Preliminary Study of the Sedimentary Surface and Subsurface of Naples Bay and the Ten Thousand Islands Using Acoustic Geophysical Techniques

Authored by: Michael Savarese[1], Tim Dellapenna[2], Aswani Volety[1]
Research Assisted by: Eddie Majzlik[2] and Bryan Fielder[2]

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[1] **Florida Gulf Coast University**
[2] **Texas A&M University at Galveston**

Executive Summary

The characterization of an estuary's sedimentary substrate is an important and necessary component of any restoration effort. In the Ten Thousand Islands and Naples Bay, two estuaries in Southwest Florida where restoration projects are pending, the substrate affects the distribution of two critical valued ecosystems, oyster reefs and sea grass beds. Unfortunately, mapping of the substrate cannot be accomplished visually because the estuarine waters are generally opaque due to dissolved organics and suspended sediment. Substrate characterization, however, can occur remotely using geophysical acoustic technologies (side-scan sonar and CHIRP). The purpose of this study was to test the applicability of side-scan sonar and CHIRP at these two localities in Southwest Florida with the intention of completing a more thorough study in the subsequent year. Substrate maps were generated using side-scan sonar, and subsurface acoustic profiles were produced for specific tracks using CHIRP for selected areas within these estuaries.

The regions studied in the Ten Thousand Islands included: (1) the interiors of Blackwater and Faka Union Bays; and (2) the coastal margins of Blackwater and Faka Union estuaries. The former regions support numerous oyster reefs; these are the most likely areas for oyster reef restoration in the future. Many substrate types are common here including: fringing oyster reefs, isolated oyster reefs, SAV-covered bottom, sandy mud, and muddy sand. The latter are regions that contain relict vermetiform gastropod reefs that occur throughout the Ten Thousand Islands' outer coast and whose development influenced the geomorphology of the coast through the late Holocene (last 5000 years). Because this substrate type is unique and common, it too was characterized. CHIRP profiles were run in the two bay interiors to determine the distribution of oyster reefs and other structures in the shallow subsurface.

Two areas were selected for study in Naples Bay, one in the north close to the mouth of the Gordon River and the second further south at the confluence with Haldeman Creek. The former region is highly developed with all the shoreline developed and no mangrove-forested edge remaining. The latter is still somewhat natural with the eastern shores of Haldeman Creek and Naples Bay containing mangrove forest and fringing oyster reefs.

Diagnostic side-scan sonar reflective patterns were produced for many of the sedimentary substrate types common to the Ten Thousand Islands and Naples Bay. Fringing and isolated oyster reefs, vermetiform gastropod reefs, and sandy muds produce very obvious mapping patterns. SAV-covered bottom produces a pattern that can be confounded with muddy sands or oyster reef. This may be a function of the density of growth of the vegetation or oyster clumps.

The CHIRP profiles provided valuable insights to both the history of estuarine geomorphologic change and to the potential for future oyster reef restoration. Buried oyster reefs are readily obvious and were found throughout Blackwater Bay and along the margins of Faka Union Bay. Interestingly, no buried reefs were found in the interior of Faka Union Bay, indicating that reefs did not pre-exist here prior to the freshwater flow inundation by the creation of the South Golden Gate Estates canal system. In addition, the interior of Faka Union does not contain the appropriate sedimentary substrate to initiate oyster reef development; appropriate substrate would have to be introduced.

CHIRP discovered both modern and ancient deltas, from the presence of seawardly dipping foresets beds, within Blackwater Bay. A modern delta exists at the present-day mouth of Blackwater River and a late Holocene delta and former river mouth was positioned in the east-central region of the bay. This position of the older river mouth suggests that a sea level low-stand persisted in the past and influenced the coastal margin significantly.

Naples Bay was studied more thoroughly. It is here that the subsequent year's investigation is expected to focus. Side-scan sonar detected many natural and anthropogenically modified substrates in the two subregions of the bay. Subtidal oyster reefs were identified in the northern region. This documents the value of using side-scan sonar to map existing subtidal oyster reef habitat and potential habitat for reef restoration. Fringing reefs, sandy muds, muddy sands, and oyster rubble substrates were also identified. Boat channels, propeller-scarred sediments, and the position of bulkheads are among the human-influenced substrate types that were detected. Side-scan sonar also detected a muddy substrate seaward of a boat canal, suggesting the presence of a suspended sediment pollutant source. The CHIRP profiles showed a complex erosional ravinement surface between 1-3 meters depth below the bottom of Naples Bay. This indicates that a former freshwater drainage system existed across this region prior to marine flooding sometime during the late Holocene.

The results from this preliminary study indicate that side-scan sonar and CHIRP are valuable geophysical instruments for substrate mapping and sub-bottom profiling in preparation for estuarine restoration planning. More importantly, the techniques are vastly useable in Naples Bay and the Ten Thousand Islands for their restoration-specific problems. We recommend furthering the application with a systematic study of Naples Bay next fiscal year.

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Introduction

The restoration of Southwest Florida's estuaries is a major component of the Greater Everglades restoration effort. Locally in Collier and Lee Counties, the issue is of high priority, as reflected by the South Florida Water Management District's funding of its Watershed Initiatives (including the Big Cypress and Naples Bay Initiatives).

Estuarine restoration cannot occur without a thorough characterization of the estuary's substrate. Many valued ecosystem components of Southwest Florida's estuaries are subtidal (e.g., sea grass beds, oyster reefs) and are therefore obscured from easy viewing. Because these estuarine waters are generally opaque due to dissolved organics and suspended sediments, a simple visual mapping of the substrate is not possible. Consequently, substrate characterization must occur remotely using acoustic technologies.

Restoration design and performance measure targeting also require an understanding of the pre-altered state of the estuary – knowing what the distribution of pre-alteration habitats was. This information was typically not recorded historically, but vestiges of those habitats may remain buried in the subsurface under a thin veneer of sediment. The distribution of oyster reefs is an excellent example. Oyster reefs generally form hummocky and hardened structures on the estuarine floor. After burial they can be recognized from sediment cores, but this type of investigation is costly, time consuming, and not geographically comprehensive. Alternatively, remote sensing, acoustic methods can be used to map structures in the shallow subsurface.

This study employed two remote sensing, acoustic, geophyscial instruments for mapping: side-scan sonar for mapping the sedimentary substrate and CHIRP for profiling the subsurface immediately below the instrument. Both instruments were owned and operated by Dr. Dellapenna and his research assistants, from Texas A&M University at Galveston. Side-scan sonar and CHIRP have been used successfully by Dr. Dellapenna for these same applications concerning oyster reef health and restoration problems in Texas (Bronikowski 2004).

Two regions of concern in Collier County for substrate mapping, because of ongoing and pending estuarine restoration projects, are the Ten Thousand Islands and

Naples Bay. The estuaries of the Ten Thousand Islands will be affected positively by the South Golden Gate Estates restoration project. The project is close to Congressional authorization and the Project Implementation Report (PIR) is in final review (U.S. ACOE 2004). Naples Bay is unduly influenced by freshwater as a point-source pollutant from storm-water management discharge from the Golden Gate Canal through the Gordon River. Although restoration design work has yet to occur, restoration science is being funded, through the Naples Bay Initiative and other, more locally funded efforts, to fulfill scientific needs in preparation for restoration planning. Both of these estuaries would benefit greatly from substrate and shallow-subsurface mapping in preparation for restoration.

Since 2001, two of us (Savarese and Volety) have been comparing the health and distribution of oyster reefs among Blackwater, Faka Union, and Fakahatchee estuaries in order to both assess the impact of the freshwater canal system in South Golden Gate Estates and to help in the design and effectiveness monitoring of the restoration effort (Savarese & Volety 2001; Savarese et al. 2003a, 2004a). We effectively demonstrated that reefs were more numerous in Blackwater while the locus of reef development in Faka Union was shifted further down the estuarine axis when compared to Blackwater (Savarese & Volety 2001). A number of relict reefs and those with very low living densities were discovered in the lower reaches of the Faka Union River and the inner region of Faka Union Bay. We hypothesized at the time that relatively young, but presently dead reefs (< 1000 years old) should exist in the shallow subsurface of Faka Union Bay. Since the time of emplacement of the SGGE canal system, these older reefs could have been buried over the last 4 decades of sedimentation. If true, the mapping of reefs in the shallow subsurface, using CHIRP technology, would further demonstrate the ill-effects caused by water management and further justify the importance of reef restoration.

Finally, in addition to the correct water quality, oyster reef development also requires appropriate sedimentologic conditions. Oyster larvae seek out coarse substrates (e.g., sands or shell gravels) and survive best on those substrates with minimal traction transport of sediment (Kennedy, 1996). Consequently, the restoration of water quality and quantity is not sufficient to ensure reef formation. The right substrate must also exist. We have facilitated oyster reef development in a number of estuaries (Henderson, Estero River, and Caloosahatchee River) by depositing a coarse shell substrate at low intertidal depths and in geographic locations having the most appropriate water quality for oyster growth and reproduction. (See web links at: http://www.floridaenvironment.com/programs/fe30602.htm; http://www.bonitanews.com/03/05/bonita/d916684a.htm; http://www.news-press.com/news/local_state/030511oysters.html.) This "gardening" approach to reef restoration is costly and time intensive. Reefs will restore naturally assuming the appropriate substrates exist. Unfortunately, the sedimentologic characteristics of the bay floors within the Ten Thousand Islands and Naples Bay have not been determined, making it difficult to assess the potential for natural reef restoration.

With these problems and applications in mind, this study's purpose was multi-fold. First, we intended to test the applicability of the side-scan sonar and CHIRP technologies in various sedimentary settings in both the Ten Thousand Islands and Naples Bay. Field work was conducted in May, 2004, and the resulting data were processed and interpreted throughout the summer and fall of this year. Ultimately, the results are very promising. Side-scan sonar correctly identified a number of substrate types in Blackwater and Faka Union estuaries in the Ten Thousand Islands and in Naples Bay; and CHIRP profiles revealed complex topographies and sedimentologic features under Naples and Blackwater Bays. Second, we used this year's research effort to document the presence or absence of shallowly buried oyster reefs under Faka Union Bay. Although our coverage of the bay was not complete, those profiles that traversed the interior portions of the bay showed no indication of shallowly buried reefs. The periphery of the bay and substrate surrounding interior bay islands did, however, exhibit reef development in the subsurface. Third, the substrate mapping results are intended to aid in the selection of sites most appropriate for oyster reef gardening or natural recruitment once satisfactory water quality conditions are achieved through hydrologic restoration. Our preliminary results show that appropriate natural substrates are abundant in Naples Bay, but sparse to non-existent in the interior of Faka Union Bay. Finally, the data collected this year have helped further our planning of a larger, more thorough study next fiscal year. Because Naples Bay shows greater promise and has greater monitoring needs, and because there is now a competing research effort in the Ten Thousand Islands (since our work began last spring, Dr. Stan Locker, University of South Florida, St. Petersburg, has begun a side-scan sonar benthic mapping study here), we plan to dedicate our benthic mapping efforts next year to Naples Bay and its neighboring waterways.

Project Scope

Two research objectives were defined for this project:

1. *Survey of subtidal bay floor for oyster reefs and substrate sedimentology.*

The principal goal of this project was the characterization of the bay floor for portions of Blackwater, Faka Union, and Naples Bays. Although subtidal oyster reefs are less common than intertidal reefs, they may exist in appreciable numbers. Unfortunately, the water clarity in the Ten Thousand Islands and Naples Bay is poor, making it impossible to see the substrate through the water column. Similar problems exist when attempting to characterize the substrate's grain size. Future reef development requires coarser sedimentary substrates (sands or gravels). Mapping appropriate substrates is not practical using grab sample techniques. Remotely sensing the substrate geophysically is the most practical and cost-effective method for both these purposes.

In addition to delineating the location of oyster reefs within the bay interiors, a similar assessment of other reef structures along the outer coast of the Blackwater and Faka Union Bays was attempted. Throughout the Ten Thousand Islands' outer coast exist reef structures that are oriented perpendicular to the coastal margin and are composed of relict skeletons of vermetiform gastropods (sessile gastropods that belong to the families Vermetidae and Turritellidae; Shier 1969). Because the coastal geomorphology of Southwest Florida's estuaries is dependent upon the development of these gastropod reefs as well as oyster reefs (Parkinson 1989; Savarese et al. 2004b), a side-scan sonar characterization of this type of substrate would prove helpful.

Side-scan sonar (see description below) was used to characterize a limited region of the bay floors (in Naples, Faka Union, and Blackwater) and outer coastal margin (offshore of Faka Union and Blackwater Bays) and to acquire bathymetric data. Because side-scan sonar generates diagnostic reflectance images for different sedimentary textures, sediment grabs were used to correlate texture against image type. This technique, however, has one critical limitation: the equipment requires a minimum water depth of 3-4 feet for operation. Consequently, the surveys were done at high tide and only in areas deeper than 3 feet.

2. Survey of shallowly buried oyster reefs.

Oyster reefs that have died over recent history due to anthropogenic influences on freshwater delivery may be partly or completely buried under thin veneers of sediment. Savarese has located shallowly buried reefs along the Southwest Florida coast inadvertently through sediment coring (Savarese et al. 2003b). Coring or probing the subsurface, however, is not practical when trying to systematically map large areas. A CHIRP subbottom profiler, a small and easily transportable acoustic device (see description below), has been successfully used to map shallowly buried oyster reefs in San Antonio, Galveston, and Lavaca Bays in Texas by Dr. Dellapenna (Bronikowski 2004). The technique has also been used locally in Charlotte Harbor to locate buried karst topography (Duncan et al. 2003); in that study the investigators detected subsurfaces shaped like oyster reefs, but they never ground-truthed their observations to confirm their identity.

A limited number of CHIRP profiles were run in Blackwater, Faka Union, and Naples Bay to elucidate the subsurface structures and topographies and to locate shallowly buried oyster reefs.

Materials and Methods

Equipment: Side-scan sonar.— The side-scan sonar makes acoustic images analogous to aerial photographs, with the bottom-return intensity reflecting sediment texture, topography, bottom roughness, and cultural debris. The side-scan sends out a pulse of sound that is narrow along track and wide across track. The pulse scatters off the seafloor to the side of the boat's track and some returns to the sonar and is converted into image pixels depending on the intensity of the sound return. With each "ping" the side-scan sonar makes a thin strip of image, showing the bottom from some distance on either side of the sonar. The side distance (swath width) of these images is dependent on the depth of the water. In very shallow water, as will be encountered in most of the area to be surveyed, the swath width will be only 60-100 meters. In deeper water, larger swath widths are possible. By repetitive pinging as it moves along, an image is built up digitally. The "backscatter" of sound off the bottom, which forms the side-scan sonar image, depends on surface roughness and scattering within the thin layer of sediment near the surface. Coarse and hard sediments typically cause strong returns whereas fine sediments give weak returns. In addition, objects with hard surfaces that face the sonar, such as mounds, trenches, and shipwrecks, also cause strong returns. Such objects also typically cause acoustic shadows (with weak returns) on the sides that face away from the sonar. Thus, the side-scan sonar makes an acoustic "aerial photo" of the sea bottom, typically with a resolution of centimeters or less. In terms of assessing and mapping artificial reefs, side scan sonar data can be used to generate a mosaic of geo-rectified images of the seabed. The mosaic provides a visual image of the seabed, and can be used to accurately determine the location of reef-building materials, geo-hazards and other potential habitat components of the seabed.

Equipment: CHIRP sub-bottom profiler.—The CHIRP profiler functions similarly to sonar, but operates at seismic frequencies that are more suitable for substrate penetration. The sub-bottom profiler creates a linear cross section of the bay bottom along the track of the tow vessel by sending out a "chirp" of energy from 2-16 kHz, with return signals differing based on the bottom type encountered. Some sound bounces off the bottom itself, whereas some penetrates and reflects off interfaces within the sediment. Repeating the send/receive action, a strip chart makes a profile showing the penetration and the characteristics of the reflections. Different bottom types have different reflection characteristics. Mud and sand bottoms have clearly different surface reflection signatures, making it possible to produce highly accurate maps of surface sediment type based on reflection characteristics. The sequence of subsurface sediments can be resolved on the decimeter scale and the sub-bottom profiler can typically penetrate up to 10-40 m into the seabed, depending on sediment type and water depth. The limitation of sub-bottom profiling is that it acquires data only along the boat track; in between there are no data.

Navigation.—Position was determined using a Trimble AG132 Differential GPS with Everest, which was fed digitally into a Gateway Laptop and logged using Hypack Coastal Oceanographic software. Hypack was also used to create survey lines and was used as a chart plotter for navigation of these lines. The layback of the tow fish (fore and aft) to the DGPS antennae was estimated by measuring the distance from the antennae to the transom and then measuring the amount and angle of the tow cable from the transom to the tow fish. The offset (a beam) was determined by measuring the offset of the DGPS antennae to the tow point of the cable on the transom. Errors for position of the fish in relation to the bottom should be limited to the error inherent in DGPS (less than 1 meter).

Data collection & processing.—Side-scan sonar data were collected using an Edgetech 272 tow fish at 100 kHz and data acquisition and processing was performed using a CODA topside computer. Each trackline was conducted with swath widths for the port and starboard channels at 100 m each. The lines were spaced 100 m apart, giving 150% coverage of most portions of the grid. The net result is that when the side-scan sonar mosaic is generated, targets are overlapped on reciprocating lines. For the processing of side-scan sonar data and the generation of the mosaic, each side scan line was read into CODA, quality control of the bottom picking was performed, and Time Variable Gain (TVG) was uniformly applied to all data. The final offset and laybacks were refined and the mosaic was output as a Georectified TIF image and imported into ArcGis as a GeoTiff image for the locations of targets and other seabed feature. Final mosaics in this paper are presented using the GeoTiff images to preserve the highest image quality. CHIRP data were collected and processed using the software package Delph Seismic Plus. Once the channels were identified, maps were made using DOQQ aerial photographs in ARC GIS.

Field locations & track positions.—Naples Bay is located north of Gordon Pass west of the spit upon which a portion of the City of Naples sits (Figure 1). Two subregions of the bay were chosen for side-scan sonar surveys and CHIRP profiles: (1) the northern region of the bay, east of the boating channel; and (2) the southern region of the bay, also east of the boating channel at the confluence of the bay and Haldeman Creek. Oral historical accounts claim that the northern subregion contained a great deal of oyster reef substrate prior to development of the coastal fringe of the bay. The coastal margin of the southern subregion is still relatively undeveloped and contains numerous intertidal oyster reefs today. Seven CHIRP lines were profiled in the northern bay (Figure 2) and 1 was profiled in the southern bay (Figure 3).

Two regions within Blackwater Bay were surveyed with the side-scan sonar, the inner bay and the outer coastal margin (Figures 4 & 5). Intertidal oyster reefs are very common within the inner bay. The outer coast has a number of vermetiform gastropod reefs that are oriented perpendicular to the outer islands. The region surveyed here covers one of those structures. Three CHIRP lines were profiled throughout the inner bay (Figure 6).

Similar to Blackwater, Faka Union estuary was surveyed with side-scan sonar both in the inner bay and along the outer coast (Figure 7). Oyster reefs are not as common within the inner bay here, though they do occur in abundance around the inner bay's perimeter. The central portion of the bay is relatively free of oyster reef development. Vermetiform gastropods reefs occur along the outer coastal margin of Faka Union as well. Six CHIRP lines were run in the inner bay (Figure 8).

Results & Discussion

Because this year's efforts were preliminary to test the applicability of the technology, the results will be presented with this purpose in mind. Consequently, this section will be organized as follows. First, the types of side-scan sonar signals, and their affiliated inferred substrate conditions, will be reviewed. These represent the most common substrate types likely to be encountered in the greater study. Second, a variety of CHIRP results will be presented. This will demonstrate both the diversity and variability among subsurface conditions potentially encountered in Southwest Florida. Third, since Naples Bay is the location of emphasis next fiscal year, results from this bay will be reviewed separately, synthesized, and interpreted. The intention of this portion of the results is to define hypotheses that will be furthered tested in the subsequent year.

Types of side-scan sonar signals & their interpretations:

Six types of signals were recognized from the side-scan sonar surveys. Each represents a characteristic acoustic reflection pattern produced by the sonar. Although sediment ground-truthing was used to confirm a substrate's environmental interpretation, these confirmations require additional testing and are therefore considered to be questionable at present.

(1) Sand / mud mix bottoms. Mixed sand and mud substrates typically have minimal reflection associated with them. Consequently, the acoustic signal looks dark and homogeneous (Figure 9). These substrates are also typically planar over large distances also adding to the dark composition.

(2) Sandy bottoms. It is difficult to distinguish, at least at present, between a mud-rich (type 1 above) and a sand-rich substrate. Sandy substrates are more likely to be influenced by traction-transport currents that can generate sedimentary structures on the bottom (e.g., ripples, dunes, channel-forms). If these structures are present, systematic patterns within the reflections should appear. Within our results, no systematic patterns appear, but slight lightening of the dark sand / mud bottom condition probably indicates a greater concentration of the sand over mud within the substrate. Further ground-truthing and calibration is needed to make these subtle distinctions.

(3) Isolated oyster reefs. Because oysters typically form hard clumps or hard pavements on the seafloor and because this is accompanied with high relief relative to the surrounding soft substrates, subtidal oyster reefs typically have bright reflections. If the reef is dominated by clumps interspersed with muds, rather than pavements, the reflectors can have a light/dark mottled appearance. Isolated reefs are usually elliptical or elongate in shape; the shape of the reflector mimics this geometry (Figures 9 & 14).

(4) Fringing oyster reefs. Fringing oyster reefs are defined as those found adjacent to mangrove islands or the coastal mangrove fringe. The reflectors generated by fringing reefs have the same brightness and mottled characteristics of isolated oyster reefs. The geometry of these reflectors, however, imitates the shape of the shoreline or the mangrove island that they surround (Figures 9 & 10).

(5) SAV-covered bottom. Sea grasses and benthic algae create diffuse reflectors in the side-scan sonar signal. This generates a mottled pattern that differs somewhat by those generated by oyster clumps. The mottles tend to be smaller in size and the transition from light to dark between mottles is more diffuse; the transition in brightness occurs over greater distances (Figures 9 & 13). Further ground-truthing is required to better recognize this substrate type and to distinguish it from others.

(6) Vermetiform gastropod reef bottom. Vermetiform gastropod reefs typically form along the exposed, outer coastal margin. Their exposure to higher energy conditions means that the sedimentary matrix in which they are immersed is generally coarse sand and skeletal gravels. The reef surface is not continuous. The reef is a mosaic of interfingering hard substrates, composed of vermetiform skeletons, and patches of skeletal gravels and sand. There may also be substantial relief between these patch types with boundstones sitting higher than the intervening sands and gravels. This generates a side-scan sonar signal that is composed of hard reflectors intermingling with mottled reflectors. The former represents the boundstones and the latter the sands and gravels (Figures 11 & 12).

Sample results from subsurface CHIRP surveys:

(1) Recent river mouth delta. CHIRP line 4, through the interior of Blackwater Bay and up through the river's mouth, exposes a deltaic structure at the present-day mouth of the river (Figure 15). Deltas, because they accumulate bedload and flocculated suspended load sediment at points within a watershed where flow velocity decelerates abruptly, are composed of high-angle beds that dip in the downstream direction. These foreset beds are obvious in profile view within the subsurface (Figure 16). The irregular surface at the top of the profile is caused by the position of the modern river channel.

(2) Ancient river mouth delta. CHIRP line 2 running across Blackwater Bay traverses a region that appears to cut across the terminus of an old channel (Figure 17). Figure 6 reveals a larger-scale view of geomorphology. An old, and presently inactive, river channel diagonals from north-northeast to south-southwest along the eastern half of Blackwater Bay and appears to terminate at the edge of a long modern oyster reef right at the position of line 2 (return to Figure 17). The subsurface structure seen in the CHIRP profile view (Figure 18) further suggests that this inactive channel terminates at an ancient river mouth. The CHIRP profile shows deltaic foreset beds, indicating that a river mouth existed here and persisted for a long enough period of time to generate a delta. This finding has significant implications for the late Holocene history (last 5000 years) of this estuary. It suggests that relative sea level stagnated for a time to permit the development of the delta.

(3) Featureless bay subsurface. We have speculated that the subsurface of the interior of Faka Union Bay should contain recently buried oyster reefs due to recent shifts in freshwater delivery through the creation of the South Golden Gate Estates canal system. This hypothesis, however, is not supported by the CHIRP tracks taken across the interior of the bay (Figure 8). The subsurface of the bay interior along these tracks shows not only a featureless substrate, but also a featureless subsurface. This is best exemplified by the CHIRP profile along line 4 (Figures 19 & 20).

(4) Protracted reef history. The margins of Faka Union Bay show a different pattern in the subsurface when compared to the subsurface of the bay interior. When CHIRP tracks approach the bay margins, buried oyster reefs are visible (Figures 21 & 22). The subsurface below line 5 shows complex domal structures under modern fringing oyster reefs, suggesting a protracted history of reef development through the late Holocene.

Naples Bay case study:

Naples Bay was chosen as a case study because it will be the site of primary concern during next year's phase of the investigation. The two regions within Naples Bay, the northern portion closer to the inflow of the Gordon River and the southern portion at the confluence of Haldeman Creek (Figure 1), selected this year were picked because they represent two developmental extremes of the bay. The northern region is highly developed with the complete loss of mangrove fringe and extensive marinas and boating canals. The area, however, appears relatively free of the effects of dredging. The southern region, alternatively, still has a partial mangrove-forested edge. Haldeman Creek is also a major tributary to the bay that historically supported a great deal of oyster reef habitat. Both the northern and southern regions were relatively free of extensive boat traffic, preventing disturbance of the acoustic signals.

The side-scan sonar results from the northern region (Figure 23) show a variety of natural and anthropogenically effected substrates. The majority of the substrate's surface area is composed of either sandy mud or muddy sand. The area immediately adjacent to two large boating canals along the northeastern shoreline appears to be experiencing greater suspending-sediment deposition. This may be indicating a source of fine-grained sediment, silts and clays, from within the boating canals' watershed. Although this interpretation is highly suspect at present – it is based on limited information – it does illustrate one of the potential utilities of side-scan sonar. The device can be used to detect the effects of anthropogenically derived, sediment-pollutants and to identify their sources.

Side-scan sonar identified two subtidal oyster reefs in the northern survey area (Figure 23). Water over these reefs is relatively deep. Consequently, these structures are subtidal and would go undetected at low tide (extreme low tides might expose them). Their identity as reefs was successfully confirmed; surface dives by a snorkeler retrieved oyster clumps. The discovery of subtidal oyster reefs here and at locations in the Ten Thousand Islands demonstrates the value of the technique at identifying existing oyster reef habitat and potential substrate for future oyster reef restoration.

The human effects on the substrate of the northern region are obvious among the side-scan sonar results (Figure 23). Bulkheads rimming the eastern shoreline generate strong acoustic shadows, as do the boating channels running along the western and eastern margins of the survey swath. In addition, numerous propeller scars cross-cutting the substrate (not shown in a figure) are indicated.

The side-scan sonar image from the southern region (Figure 24) exhibits more natural substrate conditions. Haldeman Creek's eastern shoreline is still fringed by mangroves and oyster reefs. These features are evident on the side-scan sonar tracks. The substrate near the mouth of Haldeman Creek and just downstream along the eastern half of Naples Bay is composed of dispersed oyster clumps (this was confirmed by ground-truthing). It is not clear if this represents a naturally or artificially disturbed habitat. The creek mouth may be supporting incipient reef development, but high rates of natural disturbance (from freshwater runoff, sediment deposition, or erosion) may be preventing extensive reef growth. Alternatively, the disturbance may be a human effect from boating or dredging. Further south along the eastern edge of the Naples Bay, intertidal oyster reefs become common (these are shallow enough to be detected at low tide). Our inspection of these reefs, however, indicates that oyster living densities are low and most of the reef surface is composed of dead shells.

The CHIRP results for Naples Bay were unexpected. The shallow subsurface (< 1 m) below Naples Bay is relatively featureless. In the areas surveyed, there do not appear to be any shallowly buried oyster reefs. At deeper depths (1-3 m), however, a highly irregular surface reflector with considerable vertical relief appears under the tracks from the northern region (for example, see Figure 25). This appears to be a ravinement surface, erosion created during a sea level low-stand, and may represent a former freshwater drainage system now covered by more recent estuarine sediments. There is also some evidence to suggest that the present-day boating channel, which probably followed the path of a natural channel within the bay, follows an antecedent low in the topography on that ravinement surface. The existing channel sits above a low in the ravinement structure, and recent sediments fill the channel down to that surface (Figure 26).

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