Shetland Islands Dominant Marine Biotope Map (2024 update)

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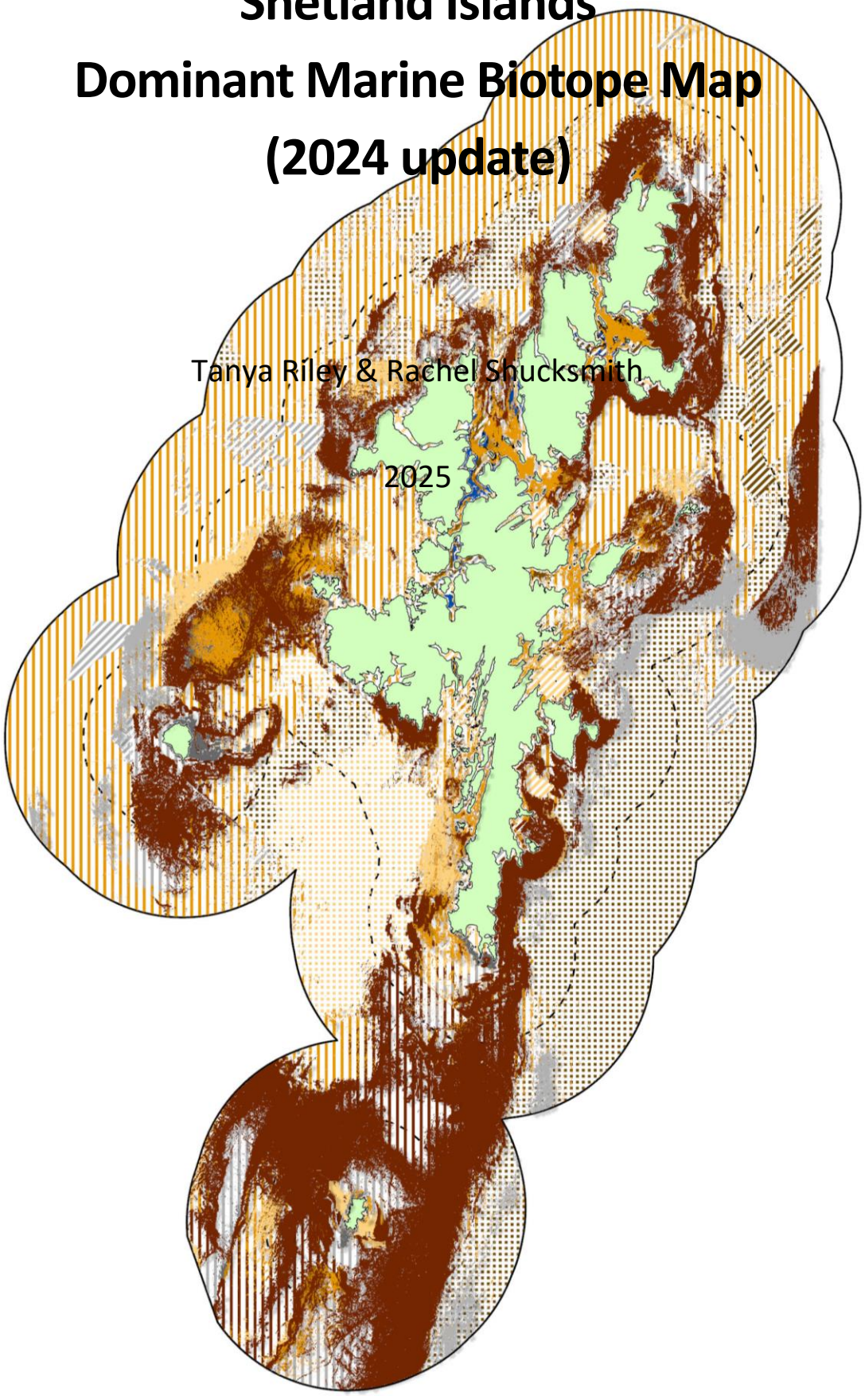

Tanya Riley & Rachel Shucksmith

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1 Summary of Updates

This report provides an update to the Shetland Islands Dominant Marine Biotope Map 2023 (Riley, 2024), incorporating an additional 240 records to now total 2836 records used to generate the model (Figure 1), derived from various sources, including GEMs[1], Fraser *et al.* (2024), Riley and Shucksmith (2025), and UHI unpublished data. Notably, the updated datasets include improved coverage around three island groups, with 126 new records from around Fair Isle (previously five records), and 17 records from around Foula (previously none) and 42 around Papa Stour (previously four).

The methodology remains consistent with Riley, Shucksmith and Mouat (2024) and follows the standard protocol template (supplementary information) for species distribution modelling developed by Zurell *et al.* (2020). A review of validation methodology confirmed that bootstrap validation remains the most suitable approach, given the small sample sizes observed in some biotope categories (Table 1).

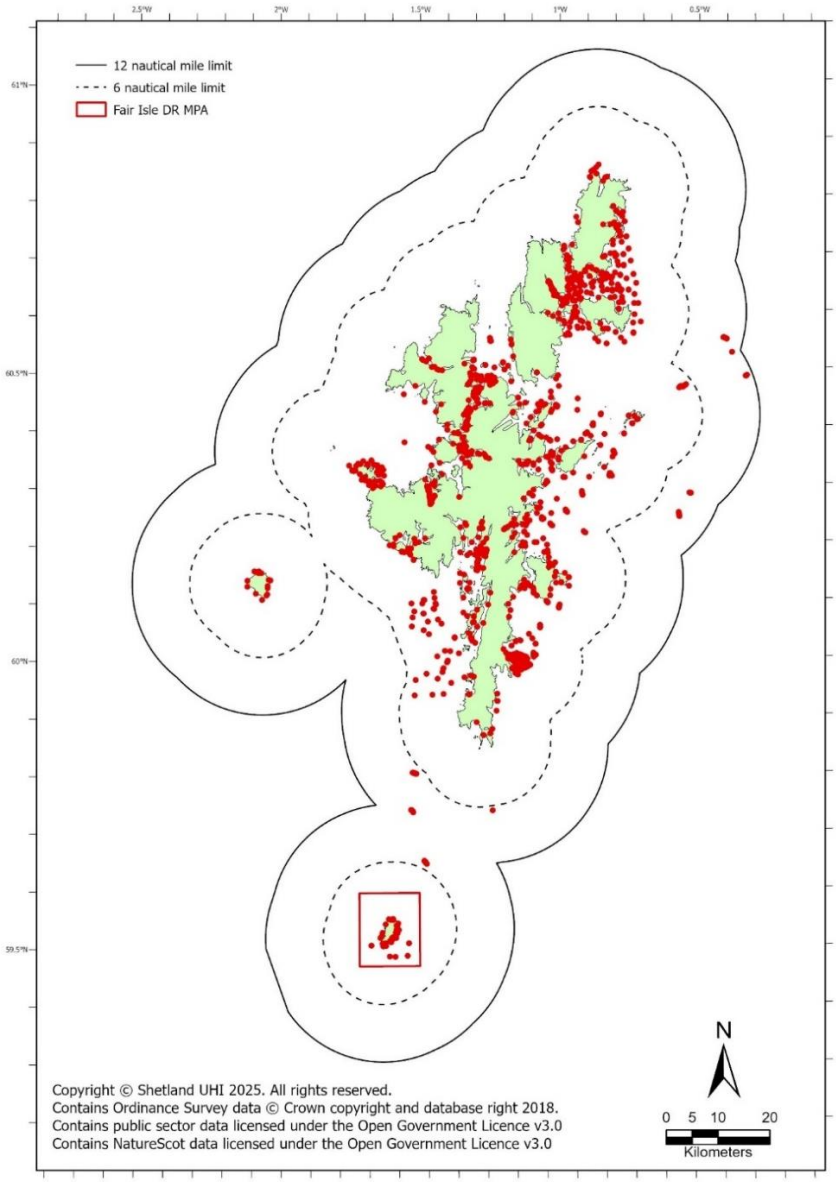

Figure 1. Records of all biotope records used in this study.

[1] Geodatabase of Marine Features in Scotland - GeMS Scottish Priority Marine Features

Table 1 Summary data of biotope groupings and records used in this study. Records coloured red represent wholly PMF biotope groups whilst those coloured purple represent biotopes with PMF subgroups.

Biotope Grouping Code	*Number of Biotopes in Group*	*Records used in SDM*	*Range*	*Historical Records*	*Model AUC*	*Coverage*	*Area km²*
CR_HCR	7	61	1987-2017	1 (2%)	0.9694	3.1%	368.6
CR_LCR	5	15	1986-2019	14 (93%)	0.9575	1.9%	224.6
CR_MCR_EcCr	10	595	1986-2024	114 (19%)	0.9584	4.0%	477.8
IR_HIR_KFar	10	192	1974-2019	119 (62%)	0.9807	0.5%	59.4
IR_HIR_KSed	7	166	1974-2024	63 (38%)	0.9850	0.1%	17.5
IR_LIR_K	11	86	1974-2019	83 (97%)	0.9932	0.1%	12.5
IR_MIR_KR	16	266	1974-2024	156 (59%)	0.9873	0.3%	32.9
IR_MIR_KT	3	19	1986-2019	15 (79%)	0.9543	0.2%	19.5
SS_SBR_SMus	5	78	1974-2019	54 (69%)	0.9899	0.2%	22.5
SS_SCS_CCS	6	393	1962-2024	29 (7%)	0.9430	23.7%	2857.1
SS_SCS_ICS	4	37	1962-2019	22 (59%)	0.9879	0.1%	15.9
SS_SCS_OCS	1	48	2011	0 (0%)	0.9978	2.5%	304.2
SS_Mp_KSwSS	11	188	1974-2019	92 (49%)	0.9911	0.2%	22.7
SS_SMp_Mrl	5	158	1986-2019	9 (6%)	0.9948	0.1%	11.2
SS_Mp_SSgr_Zmar	1	57	1968-2024	41 (72%)	0.9989	0.0%	0
SS_SMu_CFiMu	2	21	1974-2009	1 (5%)	0.9963	0.1%	17.7
SS_SMu_CSaMu	2	77	1986-2019	1 (1%)	0.9859	1.3%	158.5
SS_SMu_IFiMu	2	25	1986-2019	18 (72%)	0.9972	0.1%	7.1
SS_SMu_ISaMu	3	32	1986-2013	29 (91%)	0.9975	0.1%	7.8
SS_SMu_OMu	1	4	2013-2017	0 (0%)	0.9960	15.5%	1865.5
SS_SMx_CMx	7	194	1962-2024	30 (15%)	0.9610	2.9%	352.6
SS_SMx_IMx	2	5	1987-1994	5 (100%)	0.9998	0.1%	8.2
SS_SMx_OMx	2	4	1963-2017	3 (75%)	0.8964	32.8%	3944.9
SS_SSa_CFiSa	1	50	1987-2024	1 (2%)	0.9534	2.0%	245.9
SS_SSa_CMuSa	2	12	1986-2019	2 (17%)	0.9724	0.8%	97.8
SS_SSa_IFiSa	3	21	1986-2019	11 (52%)	0.9891	1.7%	199.1
SS_SSa_IMuSa	4	26	1986-2020	19 (73%)	0.9929	0.3%	41.6
SS_SSa_OSa	1	6	2011-2014	0 (0%)	0.9867	5.4%	650.6

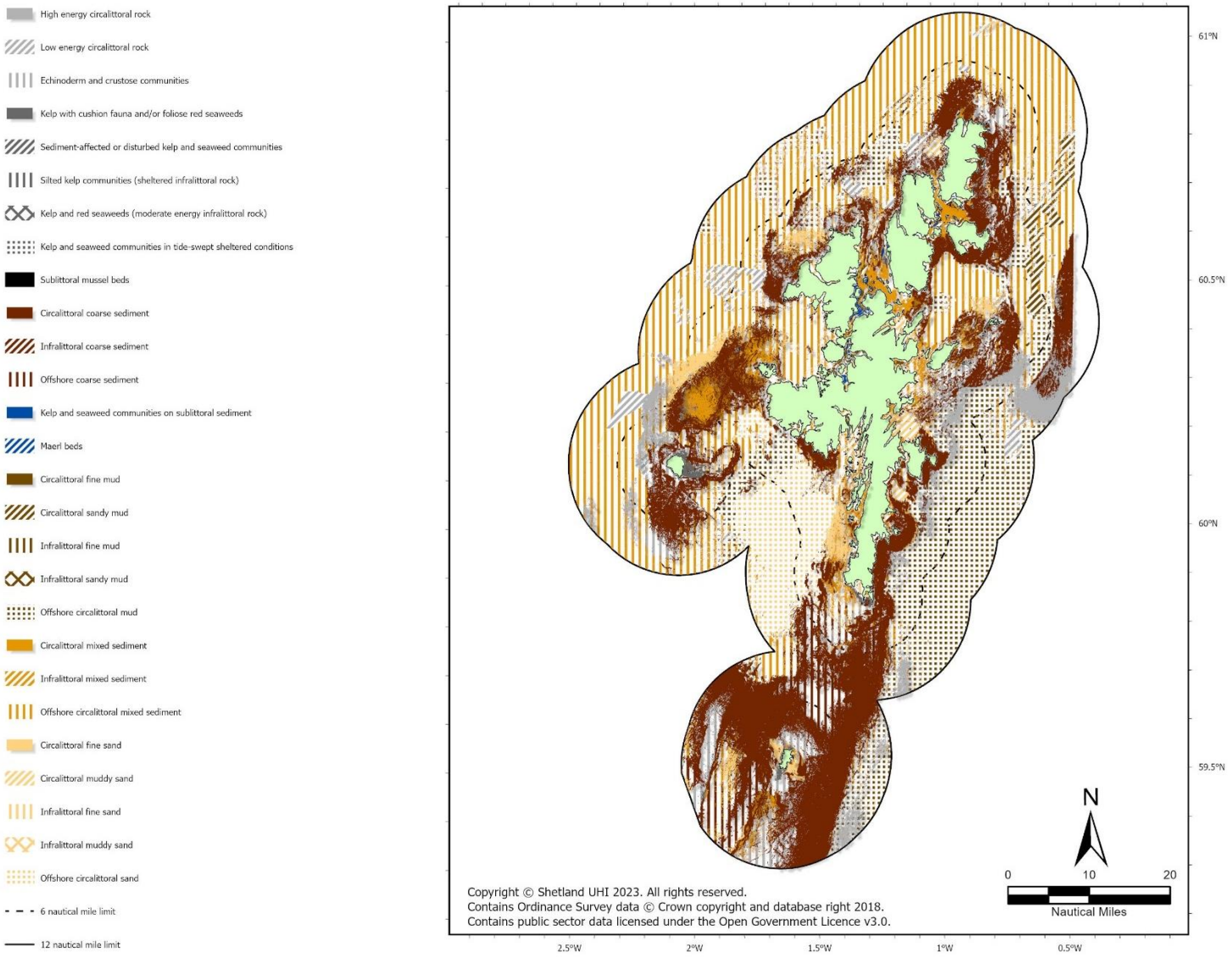

Figure 2 Shetland Islands Dominant Marine Biotope Map (2024 update).

2 Key Findings

The updated model has resulted in changes in the predicted biotope distribution. Across Shetland most adjustments were found to be less than 2.5% coverage except for biotopes listed below and silted Kelp Communities (Sheltered Infralittoral Rock), which was previously unrecorded but now accounts for 0.1% of coverage.

- **Low Energy Circalittoral Rock** has increased from **0.1% to 1.9%**
- **Silted Kelp Communities (Sheltered Infralittoral Rock)**, previously unrecorded, now account for **0.1%** of coverage.
- **Circalittoral Coarse Sediment** has increased from **13.8% to 23.7%**,
- **Offshore Circalittoral Mud** has increased from **7.6% to 15.5%**
- **Offshore Circalittoral Mixed Sediment** has decreased from **44.7% to 32.8%**
- **Circalittoral Fine Sand** has reduced from **8.5% to 2%**.

A key difference between the 2023 model and this 2024 update is a change in the predicted distribution of Circalittoral Coarse Sediment and Offshore Circalittoral Mixed Sediment, influenced by dependence on historical records of which offshore circalittoral mixed sediment relies heavily on (75%), while circalittoral coarse sediment incorporated newly collected 2024 records.

A notable improvement in this model update is the accuracy in identifying maerl beds, which were largely absent from the previous model. Coverage of maerl beds has expanded from 1.2 km² to 11.2 km², now aligning better with known mapped locations. This difference is partially explained by the increased accuracy of the mixed sediment prediction, with the reduced over prediction of this habitat allowing for these more spatially limited habitats to emerge.

Challenges remain predicting the occurrence of seagrass, with records predominantly closer to the shore than this model can predict due to the model resolution. While the accuracy of seagrass records have improved, due to UHI Shetland mapping (Giesler, Allan and Shucksmith, 2025), the biotope remains absent from the final model output of most likely biotope, although it is noted that the model predicts a high probability of occurrence in Whiteness Voe (where seagrass beds are known to occur). This highlights a limitation in the model, likely due to spatial scale and limited data availability.

Historically Dependent, Data Limited and Spatially Bias Biotopes

Certain biotope groups (**Table 2**) have been identified as heavily reliant on historical records, have limited data for robust modelling, and/or are underrepresented in specific geographic areas. Future research should focus on addressing these gaps through dedicated surveys and data collection to enhance the accuracy of the Shetland Islands Dominant Marine Biotope Map.

Overall, this updated model is considered to better reflect known habitat occurrence, with the model benefiting from a greater number of records. It is intended that this model will be updated as additional data emerges.

3 Accessing the Map

Previous, current and future versions of the Shetland Islands Dominant Marine Biotope Map can be found at: https://pure.uhi.ac.uk/en/persons/tanya-riley/datasets/

4 References

Fraser, S., Ayres, S., McAllister, M., Thomason, L., Cubbon, K. and Angus, C. (2024) 'Survey report for the 2023 Fair Isle inshore fish survey'.

Giesler, R. J., Allan K. and Shucksmith, R. J. (2025) Searching for Shetland's lost seagrass: establishing the baseline distribution and abundance of seagrass in the Shetland Islands: Shetland UHI report.

Riley, T. G. (Creator) (18 Apr 2024). Shetland Islands dominant marine biotope map 2023. UHI Research Repository. Shetland_Islands_dominant_marine_biotope_map(.lpkx).

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Zurell, D., Franklin, J., König, C., Bouchet, P. J., Dormann, C. F., Elith, J., Fandos, G., Feng, X., Guillera-Arroita, G. and Guisan, A. (2020) 'A standard protocol for reporting species distribution models', Ecography, 43(9), pp. 1261-1277.

Table 2 Biotope groups with historical dependence, limited available data, and spatial biases for future research prioritisation.

Biotope Grouping Code	*Historically Dependent*	*Data Limited*	*Spatially Bias*
CR_HCR			
CR_LCR	X	X	
CR_MCR_EcCr			
IR_HIR_KFar	X		
IR_HIR_KSed	X		
IR_LIR_K	X		
IR_MIR_KR	X		
IR_MIR_KT	X	X	X
SS_SBR_SMus	X		
SS_SCS_CCS			
SS_SCS_ICS	X	X	
SS_SCS_OCS		X	X
SS_Mp_KSwSS	X		
SS_SMp_Mrl			
SS_Mp_SSgr_Zmar	X		
SS_SMu_CFiMu		X	
SS_SMu_CSaMu			
SS_SMu_IFiMu	X	X	
SS_SMu_ISaMu	X	X	
SS_SMu_OMu		X	X
SS_SMx_CMx			
SS_SMx_IMx	X	X	X
SS_SMx_OMx	X	X	X
SS_SSa_CFiSa			
SS_SSa_CMuSa		X	
SS_SSa_IFiSa	X	X	
SS_SSa_IMuSa	X	X	
SS_SSa_OSa		X	X

Supplementary Information - ODMAP Standard Protocol

ODMAP element	Contents
OVERVIEW	
Authorship	Authors: Tanya G. Riley, Rachel Shucksmith Contact email: tanya.riley@uhi.ac.uk Title: Shetland Islands Dominant Marine Biotope Map Access: https://pure.uhi.ac.uk/en/persons/tanya-riley/datasets/
Model objectives	Objective: Mapping/interpolation. Target outputs: Maps of relative probability of presence
Taxon	• High energy circalittoral rock • Low energy circalittoral rock • Echinoderm and crustose communities • Kelp with cushion fauna and/or foliose red seaweeds • Sediment-affected or disturbed kelp and seaweed communities • Silted kelp communities (sheltered infralittoral rock) • Kelp and red seaweeds (moderate energy infralittoral rock) • Kelp and seaweed communities in tide-swept sheltered conditions • Sublittoral mussel beds • Circalittoral coarse sediment • Infralittoral coarse sediment • Offshore coarse sediment • Kelp and seaweed communities on sublittoral sediment • Maerl beds • Seagrass • Circalittoral fine mud • Circalittoral sandy mud • Infralittoral fine mud • Infralittoral sandy mud • Offshore circalittoral mud • Circalittoral mixed sediment • Infralittoral mixed sediment • Offshore circalittoral mixed sediment • Circalittoral fine sand • Circalittoral muddy sand • Infralittoral fine sand • Infralittoral muddy sand • Offshore circalittoral sand
Location	Shetland Islands to the 12nm extent
Scale of analysis	Spatial extent (Lon/Lat): 61°03 - 59°18' N and 2°31’ - 0°00’ W Spatial resolution: 50m

	Temporal extent/time period: 1962 -2024 Type of extent boundary: 12nm
Biodiversity data overview	Observation type: Boat surveys, diver records Response/Data type: Presence-only
Types of predictors	Bathymetric, benthic oceanographic and sediment
Conceptual model / hypothesis	Create an overview of benthic biotopes through Shetlands waters (12nm).
Assumptions	We assumed that: • Relevant ecological drivers/proxies of habitat distributions are included. • Detectability does not change across transects or habitat gradients. • Habitats are at equilibrium with their environment.
SDM Algorithms	Algorithm: MaxEnt. Chosen due to competitive performance on small sample sizes and presence only data. Model complexity: MaxEnt models were built with linear, quadratic, product and hinge features. Model Averaging: 10 bootstrap replicates. Chosen due to small sample sizes of several biotopes.
Model workflow	Prior to model building, all predictor variables were standardised (as detailed in 'predictor variables') and correlation analysis conducted with variables omitted where a correlation coefficient exceeded 0.7 (Davies & Guinotte, 2011).
Software	Software: Analyses were conducted in ArcGIS Pro v2.3.1 and MaxEnt v3.4.4 (https://biodiversityinformatics.amnh.org/open_source/maxent/). Data availability: Data are available in an open, online, digital repository.
DATA	
Biodiversity data	Ecological level: Biotope Level 4 Data source: Survey data taken from Geodatabase of Marine Features in Scotland (GeMS; accessed January 2025) spanning the years 1962 to 2024, and additional data from Fraser *et al.* (2024), Riley & Shucksmith (2025) and UHI unpublished data. Sampling design: As the data was taken from a collated database this resulted in a range of sampling designs including opportunistic and targeted surveys, and a variety of sampling techniques; Drop-Down Videos, grabs, core samples and dive surveys. Sample size: The data contains 2836 presence points. Regional mask: All data was clipped to the boundary of the study region. Data cleaning/filtering: Occurrences cited as "confirmed" were used. Errors and biases: Error rates deemed low as all records used in the study came from either physical dives or visual records (image and/or sample).

Data partitioning	Data Partitioning: 75% training data and 25% testing data. Model performance: assessed using bootstrap resampling (n=10 replicates).
Predictor variables	• Predictor variables: • Bathymetric: Depth, aspect, curvature, slope, hillshade, rugosity. • Benthic: chlorophyll, dissolved oxygen, iron, light, nitrate, phosphate, phytoplankton, temperature, salinity, silicate, primary production, velocity • Climate: Sea surface temperature (monthly) and tidal velocity. • Data sources: • Bathymetric: Compiled from: UK Hydrographic Office (https://www.admiralty.co.uk/access-data), Marine Scotland (Shetland Bathymetry 2012 | marine.gov.scot), UHI Shetland and EMODnet Digital Bathymetry (DTM 2020) (https://emodnet.ec.europa.eu/en/bathymetry) • Benthic and sea surface temperature: Bio-ORACLE (https://www.bio-oracle.org/) • Tidal velocity: Natural Power • Spatial resolution and extant of raw data • Bathymetric: 2-115 m resolution. • Benthic: 0.05 degrees resolution. • Sediment: 100 m resolution. • Tidal velocity: 10m resolution. • Surface temperature: 1/12th degree resolution. • Geographic projection: WGS 1984 (EPSG:4326) • Temporal resolution of raw data: • Bathymetric: 1816-2020. • Benthic: 2010-2020. • Sediment: 2018. • Tidal velocity: 2001. • Surface temperature: 2010-2020. Data processing: layers are processed to a 50m grid resolution and clipped to the 12nm limit of Shetland for use in the model. After covariation analysis layers were then mean aggregated using the Spatial Analyst tool in ArcGIS Pro to create four different spatial resolution scale .asc files for use in the model (50m).
MODEL	
Variable pre-selection	Using an *a priori* approach based on available variables known or thought to influence benthic biotope distribution, including bathymetric variables (Wilson et al., 2007), alongside sediment and benthic oceanographic variables (Brown et al., 2011).
Multicollinearity	Correlation analysis was conducted, and variables omitted where a correlation coefficient exceeded 0.7 (Davies & Guinotte, 2011).
Model settings	MaxEnt: (If italicised this has been changed from default) Log output, Feature set (Auto features: linear, quadratic, product and hinge features), Random seed (*Yes*), Remove duplicate presence records (Yes),

	Random test percentage (*25*), Regularization multiplier (1), Max number of background points (10000), Replications (*10*), Replicate run type (*Bootstrap*), Maximum iteration (*5000*), Convergence threshold set (0.00001).
Model estimates	Covariate importance calculated with jackknife analyses of the regularised gain with training data, which accounts for dependencies between predictor variables by building two sorts of models: one involving a given predictor by itself, and the other involving all features except for the given predictor.
Threshold selection	To create an overall benthic biotope map within the 12nm limit of Shetland the DM outputs were analysed. To determine the dominant raster values at overlapping locations among multiple models the "Highest Position" function was utilised in ArcGIS Pro. This function assessed multiple raster datasets on a cell-by-cell basis, returning the position of the raster with the highest value for each cell.
ASSESSMENT	
Performance Statistics	The averaged ROC AUC scores were used as model predictive performance on validation data, following a bootstrap-validation procedure with ten replicates.
Plausibility checks	Expert judgement and comparison with known habitat extent.
PREDICTION	
Prediction output	The model output represents the biotope group with the highest predicted habitat suitability value for each cell.