AWAA Aquaculture Activity Assessment:

Subtidal Seaweed Aquaculture using Ropes

Report No: 723

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Crynodeb Gweithredol

Mae’r ddogfen hon yn un o gyfres o Asesiadau Gweithgareddau Dyframaethu a ddatblygwyd fel rhan o Brosiect Asesu Gweithgareddau Dyframaethu Cymru (AGDC) Cyfoeth Naturiol Cymru (CNC). Mae pob asesiad yn cyflwyno canllaw cam wrth gam ar sut i ddefnyddio'r adnoddau amrywiol a gynhyrchir gan y Prosiect AGDC er mwyn darparu gwybodaeth am y mathau o effeithiau y gallai gweithgaredd dyframaethu eu cael ar amgylchedd morol Cymru.

Mae'r asesiad hwn yn berthnasol i'r rhai sy'n asesu effeithiau posibl dyframaethu gwymon islanwol gan ddefnyddio rhaffau. Mae'r asesiad yn arwain defnyddwyr trwy broses sy'n disgrifio'r gweithgaredd dyframaethu a'r pwysau a allai godi o ganlyniad i'r gweithgaredd. Yna defnyddir astudiaeth achos i ddangos sut y gall defnyddwyr nodi sensitifrwydd y biotopau (sy'n ffurfio cydrannau o gynefinoedd) a rhywogaethau mewn lleoliad gweithgaredd dyframaeth enghreifftiol gan ddefnyddio Offeryn Mapio AGDC a Dangosfwrdd / Taenlenni Rhyngweithiadau AGDC. Yn olaf, crynhoir effeithiau posibl pob pwysau ar yr amgylchedd morol ar sail tystiolaeth a gasglwyd fel rhan o adolygiad systematig o lenyddiaeth, ac fe’i cyflwynir yng Nghronfa Ddata Tystiolaeth AGDC.

Mae'r asesiad, ynghyd ag adnoddau’r Prosiect AGDC a ddisgrifir yn yr asesiad, yn fan cychwyn defnyddiol i gasglu a datblygu gwybodaeth a thystiolaeth y gellir eu defnyddio yn ystod proses arfarnu amgylcheddol. Dylid darllen pob Asesiad Gweithgaredd Dyframaethu ar y cyd ag Adroddiad Terfynol AGDC er mwyn deall y dulliau, y tybiaethau a'r penderfyniadau sydd wedi llywio'r asesiadau a'r adnoddau a ddatblygwyd fel rhan o'r Prosiect.

Executive Summary

This document is one of a series of Aquaculture Activity Assessments developed as part of Natural Resources Wales' (NRW) Assessing Welsh Aquaculture Activities (AWAA) Project. Each assessment presents a step-by-step guide on how to use the various resources produced by the AWAA Project to provide information on the types of impacts an aquaculture activity could have on the Welsh marine environment.

This assessment is relevant to those assessing the potential impacts of undertaking subtidal seaweed aquaculture using ropes. The assessment guides users through a process describing the aquaculture activity and the pressures with the potential to occur as a result of the activity. A case study is then used to demonstrate how users can identify the sensitivity of the biotopes (which form components of habitats) and species at an example aquaculture activity location using the AWAA Mapping Tool and AWAA Dashboard / Interactions Spreadsheets. Lastly, the potential impacts of each pressure on the marine environment are summarised based on evidence collated as part of a systematic literature review, which is presented in the AWAA Evidence Database.

The assessment, together with the AWAA Project resources described in the assessment, provide a useful starting point to gather and develop information and evidence which can be used during an environmental appraisal process. Each Aquaculture Activity Assessment should be read in conjunction with the AWAA Final Report to understand the methods, assumptions and decisions that have informed the assessments and resources developed as part of the Project.

Subtidal Seaweed Aquaculture using Ropes

Introduction

This document is one of a series of Aquaculture Activity Assessments developed as part of Natural Resources Wales' (NRW) Assessing Welsh Aquaculture Activities (AWAA) Project (the Project). Each assessment provides information and guidance on the types of impacts a proposed aquaculture activity could have on the marine environment.

The Project has developed a series of resources to support the assessment of the potential impacts of different aquaculture activities. The resources are:

- The Dashboard/Interactions Spreadsheets;
- The Mapping Tool; and
- The Evidence Database.

The assessments follow a step-by-step process that guides users on how to use these resources. They demonstrate how the resources can be used as a starting point to gather information and evidence on the potential impacts occurring from an aquaculture activity.

The step-by-step process is shown in Figure 1.

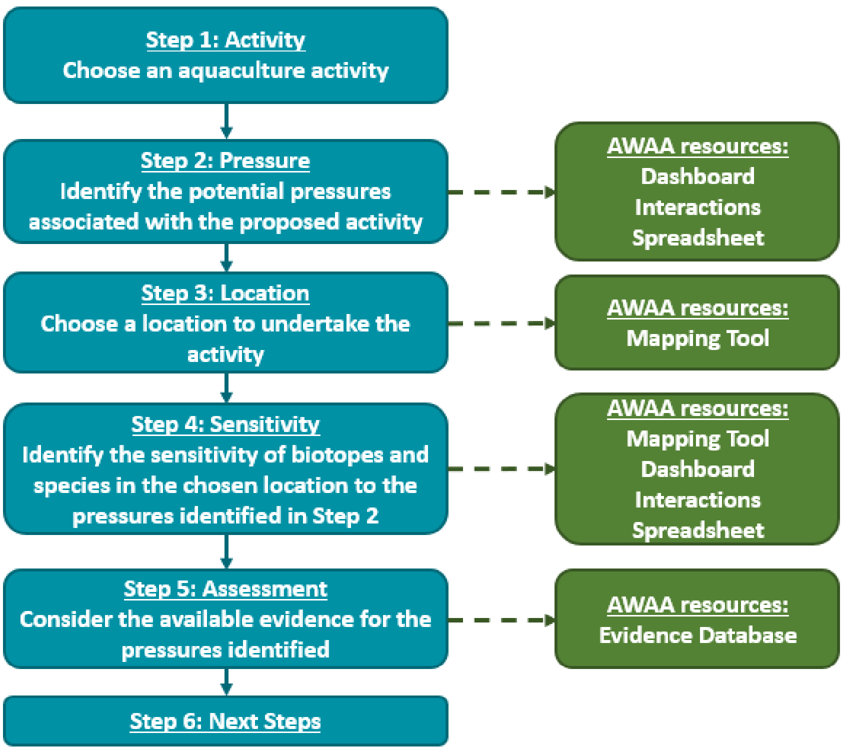

Figure 1. Flow diagram to show the step-by-step process of using the Project resources.

Aquaculture Activity Assessment General Rules

Users must remember:

- The results generated by all the AWAA resources are indicative. They are designed to provide guidance, information and evidence relating to the types of impacts that would be considered during an environmental appraisal process.
- The generic sensitivity scores, evidence summaries and mapping resources can be used as a starting point to develop a more detailed appraisal of the potential impacts the chosen aquaculture activity may have on specific marine habitats and species in an area of interest.
- The Project resources do not replace the requirement to understand the extent of the impacts a specific aquaculture activity may have on an area through, for example, consultation or by undertaking further detailed surveys to characterise an area of interest.
- Uses should add specifics about the type of activity being considered within the environmental appraisal, such as its location, infrastructure, operation, species, footprint or duration etc. These factors have the potential to change the degree of exposure natural habitats and species may have to the pressures associated with the chosen aquaculture activity. This detail may require the user to consider the applicability of the indicative sensitivity values generated by the AWAA resources in terms of whether it would increase or decrease the significance of the effect of the pressures associated with the activity.
- The Project uses the sensitivity scores for biotopes (habitat communities) and species to OSPAR pressures from The Marine Evidence-based Sensitivity Assessment (MarESA) (Tyler-Walters et al., 2022) and the Natural England Mobile Species Sensitivity Assessment (2022). The sensitivity scores are indicative across a range of marine activities that could generate the pressure, including aquaculture. The pressure descriptions and benchmarks have been checked by the Project for their appropriateness to the various aquaculture activities, and comments and confidence levels are captured in the AWAA Dashboard and the Interactions Spreadsheet.

Each Aquaculture Activity Assessment should be read in conjunction with the AWAA Final Report to understand the methods, assumptions and decisions that have informed the assessments and resources developed as part of the Project, such as the AWAA Evidence Database, Dashboard, the Interactions Spreadsheets and the Mapping Tool.

Subtidal Seaweed Aquaculture using Ropes

Step 1: Activity

Choose an aquaculture activity

When planning to develop an aquaculture activity, one of the first steps is to consider the techniques to be used to grow and harvest the chosen species. The type and scale of the activity along with the methods used during collection, construction, operation and harvesting are important factors for determining the potential impacts the activity may have on the marine environment.

This particular assessment concerns the subtidal aquaculture activity of cultivating seaweed on ropes.

Species cultivated

Seaweeds with the potential to be commercially cultivated on rope in the United Kingdom (UK) include sugar kelp (*Saccharina latissima*), oarweed (*Laminaria digitata*), dabberlocks (*Alaria esculenta*), red algae such as dulse (*Palmaria palmata*), false Irish moss (*Mastocarpus stellatus*) and Irish moss (*Chondrus crispus*) (Welsh Government, 2021; Wilding et al., 2021).

Other species which are cultivated in Europe but not in the UK include wakame (*Undaria pinnatifida)*, a non-native kelp species introduced from Asia which is commercially cultivated in France and Spain, and the red seaweed *Gracilaria* spp. which is cultivated in Spain and Italy.

Infrastructure and equipment

Subtidal seaweed aquaculture using ropes is an ‘off-bottom’ aquaculture activity where seaweed is grown in the water column. Weights or helical screw piles are typically used to anchor the aquaculture infrastructure to the seabed. Mooring lines, chains or poles can be used to attach the weights or anchors to floatation buoys at the surface of the water. Headropes or lines are strung between the buoys with ‘dropper’ ropes for cultivating seaweed suspended either horizontally and/or vertically in the water column from the headropes. Fibrous hemp or plastic dropper ropes are normally used to cultivate seaweed and are typically between 10–12mm in diameter.

Sufficient distance is needed between dropper ropes and lines to reduce the likelihood of entanglement. Ropes are typically submerged to keep the seaweed at 1.5–2.5m below the surface of the water to protect it from wave action, boat traffic and high irradiance (Wilding et al., 2021). When the seaweed grows and the weight increases, there is the potential that more buoyancy is required to keep the infrastructure in the right place to maximise the amount of energy it receives from the sun.

Figure 2. Subtidal seaweed being harvested on ropes (Photo: Car Y Mor)

General methods of growing and harvesting

Seaweed from a hatchery is normally seeded onto natural or synthetic material 1–2mm in diameter such as twine, nylon, polypropylene or polyester. When the juveniles reach around 2–10mm in length, at approximately six to eight weeks, the twine is wrapped helically around rope and deployed at sea (Kerrison et al., 2019; 2020). However, planting out slightly older seaweed from hatcheries, as sporophytes rather than gametophytes, can lead to twice the biomass yields (Kerrison et al., 2020). Ropes have also been known to self-seed with local seaweeds once deployed in the water column.

Seeded seaweed ropes are generally planted out between October and February and harvested between April and June (Capuzzo, 2022). To harvest the seaweed, the ropes are lifted out of the water by winches on vessels and the seaweed is cut from the lines by hand (Wilding et al., 2021). Techniques are being developed to mechanise this process by pulling the ropes through cutting devices. Farming kelp can be made relatively cost-effective where coppicing is undertaken, whereby the kelp is harvested in such a way that only the fronds are removed allowing the same plant to grow again (Wilding et al., 2021).

Cultivation of seaweed has the potential to take place on small to medium scales with up to 50, 200m lines or on a large scale with greater than 50, 200m lines (Marine Scotland, 2017).

After harvesting, seaweed can be placed on racks to dry out. Further onshore facilities may be required for cleaning, processing and packing.

Subtidal Seaweed Aquaculture using Rope

Step 2: Pressures

Identify the potential pressures associated with the proposed activity

Pressures are the mechanism through which an activity can have an effect on an ecosystem (Tyler-Walters et al., 2018). Aquaculture activities have the potential to impact the marine environment through physical, chemical and biological pressures and it is important to identify which pressures could occur from the proposed activity.

The potential pressures from growing subtidal seaweed using ropes are presented in Table 1. The Table includes a description of the pressure and how the potential pathways might occur. In line with the general rules of this assessment it is important to remember that, depending on the operation and scale etc. of the activity, the pressure pathways or significance of the pressure's effect could change.

Table 1. List of pressures, their descriptions and how they occur from the aquaculture activity. The pressures are a relevant subset of those used in MarESA (Tyler-Walters et al., 2022), unless otherwise specified.

Pressure name	Description	Pathway from aquaculture activity
Above water noise (Pressure from Natural England, 2022)	Any loud noise made onshore or offshore by construction, vehicles, vessels, tourism, mining, blasting etc.	Above water noise generated by machinery or vessels could disturb birds and marine mammals
Abrasion/disturbance of the substrate on the surface of the seabed	Physical disturbance or abrasion at the surface of the substratum in sedimentary or rocky habitats	Scouring caused by anchoring to the seabed could cause abrasion
Barrier to species movement	The physical obstruction of species movements and including local movements	Infrastructure, such as lines and ropes suspended in the water column, may present a barrier to the movement of some species

Pressure name	Description	Pathway from aquaculture activity
Changes in suspended solids (water clarity)	Changes in sediment and organic particulate matter and chemical concentrations can change water clarity (or turbidity)	Construction, operation and harvesting may stir up sediment and increase turbidity. Seaweed suspended in the water column may slow currents and lead to increased accretion
Collision ABOVE water with static or moving objects not naturally found in the marine environment (Pressure from Natural England, 2022)	The injury or mortality of biota from both static and/or moving structures	Vessels and machinery used for construction and harvesting may present a collision hazard above the water
Collision BELOW water with static or moving objects not naturally found in the marine environment	Injury or mortality from collisions of biota with both static and/or moving structures	Vessels or infrastructure such as ropes and lines may suspended in the water column, or vessels may present a collision hazard below the water
Genetic modification & translocation of indigenous species	Genetic modification can be either deliberate (i.e. introductions) or a by-product of other activities (i.e. mutations)	Transplanting of indigenous species from one location to another could lead to interbreeding and alter the gene pool
Hydrocarbon and polycyclic aromatic hydrocarbon (PAH) contamination	Increases in the levels of these compounds compared with background concentrations	Introduced to the environment via vessels or machinery oil or fuel leaks and spills
Introduction of light or shading	Direct inputs of light from anthropogenic activities. Also shading from structures etc.	Infrastructure and seaweed suspended in the water column may cause shading of the seabed

Pressure name	**Description**	**Pathway from aquaculture activity**
Introduction of microbial pathogens (including metazoan parasites)	Untreated or insufficiently treated effluent discharges and run-off from terrestrial sources and vessels. Also, in shellfisheries where seed stock is imported, 'infected' seed could be introduced	Diseases or parasites from imported aquaculture stocks could spread quickly amongst high densities of stock and could spread to wild populations
Introduction or spread of invasive non-indigenous species (INIS)	The direct or indirect introduction of INIS	Introduction of INIS for aquaculture purposes or introduction of INIS on farmed seaweed. Spawning from farmed INIS stock could spread to surrounding areas
Litter	Any manufactured or processed solid material from anthropogenic activities discarded, disposed or abandoned	Rope, lines, plastic or other infrastructure may be lost to the marine environment
Nutrient enrichment	Increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations	Seaweed detritus (e.g. broken fronds) may introduce nutrients to the surrounding area, however, reductions in nutrient enrichment have been recorded as seaweeds uptake nutrients
Organic enrichment	The degraded remains of dead biota and microbiota; faecal matter from marine animals; or flocculated colloidal organic matter	Introduction of organic matter from seaweed detritus (e.g. broken fronds) may be introduced to the surrounding area
Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Physical disturbance of sediments where there is limited or no loss of substratum from the system	Penetration or sub-surface disturbance of the seabed from anchors or moorings

Pressure name	Description	Pathway from aquaculture activity
Physical change (to another seabed type)	The permanent change of one marine seabed type to another marine seabed type	Introduction of aquaculture infrastructure offers an artificial substrate for colonisation
Removal of non-target species	Removal of non-farmed species associated with management and harvesting activities	Wild species, particularly invertebrates which live around or on the farmed seaweed may be removed during harvesting. Nets or lines suspended in the water column could cause entanglements
Smothering and siltation rate changes ('Light' deposition)	When the natural rates of siltation are altered (increased or decreased)	Accumulation of broken fronds, particularly after storm events
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	Increases in the levels of these compounds compared with background concentrations	The use of antifoulants to reduce unwanted settlement on infrastructure or the addition of pesticides
Transition elements and organo-metal (e.g. Tributyltin (TBT)) contamination	The increase in transition elements levels compared with background concentrations, due to their input by air or directly at sea	Introduction from antifouling compounds on infrastructure
Underwater noise changes	Increases over and above background noise levels at a particular location	Noise generated by vessels and machinery during construction, operation and harvesting
Visual disturbance	The disturbance of biota by anthropogenic activities, (e.g. increased vessel movements)	Visual disturbance to seabirds and marine mammals as a result of vessel movement

Pressure name	Description	Pathway from aquaculture activity
Water flow (tidal current) changes, including sediment transport considerations	Changes in water movement associated with tidal streams, prevailing winds and ocean currents	Infrastructure and suspended seaweed could reduce flow speeds, increase turbulence or alter water flow direction
Wave exposure changes	Local changes in wavelength, height and frequency	Infrastructure and seaweed in the water column could reduce wave action and impact local coastal processes

Subtidal Seaweed Aquaculture using Rope

Step 3: Location

Choose a location to undertake the activity

Choosing a location to undertake the aquaculture activity will depend on a range of factors, including but not limited to:

- Size of the aquaculture development;
- Accessibility of the location;
- Suitability of the environmental conditions (e.g. level of exposure to weather, tide and current);
- Suitability of the substrate;
- Land ownership;
- Location of supporting land-based infrastructure;
- Environmental considerations such as protected habitats and species in the vicinity; and
- Other users of the area.

Rope cultured kelps require fully marine sites with medium to high levels of light and average temperatures of 10–12°C. Low turbidity levels are often required to ensure optimal photosynthesis for growth (ABPmer, 2015). However, the location will depend on the seaweed being cultivated. For example, sugar kelp *S. latissima* is typically grown in sheltered areas, whereas other kelps such as *A. esculenta* and *L. digitata* can withstand higher wave and tidal exposure (ABPmer, 2015). Typically, a firm sedimentary substratum, not rock or soft mud, is usually required for deploying the concrete moorings, anchors or screw piles.

Once a general location has been decided upon, the AWAA Mapping Tool and Dashboard, developed as part of the Project, allows the user to investigate the biotopes (which form components of habitats or protected features) and species in the surrounding area and their sensitivities to the potential pressures arising from the aquaculture activity.

An example case study off the Aberaeron coast is provided in Step 4 that demonstrates how the AWAA Mapping Tool and Dashboard can be used if you are considering growing subtidal seaweed using ropes.

Subtidal Seaweed Aquaculture using Rope

Step 4: Sensitivity

Identify the sensitivity of biotopes and species in the chosen location to the pressures identified in Step 2

Once you have chosen the aquaculture activity and possible location, the AWAA Mapping Tool and Dashboard can be used to investigate how sensitive biotopes and species in Welsh waters are to the pressures associated with the activity. This information can be used if undertaking an environmental appraisal.

The AWAA Mapping Tool allows the user to identify the biotopes overlapping or nearby a proposed location and therefore have the potential to be exposed to the pressures occurring from the activity. Before investigating the sensitivity of biotopes using the AWAA Mapping Tool, it is important to consider that:

- The operation and scale of the aquaculture activity might change the level of exposure of the biotopes to the pressure and hence the significance of the effect of the pressure.
- Micro-siting of the aquaculture activity can sometimes be used to reduce or avoid the pressures from impacting sensitive biotopes. However, it is also important to note that areas with no biotope records or blank areas on maps do not mean there is no exposure of biotopes to the pressure being assessed. Rather, blank areas, particularly in the subtidal, indicate there is no available survey data describing the biotopes for that location and as such further surveys may be required to characterise the area. Additionally, depending on the pressure and its zone of influence, the pressure may have the ability to affect biotopes and species at a distance from the origin of the activity, such as pressures related to pollution or sedimentation.
- The biotope data used in the AWAA Mapping Tool are a collation of surveys which have been undertaken over the last 50 years, with the majority of data collected since 1996. It is therefore important to consider whether further surveys are needed to update and/or confirm the presence of some biotopes.

Species including birds, fish, mammals and invertebrates have not been mapped by the Project as they can be exposed to the pressures being considered potentially anywhere. This reduces the value of species maps as vast areas of the sea would be highlighted as being potentially sensitive. Instead, users producing an environmental appraisal should concentrate on the other Project resources, such as the Dashboard, to understand species sensitivity to pressures, along with information such as the scale or operation of the activity and any information available on the use of the chosen area by the species of concern. It is important to acknowledge that mobile species, that form part of a site designation, should be considered wherever they occur if the proposed aquaculture location is potentially within their range.

The Dashboard provides a complete list of the biotopes currently recorded in Welsh waters. The sensitivity of both biotopes or protected species which could be exposed to the pressures at a proposed location of an aquaculture activity can be identified using the AWAA Dashboard (or Interactions Spreadsheet). In addition, the Dashboard shows the user which biotopes or species are protected within the Marine Protected Area (MPA) network or protected under Section 7 of the Environment (Wales) Act 2016.

MPA designations and protected features can be turned on or off in the AWAA Mapping Tool to allow the user to see if the proposed location of the activity and the biotopes overlap with any of these areas. However, it is important to note that not all biotopes found within a proposed location will necessarily form part of an MPA or be protected under Section 7 of the Environment (Wales) Act 2016. The user should therefore use the AWAA Dashboard (or Interactions Spreadsheet) to identify which biotopes are protected in the area of interest at the proposed activity location.

A fictional example case study focussing on the coast near Aberaeron is presented to demonstrate how the AWAA Mapping Tool and Dashboard can be used to identify the potential sensitivity of biotopes and species in a particular area. It is important that the user considers the potential sensitivity of the biotopes and species for all of the pressures identified in Step 2 (Table 1), in their area of interest by repeating the exercise below for each pressure.

Case study

In this example, the potential sensitivity of biotopes and species are presented for two of the pressures associated with subtidal seaweed aquaculture using ropes identified in Step 2, Table 1:

1. Organic enrichment; and

2. Litter.

The first pressure is used to demonstrate how to find out the sensitivity of biotopes in the proposed activity area. The second pressure is used to demonstrate how to find out the sensitivity of protected species in the same area.

1. Organic enrichment

To examine the sensitivity of biotopes in the vicinity of the proposed activity, use the AWAA Mapping Tool to:

- Zoom in on the coast off Aberaeron;
- Select the aquaculture activity ‘Subtidal Seaweed using Rope’; and
- Select the desired pressure ‘organic enrichment’.

The user will then be able to see the individual biotopes displayed in different colours based on their sensitivity to the pressure selected.

For example, 3 shows the sensitivity of biotopes off the coast of Aberaeron to the pressure organic enrichment. When the AWAA Mapping Tool is open the biotope codes and names, and other relevant survey information can be found by clicking on each individual biotope.

The AWAA Dashboard provides a complete list of the biotopes currently recorded in Welsh waters. To check the whether the biotopes identified from the AWAA Mapping Tool are part of an MPA or listed under Section 7 Environment (Wales) Act 2016 search the AWAA Dashboard using the following filter options:

- Select the dashboard biotope screen;
- Select the aquaculture activity ‘Subtidal Seaweed using Rope’;
- Select the pressure ‘organic enrichment’; and
- Select the Welsh MPAs which overlap the proposed location.

The AWAA Dashboard will display a list of the biotopes and the designated features which the biotopes form a component. It will also indicate whether the biotopes are listed under Section 7 habitats under the Environment (Wales) Act 2016.

For the purposes of the Aberaeron example, the biotopes considered most sensitive to organic enrichment from subtidal seaweed aquaculture using ropes are shown in **Figure 3**. The biotopes *Amphiura filiformis*, *Kurtiella bidentata* and *Abra nitida* in circalittoral sandy mud (SS.SMu.CSaMu.AfilKurAnit) and *Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud (SS.SMu.CSaMu.LkorPpel) have been assessed as having a medium level of sensitivity to the organic enrichment in MarESA (Tyler-Walters et al., 2022). In addition, faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock (CR.MCR.EcCr.FaAlCr) and *Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud (SS.SMu.ISaMu.MelMagThy) have been assessed as having a low sensitivity to the pressure. Five of the biotopes in the proposed area are not considered to be sensitive to organic enrichment by MarESA. Please see the AWAA Final Report to understand the process of how confidence was assigned by MarESA to the sensitivity scores. There was insufficient evidence to assess the sensitivity of one biotope. Therefore, further investigations may be required to understand the biotope’s sensitivity to the pressure. The AWAA Final Report provides further information on assessment conclusions such as any biotope sensitivity scores considered ‘not relevant’, ‘not assessed’ and having ‘insufficient evidence’.

The majority of biotopes form a component of a number of MPA features such as sandbanks which are slightly covered by seawater all the time, and reef within the Cardigan Bay Special Area of Conservation (SAC) with some biotopes also listed as Section 7 habitats. Three biotopes, including *Amphiura filiformis*, *Kurtiella bidentata* and *Abra nitida* in circalittoral sandy mud (SS.SMu.CSaMu.AfilKurAnit), were not protected within an MPA.

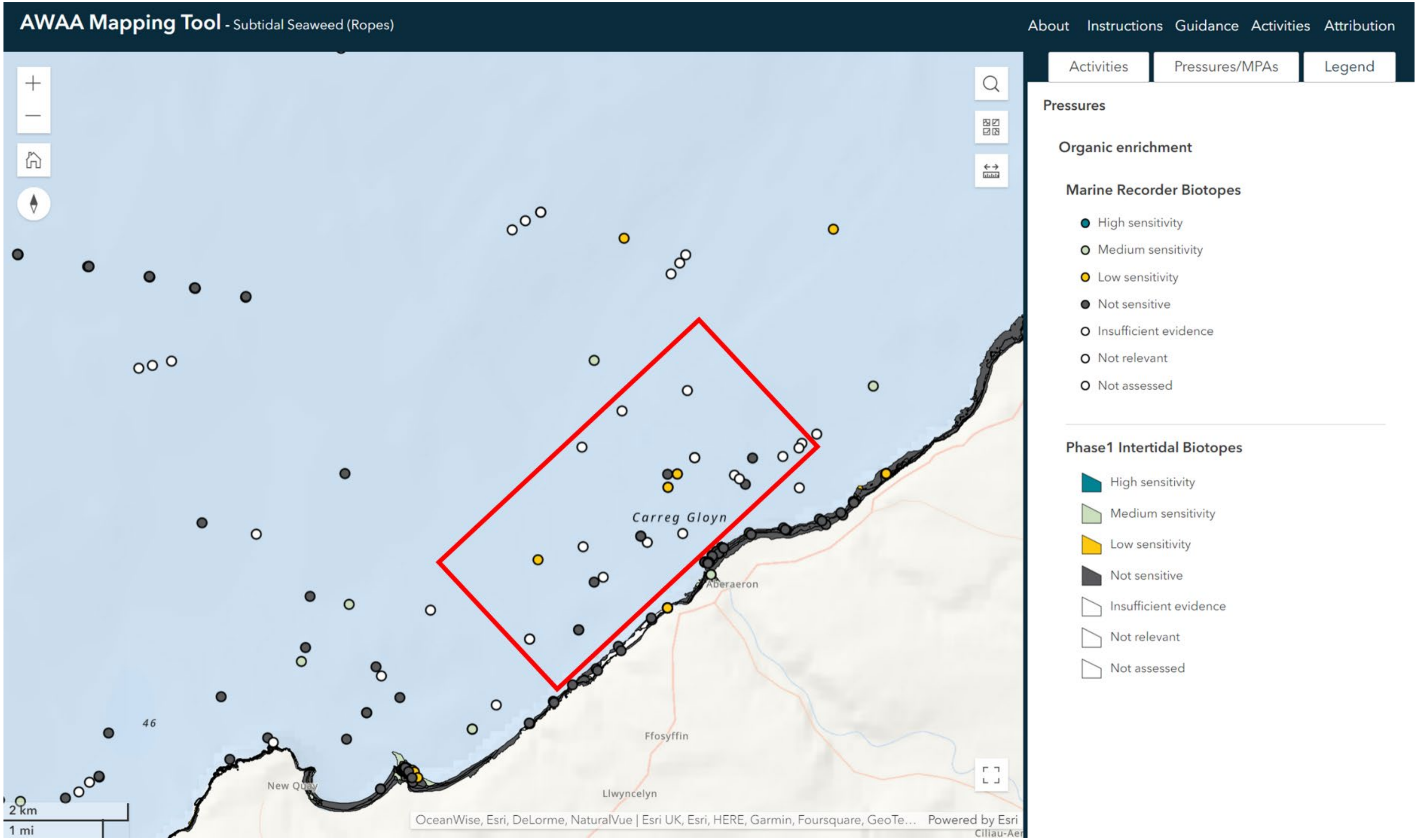

Figure 3. Use of the AWAA Mapping Tool to identify the proposed aquaculture activity location off the coast of Aberaeron and the biotopes overlapping with the proposed area (red box).

Table 2. The sensitivity of biotopes to the pressure 'organic enrichment' using the example location of Aberaeron, and the aquaculture activity of growing subtidal seaweed using ropes. Ordered from High to Low sensitivity. The Table also indicates if a biotope forms part of a Section 7 Environment (Wales) Act 2016 habitat and/or which MPAs and features the biotopes are part of.

Biotope name	Biotope code	Sensitivity [confidence]	Section 7 habitats which include the biotope	MPAs where the biotope is protected	MPA features which include the biotope
Amphiura filiformis, *Kurtiella bidentata* and *Abra nitida* in circalittoral sandy mud	SS.SMu.CSaMu.AfilKurAnit	Medium [Low conf.]	Mud habitats in deep water	Not designated as part of an MPA	NA
Lagis koreni and *Phaxas pellucidus* in circalittoral sandy mud	SS.SMu.CSaMu.LkorPpel	Medium [Low conf.]	Mud habitats in deep water	Cardigan Bay SAC	Sandbanks which are slightly covered by seawater all the time
Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock	CR.MCR.EcCr.FaAlCr	Low [Low conf.]	Not Section 7	Cardigan Bay SAC	Reef
Melinna palmata with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud	SS.SMu.ISaMu.MelMagThy	Low [Low conf.]	Not Section 7	Cardigan Bay SAC	Sandbanks which are slightly covered by seawater all the time
Dense foliose red seaweeds on silty moderately exposed infralittoral rock	IR.MIR.KR.XFoR	Not sensitive [High conf.]	Not Section 7	Cardigan Bay SAC	Reef
Bryozoan turf and erect sponges on tide-swept circalittoral rock	CR.HCR.XFa.ByErSp	Not sensitive [Medium conf.]	Fragile sponge and anthozoan communities on subtidal rocky habitats	Cardigan Bay SAC	Reef
Flustra foliacea and colonial ascidians on tide-swept exposed circalittoral mixed substrata	CR.HCR.XFa.FluCoAs.X	Not sensitive [Medium conf.]	Not Section 7	Cardigan Bay SAC	Reef
Flustra foliacea and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	SS.SMx.CMx.FluHyd	Not sensitive [Medium conf.]	Not Section 7	Cardigan Bay SAC	Reef

Biotope name	Biotope code	Sensitivity [confidence]	Section 7 habitats which include the biotope	MPAs where the biotope is protected	MPA features which include the biotope
Sabellaria spinulosa on stable circalittoral mixed sediment	SS.SBR.PoR.SspiMx	Not sensitive [Medium conf.]	Not Section 7	Cardigan Bay SAC	Reef; Sandbanks which are slightly covered by seawater all the time
Caryophyllia (*Caryophyllia*) *smithii* and sponges with *Pentapora foliacea*, *Porella compressa* and crustose communities on wave-exposed circalittoral rock	CR.MCR.EcCr.CarSp.PenPcom	Insufficient evidence	Not Section 7	Cardigan Bay SAC	Reef
Circalittoral mixed sediment	SS.SMx.CMx	Not assessed	Sheltered muddy gravels / Subtidal mixed muddy sediments [Wales]	Cardigan Bay SAC	Reef; Sandbanks which are slightly covered by seawater all the time
Infralittoral coarse sediment	SS.SCS.ICS	Not assessed	Subtidal sands and gravels	Cardigan Bay SAC	Reef
Infralittoral mixed sediment	SS.SMx.IMx	Not assessed	Not Section 7	Cardigan Bay SAC	Reef; Sandbanks which are slightly covered by seawater all the time
Kelp and seaweed communities on sublittoral sediment	SS.SMp.KSwSS	Not assessed	Not Section 7	Cardigan Bay SAC	Reef
Mixed faunal turf communities	CR.HCR.XFa	Not assessed	Not Section 7	Cardigan Bay SAC	Reef
Moderate energy circalittoral rock	CR.MCR	Not assessed	Not Section 7	Not designated as part of an MPA	NA
Sublittoral mixed sediment	SS.SMx	Not assessed	Not Section 7	Not designated as part of an MPA	NA

2. Litter

The sensitivity of protected species which could overlap with the proposed location of an aquaculture activity can be identified using the species AWAA Dashboard using the following filter options:

- Select the dashboard species screen;
- Select the aquaculture activity ‘Subtidal Seaweed using Rope’;
- Select the pressure ‘litter; and
- Select the MPAs which overlap or are adjacent to the proposed location and/or Section 7 species.

The AWAA Mapping Tool can be used to identify the MPAs which overlap with or are close to the proposed aquaculture site in the Aberaeron example case study. The AWAA Dashboard can then be used to ascertain the protected species within the MPA or on the Section 7 list and their sensitivity to the pressure being considered. The MPAs are shown in Table 3 and include:

- Cardigan Bay SAC; and
- West Wales Marine SAC.

Grey Seal, Bottlenose Dolphin and Sea Lamprey are features of the Cardigan Bay SAC and Harbour Porpoise is a feature of the West Wales Marine SAC. Grey Seal has been assessed as having a medium level of sensitivity to litter in the Natural England (2022) sensitivity assessment. In addition, Bottlenose Dolphin and Harbour Porpoise have been assessed as having a low sensitivity to the pressure. Please see the AWAA Final Report to understand the process of how confidence was assigned by Natural England to the sensitivity scores. There was considered to be insufficient evidence to assess the sensitivity of Sea Lamprey to litter by Natural England’s (2022) sensitivity assessment and hence investigations may be needed to further assess sensitivity to this pressure. The AWAA Final Report provides further information on assessment conclusions such as species’ sensitivity scores considered ‘not relevant’, ‘not assessed’ and having ‘insufficient evidence’.

To understand the potential impact of the pressure in the example case study location off the Aberaeron coast, it is important to understand the potential use of the area by the species concerned.

Table 3. The sensitivity of designated species features to the pressure 'litter' using the example location of Aberaeron, and the aquaculture activity of growing subtidal seaweed using ropes. Ordered from High to Low sensitivity. The Table also indicates if a species is a Section 7 Environment (Wales) Act 2016 species and/or which MPAs the species is a designated feature of.

Common Name	Scientific Name	Sensitivity [confidence]	Section 7 species (Y/N)	MPAs where species are part of the site designation
Grey seal	*Halichoerus grypus*	Medium [Medium conf.]	No	Cardigan Bay SAC
Bottlenose dolphin	*Tursiops truncatus*	Low [Medium conf.]	Yes	Cardigan Bay SAC
Harbour porpoise	*Phocoena phocoena*	Low [Medium conf.]	Yes	West Wales Marine SAC
Sea lamprey	*Petromyzon marinus*	Insufficient evidence	Yes	Cardigan Bay SAC

Subtidal Seaweed Aquaculture using Rope

Step 5: Assessment

Consider the available evidence for the pressures identified

Once the habitats and species in the vicinity of the proposed activity have been identified and their sensitivities determined, it may be necessary to consider the potential impacts the pressures may have alone and in combination in an environmental appraisal process.

As part of the Project, an extensive literature review was undertaken to compile an Evidence Database. The AWAA Evidence Database provides the user with the available evidence to inform an environmental appraisal by bringing together the current evidence on the pressures generated by different aquaculture activities and the impacts they could have on habitats and species.

The AWAA Evidence Database was compiled over the duration of the Project and captures the existing knowledge at the time of writing. There is the potential that new evidence becomes available following publication, therefore, the user is encouraged to conduct a search for any new evidence, particularly for those pressures for which there is little or no direct evidence identified within the AWAA Evidence Database.

Any interpretation of the evidence and the sensitivity of biotopes and species will be dependent on a number of factors including the operation and scale of the aquaculture activity. In an environmental assessment, the available evidence should therefore be considered in the context of the proposal and confidence in the evidence, particularly where contrasting information on the impacts is available. Where no evidence is available on the impacts of a pressure occurring from an aquaculture activity, the user may have to consider the applicability of evidence from other activities that could generate similar pressures and clearly state what assumptions have been made along with any associated limitations.

Summaries of the evidence sources identified in the AWAA Evidence Database for each of the pressures relating to subtidal seaweed aquaculture using ropes identified in Step 2 (Table 1) are provided below. The evidence summaries for the two pressures used in the Aberaeron case study example in Step 4 are provided below in sections 12 and 14.

1. Above water noise

Although no evidence was found in the scientific literature for this pressure with respect to subtidal seaweed aquaculture using ropes, above water noise is expected to occur during construction, maintenance and harvesting of seaweed. Above water noise has the potential to disturb bird or marine mammal species in the vicinity of the activity.

2. Abrasion/disturbance of the substrate on the surface of the seabed

Abrasion, scouring or disturbance of the seabed is likely to occur from the use of anchors/weights on the seabed to secure floating infrastructure.

Aquaculture farms sited directly over sensitive habitats, such as seagrass and maerl beds, have the potential to lead to the physical loss of these habitats through scouring from anchoring or mooring systems (Wilding et al., 2021). However, scouring impacts are expected to be relatively localised, with small-scale farming and innovative mooring technologies potentially limiting the impacts of abrasion. A review by Campbell et al. (2019) mentioned that seaweed cultivation may lead to abrasion and a subsequent loss of some macroinvertebrates, particularly if fronds have regular contact with the seabed.

3. Barrier to species movement

In general, subtidal aquaculture infrastructure has the potential to exclude species such as seals or cetaceans from habitats. Whilst there is no direct evidence relating to seaweed farming, the impacts caused by finfish or shellfish aquaculture acting as a barrier to species movement are considered to be similar. There is mixed information in the literature regarding potential cetacean or seal avoidance of aquaculture infrastructure and operations.

Some studies report that aquaculture has no impact, for example, in Ireland, seal abundance was not shown to be impacted by the presence of suspended mussel culture (Roycroft et al., 2004). While other investigations have shown marine mammals being attracted to aquaculture sites (Lopez and Methion, 2017). Compared to shellfish and finfish farms, seaweed farms have the potential to increase the local biodiversity and the abundance of prey species in their vicinity which could attract marine mammals and predators.

However, some reports indicate that cetaceans have been shown to avoid areas of aquaculture which can act as a barrier to their foraging grounds (Markowitz et al., 2004; Watson-Capps and Mann, 2005; Pearson et al., 2009; Andres et al., 2021). Therefore, subtidal seaweed farms may have the potential to displace some marine mammal species.

The variation in the literature likely reflects the difference in the scale and specific set up of the shellfish farms and also behavioural differences between marine mammals (Clement et al., 2013; Lopez and Methion, 2017). Overall, impacts will depend on scale of the activity, with the barrier to species movement increasing with the scale of the aquaculture activity. It will also depend on the species present in the area of interest as some have the potential to be attracted to aquaculture sites and some will be more sensitive than others (Clement et al., 2013).

4. Changes in suspended solids (water clarity)

Natural aggregations of macroalgae reduce water velocity and attenuate waves which can reduce the resuspension of sediment. Evidence suggests that seaweed farming will have the same effect with one paper finding resuspension of sediments reduced by 50% (Zhang et al., 2016) which has the potential to increase water transparency.

However, increases in suspended solids from disturbing the seabed could occur during construction and deployment of aquaculture infrastructure, seeding, and harvesting of seaweed lines. Suspended sediments in the water column have the potential to reduce the visibility of marine predators such as marine mammals, fish and diving or surface feeding seabirds, reduce light penetration, clog filtration mechanisms of filter feeders or lead to behavioural alterations (Todd et al., 2015; Ortega et al., 2020). However, increases in suspended solids would likely be short-term and relatively localised.

5. Collision ABOVE water with static or moving objects

There is the potential for species to collide with vessels above water. However, no evidence was found in the scientific literature relating to the collision of species above water with subtidal seaweed aquaculture using ropes. It is likely that any such instances would be relatively rare and unlikely to cause a significant impact.

6. Collision BELOW water with static or moving objects

There is the potential for species to collide with infrastructure or operational vessels during construction, operation and harvesting, however, no evidence was found for this pressure in the scientific literature. It is likely that any such instances would be relatively rare and unlikely to cause a significant impact.

7. Genetic modification & translocation of indigenous species

There are few studies investigating the impact of genetic modification or translocation of seaweed aquaculture species on the genetic structure and evolution of wild seaweed populations. However, it is expected that propagation of seaweed species from a limited number of individuals can artificially increase specific traits favourable to aquaculture such as increased reproductive fitness. Using these individuals in aquaculture could lead to genetic modification of wild populations, known as crop-to-wild gene flow. This may reduce genetic diversity and/or the ability for local adaptation (Wilding et al., 2021). Decreases in genetic diversity have the potential to increase seaweed susceptibility to disease and overall decreased fitness (Charrier et al., 2017).

8. Hydrocarbon and PAH contamination

No evidence was found in the scientific literature relating to hydrocarbon or PAH contamination from subtidal seaweed aquaculture using ropes.

However, it is expected that this pressure in the form of fuel or oil leaks and spills could occur through the use of vessels during construction and operational processes.

9. Introduction of light or shading

The introduction of seaweed aquaculture to an area could lead to shading of the seabed. A study in Sweden found that light irradiance was found to be significantly reduced underneath a seaweed farm, compared with areas outside the farm (Visch et al, 2020).

The last week before harvesting (when seaweed was at its most dense), light irradiance was reduced by 40% at 5m depth (Visch et al, 2020). Shading has the potential to alter species composition of the benthic habitat, for example, seagrass and maerl beds which rely on light for growth are likely to be sensitive to the impact of shading and could disappear from areas of seaweed cultivation. Studies have suggested that seaweed farms causing shading above seagrass beds may lead to decreases in seagrass shoot density, shoot length and growth rate (Eklof et al., 2006; Moreno et al., 2021). However, other studies have found no impacts of seaweed farming on seagrass biomass (Walls et al., 2017). The shading of benthic invertebrates is unlikely to be relevant, except where it may interfere with spawning cues (Scottish Government, 2020).

Reductions in phytoplankton as a result of intensive or large-scale farming could have impacts on a range of species in the food web, including fisheries species (Wilding et al., 2021), however, it will depend on a range of factors, notably the scale of the activity and the local hydrodynamics of the area. An ecosystem model of kelp farming in Strangford Lough, Ireland (Aldridge et al., 2021) showed that shading and nutrient competition between growing kelp and phytoplankton predicted decreases in phytoplankton chlorophyll of 23% for kelp farming that used 22% of the area of a semi-enclosed marine water body. Aldridge et al. (2021) also suggested that shading from seaweed could lead to a decrease in mussel biomass in Strangford Lough. However, this was under simulations of intensive seaweed farming over an extensive area. Campbell et al. (2019) stated that small- to medium-scale seaweed aquaculture would likely have limited impact on phytoplankton as they can travel through the site in a relatively shorter time period. However, Aldridge et al. (2021) indicate that large-scale seaweed farming activities have been shown to supress the abundance of phytoplankton during growing season due to competition for light and nutrients.

10. Introduction of microbial pathogens (including metazoan parasites)

The movement of seaweed species for aquaculture purposes has the potential to spread diseases (Cottier-Cook et al., 2021). Pathogens and disease in seaweed aquaculture can also be caused or exacerbated by abiotic stress as a result of unfavourable environmental conditions (Ward et al., 2019). Cultivated seaweed species can be particularly vulnerable to pathogens where species are not genetically diverse, typically due to stocks that have been produced from a limited pool of parent plants via sexual or asexual propagation (Cottier-Cook et al., 2016). It is recognised that disease within aquaculture has the potential to spread to wild populations, however there is limited evidence of this occurring in seaweed cultivation (Wood et al., 2017).

The use of plastics within aquaculture has the potential to act as a vector for higher abundances of pathogens and bacteria than the surrounding water, such as genera *Vibrio* (Mohsen et al., 2022). However, there is less evidence on the ability of these pathogens to transfer across to and infect aquaculture species.

Parasites occur naturally in the marine environment and can infect species used in aquaculture or wild populations. Compared to the natural environment, aquaculture facilities have high densities of stock which can facilitate parasites to spread quickly and easily. There is also the potential for parasites to spread from aquaculture sites and infect nearby wild populations or increase the parasitic load within wild populations where the parasites may already exist (Beninger and Shumway, 2018). In addition, stock imported for cultivation could harbour new and potentially non-indigenous parasites.

Parasites have the potential to lead to disease outbreaks in algae and could have negative impacts on both wild and cultivated algae (Carney and Lane, 2014). There is little evidence regarding the impacts of parasites, such as fungi and amoeba, on cultivated algae and whether this could spread to wild populations. Further research is therefore needed to understand the impacts of parasites associated with seaweed aquaculture on habitats and species.

11. Introduction or spread of INIS

Aquaculture can lead to the spread of INIS through a variety of different pathways, including the intentional introduction of INIS as the target aquaculture species and the unintentional introduction of ‘hitchhiking’ INIS which could be living on the aquaculture species and equipment. Infrastructure associated with suspended seaweed aquaculture could provide additional habitat for a range of benthic organisms including seaweeds, tunicates, razor clams and crabs (Wood et al., 2017) and have the potential to attract non-native species which can thrive on artificial structures.

In a global review of invasive macroalgae introductions, 54% of introductions were derived from aquaculture either through macroalgae cultivation or indirectly through imports for shellfish farming (Williams and Smith, 2007). Fletcher and Farrell (1998) describe that the spread of the non-native kelp species Wakame (*Undaria pinnatifida*) introduced to France in the 1980s for commercial cultivation has now spread to the south coast of the UK where it has the potential to outcompete native species.

The impacts of INIS will depend on the particular INIS, the habitat they have been introduced to, and their ability to become established (Herbert et al., 2016). INIS introduced via aquaculture could cause a range of impacts, including;

- Competition with native species for food and space;
- Predation on native species;
- Introduction of pathogens;
- Smothering;
- Modifying currents and changing sedimentation; and
- Change habitat type.

Aquaculture which adds infrastructure to the environment could enhance INIS establishment due to their typically opportunistic nature and ability to thrive on artificial substrates, such as anchors (McKindsey et al., 2011).

12. Litter

In general, aquaculture activities are recognised as a potential pathway for the introduction of marine litter. Abandoned or lost gear such as netting, ropes and lines can pose a significant entanglement threat, especially for seabirds (Massetti et al., 2021). Skirtun et al. (2022) highlighted the key risks posed to wildlife from marine plastic pollution includes entrapment and entanglement of marine organisms; ingestion of macro- and micro-plastic by animals; transfer of harmful chemicals to wildlife; transport of non-indigenous species; and smothering of marine fauna.

Macro-plastic pollution in the form of lost or abandoned gear from aquaculture can impact marine biodiversity by altering or modifying species assemblages (Werner et al., 2016). This is primarily through the introduction of foreign species transported via floating plastic debris, or sunken litter that forms new artificial habitats, both of which threaten native biodiversity

13. Nutrient enrichment

Subtidal seaweed aquaculture using ropes has the potential to add nutrients to the environment, however, the seaweed is recognised to providing a net uptake of nutrients such as nitrogen. There is a growing interest in co-cultivation, whereby seaweed is cultivated alongside bivalve shellfish or fish due to its ability to uptake nutrients. Seaweed aquaculture, therefore, has the potential to mitigate against the impacts of eutrophication. Models have shown that seaweed farming can have limited impacts regarding nutrient uptake but intensive seaweed cultivation over large areas could have a negative impact on phytoplankton or filter feeders such as mussels by competing for nutrients (Aldridge et al., 2021).

14. Organic enrichment

Studies have shown that seaweed can be a significant contributor of dissolved organic matter in coastal waters, with up to 20% of dissolved organic matter coming from kelp (Wada and Hama, 2013). Models have indicated that farming kelp has the potential to enhance benthic production and species abundance and richness (Hadley et al., 2018), however, in turn it could change local macrofaunal assemblages (Walls et al., 2017). In addition, storm events could lead to a large volume of frond break-off and subsequently increased organic enrichment if they settle in one area.

15. Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion

No studies were found that investigated the impacts of seabed penetration from stationary aquaculture infrastructure. However, penetration and/or disturbance of the substrate below the surface of the seabed could result from infrastructure such as moorings, anchors or screw piles being driven into the seabed. This disturbance has the potential to lead to direct mortality or localised displacement of infaunal species with the amount of impact dependent on the scale of the activity.

16. Physical change (to another seabed type)

Aquaculture infrastructure could potentially change a flat bottom space into an area which offers a three-dimensional artificial habitat for species to colonise and increase local biodiversity (Craeymeersch et al., 2013; Glenn et al., 2020; International Council for the Exploration of the Sea (ICES), 2020). The subtidal weights or anchors provide artificial structures for a range of benthic organisms including seaweeds, tunicates, razor clams and crabs (Wood et al., 2017), to live on and create new habitats.

Seaweed aquaculture has the potential to create a new (suspended) habitat in areas which are bare mud/sand which may attract a range of fauna associated with natural seaweed beds. A Swedish study showed that seaweed cultivation attracted mobile fauna and different algal species, thus increasing species abundance and richness compared to areas without cultivation (Visch et al., 2020). The attraction of mobile fauna such as fish and macroinvertebrates at seaweed aquaculture sites could provide a feeding ground for marine mammals and birds which predate upon these species. Unlike at fish and shellfish aquaculture sites, the presence of carnivorous predators are unlikely to have a negative impact on the yield of the seaweed farm (Wilding et al., 2021).

17. Removal of non-target species

Seaweed farms have the potential to increase the local abundance of prey species in their vicinity which could in turn attract marine mammals and birds to the area (Campbell et al., 2019; Wilding et al., 2021). There is a risk of mobile species becoming entangled with loose lines associated with aquaculture activities. Wilding et al. (2021) compared the risk of entanglement at seaweed farms to the risk of entanglement posed by static fishing gear such as suspended gill nets. Campbell et al. (2019) explained that seaweed cultivation could present an entanglement risk due to the use of moorings and marker buoys with slack lines, with the risk of entanglement increasing with as the footprint of the activity increases. Therefore, when choosing an area for a seaweed farm it is important to consider the potential use of the area by mobile species and marine predators. Reports of species becoming entangled in seaweed aquaculture equipment are rare, however, one report described a dugong drowning after becoming entangled in ropes associated with a seaweed farm in the Philippines (Poonian and Lopez, 2016).

Seaweeds provide food and shelter for a range of invertebrate species which can often be found attached to the fronds of the seaweed. An Irish study by Walls et al. (2016) showed that the holdfasts of cultivated algae hosted a wide range of taxa, with benthic cultured individuals predominately hosting nematodes, polychaetes and molluscs, and suspended culture hosting predominately amphipods, polychaetes and decapods. Suspended seaweed holdfasts contained similar numbers of individuals as benthic holdfasts (Walls et al., 2017). The harvesting of seaweed can lead to the incidental removal of these non-target species.

18. Smothering and siltation rate changes (‘Light’ deposition)

There is little evidence in the literature that seaweed aquaculture could smother habitats. Infrastructure on the seabed such as anchors or weights may lead to a highly localised smothering directly under its footprint. In addition, storm events, could lead to large scale frond break off, which could lead to localised smothering if they were to settle predominately in one location. Smothering could lead to permanent or temporary displacement of benthic species. However, more information is needed to understand the potential scale of the impact occurring from this pressure and activity.

19. Synthetic compound contamination

There is very little information regarding the use of chemicals such as pesticides and antifoulants in seaweed aquaculture (Philips et al., 1990). Wilding et al., (2021) stated that once deployed at sea, seaweed farming sea is unlikely to require the use of pesticides or fertilisers. However, there is the potential that chemicals could be used for seaweed aquaculture to reduce pests, control disease and remove fouling organisms.

20. Transition elements & organo-metal (e.g. TBT) contamination.

There was no direct evidence regarding the use of transition elements and organo-metals in subtidal seaweed aquaculture. Metals, such as copper, have been used in aquaculture as antifoulants (Bannister et al. 2019).

21. Underwater noise changes

Underwater noise can occur from the installation of aquaculture infrastructure or the use of vessels during cultivation and harvesting operations. The impacts of noise from vessels used for cultivation may be lower in magnitude than typical vessel traffic, but this will be area specific and could still potentially affect species sensitive to noise (Wilding et al., 2021).

22. Visual disturbance

Visual disturbance can occur by vessel movement directly related to the construction and cultivation practices associated with subtidal seaweed aquaculture using ropes. The construction of aquaculture infrastructure is characterised by a short period of acute disturbance, followed by the operational phase where disturbances are caused sporadically during maintenance, harvesting and reseeding activities (Becker et al., 2011).

There are concerns that birds in the vicinity of aquaculture sites could be disturbed/displaced by the presence of personnel or vessels and artificial lights (ICES, 2022).

23. Water flow changes

The presence of seaweed in the water column absorbs energy from waves and current and acts as an obstruction to water flow (Wilding et al. 2021). There is the potential for water flow changes to occur both within and outside of seaweed farms as flow is diverted around the farm. Zhang et al. (2016) showed the culture of suspended kelp led to a reduction in flow velocity by almost 50%, and bottom friction velocity by 25%. Such changes in water flow have the potential to change the hydrodynamics of the local system, affecting the erosion and deposition of sediments within the system (Cao et al., 2007; Zhang et al., 2016).

In addition, the cycles of regular growth and harvesting of seaweed has the potential to lead to variable changes in water flow during the lifetime of the activity.

24. Wave exposure changes

There is the potential that the presence of seaweed in the water column could change wave exposure of a site, for example by dampening surface waves by reducing wave energy and longshore currents (Mork et al., 1996; Morris et al., 2020). Changes in wave exposure could affect physical processes such as sediment transport and also lead to changes in habitats and species communities.

In addition, the regular growth and harvesting of seaweed has the potential to lead to variable changes in wave energy during the lifetime of the activity.

Subtidal Seaweed Aquaculture using Rope

Step 6: Next Steps

This Aquaculture Activity Assessment, along with the AWAA Mapping Tool, Dashboard, and Evidence Database, provide a useful starting point for users to further investigate the potential impacts from growing subtidal seaweed using ropes on the marine environment. Steps 1 to 5 of this Assessment have been designed to provide guidance on how the Project resources can be used to inform an environmental appraisal process.

Steps 1 to 5 provide the user with an initial understanding of the potential pressures occurring from an aquaculture activity and the tools to identify the most sensitive biotopes and species in an area of interest to the potential impacts from the proposed activity. Step 4 of this assessment should be repeated for all pressures identified in Step 2 to gain a full understanding of the sensitivity of biotopes and species to the activity.

However, to fully understand the impact of a specific aquaculture activity, the user needs to consider the footprint, location, intensity of the activity and the methods behind construction, operation and harvesting. Specific details about a proposed activity have the potential to change which pressures may occur, along with the exposure and significance of the effect of that pressure on relevant biotopes and species.

Environmental appraisals should also consider indirect impacts on biotopes and species from the proposed activities for example the impact on a habitat that provides food for a protected species. Whilst indirect impacts have not been included in the AWAA resources, it is important to consider how they could potentially have an impact. The environmental appraisal process may also consider the potential interactions between pressures which could exacerbate any potential impacts from pressures on their own.

Finally, it may be necessary to consult locally and to undertake area-specific surveys to gain further insight into potentially sensitive biotopes and species in the vicinity of a proposed activity.

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Abbreviations

AWAA	Aquaculture Activity Assessment
ICES	International Council for the Exploration of the Sea
INIS	Invasive Non-Native Species
MarESA	Marine Evidence based Sensitivity Assessment
MPA	Marine Protected Area
NRW	Natural Resources Wales
OSPAR	Cooperative of 15 governments and the EU for the Protection of the Marine environment of the North East Atlantic
PAH	Polycyclic Aromatic Hydrocarbons
SAC	Special Area of Conservation
TBT	Tributyltin
UK	United Kingdom

Data Archive Appendix

Data outputs associated with this project are archived in [NRW to enter relevant corporate store and / or reference numbers] on server–based storage at Natural Resources Wales.

Or

No data outputs were produced as part of this project.

The data archive contains: [Delete and / or add to A-E as appropriate. A full list of data layers can be documented if required]

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] A full set of maps produced in JPEG format.

[C] A series of GIS layers on which the maps in the report are based with a series of word documents detailing the data processing and structure of the GIS layers

[D] A set of raster files in ESRI and ASCII grid formats.

[E] A database named [name] in Microsoft Access 2000 format with metadata described in a Microsoft Word document [name.doc].

[F] A full set of images produced in [jpg/tiff] format.

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