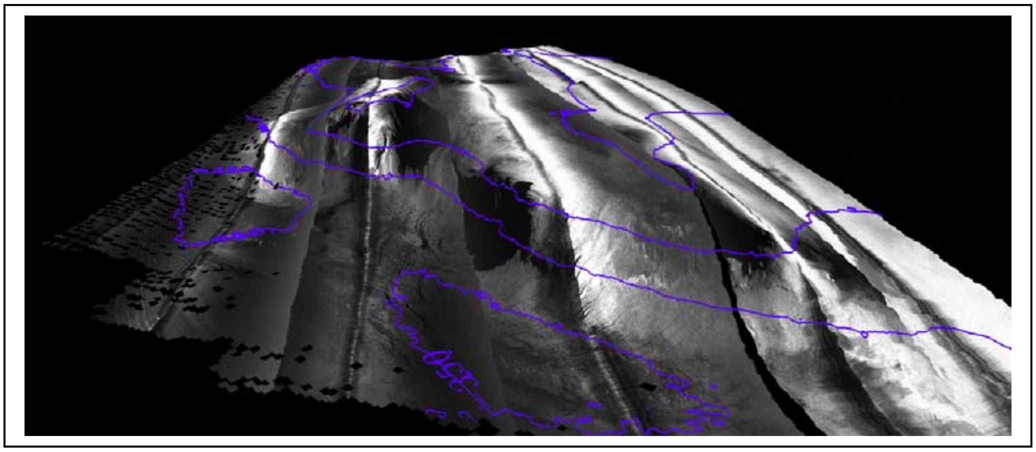
Marine Sanctuaries Conservation Series ONMS-06-01



Benthic Habitat Mapping in the Olympic Coast National Marine Sanctuary: Classification of side scan sonar data from survey HMPR-108-2002-01: Version I

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
Office of National Marine Sanctuaries

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About the Marine Sanctuaries Conservation Series

The National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries (ONMS) administers the National Marine Sanctuary Program. Its mission is to identify, designate, protect and manage the ecological, recreational, research, educational, historical, and aesthetic resources and qualities of nationally significant coastal and marine areas. The existing marine sanctuaries differ widely in their natural and historical resources and include nearshore and open ocean areas ranging in size from less than one to over 5,000 square miles. Protected habitats include rocky coasts, kelp forests, coral reefs, sea grass beds, estuarine habitats, hard and soft bottom habitats, segments of whale migration routes, and shipwrecks.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary Program. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate.

Benthic Habitat Mapping in the Olympic Coast National Marine Sanctuary: Classification of side scan sonar data from survey HMPR-108-2002-01: Version I

Steven S. Intelmann[1], and G.R. Cochrane[2]

[1]Olympic Coast National Marine Sanctuary, NOAA
[2]Coastal and Marine Geology Program, USGS

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
VADM Conrad C. Lautenbacher, Jr. (USN-ret.)
Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
John Dunnigan, Assistant Administrator

Office of National Marine Sanctuaries
Daniel J. Basta, Director

Silver Spring, Maryland
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COVER

A clipped section of the western side scan sonar mosaic draped over multibeam bathymetry data. Dark grey pixels are soft substrate and lighter pixels are mixed substrate including cobbles, gravel, and mud. Topographic relief is evident from black acoustic shadows along the rock ridges. Contour lines are 50 meter intervals.

SUGGESTED CITATION

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CONTACT

Steven S. Intelmann
Habitat Mapping Specialist
NOAA/National Marine Sanctuaries Program
N/ORM 6X26
115 E. Railroad Avenue, Suite 301
Port Angeles, WA 98362
(360) 457-6622 X22
steve.intelmann@noaa.gov

ABSTRACT

In September 2002, side scan sonar was used to image a portion of the sea floor in the northern OCNMS and was mosaiced at 1-meter pixel resolution using 100 kHz data collected at 300-meter range scale. Video from a remotely-operated vehicle (ROV), bathymetry data, sedimentary samples, and sonar mapping have been integrated to describe geological and biological aspects of habitat and polygon features have been created and attributed with a hierarchical deep-water marine benthic classification scheme (Greene et al. 1999). The data can be used with geographic information system (GIS) software for display, query, and analysis. Textural analysis of the sonar images provided a relatively automated method for delineating substrate into three broad classes representing soft, mixed sediment, and hard bottom. Microhabitat and presence of certain biologic attributes were also populated into the polygon features, but strictly limited to areas where video groundtruthing occurred. Further groundtruthing work in specific areas would improve confidence in the classified habitat map.

KEY WORDS

Benthic, habitat mapping, sediment classification, side scan sonar, textural analysis, Olympic Coast National Marine Sanctuary, essential fish habitat, groundtruthing

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION

An area of high productivity located offshore of Washington State, the Olympic Coast National Marine Sanctuary (OCNMS) supports an extensive groundfish fishery, but recent declines in various groundfish stocks have created concern over establishing conservation efforts with increasing focus being placed on examining important habitat linkages (PFMC 2004). With amendment of the Magnuson-Stevens Act of 1996, Fishery Management Councils (FMC) became responsible for evaluation and mitigation of the effects of habitat loss or degradation on their specific fishery, and essential fish habitat (EFH) became defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (Magnuson-Stevens Act, 16 U.S.C. 1801 et seq). The Pacific Coast Groundfish Fishery Management Plan, a product of the FMC, is responsible for the management of over 80 species and information describing available habitats for these species is often lacking, especially along the Washington coast.

Without an understanding of the distribution and abundance of sea floor substrates, efforts to describe, delineate, manage for, or mitigate the loss of essential fish habitat becomes increasingly difficult. The use of geological characteristics is proving to be effective for describing marine habitat (Greene et al. 2000; Valentine et al. 2003) and technological innovations such as side scan sonar and multibeam sonar are advancing our abilities to remotely delineate ocean floor substrates (Mitchell and Hughes Clark 1994; Auster et al. 1999; Cochrane and Lafferty 2002; Huvenne et al. 2002; Dartnell and Gardner 2004).

Classification of habitats and characterization of the seabed is critical for supporting management, research, monitoring, and education within the national marine sanctuaries (Barr 2003). Recognizing the importance for understanding the status of the benthic environment, coupled with the lack of existing data to do so, the OCNMS launched an active habitat mapping program in 2002 as an effort to begin characterizing sea floor substrates within its jurisdictional boundaries.

In September 2002, side scan sonar was used to image a portion of the sea floor in the northern OCNMS and was mosaiced at 1-meter pixel resolution. Video from a remotely-operated vehicle (ROV), bathymetry data, sedimentary samples, and sonar mapping have been integrated to describe geological and biological aspects of habitat and polygon features have been created and attributed with a hierarchical deep-water marine benthic classification scheme (Greene et al. 1999). The data can be used with geographic information system (GIS) software for display, query, and analysis.

SURVEY AREA

Approximately 267 km^2 of sea floor were imaged within the general vicinity of the Juan de Fuca Canyon, bounded by coordinates 48° 20'06'' N, 125° 09'00''W, 48° 4'25'' N, 124°53'23''W (Figure 1). The survey work occurred from September 20 - September 25, 2002. Depth of the project area ranged between 120 and 350 meters.

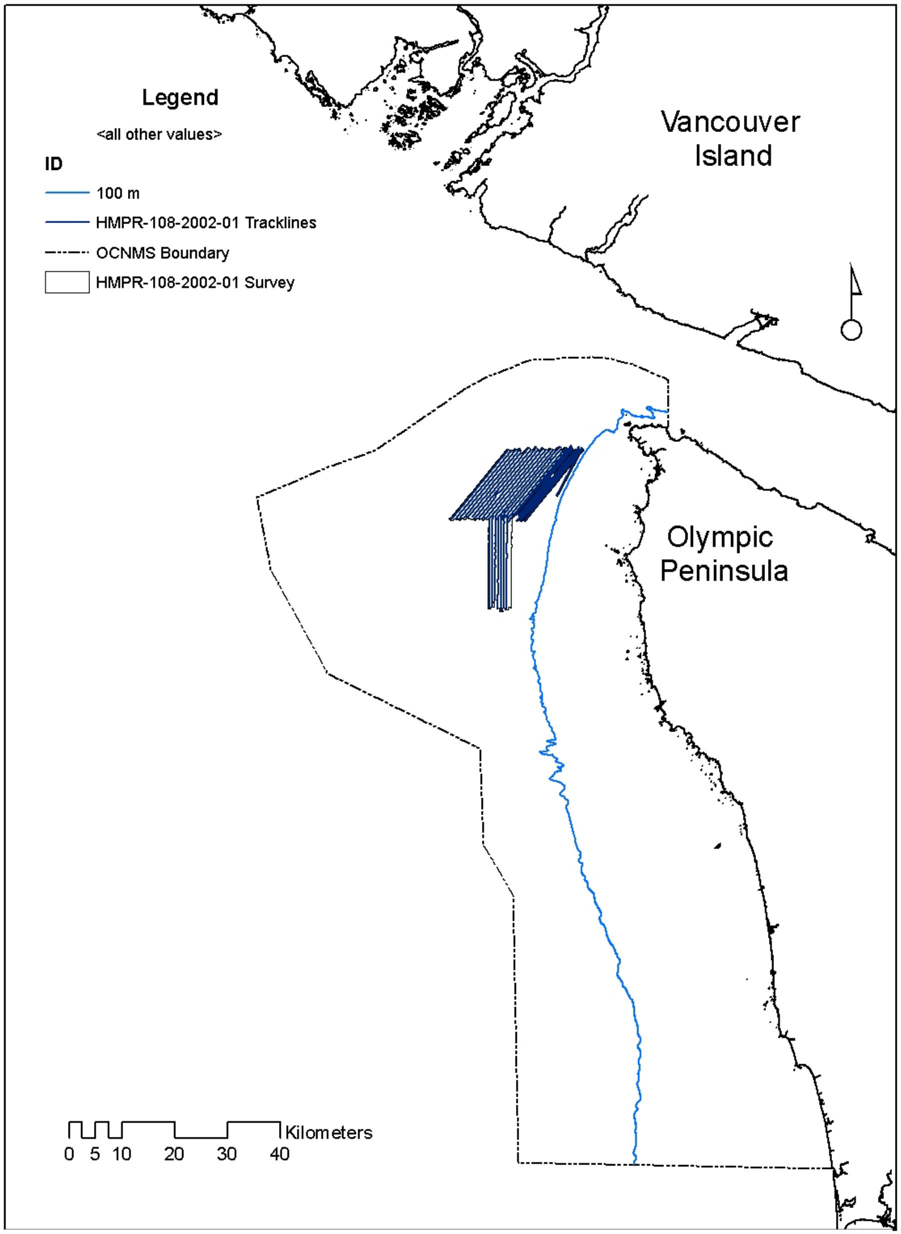

Figure 1. HMPR-108-2002-01 survey footprint shown with 100 m bathymetric contour and track lines.

SONAR ACQUISITION

The fishing vessel *Mystery Bay*, measuring 51 meters in length, was used as the survey platform (Figure 2), with the aft hydraulic crane serving as tow point. A Trimble DSM 212H differential GPS was used to acquire ship position and control line planning. A Trackpoint II ultra short baseline (USBL) was configured to track the position of the towfish, but significant layback resulting from extensive cable out produced poor navigation fixes, and as such the USBL data were not used for image mosaicing. Instead, towfish position was estimated through use of an Hydrographic Surveys digital cable counter to log line out. An SG Brown Meridian Standard survey gyrocompass, with static heading accuracy of 0.1^{o}, was used to control vessel heading. An Edgetech DF1000 dual-frequency side scan sonar was used to acquire the acoustic imagery. The sonar system has a horizontal beam width of 1.2^{o} at 100kHz and 0.5^{o} at 500kHz with a vertical beam width measuring 50^{o} and a depression angle of 20^{o} was set on the transducers. Vessel speed was maintained at 3-3.5 knots throughout operations but was increased to 12 knots on several occasions to avoid contacting the towfish with the sea floor when surveying in an upslope direction.

Figure 2. Photograph of *F/V Mystery Bay*, used as survey platform for HMPR-108-2002-01.

Positional information from the DGPS and gyrocompass were logged with Coastal Oceanographics Hypack (version 005b) software. Sonar data were logged, with 2048 samples per channel, using Triton International Inc. (TII) Isis Sonar and recorded as eXtended Triton Format (XTF). Positional information acquired from both the Trackpoint II and the Trimble DGPS were patched into Isis through the shared memory option in Hypack (Figure 3).

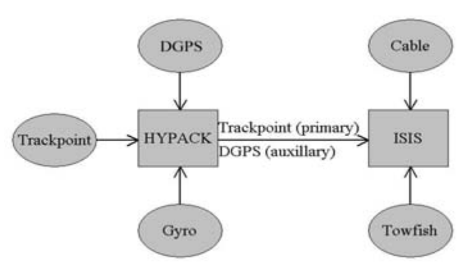

Figure 3. Data acquisition schematic for the HMPR-108-2002-01 survey on the *F/V Mystery Bay*.

The survey plan began using a 150 meter range scale with 250 meter line spacing but was altered to 300 meter range scale with 500 meter line spacing after two days of data acquisition in an effort to maximize the amount of sea floor covered and also allow for the towfish to be flown at safer altitudes in the canyons.

SONAR DATA PROCESSING AND IMAGE CLASSIFICATION

Image mosaics were created from the 100 kHz channels using Isis Sonar. Excessive noise in the Trackpoint II system precluded the use of USBL data for creating the image mosaics, therefore TII's ModXTF utility was used to swap the USBL and the Trimble DGPS positioning in each XTF. Data from the Trimble DGPS was then used to calculate a layback position from logged line out data and towfish depth, which was acquired from a digital pressure sensor mounted in the tow body. The navigation data was smoothed in Isis Sonar using a 7-point moving average filter. Slant range correction and bottom tracking were accomplished in Isis Sonar, in addition to the application of time varied gain and beam angle compensation curves. To reduce the effects of far field attenuation, a ping duration was set to 282 meters during mosaic.

Individual line mosaics were imported into TII's DelphMap, merged into three separate mosaics to split the survey into an eastern, western and southern block, and then exported as geotiff images. Leica Geosystems' Imagine software was used to export the images as raw binary format, with no header, and contained only grey-scale pixel intensities ranging from 0 to 255.

Side scan sonar data are presented as grey-scale images representing the intensity of sound received by the sonar from the sea floor and can provide information about the characteristics of the surface sediments. But several studies (Skohr 1991; Blondel 1996) have found the use of grey-level alone for assigning classification codes to side scan sonar imagery as being inadequate, and other studies (Blondel 1996; Cochrane and Lafferty 2002; Huvenne et al. 2002) have successfully used various textural indices to more effectively classify side scan sonar data. Thus we chose to use second-order textural analysis (Cochrane and Lafferty 2002) on the raw binary images to differentiate bottom types from the imagery. Using a co-occurrence matrix approach provides an alternative for classifying acoustic imagery and has been found to more effectively assess the spatial relationship of pixel intensities from remote sensing data (Haralick 1973; Blondel 1996).

Due to the substantial size of the images, the texture procedure was independently conducted for each of the three mosaics. Each of the images were classified into three categories representing soft, mixed, and hard bottom. Adobe Photoshop was used to manually edit misclassified or unclassified data, such as that occurring at nadir. The three mosaics were then merged with Leica Geosystems Imagine software and reclassified as a thematic raster image. Using ESRI's ArcInfo software a neighborhood analysis majority filter was used to "smooth" the image to reduce the number of polygons from 1.8 million to under 100,000. The raster image was then converted to a polygon feature for display in the GIS. The areas of large scale sand and mixed sediment waves, as well as several regions of high gradient slopes which existed in the southern portion of the survey area, did not emerge as distinct features from the textural analysis and as such were hand delineated.

GROUNDTRUTHING

A Phantom DHD2+2 remotely operated vehicle (ROV) was used to acquire underwater videography during a 2004 pilot survey to explore for the presence of deep coral and sponge assemblages in the OCNMS (Hyland et al. 2005). Three separate ROV deployments occurred within the footprint of the HMPR-108-2002-01 sonar survey, and provided useful video for groundtruthing the sonar mosaics and verifying the classification signatures. The USSEABED project, a database providing information on sediment and rock distributions in the waters off the United States (Reid et al. 2001), was also queried and provided 58 samples to describe sedimentology within the survey area (Figure 4).

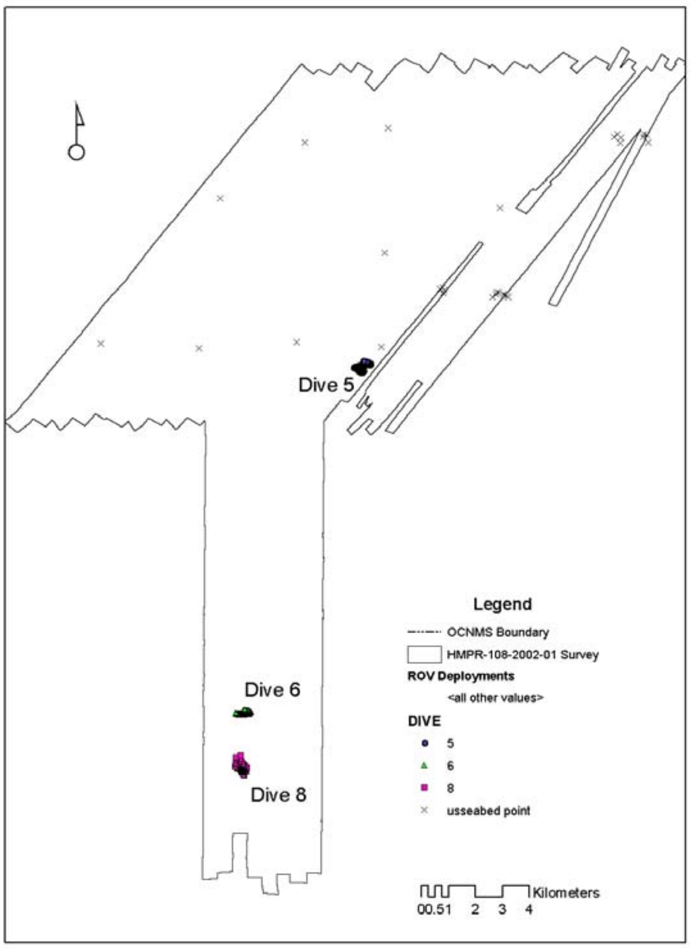

Figure 4. Sonar groundtruthing coverage, including video footage from the AR-04-04 ROV deployments and sediment samples taken from the USSEABED project.

SURVEY RESULTS AND INTERPRETATION

Over 573 km of track lines, covering an area of approximately 267 km^2 ($77.9nm^2$), yielded more than 83 hours of logged sonar data during the five day survey effort. Megahabitat was described as canyon flank in areas deeper than the 200-meter bathymetric contour, and otherwise defined as continental shelf (Greene et al. 1999). Textural classification of the imagery suggests that over 51 percent of the seafloor in this area is covered by soft substrates such as mud or silt; 48 percent is comprised of mixed sediment including cobbles, pebbles, gravel and boulders mixed with soft substrate; under 1 percent is characterized as a hard complex rocky bottom (Table 1). We discerned several areas of exposed bedrock, a few cliff-like areas having substantial relief (Table 2), and noted at least one rock pinnacle defined by a significant acoustic shadow, characteristic of such geologic features. Multiple areas were characterized as having large distinct sediment waves in the southern region of the survey area.

Table 1. Distribution of bottom hardness classified from HMPR-108-2002-01 side scan sonar survey data. Bottom induration codes are provided by area in square meters, and area as a percentage of total mapped area.

Bottom_ID	Descriptor	Square m	Percentage
h	hard	910,957	0.3
m	mixed	129,083,483	48.0
s	soft	137,557,681	51.6

Table 2. Distribution of habitat classified from HMPR-108-2002-01 side scan sonar survey data. Habitat codes are provided per Greene et al. (1999) and are presented by area in square meters, and area as a percentage of total mapped area.

Habitat Code	Descriptor	Square m	Percentage
Fh	Flank hard	534,834	0.200
Fhe	Flank hard exposed	131,923	0.049
Fhp	Flank hard pinnacle	123	<0.001
Fhs	Flank hard scarp/cliff	55,241	0.021

Table 2 continued. Distribution of habitat classified from HMPR-108-2002-01 side scan sonar survey data. Habitat codes are provided per Greene et al. (1999) and are presented by area in square meters, and area as a percentage of total mapped area.

Habitat Code	Descriptor	Square m	Percentage
Fm	Flank mixed	80,507,273	30.090
Fm _h	Flank mixed hummocky	26,019	0.010
Fms	Flank mixed scarp/cliff	466,734	0.174
Fmw	Flank mixed waves	3,153,358	1.179
Fs	Flank soft	1,186,978	0.444
Fs _u	Flank soft unconsolidated	122,918,895	45.942
Fss	Flank soft scarp/cliff	774	<0.001
Fsw	Flank soft waves	47,601	0.018
Sh	Shelf hard	181,048	0.068
Shs	Shelf hard scarp/cliff	7,787	0.003
Sm	Shelf mixed	40,986,717	15.319
Sm _h	Shelf mixed hummocky	1,506,279	0.563
Sm _u	Shelf mixed unconsolidated	649	<0.001
Sms	Shelf mixed scarp/cliff	25,631	0.010
Smw	Shelf mixed waves	2,410,821	0.901
Ss	Shelf soft	1,598,537	0.597
Ss _u	Shelf soft unconsolidated	11,786,931	4.405
Ssw	Shelf soft waves	17,965	0.006

Microhabitat and presence of certain biologic attributes were also populated into the polygon features, but strictly limited to areas where video groundtruthing occurred and where the sea floor was clearly visible in the footage. Figure 5 provides a graphical representation of this full habitat characterization including the codes for microhabitat and biologic attributes.

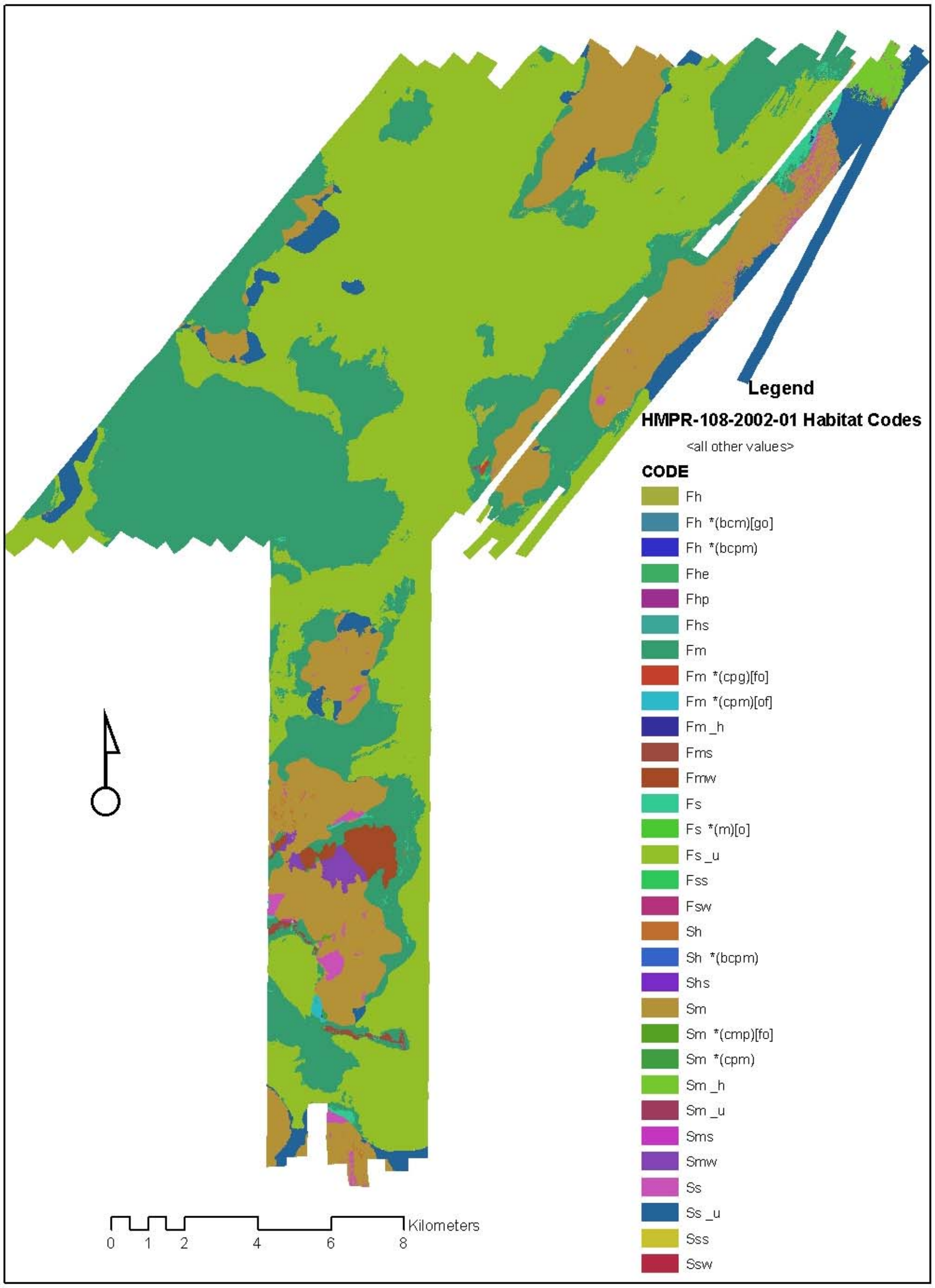

Figure 5. Classification of habitat for survey HMPR-108-2002-01. Microhabitat (in parenthesis) and biologic attributes (in brackets) are preceded by an asterisk in the habitat code.

DISCUSSION AND CONCLUSIONS

Results from this survey were supported by two unpublished side scan surveys conducted in adjacent areas. In September 2002, an unpublished side scan survey conducted on the nearshore shelf directly shoreward of HMPR-108-2002-01 revealed a seafloor consisting entirely of modern age sand. This observation was consistent with the first survey line collected on the *F/V Mystery Bay*, which ultimately led to the decision to change line plans to locate more interesting bottom features. Presence of a rock outcropping feature revealed during a July 2000 cruise aboard a Navy YP class vessel (unpublished data) was also confirmed on this survey.

The hard bottom features that we identified can provide complex habitat adequate for many of the groundfish species that inhabit this region of the coastline (NOAA 1990) as readily observed in the video imagery captured by the ROV. These hard substrates could additionally provide critical habitat for deep-sea coral and sponge assemblages, as evident from exploration by Hyland et al. (2005), where small patches *Lophelia pertusa* were observed near a rocky ledge in the OCNMS. This survey delineated several areas of similar habitat, thereby providing target areas for additional video surveillance to potentially identify similar organisms. Slow growth rates, ease of disturbance, and long life spans make these communities extremely susceptible to destruction from anthropogenic disturbances such as bottom trawling, which has been shown to impact benthic communities by altering structure (Bergman et al. 1990; Auster et al. 1996) and removing benthic fauna (Brown et al. 2000).

The sand and silt bottom occurring throughout much of the survey area are sediments from the quarternary period that are likely deposits from the Puget Sound and Columbia River (Nittrouer 1978; Sternberg 1986), and can provide useful habitat to such species as sole (Kramer et al. 1985), skate, pacific rattail (Stein and Pearcy 1982), pacific cod (Garrison and Miller 1982), and sablefish (Love 1996).

The various regions of mixed sediment are possibly of glacial origin, originating in the Olympic Mountains (Venkatarathnam and McManus 1973). These areas of mixed coarse sediment provide key habitat for many species including bocaccio (Yaklovich et al. 2000) and flounder (NOAA 1990).

Although somewhat limited by the lower native pixel resolution (created from using slow ping rates associated with a 300-meter range scale setting), textural analysis of the sonar mosaics was capable of providing a relatively automated method for delineating substrate type into three classes representing soft, mixed sediment, and hard bottom. Acquiring the imagery with a smaller range scale setting (i.e. 150-meter) would certainly enhance the textural properties of the imagery and ultimately lead to more definition in the classified polygon features; however, this would come at the cost of covering less terrain and increasing the likelihood of damaging or losing the sonar as the towfish would need to be flown at an altitude of approximately 25-30 meters as opposed to 50-60 meters, as used in this survey. The extreme relief of the Juan de Fuca canyon walls make for a challenging environment to safely acquire quality imagery at altitudes much less than 50 meters.

Even though sediment grab samples (Reid et al. 2001) and limited video imagery (Hyland et al. 2005) was available for validating the classification results, additional groundtruthing efforts would enhance the quality of the classification in this area as well as provide more detail into the microhabitat and associated biologic distribution. Further groundtruthing work around the high relief cliff-like areas and the various areas of soft and mixed sediment waves would especially improve confidence in the product. Future survey efforts and additional groundtruthing will be incorporated as updates in later versions.

ACKNOWLEDGMENTS

The authors thank the crew of the *F/V Mystery Bay* and Nicholas Perry, James Whitaker, and Danny Shaylor for assistance with acquiring the sonar imagery. Video imagery from the NOAA Ship *McArthur II* cruise AR-04-04 was made available by C.E. Bowlby, J. Hyland and M.S. Brancato.

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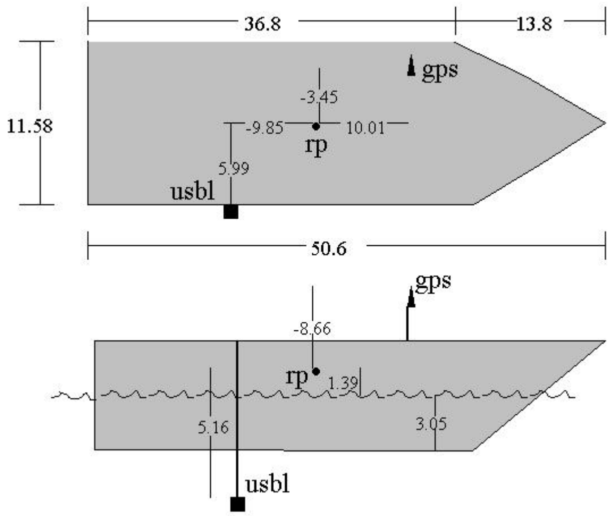
APPENDIX

Appendix 1. Vessel offset diagram including sensor offset measurements from an arbitrarily chosen common reference point (rp). gps = antennae position; usbl = pole mount position for acoustic positioning.



Appendix 2. Isis Processing Parameters

Heading Offset: use gyro with offset of 23 degrees
Lateral Offset: -3.4m
Layback Offset: 44m
Mosaic resolution:. 1m
Apply BAC
Apply duration: 282m
TVG: start at first return

- Line 1,3 (south block): -7 +.109 +(-13)
- Line 2 (south block): -3 +.03 + (-4)
- Line 4,5,6,6b,7,8: -6 + .109 + (-13)
    - ** For line6b also put an across track angle of 4 degrees in the BAC compensation
- For shallow water smaller range scale lines (East block): -1.4 + 0.22 + (-2)

ONMS CONSERVATION SERIES PUBLICATIONS

To date, the following reports have been published in the Marine Sanctuaries Conservation Series. All publications are available on the Office of National Marine Sanctuaries website (http://www.sanctuaries.noaa.gov/).

Channel Islands Deep Water Monitoring Plan Development Workshop Report (ONMS-05-05)

Movement of yellowtail snapper (*Ocyurus chrysurus* Block 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry (MSD-05-4)

The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary (MSD-05-3)

An annotated bibliography of diet studies of fish of the southeast United States and Gray's Reef National Marine Sanctuary (MSD-05-2)

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Pre-Construction Coral Survey of the M/V Wellwood Grounding Site (MSD-03-1)

Olympic Coast National Marine Sanctuary: Proceedings of the 1998 Research Workshop, Seattle, Washington (MSD-01-04)

Workshop on Marine Mammal Research & Monitoring in the National Marine Sanctuaries (MSD-01-03)

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Distribution and Sighting Frequency of Reef Fishes in the Florida Keys National Marine Sanctuary (MSD-01-1)

Flower Garden Banks National Marine Sanctuary: A Rapid Assessment of Coral, Fish, and Algae Using the AGRRA Protocol (MSD-00-3)

The Economic Contribution of Whalewatching to Regional Economies: Perspectives From Two National Marine Sanctuaries (MSD-00-2)

Olympic Coast National Marine Sanctuary Area to be Avoided Education and Monitoring Program (MSD-00-1)

Multi-species and Multi-interest Management: an Ecosystem Approach to Market Squid (*Loligo opalescens*) Harvest in California (MSD-99-1)