The conservation status of maerl habitats in northwest Scotland. A report for the Blue Hope Alliance.

Professor Jason Hall-Spencer, Cyprus University of Technology (Cyprus) and Tsukuba University (Japan).

Email: jason.hallspencer@cut.ac.cy (work) jhallspencer@gmail.com (home).

Introduction

This report explains why maerl habitats are irreplaceable marine habitats and how information collected by the Blue Hope Alliance around Loch Carron, Upper Loch Torridon, and in the Wester Ross Marine Protected Area between 2016-2025 has been analysed. This includes monitoring transects used to assess the conservation status of these ancient marine habitats. *Phymatolithon calcareum* is the main maerl-forming species in the region. Surveys in 2025 included a study of seawater nutrient levels and provided data on maerl habitat condition. Wester Ross has biodiverse maerl beds that provide herring spawning grounds, but blooms of an invasive seaweed and illegal scallop dredging are hindering their recovery. It is recommended that the Blue Hope Alliance digital archive is analysed statistically and published in peer reviewed literature and that there is follow-up monitoring of water quality around urban and fish farm inputs of organic and inorganic waste.

This digital photo., taken 21 March 2026 near Gairloch, shows herring eggs on maerl - you can see their eyes (© Chris Rickard).

Background on maerl

Maerl habitats are formed by very slow-growing unattached coralline algae (Cabioch, 1970). Individual maerl thalli can take 50 years to grow 1 cm and the habitats that they form can be thousands of years old. They are a threatened and declining habitat and considered to be a non-renewable resource under the Oslo-Paris Convention (OSPAR). Urgent need for their conservation is recognised by the International Union for the Conservation of Nature, the European Union, the Joint Nature Conservation Committee and all the UK marine conservation agencies (Mazik et al., 2015; Tillin et al., 2022).

In the northeast Atlantic, maerl habitats can be exceptionally biodiverse, supporting over 150 species of macroorganisms per square meter (Hall-Spencer, 1998; Peña et al., 2015; Grall & Hall-Spencer, 2025; Tejero-Caballo et al. 2026). These coralline algal habitats provide spawning and nursery areas for economically important fish, as well as brood stocks of edible crabs and scallops (Napier, 1993; Hall-Spencer et al., 2003, 2010; Kamenos et al., 2004a, b; OSPAR, 2024). Live maerl provides scallops with a nursery habitat (Kamenos et al. 2006) but SCUBA divers have reported that in some parts of northwest Scotland maerl beds have been destroyed by scallop dredging (Blue Hope Alliance, pers. comm.).

A wide range of wildlife use maerl as a place to live, feed and breed (Fig.1). Herring shoals were first filmed spawning on maerl near Gairloch by Subsea TV in 2019 and have been filmed spawning on maerl in this area each year from 2024-2026. Fishermen have found herring in spawning condition in creels in Wester Ross MPA and have reported an increase in herring abundance, together with greater numbers of native krill and cetaceans since 2019 (Frost & Diele, 2022; Blue Hope Alliance, pers. comm.).

Efforts are underway to value the ecosystem services of maerl habitats (Rasmusson et al. in press). Dead maerl forms ancient habitats which can be piled into banks, ridges and dunes on the seabed during storms in wave exposed locations, leaving live maerl to settle in the troughs of these often-transitory seabed structures (Hall-Spencer & Atkinson, 1999; Joshi et al., 2017). This sediment sorting by wave and tidal action does not crush, break or bury large amounts of live maerl, whereas scallop dredging does (Kamenos et al., 2003). So, while maerl beds have withstood millennia of coastal storms and shifting currents, scallop dredging since the 1950's has caused severe and widespread declines in maerl habitat extent and quality in Scotland (Hall-Spencer & Moore, 2000a, b, c).

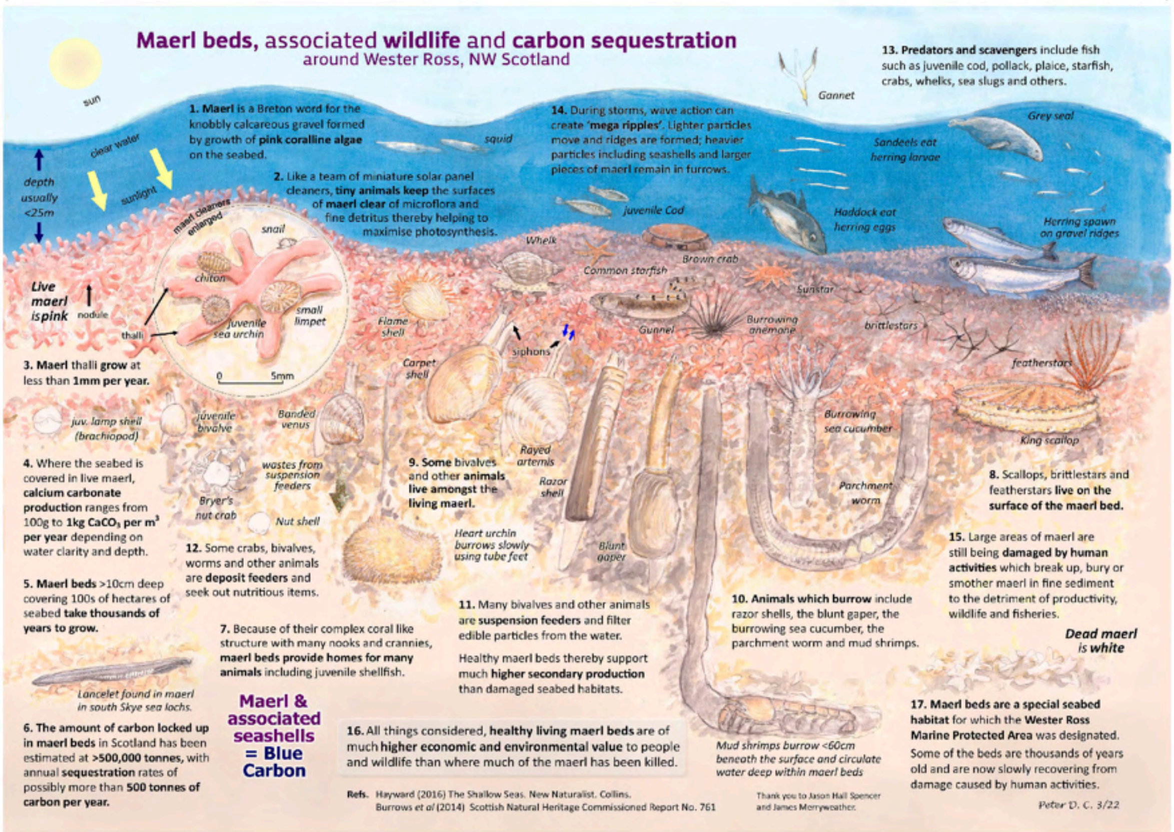

Fig. 1. Abundant and diverse marine life thrives in maerl habitats in Scotland. Poster by Peter Cunningham (see www.wrft.org.uk). The blue carbon potential for these habitats (accessed May 2026) is variable and can be low.

Laws governing MPAs are set out in the Marine (Scotland) Act 2010 and Marine and Coastal Access Act 2009 (Link: Legislation). Scotland's marine conservation strategy has MPAs, species conservation, and policies that cover wider seas. Scotland has Priority Marine Features (Link: NatureScot PMF List) and MPAs with a set of conservation objectives for protected features such as maerl. If the conservation status of an MPA feature is deemed to be good, then the aim is to 'maintain', if it is poor then the aim is to 'restore' – see Scotland's MPA Monitoring Strategy (Link: MPA Monitoring Strategy).

Maerl habitats are a protected feature in Wester Ross MPA where they are known to have declined since the 1990s and conservation objectives seek to recover their condition. Maerl beds are also a Priority Marine Feature of national importance in Scotland. NatureScot has supported research into the distribution, status and ecosystem services of maerl (e.g. Birkett et al., 1998; Donnan & Moore 2003; Burrows et al. 2014, 2017; Moore 2014, 2019; Mazik et al. 2015). The maerl-forming species in Scotland are *Lithothamnion corallioides, Boreolithothamnion glaciale, B. soriferum, Phymatolithon calcareum* and *P. lusitanicum* (Bunker et al. 2017; Simon-Nutbrown et al. 2020; Simon-Nutbrown 2023; Gabrielson et al. 2023). Table 1 lists Scottish conservation areas that contain maerl as a protected feature and Figure 2 shows where these are. Maerl area (km^2) may be underestimated as not all maerl beds have been mapped.

Table 1 Special Areas of Conservation (SAC) and Nature Conservation Marine Protected Areas (NCMPA) that are important for maerl protection in Scotland including the recent updates for maerl in Wester Ross and Loch Carron (both websites accessed May 2026).

Name	Type	Designation year	Total area (km^2)	Maerl area (km^2)
Loch Laxford	SAC	2005	12.15	0.114
Loch nam Madadh	SAC	2005	23.2	0.35
Luce Bay and Sands	SAC	2005	488	1
Sound of Arisaig	SAC	2005	45.44	1.71
Sound of Barra	SAC	2014	125	9
Wyre and Rousay Sounds	NCMPA	2014	16	6.3
Wester Ross	NCMPA	2014	599	5.53
Loch Sween	NCMPA	2014	41	0.064
South Arran	NCMPA	2014	280	15
Fetlar to Haroldswick	NCMPA	2016	216	0.94
Loch Carron	NCMPA	2019	23	0.56

The Blue Hope Alliance

This alliance began in 2015 as a coalition of groups and individuals interested in protecting marine ecosystems in northwest Scotland (www.bluehopealliance.co.uk, accessed May 2026). It was formed in response to concerns about scallop dredging damage and the expansion of fish farms in Wester Ross MPA. In 2015, a violation of a Voluntary Exclusion Zone triggered a ban on scallop dredging in this area.

Groups involved include the Scottish Creel Fishermen's Federation, North and West District Salmon Fishery Board, Sea Change Wester Ross, Wester Ross Area Salmon Fishery Board, the North Minch Shellfish Association and SubSea TV. Affiliate members include volunteer anglers, Seasearch divers and snorkelers, scallop divers, creel fishermen, underwater photographers, recreational divers and community coordinators with experience in journalism, storytelling, filmmaking and the arts (Hall-Spencer & Rasmusson, 2024). In addition, technical knowledge and support are provided by volunteer marine scientists and NatureScot.

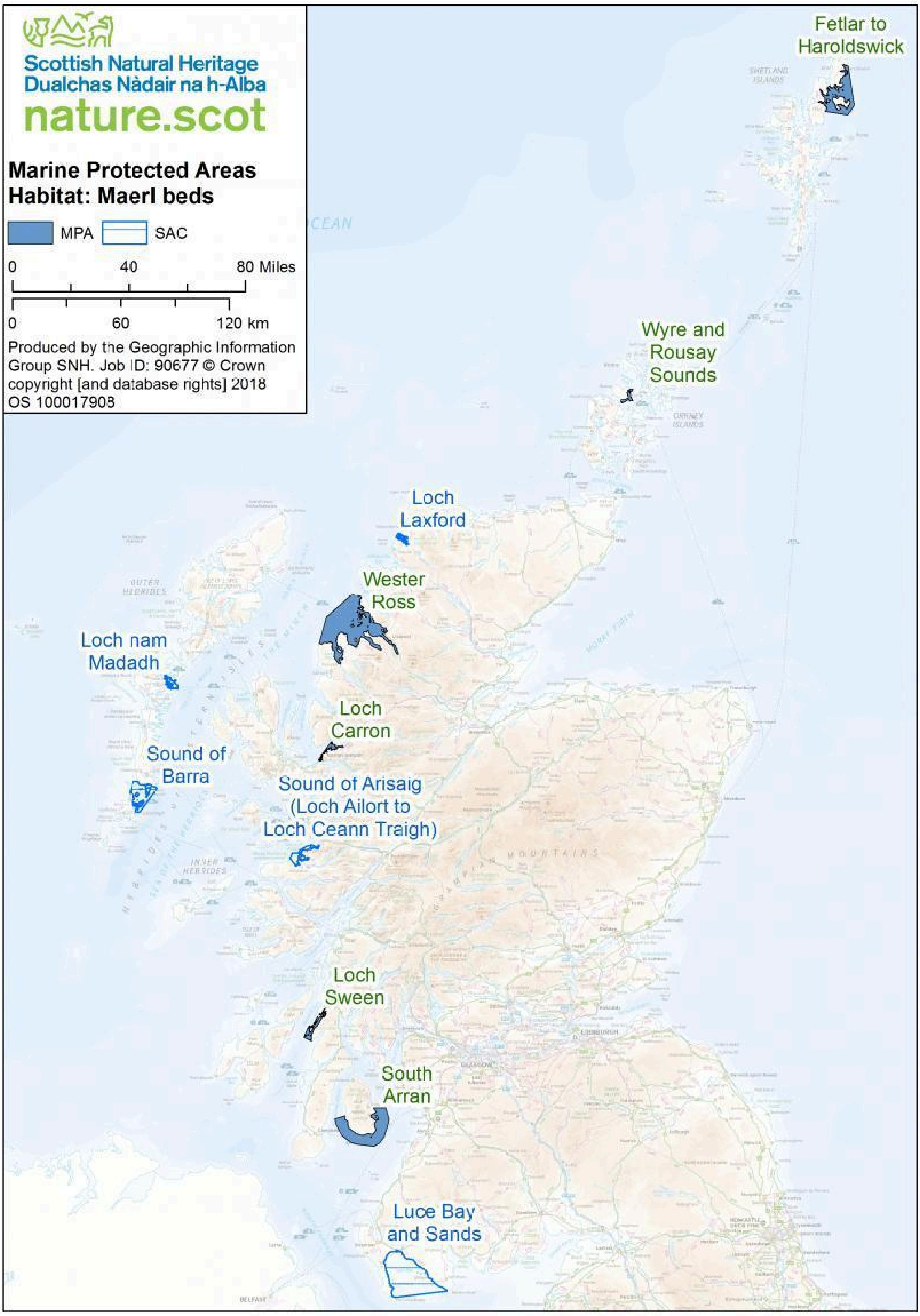

Fig. 2 Marine Protected Areas and Special Areas of Conservation that contain maerl as a protected feature in Scotland (from NatureScot accessed May 2026).

From 2016-2025, the BHA collected information about the condition and extent of maerl in Wester Ross Marine Protected Area, Loch Carron and near Gairloch. Citizen-science groups around Torridon and nearby sea lochs have recently joined this effort. BHA has established monitoring transects and extended the known distribution of maerl and recorded new species for the area, including the red-speckled anemone *Anthopleura ballii* and the sea slug *Placida dendritica.* They have documented the presence of the critically endangered flapper skate *Dipturus intermedius* which used to be common in the area until they were overfished. Survey reports up to 2024 are available on the BHA website (accessed May 2026). The Blue Hope Alliance network has curated an Open Access archive of interviews, underwater film and digital photos, including photoquadrats for quantitative analyses.

In May 2026, the BHA secured National Lottery and North & West Fisheries Board funding to make their archive more accessible and easier to use. Data from surveys carried out in Wester Ross in 2025 were reviewed and assessed by me (Jason Hall-Spencer) and the results are presented in this report

Fish farm impacts on maerl.

Salmon farm wastes have degraded and killed maerl in Scotland, even where current speeds are strong (Hall-Spencer et al., 2006). Research into this problem, commissioned by the Scottish Environmental Protection Agency, showed visible waste and the loss of live maerl and marine biodiversity 100 m from salmon farms in Shetland, Orkney and South Uist. Benthic marine invertebrate community responses to fish farm wastes align with the known effects of organic waste on other marine sediments in northern Europe (Pearson & Rosenberg, 1978). Pollution from Scottish salmon farms causes biodiversity loss, especially of large long-lived species that use maerl as nursery or refuge areas. Studies of the impacts of salmon farms in Norway have shown similar effects (Legrand et al. 2024). In Scotland, seabed biodiversity loss due to organic waste pollution can also be amplified by a sharp decline in crustacean diversity due to the chemicals that are used to control salmon sea lice infections (Hall-Spencer & Bamber, 2007).

The Blue Hope Alliance is concerned that salmon farms may be causing a decline in the conservation status of maerl beds in the Wester Ross Marine Protected Area where the aim of the Scottish Government's management orders is to take action to promote recovery of these habitats from damaging practices such as scallop dredging (see NatureScot 2014, accessed May 2026). In a January 2025 statement to NatureScot and the Scottish Environmental Protection Agency the BHA reported that they began to observe algal growth on maerl in 2018. The were worried that filamentous algae had increased on maerl near a fish farm in the Tanera-Fada channel (see Fig. 3 for named survey locations). In Moil Moire Bay a large maerl bed had been photographed as being covered in filamentous algae near the same fish farm site. The Blue Hope Alliance raised concerns that fish farm waste may be harming herring spawning areas and preventing maerl bed recovery. For this report I examined Blue Hope Alliance's digital archive for evidence of this phenomenon on a site-by-site basis.

Here, the term 'nutrients' refers to inorganic chemicals, such as those containing the elements nitrogen (N) and phosphorous (P) as used in agricultural fertilisers, as distinct from organic waste. Nutrient enrichment (beyond natural levels) from agricultural runoff, sewage discharge and aquaculture can pollute maerl habitats (Qui-Minet et al. 2018; Legrand et al. 2024). Wang et al. (2012) quantified releases of N and P wastes from Norwegian salmon farms to assess their influence on surrounding waters. Of the total feed input, 62% of nitrogen (N) and 70% of phosphorus (P) were released back into the environment, equivalent to an annual discharge of about 50,600 t of N and 9,400 t of P based on total salmon production of 1.02×10^6 t. They predicted that 45% of the nitrogen in salmon feed was excreted by the fish as dissolved inorganic nitrogen, and 18% of feed P was excreted as dissolved inorganic phosphorus. Approximately 44% of feed P was released as particles, dominating the solid waste. Their estimates of the potential for integrated multi-trophic aquaculture driven by salmon farming showed a far higher potential for seaweed production based on released dissolved inorganic nutrients than for mussel production based on released particulate organic carbon. In short, nutrient outputs can act as a fertilizer that enhances seaweed growth.

'Eutrophication' is the term used for ecosystem degradation caused by excessive inorganic nutrient enrichment, primarily nitrogen from agriculture and phosphorus from sewage. Previous fish farm impact studies have not monitored effects on the flora associated with maerl habitats and have not considered the potential role of eutrophication. Eutrophication can cause phytoplankton blooms, which can be toxic (to humans and/or marine life) or damage fish gills. Eutrophication can also cause nuisance blooms of macroalgae, particularly the green seaweeds *Ulva* spp. and the brown seaweeds *Sargassum* spp.; these seaweed blooms have caused worldwide problems because when their biomass decomposes it can lead to hypoxia and biodiversity loss (Jiang et al., 2024; Feng et al., 2024).

The Scottish Environment Protection Agency has monitored blooms of *Ulva* to assess eutrophication in Ythan Estuary, north of Aberdeen, which has an agricultural catchment area and a small population (<10,000 people). Sources of excess nutrients include sewage and agricultural runoff, particularly nitrogen fertiliser. *Ulva* blooms led to the designation of this catchment area as a Nitrate Vulnerable Zone (accessed May 2026). There have been recent improvements in wastewater treatment, including nutrient stripping.

The land around Wester Ross Marine Protected Area is not a Nitrate Vulnerable Zone, as it is not farmed intensively using fertilisers. The Scottish Environmental Protection Agency (accessed May 2026) classes the seawater quality around Wester Ross as 'good' overall, with some parameters classed as indicating 'high' quality (e.g. dissolved oxygen), others as 'good' (e.g. overall ecology) and some assessed as just a 'Pass', for example for levels of ammonia.

The extent to which maerl may be harmed by increased inorganic nutrient levels in the UK is unknown although a Feature Activity Sensitivity Tool for Scotland (accessed May 2026) suggests high sensitivity but low confidence in that judgement because of a lack of studies. In the Bay of Brest, Brittany there are no fish farms but excess inorganic nutrients have increased the growth of opportunistic fleshy algae that smother and harm maerl (Grall & Hall-Spencer 2025). Maerl habitat health has improved over the past 20 years in the north part of the Bay of Brest, following measures taken to modernise sewage treatment plants by separating sewage and rainwater (Grall & Hall-Spencer 2025).

There are concerns that eutrophication could be damaging maerl habitat in a Special Area of Conservation off Falmouth, Cornwall (Cornwall Wildlife Trust, 2024). A high cover of Trailiella was noted on maerl surveys carried out for Natural England in 2023 (Doggett & Northern 2024). The Trailiella tetrasporophyte phase of *Bonnemaisonia hamifera* has thin filaments (0.4 mm, Bunker et al. 2017) that enmesh maerl thalli. Trailiella has been spreading rapidly in Crimea where it benefits from eutrophication (Sadogurskiy et al., 2023, 2024). The land around the Falmouth and Helford Special Area of Conservation is classed as a Nitrate Vulnerable Zone (accessed May 2026) so high nutrient levels might be causing Trailiella blooms on maerl in Cornwall. Where maerl is highly mobile due to water motion it may be less vulnerable to invasive fleshy algal overgrowth than in sheltered conditions (pers. obs.).

In August 2025 the Scottish Environmental Protection Agency provided Blue Hope Alliance with data on what properties and companies had licenses to discharge sewage into the waters of the Wester Ross Marine Protected Area. They shared records of 168 licenses for the Loch Ewe area, almost all for private properties with septic tanks. Of these, only a few release untreated sewage and a similarly small number use secondary sewage treatment methods. This information did not include the amounts of sewage released. The sewage treatment works of Ullapool, and fish farms are probably the main sources of organic and inorganic pollution in the region.

Blue Hope Alliance Surveys

The BHA surveys add to work carried out by NatureScot and their subcontractors (accessed May 2026) providing a georeferenced, time-stamped digital archive of maerl bed condition. Blue Hope Alliance surveys in 2025 focused on the Summer Isles area of the Wester Ross Marine Protected Area aboard the vessel *Honeydew.* Boats from Tanera were used for additional sampling.

In August-November 2025, 48 daytime water samples were taken from 16 stations (three replicates per station). Two sets of three samples were taken at reference sites; S1 was several kilometers off north mainland Scotland and S2 was taken in the Minch, >10 km away from land. All other water samples were collected by SCUBA divers on the seabed at 3-17 m depth. The sites chosen included maerl beds as well as locations near nutrient sources such as coastal villages and fish farms (Table 2; Fig. 3).

Three 50 ml clean new bottles were used to collect water samples at each station to calculate mean nutrient levels. Water sample bottles filled with seawater and taken to the seabed, where air from a divers' regulator was used to purge the water and then refilled and sealed. These samples were stored in a fridge or cool bag in the dark for up to two hours and 5 ml poured out leaving 45 ml of seawater sample prior to freezing. Two sets of triplicate samples were taken from Planet Rock on consecutive dives (S5 on Fig. 3). The water sampling locations included multiple maerl beds. In 2025 those at Moil Moire, Planet Rock, Little Loch Broom and Loch Ewe were photographed showing a high cover of filamentous red seaweed blooms whereas

Tanera-Fada channel had maerl with a lower cover of filamentous red seaweed than recorded when a fish farm was active close by.

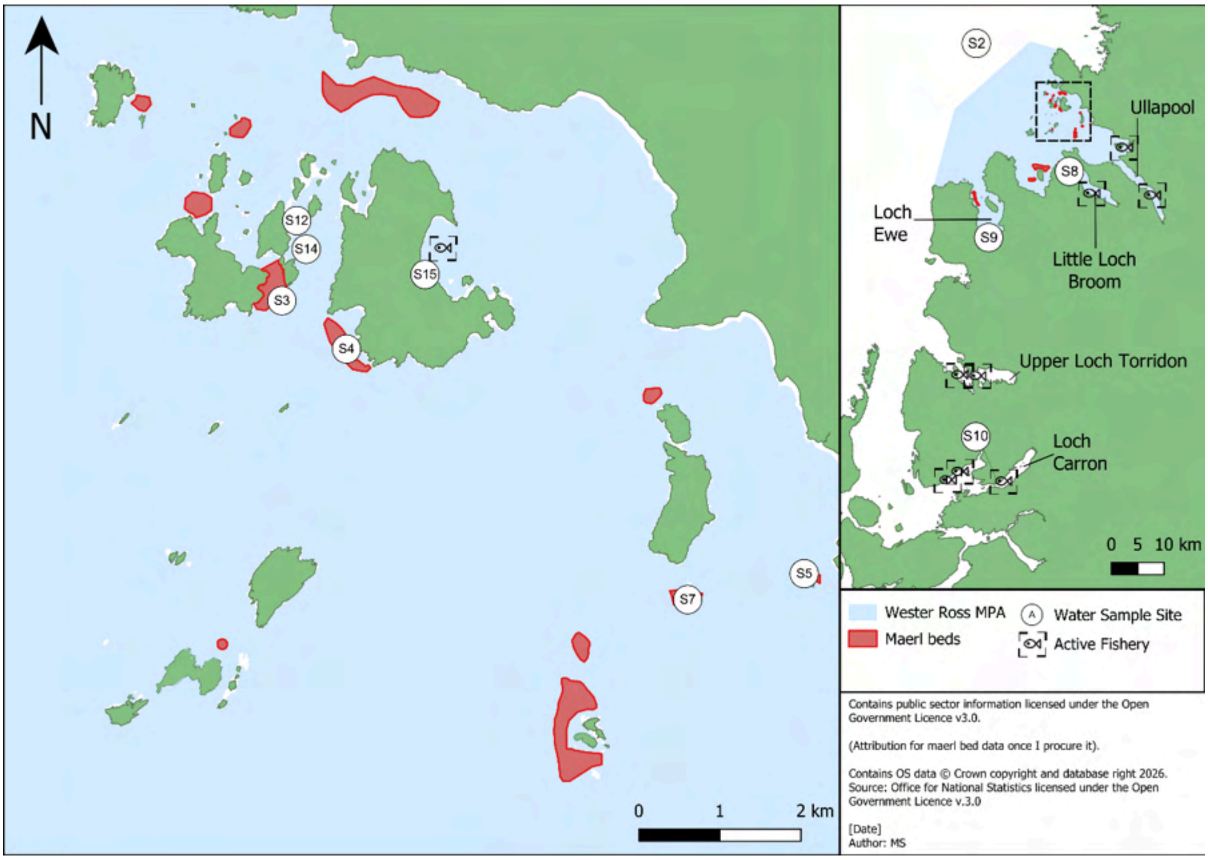

Fig. 3 Locations of salmon farms around Loch Carron, Upper Loch Torridon, and in Wester Ross Marine Protected Area (blue) in 2025. Maerl beds (red) and water sampling stations are also shown; where stations were very close together only one is shown (e.g. S15 was very close to water sample site S16). S3 is the Tanera-Fada channel, S4 is Moil Moire Bay, S5 is Planet Rock, S7 is Horse Island.

Water samples were sent frozen in a cool box with ice packs on the 20 January 2026 and arrived at Plymouth Marine Laboratory the next day. Ammonium, phosphate, silicate, nitrite, and nitrate levels were measured in the water, accurate to nM levels (Figure 4, Appendix 1).

Loch Carron (S10) and the Tanera-Fada channel (S3) had elevated ammonium (Fig. 4). Planet Rock (S5 and S6) had low levels, like the offshore reference sites S1 and S2. Anticipated high levels of nutrients were not detected close to a fish farm in Tanera Bay (sites S14-16). Perhaps the tide was running in the wrong direction to pick this up.

Site name and code	Maerl	Date	Time	Lat. N	Long. W	Depth (m)
Reference 1 (S1)	N	16.8.25	14.10	58.7827	4.1862	0
Reference 2 (S2)	N	17.8.25	13.40	58.1072	5.6988	0
Tanera-Fada transect (S3)	Y*	22.8.25		58.0066	5.4314	5-16
				58.0078	5.4340	
Moil Moire Bay, Tanera (S4)	Y*	22.8.25	15.00	50.0016	5.4174	15
Planet Rock transect (S5&6)	Y*	23.8.25	14.00	57.9793	5.3197	11-13
				57.9795	5.3120	
Horse Island transect (S7)	Y	24.8.25	12.08	57.9758	5.3437	14
				57.9759	5.3433	
Little Loch Broom transect (S8)	Y*	25.8.25	10.30	57.8976	5.3783	13
				57.8978	5.3780	
Loch Ewe transect (S9)	Y*	25.8.25	17.40	57.7777	5.6257	8
				57.7777	5.6257	
Loch Carron (S10)	Y	29.11.25	16.00	57.3579	5.5530	12
South Tanera Fada channel (S11)	Y	22.8.25	13.35	58.0076	5.4319	6
NW Fada fallow fish farm (S12)	N	23.8.25	10.15	58.0155	5.4292	16
NW of Fada fallow fish farm (S13)	N	23.8.25	11.30	58.0155	5.4279	17
S Fada fallow fish farm (S14)	N	23.8.25	14.00	58.0124	5.4269	14
Tanera Bay fish farm (S15)	N	24.8.25	13.40	58.0103	5.4018	3
Tanera Bay fish farm (S16)	N	24.8.25	14.00	58.0104	5.4018	8

Table 2. Sample site names, maerl presence (if sampled for epiphyte identification), date, time, position (upper start and lower end position data for transects) and depth data for Blue Hope Alliance monitoring in 2025. Triplicate water samples were taken at these sites.*

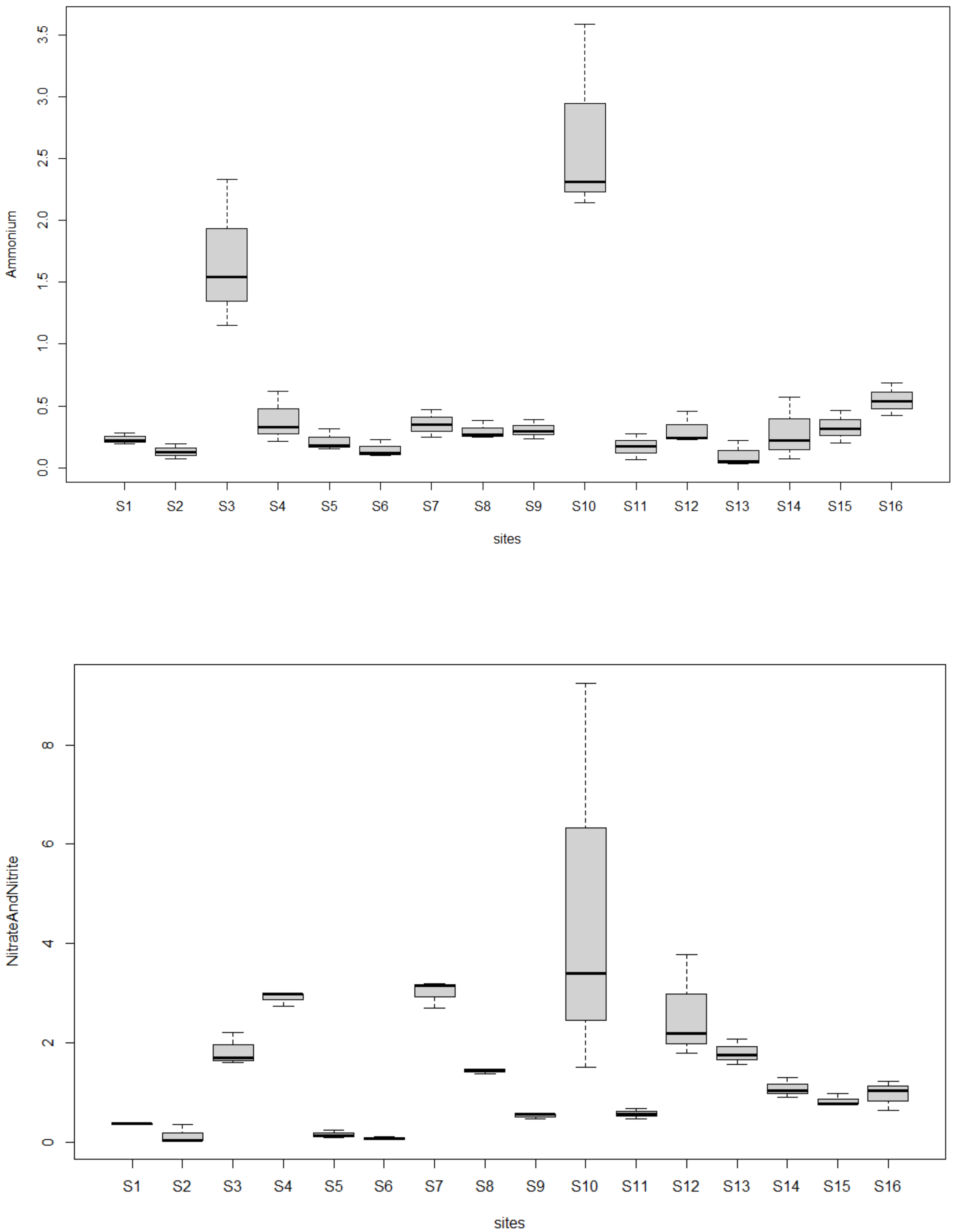

Fig. 4. Ammonium and nitrate+nitrite levels (μmol L^{-1}) for sites listed on Table 2. S1 & S2 show offshore background levels and Loch Carron (site S10) had the highest values in August 2025.

Sampling for nutrients by the Scottish Environmental Protection Agency usually takes place in winter as algal growth lowers nutrient levels in the summer (see Strickland & Parsons, 1972, Henderson & Elliot, 1989). It is standard practice to filter samples within three days of collection and to post them using dry ice. These are areas for improvement if the BHA is to continue assessing seawater nutrient levels. Because of the short transport time this should not have affected the pattern of results shown in this pilot study.

A focus on seaweed

In 2023, Blue Hope Alliance divers collected and sent maerl samples to Dr Peña (University of Coruna) who used molecular techniques to identify the maerl from Horse Island (collection site S7), Loch Carron (collection site S10) and Planet Rock (collection site S5). In 2024 maerl was collected from Upper Loch Torridon (n=1) and sent for analysis. *Phymatolithon calcareum* maerl was identified at Horse Island (n=4), Loch Carron (n=5) and Planet Rock (n=5) but the maerl from Upper Loch Torridon (n=1) was *Boreolithothamnion soriferum*. Judging by relatively slender branching and the lighter pink colour of maerl at all the sites surveyed by BHA in 2025 they were visually identified as *P. calcareum*, except *B. soriferum* in Upper Loch Torridon which was a darker red - although in situ identification of maerl is unreliable (Peña et al., 2015; Gabrielson et al. 2023).

Hily et al. (1992) found that in Brest *Ulva* sp. and *Ceramium virgatum* were the most abundant epiphytes on maerl in eutrophic conditions. On shallow eutrophic maerl beds in Galicia, Spain *Ulva* sp. is the main macroalgal bloom-forming species (Viviana Peña pers com). In August 2025, maerl was sampled by BHA surveyors in Wester Ross to assess the presence/absence of epiphytes. Maerl samples 2 cm deep x 10 cm x 10 cm were taken. The sites sampled (Table 2) were Tanera Fada channel (which had a low epiphyte load in 2025), Tanera Bay Moil Moire, Planet Rock, Loch Ewe Boor Rock and Little Loch Broom (which all had a high cover of epiphytes in 2025).

Epiphytes were typical of maerl beds in Scotland (Table 3). *Ptilothamnion sphaericum* can coat live maerl and often occurs with *Spermothamnion strictum* in equal abundance but in the maerl sample examined *S. strictum* was abundant but *P. sphaericum* was found only at Planet Rock. Records of species that are mainly associated with maerl (see Peña et al. 2014) were: *Lychaeta rhodolithicola* - a fine green seaweed and *Gelidiella calcicola* - a dark red seaweed that wraps itself around maerl (found at most maerl sites sampled). *Bonnemaisonia hamifera* is a non-native species and was the most abundant seaweed species in maerl samples from Loch Ewe and Little Loch Broom; it was not present in maerl samples from Moil Moire and Planet Rock but was visible in digital video and photoquadrats at these sites in 2025. Also present was *Dasysiphonia japonica* which is a non-native species that was first recorded in UK waters in Falmouth estuary in 2001 and has spread widely around UK coasts; it is common on maerl beds in Cornwall (Bunker et al. 2017; Doggett & Northern, 2025) and was recorded on Moil Moire maerl bed by Seasearch in Wester Ross in 2024.

Video and quadrat records 2025

In 2025, three qualitative videos were taken at Moil Moire (S4). In Tanera-Fada Channel 20 quadrat stations were surveyed and compared to the 21 quadrat stations sampled in 2023 (Fig. 5). These locations differ slightly from those surveyed by the Blue Hope Alliance prior to 2023. Elsewhere, four other sites (Planet Rock, Horse Island, Little Loch Broom, Loch Ewe) were surveyed using 20 m x 2 m band transects with start positions noted using a GPS attached to a surface marker buoy and new transects marked using a lump hammer to drive transect marks into the seabed.

On each transect a tape measure was reeled out along a recorded compass bearing. Stations along each transect line were photographed using a wide-angle lens based on randomly generated locations. At each station, a 0.5 m x 0.5 m (0.25 m^2) quadrat with an internal grid of 10 cm x 10 cm squares were placed on the seabed with digital photographs taken obliquely and from above (Fig. 6). This is like the method used by Doggett & Northern (2024, 2025) in one-off surveys of maerl beds in Cornwall. Each transect had a total survey area of 50 m^2 with the aim of recording 20 x 0.25 m^2 quadrats dispersed over the area to provide a digital record of 5 m^2 per transect. Qualitative photographs and videos were collected to support habitat characterisation.

Multiple photographs taken of the same quadrats enabled selection of the best lit and well-focused images for analyses. If a quadrat was obscured, e.g. by kelp, then % cover was estimated based on the area surrounding the obscured part. If >30% of the quadrat was obscured, then that station was not included in the quantitative analysis. Oblique photos were used for checking algal thalli from different angles and for the presence of maerl necrosis (patches of dead tissue, lacking red/pink phycobilin pigment) as they gave a detailed view of the nearest edge of the quadrat. The percent cover of live maerl, dead maerl and epiphytes was calculated in each whole quadrat sampling unit and expressed as mean ± Standard Deviation for each transect.

Table 3. Presence (1) of seaweed taxa found growing on maerl in northwest Scotland, identifications by seaweed expert Francis Bunker.

Taxa	Moil Moire Tanera 22/08/2025	Planet Rock Maerl Transect 23/08/25	Loch Ewe Boon Rock sample 1 25/08/25	Loch Ewe Boon Rock sample 2 25/08/25	Little Loch Broom 25/08/25
Acrochaetiaceae			1		
Bonnemaisonia hamifera			1	1	1
Metacallophyllis laciniata					1
Chaetomorpha linum				1	1
Lychaete rhodolithicola	1				
Cordylecladia erecta	1				
Coralline crusts	1				
Dasysiphonia japonica?	1				
Dictyota dichotoma		1			
Gelidiella calcicola		1	1	1	1
Gracilaria gracilis	1				1
Heterosiphonia plumosa	1	1			
Hypoglossum hypoglossoides				1	
Jania rubens					1
Brown crusts	1			1	1
Phyllophora crispa	1		1	1	1
Plocamium sp.	1	1		1	
Carradoriella elongata	1			1	
Vertebrata fucoides	1	1	1		1
Vertebrata nigra				1	
Polysiphonia stricta			1		1
Ptilota gunneri	1				
Ptilothamnion sphaericum		1			
Red non-calcareous crusts	1			1	1
Rhodophyllis divaricata		1			
Rhodymenia pseudopalmata					1
Sphacelaria cf. *cirrosa*			1		1
Spermothamnion strictum	1	1	1	1	1
Ulva sp. flat		1			1
Ulva sp. tubular		1			

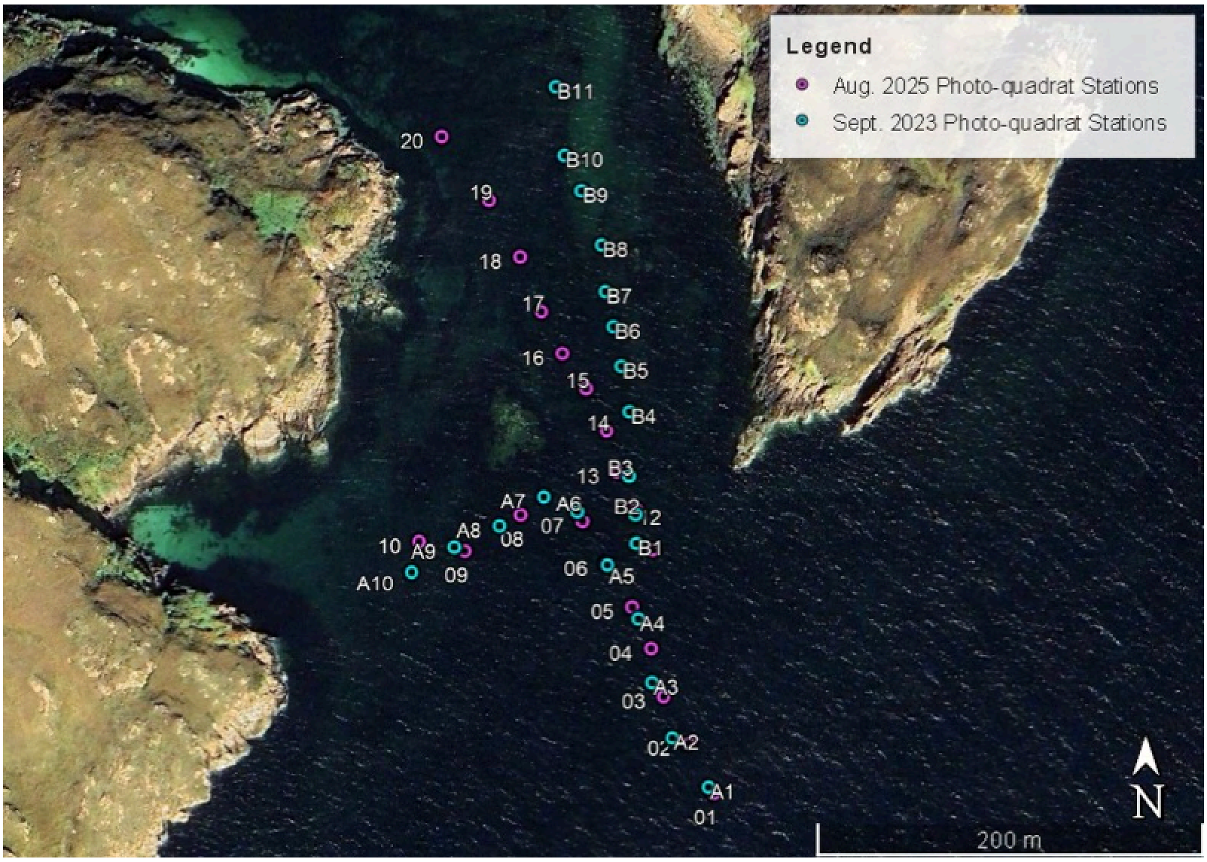

Fig. 5 Maerl bed photoquadrat stations surveyed in Sept 2023 and August 2025 in the Fada-Tanera Channel, Wester Ross Marine Protected Area, Scotland (from Graham Saunders).

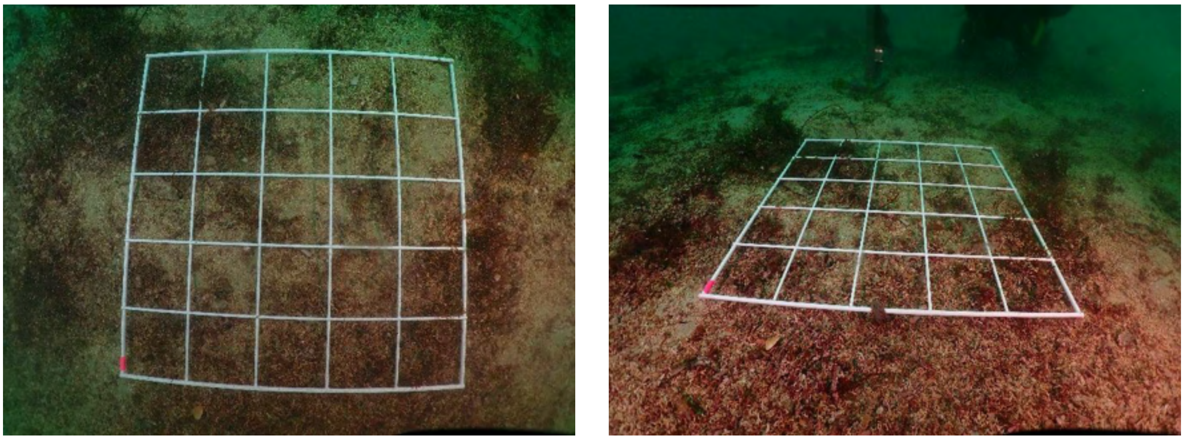

Fig. 6. 0.25 m^2 quadrat used to assess the abundance and status of maerl photographed from above and obliquely. In this example analysis of the left image by zooming in on each 10 x 10 cm square gave a live maerl cover of 48% (photos Doug Cowie).

Although the statistical design of the survey method was to collect 20 vertical view photoquadrats per transect, in practice this varied from 15-20 per site. The different numbers of replicates is not however a problem, as differences in cover among transects could be tested using a Kruskal–Wallis test. This test also accounts for non-normal data distribution, and non-uniform degree of scatter (heteroscedasticity) and so is well suited to the data collected. If significant differences are then detected between transects or over time, then pairwise comparisons could be performed using Dunn's post hoc test with Holm correction for multiple testing (Tursi et al. 2026). Statistical test results always need interpretation with consideration of ecological variations, for example transects with low % live maerl cover (e.g. <5% could either reflect natural occurrence or they could indicate human impact.

Here, due to time constraints, expert knowledge about the ecology of maerl bed habitats was used to assess differences between sites. Photoquadrats taken so far by the Blue Hope Alliance are of high quality and are suitable for statistical analysis, for example in the determination of maerl bed recovery after impacts. Follow-up funding will be sought from NatureScot and others to complete this task. Care would be needed in standardizing the method for assessing live/dead maerl abundance which might involve artificially enhancing the colour of images to bring out phycobilin pigmented live maerl more clearly. There is the potential in future to incorporate AI into the analysis of marine benthic photoquadrat data to speed up the process. These tools are currently being used to assess coral reef health in various parts of the world (Méga de Andrade et al. 2026). Interpreting the results would need care though, for example strong seasonal changes in fleshy algal cover occur (Peña & Bárbara 2008) which could mask long-term changes in live maerl abundance.

Moil Moire (S4)

The Blue Hope Alliance website notes that herring were found in spawning condition in creels deployed just outside of the marked maerl area, in the outer part of this bay in 2019 and very close to the shore southeast of Tanera.

Diving surveys in 2019, 2024 and 2025 show that shallow parts of the bay comprise sand and dead maerl gravel and that deeper areas have expanses of dead maerl megaripples with around 5% live maerl cover overall and the live thalli concentrated along the troughs of the ripples. Megarippled low live maerl cover habitat occurs around Portugal, Spain, Ireland and the UK in areas exposed to wave action (Keegan 1974; Hall-Spencer & Atkinson, 1999; Bosence & Wilson 2003; Pena et al. 2014; Joshi et al., 2017; Doggett & Northern, 2025). This habitat occurs near Gairloch and is used by herring for spawning here (pers. obs.).

Surveys in 2024 show the megarippled maerl bed at Moil Moire transitions into an area with abundant live maerl but it was heavily covered in what looks like *Trailiella* and low seaweed diversity although *Ulva* sp. blades, *Saccharina latissima* and *Desmarestia viridis* were frequent and the non-native *D. japonica* was collected in 2024.

Video taken in 2025 shows a large area of live maerl in the outer bay (seen over two separate 50 m long video recordings). On level (not megarippled) areas, patches of 100 % live maerl cover occurred in outer parts of the bay. Most of this level area had about 40% live maerl with the rest of the sediment consisting of dead maerl with a few coarse-sand patches. Habitat complexity was increased by an abundance of dead bivalve shells (*Dosinia exoleta, Lutraria* sp., *Ensis* sp., *Mya truncata, Laevicardium crassum, Gycymeris glycimeris*) indicating high infaunal biomass and the shells were intact indicating no scallop dredge damage. *Asterias rubens,* *Marthasterias glaciale* and *Cancer pagurus* were seen on the videos, likely attracted to feed on the infauna. Video from 2025 of level areas of maerl show an extensive overgrowth of filamentous red algae, including *Trailiella* and occasional small *Saccharina latissima* thalli. This might relate to the relatively high levels of nitate+nitrite recorded, possibly from nearby sewage outlets (Fig. 4). Megarippled areas of maerl had low epiphyte cover – presumably due to substratum mobility. Some areas of the maerl habitat had accumulations of drift algae including kelp, *Fucus serratus* and red algae.

Tanera-Fada Channel (S3)

This area was known as a good fishing spot for herring net fishermen in the past with shoals of herring seem in the channel since the Marine Protected Area was put in place (BHA pers. comm.). In 2016 scallop divers (Andy Holbrow and Andy Venters) took video of an area close to the farm which I have reviewed showing a mainly sandy seabed without maerl and an abundance of *Pecten maximus* and some flocculent organic material (possibly from the fish farm) on the sediment surface. In September 2018, March 2019, and September 2019 maerl was photographed in the channel off a small beach which emerges at low tide near a fish farm which was active during this period. Digital photo and video records from 2018 and 2019 show an extensive bloom of red filamentous algae. A 20-metre transect was set up in March 2019 and rephotographed in September 2019, at the same maerl bed accessible from the small beach mentioned above. A new method was adopted in 2023 to cover the whole channel using two dives covering 20 stations.

In May 2024 seaweed surveys were undertaken by BHA and Seasearch East on three live maerl habitats - in Moil Moire Bay, at the mouth of Tanera-Fada channel not far from where the 2023 maerl transect began, and at the previous 2018-2019 maerl transect site accessed from a maerl beach near a recently fallowed salmon farm. The Tanera Beg beach site (which was the area of maerl where a 25 m transect was laid in 2019) was surveyed in the most detail and has the longest species list (Table 4).

The 2024 seasearch surveys focused on seaweed species and noted epiphytic algal growth on the maerl with *Trailiella* frequent throughout. Their species list is impressive for a volunteer organisation and reflects that this maerl habitat was biodiverse despite the spread of *Trailiella*.

In 2025, the BHA survey team reverted to the 2023 transect method with live maerl cover averaged 60% at Transect 1 (first dive) and 90% at Transect 2 (n=10) with live maerl heaped several cm high in places. These transects combined had 75 % mean live maerl cover (± 30 SD), 25 % dead maerl (± 30 SD) and 40% epiphyte cover (± 13 SD). Almost all the living thalli had healthy-looking pigmentation, but all the stations surveyed also had a few thalli with pale patches of necrosis (dead tissue) revealing their white calcite skeletons.

Fig. 7. Filamentous algae on maerl in Fada and Tanera channel, Sept 2019, near a then active salmon farm (photo by Frank Melvin from a Blue Hope Alliance objection to Scottish Environmental Protection Agency about an application from Scottish Sea Farms to locate a new farm at Horse Island, 2020).

The maerl overlaid a muddy sand sediment which was probably extensively burrowed by large bivalve molluscs, judging by the presence of *Dosinia exoleta*, *Ensis* sp. and *Lutratia angustior* shells which were abundant on the seabed surface with no signs of breakage by scallop dredges. Transects 1 and 2 had mean epiphytic algal covers of 33 and 45%, which is high. The main epiphyte on maerl was *Dictyota dichotoma*, which is a brown alga that is commonly associated with maerl beds in Scotland at sites where there are low to moderate current flows. *Trailiella* was common but at a lower abundance than seen at this site in 2019 by Blue Hope Alliance volunteers. Other macroalgae recorded in photoquadrats were *Jania rubens*, branched (possibly *Scinaia* sp.) and bladed red algae. Most macroalgae are not easy to identify in photoquadrats (Fig. 8) but samples were taken for analysis. Transects 1 & 2 in the Tanera Fada Channel had large (up to 1.5 m long) *Saccharina latissima* kelp as well as smaller blades of *Ulva* sp. attached to maerl. Drift *Laminaria hyperborea* and *S. latissima* had accumulated on the maerl bed in places. Macrofauna included *Cerianthus loydii, Chaetopterus* tubes, *Carcinus maenus*, *Asterias rubens* (one was recorded feeding on an infaunal bivalve) and gobies.

This site appears not to have been damaged by scallop dredging. A salmon farm that was located nearby and is now fallow has also not caused major damage to the maerl. A few of the maerl thalli in all photoquadrats at the site were necrotic which is a concern, as this phenomenon has been noted in previous fish farm impact studies on maerl (Hall-Spencer et al. 2006). Detailed analyses of BHA records are needed to see if this necrosis is related to when a fish farm was located nearby. There was a high cover of the native brown seaweed *Dictyota dichotoma* with lower amounts of the non-native red *Trailiella* than seen at all other transect sites surveyed by the Blue Hope Alliance in August 2025. The site had high amounts of ammonium in the water.

Table 4. Seaweed presence and abundance found on three live maerl habitats on 24.05.24 in the channel between Fada and Tanera Beg near a then fallowed *salmon farm. S superabundant, A abundant, C common, F frequent, O occasional, R rare, indet. indeterminate, P present.*

Seaweed Taxa	**Tanera Beg, Picnic Beach**	**South Tanera Mor**	**Moil Moire Bay**
	58.010125N 5.435601W	58.005657N 5.431799W	58.004254N 5.417254W
	to 58.011081N 5.435780W		to 58.002953N 5.419618W
Cruoria cruoriiformis		R	
Corallinaceae crusts			O
Maerl indet .	C	F	C
Corallina officinallis	R	R	
Jania rubens	R	R	
Hypoglossum hypoglossoides	R		
Phycodrys rubens	O		
Pterothamnion plumula	O		
Delessaria sanguinea	O		R
Plumaria plumosa	R		
Halarachnion ligulatum	O	O	
Chylocladia verticellata	O	O	R
Lomentaria clavellosa		O	
Calliblepharis ciliata	O	O	
Metacallophyllis laciniata	O		
Plocamium lyngbyanum	R	R	O
Cryptopleura ramosa	O		
Erythroglossum laciniatum	R		
Nitophyllum punctatum	O	O	O
Phyllophora crispa	O	O	
Rhodophyllis divaricata	R	R	
Porphyra sp.		O	
Wildemania amplissima		R	
Vertebrata nigra	O		
Melanothamnus harveyi	O		
Rhodothamniella floridula	A		
Bonnemaisonia asparagoides	O		
Bonnemaisonia clavata	O	R	
Spermothamnion repens	R		
Dasysiphonia japonica	F	O	P
Carradoriella elongata	O	R	
Polysiphonia sp.			F
Rhodomela confervoides	F		

Bonnemaisonia hamifera (Trailliella)	F	F	F
Vertebrata byssoides	R		
Vertebrata nigra		O	
Bryopsis plumosa	O		
Ulva sp.	O	O	R
Lychaeta rhodolithicola	R		
Cutleria multifida (Aglaozonia)		R	
Chorda filum	O		
Saccharina latissima	O	O	R
Alaria esculenta			R
Sphacelaria sp.	R		
Halidrys siliquosa	R		
Filamentous brown indet.	O		
Dictyota dichotoma	R	R	O
Scytosiphon sp.	F		
Chordaria flagelliformis		R	
Desmarestia aculeata	F	O	
Desmarestia ligulata		O	
Desmarestia viridis	F	R	
Desmarestia sp.			O
Brown 'jellyweed' indet.		R	

Horse Island (S7)

In February 2026 a fisherman reported 60-70 large dead herring in his creels set at around 100 m depth between Horse Island and Tanera Mor and one in a creel in shallow water to the East of Horse Island. Horse sound was historically known as one of the best prawn fishing areas and is fished for prawn, crab and lobster (Blue Hope Alliance pers. comm.).

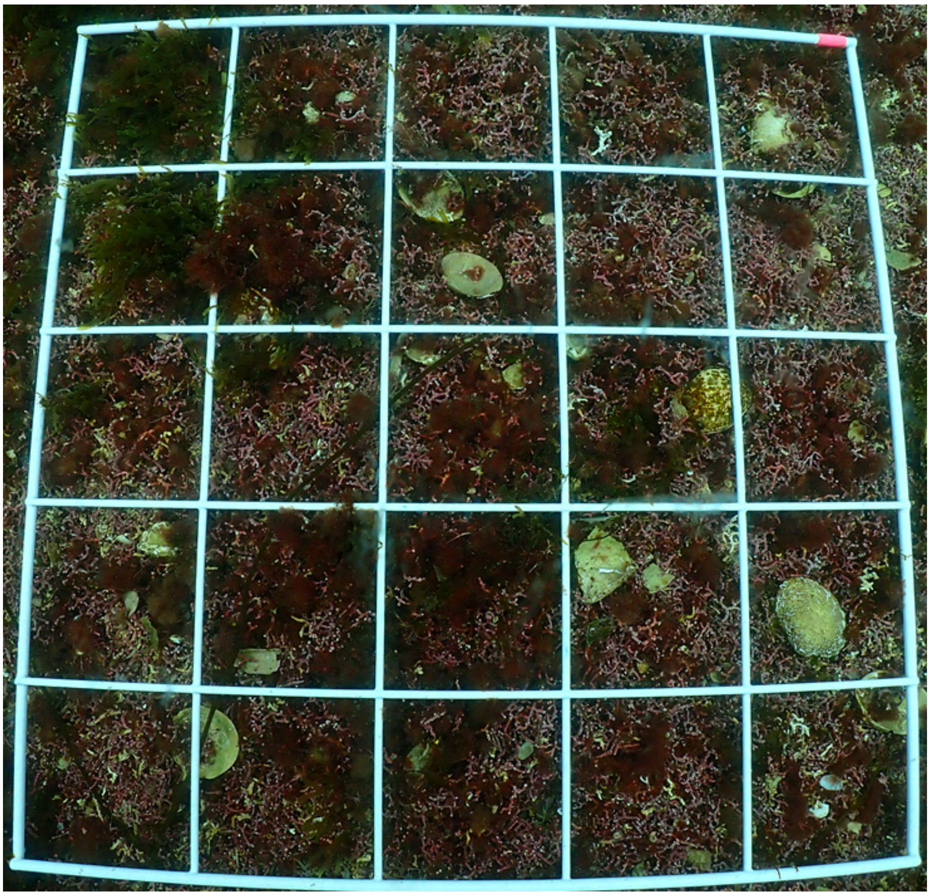

Fig. 8. High live maerl cover with bivalve shells and epiphytic Trailiella. *Tanera Fada Channel 22.8.25, 10 m depth. Quadrat width 50 cm (photo Doug Cowie).*

In 2020, Sea Change Wester Ross, a member group of the Blue Hope Alliance (BHA) argued against a Controlled Activities Regulations (CAR) application for a salmon farm at a former shellfish farm site on the southeast end of Horse Island backed by local creel fishermen who knew the area is a productive ground for catching *Nephrops norvegicus* prawns (CAR/1188421). In 2016 the BHA calculated that "*a salmon farm the size of the proposed Horse Island site is likely to drop raw sewage … equivalent to the sewage of 26000 people...around 17.5 times the amount produced by the population of Ullapool*". Scottish Sea Farms Ltd. have not taken their fish farm proposal to the Highland Council for planning approval and no farming at the site has commenced. The company received a discharge licence in January 2025 from SEPA.

The Scottish Environmental Protection Agency granted a Controlled Activities Regulations licence despite the findings of studies funded by SEPA that showed that organic wastes and the organophosphate nerve poisons that are used to treat salmon lice severely impact maerl beds and their associated fauna near fish farms with the areas impacted influenced by the strength and direction of currents and periods of slack water (Hall-Spencer et al. 2006; Hall-Spencer & Bamber 2007). In September 2021 BHA found sparse live maerl 250 m from the proposed fish farm site and a dense covering of live maerl at 300 m from the site. This site has not yet been, and may never be, used for farming fish.

June 2018 video surveys show that the Horse Island maerl bed had patches of very high (>80%) live maerl cover and extensive areas with >5% live maerl and the sea cucumber *Neopentadactyla mixta*. Some areas had large thick shells that were broken (indicating scallop dredge damage) and high levels of *Trailiella* cover in places. *Limaria hians* were constructing nest structures in this maerl bed.

In 2023, BHA took nine 0.25 m^2 photoquadrats and video records along a 20 m monitoring transect which had abundant *Limaria hians* nests made up of a mix of live and dead maerl often with a high cover of *Trailiella*. Dead shells were common on the sediment surface, some of which appear to have been broken by scallop dredges and visible live maerl cover was low (around 5%).

In 2025 this transect line was resurveyed with a start position of 57.976037°N, 5.343813°W and an end position of 57.975924°N, 5.343512°W. 21 stations were photographed but three had too much drift kelp on them to analyse. The start of this transect was the same habitat with abundant *Limaria hians* nests. Mean dead maerl cover was 55% (±34 SD, n=18) and epiphytes covered 56% of each quadrat (±29 SD, n=18). This is similar to the *Trailiella* cover recorded on video in 2018 and 2023. The mean live maerl cover for this transect in 2025 was 11% (± 14 SD, n=18) which is more than double that recorded in 2023 and indicates that live maerl patches can be moved by wave action. It cannot be due to rapid recovery of maerl since live maerl only grows about 1 mm per year (Blake & Maggs, 2003) and recovery from damage to a maerl bed in Brittany has been recorded at a rate of 0.5% per year (Grall & Hall-Spencer 2025).

The seabed habitat on this transect transitioned into a mainly dead maerl deposit without *L. hians* nests with the amount of live maerl increasing to *ca* 40% cover towards the transect end. In 2023, *L. hians* nests and low maerl cover were found all along the transect, showing that these nests can come and go over the years. At the transect end some robust shells look as if they had been broken by scallop dredging, judging by the sharp fracture angles, as also seen in 2018 and 2023. Fauna recorded in photographs of the transects in 2025 include *Marthasterias glacialis*, *Porania pulvillus*, juvenile *Asterias rubens* and *Echinus esculentus*.

Fox Point in the Summer Isles is known by the BHA to have been heavily scallop dredged. Scallop diver Andy Holbrow and other divers in communications with BHA say this area had healthy maerl. Surveys by BHA in 2016 show a mainly sandy gravel seabed type with small amounts of live and dead maerl, sparse seaweeds including *Cladostephus spongiosus*, and some broken *Lutraria angustior* and *Ensis* bivalve shells. Their 2018-2023 transect surveys show no regrowth of live maerl.

A new transect line was laid off Horse Island in 2025, where water and maerl samples were taken about 100 m from previous survey work, as shown on Table 2 (S7). Here mean live maerl cover was only 1% (±1SD, n=19) with the rest of the visible surface sediment composed of dead maerl (40% ± 12 SD, n=19) with *Limaria hians* nests covering most of the habitat (63% ± 13 SD, n=19). In some areas of the transect *L. hians* nests were covered in *Trailiella* (Fig. 9) others were covered in a more diverse range of filamentous and blade-forming red seaweeds. Between nests, the dead maerl had no attached seaweed or epibenthic animals. The dead maerl was eroded, lacked complex branching and many dead thalli had a brown hue indicating old, subfossil maerl. Drift kelp, *Porania pulvillus, Marthasterias glacialis,* juvenile *Asterias rubens* and juvenile flatfish were also recorded in photographs of the site. The abundant large *Limaria hians* nests are a certain sign of no recent scallop dredging gear impacts on this transect (see Hall-Spencer & Moore 2000c).

Fig. 9. Limaria hians *flameshell nests covered in an overgrowth of invasive filamentous red algae (Trailiella),* Horse Island 24.8.25, 14 m depth (photo Doug Cowie).

Planet Rock (S5&6)

In August 2016 observations were made on a large (ca. 80 m x100 m) maerl bed. Images show that at that time the maerl looked healthy and 'clean' (as it had no filamentous algal epiphytes or patches of necrosis/dead tissue). Some areas had a small amount of *Trailiella* cover. In some places live maerl thalli piled on top of each other several centimeters thick (Fig. 10). Video clips of the site are of exceptional quality and show maerl with reproductive conceptacles (ACJ_0944) and abundant juvenile northern feather stars (*Leptometra celtica)*.

Large unbroken bivalve shells were on the sediment surface, and king scallop *Pecten maximus* were common and included very large specimens. The variegated clam *Mimachlamys varia* were also present nestled in amongst the live maerl thalli. Other large animals present were the burr owing anemone *Cerianthus lloydii*, *Macropodia* spider crabs that were covered in *Trailiella*, *Palaemon serratus* prawns, common starfish (*Asterias rubens*), spiny starfish *Marthasterias glacialis*, seven-armed starfish *Luidia ciliaris*, cushion stars *Porania pulvillus*, ascidians, Sea scorpions *Taurulus bubalis* and flatfish (possibly lemon sole *Microstomus kitt*). Moore

(2019) considered this the best developed maerl bed of the four that were surveyed in Wester Ross in 2016 with sparse foliose and filamentous algae but common *Saccharina latissima*.

Fig. 10 Planet Rock in 2016 showing an area of very high live maerl cover and Saccharina latissima *kelp with a holdfast entangling live maerl – this a likely means by which maerl is transported to new sites. The maerl looked 'clean' with sparse epiphytic overgrowth by small seaweeds. Drift* Fucus serratus *wrack is in the middle.*

On 3 June 2018 the BHA set up a transect in the 2016 survey area starting at 57° 58.782 N 5°19.187 W, at 12.5 m depth and heading due north. Video shows around 50% high live maerl cover on dead maerl gravel, unbroken large shells and *Saccharina latissima* and other seaweeds present. Twenty 0.25 m^2 quadrats were filmed showing high live maerl cover (46% ± 17.7 SD). In September 2019 divers returned and *Limaria hians* nests made with live and dead maerl were observed not far from the transect. On the transect there was high live maerl cover (around 50%) and the maerl looked 'clean' although *Trailiella* was present in patches away from the transect.

In 2023 the site looked as if it had been scallop dredged with lower live maerl cover and an abundance of dead *Limaria hians* shells with quadrats obscured by broken up remains of their byssus nests. In 2025 there was a complete absence of *L. hians* nests along the transect but there was more cover of *Trailiella* than seen in previous years. It had a fairly high live maerl cover (mean% ± SD of 60±19 live maerl, 40±19 dead maerl, 30±9 epiphyte cover, n=18) although unlike in 2016 no areas were found with a thick layer of live thalli growing on top of one another. Each photoquadrat also had a high cover of epiphytic algae (mean 30% n=18) which was concentrated on the live maerl. Epiphytic seaweeds tended not to occur on dead maerl, probably because the dead maerl was smaller and more mobile than the interlocked live maerl thalli. *Trailiella* was the most abundant epiphyte on the maerl bed and was much more abundant than observed in the Tanera Fada Channel in

2025. 16 of the 18 photoquadrats had a few thalli with pale patches of necrosis or dead areas, revealing their white calcite skeletons which indicate poor habitat status (Fig. 11).

The maerl-covered finer sediment was extensively burrowed by large bivalve molluscs, judging by the presence of abundant *Dosinia exoleta*, *Ensis* sp. and *Lutraria angustior* shells on the seabed surface. What look like *Upogebia deltaura* burrows were flush with the sediment surface (cf. the mounds or funnel openings found in some thalassinidean species) with circular diameters of <7 mm surrounded by fine grey sediment (see Hall-Spencer & Atkinson (1999).

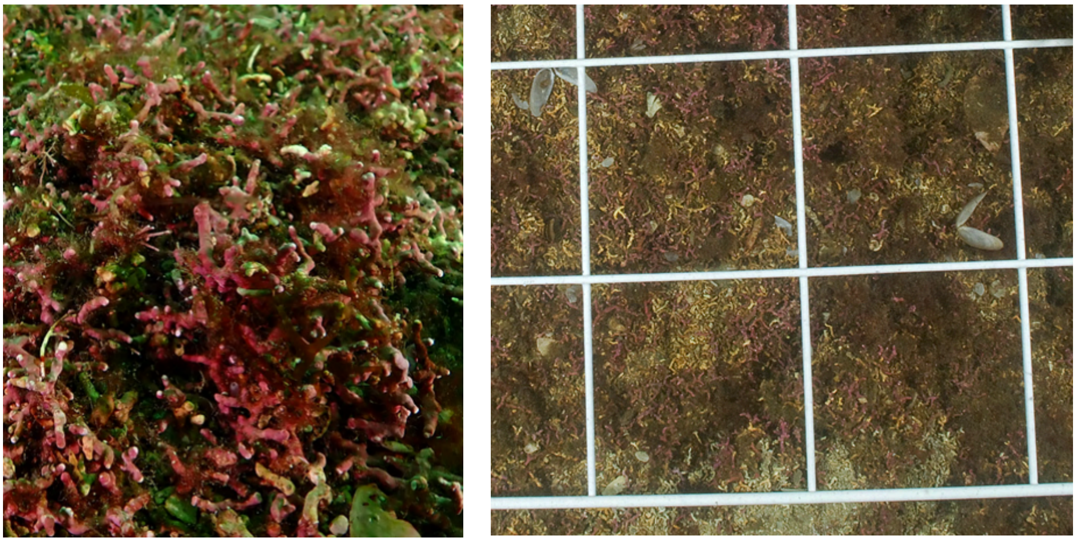

Fig. 11 Left: 2025 Maerl with abundant Trailiella *and some thalli have pale patches of necrosis or dead areas revealing their white calcite skeletons, indicating stress and habitat decline. Right: 2023 Dead* Limaria hians *shells. Planet Rock, 12 m depth, each quadrat grid 10 x10 cm. (photos Doug Cowie).*

Several bivalve mollusc shells were recorded with sharp fractures that were consistent with scallop dredge damage and unlike those inflicted by *Cancer pagurus* (Fig. 12). Dead *Limaria hians* shells were present but no living nests were seen which is also consistent with scallop dredge damage and a decline in the status of maerl at this site over recent years. Other macrofauna included *Necora puber*, *Leptometra celtica, Porania pulvillus*, *Luidia ciliaris*, *Ascidia aspersa*

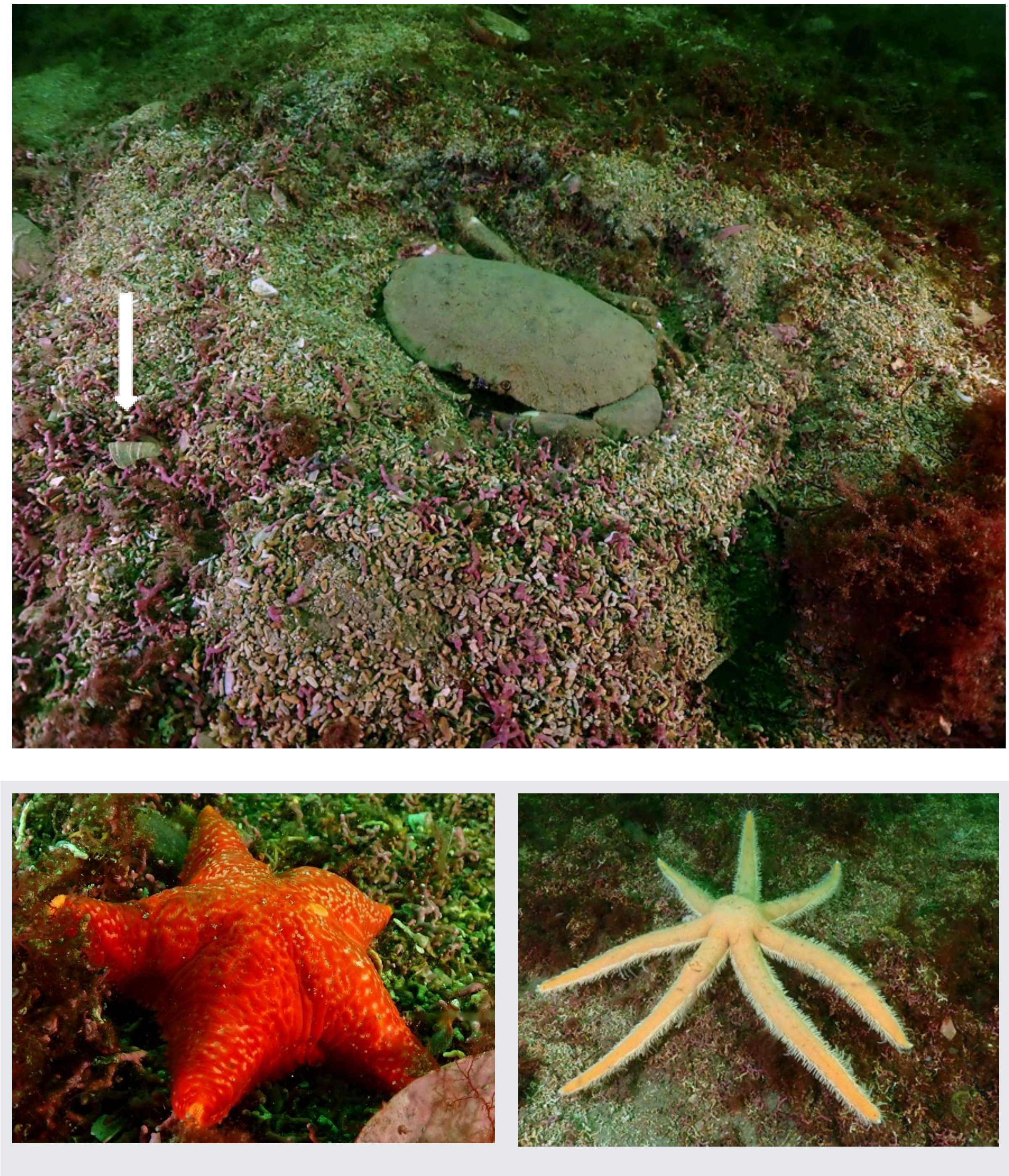

Fig. 12 Top: Edible brown crab Cancer pagurus *burrowed into maerl to feed. Arrow indicates a thick bivalve shell sharply broken in a way that is consistent with scallop dredge damage but not* C. pagurus *predation. Left:* Porania pulvillus*, Right:* Luidia ciliaris. *Planet Rock, 23.8.25, 12 m depth (photos Doug Cowie).*

Little Loch Broom (S8)

The BHA has concerns about nutrient discharges from a new hatchery installation (accessed May 2026) at Ardressie on the shore of Little Loch Broom adding to those of a long existing fish farm in the loch. The broodstock facility has cost an unspecified number of millions, including £5 million from the UK government's £100m Seafood Fund Infrastructure Scheme. In 2025, 17 stations were photographed along a newly laid transect line to provide a baseline. The mean live maerl cover for the transect was 36% (± 24, n=17), mean dead maerl cover was 62% (±24) and epiphytes covered 60% (±19) of each quadrat. Complexly branched maerl and intact large dead scallop shells suggest that there has been no scallop dredge impact here (Fig. 13). However, there were clear signs of maerl deterioration due to the mottled appearance and partial death of individual maerl thalli in all quadrats, more so than seen at all the other site surveyed in 2025. Heavy overgrowth of epiphytic *Trailiella* was at levels that indicate a maerl habitat in poor environmental status. Perhaps septic tanks from homes, holiday lets and the hotel are causing this issue. The relationship between nutrient enrichment/ invasive algal blooms and maerl bed condition is worthy of further investigation.

Saccharina latissima kelp and green *Ulva* sp. blades were attached to the maerl habitat in places. Spiny starfish *Marthasterias glaciale* were present, with some *Diplosoma* and *Ascidiella aspersa* ascidians. The maerl overlaid a muddy sand sediment which was extensively burrowed, including by *Upogebia deltaura* shrimp - judging by burrow surface appearances.

Fig. 13 Left: transect tape at top of image, with intact Pecten maximus *shell, high live maerl cover with some thallus necrosis and abundant epiphytic Trailiella. Right: Trailiella and* Jania rubens *epiphytic on maerl. Little Loch Broom, 25.8.25, 13 m depth (photos Doug Cowie).*

Loch Ewe (S9)

This is the most southern Loch in the Wester Ross MPA. The poor environmental status of maerl in Loch Ewe was raised as a likely impact of fish farms by Moore (2014) followed by Sea Change Wester Ross in a complaint to SEPA about proposals to expand salmon farm sites in the MPA (Fig. 14). BHA survey images from 2019 show all the signs of extensive damage to maerl from organic enrichment at the site of a previous fish farm at Boor Rock but with the additional phenomenon of very high epiphytic seaweed growth, not recorded in previous studies of the impact of fish farms on maerl beds in Scotland and Norway (Legrand et al. 2024). Fish farms have been moved around this loch with reports of their impact on other maerl beds in the loch which may be especially susceptible due to low water exchange. Remote Operated Vehicle survey footage from July 2022 also shows maerl in Loch Ewe in very poor condition as it was mostly dead, covered in epiphytes and with a buildup of silt and anoxic sediment.

Since 2020 there have been no fish farm in this loch as Mowi, or Marine Harvest as it was known, have left. It is considered that this was in response to protests about the collapse of the Loch Ewe and Loch Maree salmon and sea trout fishery as well as the Loch Ewe farm's failure to pass any benthic surveys during their presence in the loch.

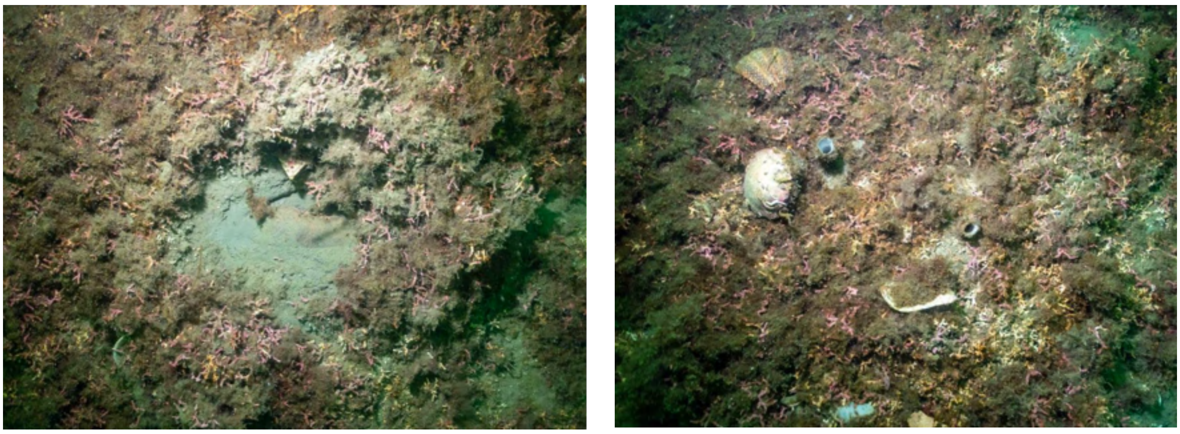

Figure 14. Photos from 2019 show maerl in Loch Ewe close to a fish farm showing filamentous algae, mottled unhealthy-looking thalli, dead maerl and silt (picture Owen Paisley).

In 2025 an old BHA transect line was not found so a new one was set up in the same area (S9). Visually, this maerl bed has by far the most degraded of those surveyed by the BHA in 2025, showing no recovery in the time they have been monitoring the site. Almost all (96% ±2 SD, n=15) of the surface layer of maerl was dead (Figure 15), yet the dead thalli were smooth surfaced and not worn down as in maerl deposits that are 100s of years old, suggesting 'the maerl died recently (few years maximum. There was 2% live maerl cover (±2 SD, n=15) but in every quadrat the living maerl had surface tissue necrosis.

A striking aspect of this site was the almost complete overgrowth of the surface of the maerl habitat by *Trailiella* with few other seaweed species present. The 90% (±4 SD, n=15) cover of the habitat by epiphytes included coverage of dead maerl thalli. At more exposed sites epiphytes were not commonly found on dead maerl but shelter from wave action appears to allow this to occur at the Loch Ewe site. A complexly branched maerl morphology of the live and dead maerl thalli suggests that there has been no scallop dredge impact at this site. The maerl overlaid very fine muddy sediment. The cephalapsid sea slug *Philine quadripartita* was common at this site, it is a predator on small molluscs and so can become common if prey is abundant. Other macrofauna included juvenile *Astropecten irregularis*, *Marthasterias glaciale* and butterfish (*Pholis gunnelus*).

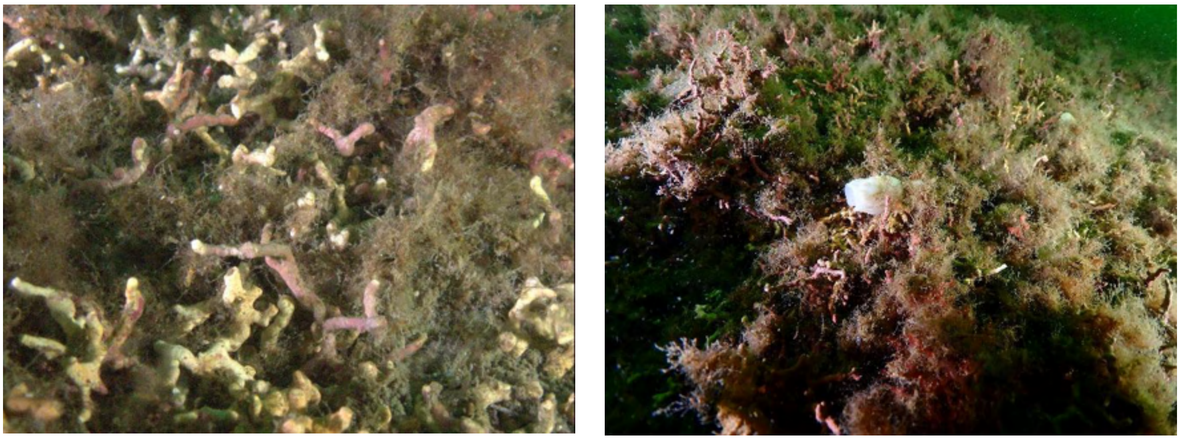

Fig. 15. Left: a mix of dead maerl (white) and necrotic live maerl (mottled pink) with and extensive Trailiella *overgrowth. Right: a 2 cm long white* Philine aperta*. Loch Ewe, 25.8.25, 8 m depth (photos Doug Cowie).*

Upper Loch Torridon

Boreolithothamnion soriferum is the maerl forming species at this site which is in a no trawling exclusion area, set up in 2000. Scottish Natural Heritage (now NatureScot) surveyed this area and produced a video in 2001 showing a biodiverse maerl bed with high maerl cover, live maerl growing several cms thick and with a 'clean' appearance without the epiphyte *Trailiella*. Queen scallops were present and there was no evidence of scallop dredge or potting damage or poor water quality. In 2023 and Sept 2024 citizen science snorkeling surveys took place in the shallows in the far eastern part of the loch. Video and still images (e.g. Fig. 16) from 57.53754 N 5.53426 W at 1 m depth show an abundance of *Trailiella* firmly attached to maerl thalli covering most of the maerl habitat, as well as some *Saccharina latissima* and *Chorda filum*.

In June 2025 Graham Saunders, a long-standing contributor to the BHA scientific advisory committee, helped the Blue Hope Alliance run a training session for new citizen scientists' groups emerging in the region. This training introduced citizen scientists to 20 m transect maerl monitoring methods using photoquadrats. BHA focused on Upper Loch Torridon to support a new group called The Friends of Loch Torridon, and in turn the group supplied local boats and skippers. During the training, BHA trainees set up two transects in the shallows in the far eastern part of the loch. The trainees photographed them both.

A transect at 6.8 m depth started at 57.54078 N 5.52713 W, on a 270 degrees heading and provided 20 photoquadrats placed using a random number generator. These show high cover of live maerl stacked several centimeters high and a lower epiphytic algal cover than recorded in shallower water in 2023-24 (Fig. 17). A nearby transect at 6.7 m depth (57°32.534 N 005°31.753 W) had very high *Saccharina* *latissima* kelp cover. This site still shows no evidence of scallop dredge or potting damage with large unbroken maerl forming a complex three-dimensional structure but a persistent bloom of *Trailiella* appears to be damaging the habitat in the shallowest areas. Monitoring a similar *B. soriferum* maerl bed in Loch Sween has shown that these habitats can withstand high variability in temperature and survive for months at lower levels of pH expected due to ocean acidification (Burdett et al. 2025).

Fig. 16. Thick cover of Trailiella *on* Boreolithothamnion soriferum *maerl with a mix of live (red) and dead (white) maerl thalli and the kelp Saccharina latissima in the shallows of eastern Upper Loch Torridon, Scotland, 22.9.24. (Photo Peter Cunningham/ Maerl Friends of Loch Torridon).*

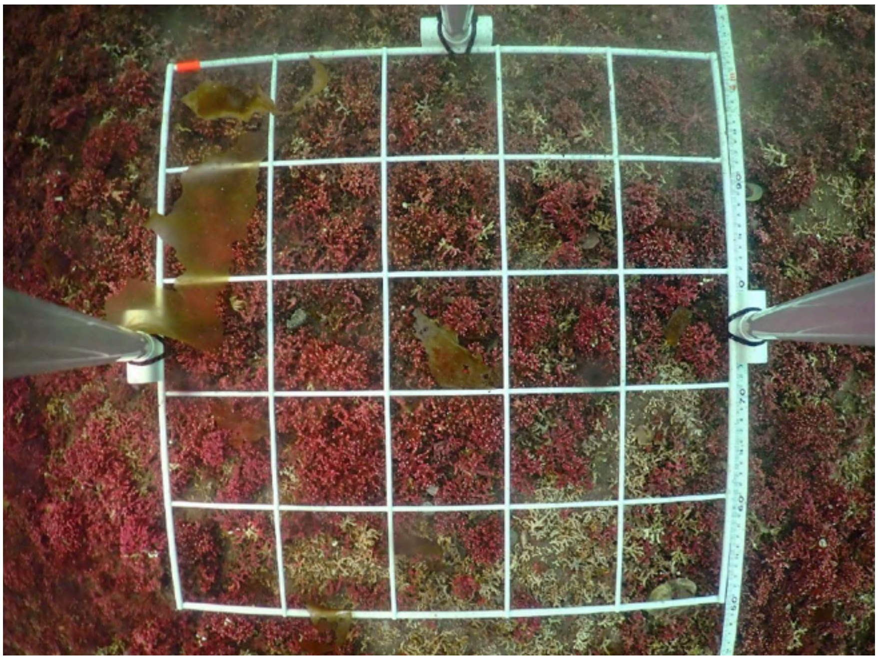

Fig. 17. Boreolithothamnion soriferum *maerl at 6.7 m depth in Upper Loch Torridon showing high live maerl (ca 78%) cover with mud visible below a patch of dead maerl (photo Vanessa Charles).*

Loch Carron

There is a maerl bed off North Strome which has been dived by BHA volunteer divers for many years as Loch Carron is a favourite site for many recreational divers across the nation. See Andy Jackson's photo from 2019 (Fig. 18). After Andy died in September 2020 the BHA and Andy's friends set up a memorial survey at his favourite dive site. Andy Jackson, SubSeaTV was the diver-cameraman who supported SCFF and Sea Change and helped found the BHA. Loch Carron contains the world's largest known flame shell bed, and this surrounds the maerl bed, it is known for its fast currents. In 2020 the maerl bed was mapped and a transect photographed that was established and surveyed by Heriot-Watt University for Scottish Natural Heritage in 2017. In 2023 to assess the interaction between flame shells and maerl and measure their interactions, 4 x 5 m monitoring transects were put along the circumference around 9-10 m apart. Each 5 m transect went 2.5 meters into the maerl area.

Photoquadrats were recorded and there were patches of high (ca 50%) maerl cover. The site looked to be in good condition with 'clean' maerl (no *Trailiella* seen). This is the site where water samples showed the highest amount of nutrients. In 2025 BHA returned to find the pins and divers reported that it appeared as if the site had changed a great deal (Blue Hope Alliance pers comm.) with more flame shell nests and kelp growth in the areas where the pins were. Three of the pins were found by ISAC divers in support of the BHA. In 2026 the BHA-ISAC collaboration intends to locate the pins and investigate the interaction between kelp, maerl and *Limaria hians* flameshells across a larger area.

Fig. 18. Maerl with high live maerl cover and 'clean' looking thalli (no Trailiella*) with brittlestars* Ophiocomina nigra*, a whelk* Buccinum undatum *and a dragonette* Callionymus *sp. in 2019 (photo Andy Jackson).*

Discussion

The BHA digital monitoring archive is testimony to their dedication and many talents, providing georeferenced high quality photographic and video evidence about the status of maerl in the region. In 2025, elevated levels of nutrients were found at maerl beds in the Tanera-Fada channel and in Loch Carron, but not near a fully stocked salmon farm in Tenera Bay which seems anomalous although the current during that point check may have carried low nutrient waters in.

How much inorganic nutrient is being released into the Wester Ross MPA by human activities is not known and any link to the adverse effects of *Trailiella* blooms is not clear. Work in Norway shows that salmon farms are major sources of nitrogen and phosphorous in coastal waters (Wang et al. 2012). Stable isotopes of nitrogen can be used to trace wastewater contamination through food webs in coastal marine environments before major ecological impacts take place (McLelland et al., 1997). Research is needed to put fish farm nutrient emissions into the context of other sources of excess nutrients within the MPA, such as urban wastewater. Research is also needed into the impacts of invasive *Trailiella* on maerl habitat.

In Brittany, opportunistic algae can become very abundant in areas affected by eutrophication (Grall & Hall-Spencer, 2025; Fig. 16). Normally the biomass of non-calcified seaweed on maerl remains low due to grazing and mobility of the surface layer of maerl thalli, although kelp can be conspicuous and transport maerl clumps in holdfasts during storms. Micrograzers, such as juvenile sea urchins and the small limpet *Acmaea virginea*, help keep maerl surfaces clean by feeding on diatoms and other microalgae.

Fig. 16. Bay of Brest showing a seahorse and maerl overgrown by fleshy seaweeds, likely due to eutrophication. Photo Francis Bunker 29.06.2018.

The following points are key findings…

- Molecular techniques confirmed that *Phymatolithon calcareum* formed maerl at all the beds sampled in 2023-2024, except Upper Loch Torridon which was *Boreolithothamnion soriferum.*
- There are clear differences in the mean values for live maerl cover between sites. Quantitative differences within sites over time have not yet been analysed. Photoquadrats taken so far by the Blue Hope Alliance are of high quality and are suitable for statistical analysis, for example in the determination of maerl bed recovery after impacts. Follow-up funding will be sought from NatureScot and others to complete this task.
- There has been no recovery so far from historical damage to maerl by fish farming in Loch Ewe, likely due to restricted water circulation at the enclosed site and possibly because of ongoing impacts of sewage.
- The diversity of seaweeds found on maerl was high in the Tanera-Fada channel but low at sites where non-native red filamentous *Trailiella* stage of *Bonnemaisonia hamifera* was abundant. The Blue Hope Alliance surveys show that *Trailiella* has become invasive, forming blooms that can smother and damage maerl habitats.

- *Trailiella* blooms peaked in the Tanera-Fada channel when a fish farm was nearby but have receded. At Moil Moire, and Planet rock *Trailiella* cover seems to have increased from 2016-2025. At Loch Ewe it has been a persistent issue since at least 2019, and it is covering a maerl bed in Little Loch Broom and the shallower parts of a maerl bed in Upper Loch Torridon. It was not recorded in digital photographs in Loch Carron in 2019 or 2023 where the tidal current may turn over the maerl sufficiently to prevent it.
- There is evidence of pre-2018 scallop dredge damage to maerl beds at Horse Island and recent damage (in 2023) at Planet Rock. Planet Rock previously had thick layers of living maerl, these have been removed and in 2025 the site had a heavy covering in *Trailiella* which was scarce before 2023.

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Additional information from Sara Nason

The Return of the Herring?

The historic richness of northwest seas was likely driven by the abundance of maerl and herring—two interconnected keystone species. Herring spawn on maerl, making their futures inseparable. Restoring marine ecosystems therefore depends on protecting both, especially live maerl beds, which underpin the wider food web supporting marine life, fisheries, and local economies.

Recent dives by local fishermen and film crews, including work alongside *Blue Planet*, confirm herring spawning on vulnerable maerl beds outside protected zones, leaving them exposed to scallop dredging. We call for urgent closure and proper enforcement across all maerl and herring spawning grounds.

Despite protections, recovery remains limited. The Gairloch area avoided trawling until the 1980s, but decades of scallop dredging have damaged habitats. Although the Wester Ross Marine Protected Area was closed to dredging in 2015, maerl recovery is hindered by illegal activity and invasive algal growth, likely driven by nutrient pollution from sewage and fish farms. Further analysis is underway to assess these sources.

Encouragingly, fishermen and communities report signs of recovery. Herring shoals are returning, alongside increased sightings of dolphins, whales, and seabirds. Juvenile herring have been observed for the first time in decades, and recent surveys, satellite data, and environmental DNA studies confirm renewed spawning activity across the region.

However, protection remains incomplete. Herring themselves are not directly protected within the Wester Ross Marine Protected Area, reflecting a narrow management approach that overlooks ecosystem interdependence. A more holistic, cooperative model—linking scientists, fishermen, and communities—is essential for effective restoration.

Evidence suggests herring prefer live maerl for spawning, yet many of these habitats remain unprotected or subject to delayed policy action. Meanwhile, nutrient-driven algal overgrowth continues to degrade conditions, threatening recovery.

Recent observations—including large herring shoals detected by fishermen, overwintering humpback whales, and a surge in marine megafaunal wildlife activity—indicate a potential ecological rebound. But illegal dredging, pollution, and gaps in protection risk undermining this progress.

Urgent priorities are clear: enforce protections, expand safeguarded areas, address nutrient pollution, and support coordinated, ecosystem-based management. Without this, continued maerl loss would be catastrophic— it will be losing irreplaceable natural heritage—and would severely limit the chances of restoring the once-abundant seas for future generations.

Gathering the data for this report has been a truly collective task supported by hundreds of people and multiple groups throughout the years, both within the communities of the northwest and beyond. Volunteer professional scientists have generously guided us throughout. At a regional level the alliance set out to model the way indigenous people closely observe and care for the natural world by building an intimate relationship over years. We rely upon a vast amount of knowledge fed to us by fishermen, anglers, divers, sailors and marine lovers of all kinds, as well as scientists. The alliance exists only because of the way multiple skillsets weave together to contribute talent, skills and expertise. Everyone shares the credit for the data that went into this report. It is vital we recognise all who contribute so by chance if I have forgotten anyone in this draft please don't hesitate to say so.

2025 THANK YOU's

We'd like to thank NatureScot for helping fund this report, as well as Prof. J. Hall Spencer for applying decades of his maerl expertise to our archive. The Blue Hope Alliance has long been reliant upon Jason's depth of knowledge and generosity in sharing his maerl specialism. We are delighted we have finally had his attention to reveal the story within the data that would have remained hidden and invisible deep in our archive without this opportunity.

We hope that this might lead to funds for a more in-depth academic assessment of the 2016-2024 to extract all the insights possible. It is our greatest hope that the hard work of so many contributors will encourage our communities, the politicians and government agencies to focus our minds on the next steps to restoring our region.

With regards to the 2025 survey, we owe some very special thanks to Jason for connecting us to Plymouth's Labs (Andy Rees) who analysed our results as well as Andrew Atfield who advised us on sampling methods and sent sampling bottles. Francis Bunker, for generously sharing sampling techniques and analysing the maerl samples received. Vital for the 2025 survey was the Honeydew team. Dr Sarah Chan and Dr Rohan Holt generously supported our planning and survey throughout the year, with contributions from Travel Chapter, and Reiff Beach Cottage donation to help fund it. We could not have achieved this without them, Nor the Tanera boat team who were supported by BSAC Hebrides and Project Baseline to gather samples. ISAC divers and Dr Graham Saunders supported the Honeydew diving, with Doug Cowie on camera. Tanera boats have been an invaluable support for many years, and Robin Irvine and Alison Macleod of Tanera have been wonderfully helpful with freezing samples in 2025. Eilidh Venters/Macneiliage hosted our water samples in her Christmas freezer, and Keltic Seafare arranged frozen shipment.

As for the 2016-2024 data, the Blue Hope Alliance data were collected by dedicated groups committing time, sometimes years with underwater photography, dive management, local and professional science guidance, boats, donations of air fills, skippers, accommodation, equipment, food, travel costs and cooking. A list of all those involved would be unwieldy - core amongst these have been Keltic Seafare scallop divers, ISAC recreational divers, Seasearchers, Tanera Island boats, Project Baseline and the local communities support with kayaks, equipment, accommodation, air fills, food, cakes, artists, storytellers, grant writers and donations. People have jumped in where needed to keep our surveys happen. I hesitate to mention names at the risk of forgetting contributors. However, the BHA steering group, Ali Hughson, Dave Barclay, John McIntyre, Peter Frazer and Jane Dick and the new local groups Maerl Friends of Loch Torridon and SAS Loch Ewe, Kishorn Sea Rangers and Applecross Sea Rangers have all input knowledge and support.

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Appendix 1 Raw nutrient sample data from a pilot survey around northwest Scotland, August 2025.

	Sites	Ammon ium (µmol L-1)	Phosphate (µmol L-1)	Silicate (µmol L-1)	Nitrite (µmol L-1)	Nitrate + Nitrite (µmol L-1)	Nitrate (µmol L-1)
S1	Honeydew Baseline 1	00.28	0.27	1.54	0.12	0.36	0.24
S1	Honeydew Baseline 2	0.22	0.28	1.54	0.12	0.36	0.24
S1	Honeydew Baseline 3	0.19	0.29	1.55	0.13	0.39	0.26
S2	Honeydew Sample 2 1	0.13	0.18	0.92	<0.02	<0.03	<0.03
S2	Honeydew Sample 2 2	0.20	0.20	0.83	<0.02	0.03	0.03
S2	Honeydew Sample 2 3	0.07	0.17	0.85	<0.02	0.35	0.35
S3	Fada Tanera Channel 1	2.33	0.84	3.07	0.28	2.21	1.94
S3	Fada Tanera Channel 2	1.15	0.48	2.64	0.21	1.69	1.48
S3	Fada Tanera Channel 3	1.54	0.56	2.26	0.20	1.60	1.41
S4	Tanera Mol Mor 1	0.62	0.55	3.37	0.35	2.73	2.39
S4	Tanera Mol Mor 2	0.33	0.55	3.97	0.38	2.99	2.61
S4	Tanera Mol Mor 3	0.22	0.52	3.62	0.38	2.99	2.61
S5	Planet Rock Sara 1	0.32	0.26	1.69	0.03	0.24	0.21
S5	Planet Rock Sara 2	0.18	0.26	1.56	0.03	0.12	0.09
S5	Planet Rock Sara 3	0.15	0.25	1.41	0.02	0.09	0.07
S6	Planet Rock Doug 1	0.12	0.27	1.29	<0.02	0.10	0.10
S6	Planet Rock Doug 2	0.10	0.27	1.09	<0.02	0.04	0.04
S6	Planet Rock Doug 3	0.23	0.26	1.11	<0.02	0.06	0.06
S7	Horse Island 1	0.35	0.48	3.36	0.29	3.19	2.91
S7	Horse Island 2	0.47	0.56	3.42	0.30	3.16	2.86
S7	Horse Island 3	0.24	0.56	2.90	0.24	2.70	2.46
S8	Little Loch Broom 1	0.25	0.46	2.43	0.21	1.47	1.26
S8	Little Loch Broom 2	0.38	0.43	2.15	0.19	1.37	1.18
S8	Little Loch Broom 3	0.27	0.53	2.38	0.20	1.45	1.25
S9	Loch Ewe 1	0.39	0.59	2.17	0.04	0.56	0.51
S9	Loch Ewe 2	0.30	0.59	2.02	0.04	0.55	0.52
S9	Loch Ewe 3	0.23	0.54	1.96	0.03	0.47	0.44
S10	North Strome Lochcarron 1	3.58	2.36	19.25	0.45	9.24	8.79
S10	North Strome Lochcarron 2	2.15	1.18	6.30	0.15	3.40	3.25
S10	North Strome Lochcarron 3	2.31	0.62	2.02	0.08	1.51	1.43
S11	Tanera-Fada Chart Pos 1 1	0.17	0.30	1.75	0.09	0.57	0.47
S11	Tanera-Fada Chart Pos 1 2	0.07	0.31	1.93	0.12	0.67	0.55
S11	Tanera-Fada Chart Pos 1 3	0.28	0.27	1.58	0.08	0.46	0.38

S12	FADA Chart Pos 2 1	0.23	0.56	3.62	0.45	3.77	3.32
S12	FADA Chart Pos 2 2	0.45	0.42	2.13	0.22	1.79	1.57
S12	FADA Chart Pos 2 3	0.24	0.47	2.45	0.27	2.18	1.91
S13	FADA Chart Pos 3 1	0.22	0.38	2.28	0.23	1.75	1.52
S13	FADA Chart Pos 3 2	0.05	0.37	2.17	0.18	1.56	1.38
S13	FADA Chart Pos 3 3	<0.03	0.40	2.54	0.24	2.08	1.84
S14	FADA Chart Pos 4 1	0.07	0.36	2.02	0.16	1.29	1.13
S14	FADA Chart Pos 4 2	0.22	0.33	1.74	0.12	0.91	0.78
S14	FADA Chart Pos 4 3	0.57	0.37	2.27	0.11	1.04	0.93
S15	Tanera Bay Mooring Site 1 1	0.46	0.33	1.98	0.13	0.76	0.63
S15	Tanera Bay Mooring Site 1 2	0.32	0.35	2.01	0.13	0.77	0.64
S15	Tanera Bay Mooring Site 1 3	0.20	0.35	2.35	0.14	0.97	0.83
S16	Tanera Bay Mooring Site 2 1	0.69	0.37	1.99	0.15	1.04	0.89
S16	Tanera Bay Mooring Site 2 2	0.54	0.29	1.67	0.10	0.63	0.53
S16	Tanera Bay Mooring Site 2 3	0.42	0.45	2.29	0.17	1.22	1.04