


This publication is available from the Geological Survey of Canada (GSC) website (<http://open.canada.ca/geo>). It can also be downloaded free of charge from GeoArchive (<http://open.canada.ca/geo>).

1610-095/268230



LOCATION MAP

OPEN FILE 6625

POTENTIAL MARINE BENTHIC HABITATS AND SHADED SEAFLOOR RELIEF

## SOUTHERN GULF ISLANDS AND SAN JUAN ARCHIPELAGO

CANADA AND U.S.A.

Sheet 2: southern Gulf Islands

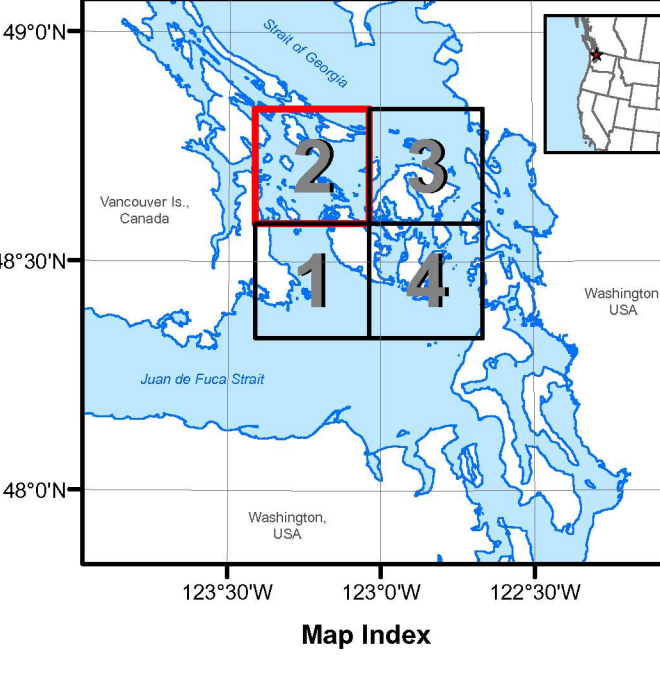
Scale 1:50 000/Échelle 1/50 000

kilomètres 1 2 3 4

kilomètres

Universal Transverse Mercator Projection, Zone 10  
North American Datum 1983  
© Her Majesty the Queen in Right of Canada 2011  
This map is not to be used for navigational purposes

Projection transverse universelle de Mercator, Zone 10  
Système de référence géodésique nord-américain, 1983  
© Sa Majesté la Reine du chef du Canada 2011  
Cette carte ne doit pas être utilisée aux fins de navigation



Map Index

Sheet 2 of 4, southern Gulf Islands  
Picard, K., Endris, C.

**Recommended citation:**  
Greene, H.G. and Barrie, J.V., 2011. Potential marine benthic habitats and shaded seafloor relief, southern Gulf Islands and San Juan Archipelago, Canada and U.S.A., Geological Survey of Canada, Open File 6625, scale 1:50 000. doi:10.4095/268230

### DESCRIPTIVE NOTES

The San Juan Archipelago-Southern Gulf Islands seafloor mapping effort is an ongoing mapping program focused on the characterization of marine benthic habitats and the mapping of geology within the Salish Sea. The Salish Sea has suffered a severe decline in several species of bottom fish over the past several decades perhaps due to environmental degradation and overfishing (Puget Sound Ambient Monitoring Program, 2002; Fisheries and Oceans Canada, Rockfish Conservation Areas, 2008). The primary objective of this mapping program is to characterize potential marine benthic habitats and geology. The final product includes interpretive maps that can be used to identify rockfish (*Sebastes* sp.) habitats, which then can be used by both Canada and the US to manage, conserve and sustain economically significant fisheries (considered outcomes) in the transboundary region. A mechanism that has been developed to address fisheries conservation and sustainability is the establishment of Marine Protected Areas (MPAs) and voluntary or mandatory no-take zones whose evaluation as a benthic habitat can be done using potential habitat maps. Therefore, a secondary objective of this mapping effort is to provide data where assessment, and if necessary modification, of established MPAs, and the establishment of new MPAs, can be made. Additional mapping objectives that evolved from this project include the identification of specific deep-water foraging habitats such as dynamic bedforms that harbor sand lances (*Ammodytes hexapterus*) and potential siliceous sponge reefs (*Neoschwabelia*), although these are not specifically identified in the maps as characterization of these specific habitat types is continuing.

The San Juan Archipelago-Georgia Basin region is an active tectonic province whose physiography and geomorphology reflect both Mesozoic to Cenozoic convergent (subduction/accretion) plate tectonic processes and Pleistocene glaciation (glacial scouring/deposition) (Barrie & Conway, 2002; England & Buslin, 1996). These processes have juxtaposed and deformed Jurassic-Cretaceous metamorphic rocks with Tertiary-Quaternary sedimentary rocks producing a complex of folds, grooves and polished bedrock outcrops, and erratic boulders and moraines. Banks of till and glacial advance outwash deposits also contribute to the variety of sedimentary deposits and relief within the region. Tidal currents have reworked much of the preexisting glaciomarine sediments into dynamic bedforms consisting of sand and gravel waves, dune fields, and other modern day sedimentary deposits, such as sandy and muddy banks (Barrie & al., 2003).

This tectonic province can be divided into two distinct zones based on bedrock types: a northern sedimentary bedrock zone (Masland & Rose, 1984) and a southern metamorphic rock zone (Vorath, 2005) separated by the Haro fault (see map sheets 2 and 3). Both zones contain large underwater bedrock exposures showing different differential erosion characteristics of sedimentary rocks, which form ridges and overhangs. In contrast, the metamorphic bedrock is highly fractured and faulted, forming cracks, crevices, and blocky boulder aggrs. The intensity and variety of geological processes have resulted in the large variety of potential marine benthic habitat types mapped in the region.

The habitat classification scheme follows an existing habitat classification code which was established to distinguish habitat types for species of interest and to facilitate ease of use and queries in GIS and other database programs. The code used in this map is modified from the scheme developed by Greene et al. (1999, 2007) for deep-water habitat characterization.

The interpretation of the high-resolution multibeam seafloor imagery into habitat type delineation was based on knowledge of the geology of the seafloor and seafloor processes in the study area (Thompson, 1981; Mesher et al., 2000; Hewitt & Mosher, 2001; Barrie et al., 2005, 2009). Geological processes, structure and morphology depicted in the imagery were used to distinguish distinct potential habitat types. Mapping of the habitats was done at 1:20 000 scale using editing tools in ESRI ArcGIS software. Resolution of seafloor features varied from 2 to 5 m pixels, depending on the type of multibeam echosounder (MBES) systems that were used in the various surveys (Greene & Barrie (Eds.), 2011a, 2011b). However, for most of the area, seafloor features such as bedrock types (e.g., sedimentary, metamorphic, volcanic, and granitic rocks), structures (e.g., faults, folds, scars, and landslides), and bedforms of unconsolidated sediments were easily distinguished. To differentiate pinnacle and/or boulder (h(b)p) habitats from simple bedrock, a specific bedrock was assigned where any known bedrock polygons with a surface area smaller than 500 m<sup>2</sup> became identified with "h(b)p".

### REFERENCES

Barrie, J.V. and Conway K.W., 2002. Contrasting glacial sedimentation processes and sea-level changes in two adjacent basins on the Pacific margin of Canada, in *Glacier-Influenced Sedimentation on High-Latitude Continental Margins*, (ed. J.J. Dowdeswell and C. O'Connell; Geological Society of London, Special Publication 203, p. 181-194.

Barrie, J.V., Hill, P.H., Conway, K.W., Iwanowicz, K., and Picard, K., 2005. Environmental. Marine Geoscience 4: Georgia Basin, western Vancouver Island and its applications. In *Mapping the Seafloor for Habitat Characterization* (B.J., Todd and H.G., Greene, Eds.), Geological Association of Canada, Special Paper 47, p. 141-155.

Greene, H.G. (ed.) and Barrie, J.V. (ed.), 2011a. Shaded seafloor relief, southern Gulf Islands and San Juan Archipelago, Canada and U.S.A., Geological Survey of Canada, Open File 6627, 4 sheets.

England, T.D.J. and Buslin, R.M., 1996. Architecture of the Georgia Basin, southwestern British Columbia. *Bulletin of Canadian Petroleum and Geology*, v. 46, p. 288-320.

Greene, H.G., Wabitsch, M.M., Stolt, R.M., O'Connell, V.M., Wabitsch, W., Sullivan, D.E., McRae, J.E., and Gallet, G.M., 1999. A classification scheme for deep seafloor habitats. *Oceanologica Acta*, v. 22, no. 6, p. 653-678.

Greene, H.G., Bizzarro, J.J., O'Connell, V.M., and Brinkley, C.K., 2007. Construction of digital potential marine benthic habitat maps using a coded classification scheme and its applications. In *Mapping the Seafloor for Habitat Characterization* (B.J., Todd and H.G., Greene, Eds.), Geological Association of Canada, Special Paper 47, p. 141-155.

Greene, H.G. (ed.) and Barrie, J.V. (ed.), 2011b. Shaded seafloor relief, southern Gulf Islands and San Juan Archipelago, Canada and U.S.A., Geological Survey of Canada, Open File 6627, 4 sheets.

Hewitt, A.T. and Mosher, D.C., 2001. Late Quaternary stratigraphy and seafloor geology of the eastern Juan de Fuca Strait, British Columbia and Washington, Marine Geology, v. 177, p. 293-316.

Mesher, D.C., Thompson, R.E., 2000. Massive submarine sand dunes in the western Juan de Fuca Strait, British Columbia, in: Trevisan, A., Corbett, T., (Eds.), *Proceedings of the international workshop on marine sand dunes*, March 23-24, 2000, University of Liege, France, p. 131-142.

Masland, P.S. and Rose, G.E., 1984. Stratigraphy and evolution of Tertiary Georgia Basin and subjacent Upper Cretaceous sedimentary rocks, southwestern British Columbia and northwestern Washington State. In *Geology and Geological Hazards of the Vancouver Region*, Southwestern British Columbia (ed. J.V.H. Monger, Geological Survey of Canada, Bulletin 481, p. 97-140.

Thompson, R.E., 1981. Oceanography of the British Columbia Coast. Canadian special publication of the Fisheries and Aquatic Sciences, v. 30, 291 p.

Yorath, C., 2005. The geology of Southern Vancouver Island. Malibu Park, Harbour Publishing Co. Ltd., 25p.

### KEY TO HABITAT TYPES

Not all units may appear on this map sheet.

#### Unconsolidated substrate (mud)

- Is(m)\_u Unconsolidated sediments
- Is(m)\_t Unconsolidated sediment terrace
- Is(m)\_h/u Hummocky unconsolidated sediments
- Is(m)\_m/u Mound
- Is(m)\_h\_e/u Pockmark
- Is(m)\_h\_s/u Scour depression
- Is(m)\_h\_a-dd/u Hummocky dredge or anchor disturbances
- Is(m)\_a-dg/u Dredge channel
- Is(m)\_h\_a/u Sawdust terrace

#### Unconsolidated substrate (sand / mud)

- Is(s/m)\_u Unconsolidated sediments
- Is(s/m)\_h/u Hummocky unconsolidated sediments
- Is(s/m)\_v/t/u Vegetated unconsolidated sediment terrace
- Is(s/m)\_m/u Linear ridge
- Is(s/m)\_h\_m/u Ice-formed mound
- Is(s/m)\_h\_u Depression
- Is(s/m)\_h\_s/u Scour depression
- Is(s/m)\_g\_s/u Scour gully
- Is(s/m)\_g\_w\_s/u Scour gully with sediment bedforms
- Is(s/m)\_s\_s/u Current-scoured scarp
- Is(s/m)\_s\_u Scarp
- Is(s/m)\_h\_a-dd/u Hummocky dredge or anchor disturbances

#### Unconsolidated substrate (sand / gravel)

- Is(s/g)\_u Unconsolidated sediments
- Is(s/g)\_h/u Hummocky unconsolidated sediments
- Is(s/g)\_w\_u Sediment bedforms
- Is(s/g)\_w\_s/u Current-scoured sediment bedforms
- Is(s/g)\_m\_u Mound or linear ridge
- Is(s/g)\_m\_u Ice-formed mound, esker or moraine
- Is(s/g)\_m\_h/u Hummocky ice-formed mound
- Is(s/g)\_h\_u Depression
- Is(s/g)\_h\_s/u Dropstone depression
- Is(s/g)\_h\_s/u Scour depression
- Is(s/g)\_g\_s/u Scour gully
- Is(s/g)\_l\_h/u Hummocky landslide deposit
- Is(s/g)\_s\_s/u Current-scoured scarp
- Is(s/g)\_a-dm/u Dredge disposal
- Is(s/g)\_h\_a-dd/u Hummocky dredge or anchor disturbances
- Is(s/g)\_a-dg/u Dredge channel
- Is(s)\_h\_a/u Forty-wash scour

#### Unconsolidated substrate (sand)

- Is(s)\_u Unconsolidated sediments
- Is(s)\_t Unconsolidated sediment terrace
- Is(s)\_w\_u Sediment bedforms
- Is(s)\_m\_u Mound or Linear ridge
- Is(s)\_m\_s/u Scour ridge
- Is(s)\_h\_s/u Scour depression

#### Unconsolidated substrate (gravel)

- Is(g)\_u Unconsolidated sediments
- Is(g)\_h/u Hummocky unconsolidated sediments
- Is(g)\_m\_u Mound or linear ridge
- Is(g)\_h\_m/u Ice-formed mound or moraine
- Is(g)\_h\_s/u Scour depression
- Is(g)\_s\_s/u Current-scoured scarp

#### Unconsolidated substrate (boulders)

- Is(b)\_m\_u Moraine

#### Sediment covered bedrock

- lme\_c/u Sediment covered bedrock

#### Hard substrate

- lh Rock fall
- lh(b)p Pinnacle or boulder
- lh\_f/s Fractured bedrock
- lh\_g/s Granitic bedrock
- lh\_d/s Sedimentary bedrock
- lh\_a-w Anthropogenic structure - Shipwreck
- lh\_a-p Anthropogenic structure - Supports
- lh\_a-s Anthropogenic structure - Pipeline
- lh\_a-g Anthropogenic structure - Former vessel loading facility, jetty or riprap

AUTHORS: K. Picard, C. Endris, H.G. Greene and J.V. Barrie

Compilation by K. Picard and C. Endris

Edited by H.G. Greene and J.V. Barrie

Digital Cartography by C. Endris, Center for Habitat Studies

ACKNOWLEDGEMENTS: Center for Habitat Studies participants J. Trépan, H. Lopez, and B. Dierler and Kim W. Conway for the critical review of the map

This map was produced by the Center for Habitat Studies at Moss Landing Marine Laboratories in cooperation with Tombolo, the Seafloor Society, Natural Resources Canada, and the Canadian Hydrographic Service

OPEN FILE  
DOSSIER PUBLIC

6625

GEOLOGICAL SURVEY OF CANADA  
COMMISSION GÉOLOGIQUE DU CANADA

2011

SHEET 2 OF 4  
FEUILLE 2 DE 4

Open file products that have not gone through the GSC formal publication process  
Les documents publiés en tant que produits ouverts n'ont pas été soumis au processus officiel de publication de la GSC.