Investigation of the shoal growth and sediment source and fate at the mouth of Clapboard Creek and the St. Johns River, Jacksonville Florida

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Goals of this study:

1. Determine the characteristics of the sediment contributing to the shoal at the confluence of Clapboard Creek and the St. Johns River.
2. Determine the source of sediment accumulating on shoals at the confluence of Clapboard Creek and the St. Johns River.
3. Determine the rate of sediment accumulation on the shoal and model the transport of sediment and a predictive model of future growth.
4. Produce a high-resolution map and model of current flow in the area of Blount Island.
5. Produce a high-resolution bathymetric map of the area of the confluence of the two waterways.
6. Determine the relative influence of chronic accumulation over long periods of time and the influence of acute storm events like tropical cyclones.

Introduction: Sediment transport

Sediment transport and sediment deposition in aquatic systems are dominated by three factors: 1) The amount and size of the sediment, 2) the hydrodynamic properties or the system, and 3) the source of sediment to the system. In fluvial systems there are well-known empirical correlations between sediment grain size and water velocity. In general, the higher the velocity the larger the grain size that can be suspended in the water body. As the velocity drops grains will fall out according to size with larger grains falling out before smaller grains.

As water flows through a system, sediment grains are disturbed and picked up in the water. This sediment is then transported along the flow path of the water. As the energy drops (water velocity) the sediment grains fall out of suspension and are deposited on the bottom of the system. The geometry and slope of a river system dictate the areas that sediment is eroded or deposited. Generally, as a river widens the water velocity slows down, and when the channel narrows the water velocity increases. When a smaller system merges with a larger system the water velocity in the smaller system slows down and sediment held in suspension is deposited in the flow path of the larger system.

In tidal systems with bi-directional flow, the acceleration and deceleration of the water during the tidal cycle can create complex bi-directional sediment deposition. In the case of a river with tidal influence the downstream velocity to the ocean will always be present. The tidal influence will either slow down the downstream velocity on an incoming tide OR accelerate the downstream velocity on an outgoing tide. This creates complex flow patterns in a system with complex sediment distribution and deposition. In addition, the growth of subaquatic features like a shoal will in turn influence the flow of water around the feature. This will generally act to slow down the water velocity and force sediments out of suspension, thereby increasing the growth rate in a positive feedback cycle. The larger a shoal gets in normal flow conditions the faster it will grow.

The St. Johns River (SJR) is dominated by medium to fine grained sediments (sand to clay sized particles). This sediment distribution is ultimately dictated by the source of sediments and the relatively slow velocities of the tributary sources, like Clapboard Creek (CC), to the sediment load to the SJR. Surveys conducted as part of our coursework at Jacksonville University (JU) using ponar sediment grabs and push core analysis show that the higher velocity areas in the sharp bends of the river are dominated by moderate to fine sands, with a component of smaller mud and silt sized grains, and organic material. The lower velocity areas around the tributary confluences are dominated by finer grained materials, with a sand and organic matter component. This relationship becomes more complex as you get closer to the mouth of the SJR and add in a stronger bidirectional flow regime typical of tidal systems.

Clapboard Creek is a broad tidally active tributary to the SJR (Fig. 1). The shoaling in the region of Clapboard Creek (Fig. 2,3) is typical of a faster flowing tributary meeting a larger slower flowing main river. The larger sand sized grains are dropped out of suspension and deposited in the larger river. The dynamics of where this sediment is dropped and what shape the deposition takes depends on the tributary mouth geometry, and the flow dynamics around the confluence of the two systems. The growth of a depositional shoal can also start to influence the hydrodynamics of the tidal flow in the area. This can slow currents down and increase the rate of deposition with time. Essentially larger shoals will grow faster by slowing down flow in the area around the shoal which encourages deposition of both larger and eventually finer sediments. This positive feedback accelerates the rate of growth. Estimates of the accumulation rates of sediment from the Florida Department of Environmental Protection (FDEP) suggest a rate of growth of 1,250 cubic feet per month. This will facilitate growth vertically, shallowing the area, and laterally, extending the size of the shoal.

Figure 1. The lower St. Johns River Basin. The area of interest is at the confluence of the St. Johns River and Clapboard Creek (marked with a green dot). This is the area where the shoaling is occurring.

Figure 2. Area of the confluence of Clapboard Creek and the St. Johns river. The USMC spoil pile is in the center of the image denoted in a green border.

Figure 3. Shoaling in the area of the confluence of Clapboard Creek and the St. Johns River. The shoaling is approximated in red. Additional shoaling is occurring to the Northwest on the opposite side of the mouth of Clapboard Creek.

Timing of deposition is also dynamic. Sediment deposition in the SJR is continuous, with sediment being added with every tidal cycle and outflowing discharge. There is most likely also an acute event depositional dynamic related to intense short term events like hurricanes, large storms, or large wind events. These acute events would be influential with large amounts being eroded and deposited during a short time. The effects of these short events are poorly understood as the hydrodynamic velocity increases, storm surge heights, rainfall intensified discharge, and accelerated watershed erosion can all vary dramatically from event to event. This dynamic could also activate sediment sources that are normally dormant in the system.

There is also a probable component of wind driven aeolian (wind-blown) sediment transport and deposition. Wind borne sediments can be removed from a source and deposited in aquatic systems. Most fine-grained sediments present on the seafloor of deep ocean is derived from dust being deposited by aeolian transport. It is likely a proportion of the sediment contributing to shoaling all through the SJR system is derived from this non-hydrologic transport process.

The shoaling in the area in question is located at the confluence of CC and the SJR near the Blount Island Terminal (BIT) (Fig. 2). CC is a shallow, slow moving, complex coastal tributary. The CC system has multiple confluences with the SJR system. This makes discharge estimates problematic without direct measurement. This will influence the estimates of sediment load by discharge as each confluence will be unique. If each outflow is measured, ideally, they would add up the total discharge of the CC system when corrected for tidal inflow and evaporation. This shoaling appears to be a recent phenomenon with depth to the shoal decreasing substantially in the last eight years. It has been suggested that the shoal growth has been interfering with watercraft navigation contributing to unintentional groundings and collisions in the area of the confluence.

There is question as to the source of the sediment on the shoal, the rate at which it is being deposited, and the overall bathymetric changes in the area in question. While depth sounding exist from previous United States Army Corp of Engineers (USACOE) surveys this data has a coarse resolution both laterally and vertically. This data can give a general view of the shoaling but is incomplete and lacks finer resolution. Sediment distribution of the shoaling material is unpublished or poorly described. The dynamics of water velocity and direction in the area are also unpublished or poorly constrained.

<u>The goals of this study:</u>

1. Determine the distribution of sediment size present in the system, both on the shoal and the areas around the shoal. This will be accomplished by a selective push core survey and ponar analysis of sediments in the area.
2. Determine the source of the sediment contributing to the shoaling. This will be accomplished by sediment tracing of the probable source(s) in the area by manufactured tracer sediment particle injection and 24 months of sediment trap and push core monitoring.
3. Determine the rate of accumulation of sediment on the shoal through time series sample collection and analysis of core data from the shoal. This will be accomplished through core analysis over a 24-month period.
4. Determine the flow dynamics of CC and the SJR in the area of the confluence under multiple tidal and rainfall events. This will be accomplished by multiple Acoustic Doppler Current Profiler (ADCP) surveys by boat and fixed moorings.
5. Create a high-resolution bathymetric map of the area to determine the exact shape and extent of the shoaling and clarify the basic geometry of the confluence region. This will be accomplished with a comprehensive Side Scan Sonar survey of the area in question.
6. Determine the effects of acute events like tropical storms. This will be accomplished by intensive sampling before and after storm events during the time of the study.

Methods

The methods proposed in this study include sediment analysis, bathymetric analysis, and water velocity analysis. All field studies and sample analysis will be conducted by Jacksonville University faculty, Graduate and Undergraduate students. This study will be conducted under rigorous scientific methods and design.

Sediment Analysis

The methods in this section will focus on the sediment provenance and deposition addressing goals 1, 2, and 3. Initial sampling will be done on the shoal, in the area around the shoal, and in any nearby spoil areas or natural sources of sediment. Sample will be collected by ponor sample grabs and shallow push core samples. This process will produce a sediment distribution measure for the sediments involved in this system. The shoal will be sampled on the upstream, crest, downstream, and distal sides. Samples will be taken from upstream of the shoal in both CC and the SJR and downstream of the shoal in the SJR. Sample of spoil material from the U.S. Marine Corps dredge storage area and far upstream in CC will also be collected to determine probable source and match the sediment distribution characteristics.

All samples will be dried in an oven at 85-degree F for 48 hours to remove all moisture. Once dried, these samples will then be analyzed in a complete Keck sieve sampling pan set and run for 5 minutes on a Rotap machine to distribute the sample in size specific pans. This analysis will help determine the sizes of sediments involved in the system, and will be used to determine the size distributions for the engineered sediment grains used in the tracing portion of the study. Samples will be sent to Partrac Geomarine (https://www.partrac.com) for use in matching the manufactured grains to the natural grains of the system.

The sediment provenance will be established by placing engineered sediment grains into hypothesized source(s) of sediment, then monitoring the shoal for the arrival and presence of these grains. These grains are reactive to ultraviolet light and are magnetic (Fig.4,5). This allows for the easy identification under a microscope and they can be trapped in transit on magnetic "lures" placed in probable flow paths. Unique UV reactive wavelengths can be produced to test multiple source areas if necessary. These grains are inert and nontoxic and will be identical to the natural grains in terms of shape, size, and visual appearance in natural light.

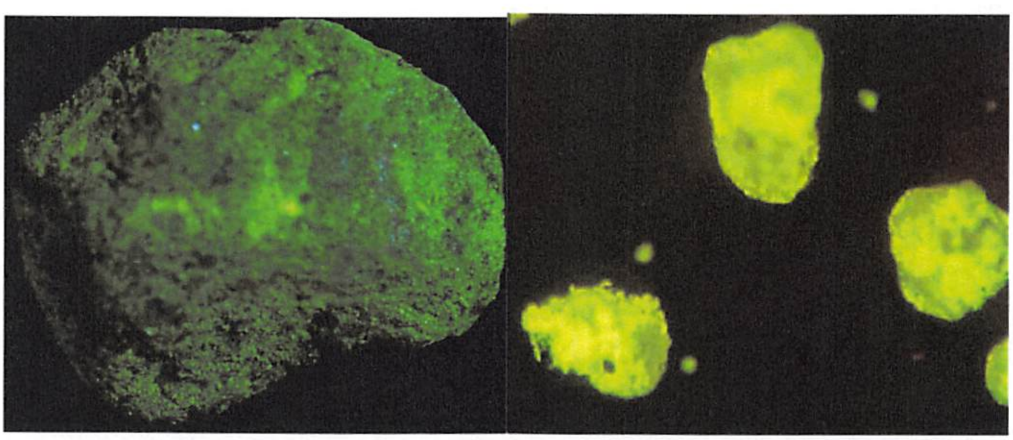

Figure 4. Close up of the engineered fluorescent sediment grains.

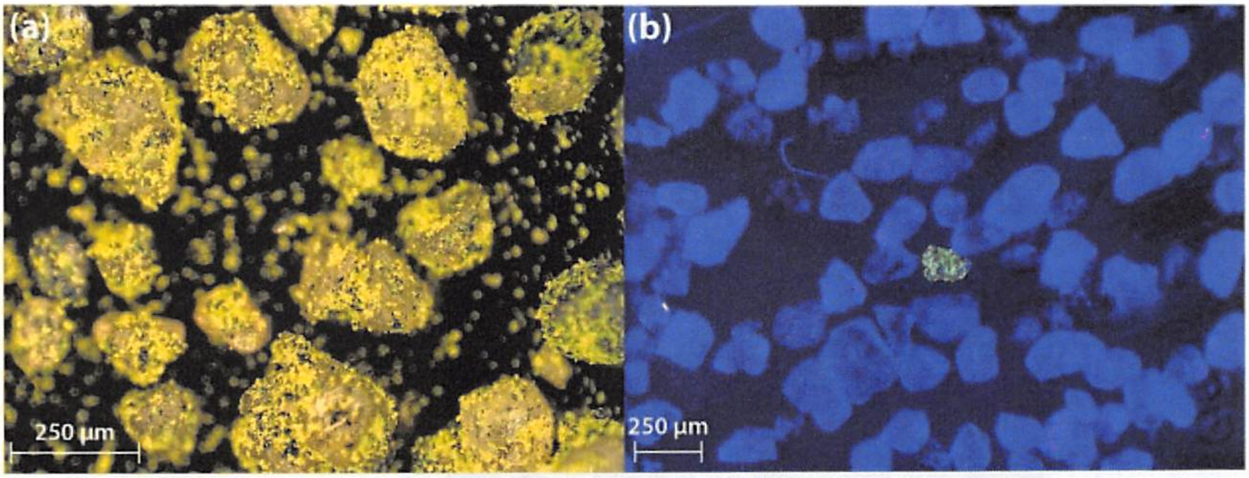

Figure 5. Ultraviolet reactive tracer sediment grains. (a) viewed under normal light, (b) Viewed under ultraviolet light (note the one UV reactive grain in the middle.

These grains will then be initially placed on the U.S. Marine Corp spoil area as this is the hypothesized area of sediment source. In consultation with Partech multiple magnetic traps will be placed in the probable flow path of sediments in the area. This will help determine the timing and direction of sediment movement in the area of the confluence. To monitor for the presence of the tracer grains, we will determine a grid structure sampling pattern to monitor both the area near the hypothesized source area and the shoal. Three other sites adjacent to the shoal and at least 3 control sites will also be monitored as well. Monitoring will take place for a span of 24 months. Each of the sampling locations will be sampled once a month by push core. These samples will be taken back to JU and dried for microscope analysis.

Each sample will be sub-sampled five times for UV analysis and five times for magnetic analysis. For the microscope analysis, a gridded petri dish will be populated with 5mg of sample and grains will be counted by trained students, graduate students, and the primary investigators. The sub samples will be analyzed to determine the presence of manufactured grains and the total count of the manufactured grains. This data will be compared across the spatial area and through time to determine the presence, rate of accumulation, and growth dynamics of the shoal. If after a pre-determined time the grains from the seeded area are not accumulating on the shoal, secondary locations can be seeded to determine the primary source of sediment.

Water flow dynamics

Objective 4 will be investigated by using an Acoustic Doppler Current Profiler (ADCP) (Fig. 6). This unit uses acoustic waves to analyze water flow velocities and direction. The device is pulled behind a vessel at low speeds or mounted to a dock or bridge. The unit produces a data set measuring the water velocity at all depths of the profile. This device will be towed behind the boat midway between the incoming and outgoing tides in the area of the confluence to map the water velocities. We will then mount the unit to a bridge or piling and left to record over a full tidal cycle to look at the change in flow velocities occurring during a 24 hour period. This will help determine the times and directions of likely sediment transport based on energy and grain size. This data will provide a data set to integrate into a flow model to predict future growth, sediment movement, and sediment direction.

Figure 6. Teledyne RiverRay ADCP.

Bathymetric Mapping

Objective 5 will support all other objectives by resolving the bathymetry and shoal geometry. This will be accomplished by use of a high-resolution Side Scan Sonar unit (Fig. 7). This instrument sends high energy sound waves down and laterally from the unit and measures the time of return from the bottom. This then builds and 3D image of the bathymetry with high (sub-meter) resolution (Fig. 8). This data will show scour, and shoaling areas in the confluence, drive sampling location selection, and provide navigational information on the current bathymetry of the area. This data could also be used to predict probable growth directions of the shoaling in the area. This device will be used in this study but will also be used to train JU Marine Science students. The students will then use this instrument to map other parts of the SJR and the coastal Atlantic.

Figure 7. Edgetech 4125i Side scan sonar unit.

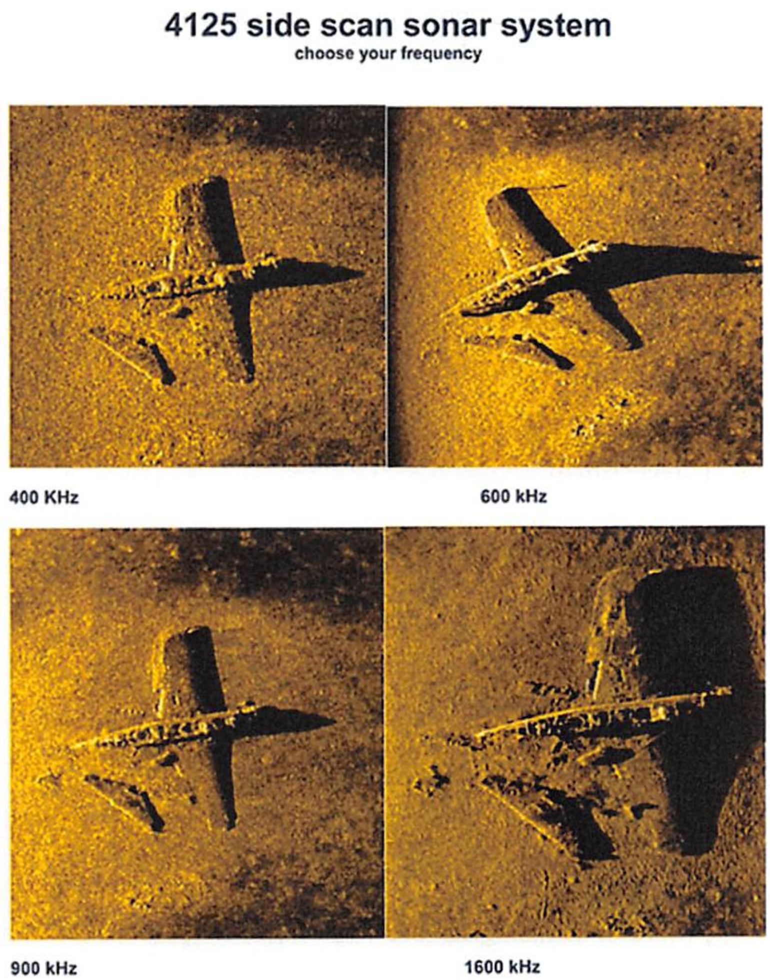

Figure 8. Image resolution of sea/river floor features.

Sediment interaction with tropical storm events

Finally objective 6 will determine the timing of sediment transport in relation to acute weather events that occur in the region. Intensive sampling identical to objectives 1, 2, and 3 will be applied to the time just before, and just after large tropical storms and hurricanes. This will help us understand when sediment transport rate is highest. This will determine if the bulk of sediment is being emplaced in gradual normal flow conditions, or during large high velocity events in short periods of time.

Deliverables

Deliverables will include 6-month updates on progress and findings and a final comprehensive report at the end of the study. All data and produced figures, images, graphs, and analysis will be included with the final report or upon request during the study. The study can be altered if the tracer grains are not appearing on the shoal within 1 year. If needed and agreed upon emplacement of unique tracer grains at other probable locations of sediment sources can be done. This will support the goal of determining the ultimate primary source of sediment to the growing shoal.

Expected results.

This study will determine if the USMC spoil site is contributing to the shoal growth at the confluence. Other outcomes will include a rate of deposition, timing of deposition, water velocity maps of the area, and a high-resolution bathymetric map of the area.

Other possible outcomes include alternative sediment sources and extended bathymetric mapping of the BIT area further upstream and downstream.

Timeline

Month	Activity	Objective addressed
1, 2	Purchase equipment, sonar and ADCP mapping, initial sediment sampling, tracer manufacture	1, 4, 5
3	Tracer emplacement	2, 3
4-11	Monthly sampling and analysis	2, 3 (possible 5) Interim report 1 at month 9
12-18	Monthly sampling and analysis	2, 3 (possible 5) Interim report 2 at month 15
18-24	Monthly sampling and analysis	2, 3 (possible 5) final report at month 24

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