 2010. A Novel Technique for Mapping Habitat in Navigable Streams Using Low-cost Side Scan Sonar. Fisheries 35 (4) :163-174.

Kaeser, A. J. and T. L. Litts. 2013. Sonar Image Geoprocessing Workbook- An illustrated guide to geoprocessing low-cost, side scan sonar imagery obtained with the Humminbird® Side Imaging System. Version 2.1. Georgia Department of Natural Resources, Social Circle, GA. U.S. Fish and Wildlife Service, Panama City Fish and Wildlife Conservation Office, Panama City, Florida.

Kelly, M. 2004. Florida River Flow Patterns and the Atlantic Multidecadal Oscillation. Southwest Florida Water Management District 2379 Broad Street Brooksville, Florida.

Lowe, J. W., G. E. Likens, and M. E. Power. 2006. Linking scales in stream ecology. BioScience 56:591-597.

Newton, R. S., and A. Stefanon. 1975. Application of sidescan sonar in marine biology. Marine Biology 31:287-291.

Prada, M. C., R. S. Appeldoorn, and J. A. Rivera. 2008. The effects of minimum map unit in coral reefs maps generated from high resolution side scan sonar mosaics. Coral Reefs 27:297-310.

Weins, John, A. 2002. Riverine landscapes: taking landscape ecology into the water. Freshwater Biology, 47 : 501–515.

Biographical sketches

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Two OPS positions will be created for this project at the research assistant level. The successful candidates will have at least a BS in one of the biological sciences, intermediate level GIS skill, and experience with boat trailoring and handling. A candidate with experience conducting field work in uncomfortable temperatures is preferred. The research assistants will be responsible for all aspects of data collection, analysis and quality assessment.

Budget Narrative

This project requests grant funding in the amount of $193,271 for OPS salary, travel for data collection and accuracy assessment, equipment, and indirect costs, with FWC funding providing $104,069 in matching funds, for a total project budget of $297,340 for the period beginning 1 July 2014 and ending 30 June 2016, with the final reports due in June of 2016. FWC's match is from salary and wages from the Fish and Wildlife Research Institute ($78,561.82), with leave estimates on the above ($7,785.40), equipment ($523.12), travel for data collection ($8,200) and office rental ($5,000).

Of the total project budget, $142,409 will be allocated for two additional OPS technicians (with indirect costs of $33,145.76) to carry out all data collection and processing. A total of $28,200 will be allocated for travel to collect data and conduct accuracy assessments. Travel estimates are based on State of Florida allowable travel costs, including 0.4450 per mile reimbursement to use personal vehicle, $36.00 per day for meals and a reasonable hotel rate of 70.00 - 75.00 per night.

Appendixes

Table 1. SCGNs occurring within the selected basins

Species	Common Name
Birds	
Anas fulvigula fulvigula	Florida Mottled Duck
Aramus guarauna	Limpkin
Egretta caerulea	Little Blue Heron
Egretta thula	Snowy Egret
Egretta tricolor	Tricolored Heron
Eudocimus albus	White Ibis
Grus canadensis pratensis	Florida Sandhill Crane
Haliaeetus leucocephalus	Bald Eagle
Ixobrychus exilis	Least Bittern
Laterallus jamaicensis	Black Rail

Mycteria Americana	Wood Stork
Nycticorax nycticorax	Black-crowned Night-Heron
Plegadis falcinellus	Glossy Ibis
Rostrhamus sociabilis plumbeus	Snail Kite
Caddisflies	
Agarodes libalis	Spring-loving Psiloneuran Caddisfly
Agarodes ziczac	Zigzag Blackwater River Caddisfly
Cernotina truncona	Florida Cernotinan Caddisfly
Hydroptila Wakulla	Wakulla Springs Vari-colored Microcaddisfly
Orthotrichia curta	Short Orthotrichian Microcaddisfly
Orthotrichia dentate	Dentate Orthotrichian Microcaddisfly
Oxyethira elerobi	Elerob's (Cream and Brown Mottled) Microcaddisfly
Oxyethira novasota	Novasota Oxyethiran Microcaddisfly
Triaenodes furcellus	Little-fork Triaenode Caddisfly
Crayfish	
Cambarus cryptodytes	Dougherty Plain (Apalachicola) Cave Crayfish
Procambarus erythrops	Santa Fe (Sim's Sink) Cave Crayfish
Procambarus lucifugus alachua	Alachua Light-fleeing Cave Crayfish
Procambarus pallidus	Pallid Cave Crayfish
Troglocambarus maclanei	North Florida Spider Cave Crayfish
Fish	
Acipenser oxyrinchus oxyrinchus	Atlantic Sturgeon
Acipenser oxyrinchus desotoi	Gulf Sturgeon
Alosa alabamae	Alabama Shad
Ameiurus serracanthus	Spotted Bullhead
Anguilla rostrata	American Eel
Atractosteus spatula	Alligator Gar
Cyprinella callitaenia	Bluestripe Shiner
Enneacanthus chaetodon	Black Banded Sunfish
Etheostoma parvipinne	Goldstripe Darter
Etheostoma proeliare	Cypress Darter
Hybognathus hayi	Cypress Minnow
Macrhybopsis n. sp. cf aestivalis	Florida Chub/Speckled chub
Micropterus notius	Suwannee Bass
Umbra pygmaea	Eastern Mudminnow
Pteronotropis welaka	Bluenose Shiner
Reptiles and Amphibians	
Apalone mutica calvata	Gulf Coast Smooth Softshell
Clemmys guttata	Spotted Turtle
Deirochelys reticularia	Chicken Turtle
Desmognathus apalachicolae	Apalachicola Dusky Salamander
Eurycea cf. quadridigitata	Bog Dwarf Salamander
Graptemys barbouri	Barbour's Map Turtle
Eurycea wallacei	Georgia Blind Salamander
Hemidactylium scutatum	Four-toed Salamander

Hyla andersonii	Pine Barrens Treefrog
Macrochelys temminckii	Alligator Snapping Turtle
Pseudemys nelsoni	Florida Redbelly Turtle
Pseudemys concinna suwanniensis	Suwannee Cooter
Mammals	
Corynorhinus rafinesquii	Rafinesque's Big-eared Bat
Lutra canadensis lataxina	River Otter
Neofiber alleni	Round-tailed Muskrat
Mussels	
Alasmidonta wrightiana	Ochlockonee Arc-mussel
Anodonta heardi	Apalachicola Floater
Elliptio mcmichaeli	Fluted Elephant-ear
Elliptoideus sloatianus	Purple Bankclimber
Medionidus acutissimus	Alabama Moccasinshell
Medionidus simpsonianus	Ochlockonee Moccasinshell
Medionidus walker	Suwannee Moccasinshell
Megalonaias nervosa	Washboard
Pleurobema pyriforme	Oval Pigtoe
Pleurobema strodeanum	Fuzzy Pigtoe
Ptychobranchus jonesi	Southern Kidneyshell
Quadrula kleiniana	Suwannee Pigtoe
Quadrula infucata	Sculptured Pigtoe
Fusconia burkei	Tapered Pigtoe
Utterbackia peggyae	Florida Floater
Utterbackia peninsularis	Peninsular Floater
Villosa amygdale	Florida Rainbow
Villosa choctawensis(obovari_choctawensis.)	Choctaw Bean
Villosa villosa	Downy Rainbow
Snails	
Aphaostracon xynoelictum	Fenney Springs Hydrobe