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Riley, Tanya; Shucksmith, Rachel; Mouat, Beth

Publication date:
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Citation for published version (APA):
Riley, T., Shucksmith, R., & Mouat, B. (2024). *Distribution modelling of the benthic habitats within the Fair Isle Demonstration and Research Marine Protected Area*. UHI Shetland.
<https://doi.org/10.13140/RG.2.2.14431.06566>

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Distribution modelling of the benthic habitats within the Fair Isle Demonstration and Research Marine Protected Area

Tanya Riley, Rachel Shucksmith & Beth Mouat

2024



Distribution modelling of the benthic habitats within the Fair Isle Demonstration and Research Marine Protected Area

Authors:

Tanya Riley¹, Rachel Shucksmith¹ & Beth Mouat¹

¹ UHI Shetland – Scalloway Campus, Port Arthur, Scalloway, Shetland, ZE1 0UN

Corresponding author:

Tanya Riley

Post Graduate Marine Scientist

Marine Sciences

UHI Shetland – Scalloway Campus, Port Arthur, Scalloway, Shetland, ZE1 0UN

tanya.riley@uhi.ac.uk

+44 (0)1595 772010

<https://pure.uhi.ac.uk/en/persons/tanya-riley>

Recommended citation:

Riley, T.G., Shucksmith, R., and Mouat, B., 2024. Distribution modelling the benthic habitats within the Fair Isle Demonstration and Research Marine Protected Area. UHI Shetland report. p36.

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Contents

1	Introduction	4
2	Materials and Methods.....	6
2.1	Biological data.....	6
2.2	Environmental data.....	6
2.3	Distribution Models	6
3	Results	8
3.1	Biotope groups.....	8
3.2	PMF-focused biotope groups.....	11
4	Discussion	14
4.1	Significance of Findings	14
4.2	Study Limitations	14
4.3	Recommendations for Future Research Work	14
5	Conclusion.....	15
6	References	16
	Acknowledgements.....	16
	Appendix 1. Biotope Groupings	17
	Appendix 2. PMF-focused Biotope Groupings	25
	Appendix 3. Environmental Layers.....	28

Executive summary

Positioned between the Orkney and Shetland archipelagos in the North Atlantic, the Fair Isle Demonstration and Research Marine Protected Area (DR MPA) plays a crucial role in marine management and conservation efforts. Designated under the Marine (Scotland) Act 2010, it offers a unique opportunity for innovative marine management strategies, focusing on sustainability, conservation, and ecotourism. Limited knowledge exists about the benthic habitats, identified as a research priority in the Fair Isle DR MPA Winter 2020/21 stakeholder consultation. This report focuses on modelling the potential benthic habitat composition within the Fair Isle DR MPA, with an emphasis on Priority Marine Features (PMFs).

Utilising Distribution Models (DMs), this study aims to address this knowledge gap by analysing biotopes with environmental data, providing a baseline for future research, and marine management initiatives. The analysis covers 28 distinct biotope groups, including PMFs, revealing their potential distribution within the Fair Isle DR MPA.

The DMs, employing MaxEnt, demonstrated robust predictive accuracy, as evidenced by high Area Under the Curve (AUC) values during validation. Eleven biotope groups and five PMF-focused subgroups were modelled within the Fair Isle DR MPA, showcasing the efficacy of DMs in delineating potential habitat distributions.

Despite the success of DMs in predicting habitat distributions, the scarcity of biotope records within the designated area underscores the need for expanded data collection efforts within the Fair Isle DR MPA. The report recommends dedicated biotope surveys, long-term monitoring, species-specific studies, and community engagement to enhance our understanding of the marine ecosystem and inform adaptive management strategies.

While the DMs provide a robust starting point, ongoing research efforts are crucial for advancing our understanding of the Fair Isle DR MPA marine environment. This study highlights the importance of localised biotope data for precise mapping and emphasises the need for comprehensive research to foster informed and sustainable marine management practices.

1 Introduction

Positioned between the Orkney and Shetland archipelagos in the North Atlantic, the Fair Isle Demonstration and Research Marine Protected Area (DR MPA) stands as an eminent hub for marine management and conservation efforts. This area hosts an extensive array of marine species, many of which possess significant importance in ecological, conservational, and biogeographical contexts.

On 9th November 2016, under the Marine (Scotland) Act 2010, the Fair Isle DR MPA was officially designated, offering opportunities for the local community to pioneer innovative or enhanced marine management strategies (Fauna and Flora, 2021), focusing on sustainability, conservation and fostering ecotourism methodologies. The Fair Isle DR MPA Designation Order states that:

"The methods of marine management and exploitation to be demonstrated and researched within The Fair Isle (Demonstration and Research Marine Protected Area) are the use of an ecosystem approach" which includes "The environmental monitoring of the factors which influence the populations of seabirds and of other mobile species;"

A detailed exposition of this project's framework is presented in Section 6 of the Fair Isle DR MPA Research and Project Plan. It remains the only DR MPA in Scottish waters.

The conservation framework for Fair Isle is additionally supported by three distinct nature conservation designations (Figure 1):

- Site of Special Scientific Interest (SSSI) encompassing several avian species in their breeding phase.
- Special Area of Conservation (SAC) pertains to 'European dry heaths' and 'Vegetated sea cliffs of the Atlantic and Baltic coasts'.
- Special Protection Area (SPA) envelops various avian species during their breeding stage, along with a notable breeding seabird assemblage.

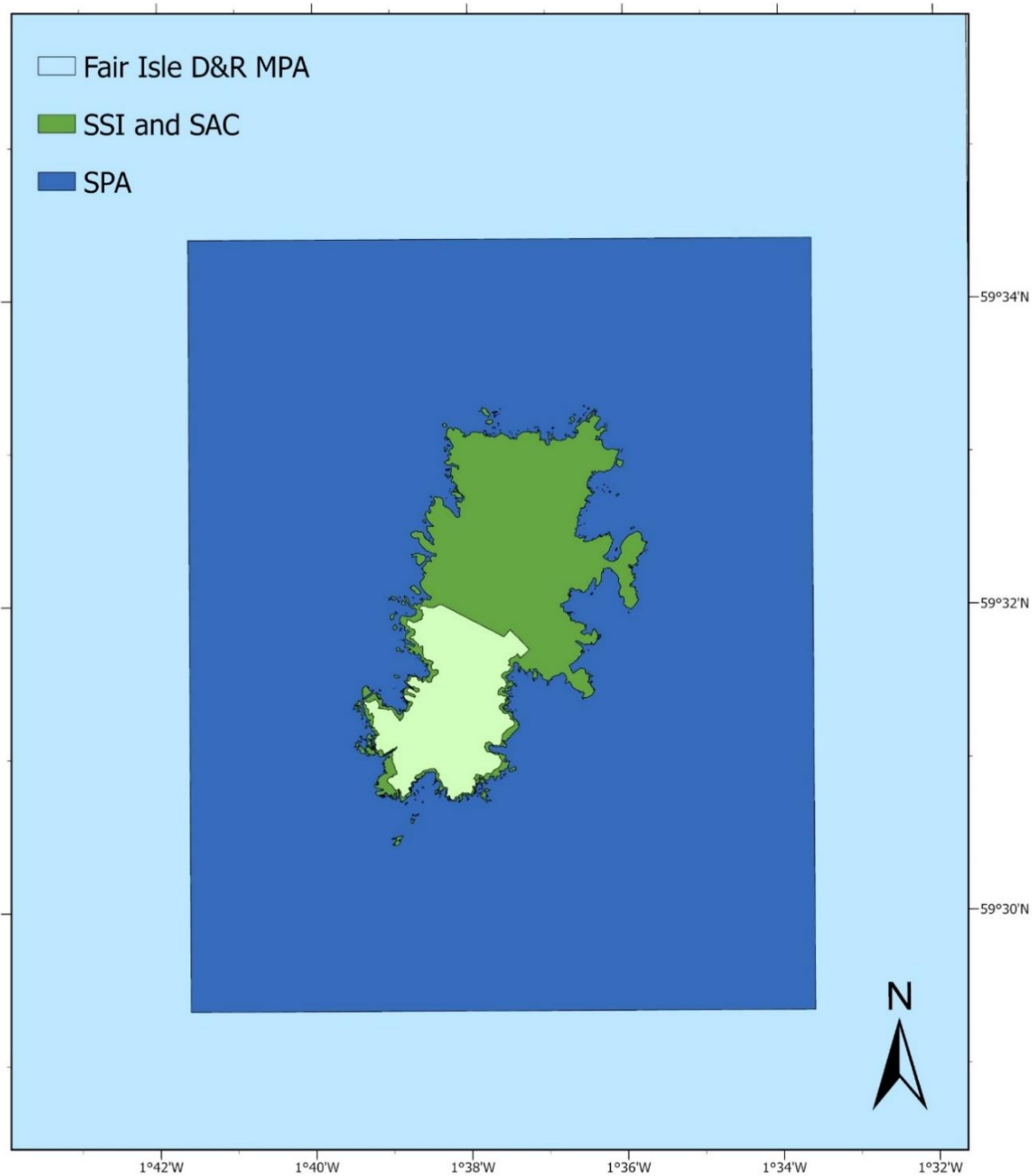
The benthic realm's importance is indisputable in marine ecology (Kaiser, et al., 1999). Unfortunately, comprehensive knowledge on Fair Isle's benthic habitats remains limited, impeding efforts to develop appropriate marine management measures. Consequently, it was identified as a research priority at the Winter 2020/21 stakeholder consultation (Fair Isle Marine Research Organisation, 2021).

Biotopes represent ecosystems where distinct groups of plants, animals, and microorganisms interact within a shared environment. These areas are described by a unique combination of physical and climatic conditions that shape the composition and functioning of the ecosystem. This classification system consists of six levels from broad habitat (Level 1) to sub-biotopes (Level 6) using a code that employs periods to denote the separation between sublevels (Connor *et al.*, 2004).

Distribution Models (DMs) over the years, have solidified their position in marine management, including to recently analyse marine biotopes (Rubanschik *et al.*, 2023), including a recent comprehensive marine assessment within the Shetland Islands (Riley, Shucksmith and Mouat, 2024). Their predictive ability offers invaluable insights into potential habitat distributions, subsequently guiding relevant management directives (de la Torre *et al.*, 2019).

This report focuses on modelling the potential benthic habitat composition, especially those of conservation interest like Priority Marine Features (PMFs) within the Fair Isle DR MPA. This will serve

as an instrumental baseline, paving the way for future research, conservation, and marine management within the Fair Isle DR MPA.



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0 0.5 1
Nautical Miles

Figure 1 The conservation framework for Fair Isle within the Fair Isle DR MPA.

2 Materials and Methods

2.1 Biological data

Initial analysis of biotope records within the Fair Isle DR MPA (157km², Fauna and Flora, 2021) identified just five records between 1962-2019, from only two biotopes. Therefore, biotope records were analysed from within the 12nm limit of the Shetland Islands, assuming geographical similarities and comparable conditions favourable to biotope presence. Records were extracted from the Geodatabase of Marine Features in Scotland (GeMS, managed by NatureScot and Joint Nature Conservation Committee, JNCC). A total of 129 distinct biotope codes (n = 2596, Figure 2) were identified within the Shetland 12nm limit. The biotopes were grouped together to create 28 distinct biotope groups for analysis (Appendix 1). Of these groups five of them were wholly Priority Marine Features (PMFs), while an additional nine sub-biotope codes were also identified for additional PMF-focused analysis (Appendix 2). For ease of reference in this report, all PMF biotopes are highlighted red.

2.2 Environmental data

A total of 13 environmental layers (Appendix 3) were identified for inclusion in the Distribution Model (DM). Data on surface tidal velocity data was derived from a model developed by Natural Power (Halliday, 2011). This dataset was processed in ArcGIS to achieve the requisite resolutions compatible with our DM.

Bathymetric data was sourced from the UK Hydrographic Office (UKHO), Marine Scotland, UHI Shetland surveys, and EMODnet. The datasets were integrated and subsequently processed in ArcGIS producing a detailed bathymetric raster representation for the Shetland region (Appendix 3).

The sedimentary data used in this study was derived from UK Sea Map 2018. These data were simplified sediment types into five primary classifications: Gravel, Mud, Rock, Sand, and a compound category labelled 'Gravel Sand Mud (GSM)' to represent general seabed sedimentary structures, as delineated by Foden, Rogers, and Jones (2010).

Benthic data, encompassing the parameters of light, salinity, temperature, and velocity, were extracted from Bio-ORACLE (Tyberghein et al., 2012; Assis et al., 2018). While the dataset provided a broad coverage, its global resolution was not ideally suited for the DM utilised here. The data was therefore subject to a refinement process.

2.3 Distribution Models

The Distribution Models (DMs) utilised in this study was MaxENT, version 3.4.4 (Phillips, Anderson and Schapire, 2006; Phillips and Dudik, 2008), which was applied to presence-only data from the individual biotope groups in conjunction with the 13 specified environmental layers. This integration resulted in the generation of biotope maps, reflecting predicted habitat suitability for the biotope groups identified. While the model mostly used default settings, some parameters were adjusted for optimisation. Specifically, the data allocation was modified such that 75% was designated for training, with the remaining 25% set aside for testing (Young, Carter and Evangelista, 2011). Further, we increased the number of iterations to 5,000 and conducted 10 replicates using the bootstrap method (Hernandez *et al.*, 2006).

The model primarily produces values ranging from 0 to 1 for each cell, which are designated as the 'likelihood of occurrence'. These values indicate the potential presence of the biotope groups, scores

closer to 1 suggest a higher probability of the biotope's presence, indicative of a more suitable habitat environment.

Following the modelling process, the resulting DM maps including all PMF layers within the Fair Isle DR MPA were combined to create a comprehensive biotope map.

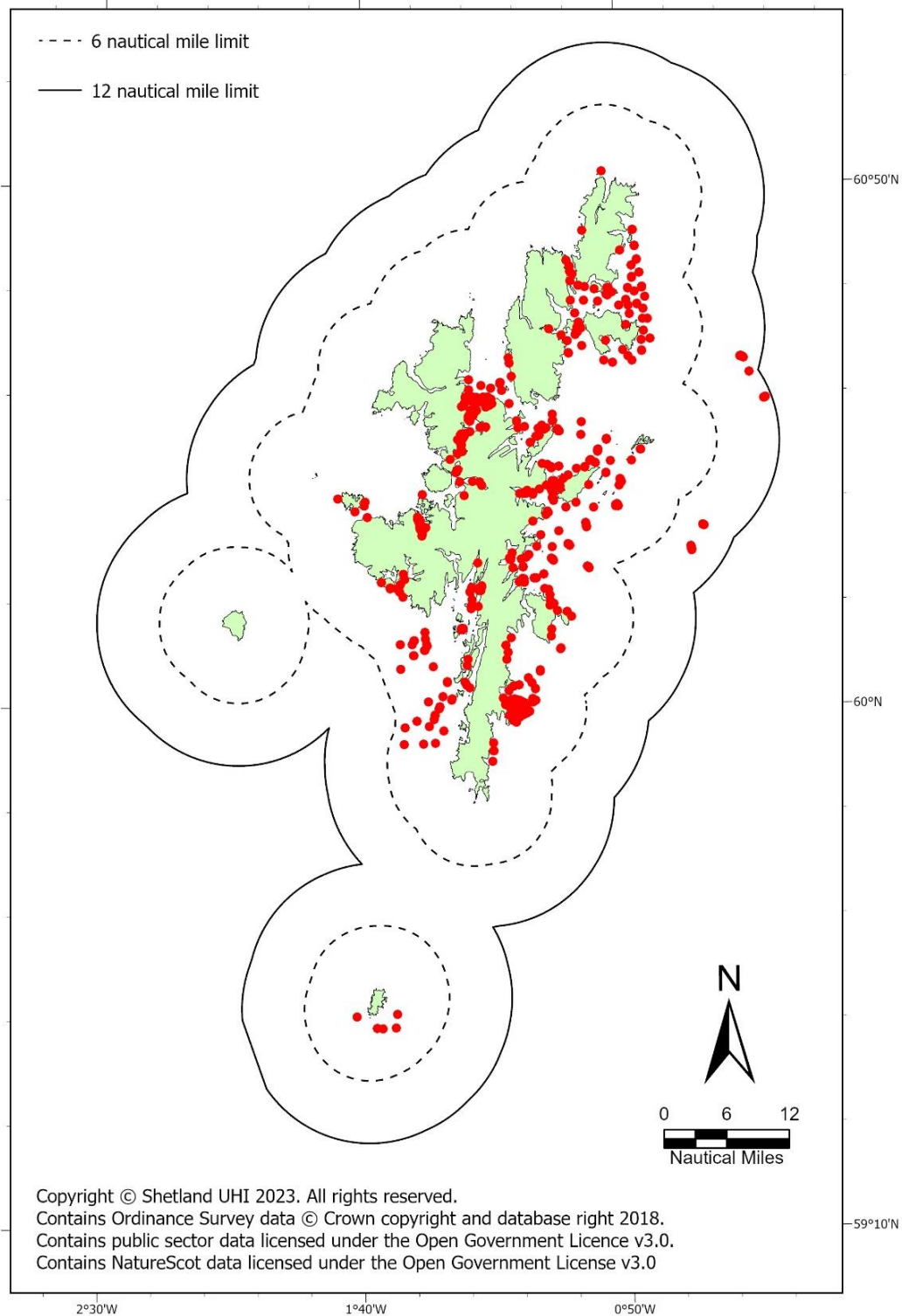


Figure 2 Records of all biotopes used in this study.

3 Results

The Distribution Models (DMs) exhibited robust results during the validation process (AUC value). All biotope groups recorded AUC values above 0.94, and those focussed on PMFs exceeded 0.92. Such scores confirm the high predictive accuracy of the models (Pearce and Ferrier, 2000).

Within the Fair Isle DR MPA the DMs recorded 11 of the modelled 28 distinct biotope groups within its boundaries (Table 1). Of the 9 PMF-focussed subgroups the DMs only recorded 5 within the Fair Isle DR MPA (Table 2). In total 11 biotope groups and 5 subgroups were modelled to be in the Fair Isle DR MPA (Figure 3).

3.1 Biotope groups

High energy circalittoral rock (CR.HCR)

In the biotope category 'high energy circalittoral rock', seven distinct biotopes were identified (Appendix 1). A single entry, accounting for 2% of the records, is deemed historical. None of the collected records from 1987 to 2017 (n=58) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 0.15km² (0.1%) within the Fair Isle DR MPA. Of which the largest predicted presence area was to the northwest of Ler Ness.

Echinoderm and crustose communities (CR.MCR.EcCR)

In the biotope category 'echinoderm and crustose communities', ten distinct biotopes were identified (Appendix 1). A small proportion, accounting for 16% of the records, is deemed historical. Two of the collected records from 1974 to 2019 (n=531) were found within 12nm of Fair Isle to the south.

The DM analysis estimated that this biotope could cover an area of 48.94km² (31.4%) within the Fair Isle DR MPA. The predicted presences were located to the northeast and south, with sparse areas in the west.

Kelp with cushion fauna and/or foliose red seaweeds (IR.HIR.KFaR)

In the biotope category 'kelp with cushion fauna and/or foliose red seaweeds', nine distinct biotopes were identified (Appendix 1). One of the biotopes (*Laminaria hyperborea* on exposed infralittoral rock) is a PMF and has also been modelled separately. A large proportion, accounting for 70% of the records, is deemed historical. None of the collected records from 1974 to 2019 (n=280) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 3.38km² (2.2%) within the Fair Isle DR MPA. The predicted presences were located all around fair isle (excluding the bays), extending down to near the southern limit of the DR MPA, and a further patch to the east.

Sediment-affected or disturbed kelp and seaweed communities (IR.HIR.KSed)

In the biotope category 'sediment-affected or disturbed kelp and seaweed communities', seven distinct biotopes were identified (Appendix 1). A moderate proportion, accounting for 37% of the records, is deemed historical. None of the collected records from 1974 to 2019 (n=148) were found within 12nm of Fair Isle). The DM analysis estimated that this biotope could cover an area of 1.29km² (0.8%) within the Fair Isle DR MPA. The primary predicted presences were located to the southwest of Fair Isle, with sparse areas also located up the west coast, to the northeast and offshore to the east.

Kelp and red seaweeds (moderate energy infralittoral rock) (IR.MIR.KR)

In the biotope category 'moderate energy infralittoral rock', fourteen distinct biotopes were identified (Appendix 1). Three of the biotopes (*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock, *Laminaria hyperborea* on tide-swept, infralittoral rock and *Laminaria hyperborea* on tide-swept infralittoral mixed substrata) are PMFs and have also been modelled separately (Section 3.2). A large proportion, accounting for 70% of the records, is deemed historical. None of the collected records from 1974 to 2019 (n=166) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 0.31km² (0.2%) within the Fair Isle DR MPA. The predicted presences were located to the northeast of Fair Isle, with sparse areas also located down the east coast.

Circalittoral coarse sediment (SS.SCS.CCS)

In the biotope category 'circalittoral coarse sediment', five distinct biotopes were identified (Appendix 1). A small proportion, accounting for 7% of the records, is deemed historical. Three of the collected records from 1962 to 2019 (n=307) were found within 12nm of Fair Isle to the southeast. The DM analysis estimated that this biotope could cover an area of 44.52km² (28.5%) within the Fair Isle DR MPA. The predicted presences were located throughout with a large area noted along the western edge of the DR MPA limits.

Offshore coarse sediment (SS.SCS.OCS)

In the biotope category 'offshore coarse sediment', a single distinct biotope was identified (Appendix 1). None of the records, are deemed historical. None of the collected records from 2011 (n=48) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 2.29km² (1.5%) within the Fair Isle DR MPA. The predicted presences were located to the southwestern corner of the DR MPA limits.

Circalittoral mixed sediment (SS.SMx.CMx)

In the biotope category 'circalittoral mixed sediment', seven distinct biotopes were identified (Appendix 1). A small proportion, accounting for 18% of the records, is deemed historical. None of the collected records from 1962 to 2019 (n=165) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 0.15km² (0.1%) within the Fair Isle DR MPA. The predicted presences were predominantly scattered along the western limit and northeastern limit of the DR MPA.

Offshore circalittoral mixed sediment (SS.SMx.OMx)

In the biotope category 'offshore circalittoral mixed sediment', two distinct biotopes were identified (Appendix 1). A large proportion, accounting for 75% of the records, is deemed historical. None of the collected records from 1963 to 2017 (n=4) were found within 12nm of Fair Isle.

The DM analysis estimated that this biotope could cover an area of 1.94km² (1.2%) within the Fair Isle DR MPA. The predicted presences were predominantly scattered to the northwest of Fair Isle.

Circalittoral fine sand (SS.SSa.CFiSa)

In the biotope category 'circalittoral fine sand', a single distinct biotope was identified (Appendix 1). A small proportion, accounting for 3% of the records, is deemed historical. None of the collected records from 1987 to 2019 (n=33) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 30.82km² (19.8%) within the Fair Isle DR MPA. The predicted presences were predominantly scattered to the northwest of Fair Isle.

Infralittoral fine sand (SS.SSa.IFiSa)

In the biotope category 'infralittoral fine sand', five distinct biotopes were identified (Appendix 1). A moderate proportion, accounting for 52% of the records, is deemed historical. None of the collected records from 1987 to 2019 (n=31) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 1.41km² (0.9%) within the Fair Isle DR MPA. The predicted presences were predominantly identified to the northeast of Fair Isle, with another smaller area identified to the southwest of the isle.

3.2 PMF-focused biotope groups

Laminaria hyperborea on exposed infralittoral rock (IR.HIR.KFaR.Lhyp)

In the biotope category '*Laminaria hyperborea on exposed infralittoral rock*', three distinct biotopes were identified (Appendix 2). A large proportion, accounting for 64% of the records, is deemed historical. None of the collected records from 1974 to 2016 (n=81) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 8.76km² (5.6%) within the Fair Isle DR MPA.

Laminaria hyperborea and foliose red seaweeds on moderately exposed infralittoral rock (IR.MIR.KR.Lhyp)

In the biotope category '*Laminaria hyperborea and foliose red seaweeds on moderately exposed infralittoral rock*', five distinct biotopes were identified (Appendix 2). A large proportion, accounting for 63% of the records, is deemed historical. None of the collected records from 1974 to 2019 (n=175) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 0.42km² (0.3%) within the Fair Isle DR MPA.

Laminaria hyperborea on tide-swept, infralittoral rock (IR.MIR.KR.LhypT)

In the biotope category '*Laminaria hyperborea on tide-swept, infralittoral rock*', three distinct biotopes were identified (Appendix 2). A moderate proportion, accounting for 50% of the records, is deemed historical. None of the collected records from 1987 to 2019 (n=6) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 9.42km² (6.1%) within the Fair Isle DR MPA.

Laminaria hyperborea on tide-swept infralittoral mixed substrata (IR.MIR.KR.LhypTx)

In the biotope category '*Laminaria hyperborea on tide-swept infralittoral mixed substrata*', three distinct biotopes were identified (Appendix 2). A moderate proportion, accounting for 44% of the records, is deemed historical. None of the collected records from 1987 to 2019 (n=9) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 0.24km² (0.2%) within the Fair Isle DR MPA.

Neopentadactyla mixta in circalittoral shell gravel or coarse sand (SS.SCS.CCS.Nmix)

In the biotope category '*Neopentadactyla mixta in circalittoral shell gravel or coarse sand*', a single biotope was identified (Appendix 2). A moderate proportion, accounting for 40% of the records, is deemed historical. None of the collected records from 1986 to 2019 (n=5) were found within 12nm of Fair Isle. The DM analysis estimated that this biotope could cover an area of 1.95km² (1.25%) within the Fair Isle DR MPA.

Table 1 Biotope groupings found within the Fair Isle DR MPA and their records used in this study.Records coloured **purple** represent biotopes with PMF subgroups.

<i>Biotope Grouping Code</i>	<i>Number of Biotopes in Group</i>	<i>Records used in SDM</i>	<i>Range</i>	<i>Historical Records</i>	<i>Area in Fair Isle DR MPA (km²)</i>	<i>Model AUC</i>
CR_HCR	7	58	1987-2017	1 (2%)	0.15 (0.1%)	0.9882
CR_MCR_EcCr	10	531	1974-2019	87 (16%)	48.94 (31.4%)	0.9597
IR_HIR_KFar	9	281	1974-2019	196 (70%)	3.38 (2.2%)	0.9809
IR_HIR_KSed	7	148	1974-2019	55 (37%)	1.29 (0.8%)	0.9847
IR_MIR_KR	13	238	1974-2019	166 (70%)	0.31 (0.2%)	0.9854
SS_SCS_CCS	5	307	1962-2019	21 (7%)	44.52 (28.5%)	0.9506
SS_SCS_OCS	1	48	2011	0 (0%)	2.29 (1.5%)	0.9982
SS_SMx_CMx	7	165	1962-2019	30 (18%)	0.15 (0.1%)	0.9581
SS_SMx_OMx	2	4	1963-2017	3 (75%)	1.94 (1.2%)	0.9452
SS_SSa_CFiSa	1	33	1987-2019	1 (3%)	30.82 (19.7%)	0.9452
SS_SSa_IFiSa	5	21	1986-2019	11 (52%)	1.41 (0.9%)	0.9800

Table 2 PMF-focused biotope groupings found within the Fair Isle DR MPA and their records used in this study.

<i>Biotope Grouping Code</i>	<i>Number of Biotopes in Group</i>	<i>Records used in SDM</i>	<i>Range</i>	<i>Historical Records</i>	<i>Area in Fair Isle DR MPA (km²)</i>	<i>Model AUC</i>
IR_HIR_KFar_Lhyp	3	81	1974-2016	52 (64%)	8.76 (5.6%)	0.9856
IR_MIR_KR_Lhyp	5	175	1974-2019	111 (63%)	0.42 (0.3%)	0.9835
IR_MIR_KR_LhypT	3	6	1987-2019	3 (50%)	9.42 (6.0%)	0.9206
IR_MIR_KR_LhypTx	3	9	1987-2019	4 (44%)	0.24 (0.2%)	0.9940
SS_SCS_CCS_Nmix	1	5	1986-2019	2 (40%)	1.95 (1.3%)	0.9741

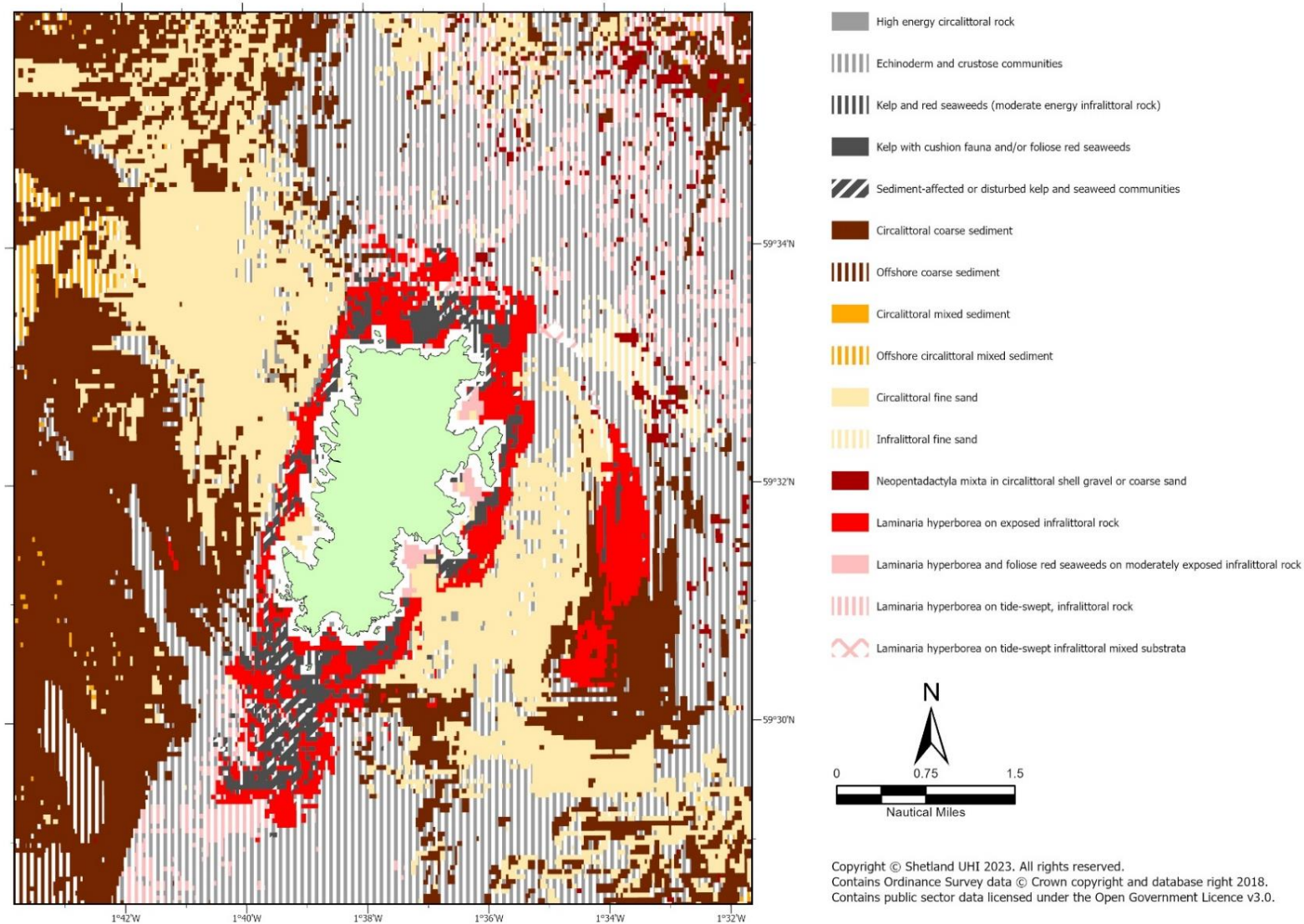


Figure 3 Predicted biotope map of the benthic habitats within the Fair Isle DR MPA.

4 Discussion

4.1 Significance of Findings

The DMs employed in this study demonstrated high predictive accuracy of 11 biotopes with the Fair Isle DR MPA, highlighting their efficacy in modelling the potential distribution of marine habitats. The identification of specific biotopes within the MPA, such as 'High Energy Circalittoral Rock (CR.HCR),' 'Echinoderm and Crustose Communities (CR.MCR.EcCR),' and 'Kelp with Cushion Fauna and/or Foliose Red Seaweeds (IR.HIR.KFaR),' provides a foundation for understanding the ecological dynamics of these habitats, shedding light on the spatial patterns of these biotopes around Fair Isle. The inclusion of PMFs in the analysis adds a conservation-focused dimension to the study. The identification of PMF-focused biotope groups, such as '*Laminaria hyperborea* on exposed infralittoral rock' and '*Neopentadactyla mixta* in circalittoral shell gravel or coarse sand,' emphasises areas for further ground-truthing and research.

The current study sets the stage for future endeavours aimed at enhancing the precision of biotope mapping within the Fair Isle DR MPA. The identified biotope groups, particularly those associated with PMFs, provide a guide for targeted data collection and ground-truthing efforts. By focusing on these specific biotopes, and areas of interest researchers can gather dedicated and detailed information, contributing to a more accurate and comprehensive benthic habitat map for the area. This localised data would enrich the models, allowing for a refined understanding of the ecological dynamics unique to the Fair Isle marine ecosystem.

4.2 Study Limitations

Despite the success of the DMs employed, several limitations should be acknowledged. A key challenge lies in the scarcity of biotope records within the Fair Isle DR MPA, which poses a challenge for robust model validation (Wisz *et al.*, 2008; van Proosdij *et al.*, 2016). The study addressed this gap by relying on data from the Shetland Islands within a 12nm limit, assuming geographical and environmental similarities. While this assumption is reasonable, the ideal scenario would involve more localised and comprehensive data specific to the Fair Isle DR MPA.

Despite this limitation, the use of DMs offers a valuable baseline for understanding potential habitat distributions within the Fair Isle DR MPA. The high predictive accuracy of the models, as evidenced by the high AUC values, establishes a foundation for informed marine management strategies. These models can serve as essential tools for guiding management efforts, especially for PMFs, and formulating directives that prioritise ecological sustainability.

4.3 Recommendations for Future Research Work

Building upon the foundations laid out in the current study the following areas for future research are recommended to advance our understanding of the marine ecosystems within the Fair Isle DR MPA:

1. **Dedicated Biotopes Data Collection:** Conducting targeted and comprehensive surveys within the Fair Isle DR MPA to gather specific biotope data. Focusing on areas identified in the DMs, especially those associated with PMFs, would contribute to a more detailed and accurate understanding of the benthic habitats.
2. **Long-Term Monitoring:** Implementing a long-term monitoring program within the Fair Isle DR MPA to track changes in benthic habitats over time. This would provide valuable data on the

resilience of the marine ecosystem to environmental variations and human activities, aiding in the formulation of adaptive management strategies.

3. **Species-Specific Studies:** Conducting species-specific studies, especially those associated with PMFs, to assess their population dynamics, distribution patterns, and habitat preferences. This information is key for targeted management efforts.
4. **Ecosystem Connectivity:** Investigating the connectivity between different marine habitats within the DR MPA and neighbouring regions. Understanding how species move and interact across different habitats contributes to a holistic approach to marine ecosystem management.
5. **Community Engagement and Education:** Involving the local community in research initiatives and fostering education programs to raise awareness about the importance of the marine environment. Engaging stakeholders enhances the success of management measures and promotes sustainable practices.
6. **Climate Change Impact Assessment:** Assessing the potential impact of climate change on the benthic habitats within the Fair Isle DR MPA. This includes studying factors such as sea-level rise, ocean acidification, and temperature changes to anticipate and address future challenges to the marine ecosystem.
7. **Incorporation of Technological Advances:** Exploring and incorporating advancements in technology, such as unmanned autonomous vehicles, underwater video recording equipment and remote sensing, to enhance data collection efficiency and coverage.
8. **Collaborative Research Networks:** Establishing collaborative research networks with academic institutions, governmental agencies, and non-governmental organisations to pool resources, expertise, and data for a more comprehensive understanding of marine ecosystems in the region.

5 Conclusion

The study of benthic habitat composition within the Fair Isle DR MPA offers valuable insights into the challenges and opportunities associated with limited biotope data. The DMs employed demonstrated a high level of predictive accuracy, emphasising their utility as baseline tools for marine management strategies. However, the scarcity of biotope records within the designated area underscores the need for dedicated and comprehensive data collection efforts to create a more detailed and accurate map of benthic habitats. Focusing on identified biotope groups, particularly those associated with PMFs, presents an avenue for targeted data collection, contributing to a refined analysis of benthic ecosystem importance within the MPA. This study highlights the importance of localised biotope data for precise mapping for enhancing our knowledge of regional marine dynamics and fostering more informed management practices. In summary, while the DMs provide a robust starting point, ongoing research efforts and projects are essential for advancing our understanding of the Fair Isle DR MPA marine environment.

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Acknowledgements

This project was supported by players of People's Postcode Lottery through the National Trust for Scotland's Love our Nature project.

Appendix 1. Biotope Groupings

Biotope code/group	Biotope name
CR.HCR – High energy circalittoral rock	
CR.HCR.DpSp.PhaAxi	<i>Phakellia ventilabrum</i> and Axinellid sponges on deep, wave-exposed circalittoral rock
CR.HCR.FaT.BalTub	<i>Balanus crenatus</i> and <i>Tubularia indivisa</i> on extremely tide-swept circalittoral rock
CR.HCR.FaT.CTub	<i>Tubularia indivisa</i> on tide-swept circalittoral rock
CR.HCR.FaT.CTub.Adig	<i>Alcyonium digitatum</i> with dense <i>Tubularia indivisa</i> and anemones on strongly tide-swept circalittoral rock
CR.HCR.FaT.CTub.CuSp	<i>Tubularia indivisa</i> and cushion sponges on tide-swept turbid circalittoral bedrock
CR.HCR.XFa	Mixed faunal turf communities
CR.HCR.XFa.CvirCri	<i>Corynactis viridis</i> and a mixed turf of crisiids, Bugula, Scrupocellaria, and Cellaria on moderately tide-swept exposed circalittoral rock
CR.LCR – Low energy circalittoral rock	
CR.LCR.BrAs	Brachiopod and ascidian communities
CR.LCR.BrAs.AmenCio	Solitary ascidians, including <i>Ascidia mentula</i> and <i>Ciona intestinalis</i> , on wave-sheltered circalittoral rock
CR.LCR.BrAs.AmenCio.Ant	Solitary ascidians, including <i>Ascidia mentula</i> and <i>Ciona intestinalis</i> , with <i>Antedon</i> spp. on wave-sheltered circalittoral rock
CR.LCR.BrAs.AmenCio.Bri	Dense brittlestars with sparse <i>Ascidia mentula</i> and <i>Ciona intestinalis</i> on sheltered circalittoral mixed substrata
CR.MCR.EcCr – Echinoderm and crustose communities	
CR.MCR.EcCr	Echinoderms and crustose communities
CR.MCR.EcCr.CarSp	<i>Caryophyllia smithii</i> , sponges and crustose communities on wave-exposed circalittoral rock
CR.MCR.EcCr.CarSp.Bri	Brittlestars overlying coralline crusts, <i>Parasmittina trispinosa</i> and <i>Caryophyllia smithii</i> on wave-exposed circalittoral rock
CR.MCR.EcCr.CarSp.PenPcom	<i>Caryophyllia smithii</i> and sponges with <i>Pentapora foliacea</i> , <i>Porella compressa</i> and crustose communities on wave-exposed circalittoral rock

Biotope code/group	Biotope name
CR.MCR.EcCr.FaAlCr	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock
CR.MCR.EcCr.FaAlCr.Adig	<i>Alcyonium digitatum</i> , <i>Pomatoceros triqueter</i> , algal and bryozoan crusts on wave-exposed circalittoral rock
CR.MCR.EcCr.FaAlCr.Bri	Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock
CR.MCR.EcCr.FaAlCr.Car	<i>Caryophyllia smithii</i> with faunal and algal crusts on moderately wave-exposed circalittoral rock
CR.MCR.EcCr.FaAlCr.Flu	<i>Flustra foliacea</i> on slightly scoured silty circalittoral rock
CR.MCR.EcCr.FaAlCr.Pom	Faunal and algal crusts with <i>Pomatoceros triqueter</i> and sparse <i>Alcyonium digitatum</i> on exposed to moderately wave-exposed circalittoral rock
IR.HIR.KFaR – Kelp and cushion fauna and/or foliose red seaweed	
IR.HIR.KFaR	Kelp with cushion fauna and/or foliose red seaweeds
IR.HIR.KFaR.Ala	<i>Alaria esculenta</i> on exposed sublittoral fringe bedrock
IR.HIR.KFaR.Ala.Ldig	<i>Alaria esculenta</i> and <i>Laminaria digitata</i> on exposed sublittoral fringe bedrock
IR.HIR.KFaR.Ala.Myt	<i>Alaria esculenta</i> , <i>Mytilus edulis</i> and coralline crusts on very exposed sublittoral fringe bedrock
IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock
IR.HIR.KFaR.FoR.Dic	Foliose red seaweeds with dense <i>Dictyota dichotoma</i> and/or <i>Dictyopteris membranacea</i> on exposed lower infralittoral rock
IR.HIR.KFaR.LhypFa	<i>Laminaria hyperborea</i> forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed upper infralittoral rock
IR.HIR.KFaR.LhypR.Ft	<i>Laminaria hyperborea</i> forest with dense foliose red seaweeds on exposed upper infralittoral rock
IR.HIR.KFaR.LhypR.Pk	<i>Laminaria hyperborea</i> park with dense foliose red seaweeds on exposed lower infralittoral rock
IR.HIR.KSed – Sediment-affected or disturbed kelp and seaweed communities	
IR.HIR.KSed	Sediment-affected or disturbed kelp and seaweed communities
IR.HIR.KSed.DesFilR	Dense <i>Desmarestia</i> spp. with filamentous red seaweeds on exposed infralittoral cobbles, pebbles, and bedrock

Biotope code/group	Biotope name
IR.HIR.KSed.LsacSac	<i>Laminaria saccharina</i> and/or <i>Saccorhiza polyschides</i> on exposed infralittoral rock
IR.HIR.KSed.ProtAhn	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock
IR.HIR.KSed.Sac	<i>Saccorhiza polyschides</i> and other opportunistic kelps on disturbed sublittoral fringe rock
IR.HIR.KSed.XKHal	<i>Halidrys siliquosa</i> and mixed kelps on tide-swept infralittoral rock with coarse sediment
IR.HIR.KSed.XKScrR	Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock
IR.LIR.K – Silted kelp communities (sheltered infralittoral rock)	
IR.LIR.K	Silted kelp communities (sheltered infralittoral rock)
IR.LIR.K.LhypCape	Silted cape-form <i>Laminaria hyperborea</i> on very sheltered infralittoral rock
IR.LIR.K.LhypLsac	Mixed <i>Laminaria hyperborea</i> and <i>Laminaria saccharina</i> on sheltered infralittoral rock
IR.LIR.K.LhypLsac.Ft	Mixed <i>Laminaria hyperborea</i> and <i>Laminaria saccharina</i> forest on sheltered upper infralittoral rock
IR.LIR.K.LhypLsac.Gz	Grazed, mixed <i>Laminaria hyperborea</i> and <i>Laminaria saccharina</i> on sheltered infralittoral rock
IR.LIR.K.LhypLsac.Pk	Mixed <i>Laminaria hyperborea</i> and <i>Laminaria saccharina</i> park on sheltered lower infralittoral rock
IR.LIR.K.Lsac	<i>Laminaria saccharina</i> on very sheltered infralittoral rock
IR.LIR.K.Lsac.Ft	<i>Laminaria saccharina</i> forest on very sheltered upper infralittoral rock
IR.LIR.K.Lsac.Gz	Grazed <i>Laminaria saccharina</i> with <i>Echinus</i> , brittlestars and coralline crusts on sheltered infralittoral rock
IR.LIR.K.Lsac.Ldig	<i>Laminaria saccharina</i> and <i>Laminaria digitata</i> on sheltered sublittoral fringe rock
IR.LIR.K.Lsac.Pk	<i>Laminaria saccharina</i> park on very sheltered lower infralittoral rock
IR.MIR.KR – Kelp and red seaweeds (moderate energy infralittoral rock)	
IR.MIR.KR.Ldig	<i>Laminaria digitata</i> on moderately exposed sublittoral fringe rock

Biotope code/group	Biotope name
IR.MIR.KR.Ldig.Bo	<i>Laminaria digitata</i> and under-boulder fauna on sublittoral fringe boulders
IR.MIR.KR.Ldig.Ldig	<i>Laminaria digitata</i> on moderately exposed sublittoral fringe bedrock
IR.MIR.KR.Lhyp	<i>Laminaria hyperborea</i> and foliose red seaweeds on moderately exposed infralittoral rock
IR.MIR.KR.Lhyp.Ft	<i>Laminaria hyperborea</i> forest and foliose red seaweeds on moderately exposed upper infralittoral rock
IR.MIR.KR.Lhyp.GzFt	Grazed <i>Laminaria hyperborea</i> forest with coralline crusts on upper infralittoral rock
IR.MIR.KR.Lhyp.GzPk	Grazed <i>Laminaria hyperborea</i> park with coralline crusts on lower infralittoral rock
IR.MIR.KR.Lhyp.Pk	<i>Laminaria hyperborea</i> park and foliose red seaweeds on moderately exposed lower infralittoral rock
IR.MIR.KR.LhypT	<i>Laminaria hyperborea</i> on tide-swept, infralittoral rock
IR.MIR.KR.LhypT.Ft	<i>Laminaria hyperborea</i> forest, foliose red seaweeds and a diverse fauna on tide-swept upper infralittoral rock
IR.MIR.KR.LhypT.Pk	<i>Laminaria hyperborea</i> park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock
IR.MIR.KR.LhypTX	[<i>Laminaria hyperborea</i>] on tide-swept infralittoral mixed substrata
IR.MIR.KR.LhypTX.Ft	<i>Laminaria hyperborea</i> forest and foliose red seaweeds on tide-swept upper infralittoral mixed substrata
IR.MIR.KR.LhypTX.Pk	<i>Laminaria hyperborea</i> park and foliose red seaweeds on tide-swept lower infralittoral mixed substrata
IR.MIR.KT – Kelp and seaweed communities in tide-swept sheltered conditions	
IR.MIR.KT	Kelp and seaweed communities in tide-swept sheltered conditions
IR.MIR.KT.XKT	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
IR.MIR.KT.XKTX	Mixed kelp and red seaweeds on infralittoral boulders, cobbles and gravel in tidal rapids
SS.SBR.SMus – Sublittoral mussel beds	

Biotope code/group	Biotope name
SS.SBR.SMus.ModCvar	<i>Modiolus modiolus</i> beds with <i>Chlamys varia</i> , sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata
SS.SBR.SMus.ModHAs	<i>Modiolus modiolus</i> beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata
SS.SBR.SMus.ModMx	<i>Modiolus modiolus</i> beds on open coast circalittoral mixed sediment
SS.SBR.SMus.ModT	<i>Modiolus modiolus</i> beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
SS.SCS.CCS – Circalittoral coarse sediment	
SS.SCS.CCS	Circalittoral coarse sediment
SS.SCS.CCS.MedLumVen	<i>Mediomastus fragilis</i> , <i>Lumbrineris</i> spp. and venerid bivalves in circalittoral coarse sand or gravel
SS.SCS.CCS.Nmix	<i>Neopentadactyla mixta</i> in circalittoral shell gravel or coarse sand
SS.SCS.CCS.Pkef	<i>Protodorvillea kefersteini</i> and other polychaetes in impoverished circalittoral mixed gravelly sand
SS.SCS.CCS.PomB	<i>Pomatoceros triqueter</i> with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles
SS.SCS.ICS – Infralittoral coarse sediment	
SS.SCS.ICS	Infralittoral coarse sediment
SS.SCS.ICS.MoeVen	<i>Moerella</i> spp. with venerid bivalves in infralittoral gravelly sand
SS.SCS.ICS.SLan	Dense <i>Lanice conchilega</i> and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand
SS.SCS.ICS.SSh	Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles)
SS.SCS.OCS – Offshore circalittoral coarse sediment	
SS.SCS.OCS	Offshore circalittoral coarse sediment
SS.SMp.KSwSS – Kelp and seaweed communities on sublittoral sediment	
SS.SMp.KSwSS	Kelp and seaweed communities on sublittoral sediment
SS.SMp.KSwSS.LsacR	<i>Laminaria saccharina</i> and red seaweeds on infralittoral sediments

Biotope code/group	Biotope name
SS.SMp.KSwSS.LsacR.CbPb	Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles
SS.SMp.KSwSS.LsacR.Gv	<i>Laminaria saccharina</i> and robust red algae on infralittoral gravel and pebbles
SS.SMp.KSwSS.LsacR.Mu	<i>Laminaria saccharina</i> with red and brown seaweeds on lower infralittoral muddy mixed sediment
SS.SMp.KSwSS.LsacR.Sa	<i>Laminaria saccharina</i> and filamentous red algae on infralittoral sand
SS.SMp.KSwSS.Pcri	Loose-lying mats of <i>Phyllophora crispa</i> on infralittoral muddy sediment
SS.SMp.KSwSS.Tra	Mats of <i>Trailliella</i> on infralittoral muddy gravel
SS.SMp.Mrl – Maerl beds	
SS.SMp.Mrl	Maerl beds
SS.SMp.Mrl.Lgla	<i>Lithothamnion glaciale</i> maerl beds in tide-swept variable salinity infralittoral gravel
SS.SMp.Mrl.Pcal	<i>Phymatolithon calcareum</i> maerl beds in infralittoral clean gravel or coarse sand
SS.SMp.Mrl.Pcal.Nmix	<i>Phymatolithon calcareum</i> maerl beds with <i>Neopentadactyla mixta</i> and other echinoderms in deeper infralittoral clean gravel or coarse sand
SS.SMp.Mrl.Pcal.R	<i>Phymatolithon calcareum</i> maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand
SS.SMp.SSgr.Zmar - Seagrass	
SS.SMp.SSgr.Zmar (subtidal)	<i>Zostera marina/angustifolia</i> beds on lower shore or infralittoral clean or muddy sand
SS.SMu.CFiMu – Circalittoral fine mud	
SS.SMu.CFiMu	Circalittoral fine mud
SS.SMu.CFiMu.SpnMeg	Seapens and burrowing megafauna in circalittoral fine mud
SS.SMu.CSaMu – Circalittoral sandy mud	
SS.SMu.CSaMu	Circalittoral sandy mud
SS.SMu.CSaMu.VirOphPmax	<i>Virgularia mirabilis</i> and <i>Ophiura</i> spp. with <i>Pecten maximus</i> on circalittoral sandy or shelly mud
SS.SMu.IFiMu – Infralittoral fine mud	

Biotope code/group	Biotope name
SS.SMu.IFiMu	Infralittoral fine mud
SS.SMu.IFiMu.Are	<i>Arenicola marina</i> in infralittoral mud
SS.SMu.ISaMu – Infralittoral sandy mud	
SS.SMu.ISaMu	Infralittoral sandy mud
SS.SMu.ISaMu.Cap	<i>Capitella capitata</i> in enriched sublittoral muddy sediments
SS.SMu.ISaMu.MysAbr	<i>Mysella bidentata</i> and <i>Abra</i> spp. in infralittoral sandy mud
SS.SMu.ISaMu.SundAasp	<i>Sagartiogeton undatus</i> and <i>Ascidia aspersa</i> on infralittoral sandy mud
SS.SMu.Omu – Offshore circalittoral mud	
SS.SMu.OMu	Offshore circalittoral mud
SS.SMx.CMx – Circalittoral mixed sediment	
SS.SMx.CMx	Circalittoral mixed sediment
SS.SMx.CMx.CIlModHo	Sparse <i>Modiolus modiolus</i> , dense <i>Cerianthus lloydii</i> and burrowing holothurians on sheltered circalittoral stones and mixed sediment
SS.SMx.CMx.CIlMx	<i>Cerianthus lloydii</i> and other burrowing anemones in circalittoral muddy mixed sediment
SS.SMx.CMx.CIlMx.Nem	<i>Cerianthus lloydii</i> with <i>Nemertea</i> spp. and other hydroids in circalittoral muddy mixed sediment
SS.SMx.CMx.FluHyd	<i>Flustra foliacea</i> and <i>Hydrallmania falcata</i> on tide-swept circalittoral mixed sediment
SS.SMx.CMx.MysThyMx	<i>Mysella bidentata</i> and <i>Thyasira</i> spp. in circalittoral muddy mixed sediment
SS.SMx.CMx.OphMx	<i>Ophiothrix fragilis</i> and/or <i>Ophiocomina nigra</i> brittlestar beds on sublittoral mixed sediment
SS.SMx.IMx – Infralittoral mixed sediment	
SS.SMx.IMx	Infralittoral mixed sediment
SS.SMx.IMx.VsenAsquAps	<i>Venerupis senegalensis</i> , <i>Amphipholis squamata</i> and <i>Apeudes latreilli</i> in infralittoral mixed sediment
SS.SMx.OMx – Offshore circalittoral mixed sediment	
SS.SMx.OMx	Offshore circalittoral mixed sediment
SS.SMx.OMx.PoVen	Polychaete-rich deep Venus community in offshore gravelly muddy sand

Biotope code/group	Biotope name
SS.SSa.CFiSa – Circalittoral fine mud	
SS.SSa.CFiSa	Circalittoral fine sand
SS.SSa.CMuSa – Circalittoral Muddy sand	
SS.SSa.CMuSa	Circalittoral muddy sand
SS.SSa.CMuSa.AalbNuc	<i>Abra alba</i> and <i>Nucula nitidosa</i> in circalittoral muddy sand or slightly mixed sediment
SS.SSa.CMuSa.AbraAirr	<i>Amphiura brachiata</i> with <i>Astropecten irregularis</i> and other echinoderms in circalittoral muddy sand
SS.SSa.IFiSa – Infralittoral fine sand	
SS.SSa.IFiSa	Infralittoral fine sand
SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna
SS.SSa.IFiSa.NcirBat	<i>Nephtys cirrosa</i> and <i>Bathyporeia</i> spp. in infralittoral sand
SS.SSa.IFiSa.ScupHyd	<i>Sertularia cupressina</i> and <i>Hydrallmania falcata</i> on tide-swept sublittoral sand with cobbles or pebbles.
SS.SSa.IFiSa.TbAmPo	Semi-permanent tube-building amphipods and polychaetes in sublittoral sand
SS.SSa.IMuSa – Infralittoral muddy sand	
SS.SSa.IMuSa	Infralittoral muddy sand
SS.SSa.IMuSa.ArelSa	<i>Arenicola marina</i> in infralittoral fine sand or muddy sand
SS.SSa.IMuSa.EcorEns	<i>Echinocardium cordatum</i> and <i>Ensis</i> spp. in lower shore and shallow sublittoral slightly muddy fine sand
SS.SSa.IMuSa.FfabMag	<i>Fabulina fabula</i> and <i>Magelona mirabilis</i> with venerid bivalves and amphipods in infralittoral compacted fine muddy sand
SS.SSa.OSa	
SS.SSa.OSa	Offshore circalittoral sand

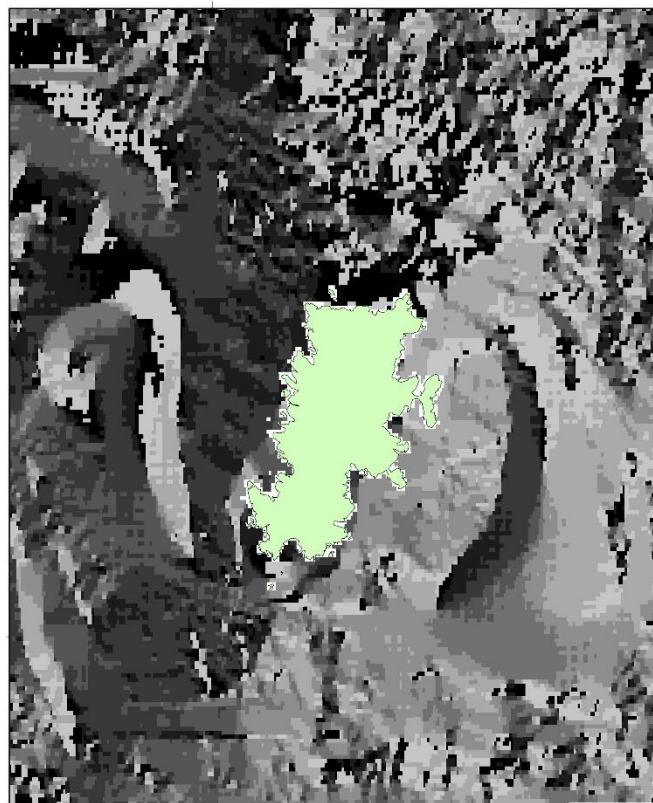
Appendix 2. PMF-focused Biotope Groupings

Biotope code/group	Biotope name
CR.HCR.DpSp.PhaAxi - <i>Phakellia ventilabrum</i> and Axinellid sponges on deep, wave-exposed circalittoral rock	
CR.HCR.DpSp.PhaAxi	<i>Phakellia ventilabrum</i> and Axinellid sponges on deep, wave-exposed circalittoral rock
IR.HIR.KFaR.Lhyp – <i>Laminaria hyperborea</i> on exposed littoral rock	
IR.HIR.KFaR.LhypFa	<i>Laminaria hyperborea</i> forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed upper infralittoral rock
IR.HIR.KFaR.LhypR.Ft	<i>Laminaria hyperborea</i> forest with dense foliose red seaweeds on exposed upper infralittoral rock
IR.HIR.KFaR.LhypR.Pk	<i>Laminaria hyperborea</i> park with dense foliose red seaweeds on exposed lower infralittoral rock
IR.HIR.KSed.XKHal - <i>Halidrys siliquosa</i> and mixed kelps on tide-swept infralittoral rock with coarse sediment	
IR.HIR.KSed.XKHal	<i>Halidrys siliquosa</i> and mixed kelps on tide-swept infralittoral rock with coarse sediment
IR.MIR.KR.Lhyp - <i>Laminaria hyperborea</i> and foliose red seaweeds on moderately exposed infralittoral rock	
IR.MIR.KR.Lhyp	<i>Laminaria hyperborea</i> and foliose red seaweeds on moderately exposed infralittoral rock
IR.MIR.KR.Lhyp.Ft	<i>Laminaria hyperborea</i> forest and foliose red seaweeds on moderately exposed upper infralittoral rock
IR.MIR.KR.Lhyp.GzFt	Grazed <i>Laminaria hyperborea</i> forest with coralline crusts on upper infralittoral rock
IR.MIR.KR.Lhyp.GzPk	Grazed <i>Laminaria hyperborea</i> park with coralline crusts on lower infralittoral rock
IR.MIR.KR.Lhyp.Pk	<i>Laminaria hyperborea</i> park and foliose red seaweeds on moderately exposed lower infralittoral rock
IR.MIR.KR.LhypT - <i>Laminaria hyperborea</i> on tide-swept, infralittoral rock	
IR.MIR.KR.LhypT	<i>Laminaria hyperborea</i> on tide-swept, infralittoral rock
IR.MIR.KR.LhypT.Ft	<i>Laminaria hyperborea</i> forest, foliose red seaweeds and a diverse fauna on tide-swept upper infralittoral rock
IR.MIR.KR.LhypT.Pk	<i>Laminaria hyperborea</i> park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock

Biotope code/group	Biotope name
IR.MIR.KR.LhypTX - <i>Laminaria hyperborea</i> on tide-swept infralittoral mixed substrata	
IR.MIR.KR.LhypTX	<i>Laminaria hyperborea</i> on tide-swept infralittoral mixed substrata
IR.MIR.KR.LhypTX.Ft	<i>Laminaria hyperborea</i> forest and foliose red seaweeds on tide-swept upper infralittoral mixed substrata
IR.MIR.KT - Kelp and seaweed communities in tide-swept sheltered conditions	
IR.MIR.KT	Kelp and seaweed communities in tide-swept sheltered conditions
IR.MIR.KT.XKT	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
IR.MIR.KT.XKTX	Mixed kelp and red seaweeds on infralittoral boulders, cobbles and gravel in tidal rapids
SS.SBR.SMus.Mod – Sublittoral mussel beds	
SS.SBR.SMus.ModCvar	<i>Modiolus modiolus</i> beds with <i>Chlamys varia</i> , sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata
SS.SBR.SMus.ModHAs	<i>Modiolus modiolus</i> beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata
SS.SBR.SMus.ModMx	<i>Modiolus modiolus</i> beds on open coast circalittoral mixed sediment
SS.SBR.SMus.ModT	<i>Modiolus modiolus</i> beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
SS.SCS.CCS - <i>Neopentadactyla mixta</i> in circalittoral shell gravel or coarse sand	
SS.SCS.CCS.Nmix	<i>Neopentadactyla mixta</i> in circalittoral shell gravel or coarse sand
SS.SCS.ICS - <i>Moerella</i> spp. with venerid bivalves in infralittoral gravelly sand	
SS.SCS.ICS.MoeVen	<i>Moerella</i> spp. with venerid bivalves in infralittoral gravelly sand
SS.SMp.KSwSS – Kelp and seaweed communities on sublittoral sediment	
SS.SMp.KSwSS	Kelp and seaweed communities on sublittoral sediment
SS.SMp.KSwSS.FilG	Filamentous green seaweeds on low salinity infralittoral mixed sediment or rock
SS.SMp.KSwSS.LsacCho	<i>Laminaria saccharina</i> and <i>Chorda filum</i> on sheltered upper infralittoral muddy sediment

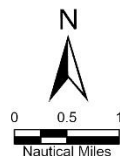
Biotope code/group	Biotope name
SS.SMp.KSwSS.LsacMxVS	<i>Laminaria saccharina</i> with <i>Psammechinus miliaris</i> and/or <i>Modiolus modiolus</i> on variable salinity infralittoral sediment
SS.SMp.KSwSS.LsacR	<i>Laminaria saccharina</i> and red seaweeds on infralittoral sediments
SS.SMp.KSwSS.LsacR.CbPb	Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles
SS.SMp.KSwSS.LsacR.Sa	<i>Laminaria saccharina</i> and filamentous red algae on infralittoral sand
SS.SMp.KSwSS.Pcri	Loose-lying mats of <i>Phyllophora crispa</i> on infralittoral muddy sediment
SS.SMp.KSwSS.Tra	Mats of <i>Trailiella</i> on infralittoral muddy gravel
SS.SMp.Mrl – Maerl beds	
SS.SMp.Mrl	Maerl beds
SS.SMp.Mrl.Lgla	<i>Lithothamnion glaciale</i> maerl beds in tide-swept variable salinity infralittoral gravel
SS.SMp.Mrl.Pcal	<i>Phymatolithon calcareum</i> maerl beds in infralittoral clean gravel or coarse sand
SS.SMp.Mrl.Pcal.Nmix	<i>Phymatolithon calcareum</i> maerl beds with <i>Neopentadactyla mixta</i> and other echinoderms in deeper infralittoral clean gravel or coarse sand
SS.SMp.Mrl.Pcal.R	<i>Phymatolithon calcareum</i> maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand
SS.SMp.SSgr.Zmar - Seagrass	
SS.SMp.SSgr.Zmar (subtidal)	<i>Zostera marina/angustifolia</i> beds on lower shore or infralittoral clean or muddy sand
SS.SMu.CFiMu.SpnMeg - Seapens and burrowing megafauna in circalittoral fine mud	
SS.SMu.CFiMu.SpnMeg	Seapens and burrowing megafauna in circalittoral fine mud

Appendix 3. Environmental Layers

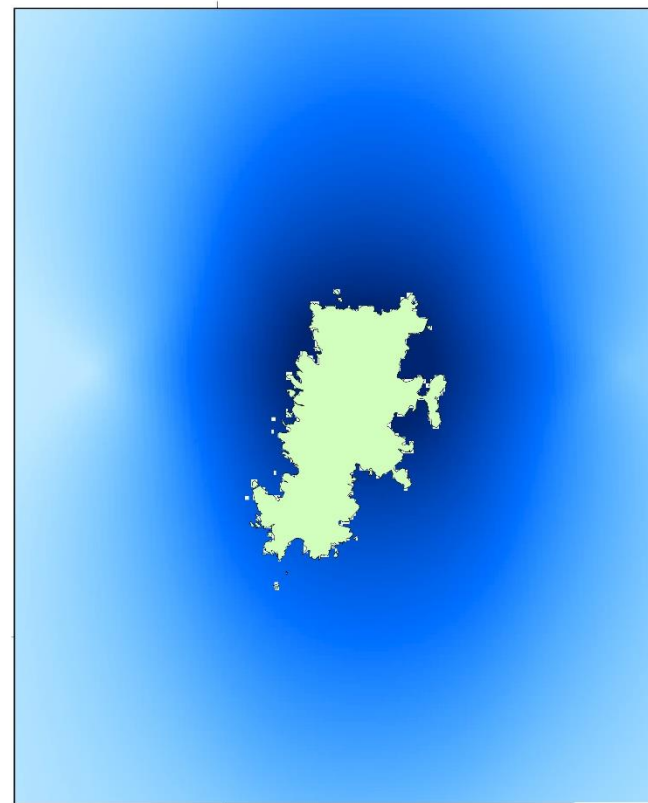


Aspect
Flat

North	Southeast	West
Northeast	South	Northwest
East	Southwest	North

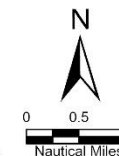


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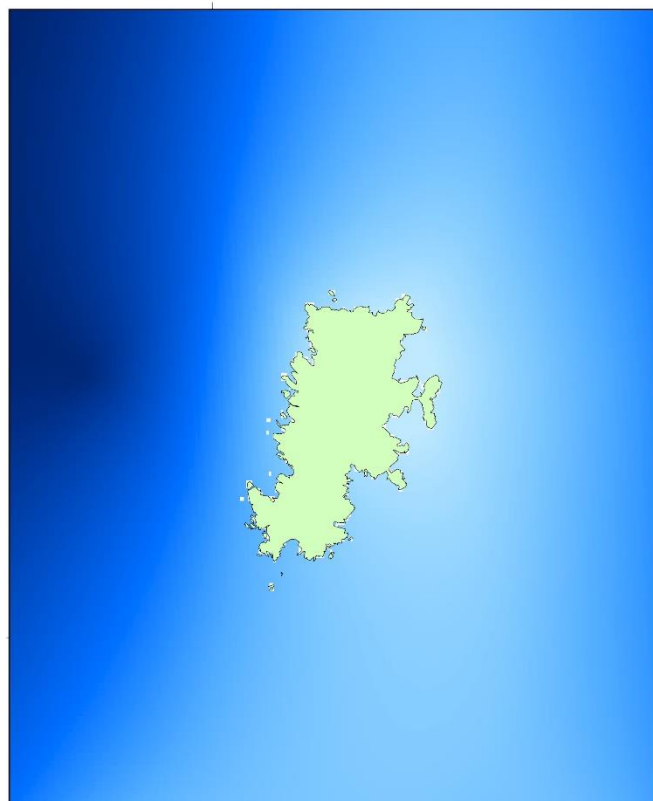


Benthic Light (E/m²/year)

0.163
0.006



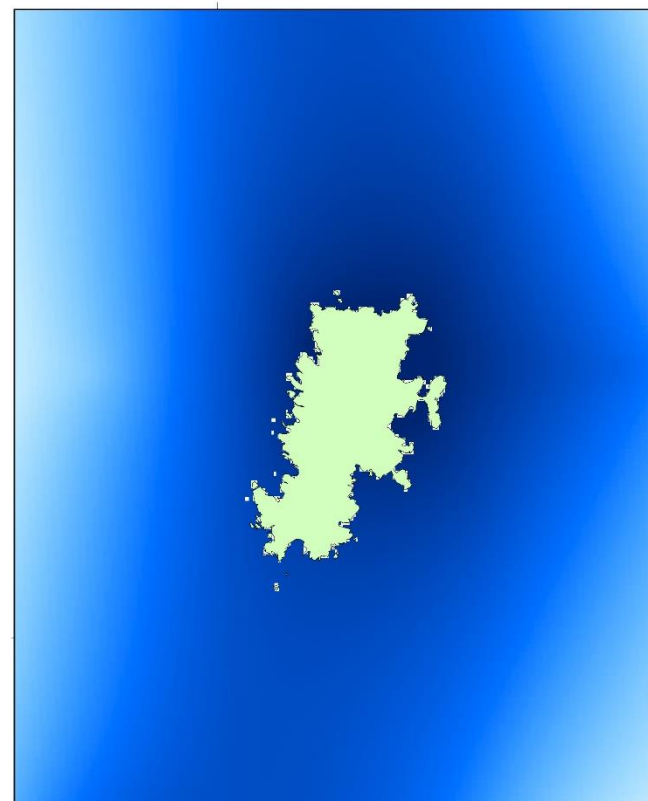
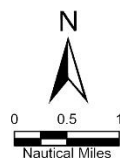
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Benthic Salinity (PSS)



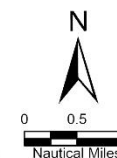
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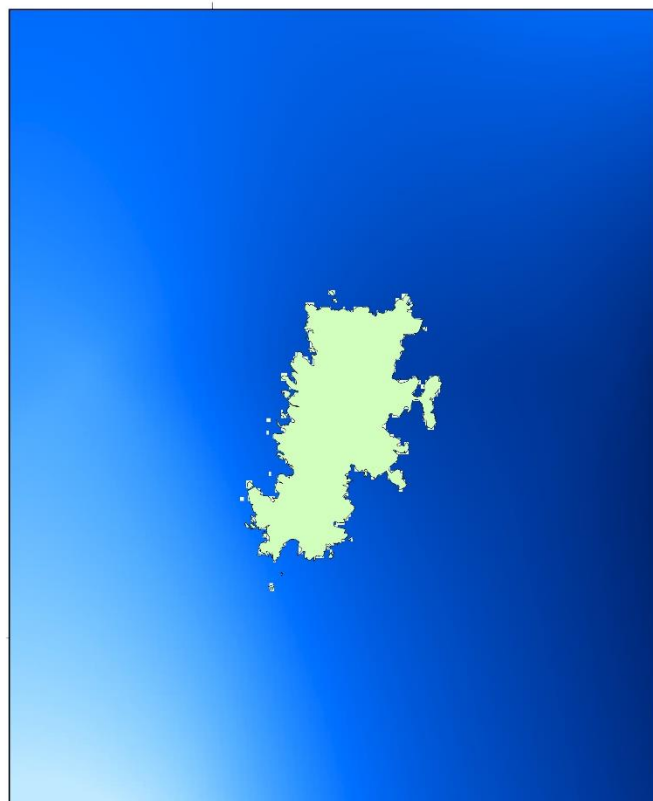


Benthic Temperature (°C)



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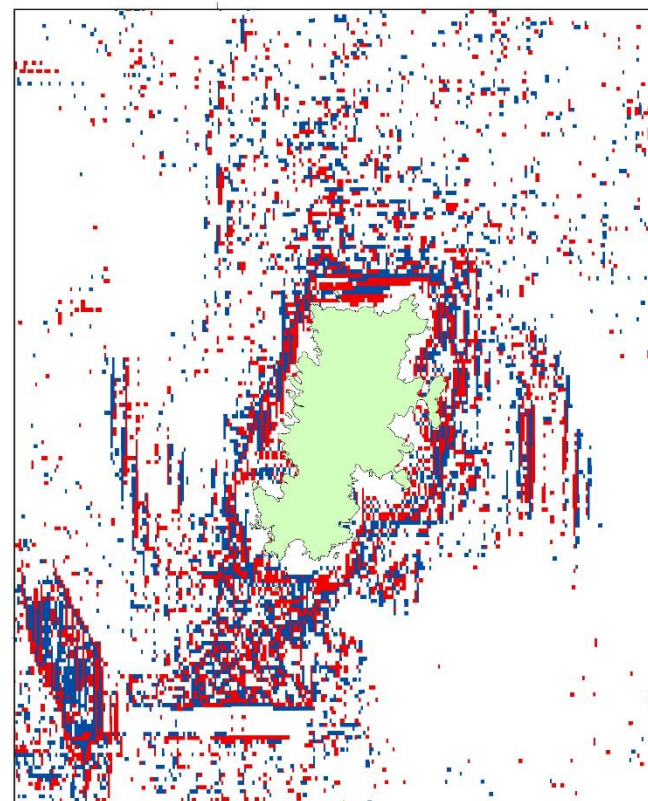
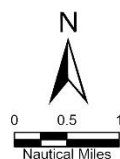




Benthic Velocity (m/s)



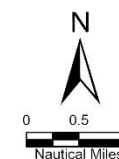
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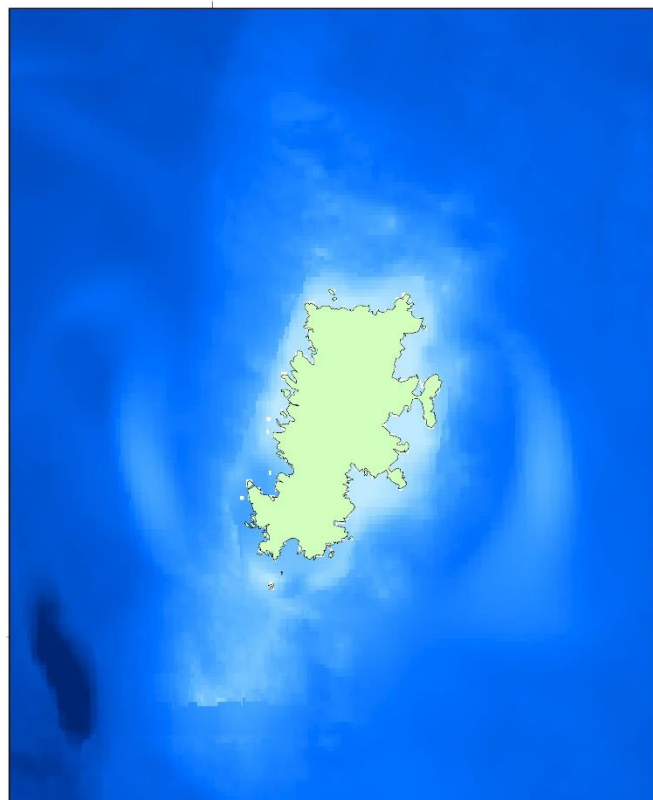


Curvature

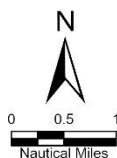


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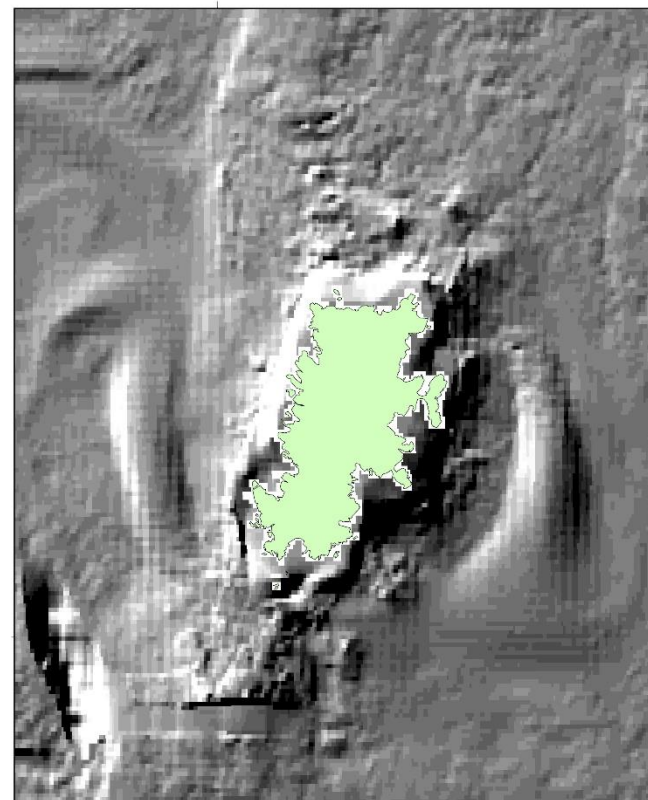




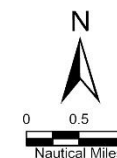
Depth (m)



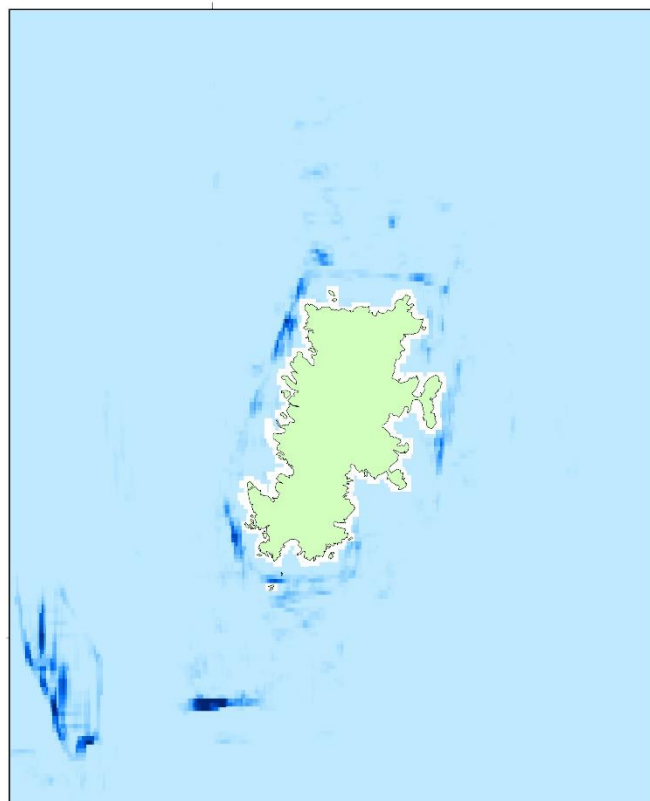
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Hillshade



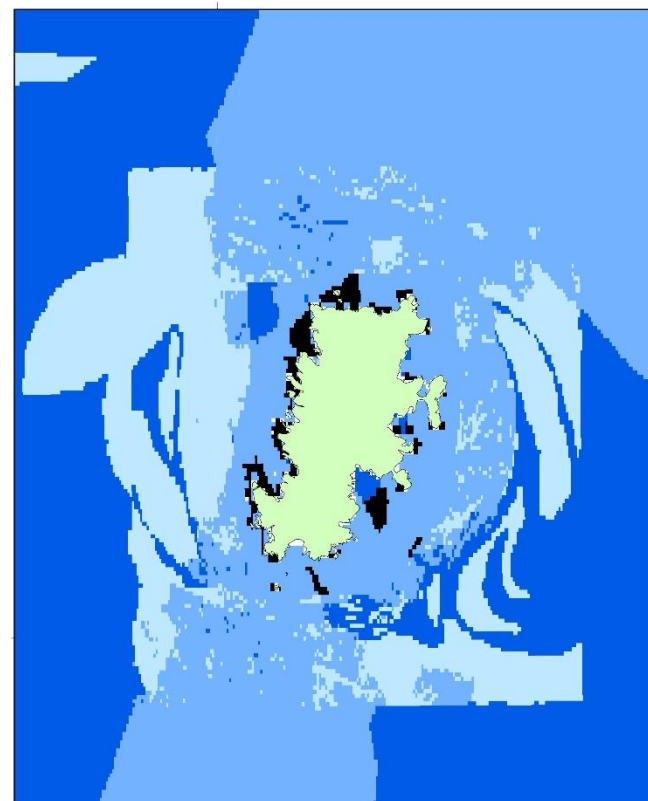
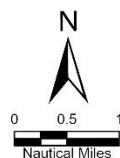
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Rugosity



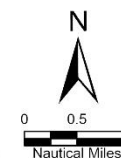
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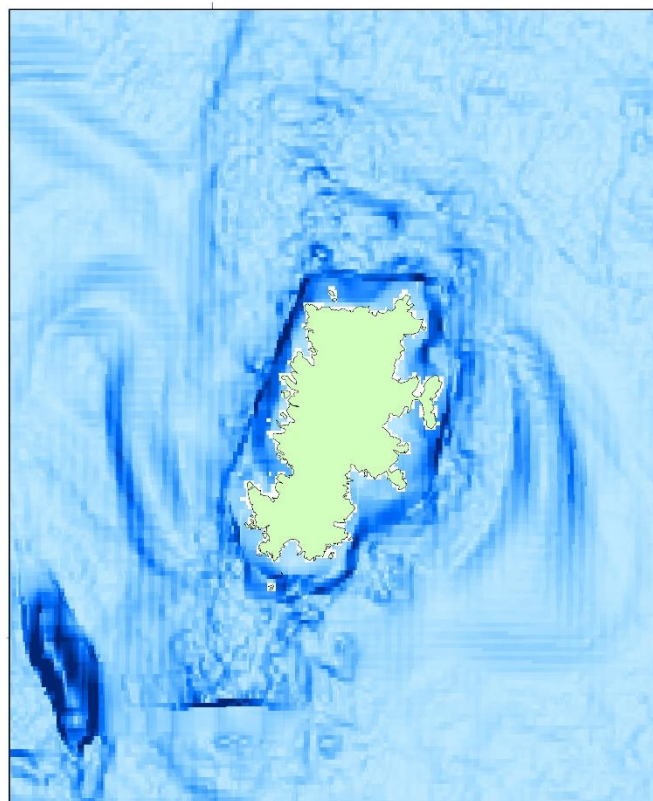


Sediment

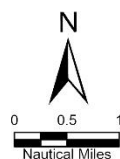


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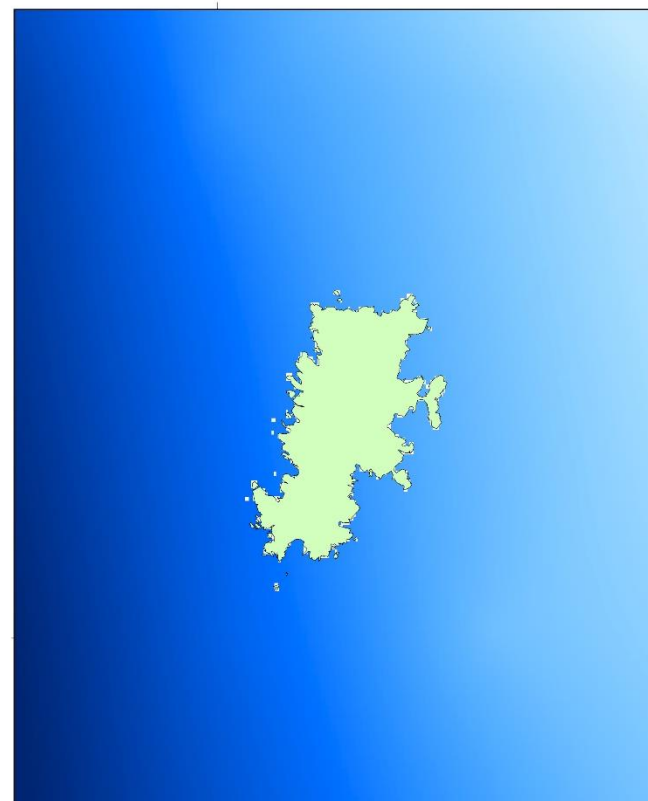




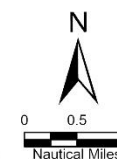
Slope Angle (°)



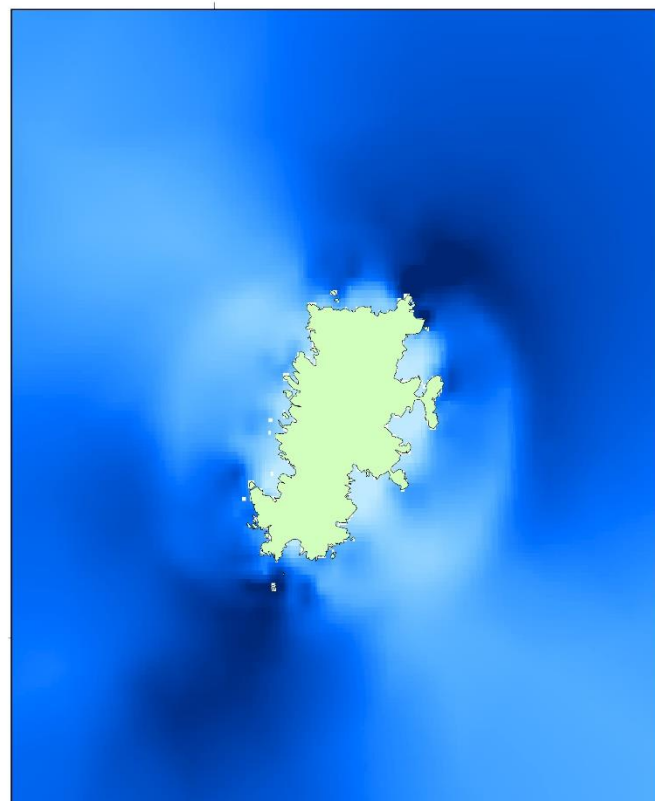
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Surface Temperature (°C)



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Copernicus Marine Environmental Monitoring Service.



Tide (m/s)



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