

Assessing Welsh Aquaculture Activities Project Report

Report No: 726

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- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well-resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

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Crynodeb Gweithredol

Pwrpas Prosiect Asesu Gweithgareddau Dyframaethu Cymru (AGDC) Cyfoeth Naturiol Cymru (CNC) yw cefnogi datblygiad cynaliadwy a rheolaeth gynaliadwy adnoddau dyframaethu a gweithrediad Cynllun Morol Cenedlaethol Cymru (CMCC).

Mae'r Prosiect AGDC, sydd wedi'i ariannu'n llawn gan Gronfa'r Môr a Physgodfeydd Ewrop, yn darparu set o adnoddau cyffredin, seiliedig ar dystiolaeth, i ddefnyddwyr er mwyn llywio penderfyniadau cynllunio morol a chanllawiau ar gyfer gweithgareddau dyframaethu.

Ymchwiliodd Prosiect AGDC i'r llenyddiaeth sydd ar gael ar effeithiau amrywiaeth o weithgareddau dyframaethu ar yr amgylchedd morol. Casglodd y Prosiect AGDC hefyd sensitifrwydd biotopau morol (sy'n cynnwys cynefinoedd) a rhywogaethau i'r pwysau sy'n debygol o godi o weithgareddau dyframaethu.

- Mae adnoddau Prosiect AGDC yn cynnwys:
- Cronfa Ddata Tystiolaeth;
- Dwy Daenlen Rhyngweithiadau a Dangosfwrdd;
- Offeryn Mapio; ac
- Wyth Aseiad Gweithgaredd Dyframaethu.

Gellir defnyddio adnoddau'r Prosiect AGDC i nodi ardaloedd a allai fod yn addas ar gyfer datblygiadau dyframaethu. Gellir eu defnyddio hefyd i gasglu a datblygu gwybodaeth a thystiolaeth er mwyn llywio gwerthusiad amgylcheddol ar gyfer gweithgaredd dyframaethu o ddiddordeb. Er nad yw adnoddau'r Prosiect AGDC wedi cyfeirio at amodau amgylcheddol penodol, nac ôl troed neu ddwysedd y gweithgareddau, gellir eu defnyddio fel man cychwyn i lywio unrhyw aseuadau neu adroddiadau amgylcheddol perthnasol.

Mae'r Adroddiad Prosiect AGDC hwn yn crynhoi'r dulliau a ddefnyddiwyd i ddatblygu adnoddau'r Prosiect AGDC ac mae'n rhoi arweiniad ar gyfer eu defnyddio. Mae hefyd yn disgrifio unrhyw fylchau, cyfyngiadau a thybiaethau perthnasol yn y dystiolaeth.

Executive Summary

The purpose of Natural Resources Wales' (NRW) Assessing Welsh Aquaculture Activities (AWAA) Project is to support the sustainable development and sustainable management of aquaculture resources and the implementation of the Welsh National Marine Plan (WNMP).

Fully funded by the European Maritime and Fisheries Fund (EMFF), the AWAA Project provides users with a set of common, evidence-based resources on which to inform marine planning decisions and guidance for aquaculture activities.

The AWAA Project investigated the literature available on the impacts of a variety of aquaculture activities on the marine environment. The AWAA Project also collated the sensitivity of marine biotopes (that comprise habitats) and species to the pressures likely to occur from aquaculture activities.

The AWAA Project resources include:

- An Evidence Database;
- Two Interactions Spreadsheets and Dashboard;
- A Mapping Tool; and
- Eight Aquaculture Activity Assessments.

The AWAA Project resources can be used to identify potentially suitable areas for aquaculture developments. They can also be used to gather and develop information and evidence to inform an environmental appraisal for an aquaculture activity of interest. While the AWAA Project resources have not referred to particular environmental conditions, or the footprint or intensity of activities, they can be used as a starting point to inform any relevant environmental assessments or reports.

This AWAA Project Report summarises the methods used to develop the AWAA Project resources and provides guidance for their use. It also describes any relevant evidence gaps, limitations and assumptions.

1. Introduction

Natural Resources Wales' (NRW) purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future. NRW has sustainable development at the heart of its evidence programme, delivering results for the people, environment and economy in Wales.

The AWAA Project was fully funded by Welsh Ministers and the European Union (EU) through Measure II.7: Article 51 (increasing the potential of aquaculture sites) of the EMFF to undertake the Assessing Welsh Aquaculture Activities Project (the AWAA Project).

The AWAA Project supports the implementation of the 2019 WNMP and the sustainable management of marine natural resources. The WNMP describes the Welsh Government's ambition to support the sustainable development of aquaculture activities in Welsh waters; and includes an indicative map of Aquaculture Resources Areas (ABPmer, 2015; Welsh Government, 2019). In 2021, to support the implementation of the WNMP, Welsh Government's Sustainable Management of Marine Natural Resources (SMMNR) Project published aquaculture reports supplemented with additional Sector Locational Guidance (SLG) for aquaculture developers in 2022 (Welsh Government, 2021; 2022). The WNMP, SMMNR and SLG mapping resources collated environmental evidence at a high level, indicating the potential ecological constraints across a range of potential aquaculture activities. The AWAA Project represents an important next step in the mapping of environmental considerations in relation to aquaculture development, as it examines in more detail the sensitivities of marine biotopes (that comprise habitats) and species to the pressures arising from individual types of aquaculture activity.

The AWAA Project provides users, such as developers, regulators and advisors, with a set of common, transparent, evidence-based resources which can inform marine planning decisions and guidance for aquaculture activities. The AWAA Project collated the sensitivity of Welsh marine habitats and species to the pressures from a variety of aquaculture activities. While the AWAA Project resources have not referred to particular environmental conditions, or the footprint or intensity of activities, they can be used as a starting point to inform any relevant environmental assessments or reports. In addition, they can be used to identify potentially suitable areas for aquaculture enterprises.

This AWAA Project Report summarises the methods used to develop the AWAA Project resources and provides guidance for their use. It also describes any relevant evidence gaps, limitations and assumptions.

In addition to this Project Report, the AWAA Project resources include:

- An Evidence Database;
- Interactions Spreadsheets/Dashboard;
- A Mapping Tool; and
- A series of eight Aquaculture Activity Assessments.

2. AWAA Resources and Methods

2.1. Geographic scope

The geographic scope of the AWAA Project is the 'Welsh Zone', defined as that part of the sea within British fishery limits adjacent to Wales by The Welsh Zone (Boundaries and Transfer of Functions) Order 2010 (Figure 1).

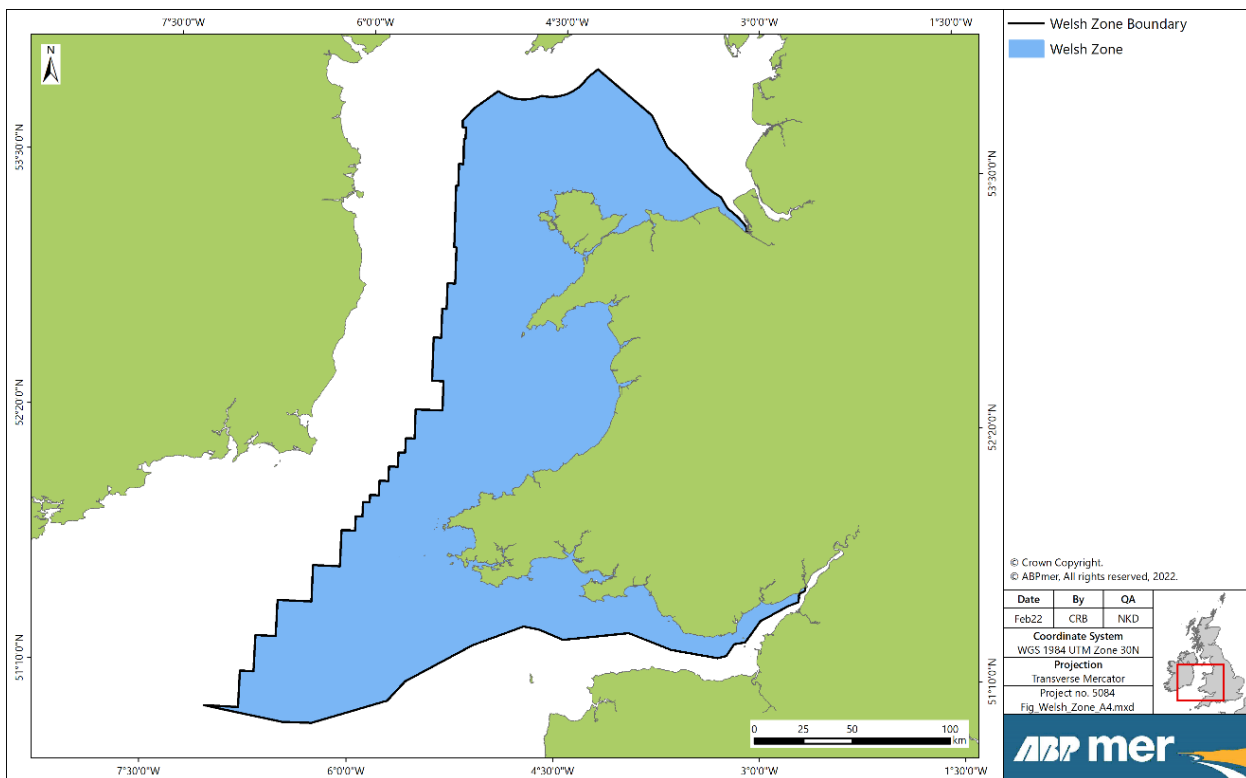


Figure 1: Geographic scope of the AWAA Project

All marine biotopes and protected species in the Welsh zone that form part of Welsh Marine Protected Areas (MPAs) are considered in the AWAA Project. MPAs include:

- Special Areas of Conservation (SACs);
- Special Protection Areas (SPAs);
- Ramsar sites;
- Sites of Special Scientific Interest (SSSIs); and
- Marine Conservation Zones (MCZs).

Often MPAs also contain biotopes that are not part of the designated habitats or features. The AWAA Project resources have been developed to assist users in identifying the biotopes that form part of the protected habitats or features.

Coastal MPAs which only include features above mean high water springs, such as sand dunes, were not included within the scope of the AWAA project. In addition, the offshore

Croker Carbonate Slabs MPA and the Irish Sea Front SPA were not included as the depth, distance and exposure of the site make it unsuitable for aquaculture.

2.2. Definition of aquaculture

The AWAA Project, like the SMMNR Project (Welsh Government, 2021), defined aquaculture as;

“the rearing or cultivation of aquatic organisms such as finfish, shellfish and algae. Aquaculture includes producing aquatic organisms for direct commercial purposes (e.g. seafood for human or animal consumption, pharmaceuticals, or algae for fertiliser or energy) or for restocking and enhancing of wild populations”.

2.3. Relevant aquaculture activities

The aquaculture activities considered in the AWAA Project were focused on activities that currently take place in Wales or are considered to have the potential for commercial development in Wales. These activities are listed in Table 1.

Table 1. Aquaculture activities

Activity Category	Description
Intertidal Shellfish (Trestles and Poles)	Intertidal shellfish aquaculture activities using trestles or poles. Shellfish can be grown on trestles in bags, baskets or lantern nets, or can be grown attached to ropes or lines attached to poles driven into the seabed.
Intertidal Shellfish (Ground Laid, Hand Harvested)	Intertidal shellfish aquaculture activities using ground laid and hand harvesting methods. Shellfish can be grown directly on the seabed and are harvested using rakes or by hand picking at low tide.
Intertidal Shellfish (Ground Laid, Mechanically Harvested)	Intertidal shellfish aquaculture activities using ground laid and mechanical harvesting methods. Shellfish can be grown directly on the seabed and harvested using dredges from vessels at high tide.
Intertidal Seaweed (Planted, Hand Harvested)	Intertidal seaweed aquaculture activities using planting and hand harvesting methods. Seaweeds can be planted directly onto the seabed or with the use of infrastructure such as hard substrates (e.g. rocks, weights, tiles) or nets. Seaweed is then harvested by hand during low tide.

Activity Category	Description
Intertidal Seaweed (Planted, Mechanically Harvested)	Intertidal seaweed aquaculture activities using planting and mechanical harvesting methods. Seaweeds can be planted directly onto the seabed or with the use of infrastructure such as hard substrates (e.g. rocks, weights, tiles) or nets. Seaweed is then harvested using trawls or dredges from vessels at high tide.
Subtidal Shellfish (Rafts)	Subtidal shellfish aquaculture activities using rafts. Shellfish are attached to ropes or grown in baskets or nets on lines and suspended in the water column from underneath the raft. Rafts can also be set on the substrate with baskets / containers placed directly on the raft.
Subtidal Shellfish (Ropes)	Subtidal shellfish aquaculture activities using ropes or longlines. Shellfish can be grown in baskets or on lines suspended in the water column from header ropes or longlines with buoys.
Subtidal Shellfish (Ground Laid, Mechanically Harvested)	Subtidal shellfish aquaculture activities using ground laid and mechanical harvesting methods. Shellfish can be grown directly on the seabed then harvested using vessels with dredges. Sometimes shellfish can be grown in baskets on the seabed or covered by cages.
Subtidal Seaweed (Rope)	Subtidal seaweed aquaculture activities using ropes. Seaweeds can be grown in baskets, nets or from lines suspended in the water column from header ropes or longlines with buoys.
Subtidal Seaweed (Rafts)	Subtidal seaweed aquaculture activities using rafts. Seaweeds are attached to ropes or grown in baskets or nets on lines and suspended in the water column from underneath the raft. Rafts can also be placed directly on to the seabed with the seaweed growing upwards into the water column.
Subtidal Fish (Cages)	Subtidal fish aquaculture activities using cages. Fish are usually contained in a net suspended in the water column from a large supporting ring on the surface.

The focus of the AWAA Project, as highlighted by the WNMP and SMMNR guidance, is the cultivation of bivalve shellfish and seaweed. An AWAA Activity Assessment on subtidal fish aquaculture using cages was not produced by the AWAA Project due to the activity not currently occurring in Wales and the volume of evidence and research that would need to

have been considered. A disproportionate amount of the AWAA Project resources would have been used on an activity with limited potential for development.

Land-based aquaculture activities and ancillary activities such as access to shore-based aquaculture sites were not considered in the AWAA Project. However, relevant AWAA Activity Assessments identify where further consideration may be needed on the impacts from ancillary activities that are beyond the scope of the AWAA Project.

2.4. Pressures associated with aquaculture activities

Marine habitats and species have the potential to be impacted by pressures caused by various aquaculture activities. The AWAA Project used, as a starting point, the standardised list of pressures resulting from human activities on the pressures developed initially by the OSPAR Intersessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR, 2011).

Minor revisions of the OSPAR ICG-C pressures and their descriptions have been made by the Statutory Nature Conservation bodies, the Department for Environment, Food and Rural Affairs (Defra), Marine Scotland, and The Marine Life Information Network (MarLIN), which have resulted in the current approach to sensitivity assessments found in the Marine Evidence-based Sensitivity Assessment (MarESA) (Tyler-Walters et al., 2022). Therefore, the AWAA Project uses the revised pressure descriptions in line with MarESA. Notably, MarESA included metazoan disease vectors and parasites when assessing sensitivity to the pressure 'introduction of microbial pathogens'. Metazoan disease vectors and parasites have, therefore, been included under this pressure for the AWAA Project.

2.4.1. AWAA Project pressures

The OSPAR/MarESA pressures initially considered relevant in the AWAA project are shown below. These pressures were later refined after a review of the current literature available on the pressures occurring from aquaculture activities (see Section 2.6.4).

- Abrasion/disturbance of the substrate on the surface of the seabed;
- Barrier to species movement;
- Changes in suspended solids (water clarity);
- Collision BELOW water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures);
- Deoxygenation;
- Electromagnetic changes;
- Emergence regime changes, including tidal level change considerations;
- Genetic modification & translocation of indigenous species;
- Habitat structure changes – removal of substratum (extraction);
- Hydrocarbon and Polycyclic Aromatic Hydrocarbons (PAH) contamination (incl. priority substances listed in Annex II of Directive 2008/105/EC);
- Introduction of light or shading;
- Introduction of microbial pathogens (including metazoan parasites);
- Introduction of other substances (solid, liquid or gas);
- Introduction or spread of invasive non-indigenous species (INIS);
- Litter;

- Nutrient enrichment;
- Organic enrichment;
- Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion;
- Physical change (to another seabed type);
- Physical change (to another sediment type);
- Physical loss (to land or freshwater habitat);
- Radionuclide contamination;
- Removal of non-target species;
- Removal of target species;
- Salinity decrease;
- Salinity increase;
- Smothering and siltation rate changes ('Heavy' deposition);
- Smothering and siltation rate changes ('Light' deposition);
- Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) (incl. priority substances listed in Annex II of Directive 2008/105/EC);
- Temperature decrease;
- Temperature increase;
- Transition elements and organo-metal (e.g. Tributyltin (TBT)) contamination (incl. priority substances listed in Annex II of Directive 2008/105/EC);
- Underwater noise changes;
- Visual disturbance;
- Water flow (tidal current) changes, including sediment transport considerations; and
- Wave exposure changes.

Three additional pressures, likely to affect species, were also included from Natural England's *Designing and applying a method to assess the sensitivities of highly mobile marine species to anthropogenic pressures* report (Pérez-Domínguez et al., 2016). These were:

- 'Above water noise';
- 'Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)'; and
- 'Vibration'.

2.5. Welsh marine habitats and species

2.5.1. Habitats

The AWAA Project determined the habitats from a range of Welsh and UK legislation with the potential to be impacted by the pressures occurring from aquaculture activities. These included habitats designated under:

- Annex 1 of the Habitats Directive, whereby certain habitats have been designated as part of SACs under the Conservation of Habitats and Species Regulations 2017 as amended;

- Wildlife and Countryside Act 1981, whereby certain habitats are designated as part of SSSIs; and
- Section 7 of the Environment (Wales) Act 2016.

The habitats used as part of systematic literature review conducted (Section 2.6) as part of the Evidence Database are listed in Appendix 6, Table 5.

Biotores, which form components of habitats or protected features, as defined by JNCC (in Connor et al., 2004; JNCC, 2022), were used in order to determine the potential sensitivity of habitats to the pressures occurring from aquaculture activities. Using biotores allowed for a more detailed consideration of a range of sensitivities within a habitat. A list of the biotores found in Welsh waters was produced from data extracted from two spatial datasets. Point-source seabed survey data, supplied by NRW, was taken from Marine Recorder (NRW, 2020) and polygon data from the Intertidal Phase 1 Coastal Habitat Survey were obtained from the DataMapWales (NRW, 2022). The Marine Recorder dataset is an Access-based repository for marine data held by nature conservation agencies. It contains biotope point source data for Wales from a range of Welsh surveys undertaken between 1969 and 2019. The Intertidal Phase 1 Habitat Survey dataset contains biotope polygon data from a 10-year intertidal survey of the Welsh coast between 1996 and 2004. These datasets provide the best available information on the biotores found in Welsh waters although caution should be exercised when considering the survey technique used and the age of the data.

Biotores were not used in the Evidence Database (Section 2.6) as the vast majority of the literature describes impacts on habitats and species, rather than biotores.

Coastal habitats, which are above mean high water springs such as sand dunes, and their component species were not included in the AWAA Project.

2.5.2. Species

Species included algae, invertebrates, fish, marine mammals, turtles and birds referred to under relevant Welsh, UK and international legislation:

- Annex 2 of the Habitats Directive, whereby certain species have been designated as part of SACs under the Conservation of Habitats and Species Regulations 2017 as amended;
- Annex 1 of the Birds Directive, whereby certain species have been designated as part of SPAs under the Conservation of Habitats and Species Regulations 2017 as amended;
- Ramsar Sites species under the Convention on Wetlands of International Importance; and
- Wildlife and Countryside Act 1981, whereby certain species are designated as part of SSSIs;
- Section 7 of the Environment (Wales) Act 2016.

The only protected species scoped out of the Project was Shoredock (*Rumex rupestris*) as they exist on cliffs or high up on the shore where the habitat is unsuitable for aquaculture. Species not designated as part of a protected site, or species which do not occur in Wales

were not included in the Project. A full list of the species used in the AWAA Project is available in Appendix 6, Table 6.

2.6. AWAA Evidence Database

The AWAA Evidence Database collates all the relevant evidence sources currently available on the impacts from the aquaculture activities being considered within the AWAA Project.

For the purpose of the Project, evidence is defined as peer-reviewed papers, data, methodology, results from data analysis, interpretation of data analysis, collations and interpretations of scientific information (meta-analysis), expert opinion or advice, industry knowledge, grey literature, and anecdotal evidence. The steps undertaken to produce the Evidence Database are provided below.

2.6.1. Systematic literature review

A systematic literature search was undertaken to identify the potential impacts of aquaculture activities on marine habitats and species. The literature search focussed on identifying evidence of the pressures likely to occur from aquaculture activities (Sections 2.3 and 2.4) and their impact on habitats and species (Section 2.5).

For the purposes of the literature search, some species were grouped by characterising behaviours (e.g. diving seabirds, migratory fish, demersal fish) or by taxonomy (e.g. cetaceans, phocids). This follows a similar approach taken with the Natural England (Pérez-Domínguez et al., 2016) and SMMNR (Welsh Government, 2021) projects. See Appendix 6 for a complete list and the categories used.

Web of Science was used to search the abstracts of both peer-reviewed and 'grey' literature using compound search terms. The general structure of the search terms is shown below:

- (“habitat / species / species group” OR “common / alternative name”) AND (aquaculture OR mariculture OR cultivat* OR farm* OR net* OR harvest* OR trestle* OR rope* OR basket*) AND (impact* OR effect* OR affect* OR pressure* OR sensitivity)

Each set of search terms comprised three parts. The first part related to a habitat, species and/or species group, the second part related to key words for identifying aquaculture activities in the literature, and the third part related to key words for identifying impacts. The last two parts of the search terms remained identical for each search. One search was also undertaken using only the second and third parts of the search term to capture any additional literature not found during the specific habitat and species searches. Each part of the search terms was separated by the Boolean operator 'AND', and within each part, terms were separated by the Boolean operator 'OR'. The asterisk was used as a 'wildcard' symbol to broaden the search to encompass variations on words.

A total of 69 searches were conducted on Web of Science in February 2022 and the results exported. The summaries for each result were then screened to remove any deemed irrelevant or those which covered aquaculture activities not applicable to Wales. Where a high number of spurious results were returned from the search, the search terms were tailored or revised to increase their relevance.

Papers, reports or studies cited within the literature found in the Web of Science searches were also included along with literature from other sources (e.g. sharing of knowledge within professional network).

Each relevant piece of literature was individually reviewed to extract the following formation (a full list of the information extracted, and descriptions are provided in Appendix 6.2, Table 7):

- Full citation;
- Source summary and overview of findings;
- Study location;
- Aquaculture species;
- Aquaculture activity;
- OSPAR pressure;
- Habitat/species impacted;
- Evidence source type (e.g. peer reviewed, grey' literature, etc.);
- Evidence type (quantitative, qualitative, review or anecdotal);
- Habitat/species impacted matching notes;
- Source provenance; and
- Confidence scoring.

2.6.2. Confidence in the evidence

To determine a level of confidence for each piece of evidence, the confidence was assessed in three components, as outlined in Table 2. A total score for confidence was given based on similar approaches used by Natural England (Pérez-Domínguez et al., 2016) and MarESA (Tyler-Walters et al., 2018) whereby scores were summed across the three components (Maximum combined score 15, Minimum score 3). High confidence was assigned to total scores >12; Medium confidence to scores 6 – 12; and Low confidence for scores <6.

Table 2: Confidence of scoring the evidence in the Evidence Database

Type of source (based on evidence type)	Applicability of location	Applicability of aquaculture species
Source is a peer reviewed article Confidence score: High = 5	Location of the evidence is Wales, England, Scotland or Ireland Confidence score: High = 5	Aquaculture species is a species that occurs in the UK and / or is already used in aquaculture Confidence score: High = 5

Type of source (based on evidence type)	Applicability of location	Applicability of aquaculture species
Source is a white paper, grey literature or book Confidence score: Medium = 3	Location of the evidence is within the Northeast (NE) Atlantic or European waters, or evidence is based on a Global review Confidence score: Medium = 3	Aquaculture species which is not specified in the source (i.e. is generic and impacts likely applicable to all of that species) Confidence score: Medium = 3
Source is a website Confidence score: Low = 1	Location of the evidence is outside the NE Atlantic or European waters Confidence score: Low = 1	Aquaculture species is not currently present in the UK Confidence score: Low = 1

2.6.3. How to use the Evidence Database

Each row of the Database relates to a particular combination of relevant information from the source material for a:

- Particular activity;
- Particular pressure; and
- Habitat or species.

This means the Evidence Database contains multiple entries (rows) for some evidence sources, as some sources include information relevant to several aquaculture activities, pressures and habitats or species combinations. In total, 267 literature sources were identified which provided over 1200 unique pieces of evidence on the potential impacts of aquaculture on the habitats and species being considered by the AWAA Project.

To facilitate searching the Evidence Database, two pivot tables were created within the spreadsheet to show the number of evidence sources found for:

1. Each aquaculture activity and pressure combination, and
2. Each habitat/species and pressure combination.

A 'Read Me' tab has been provided within the Evidence Database to inform the user of the information provided in the Database and how to search it. By selecting a cell in the pivot table, a new worksheet is created that displays all the relevant evidence records and their full details. Users can also filter the columns of the Evidence Database to further search the available literature.

2.6.4. Refinement of pressure list

Following a review of the evidence collated within the AWAA Evidence Database, the applicability of the OSPAR/MarESA pressures identified in Section 2.4 were considered further. The aquaculture activity-pressure relationship was considered for all the AWAA aquaculture activities to determine which pressures were directly relevant to each of the aquaculture activities. Where evidence was available, it was assumed the pressure has the potential to occur from the aquaculture activity. Where evidence was not available, expert judgement was used to determine if the pressures had the potential to arise from the activity. As a result, there were 11 pressures deemed not relevant to any aquaculture activities and were scoped out of the AWAA Project, these included:

- Electromagnetic changes;
- Emergence regime changes, including tidal level change considerations;
- Introduction of other substances (solid, liquid or gas);
- Habitat structure changes – removal of substratum (extraction);
- Physical loss (to land or freshwater habitat);
- Radionuclide contamination;
- Salinity decrease;
- Salinity increase;
- Smothering and siltation rate changes ('Heavy' deposition);
- Temperature decrease; and
- Temperature increase.

A matrix of the remaining 29 pressures, and the aquaculture activities they could be associated with is provided in Appendix 6.3, Table 8.

The AWAA Project indicatively describes the potential pressures that could occur from the aquaculture activities described in Table 1. However, when developing an aquaculture activity, using specific details about the location, construction methods, infrastructure used, operation and harvesting methods, will all contribute to the determination of which pressures are likely to occur from the activity, and the subsequent scale of those pressures on biotopes and species.

2.7. Interactions Spreadsheets

AWAA Interaction Spreadsheets were developed to provide searchable databases on the sensitivity of biotopes or species to the pressures associated with individual aquaculture activities.

This involved compiling a list of all the biotopes and species in Wales, determining their sensitivity to the pressures associated with different aquaculture activities, checking the applicability of the benchmark or sensitivity thresholds, and then identifying which MPAs and features the biotopes or species are part of.

It is important to note that the sensitivity of biotopes and species only considered direct impacts. Indirect impacts, for example depletion of prey species for marine predators, were not considered, however, they can have a detrimental effect on habitats and species and should be considered when assessing the impacts of a proposed aquaculture activity.

2.7.1. Biotope sensitivity

The MarESA biotope dataset was used to determine the sensitivity of marine biotopes to the potential pressures from aquaculture activities (Tyler-Walters et al., 2022). MarESA was produced by The Marine Life Information Network (MarLIN) and includes information on the sensitivity of UK marine biotopes to the pressures as defined by OSPAR ICG-C (Section 2.4). The descriptions of the sensitivity scores used in MarESA are shown in Table 3.

Table 3. Descriptions of the sensitivity scores used in MarESA

MarESA sensitivity score	Description
High	Determined by MarESA based on a combination of the resilience and resistance of the habitat or species to the pressure
Medium	Determined by MarESA based on a combination of the resilience and resistance of the habitat or species to the pressure
Low	Determined by MarESA based on a combination of the resilience and resistance of the habitat or species to the pressure
Not sensitive	The habitat or species has a high level of both resistance and resilience to the pressure (at the benchmark level) and is likely to recover quickly
Not relevant	Evidence suggests that there is no direct interaction between the pressure and the biotope or species
No evidence / Insufficient evidence	There is not enough evidence to assess the sensitivity of the specific feature/pressure combination, there is no suitable proxy information regarding the biotope or species on which to base decisions, and expert judgement alone does not allow an assessment to be made with any confidence
Not assessed	The available evidence is extremely limited, poorly understood or completely absent and hence the interaction was excluded from the assessment

As mentioned in Section 2.5.1, a list of biotopes occurring in Wales was produced from Marine Recorder (NRW, 2020) and Intertidal Phase 1 Habitat Survey (NRW, 2022). Any

biotopes from these datasets which were recorded at European Nature Information System (EUNIS) Level 2 were removed due to Level 2 biotopes not being assessed for sensitivity in MarESA¹.

The unique biotopes from Marine Recorder and Intertidal Phase 1 Habitat Survey were matched to the biotopes in the MarESA dataset, and the scores for sensitivity extracted using R programming language (R Core Team, 2022). Some of the Marine Recorder or Intertidal Phase 1 Habitat Survey biotope names and codes did not match with the MarESA dataset due to changes of the biotope classification over time by JNCC. Therefore, the unmatched biotopes were cross-checked with JNCC for updates before matching to the appropriate biotopes in MarESA. In some cases, the Marine Recorder or Intertidal Phase 1 Habitat Survey biotopes no longer existed and therefore no sensitivity assessment in MarESA was available. These biotopes were assigned a sensitivity score of 'Not Assessed'.

2.7.2. Species sensitivity

To assess the sensitivity of marine species protected in Wales to the potential pressures associated with aquaculture activities, the MarESA species dataset (Tyler Walters et al., 2022) and the Natural England Mobile Species Sensitivity Assessment (Natural England, 2022) were used.

A list of Welsh protected species was based on those identified in Section 2 and is included in Appendix 6. Similar to the biotope assessment, scores for sensitivity were extracted for each species. Where a protected species had not been assessed by Natural England or MarESA, the species was assigned a sensitivity score of 'Not Assessed'.

2.7.3. Confidence in the sensitivity

The confidence scores associated with the sensitivity assessments allow the user to interpret the robustness of the underlying evidence behind the sensitivity scores.

Confidence in the sensitivity scores were derived by MarESA (Tyler-Walters et al., 2022) and the Natural England Mobile Species Sensitivity Assessment (2022). They assessed confidence against three components, i.e. quality of evidence, applicability of evidence and degree of concordance. Table 4 shows the criteria MarESA (Tyler Walters, 2018) and Natural England (Pérez-Domínguez et al., 2016) used when determining confidence.

As part of the AWAA Project, a total score for confidence was determined based on individual confidence score produced by MarESA (Tyler-Walters et al., 2022) and Natural England (Pérez-Domínguez et al., 2016). Confidence scores were summed across the three components (High = 5, Medium = 3, Low = 1; Maximum combined score 15, Minimum score 3). High confidence was assigned to total scores >12; Medium confidence to scores 6 – 12; and Low confidence for scores <6.

¹ The EUNIS habitat classification is a comprehensive hierarchical pan-European system for habitat identification. EUNIS Level 2 is a relatively high-level classification whereby habitats are classified into two substrate types – rock or sediment. See JNCC (2022) for the EUNIS classification and Parry (2019) for guidance on the different EUNIS levels.

Where the confidence in the sensitivity score is considered to be low, it may be appropriate to undertake further investigation or studies to assess the impacts of a particular activity and pressure on a biotope or species.

Table 4. Confidence in the sensitivity assessment rules merged from MarESA (Tyler-Walters, 2018) and Natural England (Pérez-Domínguez et al., 2016).

Confidence level	Quality of evidence (information sources)	Applicability of evidence	Degree of concordance (agreement between studies)
High	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies on the feature Score = 5	Assessment based on the same pressures acting on the same type of feature (habitat, its component species, or species of interest) in the UK Score = 5	Agree on the direction and magnitude (of impact or recovery) Score = 5
Medium	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement on feature or similar features Score = 3	Assessment based on similar pressures on the feature (habitat, its component species, or species of interest) in other areas Score = 3	Agree on direction but not magnitude (of impact or recovery) Score = 3
Low	Based on expert judgement Score = 1	Assessment based on proxies for pressures e.g. natural disturbance events Score = 1	Do not agree on direction or magnitude (of impact or recovery) Score = 1

2.7.4. Sensitivity benchmark review

The MarESA and Natural England sensitivity assessments used benchmarks to provide a standard level of pressure against which to assess sensitivity.

As part of the AWAA Project, these benchmarks were reviewed for their applicability in assessing the sensitivity of pressures occurring from aquaculture activities. The benchmarks were assessed as either ‘applicable’, ‘pressure unlikely to exceed the benchmark’ or ‘not applicable’. For example, the MarESA sensitivity benchmark for the pressure ‘barrier to species movement’ was a ‘permanent or temporary barrier to species

movement over $\geq 50\%$ of water body width or a 10% change in tidal excursion'. It was considered that aquaculture activities in Wales are unlikely to cover more than 50% of a waterbody or 10% change in tidal excursion. Therefore, the aquaculture activities generating this pressure are unlikely to exceed the benchmark, however this will be project specific and the operation and scale of a proposed activity should be considered.

For benchmarks which are unlikely to be exceeded in aquaculture settings or are not considered applicable, the level of sensitivity from MarESA and Natural England should be treated with caution.

In addition, for benchmarks which are assessed as not being applicable to aquaculture activities, this does not mean that the pressure does not have an impact. In these cases, the sensitivity of biotopes or species should be reviewed on a case-by-case basis based on the scale and/or operation of a proposed aquaculture activity.

The sensitivity assessments are generic and are not site- or project-specific. Therefore, project-specific details, such as the footprint or intensity of the activity etc., will need to be considered by the user to determine if the sensitivity benchmarks are likely to be exceeded or not.

2.7.5. Zone of impact (biotopes)

To ensure the Biotope Interactions Spreadsheet showed logical interactions between activities, pressures and biotopes, it was necessary to assess which biotopes had the potential to be impacted by a particular pressure given the location of the activity and the zone of impact of the pressures.

Some pressures, such as abrasion, have a highly localised impact, for example an aquaculture activity causing abrasion in the intertidal zone will not impact biotopes in the subtidal, and vice versa. On the other hand, some pressures, such as those related to sedimentation, will have a larger impact zone capable of affecting biotopes outside of the immediate area of the activity.

To address this issue, firstly, each pressure was considered for its potential zone of impact, based on whether the pressure has a highly localised impact or has the potential to impact biotopes outside of the immediate area of the activity.

Secondly, the biotopes were grouped to determine which zone(s) they existed within. This was based on the biotope classification:

- Subtidal zone – biotopes including Infralittoral Rock (IR); Circalittoral Rock (CR) or Sublittoral Sediment (SS);
- Intertidal zone – biotopes including Littoral Rock (LR) or Littoral Sediment (LS); and
- Subtidal / intertidal zone – Infralittoral / Sublittoral fringe (IR).

The information on the location of the activity (subtidal / intertidal) and the zone of impact of each pressure (localised / outside of the immediate area) was then used to determine which biotopes have the potential to be affected by which pressures. Biotopes in the infralittoral / sublittoral fringe were considered to be relevant to both subtidal and intertidal activities.

2.7.6. Interactions Spreadsheets

Biotope and Species Interactions Spreadsheets have been created for the AWAA Project to show the combination of interactions between the activities, pressures, and biotopes or species' sensitivities. The AWAA Interactions Spreadsheets combine the matrix of the pressures associated with the aquaculture activities (Sections 2.4 and 2.6.4), the sensitivity and confidence of biotopes or species to those pressures (Sections 2.7.1 to 2.7.3) and the pressure benchmark review (Section 2.7.4).

The AWAA Interactions Spreadsheets contain information on whether the biotopes or species are designated within MPAs, and which features they form part of. There is also information on whether the biotopes or species are protected under Section 7 of the Environment (Wales) Act 2016. Section 7 biotopes and species are of principal importance for maintaining and enhancing biodiversity in Wales.

Bird, fish and mammal species are mobile in nature and whilst the sites in which they are designated are provided in the Interactions Spreadsheet, they may utilise other locations outside of their designated sites. Therefore, users should consider which protected species have the potential to be in the vicinity of a proposed activity, for example by using a combination of:

- Undertaking site-specific surveys;
- The NRW Marine ecology datasets for marine developments (NRW, 2023);
- Relevant literature, such as Evans and Waggitt (2023) on the distributions of cetaceans and seabirds in Welsh waters; and
- The MPAs within which the species is a designated feature.

The fish assemblage within the Severn Estuary SAC is a designated feature of the site and includes 114 species of fish. The majority of these fish species have not been assessed for sensitivity and have not been included in the Interactions Spreadsheet. However, if relevant to a location and activity, it is still important to consider the potential impacts from aquaculture activities on the fish assemblage feature of the Severn Estuary SAC and Ramsar site.

Bird assemblages are designated features of the Dee Estuary SPA/ Dee Estuary Ramsar sites, Skomer, Skokholm and the Seas off Pembrokeshire SPA, Liverpool Bay SPA and Severn Estuary SPA/Severn Ramsar. Bird species within the assemblages that have been assessed within the Natural England Mobile Species Sensitivity Assessment (Natural England, 2022) have been included in the AWAA Species Interactions Spreadsheet. Species that form part of the assemblage that have not had their sensitivity assessed are not included in the AWAA Species Interactions Spreadsheet. However, the potential impacts on these 'non assessed' species should still be considered if relevant to a location and pressure.

In total there are over 1,000,000 entries in the biotope Interactions Spreadsheet and 115,000 entries in the species Interactions Spreadsheet. The Interaction Spreadsheets were compiled using R programming language (R Core Team, 2022).

2.7.7. AWAA Dashboard

The AWAA Dashboard is a user-friendly tool developed by NRW to facilitate searching the Interactions Spreadsheets using PowerBI software. The Dashboard provides an interface with a selection of drop-down filters to allow the user to search for combinations of specific activities, pressures, biotopes/species, MPAs, and levels of sensitivity etc. More information on how to use the Dashboard can be found in the AWAA Dashboard instructions.

2.8. Mapping Tool

The AWAA Mapping Tool was developed to allow users to spatially investigate the potential sensitivity of biotopes in an area to various aquaculture activities.

The Tool was created by joining the sensitivity of the biotopes collated in Sections 2.7.1 and 2.7.2 to the spatial Marine Recorder (NRW, 2020) and Phase 1 Intertidal Habitat Survey (NRW, 2022) datasets. Step by step instructions on how to use the Mapping Tool can be found under 'Instructions' tab in the Mapping Tool, and within the Aquaculture Activity Assessments (Section 2.9).

The Mapping Tool shows the known biotopes from marine benthic surveys across Wales. On selecting a biotope in the Tool, it displays the biotope name, code, survey information, including the survey names, dates, and sensitivity score assigned. Where surveys were undertaken a long time ago, further surveys may be required to determine if the biotope is still present. In addition, there will be 'blank' areas of maps with no biotope records, indicating there are no survey data available describing the biotopes in these areas. Further surveys may be required to characterise these areas.

It should be acknowledged that when siting an aquaculture activity, the pressure being assessed could have a large zone of impact and hence impact upon biotopes at a distance from the activity (for example pressures covering pollution, suspended matter or disturbance). Therefore, it is important when assessing the impact of an activity on biotopes that the potential zone of impact is investigated.

Mobile species, such as fish, mammals and birds, were not mapped as part of this Project due to the variability of their distributions in space and time. In addition, data on the distribution of some mobile species is not always available. In order to understand the potential impact of pressures arising from an activity on species, it is important to consider which mobile species may occur in the vicinity of a proposed activity and the potential function of the site for the species (for example for feeding, migration, breeding etc.). This might be through searches of available literature, reports and existing surveys, or dedicated surveys where appropriate.

2.9. Aquaculture Activity Assessments

The AWAA Aquaculture Activity Assessments produced as part of the Project provide a step-by-step guide on how to use the AWAA resources to determine how different pressures associated with a chosen aquaculture activity could potentially impact protected habitats and species. This is a starting point from which further investigations into the

potential pressures, sensitivities of habitats and species, and impacts of a proposed activity should be considered.

The Activity Assessments are generic and do not take into account the footprint size, location or intensity of an aquaculture activity. To fully understand the extent of the impact of a specific aquaculture activity, details of the specific proposed activity are necessary, together with, potentially, detailed surveys, consultation, and site-specific details where appropriate.

Of the 11 aquaculture activities listed in Section 2.3, intertidal ground laid and hand harvested shellfish and intertidal ground laid and mechanically harvested shellfish activities were combined into one Activity Assessment as the majority of the activities (such as operation, scale and location) and the pressures arising from the activities are the same. The differences in harvesting activities are detailed in the Activity Assessments. Similarly, intertidal planted and hand harvested seaweed and intertidal planted and mechanically harvested seaweed were combined into one Assessment.

Finfish cage aquaculture has been considered within the AWAA Evidence Database, Interactions Spreadsheet / Dashboard and Mapping Tool Resources. However, as previously mentioned, the AWAA Project did not produce an Aquaculture Activity Assessment for Subtidal Fish (cages). To do so would have used considerable resource due to the volume of evidence available. This would not have been proportionate to the potential Welsh evidence need as currently there is no sea-based cultivation of finfish in Wales and the potential for commercial development is limited.

Therefore, there are eight Activity Assessments which reflect the activities listed in Section 2.3:

- Intertidal shellfish aquaculture using trestles and poles;
- Intertidal shellfish aquaculture using ground laid methods (including hand and mechanical harvesting);
- Intertidal seaweed aquaculture using ground laid methods (including hand and mechanical harvesting);
- Subtidal shellfish aquaculture using ropes;
- Subtidal shellfish aquaculture using rafts;
- Subtidal shellfish aquaculture using ground laid methods;
- Subtidal seaweed aquaculture using ropes; and
- Subtidal seaweed aquaculture using rafts.

Each Activity Assessment provides a fictional case study example in a hypothetical location to demonstrate how the AWAA Mapping Tool and Dashboard / Interactions Spreadsheets can be used to assess the sensitivity of the biotopes and species to a pressure from a proposed aquaculture activity. In addition, the assessments provide a summary of the potential impacts of the pressures from the aquaculture activity could have on the marine environment, based on the evidence collated in the Evidence Database.

3. Conclusions

The Evidence Database, Interactions Spreadsheet/Dashboard, Mapping Tool and Aquaculture Activity Assessments created as part of the AWAA Project provide a starting point from which users can investigate the potential impacts of aquaculture activities on habitats and species in Wales.

A step-by-step process on how to use the resources produced as part of this project is shown in Figure 2.

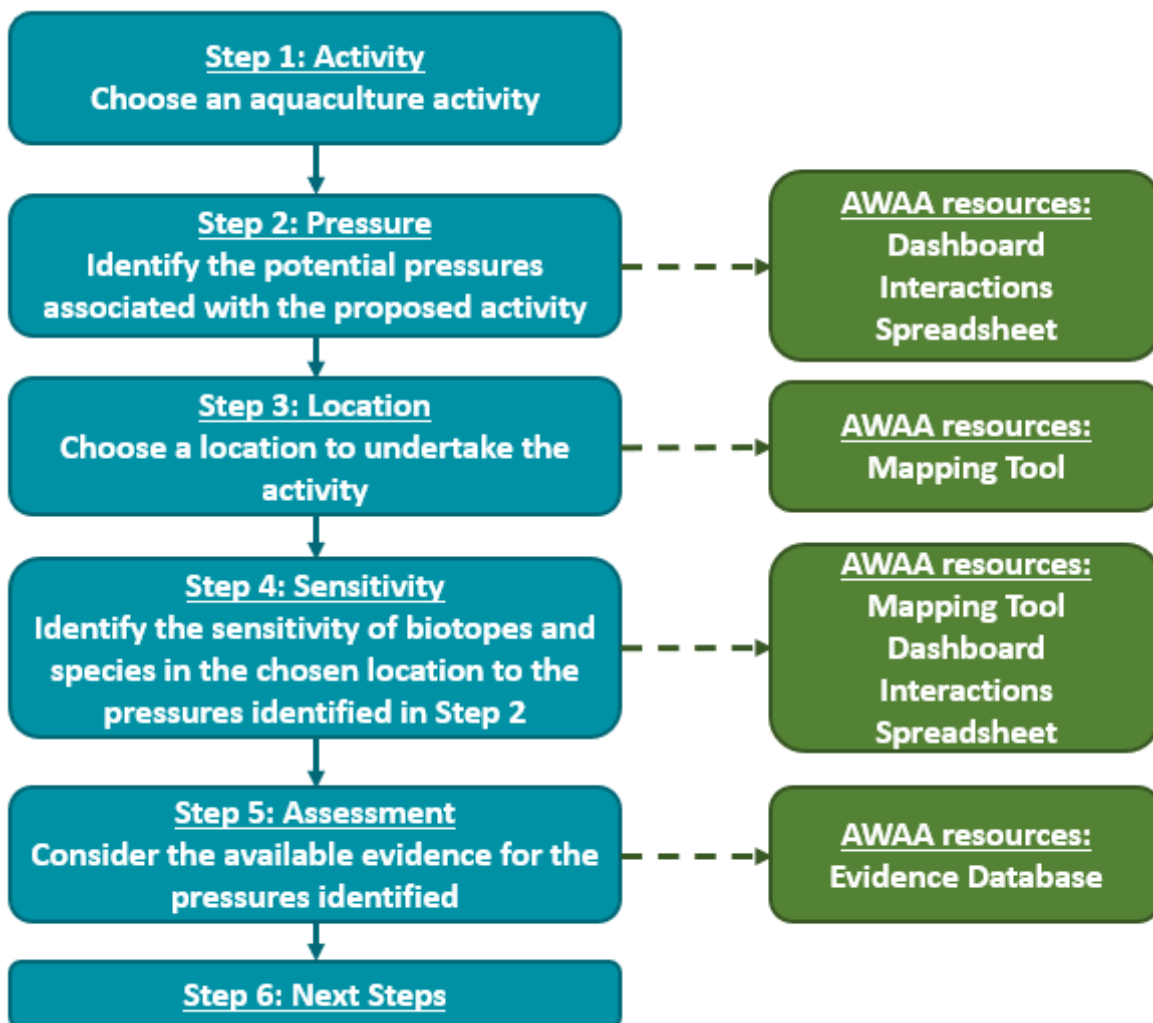


Figure 2. Flow diagram to show the step-by-step process of using the AWAA Project resources.

This process is detailed in the Aquaculture Activity Assessments which demonstrate how the resources can be used to gather and develop information and evidence to inform an environmental appraisal for an aquaculture activity of interest. 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 sensitive biotopes and species in an area of interest to the potential pressures from the proposed activity.

When undertaking an environmental assessment, it is important that the user of the AWAA resources also considers 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. Finally, it may be necessary to consult locally and to undertake area-specific surveys where appropriate to gain further insight into potentially sensitive biotopes and species in the vicinity of a proposed activity.

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5. Abbreviations

AWAA	Assessing Welsh Aquaculture Activities
CR	Circalittoral Rock
DataMapWales	Public Geographic Data Platform (Gov.Wales)
Defra	Department for Environment, Food and Rural Affairs
EMFF	European Maritime and Fisheries Fund
EU	European Union
EUNIS	European Nature Information System
ICG-C	Intersessional Correspondence Group on Cumulative Effects
INIS	Invasive Non-Indigenous Species
IR	Infralittoral Rock
JNCC	Joint Nature Conservation Committee
LR	Littoral Rock
LS	Littoral Sediment
MarESA	Marine Evidence-Based Sensitivity Assessment
MarLIN	The Marine Life Information Network
MCZ	Marine Conservation Zone
MPA	Marine Protected Area
NE	Northeast
NRW	Natural Resources Wales
OSPAR	Cooperative of 15 governments and the EU
PAH	Polycyclic Aromatic Hydrocarbons
PowerBI	Unified, Scalable Platform for Self-service and Enterprise Business Intelligence
SAC	Special Area of Conservation
SLG	Sector Locational Guidance

SMMNR	Sustainable Management of Marine Natural Resources
SPA	Special Protection Area
SS	Sublittoral Sediment
SSSI	Site of Special Scientific Interest
TBT	Tributyltin
UK	United Kingdom
WNMP	Welsh National Marine Plan

6. Appendix

6.1. Habitats and species in Evidence Review

Table 5. Welsh habitats considered in the systematic literature review for the Evidence Database.

AWAA habitats	Source/ designation	Alternative names from other designations (where available)
Blue mussel beds	Section 7; SSSI	Mixed substrata
Carbonate Reefs	Section 7	Not applicable
Coastal lagoons	SAC; SSSI	Isolated saline lagoon, Silled saline lagoon, percolation saline lagoon
Dicord mussel (<i>Musculus discors</i>)	Section 7	Not applicable
Estuaries	SAC; SSSI	Not applicable
Estuarine rocky habitats	Section 7	Not applicable
Fragile sponge and anthozoan communities on subtidal rocky habitats	Section 7	Not applicable
Horse mussel beds	Section 7	Not applicable
Intertidal boulder communities	Section 7; SSSI	Under-boulders
Large shallow inlets and bays	SAC	Not applicable
Maerl beds	Section 7	Coral maerl <i>Lithothamnion corallioides</i> , Common maerl <i>Phymatolithon calcareum</i>
Methane-derived authigenic carbonates (methane seeps)	SAC	Not applicable
Mud habitats in deep water (20-30 m)	Section 7	Not applicable
Mudflats and sandflats not covered by seawater at low tide	SAC; SSSI; Section 7	Intertidal mudflats, Exposed Sand, Moderately Exposed sand, Sheltered Mud
Peat and clay exposure / Soft piddock bored substrata	Section 7; SSSI	Not applicable

AWAA habitats	Source/ designation	Alternative names from other designations (where available)
Peat and clay exposures	Section 7	Not applicable
Reefs	SAC; SSSI; Section 7	Subtidal reefs, Intertidal reefs, Rockpools, Surge gullies, Caves and overhangs, Tide swept algae, Maritime cliff & associated cliff and ledges, Chalk and very soft rock, Exposed Rock, Moderately exposed rock, sheltered rock, mixed substrata
<i>Sabellaria alveolata</i> reefs	Section 7; SSSI	Sand influenced biogenic reefs, mixed substrata
Saltmarsh	SAC; SSSI; Section 7	Atlantic salt meadows (<i>Glauco-Puccinellietalia maritima</i>), Salicornia and other annuals colonising mud and sand, Salt-marsh, saltmarsh morphology
Sandbanks which are slightly covered by seawater all the time	SAC	Not applicable
Seagrass beds	Section 7; SSSI	Eel-grass, Dwarf eelgrass
Sheltered muddy gravels	Section 7; SSSI	Muddy Gravel
Subtidal mixed muddy sediments	Section 7	Not applicable
Subtidal sands and gravels	Section 7	Not applicable
Tide-swept channels	Section 7	Not applicable

Table 6. Welsh species considered in the systematic literature review for the Evidence Database.

AWAA species	Source/designation	AWAA species categories
Atlantic white-sided dolphin (<i>Lagenorhynchus acutus</i>)	Section 7	Cetaceans
Common dolphin (<i>Delphinus delphis</i>)	Section 7	Cetaceans
Cuvier's beaked whale (<i>Ziphius cavirostris</i>)	Section 7	Cetaceans
Fin whale (<i>Balaenoptera physalus</i>)	Section 7	Cetaceans
Humpback whale (<i>Megaptera novaeangliae</i>)	Section 7	Cetaceans
Killer whale (<i>Orcinus orca</i>)	Section 7	Cetaceans
Long-finned pilot whale (<i>Globicephala melas</i>)	Section 7	Cetaceans
Minke whale (<i>Balaenoptera acutorostrata</i>)	Section 7	Cetaceans
Northern bottlenose whale (<i>Hyperodon ampullatus</i>)	Section 7	Cetaceans
Risso's dolphin (<i>Grampus griseus</i>)	Section 7	Cetaceans
Striped dolphin (<i>Stenella coeruleoalba</i>)	Section 7	Cetaceans
White-beaked dolphin (<i>Lagenorhynchus albirostris</i>)	Section 7	Cetaceans
Harbour porpoise (<i>Phocoena phocoena</i>)	Section 7; SAC	Cetaceans
Bottlenose dolphin (<i>Tursiops truncatus</i>)	Section 7; SAC; SSSI	Cetaceans
Otter (<i>Lutra lutra</i>)	Section 7; SAC; SSSI	Otter
Grey seal (<i>Halichoerus grypus</i>)	SAC; SSSI	Seals
Cod (<i>Gadus morhua</i>)	Section 7	Demersal fish
European hake (<i>Merluccius merluccius</i>)	Section 7	Demersal fish
Ling (<i>Molva molva</i>)	Section 7	Demersal fish
Plaice (<i>Pleuronectes platessa</i>)	Section 7	Demersal fish
Sea monkfish (<i>Lophius piscatorius</i>)	Section 7	Demersal fish
Sole (<i>Solea solea</i>)	Section 7	Demersal fish
Sea trout (<i>Salmo trutta</i>)	Section 7	Migratory fish
Allis shad (<i>Alosa alosa</i>)	Section 7; SAC; SSSI	Migratory fish
Atlantic salmon (<i>Salmo salar</i>)	Section 7; SAC; SSSI	Migratory fish
Sea lamprey (<i>Petromyzon marinus</i>)	Section 7; SAC; SSSI	Migratory fish
Twaite shad (<i>Alosa fallax</i>)	Section 7; SAC; SSSI	Migratory fish
European eel (<i>Anguilla anguilla</i>)	Section 7; SSSI	Migratory fish

AWAA species	Source/designation	AWAA species categories
Herring (<i>Clupea harengus</i>)	Section 7	Pelagic fish
Horse mackerel (<i>Trachurus trachurus</i>)	Section 7	Pelagic fish
Mackerel (<i>Scomber scombrus</i>)	Section 7	Pelagic fish
Sand-eel (<i>Ammodytes marinus</i>)	Section 7	Pelagic fish
Whiting (<i>Merlangius merlangus</i>)	Section 7	Pelagic fish
Smelt (<i>Osmerus eperlanus</i>)	Section 7; SSSI	Pelagic fish
Balearic shearwater (<i>Puffinus mauretanicus</i>)	Section 7	Diving seabirds
Common scoter (<i>Melanitta nigra</i>)	SPA	Diving seabirds
Gannet (<i>Morus Bassanus</i>)	SPA	Diving seabirds
Guillemot (<i>Uria aalge</i>)	SPA	Diving seabirds
Manx shearwater (<i>Puffinus puffinus</i>)	SPA	Diving seabirds
Puffin (<i>Fratercula arctica</i>)	SPA	Diving seabirds
Razorbill (<i>Alca torda</i>)	SPA	Diving seabirds
Red-throated diver (<i>Gavia stellata</i>)	SPA	Diving seabirds
Cormorant (<i>Phalacrocorax carbo</i>)	SPA; SSSI	Diving seabirds
Great crested grebe (<i>Podiceps cristatus</i>)	SPA; SSSI	Diving seabirds
Little grebe (<i>Tachybaptus ruficollis</i>)	SSSI	Diving seabirds
Arctic tern (<i>Sterna paradisaea</i>)	SPA	Surface feeding birds
Kittiwake (<i>Rissa tridactyla</i>)	SPA	Surface feeding birds
Little gull (<i>Larus minutus</i>)	SPA	Surface feeding birds
Storm petrel (<i>Hydrobates pelagicus</i>)	SPA	Surface feeding birds
Roseate tern (<i>Sterna dougallii</i>)	Section 7; SPA	Surface feeding birds
Lesser black-backed gull (<i>Larus fuscus</i>)	SPA; Ramsar	Surface feeding birds
Shelduck (<i>Tadorna tadorna</i>)	SPA; Ramsar; SSSI	Surface feeding birds
Common tern (<i>Sterna hirundo</i>)	SPA; SSSI	Surface feeding birds
Little tern (<i>Sterna albifrons</i>)	SPA; SSSI	Surface feeding birds
Sandwich tern (<i>Sterna sandvichensis</i>)	SPA; SSSI	Surface feeding birds
Shoveler (<i>Anas clypeata</i>)	SPA; SSSI	Surface feeding birds
Dark-bellied brent goose (<i>Branta bernicula</i> subsp. <i>Bernicula</i>)	Section 7	Wading birds
Whimbrel (<i>Numenius phaeopus</i>)	Ramsar	Wading birds

AWAA species	Source/designation	AWAA species categories
European white-fronted goose (<i>Anser albifrons albifrons</i>)	SPA	Wading birds
Mallard (<i>Anas platyrhynchos</i>)	SPA	Wading birds
Lapwing (<i>Vanellus vanellus</i>)	Section 7; SPA	Wading birds
Black-tailed godwit (<i>Limosa limosa</i>)	SPA; Ramsar; SSSI	Wading birds
Dunlin (<i>Calidris alpina</i>)	SPA; Ramsar; SSSI	Wading birds
Gadwall (<i>Anas strepera</i>)	SPA; Ramsar; SSSI	Wading birds
Grey plover (<i>Pluvialis squatarola</i>)	SPA; Ramsar; SSSI	Wading birds
Knot (<i>Calidris canutus</i>)	SPA; Ramsar; SSSI	Wading birds
Oystercatcher (<i>Haematopus ostralegus</i>)	SPA; Ramsar; SSSI	Wading birds
Pintail (<i>Anas acuta</i>)	SPA; Ramsar; SSSI	Wading birds
Redshank (<i>Tringa totanus</i>)	SPA; Ramsar; SSSI	Wading birds
Teal (<i>Anas crecca</i>)	SPA; Ramsar; SSSI	Wading birds
Bar-tailed godwit (<i>Limosa lapponica</i>)	Section 7; SPA; Ramsar; SSSI	Wading birds
Curlew (<i>Numenius arquata</i>)	Section 7; SPA; Ramsar; SSSI	Wading birds
Ringed plover (<i>Charadrius hiaticula</i>)	Section 7; SPA; Ramsar; SSSI	Wading birds
Sanderling (<i>Calidris alba</i>)	SPA; SSSI	Wading birds
Turnstone (<i>Arenaria interpres</i>)	SPA; SSSI	Wading birds
White-fronted goose (<i>Anser albifrons</i>)	SPA; SSSI	Wading birds
Wigeon (<i>Anas penelope</i>)	SPA; SSSI	Wading birds
Greenshank (<i>Tringa nebularia</i>)	SSSI	Wading birds
Red-breasted merganser (<i>Mergus serrator</i>)	SSSI	Wading birds
Golden plover (<i>Pluvialis apricaria</i>)	Section 7; SSSI	Wading birds
Angel shark (<i>Squatina squatina</i>)	Section 7	Sharks, skates & rays
Basking shark (<i>Cetorhinus maximus</i>)	Section 7	Sharks, skates & rays
Blonde ray (<i>Raja brachyura</i>)	Section 7	Sharks, skates & rays
Blue shark (<i>Prionace glauca</i>)	Section 7	Sharks, skates & rays
Common skate (<i>Dipturus batis</i>)	Section 7	Sharks, skates & rays
Porbeagle shark (<i>Lamna nasus</i>)	Section 7	Sharks, skates & rays
Spiny dogfish (<i>Squalus acanthias</i>)	Section 7	Sharks, skates & rays
Thornback ray (<i>Raja clavata</i>)	Section 7	Sharks, skates & rays

AWAA species	Source/designation	AWAA species categories
Tope shark (<i>Galeorhinus galeus</i>)	Section 7	Sharks, skates & rays
Undulate ray (<i>Raja undulata</i>)	Section 7	Sharks, skates & rays
White or Bottlenosed skate (<i>Rostroraja alba</i>)	Section 7	Sharks, skates & rays
River lamprey (<i>Lampetra fluviatilis</i>)	Section 7; SAC; SSSI	Estuarine fish
Bearded red seaweed (<i>Anotrichium barbatum</i>)	Section 7	Algae
A red seaweed (<i>Gigartina pistillata</i>)	SSSI	Algae
A red seaweed (<i>Cruoria cruoriaeformis</i>)	Section 7; SSSI	Algae
A red seaweed (<i>Dermocorynus montagnei</i>)	Section 7; SSSI	Algae
Amphipod (<i>Pectenogammarus planicrurus</i>)	SSSI	Amphipod
Amphipod (<i>Gammarus chevreuxi</i>)	SSSI	Amphipod
Burrowing anemone (<i>Edwardsia timida</i>)	Section 7	Burrowing anemone
Fan mussel (<i>Atrina fragilis</i>)	Section 7	Fan mussel
Lagoon sand shrimp (<i>Gammarus insensibilis</i>)	SSSI	Lagoon sand shrimp
Lagoon sea slug (<i>Tenellia adspersa</i>)	Section 7; SSSI	Lagoon sea slug
Lagoon snail (<i>Melarhaphe littorina</i>)	SSSI	Lagoon snail
Long snouted seahorse (<i>Hippocampus guttulatus</i>)	Section 7	Long snouted seahorse
Common maerl (<i>Phymatolithon calcareum</i>)	Section 7	Maerl
Coral maerl (<i>Lithothamnion corallioides</i>)	Section 7	Maerl
Native oyster (<i>Ostrea edulis</i>)	Section 7	Native oyster
Ocean quahog (<i>Arctica islandica</i>)	Section 7	Ocean quahog
Peacocks tail (<i>Padina pavonica</i>)	Section 7	Peacocks tail
Pink sea fan (<i>Eunicella verrucosa</i>)	Section 7	Pink sea fan
Polychaete worm (<i>Ophelia bicornis</i>)	SSSI	Polychaete worm
Leatherback turtle (<i>Dermochelys coriacea</i>)	Section 7	Reptile
Loggerhead turtle (<i>Caretta caretta</i>)	Section 7	Reptile
Spiny lobster (<i>Palinurus elephas</i>)	Section 7	Spiny lobster
Sponge (<i>Thymosia guernei</i>)	SSSI	Sponge
A stalked jellyfish (<i>Calvadosia campanulata</i>)	Section 7	Stalked jellyfish
A stalked jellyfish (<i>Haliclystus auricula</i>)	Section 7	Stalked jellyfish
Tentacled lagoon worm (<i>Alkmaria romijni</i>)	Section 7; SSSI	Tentacled lagoon worm

6.2. Evidence Database categories

Table 7. The data extracted for each piece of evidence in the Evidence Database. These make up the fields/column headings in the Evidence database.

Field name in Evidence Database	Description
Source Reference	Author/s and date of source
Citation	Full citation of source
Source Summary and overview of findings	Short summary of the source including background behind the study, any key methods used and findings
Study Location	Country or region where the study has taken place or the area covered by a review
Aquaculture Species	Group and species name of the aquaculture species examined in the study. Where multiple species are examined are listed. If a species is not specified, generic terms are used.
Aquaculture Activity	Description of the aquaculture activity that is the subject of the source, from a fixed list of aquaculture activities defined for the AWAA Project (see 'Welsh Activities' tab of the Evidence Database).
Pressure	Description of the pressure that is the subject of the source, from a fixed list of pressures collated for the AWAA Project (see 'Pressures' tab of the Evidence Database).
Habitat/Species Impacted	Description of the habitat or species that is identified as having the potential to be impacted by the activity, from a fixed list of receptors (habitats and species/species groups) (see 'Receptors' tab of the Evidence Database).
Evidence Source Type	Description of the type of evidence source. Evidence source type options are: <ul style="list-style-type: none"> - Peer reviewed - Grey literature (e.g. government reports) - White paper - Book - Website

Field name in Evidence Database	Description
Evidence Type	Description of the type of evidence. Evidence type options are: <ul style="list-style-type: none"> - Quantitative - Qualitative - Review - Anecdotal
Habitat / Species Matching Notes	How well the habitats or species mentioned in the source matches the habitats and species considered in this review (based on those in tab "Receptors"): <ul style="list-style-type: none"> - Habitat / species not specified in source but pressure may have broad range of impacts - Habitat / species not specified in source but inferred by general description - Habitat / species in source similar but not identical to that in evidence review - Habitat / species in source matches that in evidence review
Source provenance	Description of how the source was found.
Weblink	Hyperlink to the location of the source on the internet (all accessed 2022-2023).
Confidence - type of source (based on evidence type)	Confidence in the evidence source, predominantly based on the type of evidence source: <ul style="list-style-type: none"> - High = peer reviewed article - Medium = white paper, grey literature, book - Low = website
Confidence - applicability of location	Confidence in how applicable the evidence is in terms of location: <ul style="list-style-type: none"> - High = location of the evidence was Wales, England, Scotland or Ireland - Medium = location of the evidence was within the NE Atlantic or European waters, or evidence is based on a Global review - Low = location of the evidence was outside the NE Atlantic or European waters

Field name in Evidence Database	Description
Confidence - applicability of aquaculture species	Confidence in how applicable the evidence is in terms of the aquaculture species: <ul style="list-style-type: none"> - High = aquaculture species is a species that occurs in the UK and is already used in aquaculture - Medium = aquaculture species is a species that occurs in the UK but is not currently used in aquaculture or aquaculture species is not specified or generic due to review nature of evidence source but impacts likely applicable across activity - Low = aquaculture species is not present in the UK
Score of Confidence - type of source	Score for the level of confidence: High = 5, Medium = 3, Low = 1
Score of confidence - applicability of location	Score for the level of confidence: High = 5, Medium = 3, Low = 2
Score of confidence - applicability of aquaculture species	Score for the level of confidence: High = 5, Medium = 3, Low = 3
Overall confidence	To determine confidence for each piece of evidence, a confidence score was given based on similar approaches used by Natural England (Pérez-Domínguez et al., 2016) and MarESA (Tyler-Walters et al., 2022) whereby scores were summed across the three confidence components (Maximum combined score 15, Minimum score 3). High confidence was assigned to total scores >12; Medium confidence to scores 6 – 12; and Low confidence for scores <6.

6.3. Aquaculture activity and pressure matrix

Table 8. Matrix of the pressures with the potential to occur from each aquaculture activity.

Pressure	Intertidal Shellfish (Trestles and Poles)	Intertidal Shellfish (Ground Laid, Hand Harvested)	Intertidal Shellfish (Ground Laid, Mechanically Harvested)	Subtidal Shellfish (Rafts)	Subtidal Shellfish (Rope)	Subtidal Shellfish (Ground Laid, Mechanically Harvested)	Intertidal Seaweed (Planted, Hand Harvested)	Intertidal Seaweed (Planted, Mechanically Harvested)	Subtidal Seaweed (Ropes)	Subtidal Seaweed (Rafts)	Subtidal Fish (Cages)
Above water noise (Natural England, 2022)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Abrasion/disturbance of the substrate on the surface of the seabed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barrier to species movement	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Changes in suspended solids (water clarity)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures) (Natural England, 2022)	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Collision BELOW water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Deoxygenation	N	N	N	N	N	N	N	N	N	N	N	Y
Genetic modification & translocation of indigenous species	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hydrocarbon & PAH contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Introduction of light or shading	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y
Introduction of microbial pathogens	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Introduction or spread of invasive non-indigenous species (INIS)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Litter	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Nutrient enrichment	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Organic enrichment	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Physical change (to another seabed type)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Physical change (to another sediment type)	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y

Removal of non-target species	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Removal of target species	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
Smothering and siltation rate changes ('Light' deposition)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Transition elements & organo-metal (e.g. TBT) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Y	N	N	Y	Y	N	N	N	Y	Y	Y	Y
Underwater noise changes	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Vibration (Natural England, 2022)	Y	Y	Y	N	N	Y	N	Y	N	N	N	N
Visual disturbance	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Water flow (tidal current) changes, including sediment transport considerations	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wave exposure changes	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y

