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Exxon Valdez Oil Spill
Gulf Ecosystem Monitoring and Research Final Report

High Resolution Mapping of the Intertidal and Shallow Subtidal Shores in Kachemak Bay

Gulf Ecosystem Monitoring and Research Project G040556
Draft Final Report

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Executive Summary

This project began in 2002 (project G020556), and data collection continued in 2003 (project G030566) and 2004 (project G040566). Dr. G. Carl Schoch, currently at the Oil Spill Response Institute in Cordova, Alaska, conducted the research in 2002-2003, and Dr. W. Scott Pegau completed the project in 2004. Dr. Schoch left the Kachemak Bay Research Reserve after conducting the fieldwork in 2003. A change occurred in the sampling techniques during the 2003 field season and data collected after the change in protocols are not incorporated in the results provided here because it required Dr. Schoch's expertise to interpret. Instead, the sampling protocols used in 2004 are described. Based on the data collected using these protocols, we have been able to complete a GIS project that includes photographs of each segment and a linked database of the biological and physical characteristics of each segment. This project allows researchers and resource managers to quickly identify characteristics of a geographic region or the locations of regions of similar characteristics.

Introduction

The ecology of the nearshore benthos (from intertidal to 10 m depth) has been studied in detail at many coastal locations in the United States. However, the processes that couple the intertidal regions with those in the nearshore ocean are poorly understood. For example, it is not apparent if production in some intertidal communities is regulated by the delivery of nutrients from the coastal ocean or by drainage from nearby rivers and estuaries. Such "edge" communities at the transition between one regime and another have rarely been studied as an integrated system. It is clear, however, that there is strong physical and biological coupling between the nearshore and the intertidal habitats. Prediction of how these communities will change over time or space is still a significant challenge. Map data of dominant habitats, as well as statistics about spatial frequency and abundance, are important to our understanding of how these systems interact and function and have many applications in resource management as well as basic research. Such understanding is especially critical as we try to make predictions about impacts of large-scale environmental phenomena, from coastal eutrophication, to oil spills, to shifts in weather patterns and wind driven processes (ENSO and global climate change).

The planet is experiencing an unprecedented loss and impoverishment of its biological wealth as measured by species extinctions and degradation of its ecological systems (Schoch 1998). Benthic organisms within the marine nearshore ecosystem are sensitive to environmental gradients and may serve as indicators of changes occurring in the coastal ocean. These benthic communities often include organisms with life spans ranging from days to seasons or years, and they frequently occur in large numbers, thus providing an attractive baseline for statistical analyses. For these reasons, and logistical accessibility, detecting change in nearshore biological communities is a key component of experimental ecological research and applied monitoring programs. But quantifying the distribution, abundance, and diversity of nearshore organisms over large spatial scales is problematic for scientists and resource managers. Monitoring biological communities for a response to natural or anthropogenic perturbations encounters two fundamental problems. The first is the large temporal and spatial variability of organism abundances in natural ecosystems, which masks our ability to statistically separate an actual change caused by a perturbation from natural cycles. Second, extrapolating or generalizing the results of localized studies to broad areas is fraught with problems; yet biological sampling is too labor-intensive to attempt everywhere (Underwood & Petraitis 1993). One solution in the marine realm involves systematic quantification and minimization of physical gradients among sample sites.

A method developed in Alaska by Dr. G. Carl Schoch partitions complex shorelines into physically homogeneous segments. Groups of physically similar segments can then be aggregated into groups of replicates that allow more rigorous monitoring of the marine environment. This method has been successfully applied to shorelines in Kenai Fjords, Lake Clark (Schoch and Chen 1995, Schoch 1996), Katmai (Schoch 1994), and Glacier Bay National Parks: http://www.nps.gov/glba/learn/preserve/projects/coastal/. The database is now in use by the Olympic Coast National Marine Sanctuary (Schoch 1999) for the basis of a marine reserve network design, resource agencies in Puget Sound (Schoch and Dethier 1998) for ecological modeling, and by the Partnership for Interdisciplinary Studies of the Coastal Ocean (PISCO: www.piscoweb.org) along the western U.S. (Schoch *et al*. 2000a, 2000b) for monitoring and comparing biodiversity at nested spatial scales. Monitoring across replicates increases the statistical power of ecological data by minimizing the variability of the biological community caused by physical forces. This method was implemented in Kachemak Bay as a first step in monitoring the changes in marine and estuarine physical and biological diversity.

Objectives
The objective is to produce a database of nearshore habitats in Kachemak Bay. This database is then to be incorporated into a GIS project to allow easy visualization of the region's habitats.

Methods
This project took place in Kachemak Bay: the north shore from Anchor Point to the Fox River, then the south shore from Fox River to Pt. Pogibski. The project focused on the intertidal areas other than salt marshes. The salt marshes are currently being mapped under another project and the GIS product will be modified in the future to include that information.

A high-resolution aerial survey conducted in 1996 was used to provide photographs of the coastline of Kachemak Bay. The photographs were orthorectified to overlay the USGS topographic map of Kachemak Bay. A mosaic of several photos was used to provide full coverage of the Bay. Based on features within overlapping areas of the photos, we determined that the mean difference in position between images was 6.26 m. The final mapping resolution of the product was 1:5000.

On top of the image mosaic we drew low and high water lines. The low-water line was initially derived from the USGS topographic maps, which were traced at a 1:10000 scale. This low-water line was modified using stereoscopic aerial photographs and the orthorectified images, both of which were collected at low tide. Modifications were only made when the images showed that the low-water line was further into the bay than the topographic maps. Polygons were drawn around any object that was larger than 10 pixels in any dimension. For smaller objects, points were drawn. The low-water line was further modified using the Shore zone aerial video footage. This was especially important in areas where there was heavy shading in the other aerial photographs, such as in Sadie Cove. The primary reference for the high water line was the vegetation or beach wrack lines seen in the aerial photographs. Therefore, this line represents an extreme high-water line rather than the mean high tide line. As with the low-water line, the high-water line was modified using the Shore zone aerial video footage by using the wrack line and storm berms to help guide positioning. The Shore zone footage was also used to locate shoreline alterations, and a separate shape file that delineates these modifications was added to the project.

Homogeneous alongshore segments (10-100 meters in length) were delineated and divided into four intertidal zones: low, low-mid, high-mid, and high. Intertidal zones were delineated at 4-foot vertical intervals, starting with the low zone at the mean low tide line (Figure 1). Mapping occurred only at times when the tide was lower than plus two feet, so all zones would be visible during data collection.

Data were collected that pertained to the entire along-shore segment (Table 1), as well as data that were specific to each of the four zones. Within each intertidal zone, the physical components of the habitat were characterized by using indices of geophysical variables (Table 2). The presence or absence of common biological communities was also noted (Table 3). For much of the survey, a photograph of a quadrat in each of the four zones was also taken. These photos are meant to be representative of the physical and biological habitat within the zone (Figure 2).

Each alongshore segment was marked on aerial photographs of the beach, and later the segments were incorporated into a GIS project. The geophysical and biological data were entered into an Access database that contains links to the segment photographs. In the GIS project, a photo point was added in each segment. The segment photo and data can be obtained by clicking on the photo point (Figure 3).

Segment Parameters (Table 1 has a complete list)
Shoreline segment ID: This is a unique shoreline segment number that corresponds the GIS map. Segments 1-1,555 were collected in 2002, Segments 1,556-2,778 were collected in 2003, and segments 11,000-20,214 were collected in 2004.

Beach Orientation: Beach orientation is the shore normal direction that the beach is facing. Data were collected using a compass (adding 21° E declination for True North), or a GPS. Data were imported to the GIS mapping project and visually edited based on the direction of the shoreline as shown in the GIS project.

Net Shore Drift: Net shore drift is the direction the prevailing current (and drift debris) is coming from. We have low confidence in the 2004 data, as we found that the prevailing current is difficult to discern on windy days, or when the tide is increasing/decreasing. The data are currently in their raw form and we hope that in the future this category can be modified based on current maps of Kachemak Bay.

Drift Exposure: Drift Exposure is derived from the Net shore drift and orientation categories, and is a relative measure of exposure risk. Because of our lack of confidence in the Net shore drift data, we did not collect any drift exposure data in 2004. Once the net shore drift data are error checked, we can calculate drift exposure.

Regional Energy Regime: Regional energy was a category that applied to the segment as a whole, and is based on fetch (length of water surface exposed to wind during generation of waves). A longer fetch caused a larger energy rating. Energy data were also collected within each of the four zones that takes into account both fetch and slope of the beach. (See 'Zone Parameters' below for more information.) Regional energy had a rating of 1-5, with five being the highest energy rating. As this category was inferred, there are some discrepancies between data collectors. The data are currently in their raw form and need to be error checked with someone who has more expertise in this field.

Rock Type: Rock Type was classified into five categories: unconsolidated, sedimentary, meta-sedimentary, granitic, and basalt. After the field data were collected, they were imported into the GIS project and edited based on the findings of Bradley *et al*. (1999).

Debris Volume: Debris volume is the amount of debris (both human and natural) found on the beach segment. Debris was rated on a scale of 1-5, with five being the most debris.

Zone Parameters (table 2, 3):
Energy: This parameter is similar to the regional energy, but it takes slope into account as well as fetch. A steeper slope can lead to a higher energy rating, and a low slope can cause a lower energy rating. Again, this parameter was inferred and was not consistent between observers in 2004. It can be error checked alongside regional energy regime when we understand more about this parameter.

Slope: The slope of the beach segment was measured in the beginning of the field season using a level, and estimated visually once we became reliable at estimating this parameter.

Dynamism: Dynamism represents the rate of change of a beach segment within a year. If we expected the beach to change significantly in one year, it was given a rating of five. A rating of three meant we expected the beach to change slightly, or seasonally. Finally, a rating of 1 meant that we did not expect the beach to exhibit change within one year.

Grain Size (primary, secondary, interstitial): The Wentworth Scale (Wentworth 1922, Appendix 1) was used to determine grain size. Primary grain size covered over 60% of the segment, while secondary grain size covered less than 40% of the segment. Oftentimes, the interstitial grain size category was interpreted as a tertiary grain size category. We also added a larger grouping to the Wentworth Scale. A “Block” was taken to be larger than a boulder and approximately the size of a small car.

Roundness (primary, secondary): The roundness of particles was rated on a 1-5 scale (Powers 1953), with the five categories listed below. Appendix 2 also provides a visual key to the roundness scale. Primary roundness was the roundness of the primary grain size that covered over 60% of the segment. Likewise, secondary roundness was of the secondary grain size that covered less than 40% of the segment.

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Angular (1): Sharp edges and corners, little or no evidence of abrasion
Subangular (2): Somewhat angular, free from sharp edges but not smoothly rounded, showing signs of slight abrasion but retaining original form. Faces untouched while edges and corners are rounded off to some extent
Subrounded (3): Partially rounded, showing considerable but not complete abrasion, original form still evident but the edges and corners are rounded to smooth curves. Original faces have been reduced to a small area
Rounded (4): Round or curving in shape; original edges and corners have been smoothed to broad curves and original faces are almost completely removed by abrasion
Well-Rounded (5): Original faces, edges, and corners have been destroyed by abrasion and the entire surface consists of broad curves without any flat areas.

Roughness/Relief: Surface roughness/relief were estimated and placed into five categories ranging from <1 cm to >1 m.

Use: Human use of a beach segment was rated on a scale of 1-5. Human use was inferred based on the presence of trails, docks, boats, and other signs of human presence. These data are in their raw form and need to be error check and/or standardized, as the ratings were not consistent between observers. We have added an ADF&G GIS layer that includes pictures of all human structures in the intertidal zone as a second measure of use.

Biological Data: We recorded 'none', 'present (0-40%)', or 'common (>40%)' in six biological categories: barnacles, verrucaria, mussels, fucus, kelp, and algae. Barnacles and algae were assessed in each of the four zones, while fucus and mussels were only recorded in three of the zones. Verucaria and kelp were only assessed in the high and low zones, respectively.

Quality Assurance and Quality Control

Data were entered into a Microsoft Access database form. The form included 'input masks' as a quality control measure that restricted the data as they were entered. For example, if a field contained values on a scale of 1-8, the computer would allow only the numbers 1-8 to be entered.

After the data were entered, data sheets were randomly picked and error checked. Two-thirds of all data entered in 2004 were error checked. Next, we ran queries to check for out of range values, duplicate entries, and data type mismatch. Finally, once data were entered into a GIS map, data such as GPS position, beach orientation, and rock type were error checked on the map.

Some values, such as regional energy, zone energy, and net shore drift, were inferred while in the field and we have low confidence in their results. These categories can be error checked on the GIS map at a later date with someone who has more expertise in these fields. Accordingly, drift exposure was a value that we did not collect in 2004, as it is derived from the net shore drift and orientation values.

Results

Fieldwork occurred during low tide sequences in May-September 2002-2004. A total of 4,207 along-shore segments were mapped in Kachemak Bay: 1,527 segments in 2002, 902 segments in 2003, and 1778 segments in 2004 (Table 4). Approximately 95% (301 miles) of Kachemak Bay has been mapped (Figure 4).

Of the data collected in 2003, 442 segments were surveyed under a change in sampling techniques and exist in the current project only as delineated along-shore segments with photographs. These data were collected by Dr. Schoch, and the physical and biological data have not been recorded. To be completed, these segments would require either his interpretation of the data, or another survey of the beach. These data represent 3% of the mapped area, and are highlighted in dark green in Figure 4.

All of the data have been entered into a Microsoft Access database, and the database is linked to a GIS mapping project.

Discussion

By the nature of being a mapping project there is not much discussion to be had concerning the results. What we have found is that there are many small-scale habitats along the complex coastline of South-central Alaska. These small-scale habitats, however, can now be grouped with other similar shoreline segments to extrapolate biological data to larger spatial scales, and to create potential replicates for ecosystem studies.

Conclusions

This project allows researchers and resource managers to quickly identify characteristics of a geographic region or the locations of regions of similar characteristics. The high-resolution mapping provides ground truth for aerial mapping, such as Shore Zone mapping. The high-resolution mapping can also be used to demonstrate how many habitat types may be incorporated into a single segment as defined by aerial mapping. The GIS project can be used to understand how to design habitat observations and experiments, as well as track changes over time. We have already begun to work with ADF&G to include their clam information to better understand the conditions that favor clam growth.

Acknowledgments

I thank Dr. G. Carl Schoch, Katie Gaut, Melissa Roberts, Dr. Mary Jo Hartman, Oriana Badajos, Dotti Harness, Melissa Keevil, and the large number of volunteers that conducted the fieldwork. Jenny Cope, Steve Baird, and Oriana Badajos inputted the data into the database and developed the GIS project produced by this program.

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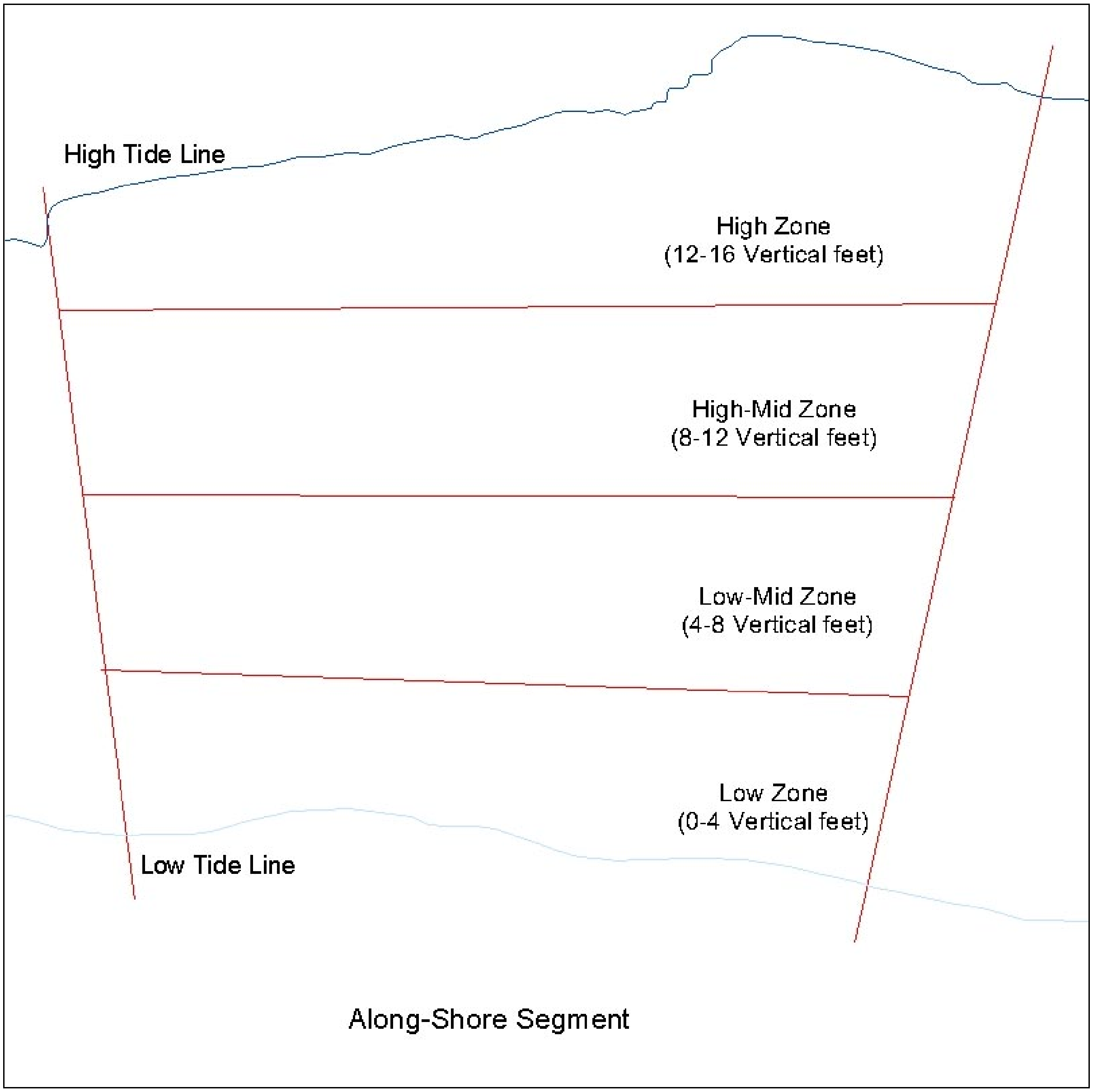

Figure 1. Homogeneous alongshore segments were delineated and divided into four intertidal zones: low, low-mid, high-mid, and high. Intertidal zones were delineated at 4-foot vertical intervals, starting with the low zone at the mean low tide line.

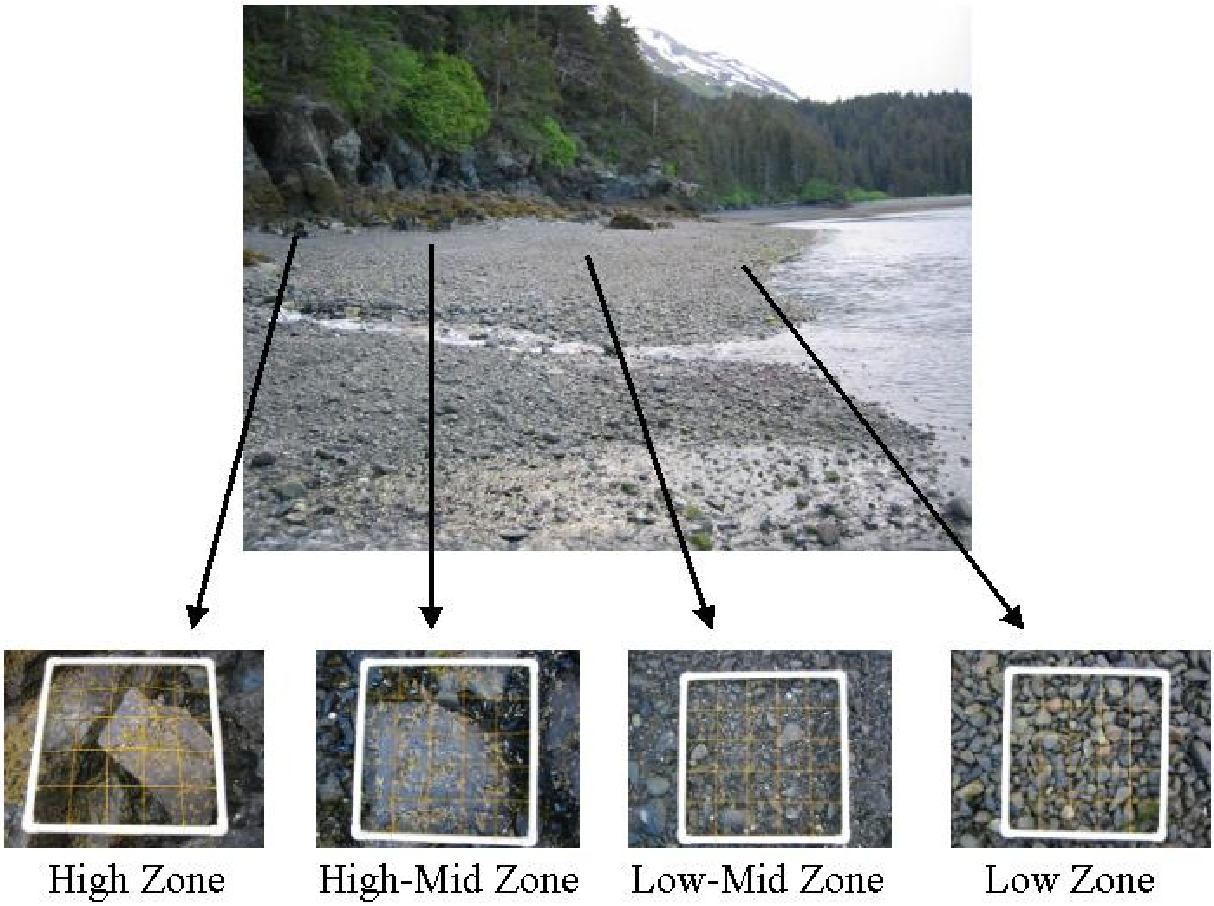

Figure 2. For much of the survey, a photograph of a quadrat in each of the four zones was also taken. These photos are meant to be representative of the physical and biological habitat within the zone.

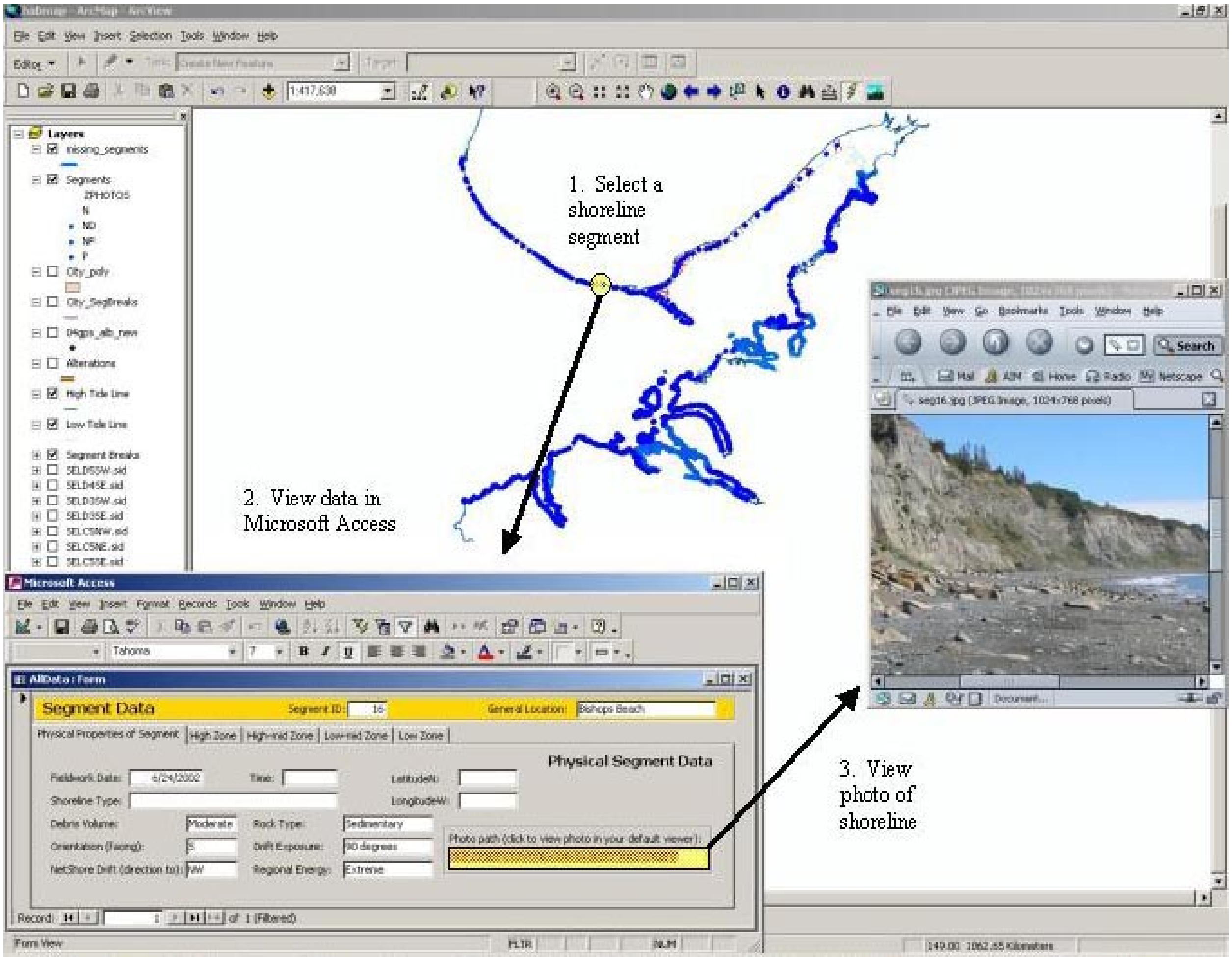

Figure 3. In the GIS project, there is a link within each along-shore segment. By clicking on the link, the user can view the segment data in a Microsoft Access window, as well as the segment or zone photos in their default browser window.

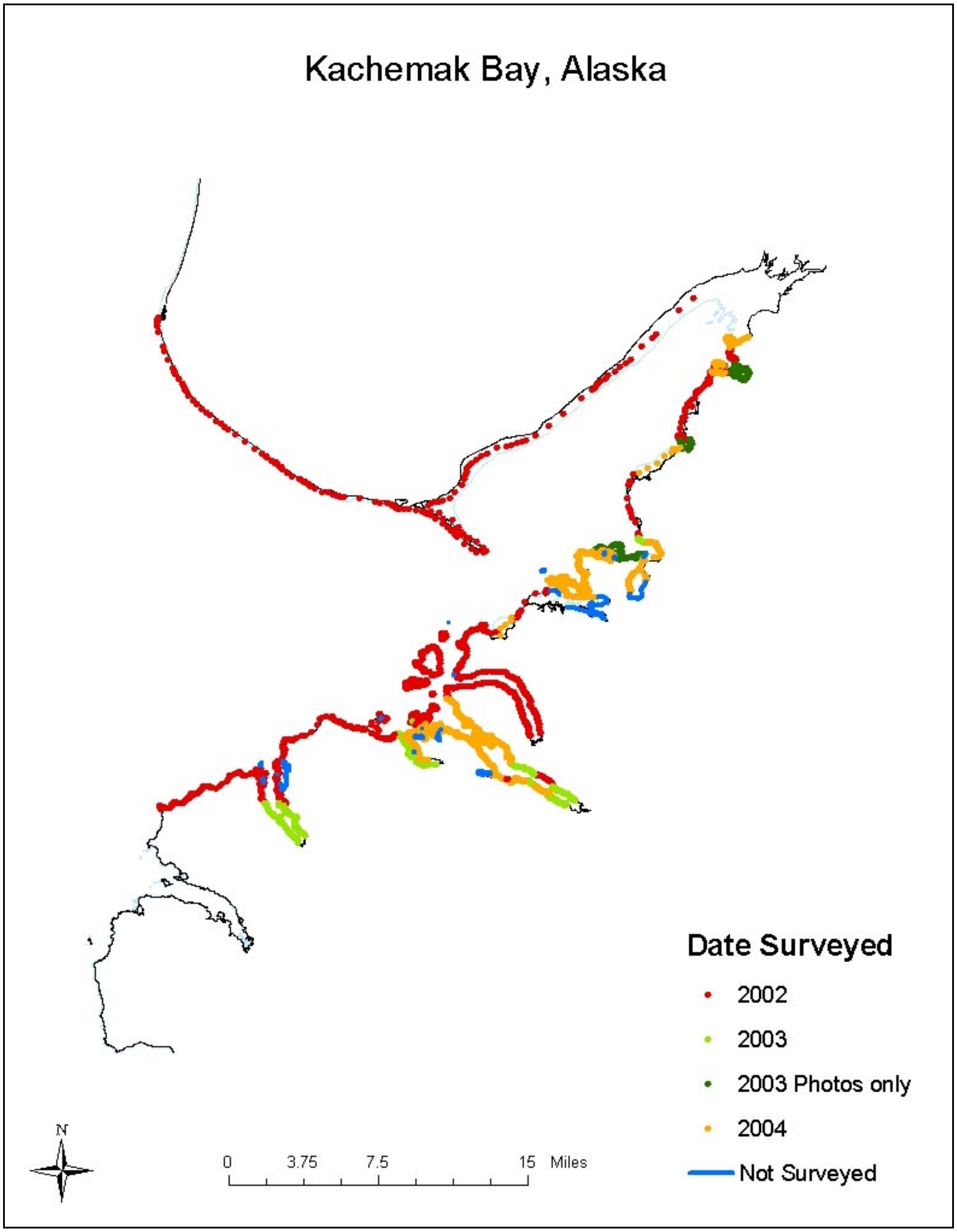

Figure 4. Map of the completed habitat characterization of Kachemak Bay, Alaska. Areas with red and light green dots were completed by Dr. Schoch in 2002-2003. Areas with dark green dots were photographically surveyed by Dr. Schoch in 2003, but are not associated with any data. Orange dots represent areas surveyed by Dr. Pegau in 2004. Finally, blue lines indicate regions that have not yet been mapped. Salt marshes are being surveyed by a different project and will fill in large areas at the head of bays and in the Fox River Flats region.

Table 1. Data dictionary, summary of data fields pertaining to the entire along-shore segment

Field Name	Codes	Description	Notes
Segment#		Unique shoreline segment number that corresponds to a segment on the GIS map	
KEY		Same as segment number, but in a text format (Link to GIS)	
Renumber_1		Old segment number (2002-2003 data only)	
Date		Month/Day/Year	
Time		Alaska Standard Time	
Location		General Location of segment (name of bay, island, etc.)	
Observer		Two or three initials of observer	
Shoreline Type		Not standardized, general description (cobble beach, steep slope, etc.)	
Lat_WGS84		GPS position using WGS84 Datum, Decimal degrees latitude	
Long_WGS84		GPS position using WGS84 Datum, Decimal degrees longitude	
Tide Height		Tide height when data were collected (should always be below +2 feet)	
Debris	1=none; 2=low; 3=moderate; 4=high; 5=lots	Amount of debris on beach segment	
Orient_Map	1=N; 2=NE; 3=E; 4=SE; 5=S; 6=SW; 7=W; 8=NW	Compass direction that the segment is facing (True North)	Field data that was error checked on GIS map
Orientation	1=N; 2=NE; 3=E; 4=SE; 5=S; 6=SW; 7=W; 8=NW	Compass direction that the segment is facing (True North)	Raw field data
NetShoreDrift	1=N; 2=NE; 3=E; 4=SE; 5=S; 6=SW; 7=W; 8=NW	Direction the prevailing current is coming from	Inferred, needs to be error checked
Energy	1=none; 2=low; 3=moderate; 4=high; 5=extreme	Regional energy, based on fetch (note: energy was also inferred within each zone segment)	Inferred, needs to be error checked
RockType	1= Unconsolidated; 2=Sedimentary; 3=Meta-Sedimentary; 4=Granitic; 5=Basalt	Rock Type	Needs to be error checked
Exposure	1=same direction; 2=135°; 3=90°; 4=45°; 5=opposite direction	Drift Exposure, derived from net shore drift and orientation fields	Data not collected in 2004
Salinity		Salinity	Data not collected in 2004
Water Temp		Water Temperature	Data not collected in 2004
Turbidity		Turbidity	Data not collected in 2004

Table 2. Data dictionary, summary of physical characteristics collected in the different tidal zones H=High; HM=High-mid; LM=Low-mid; L=Low

Field Name	Codes	Description	Zones
Energy	1=none; 2=low; 3=moderate; 4=high; 5=extreme	Inferred, based on slope of segment and fetch	H, HM, LM, L
Slope	1=<1°; 2=1-2°; 3=2-5°; 4=5-15°; 5=15-25°; 6=25-45°; 7=45-60°; 8=>60°	Slope of beach	H, HM, LM, L
Dyn	1=slow change; 3=moderate change; 5=rapid change	Inferred, dynamism or rate of change within one year	H, HM, LM, L
SizePrim	1=mud; 2=silt; 3=sand; 4=pebbles/granules; 5=cobbles; 6=boulders; 7=blocks; 8=bedrock	Primary grain size (>60% coverage) (Wentworth 1922)	H, HM, LM, L
SizeSec	1=mud; 2=silt; 3=sand; 4=pebbles/granules; 5=cobbles; 6=boulders; 7=blocks; 8=bedrock	Secondary grain size (<40% coverage) (Wentworth 1922)	H, HM, LM, L
SizeInt	1=mud; 2=silt; 3=sand; 4=pebbles/granules; 5=cobbles; 6=boulders; 7=blocks; 8=bedrock	Tertiary, or interstitial grain size (Wentworth 1922)	H, HM, LM, L
RoundPrim	1=angular; 2=subangular; 3=subrounded; 4=rounded; 5=well rounded	Roundness of primary grain (Powers 1953)	H, HM, LM, L
RoundSec	1=angular; 2=subangular; 3=subrounded; 4=rounded; 5=well rounded	Roundness of secondary grain (Powers 1953)	H, HM, LM, L
Relief	1=<1 cm; 2=1-5 cm; 3=5-10 cm; 4=10-100 cm; 5=>1 m	Roughness or relief of rock	H, HM, LM, L
Use	1=very low; 2=low; 3=moderate; 4=high; 5=very high	Inferred, human use of beach	H, HM, LM, L

Table 3. Data dictionary, summary of biological characteristics collected in the different tidal zones H=High; HM=High-mid; LM=Low-mid; L=Low

Field Name	Codes	Zones
Barnacle	1=none (0); 2=present (<50%); 3=common (>50%)	H, HM, LM, L
Algae	1=none (0); 2=present (<50%); 3=common (>50%)	H, HM, LM, L
Fucus	1=none (0); 2=present (<50%); 3=common (>50%)	H, HM, LM
Mussels	1=none (0); 2=present (<50%); 3=common (>50%)	HM, LM, L
Verrucaria	1=none (0); 2=present (<50%); 3=common (>50%)	H
Kelp	1=none (0); 2=present (<50%); 3=common (>50%)	L

Table 4. Number of segments completed and length of shoreline mapped in the 2002-2004 habitat mapping field seasons.

Year	Number of Segments completed	Distance mapped (miles)	Segment Numbers	Principal Investigator
2002	1527	224	1-1555	Schoch, GC
2003	460	13	1556-2027	Schoch, GC
2003(photos only)	442	9	2070-2778	Schoch, GC
2004	1778	55	11000-20214	Pegau, WS
Total	4207	301		

Appendix 1. Wentworth Scale (Wentworth 1922)

Name	Diameter (mm)
Clay	<0.004
Silt	0.004-0.0625
Sand	0.0625-2
Pebble/granule	2-64
Cobble	64-256
Boulder	>256

Appendix 2. The roundness scale (Powers 1953)