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Using Benthic Terrain Modeller to characterise Aotearoa New Zealand seafloor geomorphology

Jodie Robertson, Enrique Pardo, Shane Geange, Arne Pallentin, Shaun Weston



Department of
Conservation
Te Papa Atawhai



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o Aotearoa**
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Using Benthic Terrain Modeller to characterise Aotearoa New Zealand seafloor geomorphology

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Abstract

Multibeam echosounder (MBES) surveys have become a standard tool for geophysical surveying and mapping of the seafloor. This technology helps us to develop consistent models for the study of seafloor features, understanding hydrodynamics, and studying marine life. Here, we used the tools provided within the current release of the Benthic Terrain Modeler (BTM v3.0) to consistently apply BTM across different MBES datasets and create a portfolio of benthic terrain maps for Aotearoa New Zealand, providing the ability to compare seafloor topography across sites.

The portfolio includes datasets from 50 MBES survey sets conducted between 1999–2020. The datasets cover areas along the whole north–south axis of Aotearoa New Zealand’s main islands, and areas from the Aotearoa New Zealand territorial sea (12 nm) and exclusive economic zone (200 nm) between 3 m above local mean sea level (MSL) to 2,083 m below MSL. These datasets were then used to develop the benthic terrain datasets that cover an area of approximately 52,000 km². We describe the BTM tools used in the analysis, which included the Bathymetric Position Index (BPI); Surface Derivative; Rugosity; Depth Statistics; Terrain Classification; and raster functions Hillshade and Aspect.

The portfolio includes benthic terrain datasets that cover 23.1% of Aotearoa New Zealand’s territorial sea and 0.3% of the exclusive economic zone. We believe this is the first time in Aotearoa New Zealand that multibeam surveys have been analysed and published consistently at a national scale.

Keywords: Benthic terrain maps, seafloor features, terrain classification, multibeam echosounder, [Aotearoa New Zealand]

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1. Introduction

Mapping the geomorphology and biogenic habitats associated with the seafloor is essential to understanding the processes influencing species' distributions, ecological interactions, and managing the marine environment. Our understanding of Aotearoa New Zealand's seafloor geomorphology and biogenic habitats is still limited by a paucity of data, with few areas of the seafloor mapped in detail, especially in areas beyond 30 m depth.

Advances in remote sensing data technologies have lowered costs and increased the extent and quality of bathymetric data, and a small but increasing proportion of the seafloor is becoming well-mapped. Habitat mapping is a first step to further our understanding of species abundance and distribution, which is typically influenced by bathymetric gradients and geomorphology features (Brock et al. 2004). The physical terrain determines parameters such as depth, temperature, and currents, and therefore the species that inhabit specific seafloor areas. The description of the seafloor geodiversity can then be used as a surrogate for estimating biodiversity and species distribution (Kaskela & Kotilainen 2017; Lucatelli et al. 2020).

Multibeam echosounder (MBES) surveys have become one of the standard tools for geophysical surveying and mapping of the seafloor. The MBES data products include bathymetry (seafloor depth) and seafloor backscatter intensity, which can provide a metric for seafloor reflectivity, interpreted as a proxy for 'hardness', and will indicate the substrate type (Kloser et al. 2022). MBES technologies (which incorporate in-sensor error models and accurate georeferencing) can be used to capture, groom, and integrate seafloor data and develop consistent geomorphological models. These models can be used for the study of seafloor features, hydrology, and marine life (Lecours et al. 2016).

Interpretation of geomorphological models is aided by geomorphometry analysis tools in packages such as the open-source Benthic Terrain Modeler (BTM) for ArcGIS (Walbridge et al. 2018). The BTM toolbox was originally developed in 2005, at Oregon State University, under a cooperative agreement with the National Ocean and Atmospheric Agency Coastal Services Center's GIS Integration and Development program (Wright et al. 2005). The BTM toolbox is now widely used by ocean and coastal scientists and resource managers to classify bathymetric data and understand the benthic environment.

BTM can be used for creating terrain attributes such as slope, rugosity, roughness, and aspect, which can be used as covariates in predictive modelling applications (e.g., Young & Womersley 2015). BTM can also be used for classifying seafloor morphology by combining terrain attributes and mapping their ranges within a classification dictionary, and identifying benthic zones such as flat plains, scarps, cliffs, and depressions (Lucatelli et al. 2020; Mata et al. 2021). Biological information can be integrated with the benthic terrain models, or underlying geophysical or seafloor morphology data, to produce targeted habitat and habitat suitability maps with associated uncertainties (Walbridge et al. 2018).

Consistent application of BTM across MBES datasets has the potential to accelerate our understanding of processes influencing species' distributions and ecological interactions, and meaningfully inform management of Aotearoa New Zealand's marine environment. Here we utilise the tools provided with the current release of the Benthic Terrain Modeler (BTM v3.0) to consistently apply BTM across different MBES datasets and create a portfolio of benthic terrain maps for Aotearoa New Zealand, providing the ability to compare seafloor topography across sites.

2. Methodology

Toitū Te Whenua Land Information New Zealand (LINZ) holds a vast amount of marine survey data at different resolutions from around Aotearoa New Zealand. This data has been gathered over many years, mainly to help prepare nautical charts, but has the potential to be used for a range of other uses – for instance, scientific analysis and the study of seafloor features, creating hydrodynamic models, and studying marine life (Lecours et al. 2016).

The analysis described here comprises data from 50 MBES survey sets conducted between 1999 and 2020, obtained from the LINZ Data Service (<https://data.linz.govt.nz/>) by request under a Creative Commons licence (Figure 1). This allows the reuse of the data, and any derived products from this analysis.

The data were collected for safety of navigation purposes, but they cover areas along the whole north–south axis of Aotearoa New Zealand’s main islands, and areas from the Aotearoa New Zealand territorial sea (12 nm) and exclusive economic zone (200 nm). The depth range covers from 3 m above MSL to 2,083 m below MSL. The datasets analysed cover an area of approximately 52,000 km²; approximately 37,894 km² of the North Island, 11,733 km² of the South Island and 2,489 km² around offshore islands, ranging from smaller survey sets of 2.8 km² to larger survey sets covering an area of 10,254 km² (Figure 1). The West Coast is underrepresented in the coverage of the LINZ surveys, with the exemption of Fiordland, in the southwest of the South Island. The data include areas around Aotearoa New Zealand’s subantarctic islands and the Chatham Islands. The current MBES coverage includes 14% of the Type I Marine Protected Areas (MPAs) in Aotearoa New Zealand.

These datasets span more than 20 years and have been collected using a large variety of MBES systems with variable capabilities due to technological advances. Additionally, surveys are conducted in variable weather conditions and changing oceanographic conditions, which affect the quality of raw data. As a result, despite all systems and surveys adhering to hydrological standards ([LINZ Hyspec](#)), the datasets differ in their resolution (grid cell size ranging from 0.5 m – 50 m) and quality of the soundings on the seafloor.

All bathymetry datasets have a vertical datum of Lowest Astronomical Tide (LAT) in the survey area (chart datum), issue the World Geodetic System 1984 (WGS84) datum, and utilise its local Universal Transverse Mercator (UTM) Zone (e.g., 58S). A full list of the bathymetry datasets can be found here: <https://data.linz.govt.nz/layer/95574-nz-bathymetric-surface-model-index/>.

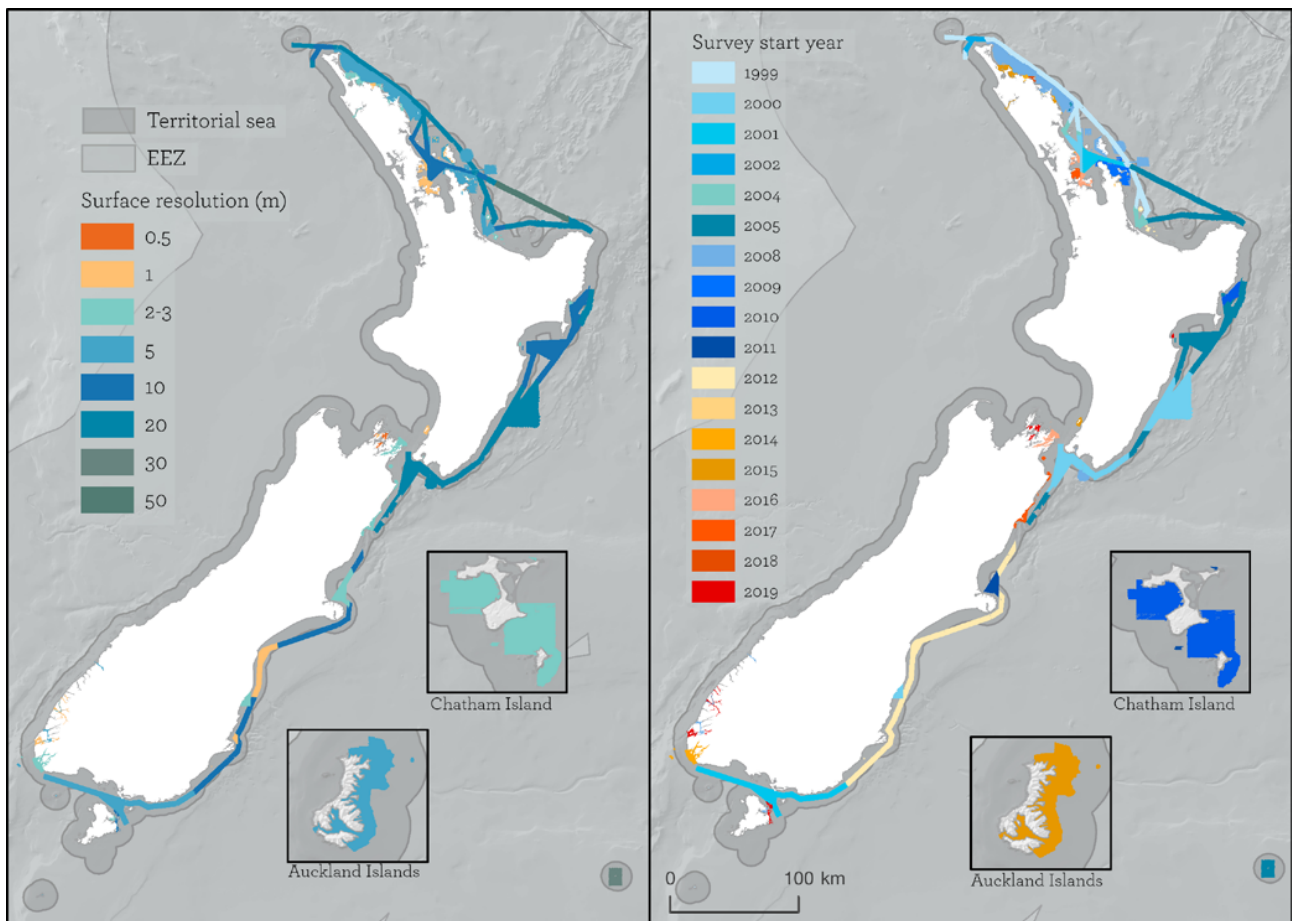


Figure 1. Coverage of the Toitū Te Whenua Land Information New Zealand (LINZ) marine survey data disaggregated by data resolution (left) and year of collection (right).

2.1 The Benthic Terrain Modeler (BTM)

We undertook data analyses using the geomorphometry analysis tools in the Benthic Terrain Modeler (BTM) v3.0 toolbox for ArcGIS Pro v2.7.0 (Walbridge et al. 2018). The exception was Hillshade, which we created using the Hillshade properties raster function in ArcGIS Pro v2.7.0.

We used the BTM toolbox to produce a series of derivative output layers, summarised in Table 1 and detailed below, to create a portfolio of benthic terrain maps that can be used to compare seafloor topography across sites.

Table 1. Outputs derived in this study using the Benthic Terrain Model (BTM) toolset (Walbridge et al. 2018) and raster functions.

TOOLSET	SCRIPT/OUTPUT	DESCRIPTION ¹
BTM – Bathymetric Position Index (BPI)	Broad-scale BPI Fine-scale BPI	Bathymetric Position Index (BPI) is a measure of where a referenced location is relative to the locations surrounding it. Fine-scale BPI allows you to identify smaller features within the benthic landscape, while broad-scale BPI allows the depiction of larger regions within the benthic landscape.
BTM – surface derivative	Slope	The maximum change in elevation between each cell and cells in its analysis neighbourhood, in degrees from horizontal.
BTM – rugosity	Terrain ruggedness (Vector Ruggedness Measure, VRM)	A measure of the variation in the three-dimensional orientation of grid cells within a neighbourhood. Ruggedness values in the output raster can range from 0 (no terrain variation) to 1 (complete terrain variation).
BTM – depth statistics	Mean Variance Standard deviation	A set of useful depth summary statistics. These metrics can be helpful predictors in understanding benthic zones, particularly when used for habitat classification.
BTM – terrain classification	Classify benthic terrain	This tool can classify the benthic terrain. However, this requires the input of an author-defined site-specific classification dictionary and requires that the user understand their input data. This dictionary is then converted into a conditional statement that is evaluated to create the terrain classification dataset.
Raster functions – Hillshade	Hillshade properties	A 3D representation of the seafloor surface, with the sun’s relative position considered for shading the image.
Raster functions – Aspect	Aspect properties	Shows which direction a pixel is facing, where 0 is due north and angles increase clockwise to 360.

¹ Adapted from tool descriptions defined in ArcGIS Pro.

2.1.1 Bathymetric Position Index (BPI)

Seafloor terrain relief can affect the distribution and diversity of marine organisms in all seascapes. Bathymetric Position Index (BPI) is a measure of seafloor terrain relief; it is the marine version of Weiss’s (2001) topographic position index (TPI). The concept of bathymetric position is central to the benthic terrain classification process utilised by the BTM. The BPI quantifies where a location on a bathymetric surface is relative to the overall seascape (Lundblad et al. 2006). Negative BPI values correspond to cells that are lower than their neighbouring cells (representing basins or valleys) whereas positive BPI values correspond to cells that are higher than their neighbouring cells (representing ridges or crests) (Figure 2). A larger number represents benthic features that are very different from surrounding areas (e.g., sharp peaks, pits, or valleys). Flat areas or those with a constant slope generate near-zero values. The BTM tool classifies landscape structure based on the change in slope position over two scales (Walbridge et al. 2018), at ‘broad’ and ‘fine’ scales.

BPI analysis requires a user defined annulus as input to obtain the BPI scale factor that is used to define the spatial scope from a focal point. The annulus, having an outer radius of 4 cells and an inner radius of 2 cells is used to analyse spatially each grid cells in comparison to its neighbouring cells that fall within the annulus (Lundblad et al. 2006). A trial-and-error approach is recommended to determine an optimal classification result (Subarno et al. 2016).

We prioritised consistency and compatibility of the results among the surveys analysed with previous Aotearoa New Zealand projects (e.g., MBES surveys at Hikurangi Channel, Queen Charlotte Sound/Tōtaranui, Pelorus Sound/Te Hoiere and Kaikōura Canyon by NIWA). To achieve this, we created a generic dataset (using a standard classification dictionary) focused on being broadly representative across all surveyed areas. This has resulted in the creation of a classification dataset which may not be optimised for individual survey areas, but provides a valuable terrain classification that is broadly representative across all surveyed areas.

We examined several combinations of scale factor in BPI scaling against those used in previous Aotearoa New Zealand projects (e.g., MBES surveys at Hikurangi Channel, Queen Charlotte Sound/Tōtaranui, Pelorus Sound/Te Hoiere and Kaikōura Canyon by NIWA). The results confirmed a consistent approach based on these studies was suitable given the large and varied study areas and generic requirements for this dataset. We selected an inner radius of 25 and outer of 125 for broad-scale BPI and an inner radius of 5 and an outer of 25 cell area for the fine-scale BPI. To avoid the influence of spatial autocorrelation in the broad- and fine-scale BPIs, we standardised the BPIs to one standard deviation as proposed by Weiss (2001). The BTM tool uses the ArcGIS raster calculator to apply an algorithm to create a BPI grid using bathymetry and user-defined radii (see Lundblad et al. 2006 for more detail).

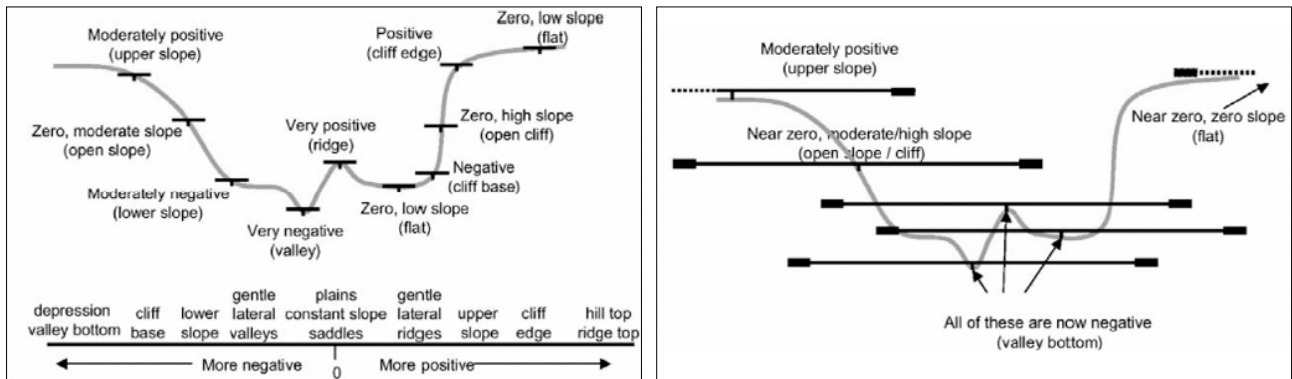


Figure 2. BPI from bathymetric data. Top describes fine-scale BPI values. Bottom describes broad-scale BPI values (from Weiss 2001, in Lundblad et al. 2006).

2.1.2 Slope

The slope of the seafloor is a key variable in a wide selection of seafloor analyses. It affects the speed of currents and consequent erosion, slumping potential, and distribution of benthic fauna (Kostylev et al. 2003). We used the BTM toolbox to calculate slope (gradient, or rate of maximum change in z-value) from each cell of a surface raster in degree units. The tool assumes that the depth or elevation units of the surface raster are the same as the x and y units (Walbridge et al. 2018).

2.1.3 Terrain ruggedness (Vector Ruggedness Measure – VRM)

Rugosity is a measure of terrain complexity or the “bumpiness” of the terrain. In the benthic environment, high rugosity often corresponds with harder substrata and high biodiversity. We measured terrain ruggedness within the BTM toolset using the Vector Ruggedness Measure (VRM) tool, which measures terrain ruggedness as the variation in the three-dimensional orientation of grid cells within a neighbourhood (Figure 3) (Wright et al. 2005). The VRM method effectively captures variability in slope and aspect (the orientation of the seafloor) into a single measure. Ruggedness values in the output raster can range from 0 (no terrain variation) to 1 (complete terrain variation). Typical values for natural terrains range between 0 and about 0.4.

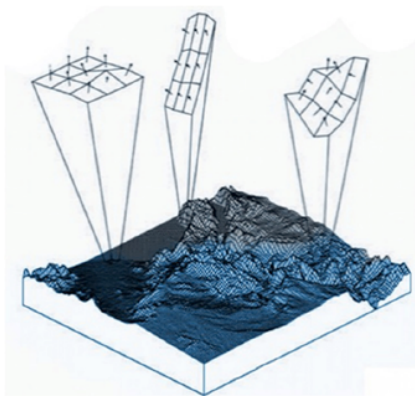


Figure 3. Vector Ruggedness Measure (VRM), image from BTM model metadata, (adapted from Sappington et al. 2007).

2.1.4 Depth statistics

The BTM toolset can also be used to generate a set of useful depth summary statistics, including mean depth, variance, standard deviation, interquartile range, and kurtosis. These metrics can be helpful predictors in understanding benthic zones, particularly when used for habitat classification. We used the BTM toolset to generate mean depth, depth variance, and standard deviation datasets to assist users in interpreting benthic zones. Depth is one of the most discriminatory factors in species distributions, with light penetration, pressure, and temperature all proportional to the depth. The photic zone is generally limited to the first 200 m depth, within which photosynthetic species occur. Nearly all marine species limit their distribution to a specific depth range.

2.1.5 Benthic terrain classification

An input required in the BTM to define the benthic terrain classification is a classification dictionary. This is user-defined based on BPIs, slope, standard deviation breaks, and depth. While there is no universally applicable approach to creating a classification dictionary for use in benthic terrain classifications, it is recommended that a unique classification dictionary is carefully built for each study area, taking into consideration the context of the input data and the goals of the analysis (Walbridge et al. 2018). The outputs of the benthic terrain classification are a series of zones that describe seafloor environments. Here, we wanted a standard classification dictionary for all analyses to ensure consistency, so we opted for a set of classification zones developed by NIWA (Neil et al. 2015) that are largely generic and suitable for all marine habitats of Aotearoa New Zealand. Using this classification dictionary means the outputs of this project are somewhat comparable with previous BTMs. The benthic classes in resulting output layers are described in Table 2.

Table 2. Descriptions of the Benthic Terrain Classifications used in this study.

	CLASSIFICATION ZONES	DESCRIPTION
1	Flat plains	Variable BPI, but slopes no steeper than 5°.
2	Broad slopes	Like 1., but with higher slope values between 5° and 20°.
3	Steep slopes	Like 2., but even higher slopes than 1., between 20° and 35°.
4	Broad depression	Broad-scale BPI is low, so wider neighbourhood is shallower.
5	Lateral mid-slope depression	The wider neighbourhood can be deeper and shallow, but the closer neighbourhood is preferentially deeper. A slight slope is present.
6	Scarp, cliff	Very high slope values dominate this class (>35°).
7	Depressions	The wider and closer neighbourhood (broad-scale and fine-scale BPI) are shallower.
8	CreVICES	The wider neighbourhood (broad-scale BPI) is deeper, but the closer neighbourhood (fine-scale BPI) is shallower.
9	Flat ridge tops	High positive broad-scale BPI indicates that a wider area is deeper.
10	Rock outcrop highs, narrow ridges	Broad-scale and fine-scale BPI high positive, indicating wider and closer neighbourhoods are deeper.
11	Local ridges, boulders, pinnacles in depressions	Broad-scale BPI high negative (wider neighbourhood) is shallower, fine-scale BPI (closer neighbourhood) high negatives values (small local highs as in boulders).
12	Local ridges, boulders, pinnacles on broad flats	Negative to positive broad-scale BPI with small (up to 5°) slope describing a wider/ broad slope (similar to class 1. and 2.), but with high positive fine-scale BPI describing local ridges, boulders, and pinnacles.
13	Local ridges, boulders, pinnacles on slopes	Like class 12., but with higher slope values.
14	Local depressions, current scours	Similar to class 12., but the local/closer neighbourhood values are deeper (fine scour marks, dredge marks).

2.2 Automation procedure using FME®

We used the data integration platform Feature Manipulation Engine (FME®) to automate the grouping and then processing of the large number of bathymetry TIFF files. FME® is a spatial extract, transform and load (ETL) tool that can be used for the automated processing of geospatial data. We used one FME® workbench to create a workspace to resample all MBES survey sets from their original resolutions of between 0.5 m and 50 m grid size to a grid size of 10 m and 20 m resolutions using FME® transformer RasterResampler, then reprojected them to WGS84 Web Mercator using FME® transformer ESRIresampler, and finally grouped individual datasets by survey group code using a PythonCaller transformer. The Python transformer calls the ArcGIS Pro Python ArcPy library to create the datasets needed for use with the ArcGIS platform in order to create a digital surface model (DSM) in equivalent grid sizes and projections for each survey area across the whole of Aotearoa New Zealand. We used a second workspace to run each survey raster through the BTM tools to create the set of derived outputs (Table 1).

Finally, we used a third workspace to create a mosaic dataset (a data model within the geodatabase used to manage a collection of raster datasets stored as a ArcCatalog and viewed as a mosaicked image) covering all datasets (extents shown in Figure 1) for each output type (Table 1). This provided a single image covering all surveyed areas for each derived output type.

3. Results

The analysis and BTM classification produced 10 outputs (Figure 4) between 3 m above MSL to 2083 m below MSL, that cover 23.1% of the Aotearoa New Zealand territorial sea and 0.3% of the exclusive economic zone (Figure 1).

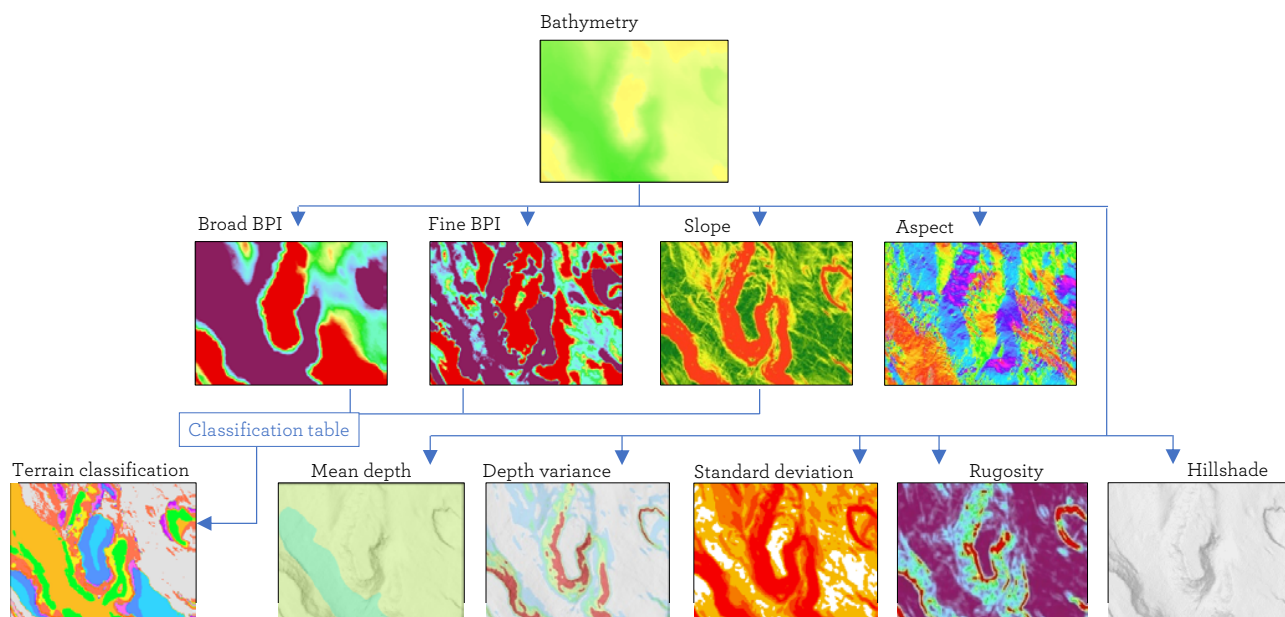


Figure 4. Flowchart of geomorphological classification of seafloor utilising BTM and raster functions and examples of the resulting 10 outputs.

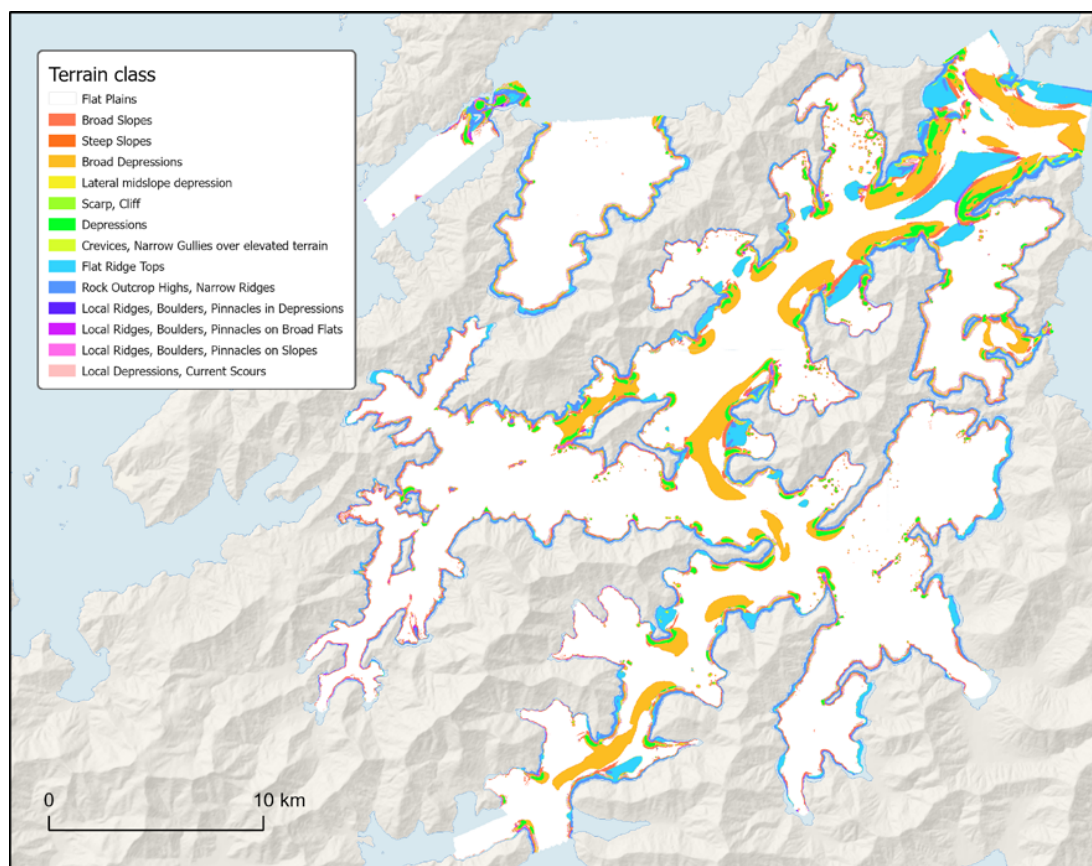


Figure 5. Typical 10 m resolution terrain classification output from the analysis for western Marlborough Sounds area from the multibeam survey series HS66 that was undertaken in 2019/20 at 0.5–2 m resolution (see Appendix 2 for the other nine outputs).

Some obvious processing artefacts were present in the project outputs, including edge effects in output pixels along the edge of a raster or beside pixels without a value, resulting from a reduction in the data available in surrounding pixels. For example, because of the mosaicking procedure we used, the edge of one survey sets only utilised input data from pixels within that survey set, and adjacent survey sets only used their own input pixels, creating an edge effect on both survey edges as illustrated in Figure 5. Striations or ‘railroad tracks’ caused by artefacts in the input data from the survey process were also evident in some areas (for an example see Figure 6). Interpretation of the outputs will be context specific and related to their intended use; however, generally outputs will be more accurate in areas that have the least edge effects and highest quality of the soundings on the seafloor (i.e., limited null data and survey artefacts).

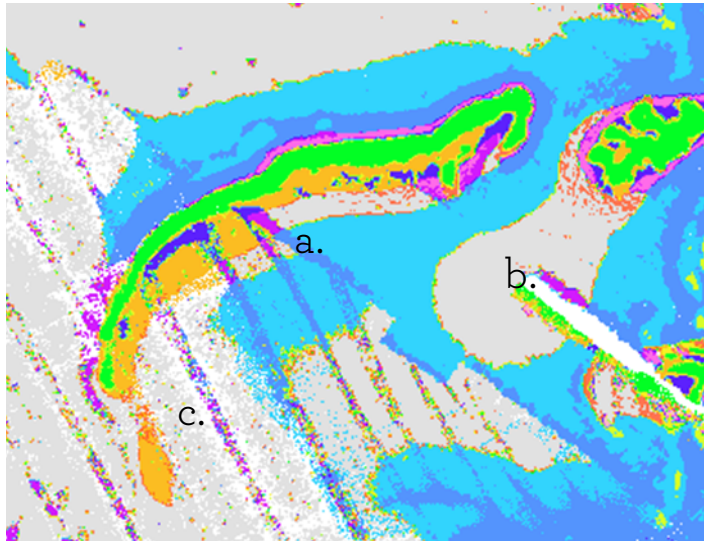


Figure 6. Terrain classification image showing examples of:
a. edge effect along the boundary between two adjacent surveys,
b. edge effect beside pixels with no value,
c. typical ‘railroad tracks’ artefact.

4. Discussion

This is the first time in Aotearoa New Zealand that multibeam surveys have been analysed consistently at a national scale. The development of this set of BTM outputs, including a benthic terrain classification for much of Aotearoa New Zealand's coastal marine environment, provides valuable information to support management, research, and monitoring activities. All 10 outputs can be freely downloaded from the DOC Marine Data Portal: <https://doc-marine-data-deptconservation.hub.arcgis.com/>. The combination of these outputs provides the best information for further developing a marine benthic habitat classification.

We plan to update these outputs as new survey datasets become available.

While all MBES surveys included in our analysis conformed to hydrographic standards, they included data with differing resolution and quality of the soundings on the seafloor. This is partly because the MBES data spanned two decades, so technological advances in MBES systems, broadscale temporal changes in oceanographic conditions, and variable weather conditions, all introduced variability in data quality between individual surveys. As a result, this introduced artefacts and small mismatches across and between surveys. For example, a typical artefact is a 'railroad track'; small ridge-like structures parallel to the survey lines. The cause of these tracks are variations in the speed of sound through the water column causing a 'bending' of the seafloor, forming what are known as 'smiles' and 'frowns' (bending up or down on the outer swath of the MBES data). While these differences in depth are a small to very small proportion of water depth, they create depth differences between overlapping lines, resulting in small ridges in the processed bathymetry grid data. While these kinds of artefacts are within acceptable limits of a hydrographic standard, they propagate throughout subsequent bathymetry derivatives (see Figure 5 for example).

This study aimed to develop a single seamless terrain classification for Aotearoa New Zealand (where bathymetry data is available); however, due to the difficulties of working with such large datasets it was necessary to process bathymetry data in blocks that led to some discrepancies between processed datasets, particularly on block edges. Therefore, we chose to process bathymetry by survey set, which, while allowing for the easy addition of new bathymetric datasets to the analysis, resulted in edge effect issues on the boundaries of each survey set.

We considered several approaches to solve the edge effect (detailed in Appendix 1). First, we considered combining all bathymetry datasets before processing; however, we did not have the computing power to run such a large, combined dataset. Second, we evaluated the use of a buffered fishnet to split the datasets before processing each block then clipping the buffered area out and mosaicking together. While this approach reduced the edge effect to some extent, it did not remove the discrepancies between separately processed datasets (see Appendix 1 for further detail). An alternative approach to resolving some of the processing artefacts, that we haven't explored yet, would be to subset the data according to survey resolution, combining all bathymetry datasets with a similar resolution before processing, and running them as a single analysis. For the high-resolution datasets (see Figure 1 for their spatial distribution) this may help resolve some of the processing artefacts seen in the broader dataset.

We have not yet added the biological information associated with each of these classes in different locations to the analysis. We are therefore unable to establish a habitat description based on the classes identified in the BTM. Consequently, the interpretation of the classification is limited to a geomorphological description of the seafloor at a national scale.

We illustrated a standard approach to developing a benthic terrain classification that can be applied across Aotearoa New Zealand and enable between-site comparisons. While we have processed all survey data in a consistent manner, the input/survey data has been gathered inconsistently resulting in outputs that are only loosely comparable. Even so, these datasets

provide a rich source of information that can be used to inform management, research, and monitoring, and can be regularly updated as new data becomes available. While not perfect, and requiring iterative improvement in data collection and computing capability to avoid artefacts introduced by batch-processing large bathymetric datasets, it does provide a significant increase in the availability of seafloor terrain data in areas that have not previously been mapped.

4.1 Recommendations

- a) Explore sub-setting the dataset used here to develop a unified benthic terrain classification across comparable high-resolution bathymetric datasets.
- b) To help address inconsistencies introduced by conducting the bathymetric analysis in blocks, using greater computational power to run future analyses on a single raster layer, potentially sub-setting the dataset and developing BTMs across comparable high-resolution bathymetric surveys.
- c) Work directly with the BTM developers to better understand the algorithms underlying BTM classifications so that future classifications can be parameterised to be more comparable across sites or surveys.
- d) Develop a standalone benthic terrain classification dictionary that can be shared with other researchers wishing to develop classifications comparable to those developed by DOC.

5. Acknowledgements

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Appendix 1

Addressing processing issues

The BTM tool is generally used on individual datasets on a localised scale. Here, the aim was to create one generic terrain classification covering all areas where we held MBES data. Initially, we projected and resampled each dataset for consistency, then applied the *run all steps* BTM tool before mosaicking the individual output layers together to create a single output layer. The BTM works by utilising the information from adjacent pixels to determine the classification of the pixel, each individually processed dataset may therefore produce different classifications along its edge to an adjacent dataset (i.e., an edge effect). When stitched together, therefore, discrepancies in the classifications between datasets result along dataset edges as shown in Figure 6.

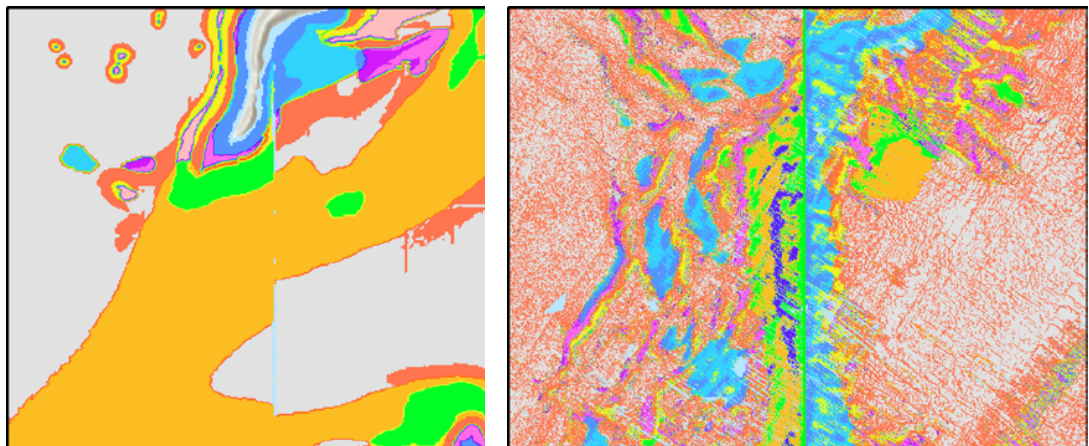


Figure A1.1 Examples of edges effect after running the BTM analysis in different surveys from adjacent locations.

With further examination between datasets, we found that in addition to an edge effect, a general variation in input was observed between a BTM run on a single dataset versus a BTM run on a mosaic of multiple datasets (Figure 7). This may indicate that the model operates by utilising information from across the entire dataset, not just the adjacent pixels to determine a pixel's class.

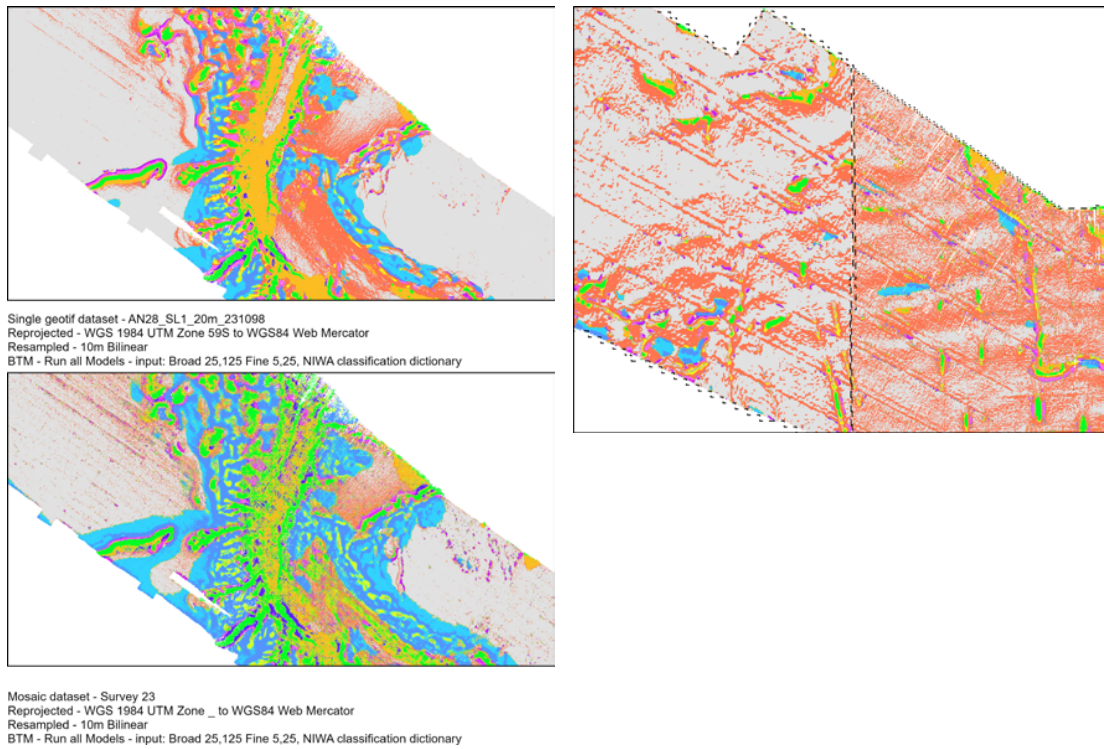


Figure A1.2 Example of discrepancies in the BTM outcomes when combining different surveys to mitigate the edges effect.

As the combined file size (34.6GB) was too large to run as a single mosaic, splitting the processing into batches was necessary. We explored the options of clipping a mosaic dataset of all MBES datasets into fishnet ‘blocks’ (Figure 8) with 15 km overlap, before running BTM ‘run all steps’ on each, then clipping off the overlap and adding the results into a mosaic dataset. The results using this approach show fewer obvious discrepancies (as shown in Figure 9), but still more than expected.

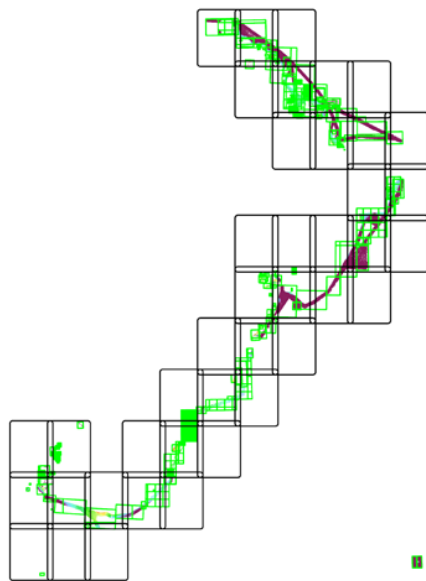


Figure A1.3 Mosaic designed on MBES surveys to attempt to mitigate the edges effect.

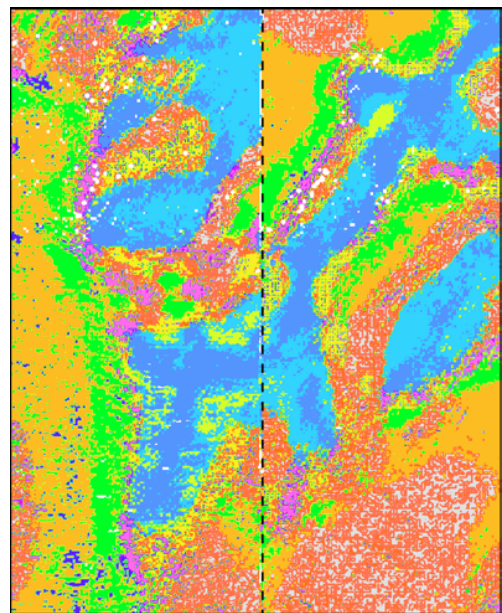


Figure A1.4 Example of edges effect result after applying the analysis with the mosaic.

Appendix 2

LINZ Survey HS66 Western Marlborough Sounds analysis

Table 3. Survey attribute data

chart_no	6152
serial_no	82
surv_org	LINZ (DML and iXBlue)
category	Public
surv_title	HS66 Western Marlborough Sounds
surv_start	11_2019
surv_end	07_2020
quality	zone of confidence A1
scale	0
surf_res	0.5-2
sound_acc	0.3
line_space	0
vert_datum	
sound_tech	found by multi-beam
sss_tech	
hor_acc	0.5-1
hor_datum	WGS 84
hor_tech	WADGNSS
surf_name	AN34_Pelorus_2m_6152-82, AN34_PelorusSound_50cm_6152-77, AO35_PelorusSound_50cm_6152-77, AN34_AdmiraltyBay_1m_6152-77, AO34_PelorusSound_50cm_6152-77, AO35_Pelorus_2m_6152-82, AN35_Pelorus_2m_6152-82, AN35_PopoureReach_50cm_6152-77, AN34_FrenchPass_50cm_6152-77,
source_ref	NZ,NZ,graph,HITS 6152-77 & 82

Analysis

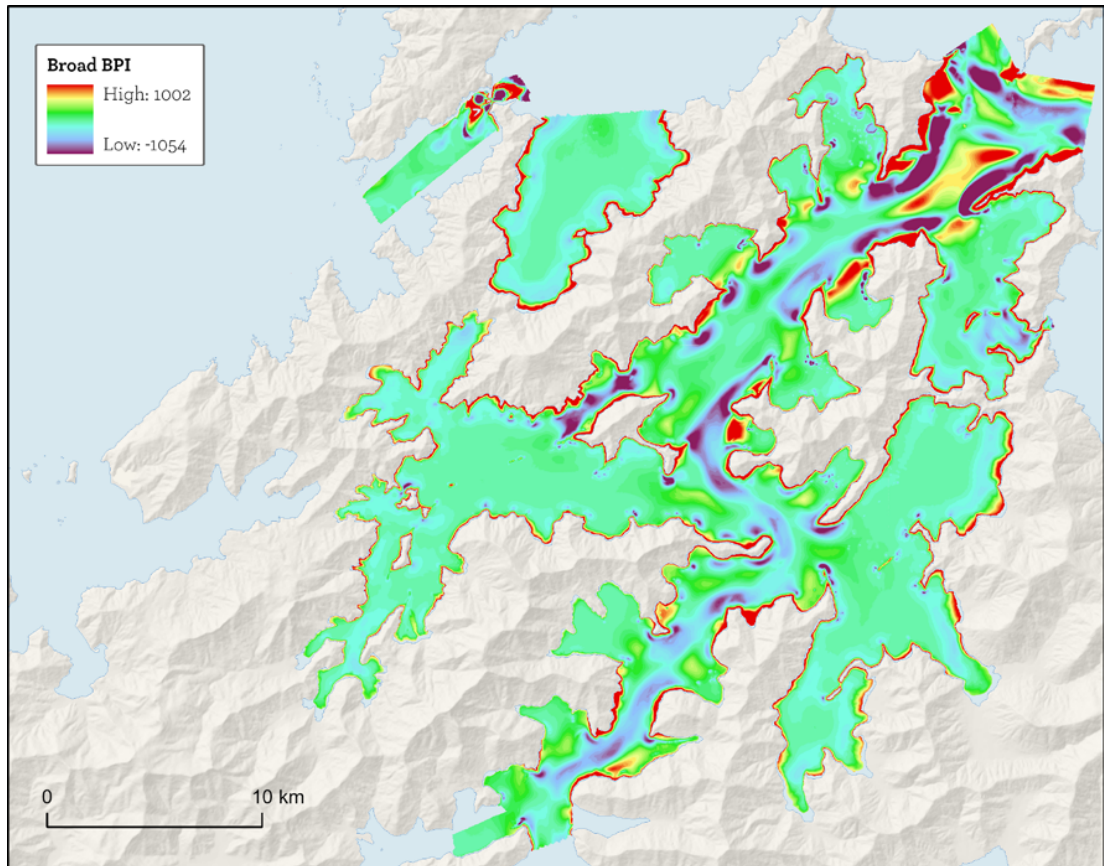


Figure A2.1 Broad BPI output from LINZ survey HS66 at Western Marlborough Sounds.

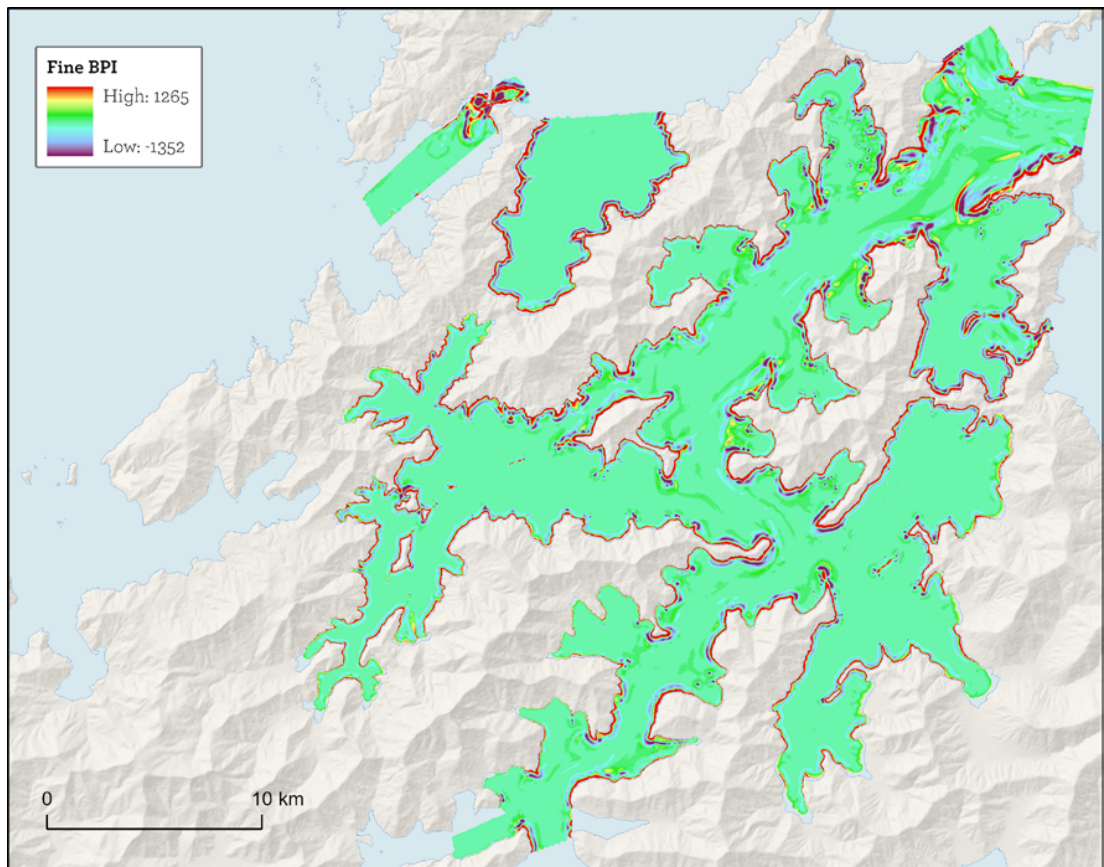


Figure A2.2 Fine BPI output from LINZ survey HS66 at Western Marlborough Sounds.

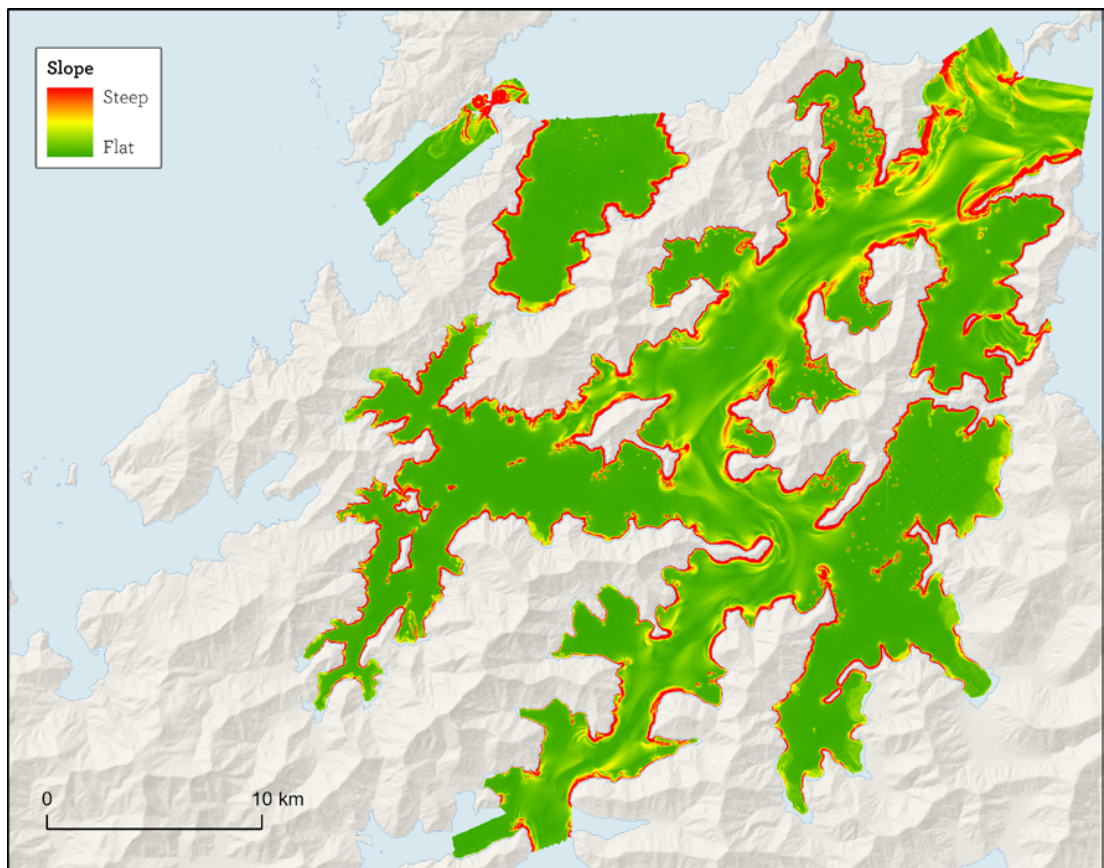


Figure A2.3 Slope output from LINZ survey HS66 at Western Marlborough Sounds.

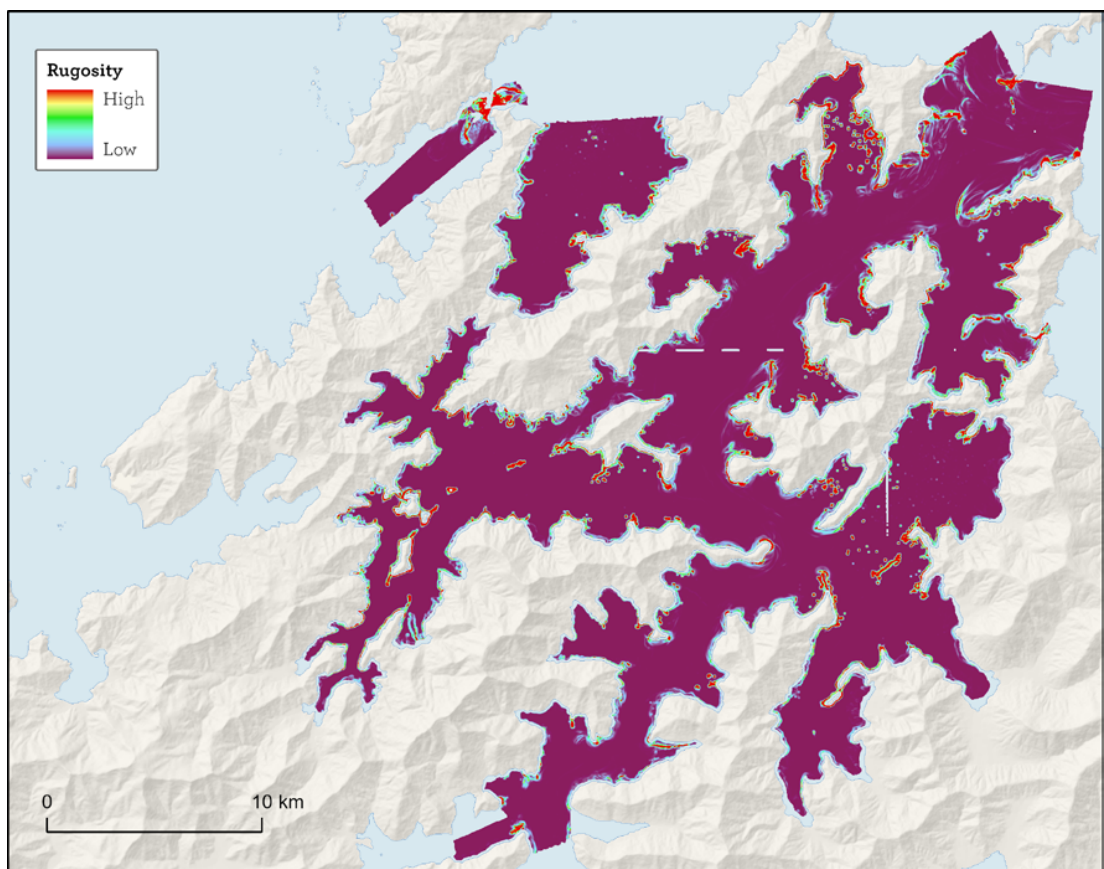


Figure A2.4 Rugosity output from LINZ survey HS66 at Western Marlborough Sounds.

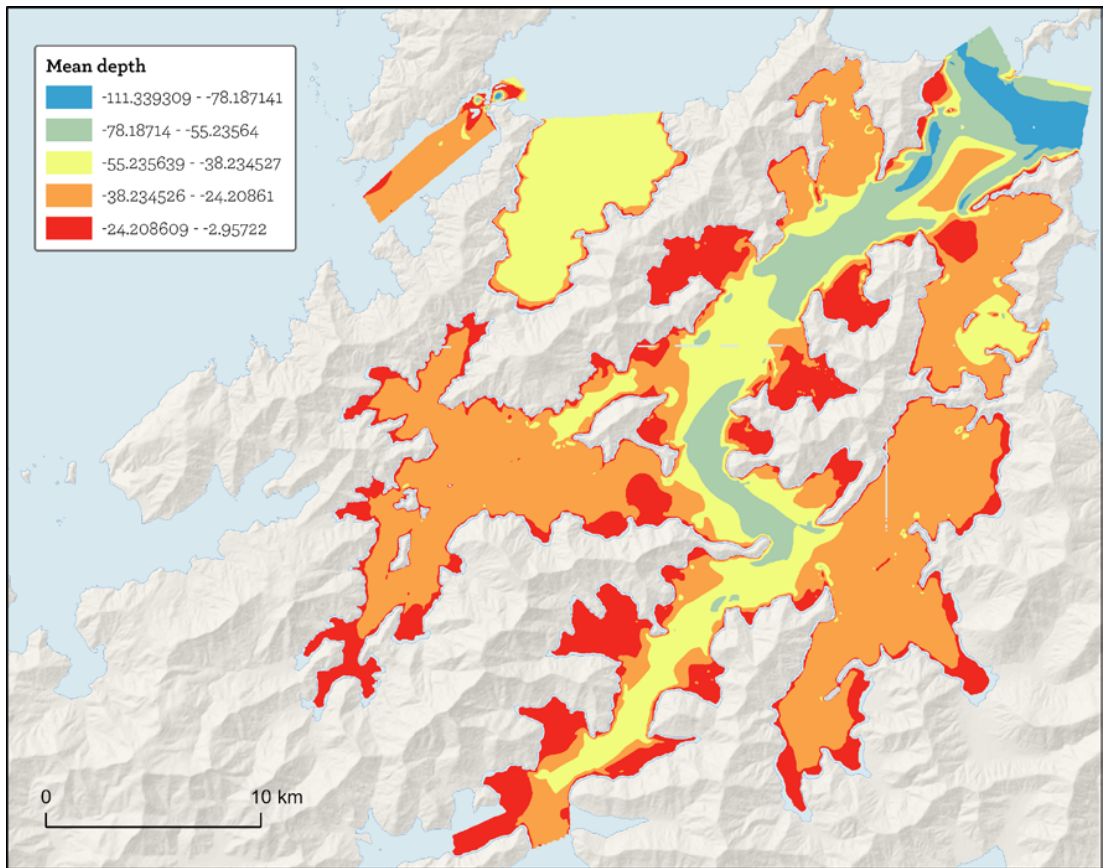


Figure A2.5 Mean Depth output from LINZ survey HS66 at Western Marlborough Sounds.

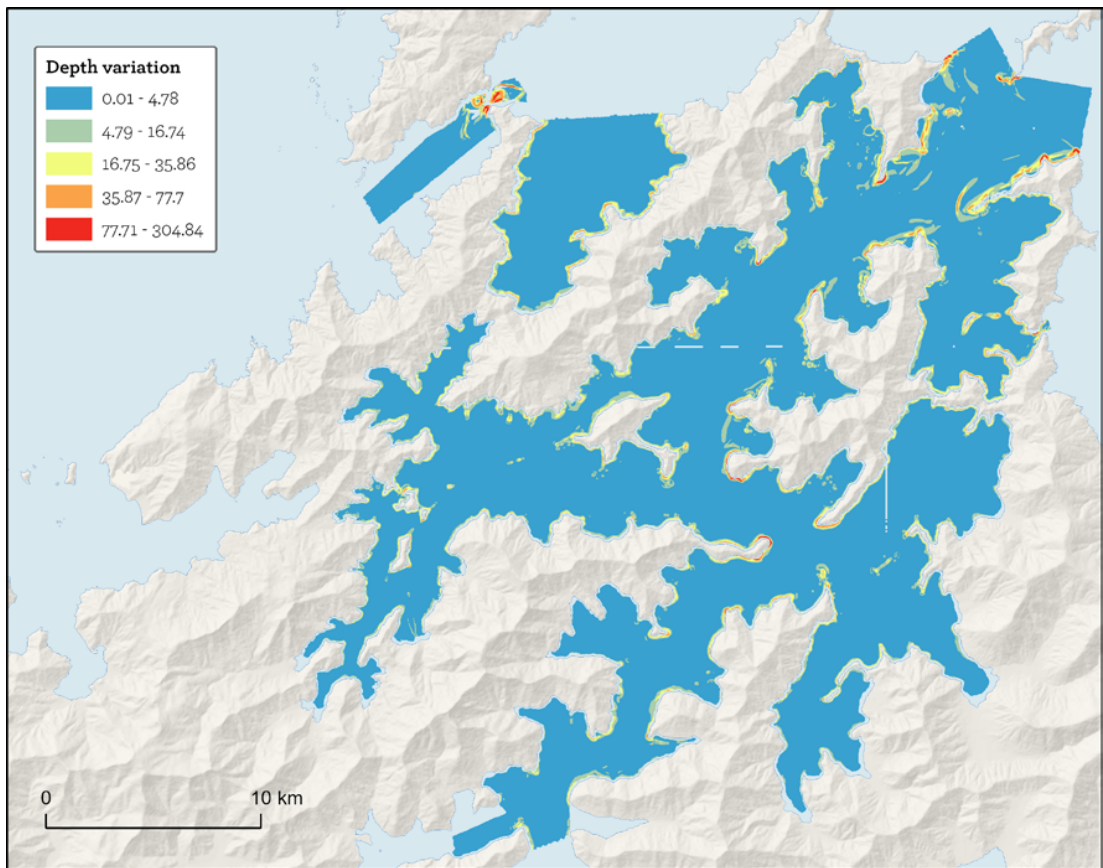


Figure A2.6 Depth variance output from LINZ survey HS66 at Western Marlborough Sounds.

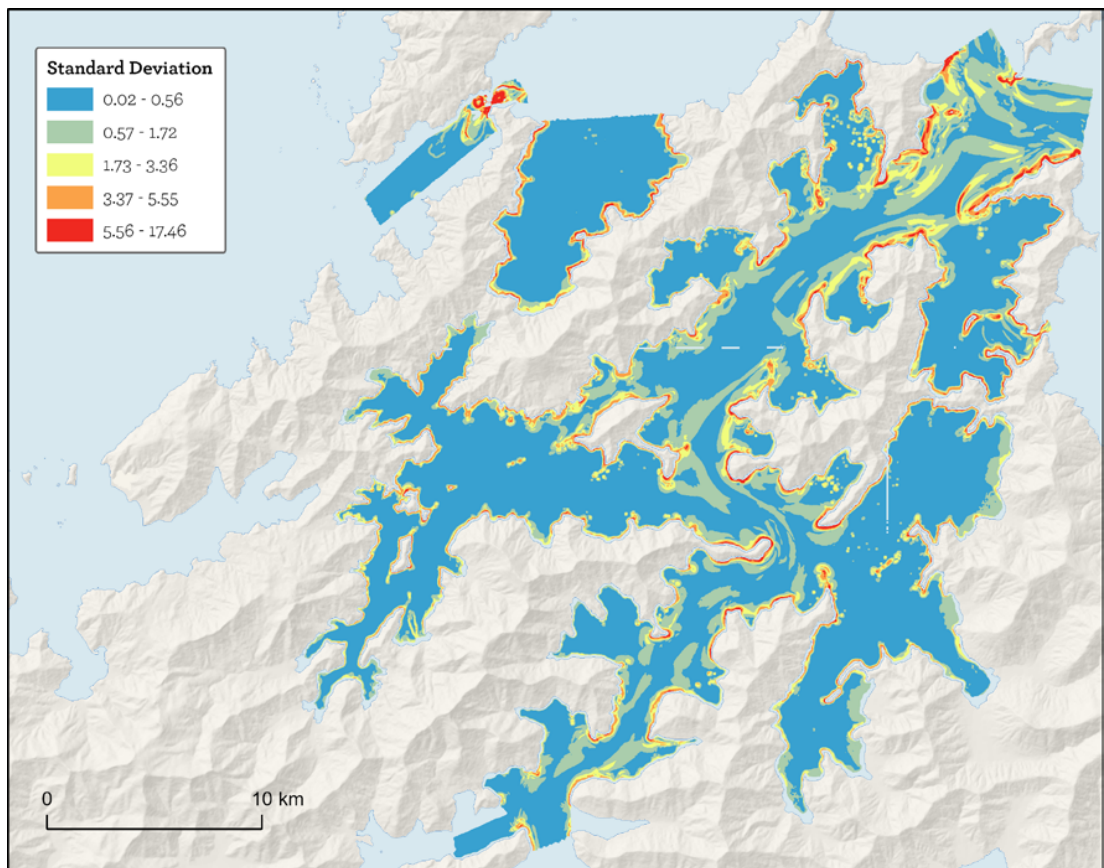


Figure A2.7 Standard deviation output from LINZ survey HS66 at Western Marlborough Sounds.

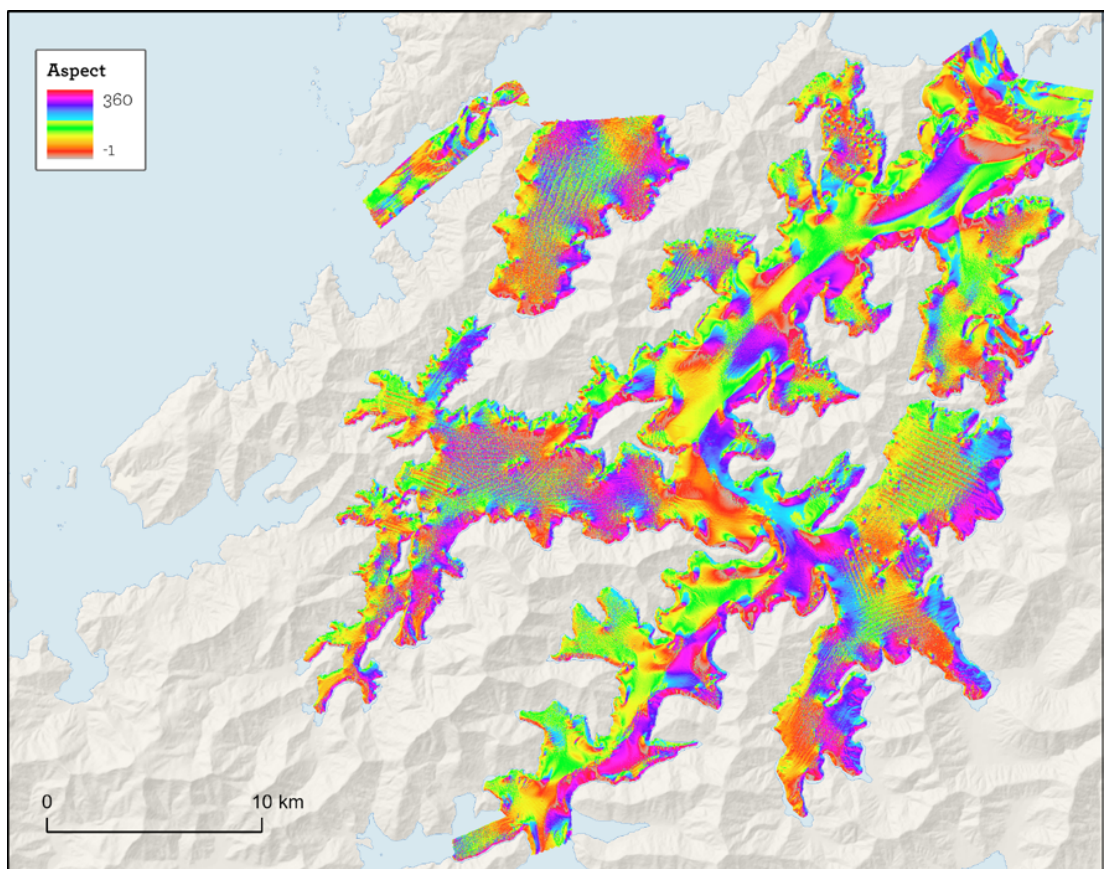


Figure A2.8 Aspect output from LINZ survey HS66 at Western Marlborough Sounds.

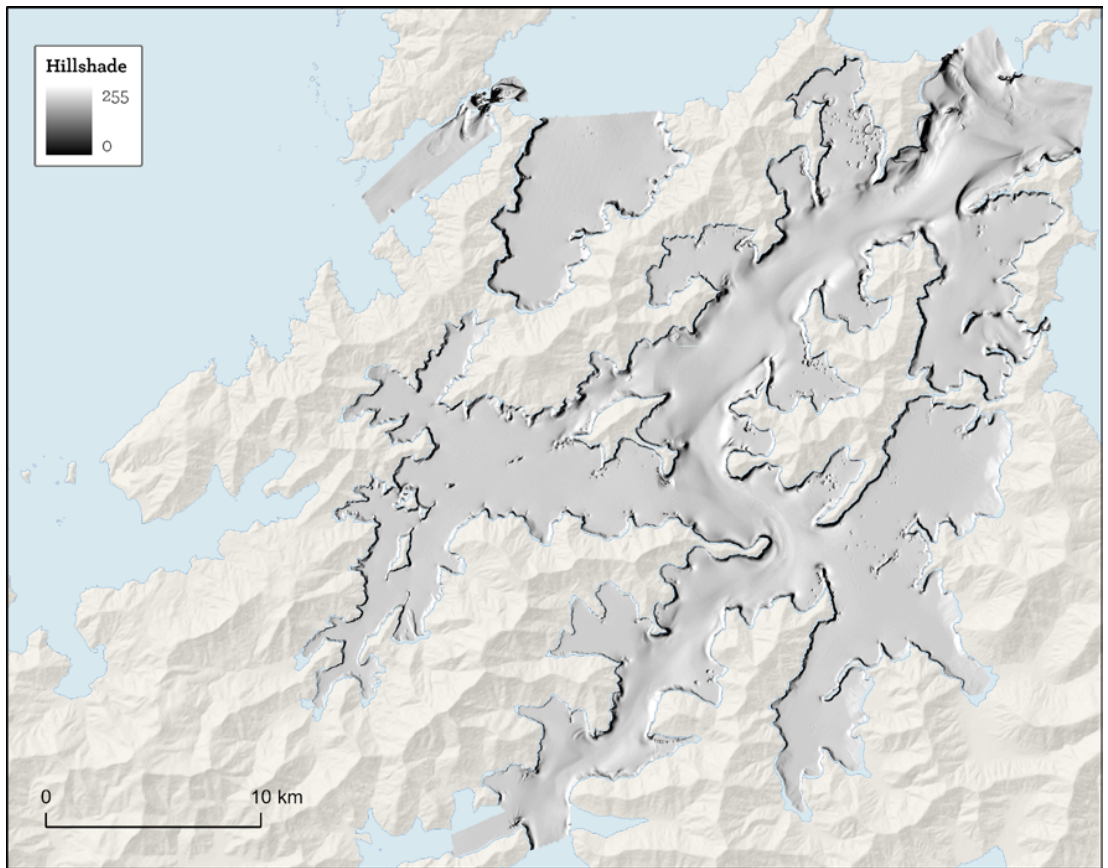


Figure A2.9 Hillshade output from LINZ survey HS66 at Western Marlborough Sounds.