Cyfoeth Naturiol Cymru
Natural Resources Wales

Guidance Note

Benthic habitat assessment guidance

A guide to characterising and monitoring intertidal rocky shore habitats and rockpools

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What is this document about?

This guidance sets out our methods and approaches for survey and monitoring of intertidal rocky shore habitats and rockpools where such work is required to support environmental and ecological impact assessments for developments and activities in or near Welsh waters.

Who is this document for?

This is best practice technical guidance for developers designing marine benthic habitat surveys and monitoring in relation to maritime developments.

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1. Introduction and summary

This guidance document is one of a series of Benthic Habitat Assessment Chapters developed by Natural Resources Wales (NRW) for key habitats of conservation importance around Wales. It has been prepared by NRW with the initial document prepared under contract by APEM Ltd and Ocean Ecology Limited.

The guidance aims to assist developers in designing and undertaking robust benthic habitat characterisation surveys and monitoring of these habitats in the context of Ecological Impact Assessment, thereby helping streamline the regulatory review and consultation process.

This chapter will be relevant if you need to characterise and/or monitoring intertidal rocky shore and rockpool habitats.

If you are unsure about the habitats present in the intertidal area you are interested in, you should consult existing information (see section 4.1) and/or you may need to carryout Phase 1 intertidal survey (section 5.1) to determine the habitats present before undertaking more focussed characterisation surveys.

This habitat chapter (GN030a) is not intended to be used alone and should always be used in conjunction with the Guidance Note GN030 and the Introductory chapter (GN030-intro).

1.1. What are rocky shores and where are they found in Wales?

Intertidal rocky shores are present in coastal areas all around Wales and comprise a range of hard bedrock and boulder formations that are inundated by the tide. These habitats often feature distinct biological zonation in relation to shore height and wave exposure and consist of a wide range of sub-habitats. Rockpools are a specialised rocky shore habitat that can be present on the upper, mid and lower shore. Specialised biotopes in intertidal rock habitats include rockpools, overhangs, gullies, under-boulders and caves (Wyn *et al*., 2006). They are considered to be of particular nature conservation interest (described as 'biotopes for additional consideration' in the SSSI Guidelines (JNCC, 1996)) as they are often species-rich and therefore increase the biodiversity of a shore. Their presence is primarily determined by the geology and topography of the coast.

1.2. The conservation importance of intertidal rocky shores and rockpools

Intertidal rocky shores have high ecosystem/biodiversity value and provide a wide range of ecosystem services (Defra, 2007). Organisms living attached to the rock substrate provide shelter and food for other species which, in turn, provide food for animals such as shore and sea birds, otters and other marine fauna. Rocky shores can provide substrate for the attachment and development of various biogenic reef habitats including *Sabellaria* spp. reefs (see *Sabellaria* reef chapter GN030d). Some rocky shore species are commercially important for fisheries. Rocky shores also provide a supporting habitat for, amongst other things, tourism, recreation, research and education.

The value of rocky shores and rockpools is recognised under a number of different pieces of national and international legislation, including:

- Habitats Directive
- Water Framework Directive
- Marine Strategy Framework Directive
- OSPAR Convention
- Environment (Wales) Act 2016
- Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way (CROW) Act 2000)
- Marine and Coastal Access Act 2009

More information is provided in section 2.4.

1.3. What kind of developments and activities might affect rocky shore habitats?

Developments and activities that could affect this habitat during construction and/or operational phases include those involving actions that could result in:

- Changes to salinity regime and temperature
- Changes to water flow and tidal inundation regime
- Changes to water quality (nutrient and organic enrichment)
- Coastal squeeze
- Loss of rocky shore habitat within operational footprint, removal and disturbance of organisms on rocky shores
- Changes to sediment transport dynamics and sediment deposition on rocky shores
- Introduction of invasive species
- Pollution and other chemical changes

Further detail relating to potential effects of developments on intertidal rock habitats is provided in Section 2.5.

1.4. Existing data and guidance for surveying and monitoring intertidal rocky shores and rockpools

A brief summary of available information is provided in section 3. Key sources of existing data and guidance for surveying and monitoring rocky shores and rockpools are:

- Joint Nature Conservation Committee (JNCC): recent JNCC guidance for the monitoring of marine benthic habitats (Noble-James *et al*, 2017)
- Common Standards Monitoring: developed for site monitoring and assessment of protected sites (JNCC, 2004). Specific habitat guidance relevant to rocky shore

habitats: Littoral Rock and Inshore Sublittoral Rock Habitats (JNCC, 2004a), Estuaries (JNCC, 2004b), Inlets & Bays (JNCC, 2004c), and Sea Caves (JNCC, 2004d)).
- Marine Monitoring Handbook (Davies *et al.*, 2001)
- Water Framework Directive (WFD) Monitoring approaches for Transitional and Coastal Water Assessment to assess the ecological health of the biological quality element 'other aquatic flora – macroalgae' (WFD-UKTAG, 2014a). Also, in transitional waters, the fucoid extent tool which evaluates the status of the water body based on the position of fucoids in relation to the median salinity at the freshwater end of the fucoid range in transitional water (WFD-UKTAG, 2014b).
- Phase I intertidal habitat mapping handbook (Wyn *et al.*, 2006).
- Mapping European Seabed Habitats (MESH) and MESH Atlantic recommended operating guidelines for:
    - Aerial photography (Piel & Populus 2007)
    - LiDAR (Piel *et al.*, 2012)
- The Royal Institute for Chartered Surveyors (RICS) guidelines for aerial survey
- Methodologies to inform assessment of Good Ecological Status for UK rocky shore habitats for the Marine Strategy Framework Directive (Burrows *et al*., 2014)
- MarClim methodology applied to investigation of the effects of climatic warming on marine biodiversity Mieszkowska *et al*. (2005; 2006; 2008)
- NRW Guidance GN006: Marine Ecology Datasets for marine developments and activities (Natural Resources Wales, 2019). Identifies data sources for intertidal habitat maps and provides information on the marine ecology data sets we hold and routinely use and how you can access them.

1.5. Survey and monitoring design

The requirements for habitat characterisation survey and monitoring design are covered in section 4. The following provides a brief summary of key points:

- The aim of the habitat characterisation survey is to collate data to describe the rocky shore and rockpool habitats within the survey area, identify any habitats and/or species of conservation importance and provide an up-to-date ecological appraisal To inform Ecological Impact Assessment (EcIA).
- The aims of any monitoring required for a proposed development or activity will depend on the potential impacts as identified through the EcIA and any conditions set by the regulator.
- A comprehensive desk-based review of all available existing data should be conducted prior to designing any habitat characterisation or monitoring programmes. This will help determine the scope of survey that may be required
- If there is little or no existing habitat data you may need to undertake a Phase 1 intertidal survey to determine the habitats present before undertaking more focussed characterisation surveys.
- A sampling window between mid-April to mid-October is preferable for habitat characterisation and monitoring of rocky shores and rockpools.
- Relevant ecological parameters need to be selected. The key parameters (section 4.2) to be assessed for intertidal rock habitats for habitat characterisation and monitoring in relation to Ecological Impact Assessment are:
    - Extent and distribution of intertidal rock habitats/biotopes

    - Biological community composition (such as number of taxa in each habitat; diversity indices)
    - Abundance data for specific taxa (counts of individuals/percentage cover)
    - Presence/absence of any species of conservation or commercial importance, or non-native species
- Ecological parameters that should be considered for rockpools include:
    - Rockpool extent and distribution
    - Associated community composition and diversity
        - Sessile flora and fauna
        - Motile fauna
        - Infauna
        - Non-native species
    - Sediment composition and depth (if present)
    - Salinity
- The aims of the habitat characterisation survey and monitoring need to be clearly stated and the survey programmes tailored to deliver these requirements. This includes defining hypotheses and trigger levels for monitoring.
- Transects from the upper to the lower shore are a common approach to characterising intertidal rock habitats with multiple transects spaced along a shore sufficient to characterise habitat transitions across the survey area. In more heterogenous environments habitat characterisation sampling designs can be more complex and random sampling or stratified random sampling is usually applied. Sample effort should provide sufficient coverage of the range of habitat types within the area likely to be affected by the proposed development or activity. Aerial imagery can be used to identify target zones for sampling at the survey design stage.
- Specialised sub habitats on rocky shores such as rockpools, sea caves and under boulder communities may require specific survey and sampling of these should be nested within the broader habitat characterisation survey. Stratified sampling will generally need to be used for rockpool habitat characterisation as it is usually not possible to sample all pools present across a shore. Sampling of pools should be distributed across the whole area of the area likely to be affected by the proposed development or activity.
- Monitoring programme design will be influenced by the specific hypotheses to be tested and the indicators to be measured. The approaches used will also be informed by the methods and outputs of the habitat characterisation survey. In areas with relatively homogenous substrates within the survey area, localised sampling, such as within transects, may be appropriate. In areas with more heterogenous rocky shore habitats a stratified monitoring design is more likely to be required. If habitat characterisation survey was based on a stratified design, this would be expected to be applied to any monitoring programme.
- Monitoring of any specialised habitats should be nested within the broader monitoring survey design. In the case of rockpools, the monitoring should adequately sample an appropriate number of pools that represent each biotope present on the shore within the survey area.
- Replicate samples are not essential for habitat characterisation but are generally necessary for monitoring in order to apply robust statistical techniques required to detect significant change in community characteristics.

- Surveys should be planned to coincide with low spring tides in order to ensure that as full an area as possible of intertidal habitat surveyed. This is particularly so for habitat characterisation and will also apply to monitoring programmes where lower shore habitats need to be surveyed. Repeat monitoring surveys need to be conducted at the same time of year as the previous monitoring surveys.
- Other parameters of the wider environment that influence rocky shore and rockpool habitats may need to be characterised and monitoring. This will depend on the nature and location of the proposed development or activity and the associated pressures arising from this. This could include parameters such as: water quality, salinity, temperature, erosion and accretion of sediment.

1.6. Survey and monitoring methods and analysis

There are various methods available for survey and monitoring of rocky shores and rockpools (section 5). The main options include:

- Aerial surveys (to infer habitat distributions on the ground)
- Phase I walkover survey and habitat mapping
- Phase II quantitative sampling (for example, quadrats to target observed habitat types and provide localised quantitative information)
- Habitat specific survey (specific methods are required to assess notable feature of rocky shores), such as:
    - Under-boulder community assessments
    - Rockpool sampling

Quality control measures for the field methods including species identification need to be clearly defined and implemented by field staff undertaking the survey work.

Not all methods will be required for a particular development or activity and proposed methods need to be defined on a project-specific basis. The JNCC Marine Monitoring Method Finder, a web-based information hub, has been developed to provide a single point of access to the numerous guidance documents and tools generated both within and outside the UK. It can be used in conjunction with this document to ensure a consistent approach to data collection and analysis.

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2. Habitat introduction

2.1. Overview

2.1.1. Rocky shores

Intertidal rock habitat encompasses bedrock, boulders and cobbles which occur in the intertidal zone (the area of the shore between high and low tides) and the splash zone (Connor, *et al*., 2004). The upper limit is marked by the top of the lichen zone and the lower limit by the top of the laminarian kelp zone (Connor *et al*., 2004). Numerous physical variables affect rocky shore communities, including wave exposure, salinity, temperature and the diurnal emersion and immersion of the shore. The degree of wave exposure is most commonly used to characterise intertidal rocky shores from 'extremely exposed' on the open coast to 'extremely sheltered' in enclosed inlets. Exposed shores tend to support communities primarily consisting of barnacles and mussels, with some robust seaweeds. Sheltered shores, however, generally have a denser cover of fucoid seaweeds, with distinctive zones occurring down the shore. On moderately exposed shores, mosaics of seaweeds and barnacles are more typical (Connor *et al*., 2004).

Intertidal rocky shores also support specialised biological communities adapted to the variety of microhabitats formed by the richly structured and sloping substrates. These include rockpool, under-boulder, cave, overhang and soft rock (chalk and clay) communities, and they are regarded as features of conservation importance in their own right due to the unique communities they support. Rockpools are under-studied and undervalued in terms of the ecosystem services they provide, despite their ubiquitous nature and susceptibility to anthropogenic pressures. Other features such as caves and under-boulder communities have been studied more thoroughly, despite being considerably less common.

2.1.2. Rockpools

Rockpools are extremely productive microhabitats that support diverse communities. However, they are isolated and patchily distributed along rocky shores and exhibit high spatiotemporal variability (Martins *et al*., 2007; Firth *et al*., 2014). This requires their inhabitants to be specially adapted to tolerate marked physico-chemical changes to their environment as a consequence of prolonged separation from the main body of the sea (Huggett & Griffiths, 1986; Zander *et al*., 1999). In general, larger and deeper pools low on the shore tend to correspond to the sublittoral habitat, with a more stable temperature and salinity regime. In contrast, small and shallow pools are especially influenced by insolation, air temperature and rainfall, the effects of which become more significant further up the shore, where pools may be isolated from the sea for a number of days or weeks (Lewis, 1964).

Weather conditions exert a considerable influence on water temperature and salinity within pools. Water temperature follows the ambient air temperature more closely than that of the sea. This means that in summer, shallow pools or the surface waters of deeper pools are warmer by day, but may be colder at night, and in winter may be much colder than the sea (Pyefinch, 1943; Metaxas & Scheibling, 1993). In deeper pools, the vertical temperature gradation usually present in summer reverses during winter owing to density stratification, so that ice may form (Naylor & Slinn, 1958).

High air temperatures cause surface evaporation of water from pools, so that salinity steadily increases, especially in pools not flooded by the tide for several days. Alternatively, high rainfall will reduce pool salinity or create a surface layer of brackish/nearly fresh water. However, the extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in a single 24 hour period (Ranade, 1957). Rockpools in the supralittoral, littoral fringe and upper eulittoral are liable to gradually changing salinities followed by days of fully marine or fluctuating salinity at times of spring tide (Lewis, 1964).

Other physico-chemical parameters in rockpools exhibit temporal change. The biological communities directly affect oxygen concentration, carbon dioxide concentration and pH, and are themselves affected by changes in the chemical parameters. Throughout the day, algae photosynthesize and produce oxygen, the concentration of which may rise to three times its saturation value, so that bubbles are released. During photosynthesis algae absorb carbon dioxide and, as concentrations fall, the pH rises, sometimes resulting in pH values of >9 (Morris & Taylor, 1983). At night respiration uses much of the available oxygen and pH decreases.

Other factors such as volume, orientation to light, shading, sediment composition where present (and type of sediment), wave exposure and shore height are all thought to have distinct influences on community structure within pools (Ganning, 1971; Metaxas & Scheibling, 1993), meaning communities can vary greatly between individual pools located only several meters apart.

2.2. Sub-habitats

2.2.1. Rocky shore sub-habitats

The Introductory Chapter of this guidance (GN030-intro, section 3.2.4) provides information on the Joint Nature Conservation Committee (JNCC) and European Nature Information System (EUNIS) classification systems for marine habitats and biotopes. We recommend the JNCC website as a reference point to determine the latest guidance documentation for habitat/biotope assignment. The information provided below is based on the latest available guidance at the time of writing.

Within the EUNIS classification system intertidal rocky shores are referred to as 'Littoral rock' (EUNIS code A1*)*, one of six Level 2 broad scale habitats under 'Marine habitats' in the classification. There are also upper shore habitats of rocky shores represented under the Level 2 broad scale habitat 'Rock cliffs, ledges and shores, including the supralittoral'

(EUNIS code B3) which is in the 'Coastal habitats' section of the classification. These broad scale habitats encompass the following five Level 3 main habitats:

- High energy littoral rock (A1.1)
- Moderate energy littoral rock (A1.2)
- Low energy littoral rock (A1.3)
- Features of littoral rock (A1.4)
- Supralittoral rock (lichen or splash zone) (B3.1)

Table 1. The overall EUNIS habitat/biotope hierarchy for intertidal rocky shore, using 'High energy littoral rock' as an example

Level	EUNIS code	Habitat	Definition
Level 1	A	Marine Habitats	Marine Habitats
Level 2	A1	Broad Habitat	Littoral rock
Level 3	A1.1	Main Habitat	High energy littoral rock
Level 4	e.g. A1.11	Biotope complex	Mussel and/or barnacle communities
Level 5	e.g. A1.112	Biotope	*Chthamalus* spp. on exposed upper eulittoral rock
Level 6	e.g. A1.1121	Sub-biotope	*Chthamalus montagui* and *Chthamalus stellatus* on exposed upper eulittoral rock

2.2.1.1 High energy littoral rock

This habitat occurs in extremely to moderately exposed, or tide-swept, bedrock and boulder shores (Connor *et al*. 2004). Extremely exposed shores are usually dominated by mussels and barnacles with occasional robust fucoids or red algae turfs. Tide-swept shores support communities of fucoids, sponges and ascidians on the mid to lower shore.

- 3 biotope complexes (in the UK) (EUNIS level 4)
- 13 biotopes (EUNIS level 5); with 7 sub-biotopes (EUNIS level 6)

2.2.1.2 Moderate energy littoral rock

Moderately exposed shores (bedrock, boulders and cobbles) are characterised by mosaics of barnacles and fucoids on the mid and upper shore, with fucoids and red seaweed mosaics on the lower shore (Connor *et al*. 2004). Where freshwater inputs or sand-scour affect the shore, ephemeral red or green seaweeds can dominate the habitat. Other moderately exposed shores support communities of mussels and fucoids in the mid to lower shore (Connor *et al*. 2004).

- 2 biotope complexes (in the UK) (EUNIS level 4)
- 7 biotopes (EUNIS level 5); with 3 sub-biotopes (EUNIS level 6)

2.2.1.3 Low energy littoral rock

This habitat comprises sheltered to extremely sheltered rocky shores with very weak to weak tidal streams which are typically characterised by a dense cover of fucoid seaweeds forming distinct zones; the wrack *Pelvetia canaliculata* on the upper shore through to the wrack *Fucus serratus* on the lower shore (Connor *et al*. 2004). Where salinity is reduced (such as at the head of a sea loch or where streams run across the shore) *Fucus ceranoides* may occur. Fucoids also occur on less stable, mixed substrata (cobbles and pebbles on sediment), although in lower abundance and with fewer associated epifaunal species. Beds of blue mussels *Mytilus edulis* are also common on these shores, and in summer months dense blankets of ephemeral green and red seaweeds can dominate (Connor *et al*., 2004).

- 2 biotope complexes (in the UK) (EUNIS level 4)
- 12 biotopes (EUNIS level 5); with 8 sub-biotopes (EUNIS level 6)

Figure 1. Intertidal bedrock on a section of coast at West Angle Bay, Pembrokeshire, partially sheltered from wave action (mid energy littoral rock), photographer Francis Bunker (left); intertidal boulder habitat at Llandudno, north Wales, exposed to wave action (high energy littoral rock) photographer Krysia Mazik (right). Images © NRW

2.2.1.4 Features of littoral rock

Features of littoral rock include lichens and algae crusts in the supralittoral zone, ephemeral algae, caves and overhangs, mussel beds and rockpools. Rockpools are described in section 2.2.2 below.

2.2.1.5 Supralittoral rock (lichen or splash zone)

This habitat encompasses communities of lichens and small green algae on supralittoral and littoral fringe rock that occurs above the main intertidal zone. The lichen communities typically form a distinct zone or band in the ‘splash’ zone on most rocky shores and the width of this zone varies depending on the exposure of the shore to wave action. Yellow and grey lichens dominate the supralittoral rock with a distinctive band of black lichen occurring below the littoral fringe. Small green algae can sometimes be found in the splash zone where localised conditions support their growth with particular species reflecting specific local conditions. Although this habitat is placed within the Coastal Habitats section of the EUNIS classification as, strictly speaking, it occurs above the marine environment, within the UK the zone has traditionally been included within intertidal surveys.

- 1 biotope complex (in the UK) (EUNIS level 4)
- 5 biotopes (EUNIS level 5); with 2 sub-biotopes (EUNIS level 6)

2.2.2. Rockpool biotopes

As features of littoral rock (A1.4) in the EUNIS habitat classification system, rockpools are represented by eight Level 5 rockpool biotopes of which only five are fully defined and recorded in the UK (Highlighted in bold in Table 2). Some of rockpool biotopes in the UK can be further subdivided into sub-biotopes. A wide spectrum of rockpool communities exists because of the unique physio-chemical conditions of each pool: however, for clarity, this document assumes that all rockpool community varieties are adequately covered by the five main Level 5 biotopes recorded in the UK.

Table 2. EUNIS biotopes for rockpools (those found in the UK only)

Level	EUNIS Code	JNCC code	Biotope description
3	A1.4	LR.FLR	Features of littoral rock
4	A1.41	LR.FLR.Rkp	Communities of littoral rockpools
5	**A1.411**	**LR.FLR.Rkp.Cor**	**Coralline crust-dominated shallow eulittoral rockpools**
6	A1.4111	LR.FLR.Rkp.Cor.Cor	Coralline crusts and *Corallina officinalis* in shallow eulittoral rockpools
6	A1.4112	LR.FLR.Rkp.Cor.Par	Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools
6	A1.4113	LR.FLR.Rkp.Cor.Bif	*Bifurcaria bifurcata* in shallow eulittoral rockpools
6	A1.4114	LR.FLR.Rkp.Cor.Cys	*Cystoseira* spp. in eulittoral rockpools
5	**A1.412**	**LR.FLR.Rkp.FK**	**Fucoids and kelp in deep eulittoral rockpools**
6	A1.4121	LR.FLR.Rkp.FK.Sar	*Sargassum muticum* in eulittoral rockpools
5	**A1.413**	**LR.FLR.Rkp.SwSed**	**Seaweeds in sediment-floored eulittoral rockpools**
5	**A1.414**	**LR.FLR.Rkp.H**	**Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools**
4	A1.42	LR.FLR.Rkp	Communities of rockpools in the supralittoral zone
5	**A1.421**	**LR.FLR.Rkp.G**	**Green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in shallow upper shore rockpools**

As indicated above, there is a range of intertidal rock habitats to be considered when designing habitat characterisation and monitoring surveys. It should be noted, however, that when designing monitoring programmes for marine developments they will generally be focussed on any habitats/biotopes of conservation importance and/or those that have a high sensitivity to particular anthropogenic pressures (see Sections 2.5 and 2.6).

2.3. Extent/distribution in Wales

Intertidal rocky shore habitats are found around the whole of Wales, primarily in areas of more exposed coastline such as the shores of Pembrokeshire and the Gower Peninsula in the south west and the Isle of Anglesey and the Llŷn Peninsula in the north west of the country (Figure 2). See section 3.7 for information about maps and other data sources for rocky shore habitats.

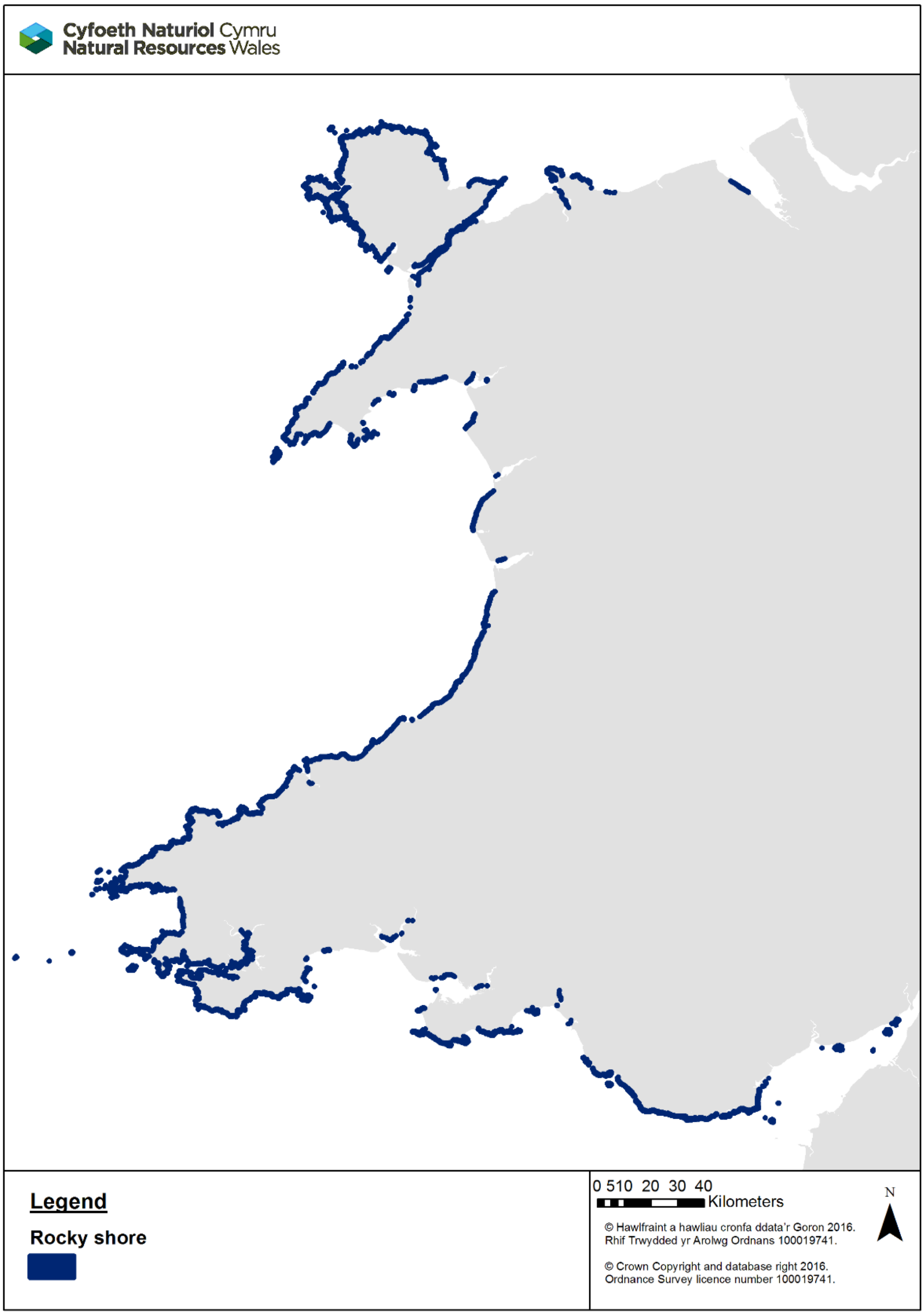

Figure 2. Indicative map of rocky shore habitat (including rockpools) in Wales

2.4. Conservation importance

Intertidal rocky shores have high ecosystem/biodiversity value and provide a wide range of ecosystem services (Defra, 2007). Such services can vary considerably between habitats (Balmford *et al.*, 2008).

The Introductory Chapter GN030-intro of this guidance (section 3.2.2) provides more general information on conservation policies and legislation, but key aspects relevant to rocky shores and rockpools are highlighted below.

2.4.1. Habitats Directive

The Habitats Directive lists habitats and species of interest in Annex I and Annex II respectively. The following Annex I habitats are relevant to the rocky shore habitats considered within this chapter:

- Estuaries (code 1130)
- Large shallow inlets and bays (code 1160)
- Reefs (1170)
- Submerged or partially submerged sea caves (code 1170)

Each of these Annex I habitats can encompass a variety of different rocky shore habitats and associated species assemblages. No intertidal rocky shore invertebrate or floral species are Annex II species.

Special Areas of Conservation (SACs) are protected sites designated under the Habitats Directive. The Annex I habitats listed above are features of a number of SACs in Wales.

2.4.2. Water Framework Directive

Macroalgae (as part of the 'Other Aquatic Flora' element) is one of the biological quality elements that is used to assess the status of Transitional and Coastal (TraC) waterbodies for the Water Framework Directive (WFD) (WFD-UKTAG, 2014a; 2014b).

2.4.3. Marine Strategy Framework Directive

Two of the 11 high level descriptors of Good Environmental Status (GES) in Annex I of the Directive relate directly to rocky benthic habitats (D1 Biodiversity and D6 Seafloor integrity), with others relating to aspects of benthic ecology (such as food webs and commercial fishing) (Defra, 2014).

2.4.4 OSPAR list of threatened and/or declining species and habitats

This chapter covers two intertidal rocky shore habitats which appear on the OSPAR list of threatened and/or declining species and habitats:

- *Ostrea edulis* beds (although they are mainly subtidal)
- Intertidal chalk communities

Sabellaria reefs associated with intertidal rock are also listed but are covered by the *Sabellaria* spp. reef chapter (GN030d).

Two OSPAR-listed marine invertebrates may be found on intertidal rock habitat:

- Native oyster *O. edulis* (mainly subtidal)
- Dog whelk *Nucella lapillus*

2.4.5. Environment (Wales) Act 2016 Section 7 list of habitats/species of principal importance

Section 7 species potentially found in rocky shore habitats in Wales are:

- Stalked jellyfish species *Haliclystus auricula* and *Calvadosia campanulata*
- Native oyster *O. edulis* (although this species is mainly subtidal)

The following rocky shore habitats are included under 'Littoral Rock' on the list of section 7 habitats:

- Intertidal boulder communities
- Estuarine rocky habitats
- *Sabellaria alveolata* reefs

Sabellaria alveolata reefs are covered by the *Sabellaria* spp. reef chapter GN030d and are not considered further within this document.

2.4.6. The Wildlife and Countryside Act 1981 (amended by the Countryside and Rights of Way (CROW) Act 2000)

The Act provides for the designation of Sites of Special Scientific Interest (SSSIs) which can include intertidal rocky shore habitats. There are more than 1,000 SSSIs in Wales, covering about 12% of the country with many having rocky shore and/or rockpool habitats of one sort or another as a designated feature. In SACs, SPAs and Ramsar sites, SSSI designations also underpin the terrestrial components of these sites.

A range of marine species are protected under Schedule 5 of the Act but none of these would be expected to be found on rocky shores.

2.4.7. Marine and Coastal Access Act 2009

This Act enables Marine Conservation Zones (MCZs) to be designated to conserve 'nationally important' features including marine flora, fauna, habitats, and geological or geomorphological structures. Rocky shore habitats can be MCZ features. Intertidal rocky shore communities including rockpools are features of the Skomer MCZ, currently the only MCZ designated in Wales.

The Act also established the requirement for marine licences for developments and activities in the marine environment.

2.4.8. Welsh Marine Protected Area network

Several rocky shore habitats are considered within the Marine Protected Area network feature list for Wales (Carr *et al.*, 2016).

2.5. Key potential pressures

The potential pressures of marine developments or activities on intertidal rock and the features it supports vary in relation to factors such as the nature of the development or activity, construction methods, mode of operation and scale of the project. In order to assess the significance of the effect of a given pressure on a specific receptor (such as a particular intertidal rocky shore habitat), you will need to identify the factors and pressures associated with your proposed development or activity. You will need to consider these, along with conservation value and sensitivity of the habitat/species present and the magnitude of effect, as part of the Ecological Impact Assessment (EcIA) (CIEEM, 2018). The main potential pressures (adapted from Tillin & Tyler-Walters, 2014) include, but are not restricted to:

- **Salinity changes** e.g. Cooling water discharges, freshwater inputs or abstraction. Construction of coastal structures (for example, lagoons, ports) resulting in changes in coastal processes.
- **Temperature changes** e.g. Cooling water discharges.
- **Water flow (tidal current) changes; Wave exposure changes; Change in tidal inundation regime and/or water levels** e.g. Construction and operation of coastal structures (such as ports, pilings, jetties, coastal defences, tidal lagoons, managed realignment).
- **Nutrient (eutrophication) and organic enrichment; Presence of pollutants** e.g. Sewage effluent; Agricultural runoff; Marinas; Aquaculture; Spillage of contaminants during development construction/operation.
- **Changes to suspended solid levels (water clarity); Changes to siltation** e.g. Construction and operation of coastal structures and developments; Discharges to marine environment; aquaculture.
- **Loss of habitat in development footprint; Changes to, removal and disturbance of substrate surface** e.g. Vehicle use; Construction and operation of coastal structures and developments; Recreation.
- **Changes to sediment transport and accretion of sediment on hard substrates; changes to intertidal habitat structure / geomorphology** e.g. Dredging; Construction and operation of coastal structures/developments; Coastal defences (e.g. managed realignment).
- **Introduction or spread of invasive non-native species (INNS)** e.g. Vessel activity; Discharges to marine environment; Marinas; Aquaculture; Construction and operation of coastal structures/developments.
- **Removal of target and non-target species** e.g. hand-picking/harvesting of organisms.
- **Biological pressures** e.g. Other anthropogenic influences e.g. Waste tipping; Recreational pressures.

2.6. Sensitivity (resistance/resilience to pressures)

Once there is an understanding of the types of species or habitat found in the Zone of Influence (ZoI) of a development or activity, it is important to understand their sensitivity to each of the specific associated pressures. Hill *et al*., (1998) provides an overview of dynamic and sensitivity characteristics of intertidal rock habitat.

In addition, MarLIN provides sensitivity reviews for individual habitats and species. You can see what is available by using the expandable UK marine habitat classification list on the website.

It is important that you read the further information and considerations related to MarLIN assessments in the Introductory Chapter (GN030-intro, section 3.2.6). It is also important to consider the sensitivities and traits of species found within these benthic habitats which are incorporated into MarLIN and its Biological Traits Information Catalogue (BIOTIC) resource, with further information in the wider scientific literature.

Some examples are provided below to illustrate the sort of information that can be obtained from the MarLIN sensitivity reviews. Whilst different habitats can show different sensitivity to particular pressures, for some pressures the sensitivity of all or many habitats is the same, for example all the rocky shore biotopes are highly sensitive to physical loss or change of habitat. Also, not all pressures are assessed in all cases and reference needs to be made to the individual sensitivity review for each habitat.

The MarLIN reviews of the sensitivity of each of the EUNIS Level 5 rockpool biotopes indicate that rockpools are relatively resilient to certain anthropogenic pressures in comparison to rocky shores in general and other more sensitive benthic habitats such *Sabellaria* spp. reefs (see chapter GN030d of the guidance). This is largely due to the tolerance of rockpool communities as a result of their exposure to marked physio-chemical changes on a daily basis. However, rockpool biotopes are highly sensitive to some pressures such as physical loss and invasive non-native species.

3. Existing guidance and data

This section identifies information and guidance that may be useful in the context of survey and monitoring of rocky shores and rockpools. Whilst some of the guidance (such as for Common Standards Monitoring and Water Framework Directive) is primarily for statutory monitoring work undertaken by ourselves and others, the documents and references may still provide useful contextual information and guidance on methods.

The JNCC has recently produced specific guidance for the monitoring of marine benthic habitats (Noble-James *et al.* 2017) which is a useful reference document for many aspects of monitoring.

3.1. Common Standards Monitoring

Common Standards Monitoring (CSM) was developed in the context of SSSIs and SACs to set and assess conservation objectives to help staff undertake site monitoring and assessment (JNCC, 2004). A key use of this monitoring data is to satisfy the requirement to report on the status of protected habitats and species under Article 17 of the Habitats Directive (see 2.4.1).

CSM is based on monitoring a set of mandatory attributes with the objective of assessing whether a site feature is in a favourable condition. As an example, the attributes that might need to be monitored for the Annex I habitat 'Reefs' (code 1170) include:

- Extent of the reef habitat
- Distribution of the reef habitat
- Distribution of rocky shore communities
- Species composition of communities

High-level guidance for monitoring these attributes is provided in the relevant CSM Guidance: Littoral Rock and Inshore Sublittoral Rock Habitats (JNCC, 2004a), Estuaries (JNCC, 2004b), Inlets & Bays (JNCC, 2004c), and Sea Caves (JNCC, 2004d)). The CSM documents provide broad guidance for feature-specific monitoring, indicating the background, targets and monitoring techniques for feature attributes. In terms of survey methods, the CSM guidance primarily directs the reader to the Marine Monitoring Handbook (Davies *et al.*, 2001). It should be noted that some of the technical details in the Marine Monitoring Handbook have been superseded due to advances in technology; however, it remains a comprehensive and widely used guidance document covering a diverse range of survey methods and survey and monitoring requirements.

However, despite the numerous guidance documents that are available for assessing rocky shores in general, there is a paucity of guidance relating to the assessment of notable features of rocky shores as independent habitats, especially rockpools. The CSM guidance does not explicitly consider rockpools, and the Marine Monitoring Handbook also lacks discussion of rockpool-specific methodologies.

3.2. Water Framework Directive monitoring

Water Framework Directive monitoring, encompassing a number of waterbody quality elements, is undertaken to assess the ecological status of waterbodies. The biological quality element 'other aquatic flora' includes monitoring of 'macroalgae'. The rocky shore macroalgal index is the main WFD quality element associated with intertidal rock and is used to assess macroalgae condition in coastal waters and the outer reaches of some transitional waters (WFD-UKTAG, 2014a). The macroalgal quality element considers taxonomic composition (disturbance sensitive taxa) and macroalgal cover and encompasses five metrics:

- Species richness (normalised using a shore factor)
- Proportion of Chlorophyta (green) species
- Proportion of Rhodophyta (red) species
- Proportion of opportunists (fast-growing nuisance algae)
- Ratio of ecological status groups

The results are used to calculate an Ecological Quality Ratio (EQR) range for each metric from 0 (major disturbance) to 1 (reference/minimally disturbed) as indicated in WFD-UKTAG (2014a).

In addition, in transitional waters, the fucoid extent tool contributes to the assessment of the condition of macroalgae (WFD-UKTAG, 2014b). The tool evaluates the status of the water body based on the position of fucoids in relation to the median salinity at the freshwater end of the fucoid range in transitional water. An EQR value is calculated from the results, which is used to determine WFD status (WFD-UKTAG 2014b).

Further information about WFD ecological monitoring and waterbody status assessments for Wales and how you can access this information is provided in our guidance note GN006 Marine ecology datasets for marine developments and activities (see 3.7).

3.3. Intertidal habitat mapping handbook

The CCW guide to mapping intertidal habitats (Wyn *et al*., 2006), provides detailed guidance for the 'Phase I' method for intertidal survey and mapping. This approach focusses on rapid survey of intertidal habitats/biotopes across large areas and provides habitat/biotope mapping outputs, as opposed to localised collection of quantitative data ('Phase II' survey). More detail is provided in section 5.

3.4. MESH guidance

The Mapping European Seabed Habitats (MESH) project produced a number of 'Recommended operating guidelines' (ROGs) for marine habitat mapping survey methods and these are hosted in the MESH archive on the EMODnet website.

The aerial photography ROG (Piel & Populus 2007) and the updated LiDAR ROG (Piel *et al*., 2012) are relevant to intertidal survey and monitoring.

In addition, aerial imagery should be captured according to the Royal Institute for Chartered Surveyors (RICS) guidelines for aerial survey.

3.5. Marine Strategy Framework Directive

Work is currently underway to develop methodologies to inform assessment of Good Ecological Status (GES) for UK rocky shore habitats for the Marine Strategy Framework Directive. To date this work has defined and validated potential indicators and makes recommendations on their use (Burrows *et al*., 2014). The indicators discussed apply to rocky intertidal systems and do not specifically relate to rockpools with the exception of some of the non-native species indicators. These two indicators measure the relative abundance (NNI_A) and number (NNI_P) of invasive species compared to that of native species, in order to determine whether the arrival and numbers of invasive species in a community increase, decrease, or have no effect on the native biodiversity and alpha diversity (see Burrows *et al*. (2014) for further details). There has been no attempt to validate either of the non-native species indicators as yet, but data collected for validation will feed into the next phase of the work to develop these indicators further.

3.7. Data sources

Distribution data for rocky shore and rockpool habitats in Wales and the UK are available from a number of sources. Our Guidance Note GN006 Marine ecology datasets for marine developments and activities (Natural Resources Wales, 2019) identifies data sources for rocky shore habitat maps. It also explains how you can access information about Marine Protected Areas in Wales including maps and supporting documentation on protected features, as well as data and maps on protected marine habitats and species in Welsh waters.

4. Survey and monitoring design

The Guidance Note GN030 and Introductory Chapter GN030-intro explain when and why habitat characterisation and monitoring may be required in relation to proposed developments and activities and the over-arching principles for both of these. It is important to understand the differences between characterisation surveys and monitoring when designing project-specific survey programmes.

4.1. Existing data

Where possible, and where timeframes allow, a comprehensive desk-based review of all available data relevant to intertidal rocky shore and rockpool habitats within the area of interest should be conducted prior to designing any habitat characterisation surveys or monitoring programmes. Our Guidance Note GN006 (Natural Resources Wales, 2019) provides information on the marine ecology data sets we hold and routinely use and how you can access them. Further information relating to sourcing and using data is provided in the Introductory Chapter GN030-intro (section 3.2.3) and Noble-James *et al*. (2017).

4.2. Selecting ecological parameters

The Introductory Chapter GN030-intro (sections 3.2.7 and 4.2.1) address the importance of selecting suitable ecological parameters for survey (known as ‘indicators’ for monitoring programmes) and the process to determine the effectiveness, appropriateness and validity of parameters.

The main ecological parameters that can be measured for intertidal rock habitats include:

- Extent and distribution of intertidal rock habitats/biotopes across the potential Zone of Influence (ZoI) of a proposed project or development (potentially in the form of a habitat/biotope map where applicable)
- Number of taxa present within intertidal rock habitats and assemblage composition
- Abundance data for specific taxa (counts of individuals/percentage cover)
- Other assemblage summary statistics (such as diversity indices)
- Presence/absence of any species of conservation or commercial importance, or non-native species
- Indication of variation in the above parameters across spatial scales

It will also be important to select suitable parameters for any notable features of the rocky shores to allow for an independent characterisation. For example, parameters that should be considered for rockpools include:

  - Rockpool extent and distribution
  - Associated community composition and diversity
    - Sessile flora and fauna
    - Motile fauna
    - Infauna
    - Non-native species
  - Sediment composition and depth (if present)
  - Salinity (likely to be covered as part of wider programme where required, so not necessarily rockpool specific)
- Temperature (likely to be covered as part of wider programme where required, so not necessarily rockpool specific)

4.3. Habitat characterisation

4.3.1. Aims of habitat characterisation for intertidal rock habitats

The aim of habitat characterisation survey is to collate data to describe the intertidal rock habitats within the survey area, identify any habitats and/or species of conservation importance and provide an up-to-date ecological appraisal to inform an EcIA.

4.3.2. Design of habitat characterisation surveys for intertidal rock habitats

Development- and activity-specific information should inform the design of habitat characterisation surveys which will also be influenced by the scale of the proposed development or activity (see Introductory Chapter GN030-intro, section 3).

The range of available survey methods for habitat characterisation of rocky shore habitats and rockpools is indicated in Section 5.1. The methods to be used should be determined on a project-by-project basis prior to survey.

Guidance for habitat characterisation survey design is provided in a range of sources including the Marine Monitoring Handbook (Davies, 2001) and Noble-James *et al.* (2017).

4.3.2.1. Survey design options

Transect based methodology

A common approach for intertidal rock habitat surveys, especially for smaller scale surveys, is to sample along transects running from the upper to lower shore. The number of transects should be sufficient to characterise transitions from the upper to lower shore across the survey area. Transect locations may be selected by analysing aerial imagery and refined once in the field, if required. Start/end positions must be recorded on GPS. Sampling is usually conducted at one or more sample stations within the upper, mid and lower shore, often with stations equidistant from each other (one station in each zone may be sufficient for small-scale surveys and narrow intertidal zones).

Random methodology

In more heterogeneous environments with a range of potential intertidal rock substrates distributed unevenly across a wide area, habitat characterisation sampling designs can be more complex. Usually random sampling, or stratified random sampling, is applied. These concepts are discussed in more detail in Ware & Kenny (2011) and Noble-James *et al.* (2017).

An initial interpretation of aerial imagery can be used to identify target zones with expected different habitat types in the upper, mid and lower shore and then, prior to sampling, randomly allocate stations within these zones to characterise the range of habitats present (so stations are not located along transects). It should be noted, however, that if the random allocation leads to placement of stations at considerable distances from each other, it can introduce logistic difficulties due to the restricted time available for survey around low water. Consequently, the station locations may need to be modified, based on expert judgement. There is also an option to select specific ‘representative’ station locations across known habitat types (i.e. judgement sampling) prior to sampling. However, this requires a high confidence in the habitat mapping forming the basis of the allocations, and the risk of bias can be high (Noble-James *et al.* 2017).

Stratified/Random methodology

In terms of biotope allocation, a finer level of detail can be determined in the field (for example, during Phase I mapping; see Section 5) than can be identified from analysing aerial imagery, and in practice there should be scope for modifying station locations once the survey is under way. For example, one effective approach can be to determine broad target areas (habitat zones) for quantitative survey from the imagery and then, using expert judgement, determine the zones in which stations should be allocated when at the survey site, based on the distribution of habitats/biotopes. The overall approach to be applied should be based on project-specific considerations.

It should also be noted that within intertidal habitats there may be some sub-habitats that could require specific survey. These include sea caves, rockpools and under-boulder communities. Sampling for these specific elements should be ‘nested’ within the broader habitat characterisation survey design to optimise survey efficiency. Specific survey design considerations for sea caves are outlined in CSM guidance for sea caves and guidance in Davies *et al*. (2001). Methods for sampling under-boulder communities and rockpools are provided within this chapter, where relevant.

Under-boulder habitat

For this habitat, specific considerations for survey design include:

- What criteria should be applied to determine which boulders are suitable for sampling (including the size of the boulder and microhabitats present)
- How many boulders will be sampled
- What data are to be recorded (e.g. Moore & Brazier, 2012; APEM, 2016).

Rockpool habitat

In the case of rockpools it will, in most instances, be inhibitive to include all pools present across rocky shore areas due to their ubiquitous nature. It will therefore be important to stratify the sampling effort by categorising pools based on the physical attributes that are known to govern rockpool community structure (such as depth and height on the shore). Suitable sampling effort should be afforded to pools distributed across the entire predicted ZoI, representative of each rockpool category (for example, shallow upper shore, deep lower shore). In an ideal scenario, rockpool habitat characterisation surveys would be stratified at a chosen biotope level (for example, EUNIS Level 5). However, it is unlikely that up-to-date and accurate biotope information will be available for all rockpools present on a rocky shore, particularly as rockpool communities are well known to exhibit high spatiotemporal variability (Firth *et al*., 2014; Martins *et al*., 2007) and are rarely monitored on a regular basis.

The pools can potentially be selected before the survey using aerial imagery (if of sufficient resolution), or appropriate pools may need to be selected in the field during the broader rocky shore survey. Mercer (2008) describes a protocol used for selecting rockpools for condition assessment monitoring which has been widely adopted for Habitats Directive monitoring of Welsh SACs (Bunker 2010; Moore, 2010; 2009). Whilst providing a useful framework for selecting pools, this protocol focuses on selecting pools of a similar size and at a similar height on the shore, meaning that the full range of rockpool biotopes are not likely to be assessed. Selecting rockpools for habitat characterisation surveys should therefore be based on a modified version of this protocol on a project-by-project basis. At this stage it will also be important to establish whether entire rockpools will be used as sampling units or whether controlled sampling units (for example, quadrats) will be used to sample each pool.

Rockpools as sampling units

Treating entire rockpools as sampling units is an approach that has been used during both Habitats Directive monitoring and targeted research studies (Evans *et al*., 2016; Moore 2010; 2009; White *et al*., 2015). This approach can assess all flora and fauna within each pool and produces a more comprehensive picture of the diversity and community composition than using controlled sampling units (see below). It is, however, much more time consuming, and means that the sampling area is not controlled, as all rockpools differ in size and shape. A possible solution is to sample entire rockpools randomly and to include factors known to influence community diversity and structure (such as depth, height on the shore) as a co-variate to control for the variation caused by factors not relevant to assessments (see approach used for kelp holdfasts by Anderson *et al*. (2005)).

Fixed sampling units

An alternative approach is to control the sampling area by using fixed sampling units (for example, by using quadrats). These have been widely adopted to address specific rockpool research questions (Evans *et al*., 2016; Firth *et al*., 2014; Martins *et al*., 2007; Methratta, 2004) as well as during Habitats Directive monitoring of rockpools (Bunker 2010; Mercer 2008). They may, however, introduce bias towards certain species (such as sessile taxa), under-sample other species (for example, fish and other motile taxa), and potentially miss some species altogether. Adapted quadrat sampling methods have also been used which include the use of plexiglass boxes (Atalah & Crowe, 2010; Van Tamelen, 1996) and periscopes (Underwood & Skilleter, 1996) to view quadrats on vertical surfaces.

In practice, it is likely that both approaches will be used for assessing different portions of rockpool communities, and the data gathered through each method be treated separately at the data analysis stage. For example, canopy algae are likely to be most appropriately sampled using quadrats to collect percentage cover data, whereas mobile taxa such as pool dwelling fish and shrimp are likely to be sampled most appropriately by searching entire pools.

4.3.2.2. Number of stations (sampling effort)

The number of stations to be sampled should be determined based on sufficient coverage of the range of habitat types within the potential ZoI of a development, with sufficient replication (number of stations) within the areas that may be affected. The number of samples will depend in part on the variability of the habitats to be surveyed, with more stations recommended for more variable habitats (Ware & Kenny, 2011).

4.3.2.3. Within-station replication

The Introductory Chapter outlines a number of benefits which can result from applying within-station replication during habitat characterisation surveys. Note, however, that within-station replication may not be essential for habitat characterisation. The preference may be to sample one quadrat at a number of different stations within a particular habitat/biotope at the survey site, rather than replicate within-station quadrats at fewer stations. The decision on whether to integrate within-station replication into the habitat characterisation survey design and, if so, how many replicates should be taken, should be made on a project-specific basis.

The approach for within-station replication for assessing rockpools will depend on whether entire rockpools will be treated as sampling stations or whether controlled sampling units will be assessed within each. If entire rockpools are to be used, it will not be possible to undertake replicate sampling at each ‘sampling station’ (i.e. each rockpool). A controlled sampling unit approach, however, would allow for a chosen number of replicates to be assessed within each rockpool and allow for averaging or pooling of data.

4.4. Monitoring

4.4.1. Aims of monitoring programmes for intertidal rocky shores

The aims of the monitoring need to be clearly defined and will depend on the potential impacts as identified through the EcIA process and relevant assessments as required (for example, Habitats Regulations Assessment, Water Framework Directive assessment) and conditions set by the regulator.

Monitoring requires repeat sampling to detect change over time in one or more indicators (i.e. selected ecological parameters). In relation to regulatory development control monitoring usually consists of pre-construction monitoring (this is known as the baseline), during, and operational monitoring (see Introductory Chapter GN030-intro section 4.1).

4.4.2. Defining hypotheses and trigger levels

Hypotheses to inform ecological monitoring are generally framed to detect change in a selected indicator over time, and to determine if any change observed is outside normal expectations. In the context of regulatory development control and EcIA, key thresholds known as 'trigger levels' are generally set to help assess whether impacts are evident on a given indicator over the course of a monitoring programme, together with management action(s) to be implemented if trigger levels are exceeded. The Introductory chapter provides further detail relating to hypotheses testing and considerations associated with the potential use of trigger levels.

As part of the EcIA process, measures may also be proposed to enhance existing or created habitats to mitigate impacts or to offset predicted biodiversity loss (Cook & Clay 2013; Defra & Natural England 2012). In the case of rocky shores, this could include incorporating artificial rockpools within coastal structures to enhance biodiversity (Evans *et al*. 2016, Firth *et al*. 2014).

4.4.3. Design of monitoring programmes for intertidal rocky shores

The targets of NRW monitoring projects (such as monitoring of condition of SACs) will differ from the targets of monitoring undertaken for marine developments or activities. The broad concepts, however, will be the same (see Introductory Chapter and Noble-James *et al.* 2017).

NRW surveys have employed several approaches to monitor intertidal rock depending on the monitoring objectives (e.g. Mercer & Brazier, 2009; Moore & Brazier, 2012; Mercer 2016). Best practice would be to study intertidal habitat maps beforehand and allow the location of sample stations to be influenced by both the habitat variation and the need to maintain a good spatial spread across the survey area. Typically, stations are selected to encompass as much of the range of intertidal rock habitat (and community) variation as possible. If the development results in a gradient of pressure from high to low from a point of source (e.g. a point source discharge), then sampling would be needed across the anticipated gradient of the discharge outputs. Stations should therefore be located at set distances from the discharge point (see Introductory Chapter GN030-intro, section 4.2).

4.4.3.1. Survey design options

Monitoring design will be influenced by the hypotheses to be tested and the indicators to be measured, and approaches used will be determined based on the methods and outputs of the habitat characterisation survey. For example, if transects were applied for the habitat characterisation survey and indicated relatively homogeneous substrates within the survey area, repeat sampling along the same transects may be considered appropriate for ongoing monitoring. On the other hand, if the transect approach and any associated Phase I mapping (see Section 5) revealed a heterogeneous distribution of rocky shore habitats, then the design may be revised to a stratified design for monitoring purposes. Where the habitat characterisation survey was based on a stratified design, this would be expected to be continued throughout the monitoring phase.

When determining the design of the monitoring programme it is important to understand the key objectives and any requirements to sample specific sub-habitat types or components of the intertidal biotic community (such requirements would be identified through the EcIA and permitting processes). For example, specific monitoring may be required for under-boulder or rockpool habitats with associated considerations for design. Similarly, monitoring could involve targeting specific indicator taxa, for example assessing the size and abundance of limpets and/or recording barnacle abundance (for example, Mercer, 2016), or recording the population structure of a particular macroalgae species (for example, Mercer & Brazier, 2009). Each of these would require specific methods and design considerations.

Monitoring of notable features of rocky shores should be appropriately ‘nested’ within the broader rocky shore survey design (see Noble-James *et al*., 2017). For rockpools, however, rather than stratifying the sampling effort based on their physical attributes (such as depth, height on the shore) the survey design should (where possible) seek to adequately sample an appropriate number of pools which represent each biotope present on the shore (derived from the habitat characterisation surveying) within all relevant areas of the ZoI and control area(s).

A range of considerations for the design of monitoring programmes is provided in the Introductory Chapter GN030-intro (section 4).

4.4.3.2. Number of stations (sampling effort) and BACI design

To be able to detect change in the benthic environment due to a development or activity, sufficient stations should be allocated to areas within the ZoI of the development or activity, and outside the ZoI and across habitats of interest. Power analysis is an important tool that can help determine an appropriate number of stations for a monitoring programme. The selection of an appropriate number of control sites/stations, and the characteristics of these stations, is a key aspect of Before-After-Control-Impact (BACI) monitoring designs which involve surveying before and after development works or a given activity. Further information relating to the use of power analysis and the different types of BACI design is provided in the Introductory Chapter GN030-intro (sections 4.2.4 and 4.2.5).

4.4.3.3. Within-station replication

For rocky shore monitoring purposes, it is generally recommended to sample three replicate quadrats at each sample station (for example, APEM & MESL, 2014; APEM, 2014), and the additional replicates at each station can be sampled relatively rapidly. In some instances, however, replication may not be required (for example, Mercer, 2016). The amount of replication to be applied should be based on project-specific monitoring requirements.

When monitoring notable features of rocky shores (such as rockpools) the approach for within-station replication will depend on whether entire features will be treated as sampling stations or whether controlled units will be sampled within them (see Section 4.3.2.4).

4.4.4. Sampling timing, frequency and duration

4.4.4.1. Timing

Marine communities exhibit seasonal change, although the precise effects are poorly understood for many communities. For intertidal rock habitats, some of the more obvious visual changes occur in algal assemblages and following massive settlements of juvenile animals such as mussels and barnacles (JNCC, 2004a). The degree to which seasonal change will influence the monitoring of intertidal rock attributes will depend on the community under investigation. Where possible, a community should be investigated either directly or via a literature review, to gather information on the likelihood of seasonal change affecting an attribute (JNCC, 2004a). In general, algal assemblages should be studied during the summer months (JNCC, 2004a). This is an important consideration for biotope allocation, as many biotopes are defined based on the presence of characteristic species of macroalgae which are likely to be far more prevalent in summer than winter. The recommended sampling times in Table 4 below take these points into consideration.

For habitat characterisation, surveys should be planned to coincide with low spring tides in order to ensure that as full an area as possible of intertidal habitat is surveyed. This will also apply to monitoring programmes where lower shore habitats need to be surveyed. As far as possible, repeat monitoring surveys of intertidal rock habitats should be conducted at the same time of year as this will optimise comparability of data across years.

Table 3. Recommended times of year for surveying intertidal rock habitats based on Water Framework Directive and Common Standards Monitoring guidance
*for CSM guidance, green shading is recommended timeframes, blue shading is possible window.

Guidance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Framework Directive (WFD-UKTAG, 2014a)				Green	Green	Green	Green	Green	Green	Green		
Common Standards Monitoring (JNCC, 2004a) *				**Blue**	**Blue**	**Green**	**Green**	**Green**	**Blue**	**Blue**		

4.4.4.2. Frequency and duration

There is no set guidance on the frequency of sampling of intertidal rocky shore habitats for monitoring purposes. More information on relevant considerations when determining potential frequency and duration of monitoring is provided in the Introductory Chapter GN030-intro (section 4.3).

4.4.5. Supporting environment

It is important to consider other parameters that may underpin the assessment for intertidal rock habitats, including physical processes and water quality. This could include:

- Acquiring surface scrapes from nearby infrastructure (such as jetties or sea walls) to provide quantitative data for biotic communities present;
- Measuring water quality parameter data from inshore waters adjacent to the intertidal sampling locations (for example, salinity or dissolved oxygen concentrations);
- Monitoring sediment deposition and accretion on an area of intertidal rock (if identified as a potential effect of a proposed development).

It may also be necessary to monitor additional measurements of environmental variables known to play a key role in structuring specific notable features within the project ZoI (for example, the salinity and temperature of rockpools). In addition, any anthropogenic impacts observed should be recorded during an intertidal survey, including the nature of the impact and coordinates where possible.

Any requirements for the monitoring of the supporting environment should be described in the monitoring plan.

5. Survey and monitoring methods and analysis

5.1. Field methods

A range of survey methods could be appropriate for survey and monitoring of intertidal rocky shores depending on the specific habitats involved and the specific parameters or indicators being measured or assessed. The main options include:

- Aerial surveys
- Phase I walkover survey and habitat mapping
- Phase II quantitative sampling (e.g. quadrats)
- Habitat specific survey, such as:
    - Under-boulder community assessments
    - Rockpool sampling

These methods are discussed in further detail below, with respect to the parameters or indicators that can be surveyed using these approaches. The types of methods that are appropriate will vary in relation to both the scale and nature of the proposed development or activity. Standard protocols are available for the most commonly used field methods and are indicated where applicable.

Specific methods will be needed for assessing notable features of rocky shores, if present. Detailed methods are provided below for both rockpools and under-boulder communities.

The JNCC Marine Monitoring Method Finder, a web-based information hub, has been developed to provide a single point of access to the numerous guidance documents and tools generated both within and outside the UK and can be used in conjunction with this document to assure a consistent approach to data collection and analysis.

5.1.1. Littoral rock ecological parameters

5.1.1.1. Extent & distribution of habitat

Remote Sensing

Remote sensing can be an extremely effective way of collecting data quickly and efficiently in intertidal areas. It can be used to identify the extent and distribution of intertidal rock broad-scale habitats and may be particularly useful where other ground-based survey methods are difficult due to access or health and safety reasons. Field survey is then required to ground-truth the boundaries, identify intertidal rock habitat transitions not evident from the aerial imagery, and collect qualitative and quantitative data for assessment.

Low and medium resolution data can be obtained via satellite data, although its availability is often a problem for intertidal areas as it relies on the satellite passing overhead on a clear day at low water.

Airborne imagery is therefore more commonly used to collect data for intertidal areas. Where possible, bespoke flights should be conducted at low water on a spring tide, either to capture high resolution imagery (for example, APEM, 2013), use LiDAR, or apply a combination of both.

- For imagery surveys, data should be collected at a resolution that is typically between 5 and 15 cm (depending on the level of detail required) and with stereo overlaps allowing orthomosaics and height models to be generated using photogrammetric software. Imagery should be captured according to RICS guidelines for aerial survey (section 3.4).
- LiDAR data are typically captured at a point density of between 1 and 16 points per m^2 depending on the level of detail required.

Both imagery and LiDAR survey methods are typically paired with ground control data to improve upon positional and height accuracy. Guidance on aerial photography and LiDAR is provided in MESH and MESH Atlantic recommended operating guidelines (Piel & Populus, 2007; Piel *et al.*, 2012). Further guidance for aerial imagery requirements is provided in Wyn *et al*. (2006).

For smaller scale survey requiring higher resolution outputs, or more detailed information on a particular rocky shore feature, Unmanned Aerial Vehicles (UAVs, otherwise known as drones) can be used. General guidance on UAV mapping techniques is provided in Kakaes *et al*. (2015), whereas specific UAV methodologies for mapping coastal habitats, including the challenges to be faced, are detailed in Jaud *et al.* (2016), Duffy *et al.* (2017) and Pratt (2016). Further detail relevant to the use of UAVs for assessing rocky shores is provided in the chapters for *Sabellaria* reefs (GN030d) and seagrass beds (GN030f).

Habitat/biotope mapping

Phase I survey

Phase I survey should be conducted around low water on a spring tide to optimise the extent of intertidal habitat that can be surveyed and the length of the tidal window available for survey.

Phase I survey is the mapping of different intertidal rock habitats/biotopes (i.e. combinations of substrate type/characteristics, degree of wave exposure and biotic communities) on foot using a hand-held GPS. The aim of the survey is to provide broad habitat/biotope mapping outputs for intertidal rock habitat indicating key features of interest, the main taxa present and the type of intertidal rock habitat present (e.g. bedrock, boulders etc.). Phase I *in situ* biotope mapping should follow best practice guidance, such as the CCW Handbook for Marine Intertidal Phase I mapping surveys (Wyn *et al*., 2006), Marine Monitoring Handbook (Davies *et al*., 2001) and CSM guidance (JNCC, 2004a).

Typically, a ‘wire-frame’ map of expected biotopes will be prepared from aerial photographs and these are taken on the shore survey (Wyn *et al*., 2006). Any interest features, including species or habitats of conservation interest, should then be marked using a hand-held GPS unit (accuracy better than 5 m) and noted on the map. The boundaries of habitat types can be recorded using the GPS tracking function to aid subsequent refinement of the broad-scale habitat mapping.

Biotopes can be assigned according to the JNCC Marine Habitat Classification Scheme. This has been incorporated into the European Nature Information System (EUNIS) classification (EEA, 2017), within which each habitat/biotope type has been allocated a EUNIS code (see section 2.2). JNCC provides correlation tables between the two systems and the EUNIS system is now more commonly applied to biotope mapping.

Specialised biotopes in intertidal rock habitats include rockpools, overhangs, gullies, under-boulders and caves (Wyn *et al*., 2006). They are considered to be of particular nature conservation interest (described as ‘biotopes for additional consideration’ in the SSSI Guidelines (JNCC, 1996) as they are often species-rich and therefore increase the biodiversity of a shore. A full list of specialised biotopes is given in Wyn *et al*. (2006). They are often less than 5 x 5 m in area – too small to map – and are therefore target noted. A species list should be taken from at least one representative of each biotope in the intertidal survey to meet the needs of nature conservation evaluation (Wyn *et al*., 2006). Each feature should be photographed extensively, including pan view and underwater photos (for rockpools), macro photos for key/cryptic taxa (for example, sponges) and general site photographs in a north, east, south and west orientation. Voucher specimens should also be collected where necessary.

Nationally Important biotopes are considered to be of particular nature conservation interest and are described as ‘Nationally or more than nationally important communities’ in the SSSI Guidelines (JNCC, 1996), as they tend to be rare or of restricted distribution in the UK (Wyn *et al*., 2006). They fall into seven categories: chalk biotopes, piddock biotopes, tide-swept algal biotopes, sand-scoured rock biotopes, extremely exposed and extremely sheltered fucoid biotopes, and muddy gravel biotopes (Wyn *et al*., 2006). Species lists are taken, and they are mapped in the same way as specialised biotopes. A full list of Nationally Important biotopes is given in Wyn *et al*. (2006).

For each habitat/biotope the following should be recorded:

- Brief notes relating to the biotic assemblage (including species list and key taxa present)
- Substrate type (bedrock, cobbles, boulders, etc.)
- Anthropogenic pressures
- Target notes for features of interest

Physical dimensions of such features should also be measured. For rockpools, volume can be estimated by measuring length (maximum distance across the surface of the rock pool), width (mean distance from multiple measurements) and depth (mean derived from multiple measurements) using transect tape and/or a measurement stick using the formula for a 3D shape that is most closely related to the shape of the pool (i.e. cylinder = $\pi r^2 d$, half ellipsoid = 0.083 πlwd and cube = lwd) (White *et al.*, 2015). Volume can also be estimated by pumping water out into a graduated container using a bilge pump or similar (Paijmans *et al.,* 2017)

Wyn *et al*. (2006) provides a range of forms to record the information required from Phase I survey.

The outputs of the Phase I surveys are usually used to inform the selection of sampling station locations for detailed investigation as part of the Phase II survey.

5.1.1.2. Biological community composition

Quantitative sampling (e.g. quadrats) – Phase II survey

As with Phase I, Phase II survey should be conducted around low water on a spring tide to optimise the extent of intertidal habitat that can be surveyed and the length of the tidal window available for survey.

The objective of Phase II survey is to obtain quantitative data for the biotic assemblages present and to record further detailed information relating to the type of intertidal rock habitat present (for example, bedrock, cobbles, boulders) (Hiscock, 1996).

These data are usually gathered using quadrats. A standard size of 0.5 x 0.5 m (i.e. 0.25 m^2) is suitable for rapid deployment when surveying the overall community present at stations. Alternative sizes, however, may be considered depending on survey objectives (for example, 1 m^2 quadrats have been used for NRW surveys such as Mercer (2016). At the sampling station, quadrats should be placed randomly within 5 m of the selected sample point, and biota within the quadrats are then enumerated. Abundance of encrusting, colonial and canopy-forming (i.e. macroalgae) taxa should be quantified based on percentage cover, while abundance of other organisms is recorded based on numbers of individuals.

The community composition data acquired during quantitative sampling will help to further refine any biotope assessments made *in situ* as part of the Phase I surveys and should be incorporated into any relevant post-survey spatial mapping and reporting.

If it is necessary to collect data in accordance with WFD macroalgae monitoring methods, the characterisation surveys should also follow sampling guidance in the WFD-UKTAG Macroalgae tool (WFD-UKTAG, 2014a) to gather data on the metrics indicated in Section 3.2.

All sampling activity should be noted in a field log, and images taken for all the quadrats sampled, as well as site reference photos taken for all station locations.

5.1.1.3. Rockpool assessments

Quantitative sampling of rockpools will require a variety of sampling techniques to adequately sample different community guilds present in the pools.

Canopy algae, sessile and low mobility taxa

The methods used for assessing rockpool canopy algae (such as *Corallina* spp. algal turf), sessile and low mobility taxa will depend on whether entire pools are to be used as sampling units or whether controlled sampling units are to be employed (see section 4.3.2.4).

Where entire pools are to be used, surveyors should search all pool surfaces (i.e. both the horizontal and vertical surfaces) to record all visible taxa and record an estimated percentage coverage of:

- The canopy algae
- The sessile taxa (e.g. barnacles, mussels and sponges) after moving the canopy aside

These percentages should be expressed as estimated coverage of the total pool surface area. Abundances of low mobility taxa (e.g. gastropods, starfish) should also be recorded. This can be facilitated by using a proforma, listing frequently recorded/expected taxa (see Moore, 2010).

If controlled sampling units are to be employed, an appropriately sized quadrat should be haphazardly placed on a number of both horizontal and vertical surfaces and the same percentage coverage estimations described above should be made. This can be facilitated by dividing the quadrat into a number of smaller squares (e.g. 5 x 5 cm squares) and using the intersection points as a means of estimating percentage coverage and subsequently reducing surveyor bias (see Figure 3). Note that quadrat sizes used for previous rock pool studies vary dramatically. They are generally much smaller than those used for rocky shore sampling (0.25 m^2) (hence termed micro-quadrats) and range from 4 cm^2 to 12 cm^2 (see Firth *et al*., 2014; Underwood & Skilleter, 1996). Noble-James *et al*. (2017) contains on how to select appropriate sampling unit sizes.

For vertical surfaces, controlled quadrat areas can be viewed by pressing plexiglass boxes against the vertical surfaces of pools (see Van Tamelen, 1996; Atalah & Crowe, 2010) or by using periscopes to reflect the view of quadrats held against the surfaces (see Underwood & Skilleter, 1996). Approaches using endoscopic cameras with integrated lighting, viewing screens and a quadrat fixed in the field of view may also provide a means of rapidly assessing vertical surfaces in a standardised manner.

If necessary, cryptic flora and fauna should be collected and preserved for post-survey identification and some samples should be retained as voucher specimens. There is also the option to collect canopy turf samples in order to assess the associated invertebrate assemblages (see Bunker, 2010), and to collect core samples if or when sediments are present on the pool floor, in order to assess the associated infaunal communities present. The most appropriate core size to use for rock pool assessments should be determined by considering the guidance on selecting appropriate sampling unit sizes provided in Noble-James et al. (2017).

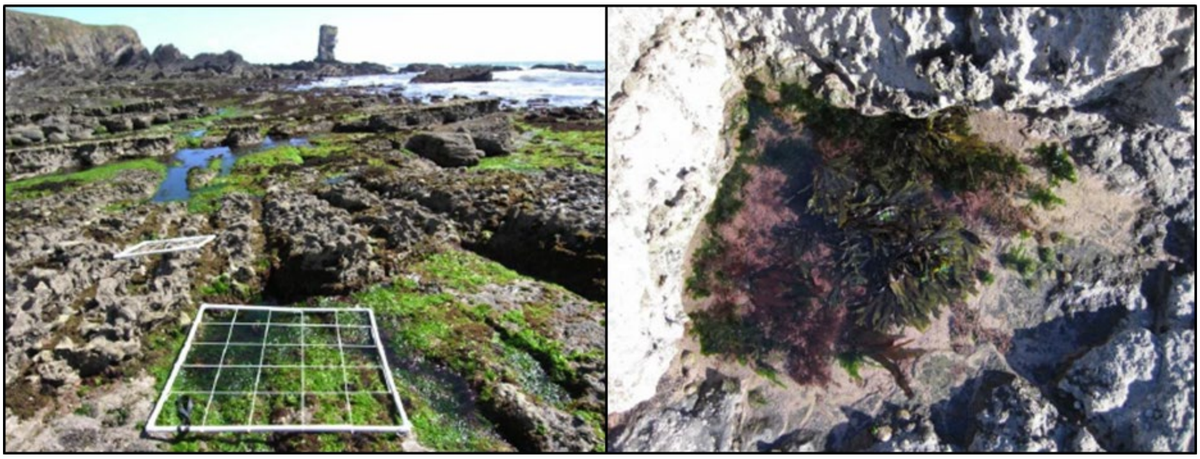

Figure 3. Quadrat sampling of a rockpool dominated by *Ulva* sp. (left) and a shallow rockpool with abundant *Corallina* spp. (right). Photographer Francis Bunker (Bunker, 2010). Images © NRW

Motile taxa

Several methodologies exist for sampling fish within rockpools. These include sampling by anaesthetisation, net sampling, visual assessment, and mark and recapture (see Procedural Guideline No. 4-4 of the Marine Monitoring Handbook for full details (Davies *et al*., 2001). Sampling by anaesthetisation is regarded as the most effective method for sampling all fish present. However, this method is not applicable to other motile fauna typical of rockpools (such as shrimp, prawns, crabs) and its effects on other pool inhabitants are unknown. Sampling motile taxa using hand-held nets and transferring to fresh aerated buckets of seawater (see White *et al*., 2015) is considered to be the most appropriate method. This can be facilitated by bailing or using a pump to reduce the volume of water in the pool. Bailing/pumping should be undertaken as close to the time of inundation by the incoming tide as possible, to minimise the time that other pool inhabitants are exposed.

For very large pools where such sampling will not be feasible, visual census methods should be considered. This will involve multiple surveyors making slow laps of the pool circumference for set periods of time (e.g. 30 minutes) and recording taxa observed from above the surface (see White *et al*., 2015). This could potentially be facilitated by snorkelling and/or the use of endoscopic cameras. Using small baited remote underwater video (BRUV) techniques may also be considered. These systems have been used to sample large epibiota in coastal and offshore environments (Griffin *et al*., 2016) and in rockpools (Hrasati *et al*., 2018, Davis *et al*., 2018).

However, the most appropriate method will be project-, impact- and rockpool-specific.

Environmental sampling

Variation in temperature and salinity has been identified as a pressure to which most rockpool habitats (other than those under high levels of natural salinity variation) have medium levels of sensitivity. For example, prolonged reduction in salinity, e.g. from full (30-40 ppt) to reduced (18-30 ppt), is likely to reduce the species richness of the biotope due to the loss of some intolerant invertebrates from the assemblage associated with the *Corallina* spp. turf within the Coralline crust-dominated shallow eulittoral rockpools biotope.

Where development or activity-specific effects on temperature and salinity are predicted, it will probably be necessary to monitor these parameters. It is likely that temperature and salinity loggers would be deployed as part of a wider monitoring programme for the site and may not be targeted to rockpools. If specific data for rockpools are required, however, it is possible to deploy permanent loggers within these habitats to collect data over time. Furthermore, as temperature and salinity are likely to be spatially heterogenous, multiple loggers positioned in pools within different habitats/biotopes in the ZoI can be considered to more accurately assess patterns in variability and any potential changes as a result of coastal developments /activities. The requirement for such loggers will be project-, impact- and rockpool-specific

5.1.1.4. Under-boulder assessments

Semi-quantitative sampling

Methods for surveying under-boulder communities will depend on the size of the boulder. For smaller boulders, each boulder should be turned over and communities recorded using a modified Marine Nature Conservation Review (MNCR) habitat form (Hiscock, 1996). Conspicuous biota should be recorded to the lowest level possible, either as counts or on a SACFOR scale. Algal species should be identified to the best taxonomic level possible and at least to the level of the WFD reduced species list (WFD-UKTAG 2014a). Any boulders overturned are then returned to their original positions to minimise any potential impact on the communities living beneath (Moore & Brazier, 2012)(Figure 4). Micro-quadrats (for example, 5 or 10 cm^2) may be used to help quantify organisms such as barnacles which are directly attached to the boulder surface (for example, APEM, 2016).

For larger boulders that cannot be turned easily, an endoscopic camera with integrated lighting and viewing screen may be used for viewing organisms between small gaps and crevices (for example, APEM, 2016). The images, viewed in real time, can be used to assign SACFOR scores to the taxa identified. This method ensures that there is no bias against larger boulders and that community assessments can be conducted without health and safety implications. It is ecologically sound, further minimising potential impacts on the organisms beneath the boulders.

Figure 4. Quadrat sampling (left) and under-boulder sampling (right). Images © APEM Ltd.

5.1.2. Quality Control

All fieldwork should be carried out by experienced field scientists, with necessary health and safety provisions and excellent *in situ* organism identification skills. There should be full sample tracking documentation and field notes for the sampling procedures. Where there is more than one survey team it can be useful to conduct a pre-survey sampling session with all of the surveyors together, or to sample the first station together to ensure consistency.

Across all methods it is important to obtain accurate detailed records and to retain records/data for quality assurance procedures. There should be full documentation and field notes for the sampling procedures, and photographs taken of key taxa. By photographing all quadrats, subsequent quality control can be conducted by a second taxonomist following the field survey. All processes should be witnessed and documented, with documentation retained after completion of surveys.

The NE Atlantic Marine Biological Quality Control (NMBAQC) scheme Macroalgal Component provides training exercises for organisations conducting surveys, to improve consistency of records and identification.

5.2. Analytical methods

5.2.1. Aerial imagery

Specialist image-processing software should be used to perform the following functions:

- Geometric image correction
- Radiometric image correction
- Quality control image data before, during and after download

The pre-processing functions above are used to create colour-balanced, distortion-free aerial imagery which is then mosaicked and orthorectified using specialist proprietary photogrammetric software. The imagery should be aligned using pixel-matching algorithms which identify common features between each image pair. The post-processed GPS data from the aircraft flight log are then used to triangulate the block, creating a continuous model of the site. Once the initial triangulation is complete, any Ground Control Point (GCP) data captured in the field can be imported into the block to enhance the accuracy of the model. A final seamless, accurately georeferenced image mosaic is then produced.

5.2.2. Macrobiota samples

Identifications of biota in the field should be to species level but there will always be some taxa for which higher taxonomic levels are used (due to identification difficulties). Taxonomic nomenclature should follow the World Register of Marine Species (WoRMS).

5.2.3. Analytical Quality Control

5.2.3.1. Identification of biota

It is possible to provide quality assurance of *in situ* identification for less common taxa (for example, some invertebrates, macroalgae) by retaining some specimens for laboratory verification. For macroalgae this could involve maintenance of a herbarium of dried specimens. Photographs of specimens should also be taken in the field, as live specimens can vary in colour and other features from those in the lab.

5.3. Data analysis and interpretation

The Introductory Chapter GN030-intro (section 4.4) outlines approaches which are available for data analysis. The most suitable approach for each habitat should consider a variety of factors such as whether data are being analysed for a habitat characterisation or monitoring survey and the survey design. Further detail is provided in a wide range of published and grey literature such as Noble-James *et al*. (2017).

5.3.1. Habitat Characterisation and Monitoring

The main purpose of habitat characterisation in the context of proposed developments and activities is to provide the data outputs necessary for the EcIA process and to provide evidence in support of any associated assessments as required (see Guidance Note GN030 and Introductory Chapter GN030-intro).

For intertidal rocky shore habitats, the range of statistical analyses to be applied are within the ‘identifying patterns in multivariate community data’ grouping of statistical approaches (Noble-James *et al*. 2017).

Monitoring data should be subject to in-depth statistical analysis and interpretation to test the hypotheses set out at the design stage. A wide range of suitable univariate and multivariate analysis and mapping techniques are available to achieve this and, as a result, those chosen are likely to vary markedly between projects. A full account of the proposed statistical tests to be used to monitor change should be described at the monitoring programme design stage.

5.3.1.1. Biota

Analyses will involve calculating a range of appropriate metrics to characterise biotic communities/assemblages within rocky shore habitats. These could include abundance, biomass, taxon richness, evenness, diversity, taxonomic distinctness, and biological traits metrics. Distributional techniques can also be used that provide visual outputs such as a curve or histogram, including ranked species abundance curves, species accumulation curves and abundance-biomass comparison curves (Noble-James *et al*., 2017).

Multivariate analyses using PRIMER software and/or the vegan package in R, can be used to determine variation in communities/assemblages including cluster analysis (usually run with a Similarity Profile (SIMPROF) test) and multi-dimensional scaling (MDS), which allows creation of a 'map' of samples indicating how closely related they are to each other. Variation across samples can be analysed further using Similarity Percentages (SIMPER) analysis, which calculates within-cluster similarity, and identifies the most influential taxa within each cluster by ranking average abundances and similarity contributions (Noble-James *et al*., 2017). Further analyses can be used to assess potential relationships between biotic data and environmental data (see the Introductory Chapter GN030-intro).

5.3.1.2. Habitat mapping

Intertidal rocky shore survey data may be most usefully presented as detailed survey maps, typically using GIS software packages. The Introductory Chapter provides further information relating to the types of classification systems that can be used to map benthic habitats and the inclusion of point sampling data within the mapping outputs.

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