Appendix 7.1:
Synthesis of Maerl Survey Data

Hellisay Environmental Impact Assessment (EIA) Report

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[redacted]

Contents

1 Introduction

Mowi (Scotland) Ltd proposes to modify the existing fish farm at Hellisay, which has been operating as an Atlantic salmon fish farm since 2011. The main objective of the site modification is to replace the existing infrastructure (12 X 120 m circumference pens) with a new infrastructure configuration (5 x 200 m pens) (the 'modified development'). No change in the existing maximum standing biomass (2,150 tonnes) is proposed.

The site is located within the Sound of Barra Special Area of Conservation (SAC)[1], illustrated on Figure 1. Surveys within and around the site have continually recorded the presence of maerl biotope[2], a component of one of the qualifying features of the Sound of Barra SAC (subtidal sandbanks). A substantial volume of survey work has been undertaken across the fish farm covering predevelopment conditions (2010) until 2021. These surveys confirm the continued presence of a maerl biotope within and around the footprint of the fish farm, comparable to pre-development surveys. Previous studies on the impact of fish farms on maerl, notably Hall-Spencer *et al.* (2006), indicate that organic enrichment arising from fish farms negatively influences the composition of live maerl. Laboratory evidence also indicates that maerl is particularly sensitive to siltation and sediment chemistry (Wilson, 2004)[3].

This report supports Chapter 7: Benthic Ecology, of the Environmental Impact Assessment (EIA) Report and Annex C: Information to Inform a Habitats Regulations Appraisal (SACs) and has been collated to provide further context regarding maerl health and distribution at the site to inform both the EIA and support the HRA process. This report aims to report the trends in maerl distribution and density based on five surveys dating from 2010 (pre-development), through to the most recent survey in 2021. The report also collates and interprets the results of benthic sampling undertaken from 2013 to 2021 to understand wider impacts relating to seabed health. A key consideration in interpreting the surveys relates to the limitations associated with the surveys that have been undertaken to date, and how these limitations may impact overall confidence in any conclusions derived from the data.

The analysis is based on a basic methodology using information derived from maerl surveys and benthic sampling since 2010 to present trends in maerl distribution. It is acknowledged that there are multiple factors that have potential to impact maerl health and distribution at this location, particularly in relation to the unique hydrodynamic characteristics of the site and exposed mega ripple habitat. There are additional insights that could be determined through a rigorous systematic academic assessment of the substantial volume of information gathered to date. Chapter 7: Benthic Ecology of the EIA sets out a series of commitments to undertake further analysis of the substantial body of information gathered to date with an academic partner, in addition to future initiatives to map changes in habitat.

[1] Designation status is Site of Community Importance (SCI which is an adopted cSAC).
[2] SS.SMO.Mrl, probably SS.SMP.Mrl.Pcal.
[3] Maerl was affected by siltation of fine sediments due to the reduction of water movement around the thalli which is likely to limit gaseous exchange with detrimental effects on the algae.

2 Maerl Ecology

Maerl beds refer to free-living coralline algae (*Corallinophycidae, Rhodophyta*), also called rhodoliths, which accumulate on a soft sediment seafloor to form complex biogenic benthic habitats (Foster *et al.,* 2013). Maerl is primarily made up of maerl forming species such as *Phymatolithon calcareum*, but also the less common *Lithothamnion glaciale* in Scottish waters, which may grow as nodules or medallions. Although, *Phymatolithon lusitanicum* has also been recorded in the Sound of Barra (Bunker *et al.,* 2018). The structural complexity of this habitat arises from the creation of numerous ecological niches within interstitial spaces between algal branches or thalli (Hall-Spencer *et al.*, 2006) that can host diverse and abundant benthic fauna communities. These are characterised by a mixture of hard and soft substrate species, as well as rich algal communities (Pena *et al.,* 2014). Maerl can also constitute nursery areas for several fish and shellfish exploited species (Hall-Spencer, 2014). Maerl beds are also highly productive habitats that can be compared to seagrass meadows in terms of their contribution to overall ecosystem function and may play a major role in biogeochemical cycles as significant carbon and nitrogen sinks (Bernard *et al.*, 2019).

The distribution of live maerl is determined by a series of physical conditions including depth (driven by the requirement for light), which usually restricts production to depths less than 32 m in the relatively turbid waters of northern Europe (Haskoning, 2006). However, maerl bed depth range is reported to be 0 – 20 m in the UK (Marlin, 2022)[4]. Maerl also require a degree of shelter from wave action, to prevent dispersal into deep water, but require sufficient water movement to prevent smothering with silt (Hall- Spencer, 1998).

Growth of maerl is slow, with recent studies suggesting that the growth rates of the three most abundant species of maerl in Europe (*Phymatolithon calcareum*, *Lithothamnion glaciale* and *Lithothamnion coralloides*) ranged between 0.5 to 1.5 mm per tip per year under a wide range of field and laboratory conditions (Blake & Maggs, 2003). Subsequently, if maerl is removed or killed it has almost no ability to recover (Marlin, 2022), and is sensitive to a range of physical, biological, and chemical pressures. Studies on maerl tolerance also suggest that fine sediment and lowered oxygen levels are particularly damaging to maerl (Wilson *et al*., 2004). Maerl is also sensitive to physical disturbance and abrasion (Marlin, 2022), and although fragmentation of maerl does directly result in death, subsequent death may arise through reduced water flow (Marlin, 2022) and increased vulnerability to movement and subsequent breakages through wave action.

3 Context

3.1 Designations

The Hellisay Atlantic salmon fish farm is located within the Sound of Barra SAC (Figure 1). The SAC is approximately 12,500 hectares and has been designated for three qualifying features; harbour seal (*Phoca vitulina*), reefs and subtidal sandbanks (sandbanks which are slightly covered by sea water all the time) (SNH, 2019).

Maerl is a component of the qualifying feature of subtidal sandbanks. Maerl beds are listed on Annex 1 of the EU Habitats Directive, classified as a Priority Marine Feature (PMF), and are listed on the Scottish Biodiversity List, the UK Biodiversity Action Plan (BAP) and OSPAR Annex

[4] International analysis of maerl ecology suggest distribution in depths of up to 40 m, with the deepest ranges in Madeira and the Canaries (Hall-Spencer, 2010).

IV. In addition, the main maerl forming species within Scottish waters (*Phymatolithon calcareum* and *Lithothamnion coralloides)* are listed on Annex V of the Habitats Directive.

3.2 Hydrodynamic Characteristics

The site at Hellisay represents a hydrodynamically energetic and complex environment. The area experiences average mean tidal speeds ranging from 5.7 cm/s (near seabed) to 9.1 cm/s (near surface), considered 'moderate' in relation to the other fish farm sites operated by the Developer. However, the site also experiences a substantial contribution of south-southeast swell from the proximity to the Minch, which is further exposed to long-fetch swell generation from the southwest. Image 1 compares the effective fetch of the Hellisay site against five other exposed 'open water' sites operated by the Developer, suggesting that this site is the most exposed site in the Developer's portfolio. In-house monitoring undertaken by the Developer also measured significant wave heights (Hs) of up to 6 m Hs and maximum wave heights of 13 m, with observations of the site under conditions of high swell indicating a substantial backwash component from the coastal cliffs, creating further complexity in assessing directional current and wave propagation movements (L. Stove, 03 March 2022, *Pers. Comm.*).

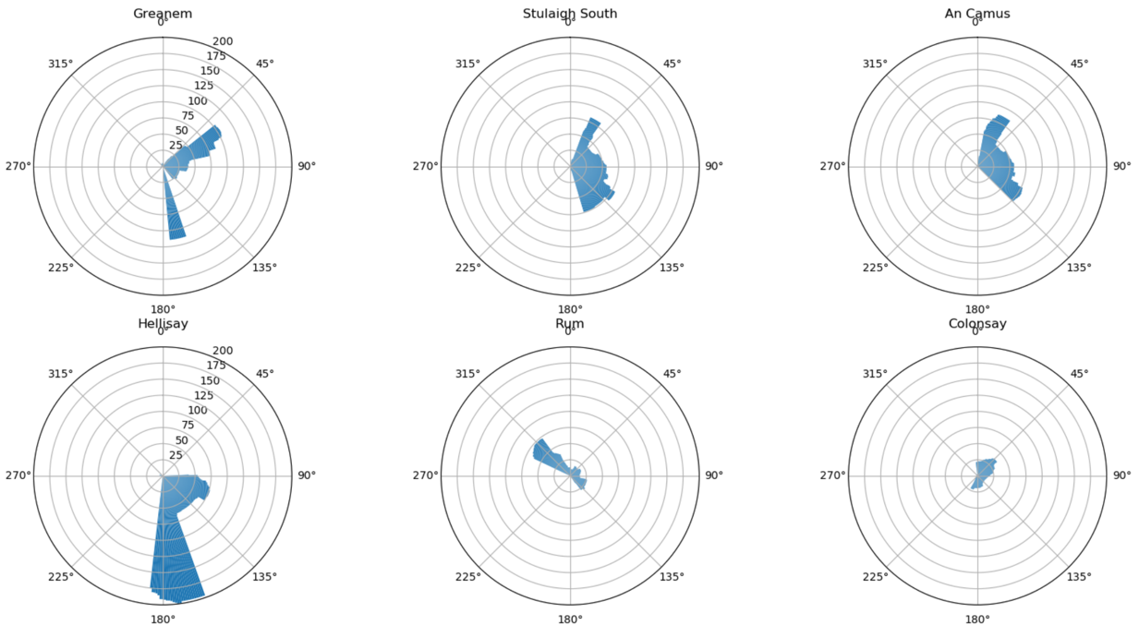

Image 1 The effective fetch lengths[5] at six exposed 'open sea' Mowi sites. Radial values are all the same scale and are in kilometres to facilitate comparison of exposure at these sites.

To illustrate the currents experienced at the site in relation to the immediate surrounding environment, modelled flood and ebb velocity vectors at spring tides are illustrated in Image 2. The modelling provides a visual indication of highly localised current speeds experienced at the site.

[5] Effective fetch length is defined in the Scottish Technical Standard as: *The fetch length will be measured at each of the eight directions at 1° intervals across an opening of ±12°. The effective fetch shall be taken as the median value of each set of 25 measurements for each of the eight directions*"

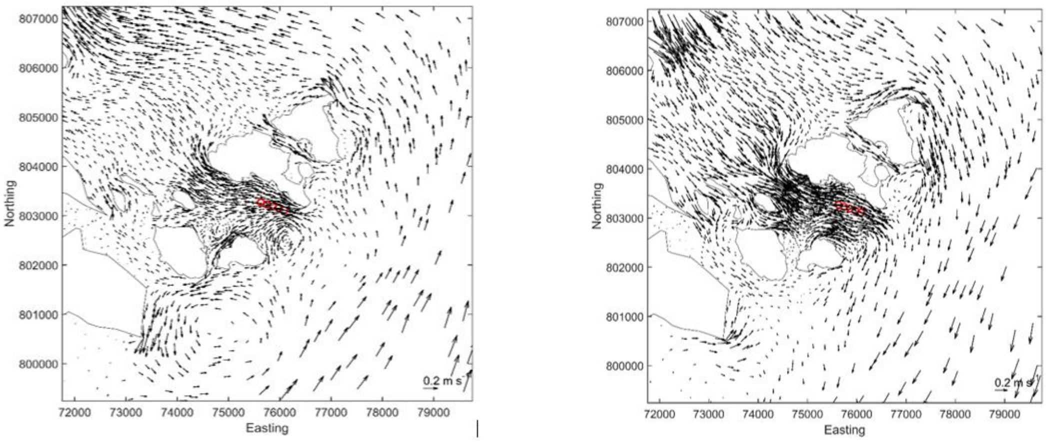

Image 2 Modelled flood (left) and ebb (right) surface current vectors during spring tides (extracted from Appendix 4.10).

3.3 Anthropogenic Activity

Chapter 12: Navigation, Commercial Fisheries and Maritime Users, presents the results of the Automatic Identification System (AIS) transits across the area. Fishing activity for vessels carrying AIS (generally >15 m overall length) in the vicinity of the fish farm mainly comprise dredgers, with an average intensity (hours) of fishing of two days to one week in the area per year from the period 2010 to 2020 (ICES, 2022). There is an overall low level of activity from vessels <15 m length for crab creeling, lobster creeling, scallop dredging, scallop diving, and *Nephrops* trawls around the vicinity of the current site. Fishing intensity is greatest east and south of the Hellisay fish farm. There is an estimated fisheries dredging footprint overlapping the site based on a 2009-2016 dataset (NMPi, 2022), although AIS data suggests and average of <5 transits/week in several areas out with this area and no dredging around the development site itself (NMPi, 2022).

Subtidal sandbanks within the Sound of Barra SAC are classified as ‘unfavourable’ status (NatureScot, 2022) and is reflective of the loss and degradation of seagrass beds and maerl beds within the site. Recent management advice published by NatureScot (NatureScot, 2022) attribute degradation of maerl beds in the outer, eastern part of the site to disturbance by towed bottom-contacting fishing gear and upgrades to Eriskay causeway. Fishing activity data also show a spatial overlap with maerl habitats in this area.

3.4 Hellisay Fish Farm

The fish farm currently comprises of 12 pens of 120 m circumference moored on 26 anchor points and a feed barge with 8 mooring points. Other infrastructure comprises nets, top nets, lighting, and navigational markers; however, these are not considered relevant to this assessment. The site is consented for a maximum standing biomass of 2,150 tonnes. The site infrastructure is currently located approximately 200 m west of its consented location due to on-site decisions implemented by the construction contractor during installation (Figure 2).

4 Methodology

4.1 Benthic Surveys

A total of five benthic surveys have been undertaken and interpreted across four reports (Appendix 7.2 – 7.5). These include one pre-development survey completed in 2010 and subsequent surveys in 2016, 2017, 2020 and 2021. Notably, the 2017 survey extended the 2016 survey which was limited in its coverage beneath the pens. The 2021 survey extended the 2020 survey further east of the original survey area. The 2020 and 2021 surveys were combined due to the short time period and limited change in distribution between the survey years.

4.2 Survey Methodologies

The 2010 survey was based on photographic survey (frame-mounted drop-down camera) with stills acquired every 3-5 m over 100 m transects. Spot photography was acquired at 14 locations approximately 200 m apart to the south and west of the main site. Grab samples (modified 0.1 m^2 Van Veen) were collected in line with the baseline survey requirements for the EIA, current with SEPA guidance at the time.

Subsequent methodologies were broadly similar in equipment and approach, although surveys after 2010 used continuously recorded high-definition video footage, with stills captured every 10-15 seconds instead of drop-down camera. Transect locations and survey area boundaries were also modified depending on the specific objectives of each survey. Figure 3 presents differing boundaries for each survey.

Geophysical side scan sonar (SSS) was acquired in July 2021. The survey lines covered an approximate area of 1.5 km x 1 km. The range was set to 100 m either side of the tow fish which enabled data acquisition below the fish farm cages.

4.3 Substrate

Seabed substrate types were grouped into several broad categories. A system of substrate categories was developed, which was used to delineate the survey area into a seabed substrate map for each survey.

4.4 Maerl Distribution

Photographic stills (2010) or HD video camera footage (2016, 2017, 2020, 2021) were interpreted to record live maerl coverage based on screenshots. The categorisation criteria developed was based on live maerl density and is described in Table 1. Findings were interpolated to generate maerl distribution maps by each density category.

Table 1 Maerl coverage categories (extracted from Benthic Solutions Ltd, 2022)

Representative Image	Live Maerl Coverage	Description
	0%	Dead maerl or gravel recorded.
	<5%	Occasional branches recorded.
	<25%	Maerl aggregations and noted as distinct patches, associated with sediment hollows, ripple troughs or sheltered parts of the seabed.
	<50%	Maerl recorded in foliose form and covering a larger area.
	>50%	Significant coverage by foliose form.

4.5 Benthic Grabs

Infaunal sampling (cores / grabs) are thought to provide a reasonably accurate method to determine overall seabed health. Both compliance and in-house benthic samples are assessed in Section 5.3 to determine seabed health. Pre-development (2010) and collated benthic samples from 2013 to 2022 are illustrated on Figure 4, colour coded for each ecological status class based on the Infaunal Quality Index (IQI) category (Environment Agency, 2012). Figure 4 also shows the locations of in-house grab samples taken in 2018 (assessed for species abundance only).

Although there is a detailed record of grab samples since 2013, until 2022, these were spatially confined to two transects orientated to the west and southwest of the site due to the extent of hard substrate across the site and limitations with the original modelling software for energetic environments. Detailed bedrock mapping undertaken in 2022 has enabled grabs to be located in discrete areas of soft substrate between outcrops of reef and bedrock and provides a more complete picture of the seabed health.

4.6 Analysis

Maerl Distribution

To provide a basic characterisation of changes in distribution since the baseline survey in 2010, the area of maerl coverage was calculated by each individual density category and compared by year. The survey areas have varied over survey years, and to maintain consistency when calculating changes in maerl area, all shapefiles were 'clipped' against the 2018 survey boundary, selected as being the most representative area across all the surveys. Figure 3 illustrates the different survey boundaries adopted over each survey campaign.

Following the results of side scan survey outputs undertaken in 2021, accurate mapping of extensive swathes of bedrock was possible, in contrast to interpolation methods undertaken previously. The maerl biotope is not compatible with the bedrock biotope (instead limited to mega-rippled coarse sand habitat), and the bedrock mapping exercise highlighted limitations to previous mapping / interpolation exercises for surveys undertaken previously which mapped maerl biotope in areas of incompatible bedrock areas.

Given the extent of the interpolation limitations associated with previous maerl mapping, all maerl layers, across all years were clipped against the accurate bedrock mapping derived from side scan sonar surveys. The area of each 'clipped' interpolated maerl density shapefile was calculated to provide a basic indication of maerl distribution by survey.

Carbon Deposition Impacts

To support the impact assessment, NewDepomod modelling was undertaken to model the carbon deposition footprint across consented, existing and proposed footprint (see Section 3.4). The detailed methodology for deriving the carbon deposition footprint is provided in Appendix 7.8: Waste Solids and In Feed Deposition Modelling. Figure 5 illustrates the modelled carbon deposition footprints against benthic grab data.

Habitat Quality

An interpretation of habitat quality was undertaken based on a literature review of maerl habitats.

5 Results

5.1 Substrate

Surveys undertaken since 2010 consistently identified five main habitats across broadly similar survey areas: exposed bedrock, mixed sediment, coarse sand, gravels, and fine-medium sand. Figure 6 illustrates the substrate mapping for all surveys[6].

[6] Note only the 2020/21 survey represents the accurate distribution of bedrock following SSS surveys in 2021.

Surveys consistently recorded swathes of exposed bedrock in all directions around the fish farm, which are noted to support a diverse epifaunal community. Recent side scan sonar mapping undertaken on 22 July 2021 has – for the first time since surveys were initiated in 2010 – provided an accurate picture of the nature and extent of the bedrock / reef formations. The bedrock formations were assessed as areas of 'reef', a qualifying feature of the Sound of Barra SAC (Chapter 7: Benthic Ecology).

Coarse rippled sand is continually well represented across the surveys and is associated with a 'mega ripple' form with accumulations of maerl, detritus and other coarse material in the troughs. Surveys conclude that materials deposited in this area are transitory before being subject to further dispersive forces. Other substrate categories include fine-medium sands, classified as 'lower energy sand' found to the south and west of the site, often sub-cropped by mixed sediment. Pebbles and cobble pavements are located to the northwest of the survey area and may show red encrusting algae. Mixed sediments comprised thin mobile sands underlying mixed gravels and shell and were common over most of the survey area.

5.2 Maerl Distribution

Processed maerl distribution layers were calculated by density layer and year to provide an indication of key trends in maerl distribution by density (in line with the criteria provided in Section 4.4). Figure 7 illustrates the *unprocessed* maerl density categories by year. To allow a direct comparison between years and identical boundaries, all the shapefiles were 'clipped' against the 2018 survey area, selected as being the most representative across all the surveys (survey boundaries illustrated in Figure 3). Table 2 provides a numerical comparison of the changes of the areas of maerl density by year between 2010 (pre-development) and subsequent surveys up to 2021. These are also illustrated on the graphs in Image 3. It is important to reiterate that the original maerl data layers have also been processed to remove maerl overlapping accurately mapped bedrock features following side scan sonar surveys undertaken in 2021 (Section 4.4).

Table 2 Summary of maerl density distribution by year. Coloured entries reflect highest values and lowest values recorded in each survey.

Survey Year	Total Area of Maerl (over 50%) 'High' Density	Total Area of Maerl (25-50%) 'Moderate to High' Density	Total Area of Maerl (5-25%) 'Moderate to Low' Density	Total Area of Maerl (0-5%) 'Low' Density	Total Coverage
2010	838 m²	1,761 m²	6,240 m²	176,093 m²	**184,932 m²**
2016	314 m²	4,010 m²	60,442 m²	223,266 m²	**288,032 m²**
2017	139 m²	5,784 m²	73,692 m²	315,559 m²	**395,174 m²**
2020/2021	603 m²	11,703 m²	76,880 m²	291,209 m²	**380,395 m²**
Percentage Change Since 2010	**- 28%**	**+ 664%**	**+ 1,232%**	**+ 165%**	**+ 205%**

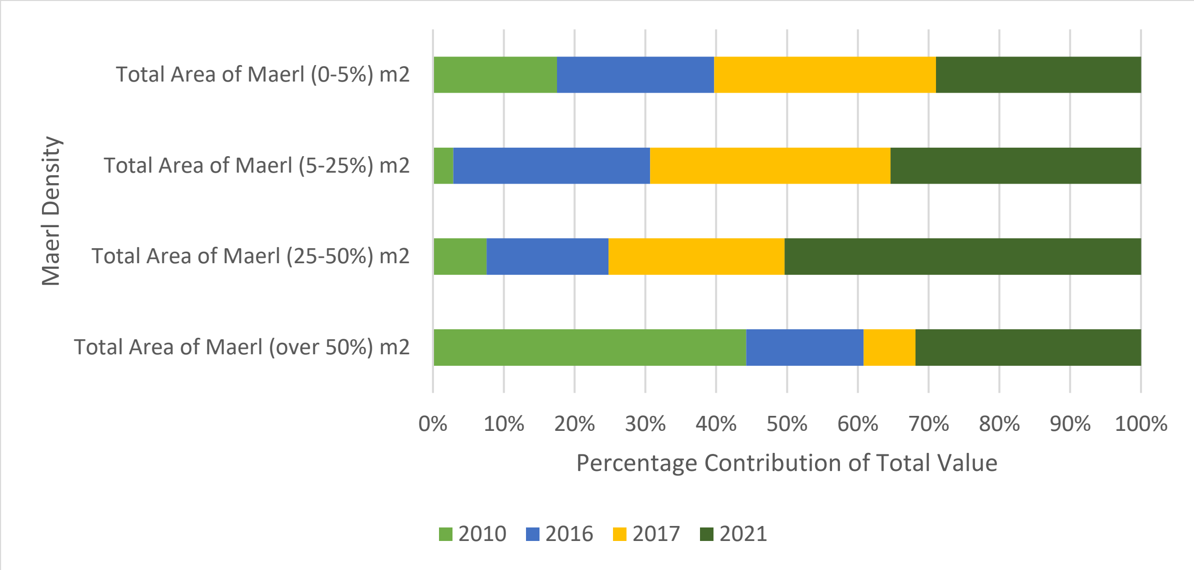

Image 3 Comparison of maerl density by year as a percentage contribution to the total value by density category.

- **High Density Maerl Distribution (> 50%)** - Figure 8 and illustrate the change in high density maerl distribution from 2010 to 2021. In 2010, three large high-density patches are recorded to the northwest of the pen group. In 2015, the high-density patches have disappeared and instead several small patches are recorded distributed to the northwest of the existing pens. In 2021, a series of high- density patches are recorded to the northwest and intermittently to the north. The overall change from 2010 to 2021 of this maerl density category is a reduction of 28% coverage (838 m^2 to 603 m^2).

- **Moderate Density Maerl (25% - 50%)** - Figure 9 illustrates the change in moderate density maerl distribution from 2010 to 2021, the calculated area change of coverage is also provided. In 2010, moderate density maerl was closely associated with the lee of bedrock under, and to the northwest of the actual pen locations. In 2015 /2017, these areas are scattered to the northwest of the pens with minimal evidence of this density category beneath the pens. By 2021 numerous patches are scattered across the north and northwest of the pens, with additional areas recorded to the southwest. The change of the distribution of this density category is a 664% increase in coverage since 2010 (1,761 m^2 to 11,703 m^2).

- **Moderate to Low Density Maerl (5% - 25%)** - Figure 10 illustrates the change in the moderate to low density maerl distribution category from 2010 to 2020/2021. Since 2010, the extent of area occupied by this density category has substantially extended to the northwest. The area of moderate to low density maerl has substantially increased from 6,240 m^2 to 76,880 m^2, an increase of 1,232 %.

- **Low Density Maerl (<5%)** - Figure 11 illustrates the change in low density maerl distribution from 2010 to 2020/2021. The area of low density maerl has grown from 2010 peaking in 2017, with a slight reduction (7.72%) in area in 2021, compared to 2017. However, overall, there has been an increase in area of 165% from 176,093 m^2 in 2010 to 291,209 m^2 in 2021.

Overall, maerl surveys from 2010-2021 show substantial oscillations in the distribution of live maerl across the site. In comparison to the 2010 (pre-development) survey levels, maerl coverage has increased across all density categories, with exception of the highest (>50%) density category, which has decreased in coverage by 28% since 2010. However, the current coverage of high density maerl represents an increase of 464 m^2 since the lowest levels were recorded in 2016[7]. Overall coverage of maerl (the total area of maerl recorded in each year) was greatest in 2017, and in recent years there has been a slight reduction in overall maerl coverage between 2017 (395,174 m^2) to 2021 (380,395 m^2).

Carbon Deposition Footprint

A visual assessment of maerl distribution against the existing modelled carbon deposition (Figure 12) footprint suggests that overall maerl distribution has expanded into areas with the highest modelled carbon deposition footprint, although the high-density patches of maerl appear to have decreased in these areas. Maerl continues to occupy the areas modelled to experience the higher rates of carbon deposition, although the density of these areas has reduced in some cases.

5.3 Maerl Health

Compliance Grab Sampling

Collated benthic samples from 2013 to 2022 are illustrated on Figure 4, colour coded for ecological status class based on the Infauna Quality Index (IQI) category (Environment Agency, 2012). Until 2022, benthic grab samples undertaken for compliance monitoring were based on two transects which have been continually sampled on a westerly and southerly orientation across 16 grab locations and four reference stations. Accurate mapping of bedrock outcrops has enabled areas of soft sediment within the site to be identified between the hard substrate areas and have provided a more complete view of seabed health (Figure 4).

The most recent compliance report (January 2019) indicates that enrichment, evidenced by high faunal abundance was highest at the pen edge, and was accompanied by the lowest diversity with six species accounting for 6,856 individuals. Degraded ITI scores on the westerly transect continue to 55 m from the pen edge. Similarly, diversity results also fell short of the compliance standards within the Allowable Zone of Effect (AZE); however, were satisfactory 10 m from the AZE when directly compared to three of the four reference stations.

Additional Grab Samples

Five grab samples were gathered in 2018 which were analysed for benthic fauna (Figure 4). Results were undertaken with metrics reported on species abundance only (Appendix 7.4b). All stations showed a high species richness, the number of taxa ranging between 18 to 154. The numbers are comparatively high and show diversity of organisms within the habitat. Many of the species confirm the predominant sediment type within the area, rather than soft deposition mud that would be expected below fish farm pens.

Species identified in these samples include Annelida species such as *Syllis armillaris,* which are normally found in coarse sand/shell habitat, were found directly below the pens in the middle of the group. Other species including *Galathowenia oculata, Lagis koreni, Spirobranchus*

[7] Note however, there were several areas within the survey boundary omitted from survey in 2016 due to survey limitations, which were subsequently covered in the 2017 survey.

triqueter and *Phyllodoce mucosa*, were also recorded. These species are sensitive to smothering and indicative of sandy habitats. They are not associated with fine sediment habitats normally found below fish farm pens. Other species of Porifera (sponge), which do not thrive in high siltation environments, are present across the survey area, as is the tube anemone *Cerianthus lloydii* and the Sipunculid *Thysanocardia procera*.

A high diversity of crustacea species was identified with 50 separate species of crustacea identified across the five grabs. A similar diversity and abundance can be seen for the molluscs on site, with 62 individual species and mollusc egg sacs present, indicative of a healthy, normal community and some showing markedly prominent levels of abundance. These species are generally intolerant to smothering and indicative of good seabed health and faunal diversity.

Observations
SEPA compliance record reports for the following dates were reviewed for observations of enrichment (*Beggiatoa*, feed pellets and faeces):

- 15 October 2019
- 16 March 2018
- 28 October 2015
- 17 June 2014

No record of smell, gas, fungus, or waste were noted at any station.

A review of benthic survey reports covering the 2016, 2017 and 2020/21 survey campaigns was undertaken to identify any records of enrichment, including evidence of faecal pellets. One survey report published in 2018 covering the 2017 survey campaign, observed organic derived fines (with faecal pellets) near the feeding barge, where the sediment was composed of fine to medium sand. No other visual evidence of enrichment was recorded in any of the surveys. However, deck logs from the recent benthic survey undertaken in 2022 record olfactory observations of anoxia from some samples subsequently recorded as degraded.

6 Data Gaps and Uncertainties

There are several limitations that require consideration when drawing conclusions from the available data. A more comprehensive discussion of these limitations is provided in Chapter 7: Benthic Ecology, summarised below:

- **Hydrodynamic variables** - the site shows clear evidence of substantial temporal change and sediment re-sculpting over time. The nature and frequency of sediment movement is unknown and generates substantial uncertainty in relation to attributing changes in maerl distribution to other variables e.g., impacts associated with the fish farm.
- **Survey methodology and interpolation** - recent detailed mapping of exposed bedrock areas, mapped against previous interpolated maerl distribution maps illustrates anomalies in interpolation methodology.
- **Maerl density records** - surveys noted that estimating the distribution of maerl from survey findings is open to error. The mega ripple form of the main maerl biotope on coarse sand resulted in localised accumulations of maerl in troughs of the mega ripples. Camara footage and image field of views occasionally focused on the ‘peak’ or a trough of a mega ripple, underestimating or overestimating the presence of maerl.

- ***Survey Methodology (maerl categorisation)*** - categorisation of the relative abundance of live versus dead maerl enables determination of the impact of a particular pressure(s) on existing maerl beds. If impacts from a fish farm (e.g., abrasion, carbon deposition) are impacting maerl health, higher relative densities of dead maerl to live maerl would be indicative of these impacts. In the surveys undertaken at the site, live maerl only was measured as a percentage component of sediment type, limiting a full analysis of impact.

7 Interpretation

7.1 Maerl Distribution

Maerl surveys from 2010-2021 show an oscillating distribution of live maerl across the site, with both density and distribution closely associated with a 'mega ripple' habitat, as part of the coarse sand biotope. The overall distribution of maerl has increased since 2010 in all but the highest maerl density category (>50%), which experienced a 28% reduction of coverage between 2010 and 2020/21. However, distribution mapping also suggested a substantial increase of coverage of this category in 2017, although the particularly low coverage in 2016 is likely to be influenced by incomplete survey coverage due to vessel limitations.

In total, there has been an overall increase of maerl coverage (across all density categories) of 205%. The increases of maerl coverage observed in the surveys cannot be attributed to growth rates of maerl due to its slow growing nature (Wilson *et al*., 2004), but instead suggest that maerl is likely to be transported from other sites. This observation is consistent with research of maerl accumulation around a fish farm in Shetland (Hall-Spencer, 2007), which also identified maerl associated with mega rippled seabed habitats. This research suggested that live maerl may be transported into the area during rough weather and highlighted that maerl fragments are often transported in and out of the area during storm events, also consistent with the exposed nature of the site at Hellisay.

Survey observations consistently describe the distribution of maerl within the troughs of mega ripples in the coarse sand habitat and less frequently on the peaks (Image 4Image 4 Left - example live maerl coverage in the troughs of mega ripples (<5%). Images extracted from 2016 Survey (Appendix 7.3). Right - example image of the depth extent of mega ripples.
). Live (and dead) maerl tended to be more abundant in the troughs where maerl thalli accumulate together with other coarse material and foliose algae detritus. Maerl was also observed to accumulate in the lee of bedrock outcrops, suggesting hydrographic characteristics also have a definitive role in determining the distribution of maerl on site.

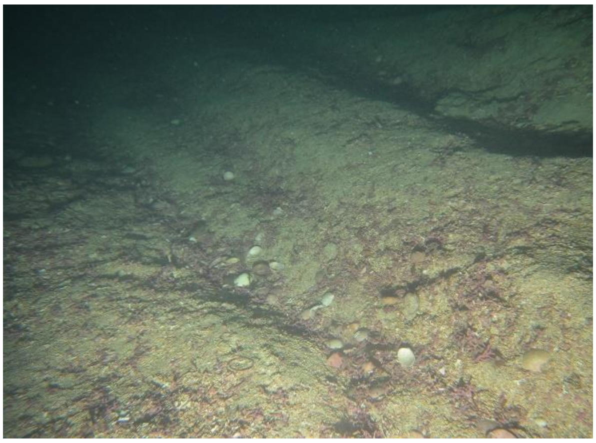

Image 4 Left - example live maerl coverage in the troughs of mega ripples (<5%). Images extracted from 2016 Survey (Appendix 7.3). Right - example image of the depth extent of mega ripples.

Carbon Deposition Modelling

In comparing the maerl distribution with the existing modelled carbon deposition footprint, maerl continues to be present in areas subject to modelled areas of high carbon deposition (deposition levels up to 250 g / m^2). Figure 12 illustrates the existing 250 g/ m^2 deposition contour against recently surveyed maerl density categories illustrating that low density maerl continues to occupy substantial areas of areas modelled to experience high deposition. The continued presence of live maerl within an area modelled to experience high levels of carbon deposition is unusual, particularly over the length of operation of the site (10 years). The impacts of fish farm siltation on maerl are well established (Hall-Spencer, 2007), and other studies indicate a range of detrimental impacts on maerl from impacts associated with fish farming (Marlin, 2022). The continued presence of live maerl in these areas suggest that one or more of the following factors may be influencing the continued presence of maerl:

- **Rapid resuspension of carbon** - deposits of carbon are more rapidly flushed out / resuspended than suggested by modelling. Although some settlement may occur (most likely during slack tides), current speeds may be sufficient to remove settled material before maerl is impacted. Studies suggest that maerl can survive extended periods of time under buried sediment depending on the nature of the sediment (Marlin, 2022) and it is possible that these resuspension events occur at a frequency which supports the ongoing survival of maerl.
- **Maerl fragment transportation** - maerl accumulations at the site may be transitory, and any maerl potentially damaged by siltation may be transported out of the site. Hydrodynamic modelling suggests that material may be transported into the site from the southeast and transported out of the site to the northwest. However, the flood and ebb modelling (Image 2) suggests relatively low current speeds in the Minch, and maerl transport events are likely to be limited to storm events rather than frequent movements.
- **Other hydrodynamic complexities** – the area is subject to a complex interaction of wave, tide and refraction processes which may not be fully captured in the model.

High Density Maerl

Two areas of high density maerl identified from the 2010 baseline survey were previously thought to be static maerl bed habitat. Interest from statutory consultees (Chapter 7: Benthic Ecology) has focused on these patches of high density maerl, thought to represent maerl as a component of the 'sandbank' qualifying feature of the Sound of Barra SAC. The extent of the patches identified in 2010 has substantially decreased following the application of detailed bedrock mapping, and the original extent of the habitat may be an overestimate generated as an artefact of interpolation given the incompatibility of the maerl biotope with bedrock. However, fragmented patches of high density maerl continue to be mapped adjacent to areas of bedrock areas over each of the survey, possibly representing an accumulation of material as static features.

Photograph stills were requested from the 2018 survey at Grab 11 (Image 5), located at the approximate area of the high-density maerl patches (Image 6) and modelled area of high carbon deposition. Images of the still photographs show the typical coarse sand habitat and mega ripple topology, with evidence of live maerl accumulation. There is also an accumulation of smaller dead maerl fragments apparent on the 'peak' of the mega ripple formation. There is very little evidence of siltation, although there appears to be dead maerl evidence on the peaks of the ripple formations.

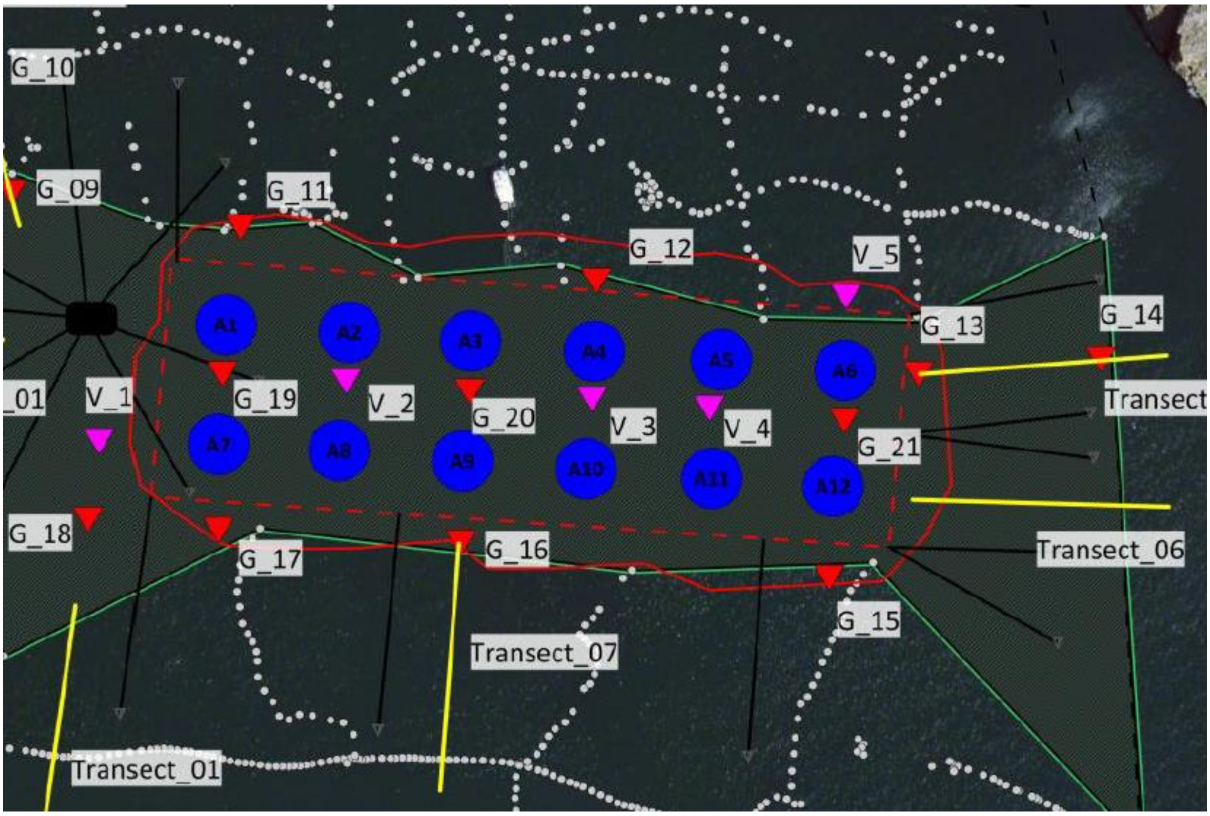

Image 5 Extract of the camera transects and grab locations undertaken for the 2018 survey. G-11 is located at the approximate area modelled to be subject to high carbon deposition and in an area of high density maerl deposition.

Image 6 Still photographs from camera transects at G_11, provided by Benthic Solutions Ltd via Mowi (Scotland) Ltd.

Given the hydrodynamic nature of the site and evidence of continuous sediment re-working, limited conclusions can be drawn from changes in density and distribution of maerl recorded across the survey period. Limitations with the survey, notably the restriction of observations to live maerl only, limits understanding of potential impacts generated by external factors, including the fish farm. Other issues around interpolation and mapping of maerl further reduce confidence in drawing detailed conclusions on the impact of the fish farm on maerl habitat beneath the site. Despite these limitations, broad interpretation of the findings of the surveys over time suggest that a live maerl habitat continues to successfully coexist with the fish farm, with substantial increases in coverage across all but one density category (the > 50% high density category) recorded.

7.2 Maerl Health

Several metrics were identified and explored that can provide useful indicators of seabed health as a proxy for understanding impacts on maerl. These include observations of enrichment, benthic health and habitat quality described below.

Observations of Enrichment

None of the SEPA compliance reports reviewed reference any observations of enrichment i.e., *Beggiatoa* mats, food pellets and other evidence of farm impacts (faeces, bubbling, anoxia). However, a review of benthic survey results indicated that an isolated record of food pellets was observed during the 2018 survey. These observations are limited to the southwest of the pens and in the fine sand habitat, which is not consistent with the maerl biotope. However, deck log observations from the 2022 benthic grab survey do record some olfactory observations of anoxia associated with grabs; although, these are limited to westerly transects. The absence of clear visual evidence of enrichment in areas of maerl habitat distinguishes the Hellisay site from previous research undertaken to determine impacts on maerl from fish farms which routinely observed clear evidence of anoxia, pellet / faeces and *Beggiatoa* (Haskoning, 2006).

Benthic Health

Pre-Development

Pre-development surveys undertaken in 2010 and analysed based on the Infaunal Trophic Index (ITI) recorded benthic samples as 'modified' only (Figure 4). Maerl bed communities typically show higher diversity and abundance of infaunal and epifaunal species than those of more common benthic communities (Bates *et al*., 2004). Studies in Scotland indicate (Haskoning Ltd., 2006) that in undisturbed maerl beds, the number of benthic macrofauna species ranged between 55 and 164 per 0.1 m^2 across three sites in Uist, Orkney and Shetland. However, site condition monitoring undertaken in Barra indicates that the richness of taxa within the Sounds of Barra maerl beds were slightly on the low side compared with other locations with a range between 43 – and 74 taxa, compared to averages between 56 and 122 species described in other studies assessing maerl in Scotland (Moore, 2011 cited in SNH, 2018).

The number of benthic macrofauna in the study area at Hellisay recorded in 2010 suggest that the habitat is already poor and / or mobile. There was either no presence of larger, slower growing species e.g., molluscs, or where present, these species were represented in low numbers e.g., *Ensis* or *Parvicardium* spp. Overall, the baseline survey conducted at Hellisay in 2010, suggested that the benthic community would be considered 'impoverished' in terms of diversity and abundance, particularly so if the area was to be viewed as a maerl habitat (Appendix 7.2).

Post Development

Since construction of the farm, a compliance sampling regime has generated a chronological dataset of benthic compliance samples across two transect locations up to 2019. More recently, benthic sampling has provided – for the first time – an indication of benthic health beyond these two transects which were previously limited by the extent and distribution of hard substrate across the area (Figure 3). Further in-house benthic samples were taken in 2018 across the central area of the site (Appendix 7.4b, Figure 4). A full analysis of IQI was not undertaken and species abundances only were recorded; however, results indicated that much of the seabed beneath the pens remains healthy with a range of siltation intolerant species present.

Compliance monitoring undertaken since 2013 indicates that areas of enrichment have previously been identified to the south and west of the site. Observations from surveys also identify enrichment at locations around the feed barge to the west of the site, also consistent with observations in the 2018 survey (Appendix 7.4). Recent benthic samples (2022) now cover a wider range of orientations around the site and indicate that areas of enrichment continue to be present to the west of the site within a narrow zone of impact adjacent to, and west of the pens. However, a possible new area of enrichment[8] is identified in two areas to the north at samples locations at the pen edge only. Beyond the pen edge, benthic samples are immediately classified as 'moderate' to 'high'. It is notable that no samples with an IQI score below 'moderate' were taken from the east of the site and several areas with degraded IQI scores were co-located in areas mapped with low densities of live maerl. The limited areas of enrichment are broadly consistent with the 250 g m^2 carbon deposition contour (Figure 5).

Habitat Quality

The ecological niche maerl forming species *Lithothamnion corallioides* and *Phymatolithon calcareum* is relatively narrow and subject to a balance of factors. The benefits of moderate current and wave action are impacted by contrasting, but related conditions created by sedimentation and turbidity, limiting spatial distribution of these species in shallow coastal temperate waters.

[8] At the time of writing the accompanying survey report was not yet available.

The distribution of live maerl is also limited by depth (driven by the requirement for light), which usually restricts production to depths less than 32 m in the relatively turbid waters of northern Europe (Haskoning, 2006). Although, maerl bed depth range is reported to be 0 – 20 m in the UK (Marlin, 2022). The Hellisay site is located within a deeper channel within the sound of Hellisay, with a maximum survey depth of 28 m, suggesting that while maerl can survive at these depths, the area sits at the upper end of the range where beds would normally occur.

Maerl also require a degree of shelter from wave action, to prevent dispersal into deep water, but require sufficient water movement to prevent smothering with silt (Hall- Spencer, 1998). The site occupies a 'moderately flushed' tidal site like sites assessed in Haskoning (2006); however, the level of wave exposure is substantially higher, and the interaction of wave / current action is evidence by furrowed mega ripples, and substrate composition. The nature of the habitat has informed previous assessments of the site. The findings of the Appropriate Assessment conducted as part of an application for planning permission[9], taking advice from NatureScot (SNH) and SEPA, states:

> *"The conclusion reached on appraising the seabed surveys was that the majority of the maerl present within the vicinity of the proposed fish farm is of insufficient quality to be considered an established maerl-bed. This is reflected in the sparseness of the infaunal communities found within this habitat….*
>
> *It is likely that the maerl found in the sand ripples has been transported there from areas with established maerl-beds. The hydrographic data collected by the applicant showed the major current direction to be to the south-east. Therefore, in relation to the conservation objectives 'distribution of the habitat' and 'viability of typical species as components of the habitat', the poor-quality areas of maerl are unlikely to be acting as a source population to the small high quality maerl-beds."*

The evaluation undertaken in 2011 corresponds with the visual observations of maerl distribution and transport. Comparative analysis of distribution between each survey year confirms changes in maerl distribution that cannot be attributed to growth.

Hydrodynamic Characteristics

The maerl present at Hellisay occurs as mobile mega ripples, and not as a typical static maerl bed. Studies of an open bay maerl bed in the Firth of Clyde showed that high near-bottom turbulence during occasional storms flushed-out fine particulates and re-sculpted the maerl bed topography into a series of mega ripples". Hellisay has very high wave exposure and is frequently subject to storm event conditions; combined with a lack of build-up of organic particles around the site, it is likely that the area is being flushed as evidenced by the occurrence of mega ripples.

[9] Planning Application Reference 10/00430, Appropriate Assessment by CnES (4/11/2011).

8 Conclusions

Maerl distribution and density at the current operational fish farm at Hellisay has been mapped and interpreted over five surveys and presented in four reports. Pre-development surveys evaluated the habitat as a relatively impoverished example of a maerl community, due to the mobile nature of the substrate. Since 2012, a fish farm has been continuously operated on site with a maximum consented biomass of 2,150 tonnes.

Analysis of changes in maerl distribution and density suggest a fluctuating distribution of live maerl, with both density and distribution closely associated with hydrodynamically reworked 'mega ripple' habitat, as part of the coarse sand biotope. In total, there has been an overall increase of maerl coverage (across all density categories) of 205%, although the percentage coverage of the highest maerl density category has decreased by 28%. The increases of maerl coverage observed in the surveys cannot be attributed to growth rates of maerl due to its slow growing nature (Wilson *et al*., 2004), but instead may suggest that maerl is transported from other sites.

Carbon deposition modelling indicates the continues presence of live maerl within areas modelled to experience high levels of carbon deposition (within the 250 g/ m^2 carbon deposition contour). Benthic sampling indicates that there are areas to the west and south which have continually been recorded as experiencing enrichment, there are also two areas recently sampled to the north which show degraded fauna and are also assumed to be enriched. However, a number of samples extracted from beneath the pens in 2018 show a diverse species composition with a range of siltation intolerant species. It is notable that out of the four transects where enrichment is identified, three of the degraded samples are co-located with live maerl habitat (<5% density).

It is not clear why maerl continues to co-locate with areas of high modelled deposition, and the continued presence of maerl conflicts with assumptions of established impacts of fish farms on maerl. Research indicates that maerl can survive extended periods of time under burial depending on the nature of the sediment (reviewed in Marlin, 2022) and it is possible that resuspension events occur at a frequency which supports the ongoing survival of maerl. Similarly, maerl accumulations at the site may be transitory. Hydrodynamic modelling suggests that material may be transported into the site from the southeast and transported out of the site to the northwest, although transport events are likely to be limited to storm events rather than frequent movements.

The variables influencing maerl health and distribution in the complex hydrodynamic environment experienced at Hellisay are not fully understood; however, it is apparent that the operational fish farm appears to co-locate with the maerl habitat. The increased coverage of maerl distribution at the site cannot be attributed to the natural growth of maerl, and it is highly likely that transportation combined with sediment resuspension processes are the key factors driving distribution of maerl at the site.

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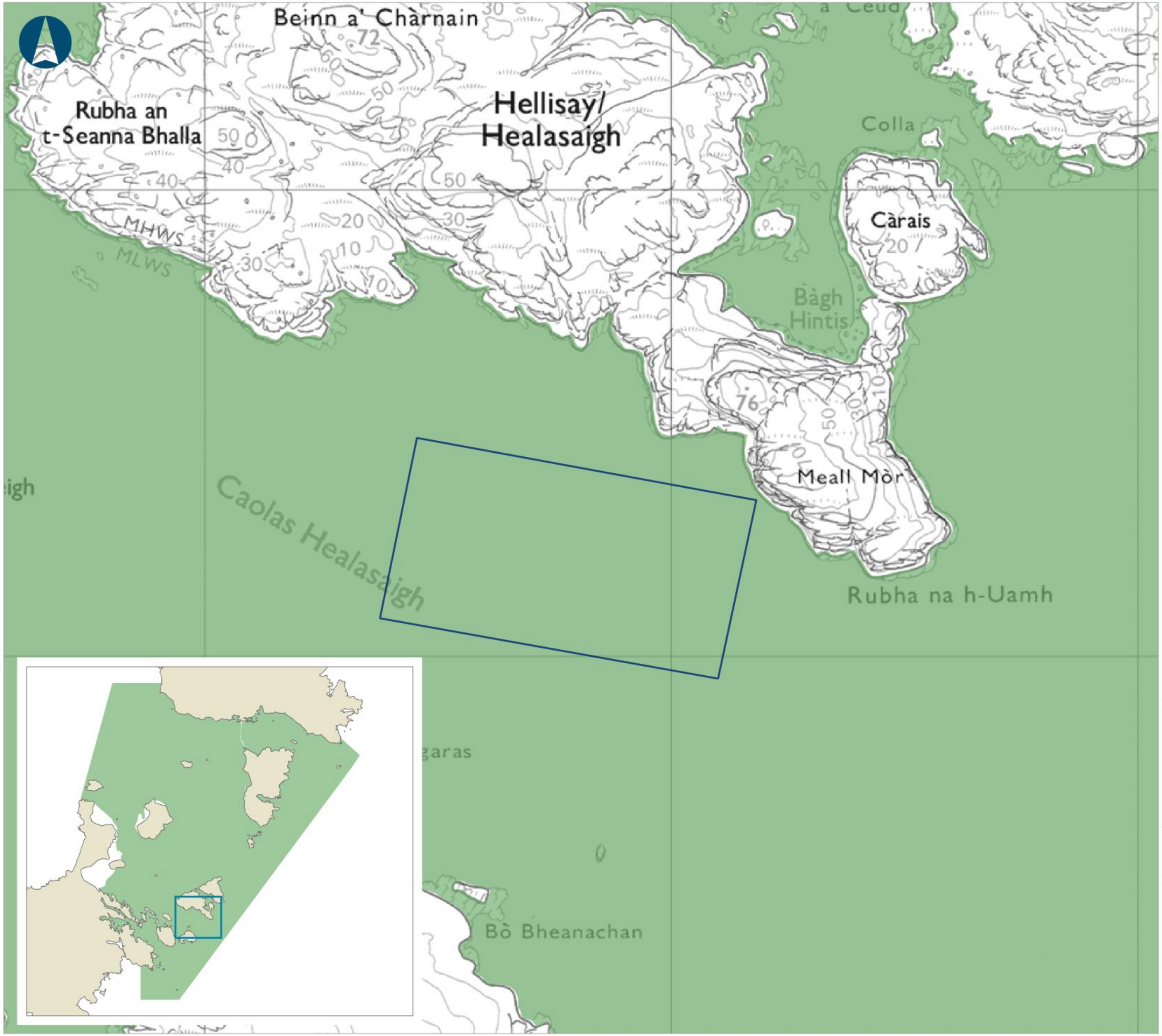
Figures



HELLISAY EIA

Figure 1 Site location

LEGEND

- Existing mooring extent
- Sound of Barra SAC

0 100 200 300 400 500 600
SCALE (m)

Project: P985 Date: 01/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:8,000

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Figure 2
Consented and existing location

LEGEND

- Existing mooring extent
- Existing pens
- Existing feedbarge
- Consented mooring extent
- Consented pens

0 100 200 300 400 500 600
SCALE (m)

Project: P985 Date: 30/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:8,000

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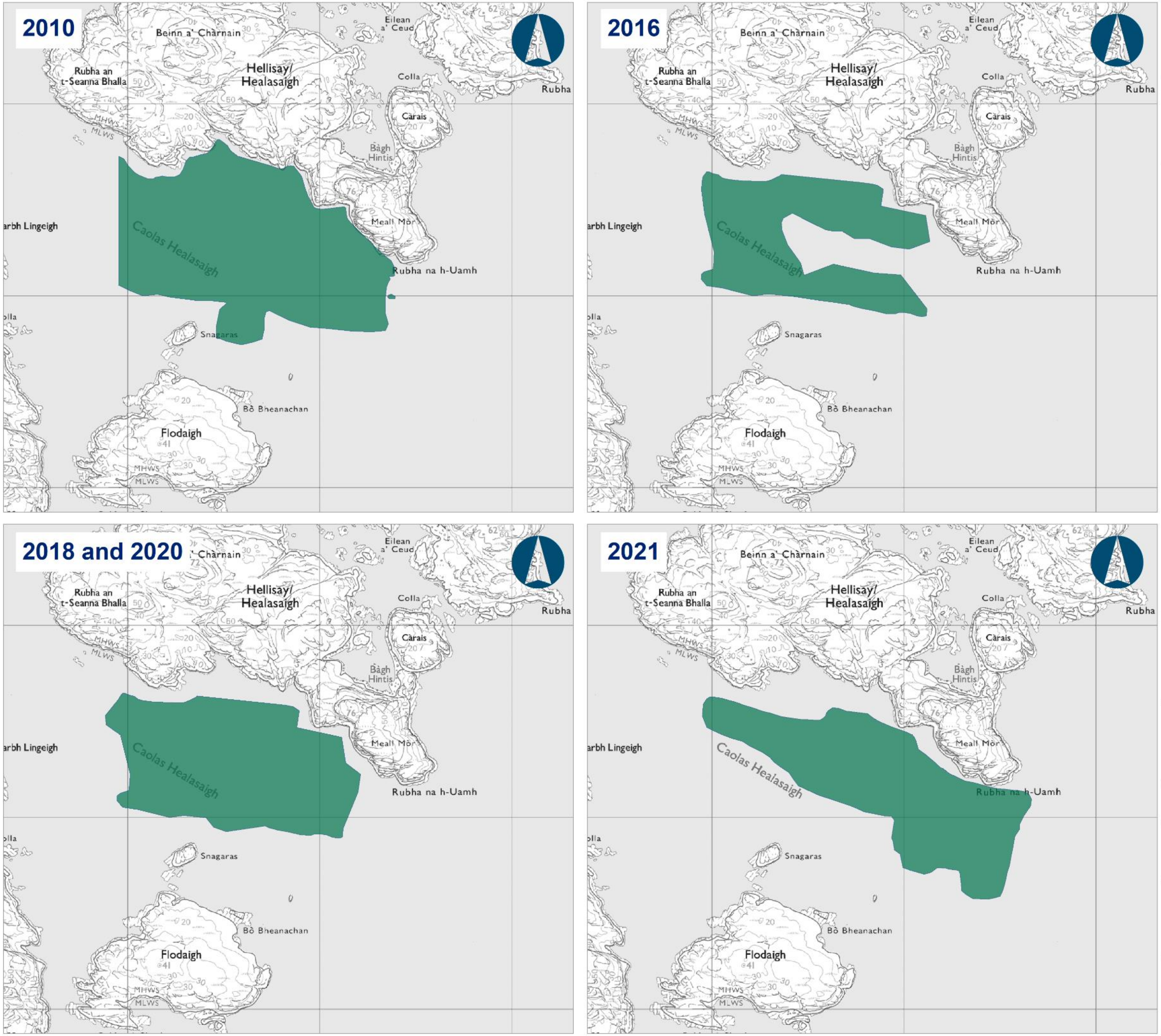

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Figure 3 Survey boundaries

LEGEND

Survey boundary

0 300 600 900 1,200 1,500

SCALE (m)

Project: P985 Date: 01/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936

Projection: Transverse Mercator Scale @ A3: 1:19,430

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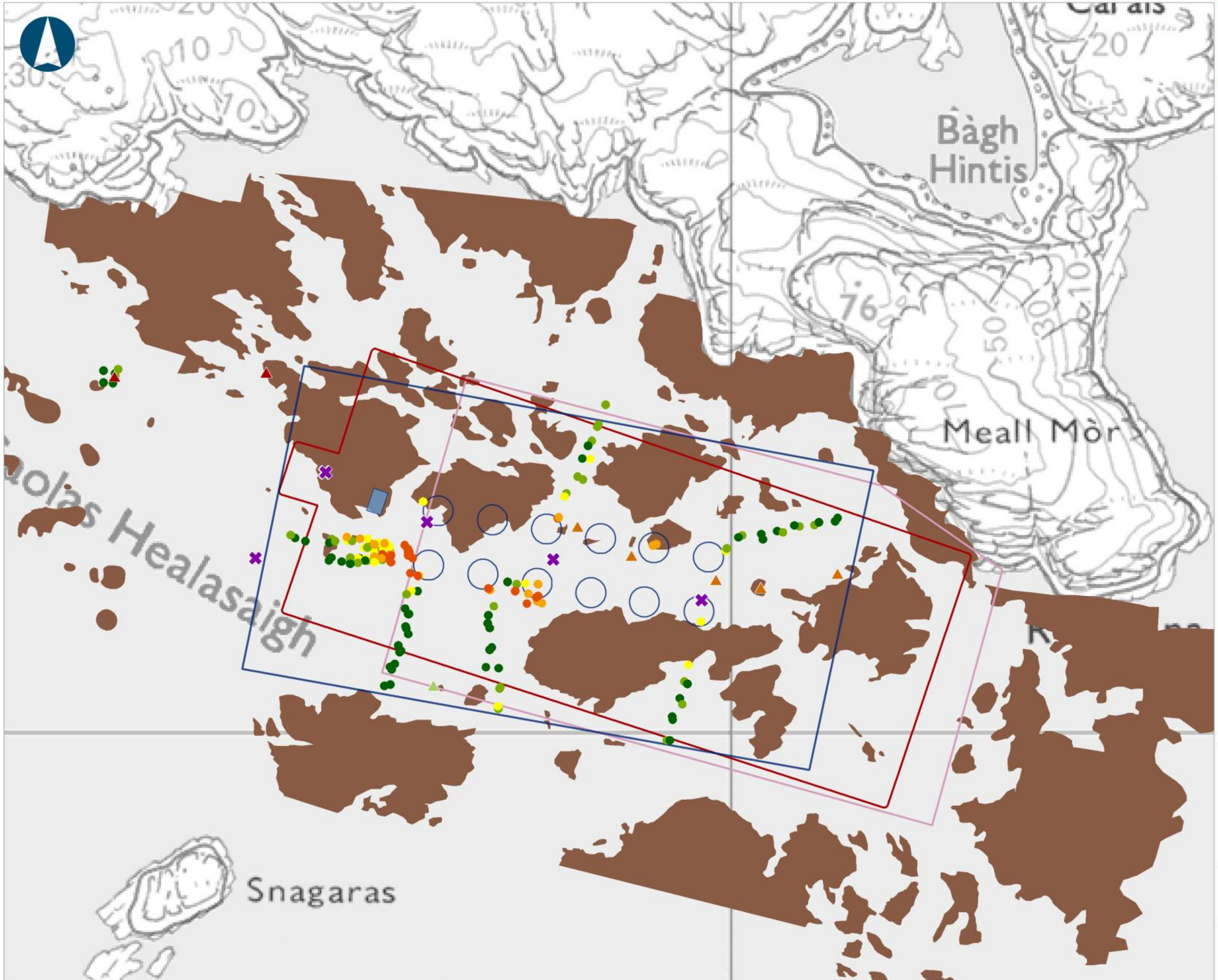

NOTE:
Grab sample locations from 2018 were digitised visually from charts, no coordinates were available for the grab sample locations.

Predevelopment samples are classified according to the Infaunal Trophic Index (IT) in contrast to compliance samples which are classified to Infaunal Quality Index (IQI).

HELLISAY EIA

Figure 4
Compliance and in house benthic grab samples

LEGEND

- Proposed mooring extent
- Consented mooring extent
- Existing mooring extent
- Existing pens
- Existing feedbarge
- Bedrock/reefs (2020/21)

Compliance samples (2013-2022)
IQI category

- High
- Good
- Moderate
- Poor
- Bad

2010 Grab Locations

- 0 - 30 Degraded
- 30 - 60 Modified
- 60 - 80 Degraded
- In house samples (2018)

0 100 200 300 400
SCALE (m)

Project: P985 Date: 30/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:5,000

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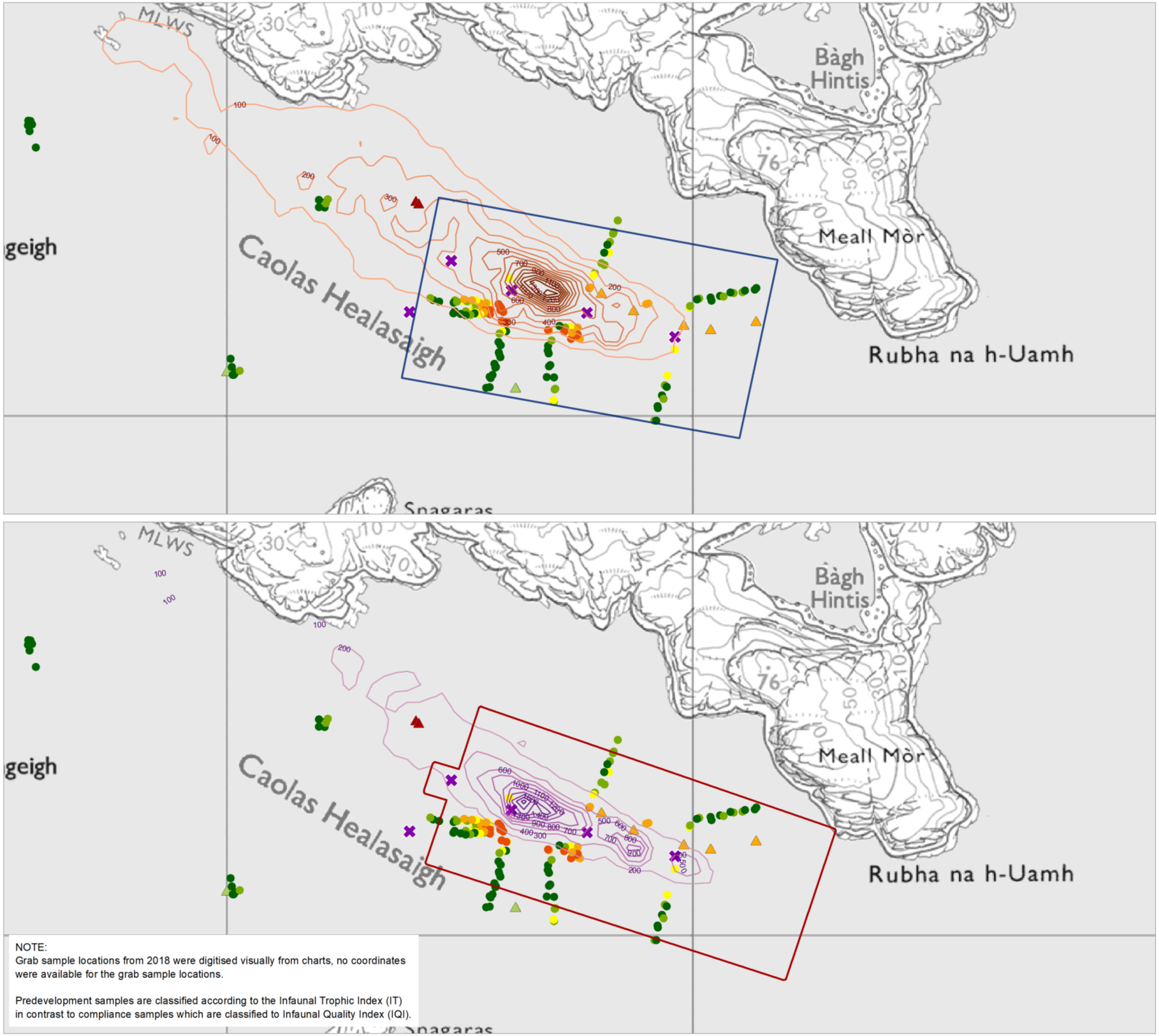

NOTE:
Grab sample locations from 2018 were digitised visually from charts, no coordinates were available for the grab sample locations.

Predevelopment samples are classified according to the Infaunal Trophic Index (IT) in contrast to compliance samples which are classified to Infaunal Quality Index (IQI).

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Figure 5
Existing and proposed modelled carbon deposition footprint

LEGEND

Existing mooring extent
Proposed mooring extent

Hellisay 12 x 120 m Carbon deposition g/m^2	Hellisay 5 x 200 m Carbon deposition g/m^2
100	200
200	400
300	600
400	800
500	1000
600	1200
700	1400
800	1600
900	1800
1000	2000
1100	
1200	
1300	
1400	

Compliance samples (2013-2022)
IQI category
- High
- Good
- Moderate
- Poor
- Bad

2010 Grab Locations
- 0 - 30 Degraded
- 30 - 60 Modified
- 60 - 80 Degraded

In house samples (2018)

0 100 200 300 400 500 600 700
SCALE (m)

Project: P985 Date: 08/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:8,000

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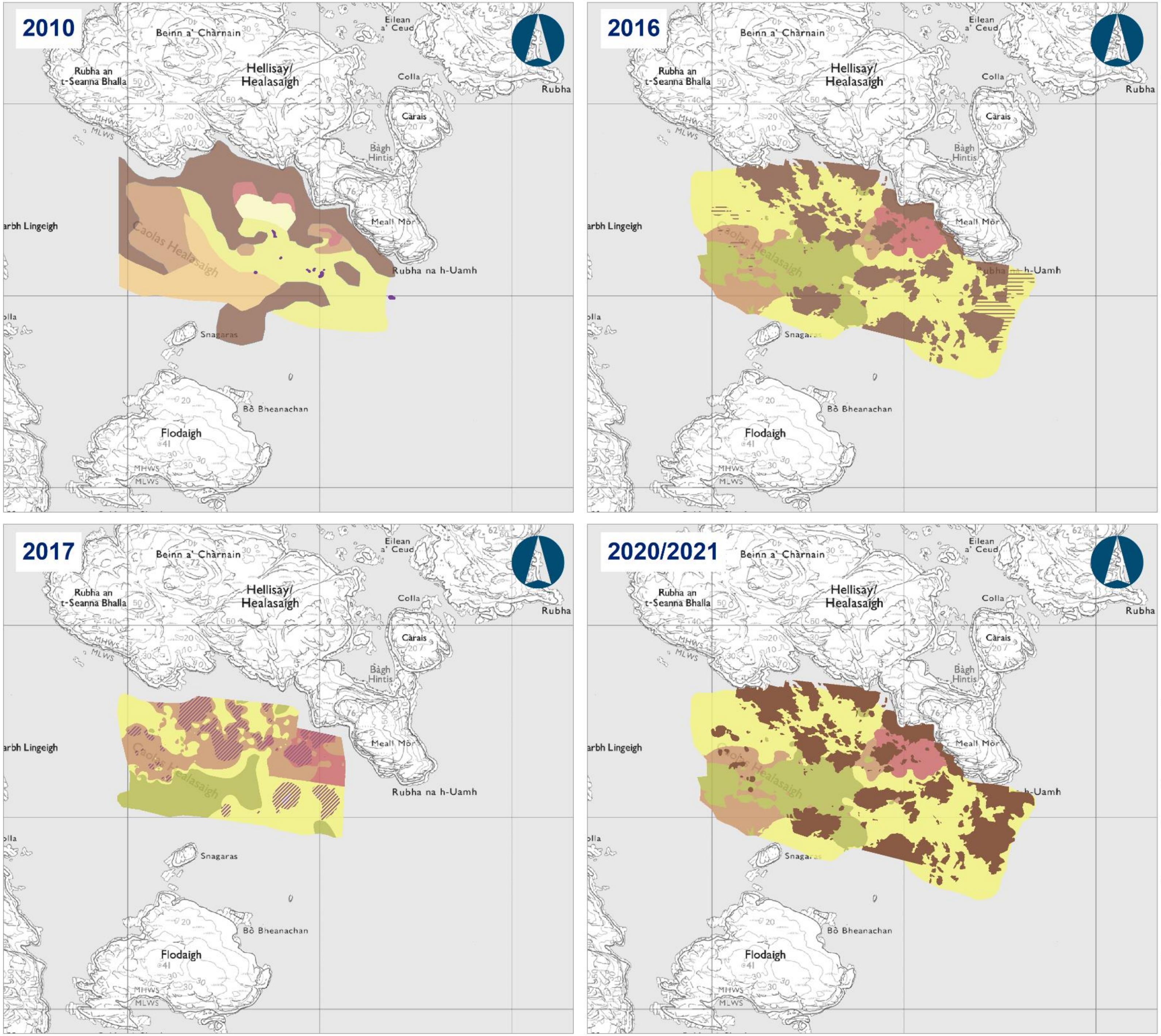

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Figure 6
Substrate mapping outputs

LEGEND

- Gravel
- Mixed sandy gravel
- Fine medium sand
- Fine Sand
- Coarse rippled sand
- Coarse sand no ripples
- Rock
- Interpolated bedrock
- Bedrock
- Bedrock outcrop

0 300 600 900 1,200 1,500

SCALE (m)

Project: P985 Date: 14/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:19,430

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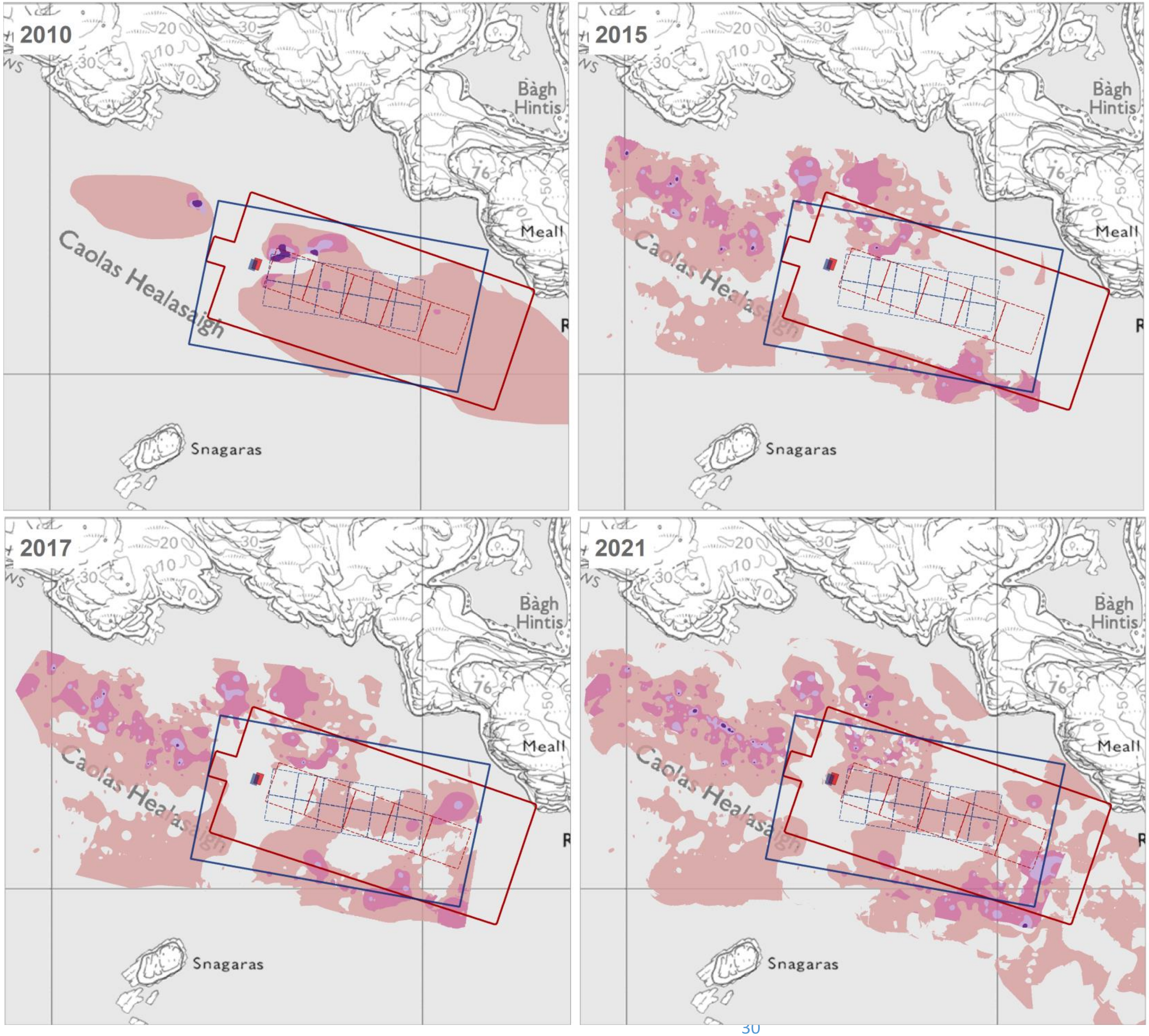

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Figure 7
Unprocessed maerl density by year

LEGEND

Existing infrastructure

- Existing mooring extent
- Pen grid
- Existing feedbarge

Proposed infrastructure

- Proposed mooring extent
- Pen grid
- Feedbarge
- Over 50% maerl
- Under 50% maerl
- Under 25% maerl
- Under 5% maerl

0 200 400 600 800
SCALE (m)

Project: P944 Date: 30/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:10,000

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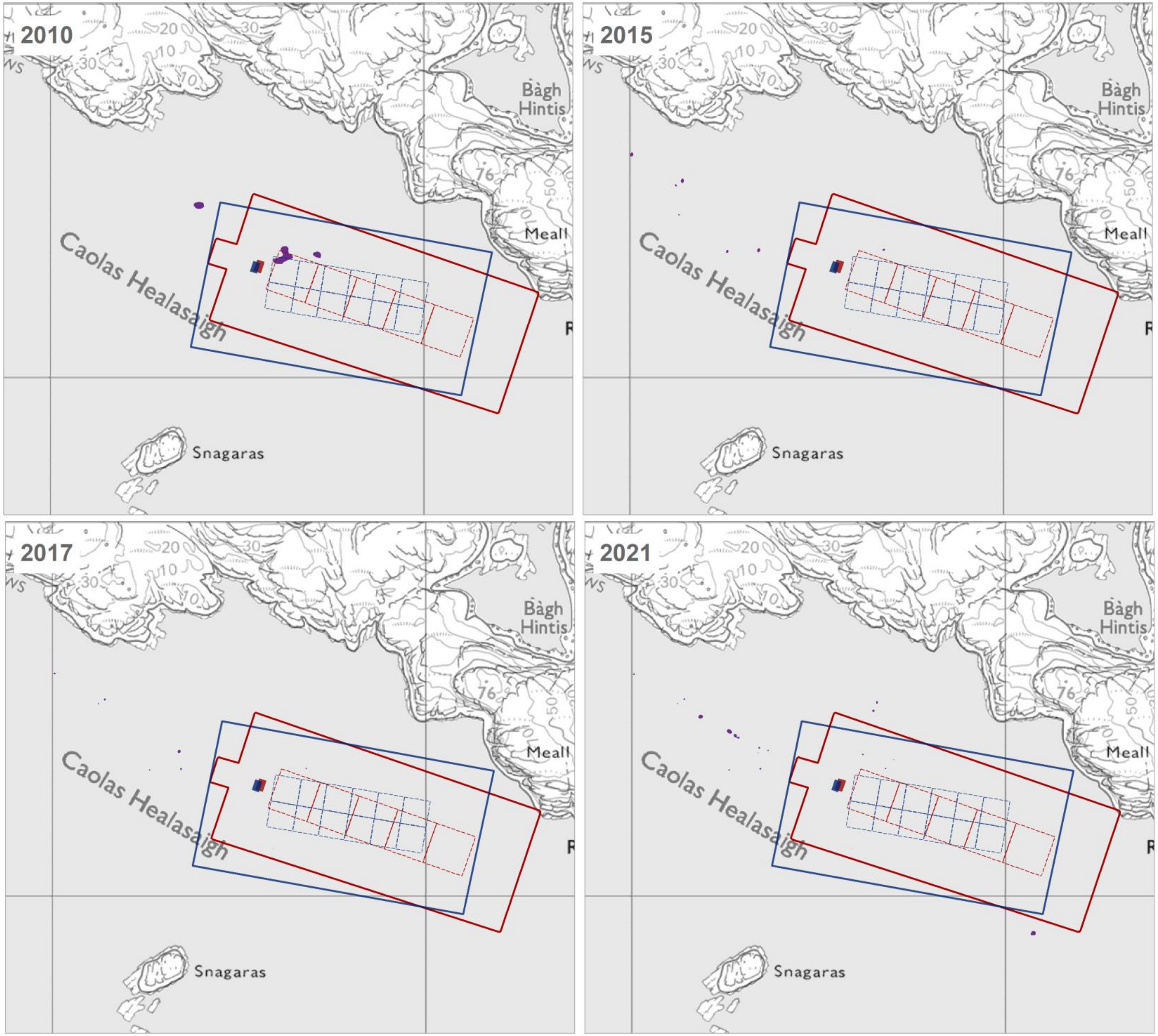

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Figure 8
Live maerl density greater than 50% of sediment component by survey year

LEGEND

Existing infrastructure
- Existing mooring extent
- Pen grid
- Existing feedbarge

Proposed infrastructure
- Proposed mooring extent
- Pen grid
- Proposed feedbarge
- Over 50% maerl

0 200 400 600 800
SCALE (m)

Project: P944 Date: 07/10/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:10,000

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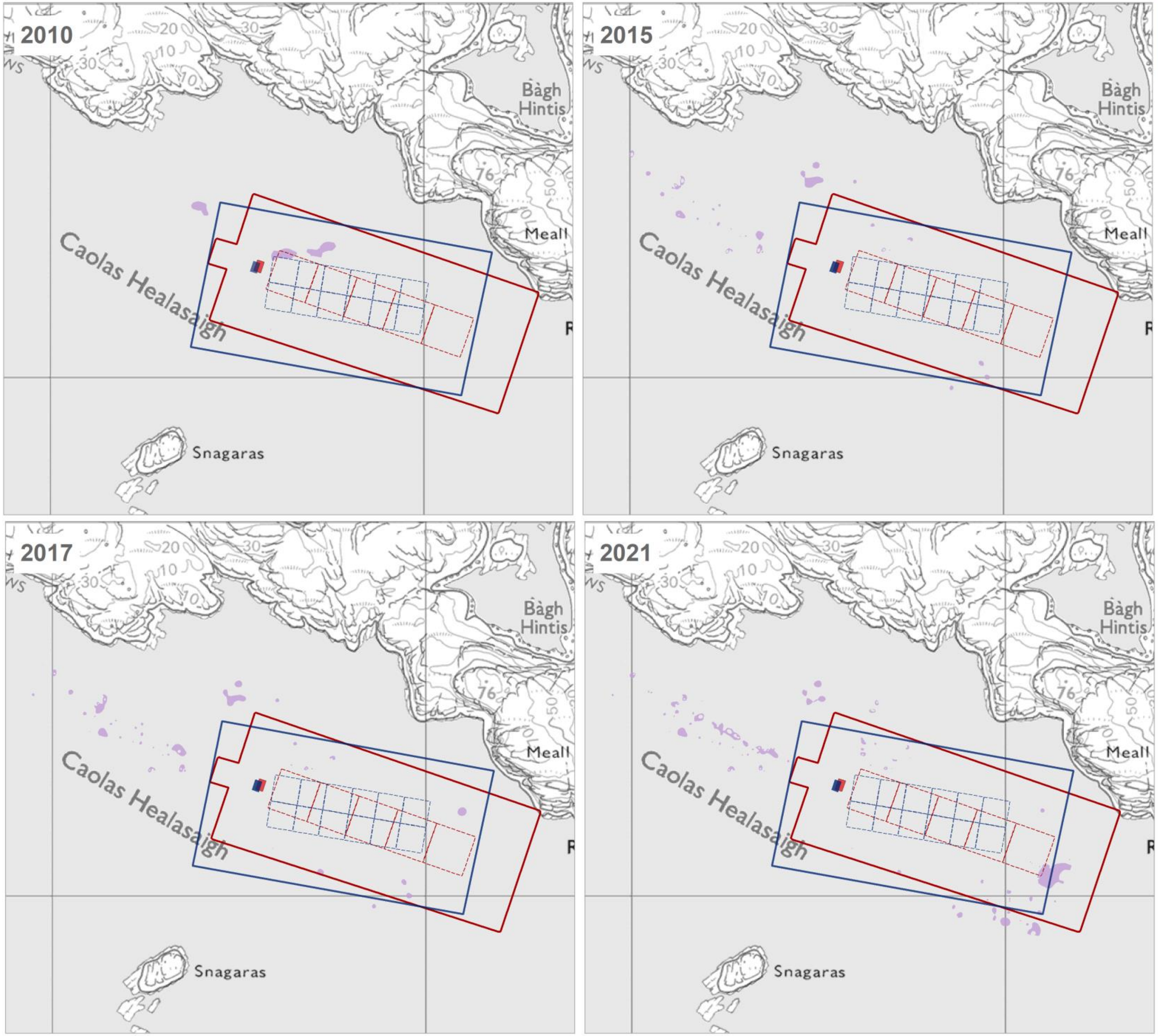

HELLISAY EIA

Figure 9
Live maerl density between 25% and 50% of sediment component by survey year

LEGEND

Existing infrastructure
- Existing mooring extent
- Pen grid
- Existing feedbarge

Proposed infrastructure
- Proposed mooring extent
- Pen grid
- Proposed feedbarge
- Under 50% maerl

0 200 400 600 800
SCALE (m)

Project: P944 Date: 07/10/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:10,000

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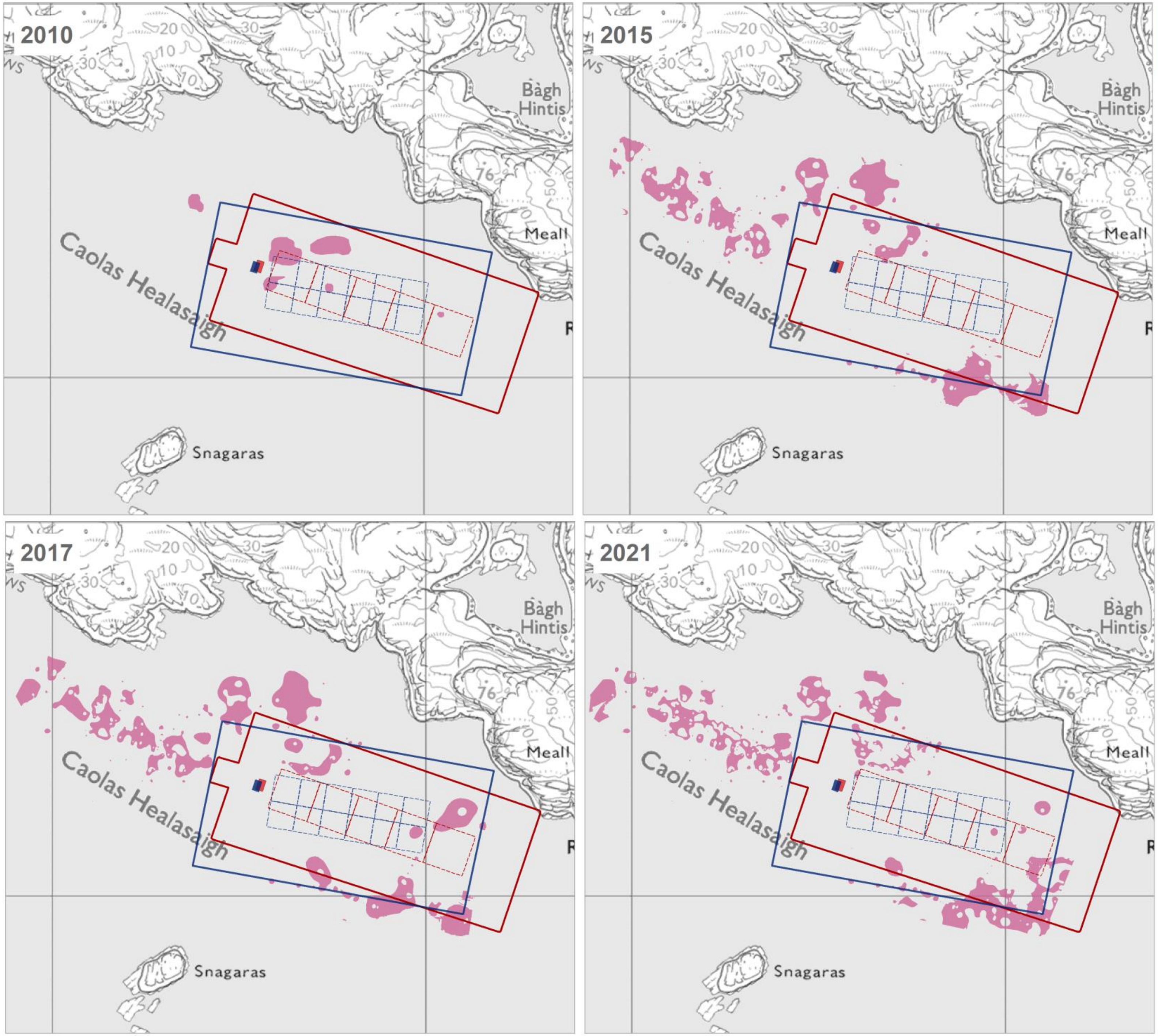

HELLISAY EIA

Figure 10
Live maerl density between 5% and 25% of sediment component by survey year

LEGEND

Existing infrastructure
- Existing mooring extent
- Pen grid
- Existing feedbarge

Proposed infrastructure
- Proposed mooring extent
- Pen grid
- Feedbarge
- Under 25% maerl

0 200 400 600 800
SCALE (m)

Project: P944 Date: 07/10/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:10,000

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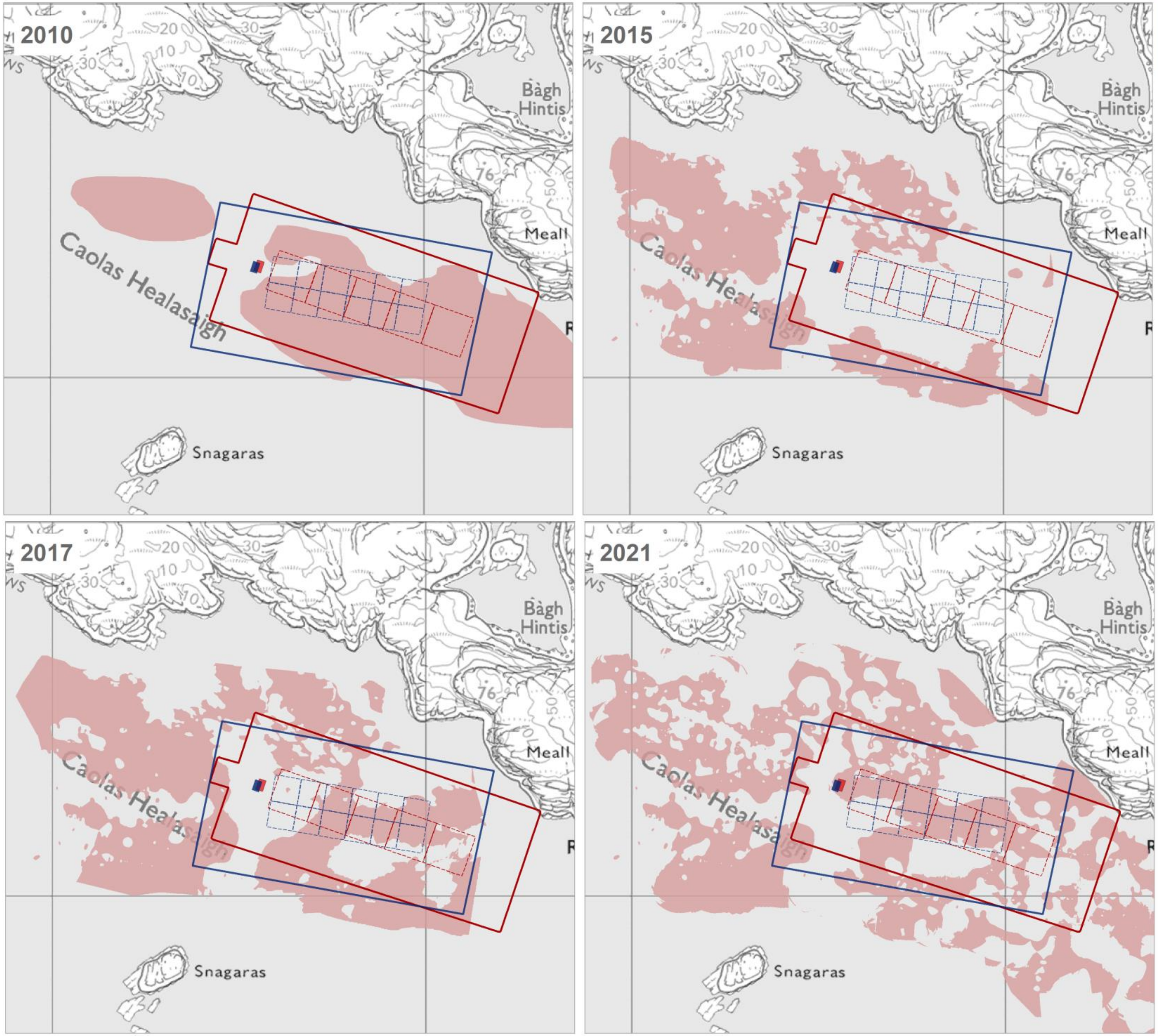

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Figure 11
Live maerl density under 5% of sediment component by survey year

LEGEND

Existing infrastructure
- Existing mooring extent
- Pen grid
- Existing feedbarge

Proposed infrastructure
- Proposed mooring extent
- Pen grid
- Feedbarge
- Under 5% maerl

0 200 400 600 800
SCALE (m)

Project: P944 Date: 30/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:10,000

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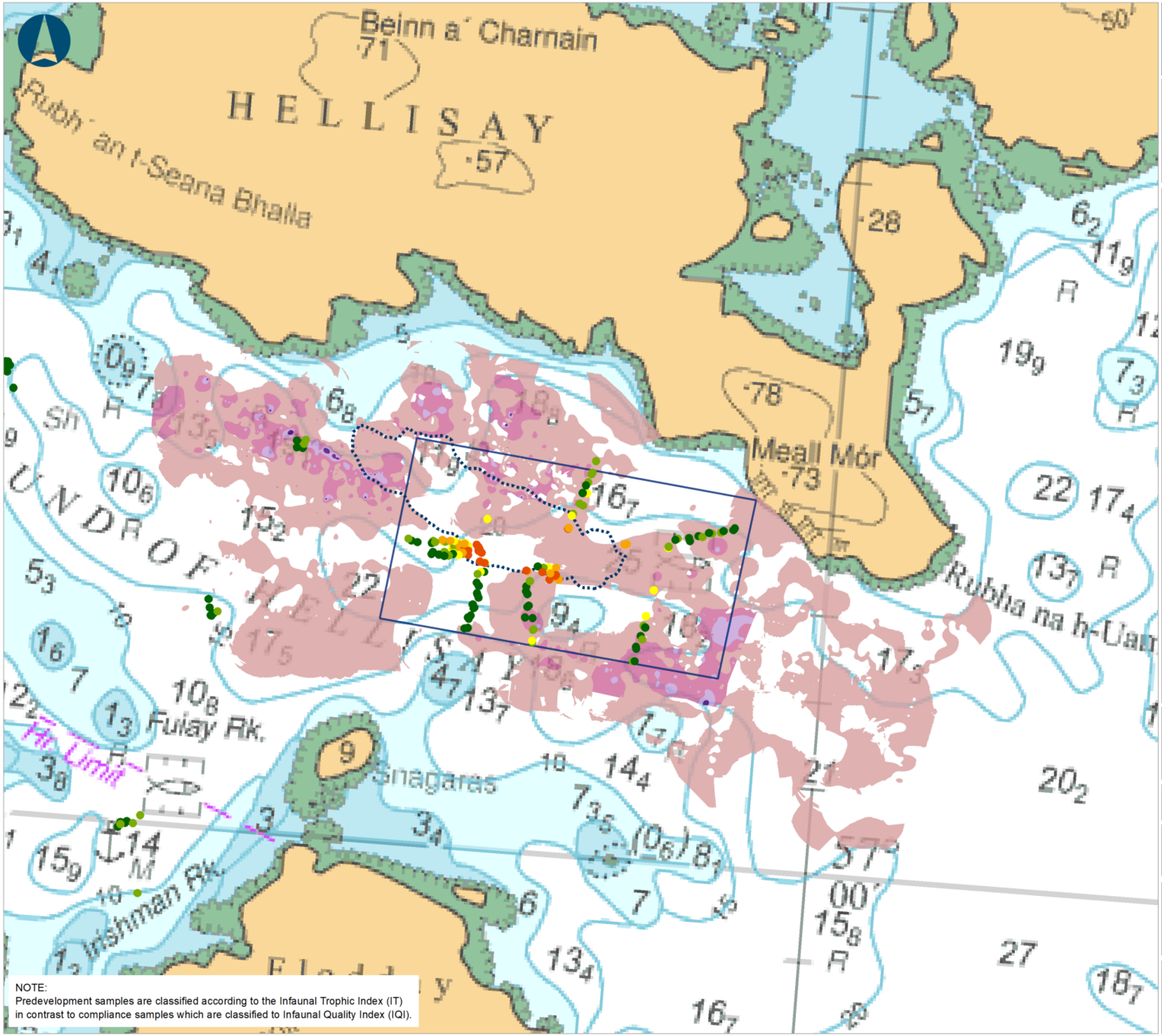

NOTE:
Predevelopment samples are classified according to the Infaunal Trophic Index (IT) in contrast to compliance samples which are classified to Infaunal Quality Index (IQI).

HELLISAY EIA

Figure 12
Existing modelled carbon deposition footprint: 250 g/m^2 contour against maerl distribution (2020/21)

LEGEND

- Existing mooring extent
- Existing modelled 250 g/m^2 contour

2020/21 maerl survey

- Over 50% maerl
- Under 50% maerl
- Under 25% maerl
- Under 5% maerl

Compliance samples (2013-2022)

IQI category

- High
- Good
- Moderate
- Poor
- Bad

0 100 200 300 400 500 600
SCALE (m)

Project: P985 Date: 08/09/2022 [redacted]

Coordinate System: British National Grid Datum: OSGB 1936
Projection: Transverse Mercator Scale @ A3: 1:8,000

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