North Devon Marine Pioneer

Part 1: State of the art report of the links between the ecosystem and ecosystem services in the North Devon Marine Pioneer

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Contents

1 Introduction

"Natural capital refers to the elements of nature that produce value or benefits to people (directly or indirectly), such as the stock of forests, rivers, land, minerals and oceans, as well as the natural processes and functions that underpin their operation" (Natural Capital Committee, 2014).

Marine ecosystems provide a number of essential functions, such as primary production and climate regulation, which underpin life on earth (Millennium Ecosystem Assessment, 2005). These essential functions, in turn, deliver flows of ecosystem services that support human wellbeing e.g. food, flood protection, opportunities for recreation (Arkema *et al.*, 2013; Arkema *et al.*, 2015; Potts *et al.*, 2014; Rees *et al.*, 2014; Rees *et al.*, 2010; Roberts *et al.*, 2001). In recognition of the crucial interdependencies between the natural and the human system, targets to sustainably manage marine ecosystems are embedded in international (CBD, 1992; CBD, 2010; OSPAR Convention, 2002; United Nations, 2014) and national policy targets (UK Government, 2009).

In 2011, the United Kingdom (UK) National Ecosystem Assessment (NEA) identified that UK ecosystems provide a wealth of benefits to society. However, due to pressures exerted though population growth, technical developments, globalisations and food production, many ecosystems remain in a state of long-term decline. The report highlighted a need to fully incorporate the role of ecosystems in supporting the delivery of ecosystem services and human well-being into decision making (UK National Ecosystem Assessment, 2011). The subsequent UK Government Natural Environment White Paper set out to mainstream "the value of nature across our society, create a green economy, strengthen the connections between people and nature and for Government to show international leadership to protect and enhance natural assets globally" (HM Government, 2011). Commitments were made to a "net gain" policy for biodiversity though supporting healthy, well-functioning ecosystems and ecologically coherent protected area networks; to establish clear institutional frameworks for delivery; to put natural capital at the heart of economic thinking; to reconnect people with nature; to show environmental leadership internationally and within the EU and; to track progress on the ambition of the white paper through the development of a key set of indicators (HM Government, 2011).

In 2015, the Natural Capital Committee (NCC), acting as an independent advisory body to UK Government released their third report to Government setting out a clear recommendation on how to achieve the governments vision to 'to be the first generation to leave the natural environment in a better state than it inherited' (Natural Capital Committee, 2015). The NCC proposed the development of strategy and a corresponding 25 year plan to protect and improve natural capital in three parts: building blocks; investment; and financing (Figure 1).

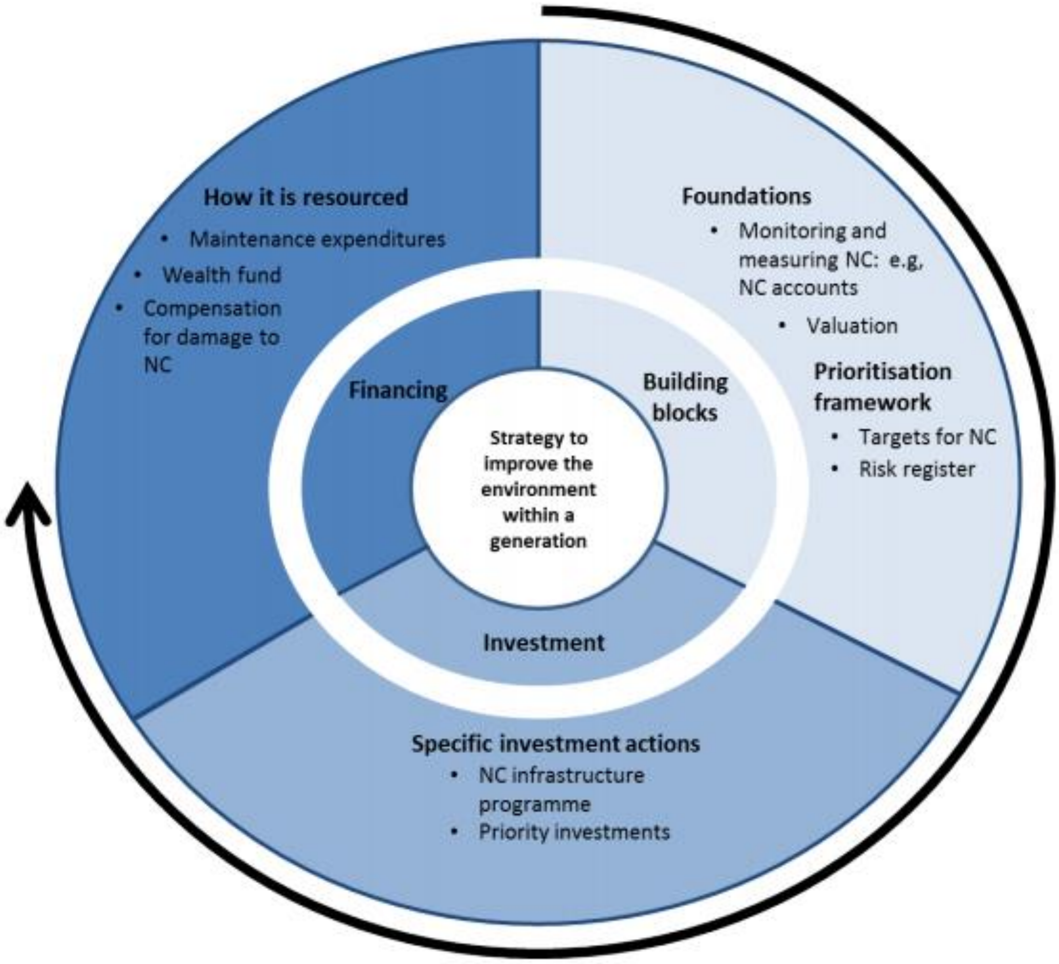


Figure 1 Strategy to improve natural capital (Natural Capital Committee 2015)

The UK Government committed to the recommendation of the NCC in the 2017 manifesto, "to pledge to be the first generation to leave the environment in a better state than we inherited it. That is why we shall produce a comprehensive 25 Year Environment Plan that will chart how we will improve our environment as we leave the European Union and take control of our environmental legislation again" (The Conservative and Unionist Party Manifesto, 2017). In 2018, the Natural Capital approaches recommended by the NCC are anchored at the centre of the UK Government's *25 Year Plan to Improve the Environment* (HM Government, 2018).

To operationalise the Natural Capital approach Defra has created four pioneer projects to inform the development and implementation of the 25 Year Environment Plan. The Marine Pioneers are located in North Devon and Suffolk. The North Devon Marine Pioneer (NDMP) is intended to test, at a local scale, how marine natural capital can be effectively managed to deliver benefits to the environment, economy and people, and identify how best to share and scale up this learning.

2 Aims and Objectives

The aim of the study is to develop the framework for the application of the Natural Capital approach in the marine environment that will specifically support the WWF led UK SEAS programme sustainable finance work stream and the delivery of the Pioneer programme in North Devon

Project objectives:

1. To demonstrate the pathways between ecology, ecosystem services and benefits that influence human wellbeing.
2. Identify how stakeholders are linked (directly or indirectly) to natural capital.
3. Identify relevant indicators, data sources and potential means for valuing ecosystem service benefits (monetary and non-monetary).

3 Overview of the North Devon Marine Pioneer Area

3.1 North Devon Marine Pioneer

The North Devon Marine Pioneer boundary encloses over 5500km² of the outer Bristol Channel and eastern Celtic Sea, extending offshore of the north east Cornwall, north Devon and west Somerset coasts. Offshore, Lundy island lies within NDMP. A major estuary, the Taw Torridge estuary also lies within the NDMP boundary (Figure 2). The region within the NDMP supports marine fisheries and recreation industries (Bell, Le Helloco & Stainthorp, 2015). The beaches and coastal landscape are of importance as a UNESCO Biosphere Reserve and attract national and international tourists supporting a large tourism and hospitality industry (Bell, Le Helloco & Stainthorp, 2015).

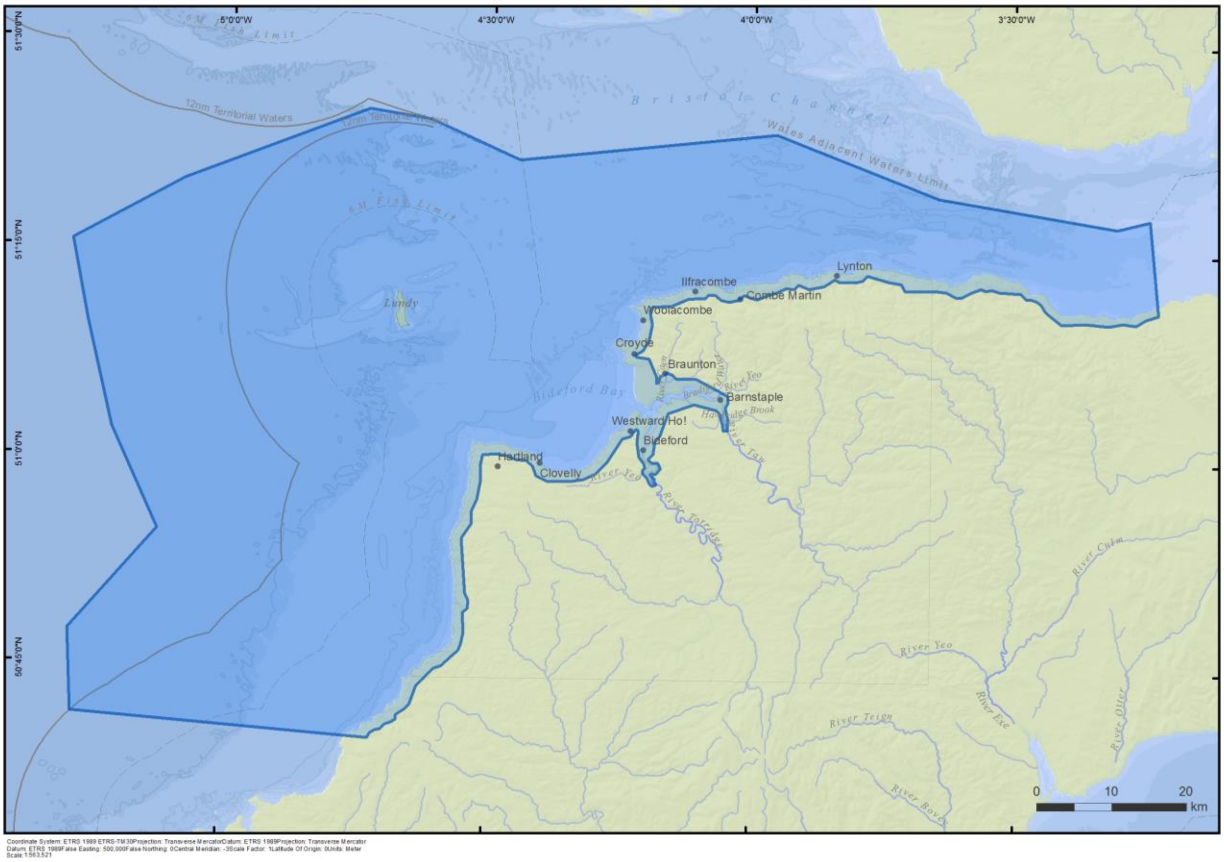


Figure 2 The North Devon Marine Pioneer boundary (dark blue)

3.2 Protection and management of natural environment

Within the NDMP there are two forms of marine protected area (MPA) sites, European Marine Sites (EMS) (e.g. Special Areas of Conservation (SAC)) and Marine Conservation Zones (MCZ) (Figure 3) (Annex I). Special Areas of Conservation protect habitats and species of European importance designated under the Habitats Directive (EEC, 1992). Marine Conservation Zones are designated under the United Kingdom Marine and Coastal Access Act 2009 (MCAA) to protect nationally important habitats and species. As a network of sites, these zones contribute to fulfilling the United Kingdom's obligations under the Convention of Biological Diversity (CBD) as well as non-binding instruments such as the recommended coherent network of marine protected areas under the OSPAR (Oslo and Paris Conventions) Recommendation 2003/3 (Christie *et al.*, 2014).

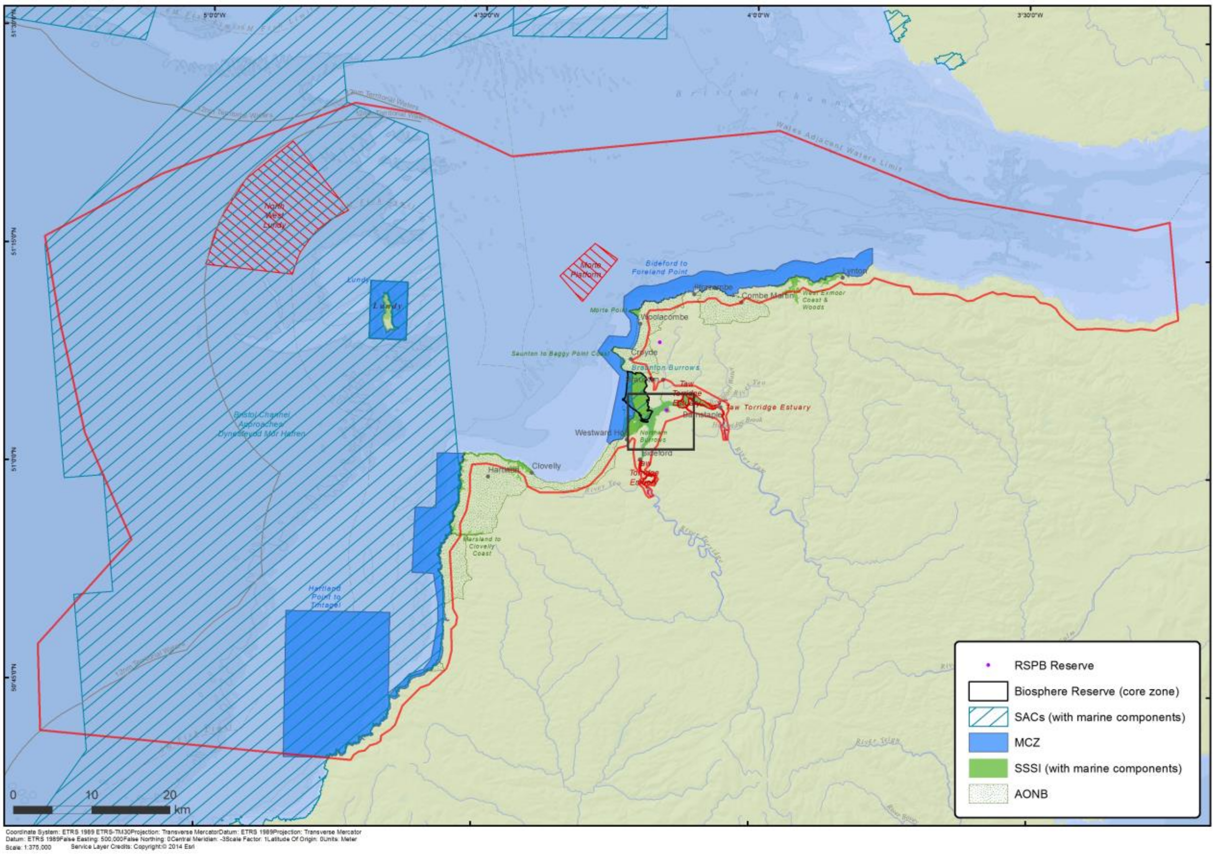


Figure 3 Designated and proposed marine and intertidal conservation sites within NDMP

All MPA sites require the designated habitat or species features they contain to be "recovered" or "maintained" to "favourable condition". Favourable condition is "… the condition that would be expected in the absence of significant anthropogenic pressures which have an adverse effect" (Carr *et al.*, 2016; JNCC, 2010). For a habitat in an MCZ to be in favourable condition, "… the extent is required to be stable or increasing and its structures and functions, its quality and the composition of its characteristic biological communities are such as to ensure that it remains in a condition which is healthy and not deteriorating" (Carr *et al.*, 2016; JNCC, 2010). Favourable condition in a SAC is assessed as whether "… the natural range and area of a habitat feature is stable or increasing and which are necessary for its long-term maintenance are present and are likely to continue to exist for the foreseeable future" (JNCC, 2017).

Under the Marine and Coastal Access Act 2009, the Marine Management Organisation (MMO) are responsible for the management of MCZs and EMSs. Between 0-6 miles, Inshore Fisheries and Conservation Authorities (IFCAs) are the lead regulators for fisheries within their Districts. They have duties under the MCAA (s.154) to 'further the conservation objectives of MCZs' and The Conservation of Habitats and Species (Amendment) Regulations 2012 which requires the competent authority (e.g. IFCAs) to exercise their functions which are relevant to nature conservation, including marine conservation, so as to secure compliance with the requirements of the Directives. The MMO and IFCAs coordinate enforcement roles.

Condition assessments have been undertaken by Natural England to identify if features within SACs and MCZs are in favourable condition and a conservation objective of 'maintain' can be applied. If the feature is in unfavourable condition a conservation objective of 'recover' (to favourable condition) is applied (Annex I).

Within EMS, and MCZs, the management of fisheries within MPAs is based on the level of risk that a fishing activity presents to protected features, either habitat or species, to conserve important habitats and species in line with the EU Habitats and Birds Directives (Marine Management Organisation, 2014). Assessments of impact of each fishing activity on features of MCZs in NDMP have been undertaken by Devon & Severn Inshore Fisheries and Conservation Authority, in coordination with advice from Natural England, to identify where management measures are required.

MCZs are being designated in 3 tranches, between 2013-2018, once designated, assessment of impacts of fishing activities on designated features have been undertaken and (fisheries) management measures applied as necessary by regional IFCAs (Figure 4). Management measures were assigned for Tranch 1 MCZs (designated 2013) in January 2017. Management measures will be applied for Tranch 2 MCZs (designated 2016), following completion of impact assessments. Tranch 3 (designation expected in 2018).

Prior to the MCZ process, a No Take Zone (NTZ) has been in place off the east coast of Lundy island since 2003 (Figure 4). Within a NTZ it is illegal to remove sea life. IFCA byelaws restricting netting and mobile gear were extended across the Lundy MCZ (2014), mobile gear is also prohibited within Taw Torridge estuary. Netting permit area byelaws prohibit the removal of spiny lobster in Bideford to Foreland Point MCZ, and restrict net types to drift or seine nets in the coastal locations indicated. Seine nets under 20m for sand eel only are permitted under license conditions in Taw Torridge estuary (Figure 4). The Trevose Box has been closed under EU regulations, to fishing activities between January and March since 2005, with the intention of reducing the fishing mortality of Atlantic cod. The Ray Box is a voluntary effort, initiated in 2005 by North Devon fishermen, Welsh and Belgium fishers in which an area is closed to mobile fishing for 6 months of the year to protect nursery grounds for Ray species and allow spawning to take place (Figure 4). The Whelk Box is a gentleman's agreement between local and visiting fishermen who use static and mobile gear (Figure 4).

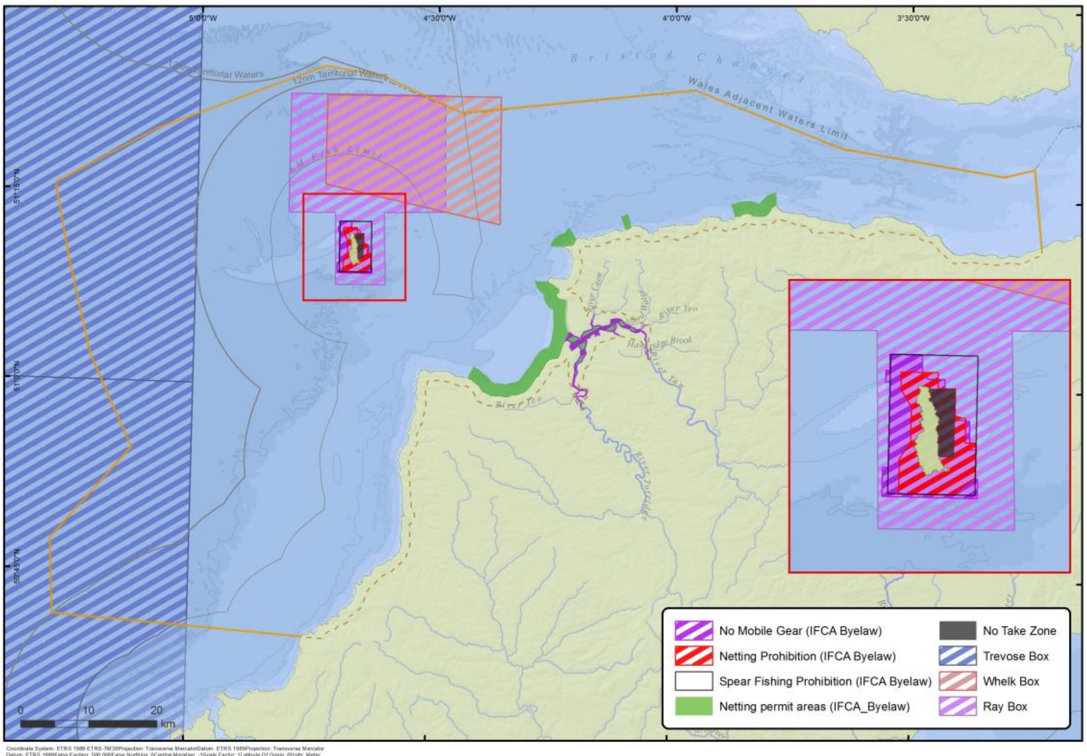


Figure 4 Fishing activity management in NDMP, including IFCA byelaws

Sites of Special Scientific Interest (SSSI) notified under the Wildlife and Countryside Act 1981 (amended 1985) are also present on the terrestrial and coastal border of the NDMP. The UK Government has a duty to notify as a SSSI, any land, which in its opinion is of special interest by reason of any of its flora, fauna, geological or physiographical features. Natural England provide condition assessment of SSSIs and can advise on appropriate management measures. Marine/intertidal SSSI features in NDMP include Grey seal *Hallichoerus grypus,* saltmarsh and littoral sediment (Annex I).

4 Pathways between Natural Capital assets, ecology, ecosystem services and related benefits.

Stocks of natural capital assets, such as the extent and condition of habitats, species and the water bodies that support them provide the base for the flow of ecosystem services and monetary and non-monetary benefits supplied within NDMP. In this section, the extent of marine and intertidal habitat assets are calculated and mapped. The level of provision from the habitats present in NDMP of each intermediate service and ES goods/benefits classified in line with the UK National Ecosystem Assessment Follow On (UK NEA FO) framework (Figure 5) are assessed, using a matrix approach with supporting literature reviews. Habitats were assessed at EUNIS level 3 for the whole NDMP, and Eunis level 4+ for features of designated sites. The matrix assessment builds on previous matricies of the level of provision of ES from UK marine habitats (Fletcher *et al.*, 2012; Potts *et al.*, 2014; Saunders *et al.*, 2015).

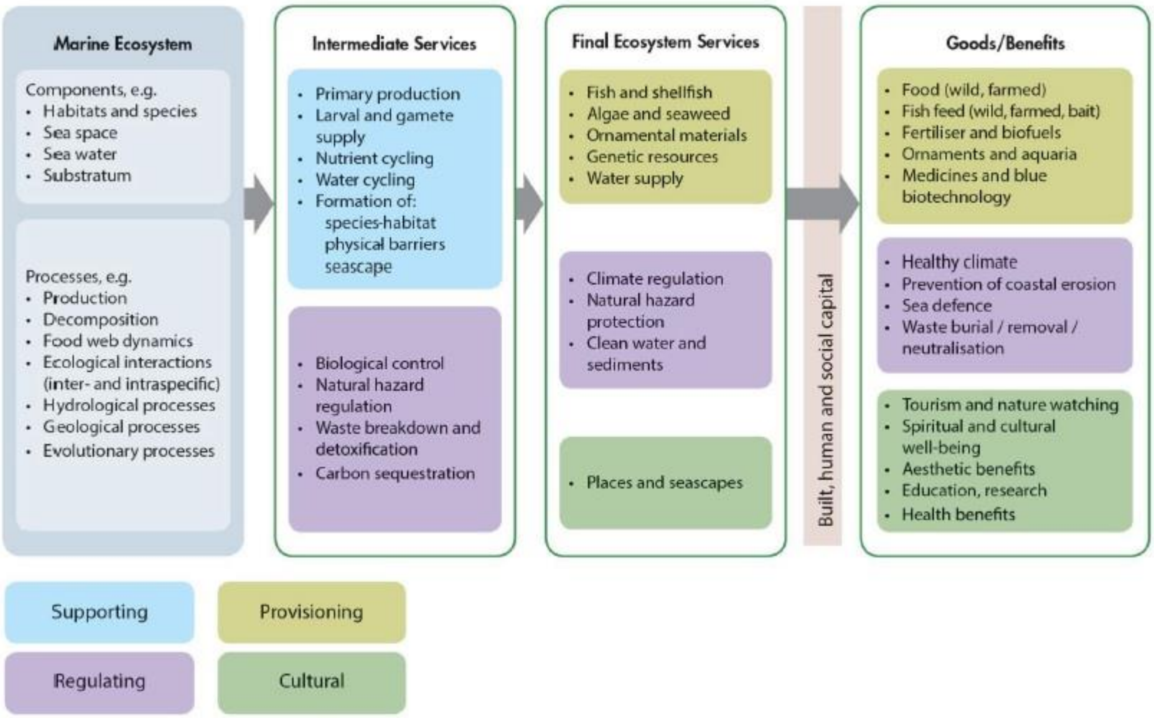


Figure 5 NEA FO framework (applied to coastal and marine ecosystem services from Turner et al. 2014)

Defining the pathways between ecology and ecosystem services has been undertaken through a staged approach:

- Mapping natural capital assets.
- Review and assessment of provision of ecosystem services from natural capital in NDMP (Matrix Assessment).

4.1 Mapping Natural Capital Assets

4.1.1 Method

The environmental features, and habitats present within the NDMP, up to mean high water, were derived from best available habitat map data available for the region. A composite habitat map was generated that combined spatial data sets. Data were accessed through two sources 1) A Natural England internal habitats dataset, compiled from best available survey maps 2) Modelled data from EMODnet/EUSeaMap.

When using two data sets, over the same area, spatial data will overlap. To retain the spatial data from surveys (that provides the greatest detail and so confidence when assessing habitat extent and species communities), and produce a single map layer of best available data, a 'compilation' method was undertaken in ARC GIS 10.3. Best available data, were retained on the basis of Mapping European Seabed Habitats project (MESH) confidence scores[1]. The map aims to provide habitat data, where possible at EUNIS level 3. The corresponding EUNIS habitat was consistently identified for areas where habitat attributes were labelled under different designation types (e.g. EMS Annex I, Annex II features and sub features and corresponding MCZ Habitats of Conservation Interest (HOCI) and Species of Conservation Interest (SOCI) were all identified to a common EUNIS habitat). Finally, for areas where spatial overlap of habitat features from surveys occurred (from overlapping data or ambiguous classification by map creators/interpreters), the ES provision from each habitat was reviewed using matrix data provided in Potts et al. (2014) and Saunders et al. (2015) on supply of ES from habitats. The habitat with the highest provision across ES was retained. The method detail, including tools used for each step in ARC GIS is provided in Annex II.

A confidence map layer was also produced, confidence was based on MESH confidence scores. The MESH Confidence Assessment Scheme is a systematic approach using a multi-criteria questionnaire to score habitat maps derived from survey data according to three key aspects: remote sensing

[1] http://www.emodnet-seabedhabitats.eu/default.aspx?page=1635

methods, ground-truth data collection and data interpretation (JNCC, 2008). The scoring framework assigns each habitat map with a score between 0 and 100 (Figure 6). The broad-scale modelled habitat data from EUSeaMap, used in areas where habitat maps from surveys were not available, has associated confidence measures, but these were developed more to illustrate some of the uncertainties around the modelling process (Cameron, Askew & 2011; EUSeaMap, 2017). These result in a qualitative score (Low, Moderate or High) derived from confidence in the underlying continuous physical variables (e.g. depth, light at the seabed) and the confidence in the classification of habitat descriptors (i.e. the thresholds applied to the physical variables).

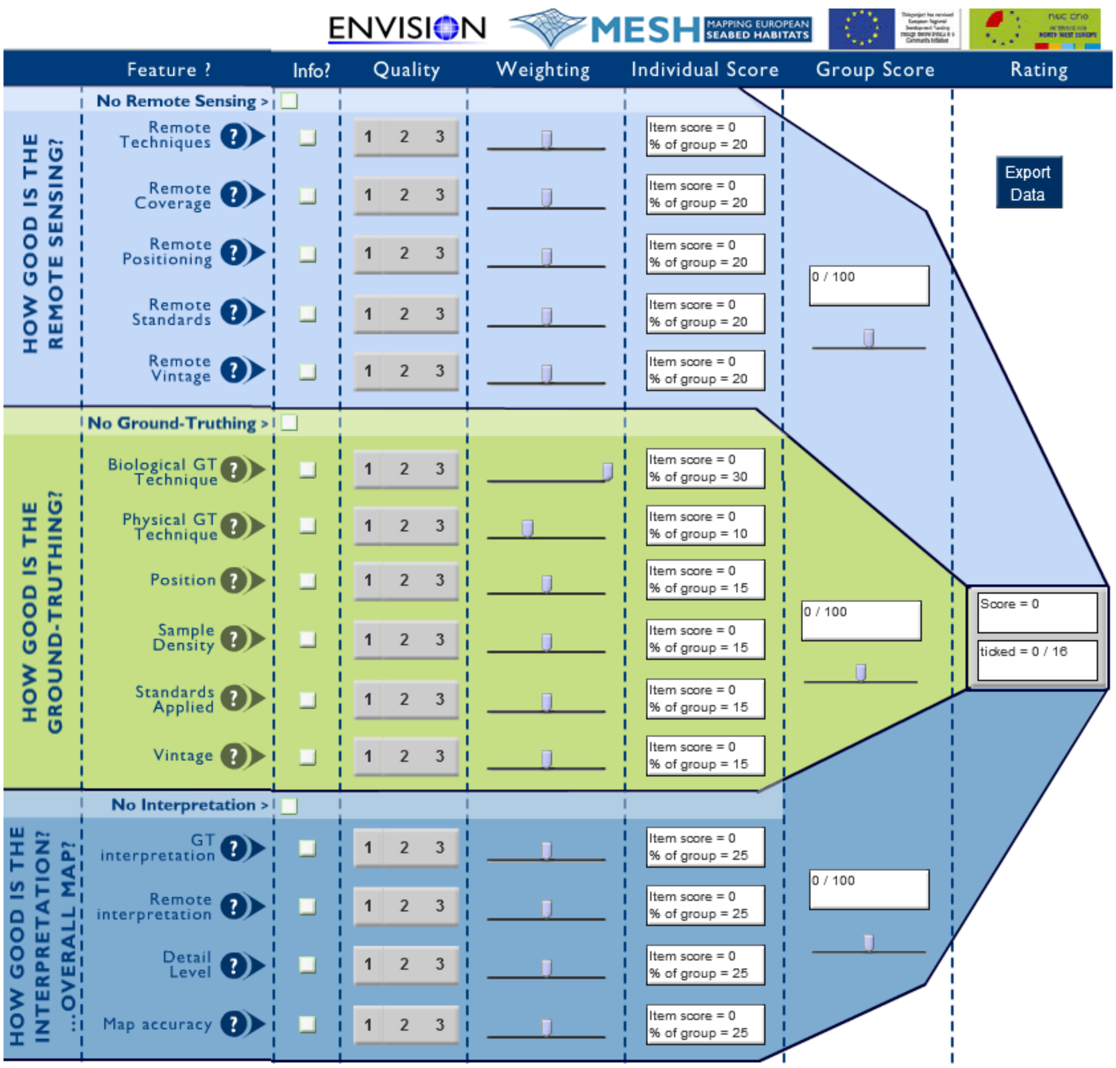


Figure 6 The MESH confidence assessment framework (MESH, 2008)

4.1.2 Results

The composite map constructed from Natural England's most up to date habitat data (as of December 2017) and from EMODnet/EUSeaMap data depicts 142 distinct EUNIS habitat types (26 at EUNIS L2/3) (Figure 7). The confidence associated with the spatial data shows high confidence in survey data within MPA sites and lower confidence in survey data outside MPA sites. Modelled data were the only available data resource for large extents of the offshore area of NDMP, particularly the western section, where confidence in the data were lowest (Figure 8). Data sources used to construct the habitat map are summarised in Table 1.

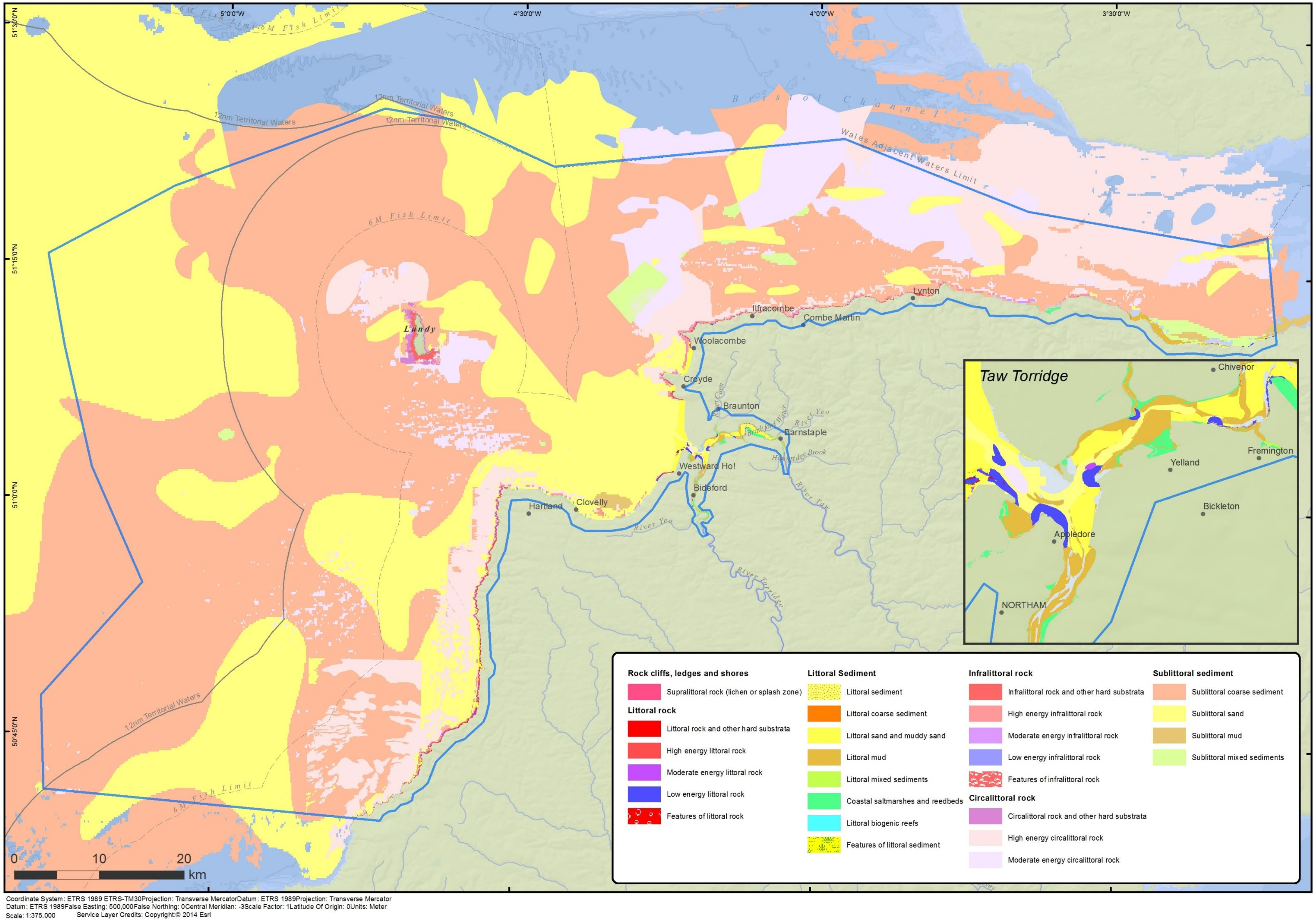
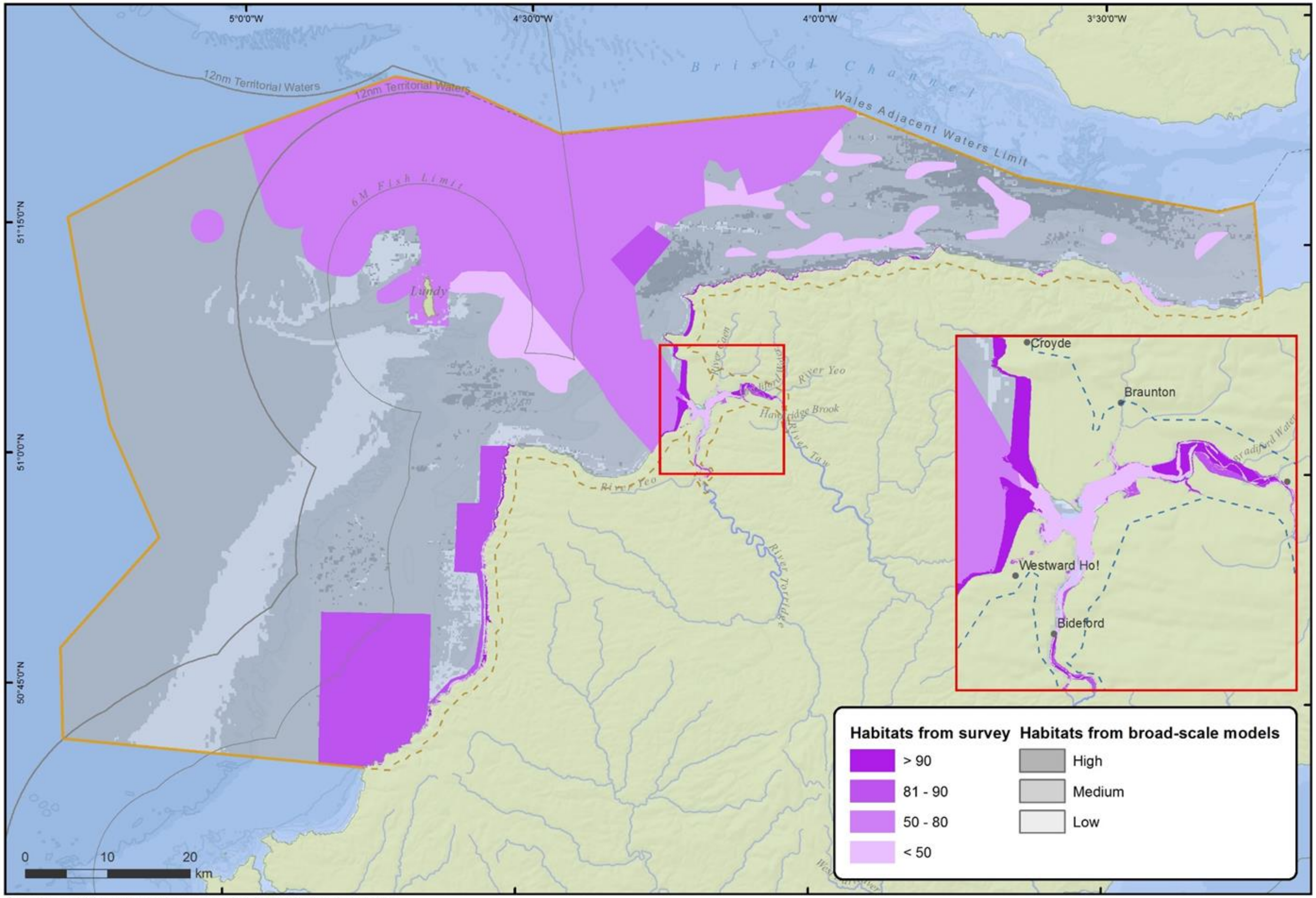


Figure 7 Mapped extent of habitat (Eunis L2/3 or greater) within NDMP



Coordinate System: ETRS 1989 ETRS-TM30Projection: Transverse MercatorDatum: ETRS 1989Projection: Transverse Mercator
Datum: ETRS 1989False Easting: 500,000False Northing: 0Central Meridian: -3Scale Factor: 1Latitude Of Origin: 0Units: Meter
Scale:1:550,000

Figure 8 Data confidence in relation to MESH confidence scores (habitats from surveys) and low-high assessment (habitats from broad scale models)

Table 1 Source habitat data available for North Devon. FSM = Fine-scale mapping, MSM = Medium-scale mapping, BSM = Broad-scale mapping

Dataset	Dataset Name	Source	Type	MESH Confidence Score	Notes
GB100217	2013 Natural England MCZ Verification Survey - Bideford to Foreland Point	NE/JNCC	Survey	97	
GB100281	2013-2014 Ecospan NE Taw Torridge Estuary rMCZ Intertidal Verification Survey	NE	Survey	97	
GB100220	2013 Natural England MCZ Verification Survey - Hartland Point to Tintagel	NE/JNCC	Survey	96	
GB100218	2013 Natural England MCZ Verification Survey - Bideford to Foreland Point	NE/JNCC	Survey	96	
GB100221	2013 Natural England MCZ Verification Survey - Hartland Point to Tintagel	NE/JNCC	Survey	94	
NE_1600	EA Saltmarsh Zonation - December 2016 update	NE	Survey	90	
GB001494	2013 CEFAS Hartland Point to Tintagel Subtidal Verification Survey - HRPT_20150821_BSH	NE	Survey	87	
GB100267	Coastal Observatories South West Regional Coastal Monitoring Programme Habitat Mapping	PCO	Survey	86	Significant areas mapped only to EUNIS L2 (discarded)
GB001494	2013 CEFAS Hartland Point to Tintagel Subtidal Verification Survey - HRPT_20150821_BSH	NE	Survey	83	
GB001548	2014 Cefas Morte Platform rMCZ Subtidal Verification Survey	NE	Survey	82	
GB100239	2007 Marine Benthic Biotope Mapping of Sedimentary Environments, Lundy Marine Protected Area	NE	Survey	78	
GB000227	Broad scale biological mapping of Lundy Marine Nature Reserve with particular reference to reefs	EMODnet MSM	Survey	77	
D_00001	2011 Atlantic Array Benthic Ecology Characterisation Report - (D_00001) - JER4290_AA_Benthic_CombinedBiotopes_RPS_110721_A	NE	Survey	59	
GB100335	2014 ERCCIS North Cornwall Biotope Mapping Cornwall Wildlife Trusts - Intertidal Discovery Project	NE	Survey	49	
GB000579	The distribution of sublittoral macrofauna communities in the Bristol Channel in relation to substrate	NE	Survey	47	
GB000284	MNCR Area Summaries - Inlets in the Bristol Channel and approaches	EMODnet MSM	Survey	42	
GB001072	Intertidal mudflats layer for England	EMODnet FSM	Survey	36	
GB001070	Futurecoast	EMODnet FSM	Survey	NA	
EUSM16aa	EUSeaMap 2016	EMODnet	Modelled	NA	
EUSM2012	EUSeaMap 2012	EMODnet	Modelled	NA	

4.2 Review and assessment of provision of ES from Natural Capital in NDMP (matrix assessment)

4.2.1 Method

Habitat Assets: Level of provision from each NDMP habitat of each intermediate service and the goods and benefits identified in the NEA FO ecosystem service classification framework (Figure 5) were assessed. The approach built on previous matricies of level of provision of ES from UK marine habitats (Saunders et al. 2015; Potts et al. 2014; Fletcher et al. 2012). Literature between 2014 and 2017 on provision of ES from marine and coastal habitats was reviewed to identify any updated evidence for supply of ecosystem services from marine habitats. Wider relevant studies from both peer and grey sources were reviewed to support the matrix results. The extent (km^2) of each habitat occurring within NDMP, within designated MPAs, and the extent (km^2) of each habitat with a management measure associated with it (i.e. habitat extent in an MPA with a byelaw, such as bottom towed fishing gear restrictions) were calculated from the spatial habitat layer, in ARC GIS (Figure 7). The calculation only takes into account measures designed to reduce adverse effects on habitats in MPAs and thus, only includes IFCA byelaws. Seasonal closures and voluntary agreements to reduce fishing pressure on commercial species were not included, as condition assessments and monitoring have not been undertaken to for these sites. Potential further benefits from voluntary closures are important to consider when interpreting these results, and in relation to future management.

Species Assets: The relationship of fish and shellfish species of commercial importance and conservation importance, to the habitats within NDMP, the food resources available and the season they occurred were reviewed. Associations with juvenile or reproduction (spawning) life history stages were recorded for species where appropriate. The results of the review were summarised in a table.

4.2.2 Results

Habitat Assets: Review of evidence on provision of ecosystem services (intermediate services and ES goods/benefits) from habitat features in the NDMP, identified significant contribution of multiple ES from the habitat features within NDMP (Table 2). In particular, there is high provision of Goods/Benefits from: 1. Provisioning services of Food, 2. Regulating services of i) Healthy climate, ii) Prevention of coastal erosion, iii) Sea defence, 3. Cultural services of i) Tourism/nature watching, ii) Aesthetic benefits (Table 2).

Table 2 Matrix assessment of provision of intermediate services and Goods / Benefits (UK NEA FO) from habitats in NDMP, including habitat features of MPAs (building on Potts et al. 2014; Saunders et al. 2015)

	Natural Capital Asset: Habitats in North Devon Marine Pioneer	Area (km²)	Area in MPAs (km²)	Area in management measure (km²)	**Intermediate services**											**Goods / Benefits**													
					Supporting services							Regulating services				from Provisioning services					from Regulating services					from Cultural services			
					Primary production	Larval / Gamete supply	Nutrient cycling	Water cycling	Formation of species habitat	Formation of physical barriers	Formation of seascape	Biological control	Natural hazard regulation	Regulation of water and sediment quality	Carbon sequestration	Food	Fish feed	Fertiliser (and biofuels)	Ornaments (incl. Aquaria)	Medicines and blue biotechnology	Healthy climate	Prevention of coastal erosion	Sea defence	Clean water and sediments	Imobilisation of pollutants	Tourism/nature watching	Spiritual / cultural wellbeing	Aesthetic benefits	Education
Coastal margins	Saltmarsh	2.80	2.01	0.62	2	3	3		3	3	3		3	3	3	3		3			3	3	3	3	3	3	1	3	1
Coastal margins	B3.1: Supralittoral rock (lichen or splash zone)	0.85	0.58	0.00																									
Marine	A1: Littoral rock and other hard substrata	11.31	10.42	1.02																									
Marine	A1.1: High energy littoral rock	5.73	5.21	0.00	3	2	3		2	1	1		1		2	3					2	1	1			1	1	1	1
Marine	A1.2: Moderate energy littoral rock	2.98	2.83	0.03	3	2	3		2	1			1		2	3					2	1	1			1	1	1	1
Marine	A1.3: Low energy littoral rock	1.69	1.52	0.98	3	2	3		2	1			1		2	3					2	1	1			1	1	1	1
Marine	A1.4: Features of littoral rock	0.38	0.37	0.01																									
Marine	A2: Littoral sediment	29.31	22.03	9.22																									
Marine	A2.1: Littoral coarse sediment	0.76	0.61	-	1	3	1		3	1	1		3			1						3	3			1	1	1	1
Marine	A2.2: Littoral sand and muddy sand	14.99	14.56	4.21	3	3	3		2	1	3		3		2	1					2	3	3			1	1	3	1
Marine	A2.3: Littoral mud	9.98	4.27	4.27	3	3	3		1		1		3	3	3	3					3	3	3	3	3	1	1	1	1
Marine	A2.4: Littoral mixed sediments	0.45	0.33	0.03	3	3	3		2	1	1		3		2	1					2	3	3			1	1	1	1
Marine	A2.7: Littoral biogenic reefs	0.01	0.01	-	1	1	2		3		1		2	1	1	2					1	2	2	2	2	1	1		1
Marine	A2.8: Features of littoral sediment	0.03	0.03	-																									
Marine	A3: Infralittoral rock and other hard substrata	17.27	12.51	4.91																									
Marine	A3.1: Atlantic and Mediterranean high energy infralittoral rock	11.19	7.43	0.23	2	2			2	1			1		2	3					2	1	1			1	1		1
Marine	A3.2: Atlantic and Mediterranean moderate energy infralittoral rock	2.12	1.21	0.79	2	2			2	1			1		2	3					2	1	1			1	1		1
Marine	A3.3: Atlantic and Mediterranean low energy infralittoral rock	0.07	-	-	2	2			2	1			1		2						2	1	1			1	1		1
Marine	A3.7: Features of infralittoral rock	0.00	0.00	-																									
Marine	A4: Circalittoral rock and other hard substrata	875.90	180.76	9.17																									
Marine	A4.1: Atlantic and Mediterranean high energy circalittoral rock	476.58	173.89	1.81	2	2			2	1			1			1						1	1			1	1		1
Marine	A4.2: Atlantic and Mediterranean moderate energy circalittoral rock	393.68	1.26	1.73	2	2			2	1			1			1						1	1			1	1		1
Marine	A5.1: Sublittoral coarse sediment	2,845.22	175.73	8.56	3	3	3		3				3	1		2	3					3	3	3	1		1		1
Marine	A5.2: Sublittoral sand	1,690.03	52.81	4.50	3	3	3		3				3	1		2	3					3	3	3	1		1		1
Marine	A5.3: Sublittoral mud	10.85	0.21	-	3	3	3		3				3	1		2	3					3	3	3	3		1		1
Marine	A5.4: Sublittoral mixed sediments	48.56	2.04	-	3	3	3		3				3	1		2	3					3	3	3	3		1		1
Marine	**EUNIS >Level 3**																												
Marine	Intertidal underboulder communities [A1.2142, A3.2112]	0.029	0.029	-	1	1			2				1			2						1	1			1	1	1	1
Marine	Littoral chalk communities [B3.114, B3.115, A1.441, A1.2143]	0.002	0.002	-	1	1			3																	1	1		1
Marine	Honeycomb worm, *Sabellaria alveolata* reef [A2.71, A2.711, A5.612]	0.004	0.004	-		1	1		3	1		1	2	1	1	1					1	1	1	1	1	1	1		1
Marine	Tide-swept algal communities (L.hyperborea) [A3.126, A3.213,]	0.680	0.670	0.67	1	1	1		1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1
Marine	Fragile sponge & anthozoan communities on subtidal rocky habitats [A4.12, A4.121, A4.131, A4.1311, A4.1312, A4.133, A4.211, A4.2111, A4.2112]	-	-	-		1			3			1				3									1	3	1		1
Marine	N/A Areas of high planktonic primary productivity	TBD	TBD	TBD	3	1	3		1	1		1	1		2	2	3				2	1	1	1	1	1	1		1

# Significant contribution	3 Peer reviewed literature
# Moderate contribution	2 Grey / overseas literature
# Low contribution	1 Expert opinion
# No or negligible contribution	Not assessed
Not assessed	

Coastal saltmarsh, and **tide swept algal communities** associated with **infralittoral reef** provide significant contribution to multiple ecosystem services, with confidence in the association greatest for saltmarsh (Table 2).

Of the entire spatial extent of habitats within NDMP, 8.3% are contained within MPAs. At present (2017/18), 7.1% of habitat features in MPAs interact with management measures that reduce benthic disturbance (e.g. in relation to Lundy fishing restriction byelaws (Annex I)). Out of the entire spatial extent of habitat within NDMP, 0.6% of the habitat assets interact with management measures that reduce benthic disturbance (Table 2) (Annex I).

In respect to habitats that were identified to have significant contributions to multiple ES; 71.8% of saltmarsh (A2.5) extent within NDMP is also within MPAs (including intertidal components of SSSI), 30.8% of saltmarsh extent in MPAs has management measures associate with it (IFCA Fishing Restriction Byelaws, Taw Torridge) (Table 2). For tide swept algal communities, that deliver moderate or significant provision of multiple ES 99.2% of the known extent is contained within MPAs, and 100% of this extent is associated with management measures restricting fishing activity (Table 2).

Saltmarsh provide significant benefits to ES benefits of 'healthy climate,' 'clean water and sediments,' (Burden *et al.*, 2013; Chmura *et al.*, 2003 ; Jones *et al.*, 2011). Chmura *et al.* (2003) calculated saltmarsh habitats provided a carbon sequestration value of 210 C m^{-2} yr^{-1}, while Cannell et al. (1999) calculated sequestration from UK saltmarshes to be 0.64–2.19 t C/ha/yr (Cannell *et al.*, 1999). Vegetation within saltmarsh has the ability to baffle water currents and stabilize sediments, resulting in organic matter and nutrients becoming stored within the accreting sediments, sequestering carbon, nitrogen and phosphorous, while the remaining organic material is recycled or exported (Burden *et al.*, 2013; Coverdale *et al.*, 2014). The flood water storage and attenuation of water currents and wave energy provided by saltmarsh also delivers significant benefits to natural hazard regulation (Jacobs, 2013; Potts et al, 2014). Shelter and food availability within the three dimensional structure of saltmarsh vegetation during high tide, provides significant benefits to juvenile fish species (Laffaille, Feunteun & Lefeuvre, 2000).

Reef habitats in the infralittoral zone (mean low water to a depth where only 1% of light reaches the seabed (JNCC, 2010)) (A3), deliver significant provision of intermediate services: formation of species habitat. Goods / benefits provided include food (significant provision), healthy climate (carbon sequestration), prevention of coastal erosion, sea defence, and tourism nature watching (moderate provision). Of 17.3km² of infralittoral reef habitat in NDMP, 72.4% is within MPAs and 39.2% of that extent interacts with MPA management measures. Algae communities such as kelp *Laminaria spp.*

communities, associated with infralittoral reef provide a high contribution to productivity, species habitat, carbon sequestration and sea defence benefits in comparison with other NDMP habitats (Smale, 2015; Smale *et al.*, 2013; Smale, Wernberg & Vance, 2011).

Kelp communities provide shelter for juvenile stages of commercially targeted fishes, crustaceans and bivalve molluscs (Gonzalezgurriaran & Freire, 1994). Canopy-forming kelps influence their environment and other organisms, thereby functioning as "ecosystem engineers" (Smale *et al.*, 2013; Smale, Wernberg & Vance, 2011). Kelp holdfasts, the attachment between kelp and reef features, provide food resources for flatfish, sea bass and gadoid species (Jones, 2000; Snelgrove, 1999). By altering light levels (Connell, 2003), water flow (Rosman *et al.*, 2007), physical disturbance and sedimentation rates (Eckman, Duggins & Sewell, 1989; Wernberg & Thomsen, 2005), kelps, thereby, modify the local environment for other organisms and provide benefits related to the ES: 'natural hazard protection'. Moreover, through direct provision of food and structural habitat, kelp forests support higher levels of biodiversity and biomass than simple, unstructured habitats (Dayton, 1985; Dayton *et al.*, 1999; Steneck *et al.*, 2002). Healthy climate ES benefits are supported by Kelp communities *Laminaria spp.* role as fuels for marine food webs, through the capture and export of carbon (Dayton, 1985; Krumhansl & Scheibling, 2012).

Broad scale habitats associated with reef features (Eunis A3, A4), provide surfaces for epibiota such as corals and sponges to attach. Habitat and species features of Hartland Point to Tintagel MCZ and Bideford to Foreland Point MCZ (e.g. Fragile sponge and anthozoan communities on subtidal rocky habitats and pink sea fan) provide complexity and shelter resources for commercially targeted fish and shellfish (Bradshaw, Collins & Brand, 2003; Lindholm, Auster & Valentine, 2004; Lindholm *et al.*, 2001). Sessile epifauna, that colonise reef features, capture and recycle water column nutrients through filter feeding and produce planktonic larvae (Beaumont *et al.*, 2007), further supporting higher trophic levels, which includes fish and shellfish species (Sheehan *et al.*, 2013). Biodiveristy related to reef features supports fishing activities and recreational diving/nature watching (Broszeit *et al.*, 2017).

Littoral sediments (A2.1 to A2.4) were identified to deliver moderate or significant provision of ES including; Formation of species habitats, food, carbon sequestration (healthy climate) and natural hazard regulation linked to sea defence and prevention of erosion. For combined littoral sediment habitats (A2.1 to A2.4), 75.5% of the extent within NDMP are contained within MPAs. This results in 43% of littoral sediments interacting with management measures within MPAs. Currently, in NDMP littoral sediments are not directly protected by byelaws, but occur in areas where byelaws protect other MPA features (Annex I). As a result not all soft substratum habitat types interact with management measures. For example, none of the extent of littoral coarse sediment, that provides moderate levels of the ES; ‘formation of species habitat’ and ‘natural hazard regulation’ has management measures associated with it, despite 80.2% of the extent of coarse sediment being contained within MPAs.

Littoral (intertidal) sediments, such as littoral mud provide high biological productivity and abundance of organisms, that provide food resources for fish, shellfish and wildfowl (Maddock, 2008). Littoral sediment habitats also dissipate wave energy, thus reducing the risk of damaging coastal defences and flooding low-lying land (Maddock, 2008). Alonso *et al.* (2012), report levels of carbon sequestration in littoral mud sediments within the UK (16 g C m-2 yr-1) and Andrews, Samways and Shimmield (2008) report littoral mud habitat, adjacent to salt marsh in the Humber estuary, UK provides high accretion and burial of organic carbon. There is, however limited evidence for actual levels of carbon sequestration for littoral sediment habitats for the NDMP site. Littoral mud was reviewed to provide good provision of ES goods / benefits: ‘healthy climate’ (carbon sequestration), ‘clean water and sediments’ and ‘immobilisation of pollutants’ as well as ‘food’ (Table 2). All littoral mud habitat in NDMP was within MPA boundaries and 42.8% was associated with MPAs with management measures that restrict fishing activity.

Littoral biogenic reefs: The known extent of Honeycomb worm *Sabellaria alveolata* reef present in data sources for NDMP is all within MPAs, but no management measures are currently associated with the habitat (Table 2). These habitats are, however, within recently designated MPAs (2016) and HRA assessments in relation to fishing activity management requirements are being undertaken (IFCA). Adequate management for *S. alveloata* reef is important as *S. alveloata* is considered an ecosystem engineer, building large biogenic reef structures, which shelter a high number of species. Small-scale topographic environmental complexity creates numerous spatial and trophic niches for colonisation by other invertebrates (Dubois *et al.*, 2006). Fish and crustacean species, including those supporting recreational and commercial fisheries find food resources amongst *S. alveloata* reefs. Large extents of *S. alveloata* reef also form physical structures that aid the ES: natural hazard regulation, as features reduce sheer stress, slow water currents and reduce wave heights, thus reducing erosion in coastal regions (Jacobs, 2013; Potts et al, 2014).

Subtidal sediments (A5.1 to A5.4) cover the greatest extent of all the habitat assets in NDMP, particularly sublittoral coarse sediment (2,845km^2) and sublittoral sand (1,690km^2). All subtidal sediments in NDMP provide significant provision of food resources for fish with high confidence in the association (Table 2). All subtidal sediments supply moderate provision of ES good / benefit of clean water and sediments. Sublittoral mud and mixed sediments also supply moderate provision of

ES good / benefit: immobilisation of pollutants. Only 5% subtidal sediments are contained within MPAs and only 5.7% of subtidal sediments in MPAs interact with management measures. The 'recover' objective for subtidal sand and subtidal coarse sediment in Hartland Point to Tintagel MCZ provides an opportunity to increase this percentage.

Bottom towed fishing activity (trawl and dredge), mooring and anchoring of large vessels and aggregate extraction are activities that may adversely impact subtidal sediment communities, and provision of food resources for fish. In the subtidal, formation of species habitat is strongly influenced by sediment type, with particle size distribution, organic content and chemical composition of importance to species distribution. Stability is provided by the presence of species such as Sand mason *Lanice conchilega* (Van Hoey *et al.*, 2008), and habitat complexity is increased where benthic fauna are diverse and abundant due to the presence of tubes and burrows (Paramour, 2006). Intensive bottom fishing using towed nets and dredges has been shown to alter species composition in soft substratum seabed habitats, removing high biomass species contributing to topographic complexity (Kaiser *et al.*, 2000). Experimental trawling has shown *Lanice conchilega* in particular are impacted by bottom towed fishing gears (Rabaut *et al.*, 2008). Although interaction with byelaws are limited, seasonal closures to fishing activity in NDMP do interact with extent of subtidal sediments.

Bioturbation (biogenic modification of sediments through particle reworking and burrow ventilation) by benthic organisms living within soft substratum habitats provides a mechanism for nutrient cycling (Queirós *et al.*, 2013). Through burial and release of pollutants, behaviour traits of bioturbating organisms also influence the provision of clean water and sediment ES benefits (Queirós *et al.*, 2013).

Species Assets: Habitat, prey and seasonal associations of fish, cephlapod and shellfish species of key commercial and conservation importance in NDMP are summarised in Table 3 (a review of supporting evidence is provided in Annex III). Table 3 displays the importance of saltmarsh habitat as nursery areas to 6 of the 18 species that are either commercially targeted, or are species of conservation importance. The importance of reef habitat to the intermediate service of *formation of species habitat* can be seen by the moderate or significant use of this habitat by 14 of the 18 species (Table 3). The large proportion of infralittoral reef habitats currently within MPAs in NDMP (72.4%) will potentially provide benefits to species of commercial and conservation importance. Continued condition assessment will be beneficial to assess if the current extent with management features associated with the habitat is sufficient (39.2%). Lundy fishing activity restriction byelaws currently interact with infralittoral reef habitat. A much smaller proportion of circalittoral reef (from 1% of light to 200m) in NDMP is within MPAs (20.6%) and of this only 5% interacts with management measures. The ‘recover’ objective associated with cicalittoral reef in Hartland Point to Tintagel MCZ (Annex I), suggests further reef features require management measures within NDMP.

Sublittoral (subtidal) coarse and mixed sediments and sublittoral (subtidal) mud and sand habitats are also important to supporting fish and shellfish species populations in NDMP. As only 5% of subtidal sediments (A5.1-5.4 combined extent) are contained within MPAs and only 5.7% of subtidal sediments in MPAs interact with management measures, there is a risk the habitats may be in adverse condition and not providing maximum benefits to food resources for fish and other ES provision identified. Extent and condition data for sublittoral soft sediments within NDMP are largely based on modelled data resources (Figure 7, Figure 8). Verifying the extent of each subtidal sediment (A5.1-A5.4) and assessing condition, would benefit management decisions and ensure habitat and food resources for fish species are maximised. Surveys, fisher-science partnerships, or assessing interaction with activities that may adversely impact habitat condition provide potential means of achieving this.

Small areas of other subtidal sediments interact with Lundy fishing and activity restriction byelaws. As subtidal sediments have a conservation objective or ‘recover’ in Hartland Point to Tintagel MCZ (Annex I), further management measures are likely within NDMP.

Table 3 Importance of NDMP habitats, food resources and seasons to key commercial fish species and species of conservation importance in NDMP. Blank cells indicate low or no association, grey indicate a moderate contribution, dark grey indicate a significant contribution (jv. Importance to juvenile life stage, spn. Indicates importance to spawning)

Habitat interactions		Key commercial species of the North Devon fishery (D&S IFCA)																	
		Buccinum undatum	*Cancer pagarus*	*Homarus gammarus*	*Maja squinado*	*Palinurus elephas*	*Sepia officinalis*	*Loligo vulgaris*	*Alloteuthis subulata*	*Clupea harengus*	*Dicentrarchus labrax*	*Gadus morhua*	*Solea solea*	*Pleuronectes platessa*	*Raja clavata*	*Raja brachyura*	*Raja microocellata*	*Pecten maximus*	*Aequipecten opercularis*
Broadscale habitats (EUNIS level 3) present in North Devon Marine Pioneer	Coastal saltmarshes and saline reedbeds (A2.5)									jv.	jv.	jv.	jv.	jv.	jv.				
	High Energy, Moderate Energy and Low Energy Infralittoral Rock (A3.1, 3.2, 3.3)											jv.			jv.			jv.	jv.
	High Energy, Moderate Energy, Circalittoral Rock (A4.1, 4.2.)											jv.						jv.	jv.
	Sublittoral Coarse Sediment (A5.1)			jv.						spn.									
	Sublittoral Sand (A5.2)			jv.															
	Sublittoral Mud (A5.3)			jv.															
	Sublittoral Mixed Sediments (A5.4)																		
Prey resources supporting commercial species (food web interactions)																			
Food web interactions (bottom up)	Phytoplankton																		
	Zooplankton											jv.							
	benthic fauna (polychaeta)																		
	benthic fauna (crustacea)																		
	benthic fauna (mollusc)																		
	benthic fauna (fish)																		
Seasonal presence of species within North Devon Marine Pioneer site																			
Season	Winter											spn.		spn.					
	Spring												spn.		spn.				
	Summer														spn.				
	Autumn									spn.									

4.3 Key findings

Coastal saltmarsh and saline reed beds, and tide swept algal communities provide significant contribution to multiple ecosystem services, with confidence in the association greatest for saltmarsh (Table 2). Reef features provide a significant contribution to species habitat and the good/benefit of 'food' (fisheries) (Table 2). Subtidal sediments, provide contribution to the intermediate ES: 'formation of species habitat', 'food resources for fish', 'nutrient cycling' and muddy sediments in particular contribute to ES goods/benefits of 'clean water and sediment' and 'immobilisation of pollutants'. Habitats within NDMP also provide good or significant benefits to 'tourism/nature watching' and associated recreational activities (Table 2Table 3).

The importance of coastal saltmarsh as nursery habitat to bass, herring, cod, sole, plaice and thornback ray indicates this habitat is important in maintaining populations of these commercially important species (Table 3; Annex III). Shallow coastal marine habitats are recognised to be of greatest importance to juvenile fish species (Perry, Staveley & Gullström, 2018), highlighting the importance of maintaining condition of coastal habitats in favourable condition.

NDMP contains spawning grounds for multiple commercially important species including; cod (winter), sole (spring), plaice (winter), thronback ray (spring and summer), and herring (autumn) (Table 3) (Ellis *et al.*, 2012). The occurrence of different species at this important life history stage, indicates the value of the NDMP, in supporting food and fisheries benefits. Condition of the habitats and water quality within the NDMP is essential in relation to supporting species populations, throughout life stages. For instance, inshore coarse sediment is of importance to herring as this habitat supports spawning grounds, while saltmarsh and shallow subtidal habitats provide nursery areas in NDMP. Maintaining favourable condition of coarse sediments, saltmarsh and other shallow subtidal habitats, as well as water quality of water bodies ensures populations of herring are supported at every life stage. **Shallow subtidal features within Hartland Point to Tintagel MCZ and subtidal sand in Bideford to Foreland Point MCZ have conservation objectives of 'recover'. Identifying management options to restore these habitats to favourable condition will benefit multiple ES, particularly habitat provision for juvenile and adult fish and shellfish.**

Deeper subtidal sediment and reef habitats in NDMP provide habitat and specifically food resources for skate and ray species of commercial importance and species of conservation importance such as Common skate (Table 3). **Subtidal sediment habitats are within voluntary, seasonal fishing activity closures, but only a low percentage (5%) of these habitats interact with management measures to reduce benthic disturbance.** The importance of these habitats to regulating services (clean water and sediments, immobilisation of pollutants benefits) indicates their importance to the broader NDMP ecological system and relationship to water quality and tourism and recreation benefits. To effectively provide ES benefits, these habitats need to be in favourable condition. **As larger extents of subtidal sediment habitats currently overlap with voluntary fishing gear closures than byelaws, there are opportunities to investigate potential for fisher-science partnerships to monitor effectiveness of closures on fish stocks and the habitats that support the stocks.**

Ensuring favourable condition across inshore habitats and all water bodies also maximises the provision of goods/services related to cultural activity, such as tourism or nature watching, and recreational water sports and bathing. Species such as harbour porpoise, grey seal and Atlantic salmon also provide a good or significant contribution to tourism and nature watching goods/benefits, while biodiversity of reef habitats is recognised as indicating quality of the resource to recreational divers (Broszeit *et al.* 2017).

Many MPAs in NDMP have only recently been designated (as of 2017/2018) and, as such, only 7.1% of extent habitats within MPAs have management measures associated with them. In relation to provision of all ecosystem services, saltmarsh, littoral sediments, tide swept algal communities and infralittoral reef features were assessed as having significant contributions to provision of multiple ES (intermediate services and goods/benefits). Although >70% of each of these habitats are within MPAs and 30-43% of the habitat extent within MPAs interact with management measures for activities that adversely impact benthic habitats the management measures currently target reef and spiny lobster. **Management measures (such as restriction on bottom towed fishing activity) reduce pressures from activities for all benthic habitats within the MPA/byelaw extent. As such, it will be beneficial to monitor effect of the management activities on all habitats within the byelaw extent as well as the main feature of interest.**

I**n intertidal (littoral) zones, byelaws restricting boat based fishing activity are unlikely to be effective for littoral habitats at low tide.** Activities that may have adverse effect on these habitats and so provision of ES include bait digging and crab tiling. Littoral sediment communities have some resilience to bait digging if spatial and temporal frequency are low, but regular, extensive bait digging and crab tiling activity is likely to lead to adverse effects on species communities (Carvalho *et al.*, 2013; Sheehan *et al.*, 2010). Voluntary codes of conduct exist in the Taw Torridge estuary for bait digging and crab tiling. **The Taw-Torridge estuary Management Plan 2010-2015 identified the need to re-investigate the location of the crab tiling zones and bait digging areas, update the code maps and ensure information was advertised well (North Devon AONB, 2010). Ensuring these**

management activities are continued and code of conducts taken up, will benefit provision of ES from littoral sediments.

Anchoring and mooring at high intensity are also likely to adversely impact species communities in soft sediment habitats (Latham *et al.*, 2012). Recreational boating is an important activity in the region, supporting tourism and nature watching ES and recreational fishing (North Devon AONB, 2010). **Voluntary no-anchor zones, and instillation of eco-moorings in place of single block and chain, sub-tidal, permanent moorings provide more sustainable management solutions where activity interacts with sensitive habitats.**

Circalittoral rock, subtidal coarse sediment, subtidal sand and fragile sponge and anthozoan communities within Hartland Point to Tintagel MCZ and subtidal sand in Bideford to Foreland Point MCZ have conservation objectives of 'recover' (Annex I). It will be important to ensure management measures to enable recovery for these features to favourable condition are effective, to ensure maximum provision of ES goods/benefits associated with them. **Ensuring all habitats that support species across life stages are in favourable condition will benefit the goods/benefits associated with food provision, tourism and recreation ES, and the activities and value associated with them.**

5 How stakeholders are linked to natural capital in North Devon

Assessments of the impacts of activities on natural capital often focus on the economic sectors that place direct pressure on marine ecosystems or stakeholders who directly benefit from the exploitation of the natural capital assets or stocks. To effect large-scale transformations in how the natural environment is managed it is necessary to place natural capital and ecosystem services into the broader decision making context (Guerry *et al.*, 2015). In any given location, there is a range of stakeholders who exert influence over natural capital. The identification of the wide range of stakeholders linked across the value chain to the natural capital assets supports the process for the identification of shared responsibilities and solutions for the sustainable use.

5.1 Method

1. To test this approach for North Devon two key ecosystem services that are linked to the local economy were selected 1) Fisheries and aquaculture and; 2) Recreation and tourism.
2. Using literature review and meetings with key local stakeholders the main activities within the economy that are linked directly or indirectly to natural capital were identified and mapped in a synthetic way in order to have a global view of systems components, interactions and activities. The lists of stakeholders identified at this stage are not considered exhaustive. They are illustrative of the range of stakeholders linked to natural capital.
3. Linked stakeholders were identified from Guilbert et al (2017) and subjectively categorised according to the following typology (adapted from (Sundblad *et al.*, 2014)):
    - Direct stakeholder: individuals or organizations who directly exploit the natural capital assets or stocks.
    - Indirect stakeholder: individuals or organizations influencing the exploitation of natural capital by using products or services linked to natural capital (flows)
    - Supporting stakeholder: services provided by various actors who never directly deal with natural capital but support the value chain.
    - Governance stakeholder: Regulatory framework, policies, infrastructures. People, organizations and institutions responsible for setting up and managing the regulatory framework for natural capital.
    - Influence stakeholders: Groups or individuals who influence how natural capital is used and/or managed.

5.2 Results

Fisheries

A full review of the market and supply chain for fish caught and landed in North Devon was undertaken in 2013 for the North Devon Fisheries Local Action Group (FLAG) (ABP MER, 2013). In 2013 landings into North Devon ports (Ilfracombe, Appledore, Bideford and Clovelly) were valued at £2.1 million per year representing a landings weight of 1,350 tonnes per year (ABP MER, 2013). Landings of Skates and Rays represented £600,000 of this value. In 2014, a ban was implemented on the Ray fishery leading to a decline of this fishery in North Devon. In 2016, landings into North Devon ports were valued at £1.5million per year representing a landings weight of 945 tonnes per year (MMO 2017) (Table 4). Landings of whelk are the most valuable species with 603 tonnes landed into North Devon ports in 2016 representing £726k in landings value (Table 4).

Table 4: 2016 landings into North Devon Ports. Represented as sum of live weight, landed weight and value (Source MMO 2017)

Row Labels	Sum of Live Weight (tonnes)	Sum of Landed Weight (tonnes)	Sum of Value(£)
Bass	10.741	10.733	83843.920
Brill	0.427	0.396	2366.480
Cod	2.177	1.866	5063.510
Conger Eels	1.503	1.336	1297.700
Crabs	47.940	47.709	57247.280
Cuttlefish	0.089	0.089	185.440
Dabs	0.004	0.004	2.840
Dogfish	63.730	63.597	12206.130
Fish Roes	0.057	0.057	55.700
Flounder or Flukes	0.371	0.362	178.170
Gurnard	1.164	1.160	1207.900
Haddock	2.236	1.914	3028.780
Hake	0.012	0.011	19.400
Herring	0.078	0.078	166.740
Lemon Sole	0.174	0.167	555.610
Ling	0.047	0.042	48.680
Lobsters	25.965	25.965	287896.320
Mackerel	0.167	0.167	471.890
Megrim	0.001	0.001	3.800
Monks or Anglers	0.344	0.117	1136.010
Other Demersal	25.441	23.462	12916.590
Plaice	3.777	3.604	4115.830
Pollack (Lythe)	0.874	0.752	1473.840
Saithe	0.013	0.011	10.140
Scallops	9.486	9.486	21702.750
Skates and Rays	217.796	142.951	304715.930
Sole	4.297	4.101	35454.240
Squid	0.392	0.392	2305.970
Turbot	1.033	0.955	8179.400
Whelks	603.239	603.239	725768.480
Whiting	1.019	0.866	523.480
Witch	0.001	0.001	1.440
Grand Total	**1024.596**	**945.589**	**1574150.390**

Figure 9 demonstrates the links between natural capital in North Devon and the stakeholders linked to fisheries. The direct beneficiaries of natural capital are the fishermen who exploit the natural resource for capital gain. The majority of the North Devon landings are sold to processers and traders. These sales are not limited to North Devon with traders arranging transport for seafood landed from North Devon ports to the wider market (regional to international). A small amount of catch (fishermen using pots and day boat landings) is sold directly to the consumer market (restaurants). Primary processors located in North Devon will source directly from local landings but the majority of seafood for processing is sourced from outside the region and then sold to national and international markets. Most seafood landed in North Devon is destined for sale outside the region. It is reported that North Devon fishmongers source 58% of seafood from outside the region and restaurants source 64% of seafood from outside the region (ABP MER, 2013). The value added to landings was estimated to be between £7.9million and £16.1million per year (ABP MER 2013). There are a wide range of governance stakeholders who have influence over Natural Capital linked to fisheries (Figure 9). Financial input is required from central government to fund these organisations to effectively carry out their duties. There are also several influence actors who are linked to natural capital via research, advisory and consultancy and conservation groups. It must be noted that research is also undertaken by governance stakeholders e.g. the IFCA and CEFAS as part of their duties.

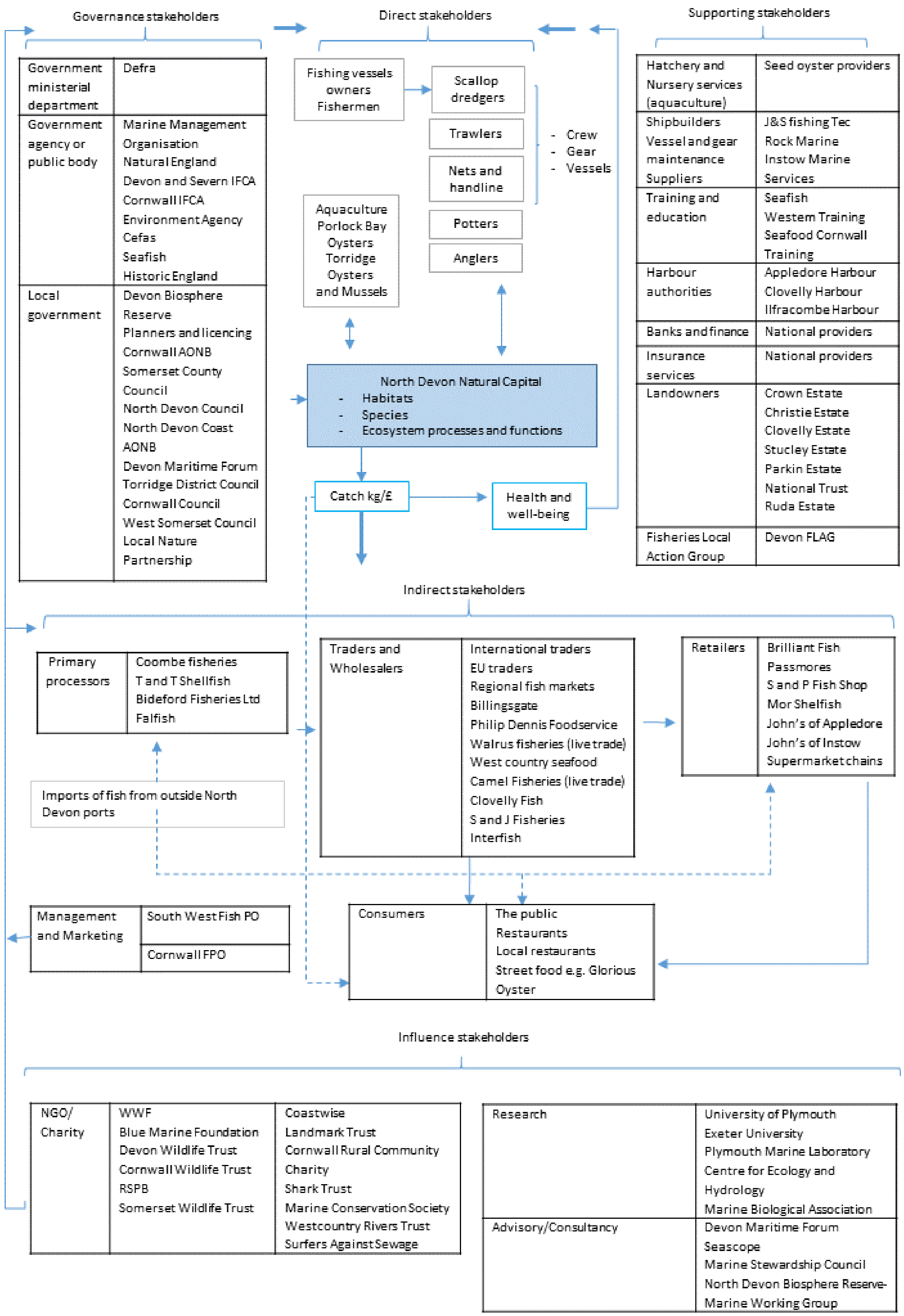


Figure 9: North Devon Fisheries: The links between stakeholders and natural capital.

Recreation and Tourism

The ecosystem service benefit of recreation and tourism in North Devon is linked to the marine environment though the activities and businesses associated with watersports and coastal recreation. In 2009, the watersports sector in North Devon employed over 2000 staff and generated an estimated 80 million in turnover (NEA 2009). In a separate study the North Devon surfing economy was valued at £52.1million per year associated with approximately 42,000 surfers (Trisurf 2007). Figure 10 demonstrates the links between natural capital in North Devon and the stakeholders linked to recreation and tourism. The direct beneficiaries of natural capital are individuals who take part in recreation activity (e.g. surfing, kayaking) and businesses who rely on the presence and quality of natural assets as the foundation for their business activities. There are a wide range of governance and supporting stakeholders whose activities facilitate the flow of benefits from natural capital to those direct and indirect stakeholders. These stakeholders either receive funding from central government sources (e.g. Natural England), are charitable organisations (e.g. RNLI) or are private enterprise (e.g. banks). Indirect stakeholders (e.g. tourism associated businesses) also benefit from the expenditure and turnover from the direct stakeholders though they often have no direct association with the natural resource.

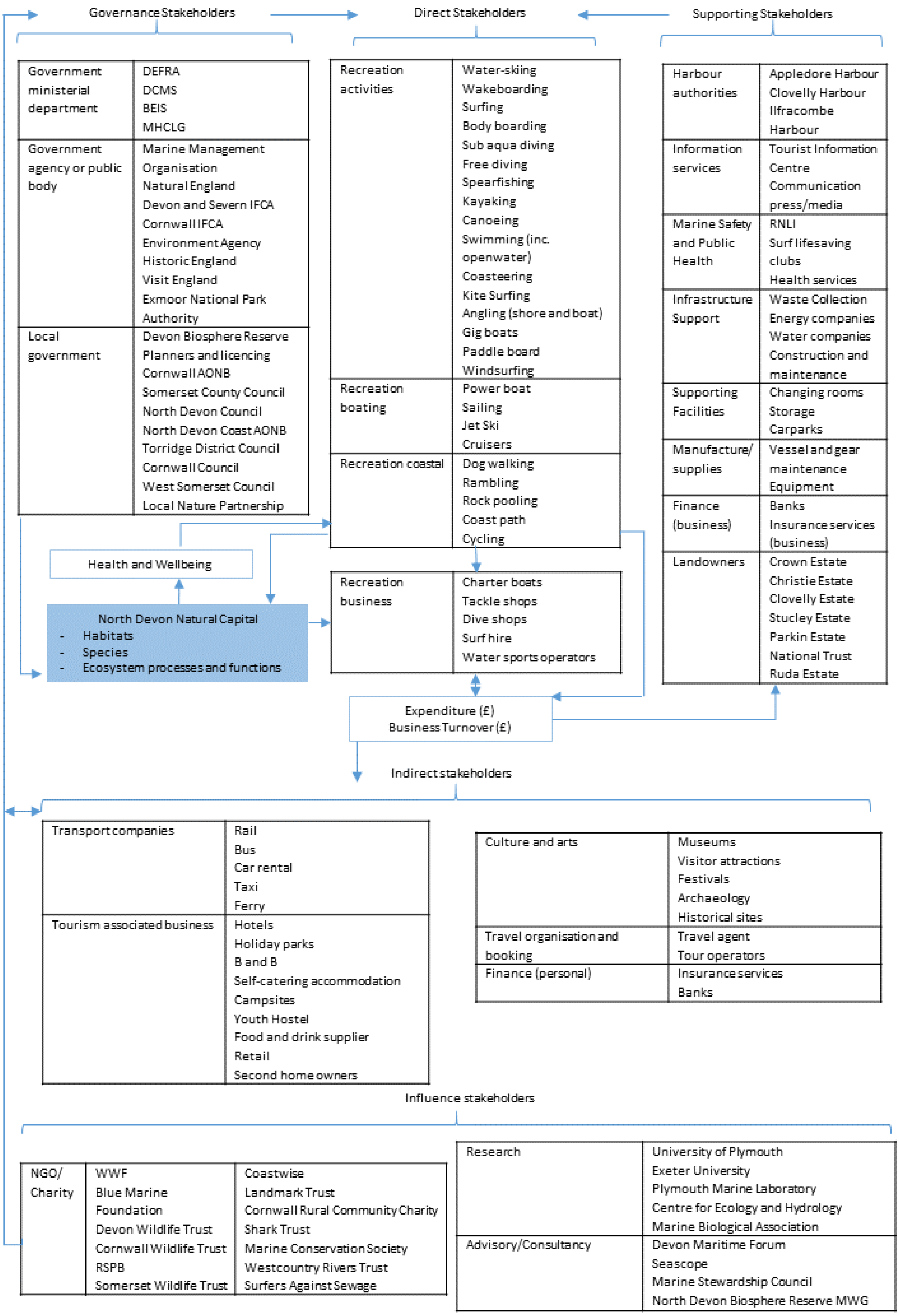


Figure 10 North Devon Recreation and Tourism: The links between stakeholders and Natural Capital.

5.3 Key findings

This review demonstrates that there are a wide range of stakeholders who can potentially exert influence over natural capital in North Devon. Traditional approaches to marine management have often focussed on the economic sectors that directly benefit from the natural assets and the governance actors who manage the natural asset and levels of exploitation. This review encourages wider consideration of the indirect and supporting actors who facilitate stakeholders' ability to access the resource and (in some cases) financially benefit from an indirect association with the natural asset. For example, North Devon landowners benefit from recreation and tourism via car parking levies and expenditure at locally owned businesses.

The UKSEAS project focusses on the role of Marine Protected Areas (MPAs), more specifically MPA management to secure a sustainable future for linked industries, communities and nature. The key ecosystem services considered here fisheries, recreation and tourism are partially linked to MPA management and effectiveness. A potential next step for WWF would be **to focus on key segments of the value chain to link more strongly to natural capital protected by MPA management measures.** For example, the lobster fishery is strongly linked to the MPAs that protect reef habitat. Spiny lobster in particular is a protected species with North Devon MPAs with no management measures, other than gear and activity restrictions for sites at Lundy, currently in place and an emerging market.

From a perspective of sustainable management of natural capital across the Marine Pioneer, it is necessary **to demonstrate a hierarchy of stakeholders' impact/proximity and influence/power on natural capital and to work with stakeholders to identify shared responsibilities and solutions for sustainable use.**

The development of sustainable finance mechanisms to support marine (MPA) management requires that there is a clear understanding of input/output or **the cost/benefit of the range of stakeholders linked to the natural capital asset**. This process may reveal new avenues for sustainable finance mechanisms. The identification of 'risk' is an essential component for financial investment. **The identification of 'natural capital key performance indicators', relevant to the scale of the North Devon Pioneer will be essential to understand the impact of sustainable finance mechanisms on sustainability.**

Finally, a full baseline natural capital account at a scale relevant to North Devon that considers the extent and condition of the natural capital assets and the stocks and flows of ecosystem services (jobs, values) is essential. A baseline account will act as a tangible tool to support decision-making and to document and share with stakeholders (including stakeholders linked to the proposed sustainable finance mechanism) the ‘performance’ of MPA management measures and regional sustainable management.

6 Indicators – Flow of Ecosystem Services from Natural Capital

In this section a framework is presented to assess the provision of ES from natural capital assets in NDMP and the economic and social benefits to stakeholders, using a natural capital approach (Natural Capital Committee, 2017; Office for National Statistics, 2016b). Data collected at regional or national scales (e.g. in relation to EU Marine Strategy Framework Directive (MSFD), EU Water Framework Directive (WFD) and MMO Marine Plans), and site specific local scale data sets (e.g. fishing activity data for vessels from North Devon ports), were identified. These data allow changes in stocks and health of stocks of natural capital to be related to level of delivery of ES and delivery of economic and social benefits to stakeholders. Data sets were related to 'indicator' metrics that have been identified in national and international studies on natural capital approaches and assessment of delivery of ecosystem services.

Indicators provide measures of natural capital assets, ecosystem processes and ecosystem service benefits, allowing for study of the linkages between ecological, social and economic systems and changes in relationships over time (Bohnke-Henrichs *et al.*, 2013; Hattam *et al.*, 2015). The selection and analysis of indicators can contribute to the development of a more detailed understanding of the social-ecological system as a whole, potentially leading to more informed management plans and a transparent decision making process (Hattam *et al.*, 2015). The identification and analysis of changes in indicators following an intervention, such as an MPA designation, can also aid evaluation of impact upon ecosystem service delivery and related wellbeing. Potential indicators may be linked to environmental and socio economic (value and wellbeing) categories, within an ES framework (Figure 11).

Indicators allow stocks of natural capital to be monitored over time and changes in delivery of ES and economic and social benefits to be assessed in relation to changes in those stocks. The matrix in section 0 (Table 2) reviewed data on theoretical provision of ES if natural capital stocks are in good (favourable) condition, assessment of indicators utilises site specific data to assess actual ES delivery and response to management measures within NDMP.

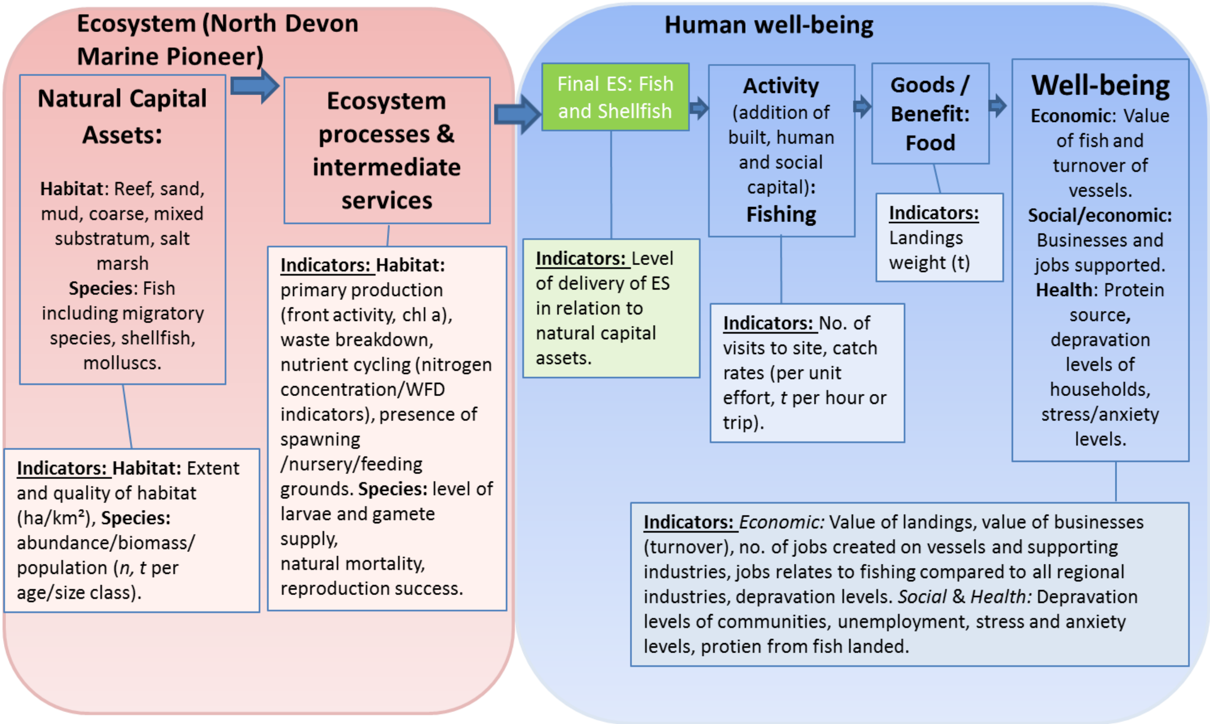


Figure 11 Flow of ES from natural capital, through to value and human well-being benefits

Guidelines and examples of indicator selection have received increasing attention (Hattam *et al.*, 2015; UNEP-WCMC, 2011). Indicators have been identified in relation to UK NEA FO (Atkins, Burdon & Elliott, 2015; Turner *et al.*, 2014), TEEB (Bohnke-Henrichs et al. 2013; Hattam et al 2015), CICES (Maes *et al.*, 2016) and application to marine spatial planning (Bohnke-Henrichs *et al.*, 2013). The indicators provided in these studies were reviewed for application within NDMP.

In response to UK commitments under MSFD and WFD, environmental monitoring indicators have also been identified. Data in relation to these indicators are collected routinely at a national level. Certain MSFD and WFD indicators can be applied to assessing condition and extent of natural capital assets such as habitats, species and water bodies (Broszeit *et al.*, 2017). Wellbeing indicators to monitor social and economic impact of marine plans have also been identified for the English Marine Planning process (MMO, 2014). These indicators therefore provide data sources which can be integrated into natural capital and ecosystem service assessment.

Indicators identified in natural capital and ES literature and in relation to monitoring of targets under MSFD (indicators monitored in the UK (Defra, 2014), including those identified by Broszeit *et al.* (2017)); WFD (indicators monitored in the UK by Environment Agency for sample points and water bodies in NDMP (Environment Agency, 2018d; Environment Agency, 2018a); and English Marine Plans (MMO, 2014) can be applied at a small-scale site level, and are transferable across local, national and international scales. The application of these indicator metrics, and relevant data sets aims to provide a framework that is applicable to other sites and scales than solely the NDMP. Assessment of indicators for stocks and health of stocks of natural capital, level of delivery of ES and delivery of economic and social benefits to stakeholders can be performed as a baseline, and repeated over time to detect change, in stocks or flows, for instance in relation to management measures or outside events.

6.1 Method

Indicators were identified for each ES within the framework presented in Table 5. Categories in the framework were identified based on guidance on applying a Natural Capital Approach, provided by Natural Capital Committee (2017) and Office for National Statistics (2016b). Indicator metrics and data sources were assigned to categories on:

1. Extent natural capital asset (habitats, species or environmental feature).

2. Condition or quality of natural capital assets.

3. Level of delivery of an ES (goods/benefits) (in relation to the natural capital assets within NDMP), including activities supported.

4. Economic benefit (value and employment) associated with the level of delivery of the ES and supported activities.

5. Further social and health benefits.

Table 5 Framework for application of indicator metrics and data sources to assess flow of an ES from Natural Capital resources through to economic and social benefits

Indicators Selected to Assess Flow of Ecosystem Service from Natural Capital Assets through to Well-being benefits										
							Indicators: Well-being (economic and social benefit)			
							Economic (value)	**Social / Economic (employment)**		**Social (health)**
Natural Capital Assets	**Indicators: extent**	Data source	**Indicators: condition**	Data source	**Indicators: Level of delivery** of **ecosystem service** (goods/ benefit)	Data source	Value indicators (+ data source)	Employ-ment indicators (+ data source)	Labour market indicators	Physical and mental health indicators

A 3 stage process was undertaken, to identify key ES to assess, indicators and data sources, the steps are summarised below:

- Complete an inventory of ES provided within NDMP to identify ES to take forward to assessment.

- Review ES literature and indicator guidance to identify potential indicators for each ES.
- Select best available indicators to assess flow of ecosystem services and associated wellbeing from natural capital assets in NDMP, applying guidelines provided by Hattam et al (2015).

6.1.1. Stage 1: Inventory of ecosystem services provided within NDMP.

The Common International Classification of Ecosystem Services (CICES) classification framework was used and CICES classes were linked to the ES and goods/benefits identified in the NEA FO. ES (Final Ecosystem Service and Goods/ Benefits) were reviewed by the authors in consideration of the questions:

i) *Is this ES relevant to NDMP*?

ii) *If so, what is the level of importance of the ES to NDMP, e.g. in terms of known stakeholder activity*?

CICES classes were used within the review, and associated ES & goods/benefits in the NEA FO classification framework were identified, to provide a means of relating the ES inventory and indicator selection to other national and international studies.

6.1.2 Stage 2: Review of indicators

Existing indicators, from ES literature, North Devon Biosphere Reserve '*State of the Biosphere Report*' (Bell et al. 2015) and recent Natural England workshops (on natural capital assessment in north Devon), were reviewed. Indicators in relation to monitoring required by the MSFD and WFD and social impact of marine plans (MMO, 2014) were also reviewed. Relationships of MSFD, WFD, and MMO monitoring to assessment of natural capital assets and provision of ecosystem services, including wellbeing benefits were identified. This ensured natural capital approaches, assessment of delivery/provision of ES and monitoring of indicators in relation to international obligations were coordinated where possible. The review also allowed the selection of indicators in this study to be carried out using a transparent process that could be repeated as indicator studies and data availability evolve.

Applicable ES indicators identified in peer reviewed literature, grey literature and recent Natural England workshops, were reviewed in relation to CICES classes. The CICES framework was used, as this allows interpretation between the various classification frameworks the reviewed studies had used (e.g. NEA FO, TEEB). Class levels were used as they provided the greatest level of detail.

MSFD and WFD indicators are applicable to assessment of extent and condition of natural capital assets. Indicators identified by MMO (2014) to monitor social impact of marine plans are relevant to provision of economic and social benefits from natural capital and ES. These indicators are monitored across sites, nationally and internationally and it was considered important to be able to apply them where possible in this assessment, and/or identify how they relate to the framework being applied in this study. MSFD, WFD and MMO indicators were therefore reviewed and summarised within the categories presented in Table 5.

6.1.3 Stage 3: Selection of indicators to assess provision of ES from natural capital assets within NDMP

Suitability of indicators for assessing provision of ES in NDMP, was undertaken (by the authors) through application of guidelines provided by Hattam et al. (2015):

i) **Measurabilit**y: are there data available for the measurement and quantification of the indicator?

ii) **Sensitivity**: does the indicator detect change in the ecosystem service over time?

iii) **Specificity**: can the indicator respond over time to changes in management as opposed to natural variability? Is this response predictable and does it have low variability?

iv) **Scalability**: can the indicator be aggregated or disaggregated to a different spatial scale and still retain its ability to indicate the change of interest.

v) **Transferability**: is the indicator useful for other locations and hence studies?

With the additional criteria that:

vi) The Indicator can be **relatable to MSFD and WFD indicators** where relevant.

viii) The indicator can be **relatable to MMO marine plan indicators of social impact** where relevant.

The 3 stage process was intended to provide the final short list of suitable indicators that were taken forward to assess flow of ES goods/benefits from natural capital assets in NDMP.

6.2 Results

6.2.1 Stage 1: Inventory of ecosystem services provided within NDMP.

An inventory of ES (identified in CICES down to class level) provided by the natural environment within NDMP, showed provision of all ES, apart from terrestrial crops and reared animals occurred within the NDMP (Table 6).

Relevance to stakeholder activity in NDMP was reviewed to be high for the ES (within the NEA FO classification) of: Food, in relation to the commercial fishing activity in North Devon and related beneficiaries (see section 5), and aquaculture operations that occur in the Taw Torridge estuary. ES of Tourism/Nature watching, including recreation activities, particularly the water sports sector are also of high relevance to the region (see section 5).

The following ES were identified as having a high level of provision in NDMP and of importance to multiple stakeholder, and therefore, were taken forward to assessment:

- Food (wild food – fish and shellfish, including migratory fish)
- Natural hazard regulation – sea defence (flood prevention).
- Climate regulation – carbon sequestration
- Tourism and Recreation (mainland and Lundy), under the following sub categories:
    - I. Walking and coastal access (including beach use)
    - II. Diving and snorkelling
    - III. Recreational Fishing
    - IV. Surfing
    - V. Boating, kayaking, SUP - coasts and estuaries
    - VI. Wildlife watching, including tours and Lundy activities

Regulating ES that are provided within NDMP can be distinguished between those that provide benefits beyond the NDMP region, and those that provide benefits at a site level. 'Healthy climate' benefits from the ES of 'climate regulation', including 'carbon sequestration by species and ecosystems' provide benefits at a global level. ES such as 'burial removal and neutralisation of waste' provide benefits at a regional scale, beyond the NDMP site.

Goods and Benefits such as 'sea defence' and 'prevention of coastal erosion', including ES of 'natural hazard protection'/'sea defence', reduce impacts on businesses and communities from flooding and storm events within north Devon.

Goods and Benefits relating to water quality, such as 'waste burial / removal / neutralisation' (by species and ecosystems) (ES 'clean water and sediments') are of high relevance to supporting 'tourism/nature watching' activities, and especially recreational water sports. Water quality is also vital to supporting habitats and species in the marine environment and so vital to supporting 'food from fisheries' (wild and aquaculture). Although not considered by reviewing ES goods/benefits in the UK NEA FO and CICES classes, ecosystem processes, such as hydrological processes, and intermediate services, such as productivity are also vital to supporting species communities and goods/benefits, such as Food from the marine environment (see Section 4).

*Table 6 Inventory of ecosystem services provided within NDMP (identified within CICES classes and related to UK NEA FO classification (Relevance to NDMP assessed as Y (Yes), N (No), Un (unknown) (Relevance to stakeholder benefits assessed as: –(not relevant), *(low relevance), **(moderate relevance), ***(high relevance).*

ES Category	CICES Class *The class level provides a further sub-division of CICES group categories into biological or material outputs and bio-physical and cultural processes.*	Equivalent ES or Goods / Benefits in NEA FO	Is the ES relevant to NDMP ecosystem ?	Relevance to stake - holder activity in NDMP	Taken forward to assess Y/N	ES Good/Benefit and Activity to assess / map
Provisioning	Cultivated crops	n/a	N	_	N	
	Reared animals and their outputs	n/a	N	_	N	
	Wild plants, algae and their outputs	Food / Fertiliser	Y	*	N	
	Wild animals and their outputs	Food (wild)	Y	***	Y	Food - Fishing
	Plants and algae from in-situ aquaculture	Food / Fertiliser	Y	_	N	
	Animals from in-situ aquaculture	Food (farmed)	Y	**	Y	Aquaculture
	Surface water for drinking	Water cycling	Y	*	N	
	Ground water for drinking	Water cycling	Un	*	N	
	Fibres and other materials from plants, algae and animals	Biofuels, ornaments	Y	*	N	
	Materials from plants, algae and animals for agricultural use	Fertiliser	Y	*	N	
	Genetic materials from all biota	Genetic resources	Y	**	N	
	Surface water for non-drinking purposes	Water cycling	Y	**	N	
	Ground water for non-drinking purposes	Water cycling	Un	_	N	
	Plant-based resources	Species	Y	**	N	
	Animal-based resources	Species	Y	***	Y	Food - Fishing
	Animal-based energy	Food / Fertiliser	Y	***	Y	Food - Fishing
Regulating	Bio-remediation by micro-organisms, algae, plants, and animals	Burial/removal/neut.	Y	***	(Y)	Bio-remediation
	Filtration/sequestration/storage/accumulation by organisms	Carbon sequestration	Y	***	Y	Carbon seq.
	Filtration/sequestration/storage/accumulation by ecosystems	Carbon sequestration	Y	***	Y	Carbon seq.
	Dilution by atmosphere, freshwater and marine ecosystems	burial/removal/neut.	Y	***	N	
	Mediation of smell/noise/visual impacts	n/a	Y	*	N	
	Mass stabilisation and control of erosion rates	Prevention of erosion	Y	**	Y	Sea defence
	Buffering and attenuation of mass flows	See defence / erosion	Y	***	Y	Sea defence
	Hydrological cycle and water flow maintenance	Hydrological processes	Y	***	Y	Water quality
	Flood protection	Sea defence	Y	***	Y	Sea defence
	Storm protection	Sea defence	Y	***	Y	Sea defence
	Ventilation and transpiration	Climate regulation	Y	*	N	
	Pollination and seed dispersal	Hydrological processes	Y	*	N	
	Maintaining nursery populations and habitats	larvae dis. / from. Hab.	Y	***	Y	Food - Fishing
	Pest control	Biological control	Y	*	N	
	Disease control	Biological control	Un	*	N	
	Weathering processes	Formation hab./seascape	Y	**	N	
	Decomposition and fixing processes	Waste breakdown	Y	***	N	
	Chemical condition of freshwaters	Waste bur./rem./neut.	Y	***	Y	Water quality
	Chemical condition of salt waters	Waste bur./rem./neut.	Y	***	Y	Water quality
	Global climate regulation by reduction of greenhouse gas conc.	Climate regulation	Y	***	Y	Carbon seq.
	Micro and regional climate regulation	Climate regulation	Y	***	Y	Carbon seq.
Cultural	Experiential use of plants, animals and land-/seascapes	Tourism / Nature watch.	Y	***	Y	Recreational activities: (e.g. walk, dive, fish, surf)
	Physical use of land-/seascapes	Tourism / Nature watch.	Y	***	Y	
	Scientific	Education, research	Y	***	N	
	Educational	Education, research	Y	***	N	
	Heritage, cultural	Spiritual, cultural wellbeing	Y	***	Y	Recreational activities: (e.g. walk, dive, fish, surf)
	Entertainment	Tourism / Nature watch.	Y	***	Y	
	Aesthetic	Aesthetic benefits	Y	***	Y	
	Symbolic	Spiritual, cultural wellbeing	Y	_	N	
	Sacred and/or religious	Spiritual, cultural wellbeing	Y	_	N	
	Existence	(all)	Y	_	N	
	Bequest	(all)	Y	_	N	

6.2.2 Stage 2: Review of indicators

ES indicators identified in peer reviewed literature, and recent Natural England workshops, were reviewed in relation to CICES classes. The results of the review are summarised in Annex IV. Indicator metrics identified were similar across studies, with a focus on ES delivery and economic benefit (value and employment supported). Atkins, Burdon and Elliott (2015) and Hattam *et al.* (2015) identified indicator metrics for natural capital assets and Atkins, Burdon and Elliott (2015) identified data sources associated with metrics that were relevant to the NDMP. Only Bohnke-Henrichs *et al.* (2013) provided indicators relevant to broader social benefits (health). Rees *et al.* (2016) provide a survey (interview) based method for gathering well-being indicators from participants (in relation to fishermen working within an area with long-standing byelaw restrictions on bottom towed fishing activity within MPAs).

MSFD (Defra, 2014) and WFD indicators (Environment Agency, 2018a; Environment Agency, 2018b) and MMO social impact indicators, related to Marine Plans (MMO, 2014) were reviewed in relation to categories within the framework presented in Table 5. The results of the review are presented in (Annex V a,b). MSFD and WFD indicators were relevant to extent and condition of natural capital assets (habitats, species and water bodies). MSFD indicators relating to habitats and species are monitored in relation to MPA sites, therefore data appear to be limited to designated MPA sites. WFD indicators are collected across water bodies and during spring and summer months samples are collected for bathing waters, providing an extensive data set for condition of water bodies.

Indicators identified by MMO (2014) provide broad scale data at regional level from national or local government statistics (Devon County Council, 2015; Office for National Statistics, 2016a), or MENE survey data, collected by Natural England (Natural England, 2016). The data sources identified do not provide detail on individual marine sector employment (such as marine recreation, or fishing) or the fine spatial scale possible in survey approaches. However, the regional scale social indicators, such as un-employment levels and deprivation levels of communities provide a useful reference data set to utilise over time.

Finer scale more detailed data on employment within marine industry sectors and value associated with recreational activities, such as spend per day, gathered from surveys are preferable. The indicators identified by MMO (2014) provide an interesting regional comparison to such finer scale data, to monitor broader scale impacts of changes over time in economic and social benefits from ES provided by natural capital assets in NDMP. Data are also provided by MMO indicators that does not require bespoke survey design and fieldwork.

6.2.3 Stage 3: Selection of indicators for provision of ES from natural capital assets within NDMP

Selection of indicators for key ES and related activities (identified in stage 1 (0), and Section 0) for assessing provision and flow of ES from natural capital in North Devon Marine Pioneer are summarised in the following section. Indicators identified in Annex IV and Annex V were reviewed in relation to the criteria identified by Hattam *et al.* (2015) (stage 3 (0)). Certain indicators and data sources to assess extent and condition of habitats and water bodies were identified that were relevant across all ES. These indicators are presented first. Indicators relevant to specific ES, taken forward to assessment are then presented in relation to each ES.

6.2.3.1 Indicators on extent and condition of habitat and water body natural capital assets in NDMP

Indicators on extent and condition of habitats and water bodies were applicable to all ES in NDMP. Across ES literature similar indicators were identified in relation to extent and condition of natural capital assets (e.g. area of habitat, % cover of habitat, abundance/biomass of key species, biodiversity, extent and volume (sea water/water bodies) (Maes *et al*; 2016; Atkins *et al*. 2015; Hattam *et al*. 2015; Bohnke-Henrichs *et al.* 2013) (Annex IV). Extent and condition indicators also overlapped with indicators related to monitoring of GES targets within MSFD and WFD (Broszeit *et al.* 2017) (Annex Va).

National data sets, such as Natural England and EMODnet habitat data layers provided generic indicators within NDMP for natural capital assets, that were relevant to multiple ES (Atkins, Burdon & Elliott, 2015). Assessment of ES that relied on natural capital assets related to specific species, such as commercial or recreational fishing, required additional data on abundance/biomass and health and condition of populations (e.g. ICES stock assessment data).

Indicators in relation to goods/benefits from ES were specific to each ES, as were indicators of activities and values related to those ES.

Indicators for extent and condition of habitats that were generic across ES are summarised as:

Extent of habitats in NDMP are provided by the habitat maps generated from Natural England and EMODnet data (Section 4.1). Confidence in the evidence relating to assigning the spatial extent of a habitat is provided in Figure 8. Habitat extent derived from more detailed surveys received the highest confidence and habitat extent form modelled data received the lowest confidence data. Provision of ES benefits from habitats within NDMP are summarised in Table 2 (Section 0).

Condition of habitats within designated MPAs are provided through conservation objectives assigned to each feature (in Conservation Advice packages produced by Natural England for each site).

Outside of designated MPA sites, detailed survey data of habitat and species communities (and so confidence in condition of the assets present) are limited (Figure 8, Section 0). For habitat extents where detailed survey data are not available, condition of habitats can only be predicted through associating the sensitivity of habitats to the spatial extent of activities that occur/have occurred recently (Natural England, 2017). Sensitivity of habitats can be assessed based on the sensitivity of species communities present, (or typical species communities associated with the habitat based on expert opinion) to pressures associated with the activities that interact with the habitat (Tyler-Walters *et al.*, 2017). This approach utilises the sensitivity assessments provided for UK habitats in Marine Evidence based Sensitivity Assessments, provided by MarLIN (Langmead *et al.*, 2017; Tyler-Walters *et al.*, 2017). A precautionary prediction can be made of the likely condition of the habitat in relation to favourable condition as defined by MCZ and SAC objectives. Sensitivity of ES provision to activities can also be mapped and assessed using this approach (Hooper *et al.*, 2017).

Extent and Condition (water bodies): Monitoring in relation to WFD indicators (Annex Va), carried out by the Environment Agency provides data on condition of the water bodies within NDMP (Environment Agency, 2018d; Environment Agency, 2018a). The condition of the water body (water body status) was selected as a broad scale indicator for NDMP water bodies (Environment Agency, 2018a). At a more detailed level specific chemical and biological indicator data were selected from Environment Agency data sets for individual water bodies (Environment Agency, 2018a). Point data are also available in relation to biological and chemical indicators related to monitoring bathing water quality (Environment Agency, 2018c). Frequency of events in a year when results at a sample point were above threshold levels for these indicators provides an indicator for finer spatial scale assessment.

Production/primary productivity (water bodies/water column). Production is a vital supporting process and primary productivity a vital intermediate ES, supporting flow of ES and ES goods and benefits from marine ecosystems, such as those of NDMP. ES indicator literature suggests community production (kcal/ha/yr) and quantity of primary production (g C per unit area) as indicators for production/primary production (Atkins, Burdon & Elliott, 2015). Data on these indicators and metrics area limited within NDMP to broad scale assessment of chlorophyll *a* concentrations and productivity measured as grams of carbon per square meter of sea surface per day (g C m-2 d -1) or yearly mean primary productivity (g C m-2 y -1) (Ocean Colour - CCI, 2018).

These data sources were selected as broad scale indicators for primary production across the NDMP site. Data were identified through online data resources supplied by Plymouth Marine Laboratory (Ocean Colour - CCI, 2018).

Hydrographic conditions that provide conditions that support high productivity, such as strong and persistent fronts (forming the transition zone between nutrient rich mixed water and stratified water), were also selected as a generic indicator of water column primary productivity. Front frequency map data layer were accessed through data produced by Plymouth Marine Laboratory, available through Defra MB102 (Miller, 2009; Miller & Christodoulou, 2014; Miller, Christodoulou & Saux Picart, 2010).

6.2.3.2 Indicators for individual Ecosystem Services and related goods/benefits

For each of the ES identified in section 6.2.3 to be taken forward to assessment, the indicators specific the ES are identified in the following sub-sections below. Extent and condition of natural capital assets related to species are considered in this section as certain species are specific to provision of individual ES (such as fish species to ES food goods/benefits, and nature watching/recreational activities). Indicators for extent and condition of habitat and water bodies, relevant to all ES, have been identified in section 0.

1. *Food (wild food – fish and shellfish, including migratory fish)*

Table 7 Indicators and data sources to assess flow of the ES 'Food' (fish and shellfish) from natural capital assets in NDMP (indicators that are specific to this ES are highlighted in bold)

ndicators Selected to Assess Flow of Ecosystem Service: **Wild food (fish and shellfish, including migratory fish)** from Natural Capital Assets through to Well-being benefit

Natural Capital Assets	**Indicators: extent**	Data source	**Indicators: condition**	Data source	**Indicator: Level of delivery** of ecosystem service (goods/ benefit)	Data Source	**Indicators: Well-being (economic and social benefit)** – **Economic (value)**: Value indicators (+ data source)	**Social / Economic (employment)**: Employ-ment indicators (+ data source)	Labour market indicators	**Social (health)**: Physical and mental health indicators
Habitats	Extent (km^2/ha)	1. Natural England and EMODnet habitat data	1. Condition assessment (features designated sites).	1. Natural England Designated Sites System.	1. Mapped matrix data (Potts et al. 2014; Saunders et al. 2015) for provision of wild food - fish and shellfish 2. Mapped matrix data for provision of nursery habitat for species. **3. CPUE (spatial) by gear type / species (or mobile/ static). ii). Fishing effort (spatial) by gear type / species (or mobile /static). iii). Landings (weight) species. 4. CPUE of salmon fishery (commercial nets and recreational rod and line).**	1.- 2. Review of ecological and ecosystem service literature (Potts et al. 2014; Saunders et al. 2015; Rees et al. 2016; Langmead et al. 2018). **3. MMO fishing activity data. 4. CPUE of recreational fishers (EA salmon rod and line data).**	**1. Landings value (by species/gear) (linked spatially to grounds) (MMO data) 2. No. vessels supported (MMO vessel lists). 3. Value of fishing businesses (turnover) from survey or estimated data (based on previous studies (e.g. Rees et al. 2016)) 4. Supporting businesses value (surveys, as 3. above, or applications of values from SEAFISH processing industry reports and MMO fishing activity reports).**	**1. Fishing industry: No. employed (MMO vessel lists + crew numbers (from consultation with IFCA, MMO or interview with fishers), 2. Survey of local supporting businesses.** 3. Employment Statistics (ONS, local government).	Employment in fishing industry compared to other regional industries (MMO data and ONS data).	**1. Survey methods applied in Rees et al. (2016)** 2. ONS and local government statistics-regional deprivation levels, unemployment levels (see MMO, 2014).
			2. Exposure to activities for which the habitat is sensitive to pressures from that activity.	Natural England Conservation Advice, '*Advice on operations*.' Relevant spatial activity data.						
Species	Abundance/ biomass	1. ICES (Cefas) stock assessment records. 2. Environment Agency & NRW fish surveys (estuaries)	Population assessment (demographics, health of population (e.g. reproduction success))	1. ICES (Cefas) stock assessment records. 2. Environment Agency fish surveys (estuaries).						
Water bodies	Extent (km^2/ha)	Hydrographic charts, EMODnet, Magic Map, ARC GIS base maps.	1. Water quality, 2. Productivity.	1. i) Environment Agency monitoring data, ii) **Shellfish water monitoring data. 2. PML front maps (Defra MB102) and chl a (oceancolour.org).**						
	Depth: bathymetry	Hydrographic charts	Modification of water body.	Environment agency monitoring: (modified - yes / no and hydro - morphology status).						

Extent and Condition (species). Established indicators in relation to Food (wild fish and shellfish) include biomass (tonnes/km^2), abundance (No./ km^2) and species diversity (Hattam *et al.* 2015; Atkins *et al.* 2015) (Annex IV). Within NDMP, ICES and IFCA stock assessment data provide data for key species. However, these data are limited as they assess stocks at a broad scale, or are based on limited samples and may not accurately reflect stocks within NDMP. Reproduction success (indicated by yr 1 abundance in stock assessment data) is a key indicator of condition of the population (Broszeit *et al.* 2017) (Table 7). Environment Agency monitoring of salmon populations in rivers and estuaries (Taw Torridge and Lyn) provide data on migratory fish populations, including assessment of abundance of returning adults and juvenile stock in river systems (Cefas, Evironment Agency & Natural Resources Wales, 2016; Environment Agency & Natural Resources Wales, 2017).

It is important to consider importance of different habitats across life stages to fish and shellfish within NDMP. The inshore regions of the Bristol Channel (and Lundy Island) (<10m depth) provide important nursery habitats for a number of commercial fish and shellfish species, while deeper offshore habitats support adult life stages (Ellis *et al.*, 2012). As an example, saltmarsh habitat was identified as an important nursery area for juveniles of species that also utilise reefs and offshore (subtidal) sediments habitats during adult life phases (Table 3, Section 0). Water quality, and productivity, are also important to supporting fish and shellfish populations (Table 7).

Delivery of ES (goods, benefits and related activity). Ecosystem service indicator literature identified i) landings statistics/amount of seafood harvested (Hattam *et al*. 2015; Atkins *et al.* 2015; Hooper et al. 2014) and ii) nutrition from seafood consumption (protein/year) (Atkins *et al.* 2015; Bohnke-Henrichs *et al.* 2013) in relation to Food ES goods/benefits.

For NDMP, MMO fishing activity data on fish landings used in combination with data on spatial fishing activity provides the most detailed data source in relation to these indicators (VMS data for vessels >12m and overflight and patrol surveillance data (all vessels, but limited frequency of coverage)) (Table 7). These data sets provide resources to map spatial fishing effort for mobile bottom towed fishing activities (trawl and dredge) and static fishing activities (static pots and nets) (Mangi *et al*, 2012; Vanstean & Brean, 2014). The landings for species associated with the activities can be related to the spatial fishing effort for those gear types to provide a proxy for spatial delivery of the ES wild food, and the activity of commercial fisheries, by species.

Economic benefits Value of landings associated with fishing grounds, for static and mobile gear types from MMO fishing activity data provide the most accurate data source available for NDMP (Table 7). Data analysis methods applied by Mangi *et al.* (2012), Vanstean and Brean (2014) and Rees et al. (2016)) were selected to be used for NDMP data.

National statistics (e.g. ONS Business Register and Employment Survey) provide a coarse level of detail on businesses and employment in the fishing sector (MMO, 2014). Within NDMP, number of licensed vessels in ports, from MMO fishing activity data sets and estimated crew numbers provide an indicator of direct jobs supported in commercial fishing industries (MMO, 2014). Surveys with local business owners were also considered, which can then be sense checked with Devon and Severn IFCA and local Fishermen’s Associations, to provide a more accurate representation of employment across the sector and supply chain (MMO, 2014; Rees et al. 2016) (Table 7).

Social benefits Livelihood provision and employment within sector are identified as wellbeing indicators in existing studies (Bohnke-Henrichs *et al.* 2013; MMO; 2014) (Annex IV). Broad scale data sets include ONS statistics on deprivation levels and unemployment levels compared to regional and national averages (MMO, 2014). Surveys can also be conducted to collect more detailed well-being data from fishermen and local business owners and staff, applying methods developed by Rees *et al.* (2016) (Table 7).

2. *Healthy Climate (Carbon sequestration)*

Table 8 Indicators and data sources to assess flow of the ES 'Health climate' (carbon sequestration) from natural capital assets in NDMP (indicators that are specific to this ES are highlighted in bold)

Indicators Selected to Assess Flow of Ecosystem Service: **Healthy climate (Carbon sequestration)** from Natural Capital Assets through to Well-being benefits

Natural Capital Assets	**Indicators: extent**	Data source	**Indicators: condition**	Data source	**Indicator: Level of delivery** of ecosystem service (goods/ benefit)	Data source	**Indicators: Well-being (economic and social benefit)** – **Economic (value)**: Value indicators (+ data source)	**Social / Economic (employment)**: Employ-ment indicators (+ data source)	**Social / Economic (employment)**: Labour market indicators	**Social (health)**: Physical and mental health indicators
Habitats	Extent (km^2/ha)	1. Natural England and EMODnet habitat data, e.g. assessment of saltmarsh extent.	1. Condition assessment (features designated sites). 2. Benthic community data.	1. Natural England Designated Sites System. 2. Biodiversity detail from Conservation Advice (NE) and Atlantic Array site data.	1. Mapped matrix data (Potts et al. 2014; Saunders et al. 2015) for provision of 'Healthy climate' benefit. 2. Integration of existing research with values for carbon sequestration and burial by habitat types in the study site or comparable locations.	1.- 2. Review of ecological and ecosystem service literature (Romero et al., 1994; Chmura et al., 2003; Andrews et al., 2006; Jones et al., 2008; Painting et al., 2010; Alonso et al., 2012; Potts et al. 2014; Saunders et al. 2015; Rees et al. 2016; Langmead et al. 2018).	Climate regulation benefits pass beyond the local area, by their very nature they support the economic activities in the region and beyond. Social cost of Carbon (SCC) provides a value relating to this (data.gov.uk).	*not directly relevant*	*not directly relevant*	*not directly relevant*
			2. Exposure to pressures from activities that feature is sensitive to.	Natural England Conservation Advice, '*Advice on operations*.' Relevant spatial activity data.						
Species	Species and Communities present, extent / abundance/ biomass	1. EMODnet habitat data layers. 2. Saltmarsh extent. **3. Chl a (ocean colour.org)** 4. Benthic community (DSS, Atlantic Array data).	As above	As above						
Water bodies	Extent (km^2/ha)	Hydrographic charts, EMODnet, Magic Map, ARC GIS base maps.	1. Water quality, 2. Productivity.	1. i) Environment Agency monitoring data, ii) Shellfish water monitoring data. 2. **PML front maps (Defra MB102) and chl a (oceancolour.org).**						
	Depth: bathymetry	Hydrographic charts	Modification of water body.	Environment agency monitoring: (modified - yes / no and hydro - morphology status).						

Delivery of ES (goods, benefits and related activity). Indicator literature suggest carbon dioxide sequestered (tonnes of CO_2 per m^2 or m^3), net carbon burial (tonnes per ha per year) and physical damage avoided (through net GHG sequestration and effects on climate parameters) are preferred indicators (Maes *et al*. 2016; Atkins *et al*. 2015; Hattam *et al.* 2015; Bohnke-Henrichs *et al*. 2013) (Annex IV).

As site specific data on carbon sequestered or net carbon burial are not known to be available for NDMP reviewed data from comparable sites, presented in the matrix in Table 2 (section 0) were used.

Provision of healthy climate benefits in relation to carbon sequestration is dependent upon the extent of habitats and condition of habitats and the water quality within NDMP water bodies, identified through indicators identified in Section 6.2.3.1. Extent and condition of specific species within habitats such as saltmarsh and kelp *Laminaria sp.* communities on reef, coarse and mixed sediment, are important in relation to provision of high levels of carbon sequestration in comparison to other habitat types (Table 2 (section 0)).

The provision of ES from natural capital, identified in existing literature (e.g. Potts *et al.* 2014; Saunders *et al.* 2015) can only be assumed for habitats in good/favourable condition. If habitats have been adversely impacted by human activities or environmental change, the provision of ES benefits are likely to be lower than reviewed evidence suggests. As well as extent of habitats which are assessed as having high/significant provision of the ES 'Healthy climate', it is important to consider the condition of these habitats in NDMP, and identify sensitivity of these habitats in relation to spatial extent of activities occurring in NDMP, to confidently assess provision of benefits.

Economic and Social benefits (employment, labour markets, health and recreation). Carbon sequestration and the associated healthy climate benefits encompass many, or even all other human benefits from ecosystems. The social cost of carbon metrics were selected for assessing these values. Social cost of carbon values can be used to calculate the cost of damage alleviated for each tonne of CO2 sequestered – buried in relation to habitats and species assets present in NDMP (Watkiss. *et al.*, 2005).

Indicators applied for these categories are summarised in Table 8.

3. Sea defence (natural hazard regulation)

Table 9 Indicators and data sources to assess flow of the ES 'Sea defence' (including natural hazard protection and protection from coastal erosion) from natural capital assets in NDMP (indicators that are specific to this ES are highlighted in bold)

Indicators Selected to Assess Flow of Ecosystem Service: **Sea defence (including protection from erosion)** from Natural Capital Assets through to Well-being benefits

Natural Capital Assets	Indicators: extent	Data source	Indicators: condition	Data source	Indicators: Level of delivery of ecosystem service (goods/ benefit)	Indicators	Indicators: Well-being (economic and social benefit) – Economic (value): Value indicators (+ data source)	Social / Economic (employment): Employment indicators (+ data source)	Social / Economic (employment): Labour market indicators	Social (health): Physical and mental health indicators
Habitats	Extent (km²/ha)	1. Natural England and EMODnet habitat data.	1. Condition assessment (features designated sites).	Natural England Designated Sites System.	1. Mapped matrix data (Potts et al. 2014; Saunders et al. 2015) for provision of Sea defence benefit and protection from erosion benefit (and provision of intermediate service: natural hazard protection). 2. **Environment Agency data: 'historic flood map' and 'Recorded flood event outlines', 'Flood Risk' data.** (3. Modelled data of erosion risk or flood risk for NDMP coast, using environmental features as inputs, this option provides preferred data, but outputs not currently available).	1. Review of ecological and ecosystem service literature (incl. Potts et al. (2014), Saunders et al. (2015)). 2. Potential studies within SWEEP (in progress).	**1. Property value protected (house price index). 2. Land use / economic activities protected (land use data). 3. Value / cost avoided for not constructing flood prevention modifications in an area due to benefits provided by habitat/environmental characteristics.**	*not assessed, although employment in relation to the land and businesses protected may be relevant.*	*not assessed, although employment in relation to the land and businesses protected may be relevant.*	**1. Frequency of accidents or loss of life as a result of sea conditions-natural hazards. 2. Weather warnings issued as a result of sea conditions-coastal erosion (including road closures, or loss of property) 3. No. Insurance claims in relation to sea conditions/coastal erosion from 'Flood Risk' data by postcode.**
			2. Exposure to pressures from activities that feature is sensitive to.	Natural England Conservation Advice, '*Advice on operations*.' Relevant spatial activity data.						
Species	Species and Communities present, extent / abundance/ biomass	1. Natural England and EMODnet habitat data, e.g. assessment of saltmarsh extent, presence of kelp communities.	As above	As above						
Water bodies	Extent (km²/ha)	Hydrographic charts, EMODnet, Magic Map, ARC GIS base maps.	Modification of water bodies	Environment Agency monitoring data						
	Depth: bathymetry	Hydrographic charts	Modification of water body.	Environment Agency monitoring data						

Delivery of ES (goods, benefits and related activity). Indicators identified in studies for the provision of benefits from habitats, to the ES 'Sea defence' include: the presence and elevation of habitat features; capacity of water storage for intertidal habitats (m^3/ha or km^2), change in wave energy attributed to habitat (*j* per m^2) (Hattam *et al*. 2015), attenuation of currents by habitats (Jacobs, 2013) and flooding days per year (combined with rainfall) (Atkins *et al.* 2015). Indicators of economic and social benefits included: amount of man-made infrastructure no longer required; businesses and people protected from flooding and number of flood related mortalities (Atkins *et al.* 2015).

Matrix data (Table 2), linking habitats to provision of 'sea defence' (natural hazard protection) (Potts *et al*. 2014; Saunders *et al.* 2015) were selected to provide an indicator of provision of benefits from habitats within NDMP, as site data and/or modelled data were currently unavailable. Historical flood data and predicted flood risk data layers, available through Environment Agency were selected to compare to spatial extents of habitats with high provision of 'sea defence' benefits (Table 9).

As with healthy climate (carbon sequestration benefits), the level of provision indicated by matrix data is assumed to be from habitats in favourable condition. Confidence in the habitat data provided, and assessment of condition, either from condition assessment provided by Natural England for designated sites, or level of interaction between habitats and activities that may have an adverse effect on habitats are important to consider when interpreting results from matrix data (section 0).

Current studies are underway as part of the SWEEP project that will inform the role of beach profile and grain sizes in flood prevention in the North Devon region of the study site (Dr. Christopher Stokes, Plymouth University, personal communication). When available, model outputs will more accurately assess provision of benefits form intertidal soft sediment habitats in NDMP.

Future consideration in relation to this ES include assessment of future scenarios under predicted sea level rise, and the ability of existing environmental and man-made features to alleviate risks. This could be considered as a future mapping option, taking into account the results of upcoming SWEEP funded projects and outputs of risk strategy reports, such as regional Flood and Coastal Risk Management Studies (Environment Agency, 2010).

Economic and Social benefit (employment, labour markets, health and recreation).

Indicators of economic and social benefits from 'sea defence' ES, identified in previous studies include: Population of local rural and urban communities; value of property; and land use and employment activities (Annex IV, Vb). These metrics provide an indication of businesses and people protected from flooding within NDMP and adjacent communities. Data are available for these indicators from ONS and local government population data, land registry UK house price index, ONS land use data layers and ONS and local government statistics on employment.

To highlight risk from natural hazards, and benefit from provision of 'sea defence' ES, flood probability data (spatial data on flood zones and flood risk) (Environment Agency), indicate the areas of the shore and coastal communities in NDMP that are in low, medium and high probability of river flooding; or annual probability of sea flooding. Coastal erosion risk data are also available as a mapped layer (Environment Agency, *National Coastal Erosion Risk Mapping*). Flood frequency data are available from Environment Agency and Defra resources, (e.g. spatial data layers: *'historic flood map*' and '*Recorded flood event outlines'*) (Environment Agency, 2018b). These data can be assessed for a baseline ES study but will be of most benefit to analysis over time, in relation to changes in extent and condition of habitats providing 'sea defence' ES benefits.

Cost of constructing sea defence and flood defence infrastructure provides data on 'cost avoided' for areas of coast within NDMP that are protected by habitat features. Costs can be estimated, from cost of existing infrastructure, for the extent of coast where natural features provide significant contribution to provision of the ES 'Sea defence'. Regional flood risk strategies provide data on existing man-made flood protection schemes and infrastructure in NDMP (Environment Agency, 2010) (as does the Defra '*flood map for planning'* resource (Environment Agency, 2018b)).

More specific well-being indicators available for NDMP, include the frequency of accidents or injury related to natural events, and number of insurance claims in relation to damage caused by adverse sea conditions (including sea flooding, coastal erosion). Number of insurance claims are shared with insurers and environment agency through data sets such as *Flood Risk*, created by Crawford & Co. The *Flood Risk* dataset was produced by comparing the number of flood insurance claims made to the number of properties in the postcode sector. The rating system has five levels, ranging from "Very Low‟ to "High‟ (Environment Agency, 2018b). Data on frequency of accidents or injury require enquiries to local authorities and potentially searches of local newspaper records.

Indicators applied for these categories are summarised in Table 9.

4. *Tourism and Recreation (mainland and Lundy)*

Table 10 Indicators and data sources to assess flow of the ES 'Tourism and nature watching (including recreational activities) from natural capital assets in NDMP (indicators that are specific to this ES are highlighted in bold)

Indicators Selected to Assess Flow of Ecosystem Service: **Tourism and nature watching** from Natural Capital Assets through to Well-being benefits

							Indicators: Well-being (economic and social benefit)			
							Economic (value)	**Social / Economic (employment)**		**Social (health)**
Natural Capital Assets	**Indicators: extent**	Data source	**Indicators: condition**	Data source	**Indicators: Level of delivery** of ecosystem service (goods/ benefit)	Data source	Value indicators (+ data source)	Employ-ment indicators (+ data source)	Labour market indicators	Physical and mental health indicators
Habitats	Extent (km²/ha) ⍰	1. Natural England and EMODnet habitat data. 2. Habitat at accessible depth to recreational activity (diving)	1. Condition assessment (features designated sites). 2. Biodiversity	1. Natural England Designated Sites System. 2. Biodiversity detail from 1. above, and Atlantic Array site.	1. **Access and frequency of use**. 2. Habitat quality and water quality, 3. **Abundance of species of interest**. 4. Biological Diversity. 5. **Access to sites of interest (e.g. reefs of interest to divers within diving depth limits, coastal path access**).	1. Extent and quality of natural assets, including i) habitats, ii) Species supporting activity, iii) Water quality, iv) **Wave quality X consistent-cy (magic seaweed)** 2. MMO 'land with sea view' data layer. 3. **Access points: Car park and coastal path use (National Trust) and slipways (Council) 4. Location of sites of interest and frequency of use. i) Car park use, ii) EA number of beach visitors.**	1. **Spend per day and value related to coastal visitors. (collected by survey or apply figures from existing studies, e.g. review and incorporate i)*National Sea Angling Survey*** **(Armstrong et al., 2012). Ii) Surfers Against Sewage *'Economic Impact of Domestic*** *Surfing on the United Kingdom'* (Mills and Cummins, 2013))	1**. No. of businesses (e.g. charter boat operators, tour operators, surf schools/shops) 2. Employment in marine recreation industry (survey or estimate from no. businesses and check with regional experts) 3. Employment in supporting tourism industries such as hospitality (hotels and restaurants)** ((i) estimate from no. busineses, ii) ONS and local government employment data)	1. Marine recreation sector employment / tourism and recreation industry, as proportion of total coastal community employment 2. Unemploy-ment.	**1. Apply surveys e.g. Rees et al. (2016)**. 2. Apply MMO (2014) indicators: i). Deprivation levels of communities ii). Unemployment
			2. Exposure to pressures from activities that feature is sensitive to.	Natural England Conservation Advice, '*Advice on operations*.' Relevant spatial activity data.						
Species	Abundance/ biomass	1. ICES (Cefas) stock assessment data. 2. Environment Agency fish surveys (estuaries). 3. Species presence and diversity (Nat. Eng. Condition Assessment, Atlantic Array data)	1. Population assessment (demographics, health of population (e.g. reproduction success)), 2. Biodiversity.	1. ICES (Cefas) stock assessment records. 2. Environment Agency fish surveys (estuaries). 3. **IFCA potting survey, IFCA skate and ray survey.** 4. Species presence and diversity (Nat. Eng. Condition Assessment, Atlantic Array data)						
Water bodies	Extent (km²/ha)	Hydrographic charts, EMODnet, Magic Map, ARC GIS base maps.	1. Water quality 2. Productivity.	Environment agency water body monitoring (including bathing water monitoring). 2. Shellfish water assessments (Food Standards Agency (Cefas)). 3. **PML front maps (Defra MB102) and chl a (oceancolour.org).**						
	Depth: bathymetry	Hydrographic charts	Modification of water body.	Environment agency monitoring: (modified - yes / no and hydro - morphology status).						

Indicator literature provides generic indicators that can be applied to individual tourism and recreation activities (Annex IV, Vb, Table 10). Indicators associated with extent and condition of habitats and water bodies relate to the data sets identified in section 0. Natural capital assets in NDMP support the following activities in relation to the ES 'Tourism and nature watching' (including recreational activities):

I. Walking and coastal access (including beach use)
II. Diving and snorkelling
III. Recreational Fishing
IV. Surfing

V. Boating, kayaking, stand up paddle boarding - coasts and estuaries
VI. Wildlife watching, including tours and Lundy activities

Extent and condition of natural capital assets

Indicator literature and guidance identifies additional indicators in relation to extent and condition of natural capital assets supporting recreation to those in section 0. These are: sea space available for recreation; number and quality of sites (e.g. beaches); abundance and diversity of key species of recreational interest; and extent of water bodies with safe water quality for recreational use (Hattam et al. 2015) (Annex V). Within NDMP, indicators on extent of sea space and water quality are available through the data sets identified in section 0. Data on abundance and diversity of key species of recreational interest depend on the activity considered. For instance, recreational diving is supported by reef sites with high biodiversity and presence of species of interest, within accessible depths and safe current regimes. Data on habitats and species of interest are available through Natural England and EMODnet habitat extent data layers, and National Biodiveristy Records. Cultural heritage assets are also relevant to tourism and recreation benefits, such as ship wrecks, of interest to recreational diving. Review of local guide books and online resources, sense checked with local diving clubs provides data on the sites of interest. Sites within proximity to access points and towns/communities are likely to increase frequency of use for certain activities.

Walking and coastal access: a record of sections of coast path in good condition provides an indicator of extent of an asset (Natural England and National Trust data). Records of beach closures due to pollution incidents are relevant to beach use (Environment agency bathing water monitoring data).

Recreational fishing: Habitat extent and condition and abundance/biomass and condition indicators and data resources for fish species targeted by recreational fishers are the same as those for commercial fisheries (Table 7, Table 10). With the addition of Environment Agency data on juvenile salmon abundance in Taw Torridge and Lyn rivers, available in annual monitoring data (Cefas, Evironment Agency & Natural Resources Wales, 2016; Environment Agency & Natural Resources Wales, 2017).

Surfing: Extent (quantity) of surf spots are available through review of guide books and online resources and sense checking with local surf and lifesaving cubs. Quality of surf spots is dependent on wave type desired by the participant as well as beach or reef bathymetry, and daily wind and swell conditions. *MagicSeaweed*, a surf forecasting website provide a quality rating (1 (low) to 5 (high)) for daily forecasts, based on the likely quality of waves at a spot given the wind and swell conditions. A generic indicator of quality can be provided by assessing the number days a year that receive >3 quality score, for the main spots in the region. Unpredictable weather conditions influence these results and so they should be treated with caution.

Boating, kayaking, stand up paddle boarding and **Wildlife watching, including tours and Lundy activities** are supported by extent and condition of estuary and accessible coastal water bodies and species of interest. These indicators are supported by Natural England and EMODnet habitat extent data layers, and National Biodiveristy Records (Table 10).

Water quality indicators and data resources discussed in section 0 are relevant to all recreational activities. Environment Agency data sets on bathing water monitoring, provide a more detailed spatial scale relevant to recreational activities.

Delivery of ES (goods, benefits and related activity)

Indicators in relation to Tourism and recreation (e.g. nature watching) are identified as: Number of participants (number per yr); number of facilities (number visitors per facility/yr); amount of time spent participating (hours/days) (Atkins *et al*. 2015), number of overnight stays, number of hotel rooms in a region, number of tour operators, and provision of species of interest, such as, catch rates of recreational fish species (Bohnke-Henrichs et al. 2013) (Annex IV).

NDMP area supports multiple recreation activities in relation to experiencing the natural environment. Broad scale indicators for tourism, such as number of hotels and tourist accommodation/rooms provide an indicator that across the ES Tourism. Surveys with participants would be required to relate overnight stays to individual activities, although there are transferable values in existing reports of economic impacts of activities (Defra, 2013; Mills, 2013). Recreational activity indicators identified by MMO (2014) include Natural England MENE survey data, however the data do not provide added detail on specific activities and do not address the finer spatial scales required.

Walking and coastal access (including beach use): Access points such as car parks, slipways and sections of coast path in good condition were selected to be recorded in the area as these increase accessibility to recreational activity (Langmead et al. 2017). Usage statistics are available for some car parks and coastal path locations through National Trust and local government data resources. Environment agency bathing water monitoring resources also include data on number of beach users and activities undertaken (Table 10).

Recreational fishing: Number of charter operators and businesses and number of participants and frequency of use of sites, for recreational angling are provided at a broad scale by national sea angling survey data (Defra, 2013) and advertised trips. Number of participants can be transferred from these reports. Total number of charter vessels in the local area can provide estimates of passenger numbers, although private vessels are not considered by this data. Sense checking data with local clubs and businesses was selected as a preferred method. To obtain the most reliable site specific data, surveys with participants would be required.

Catch rates of trophy fish can be estimated through trophy fish records to assess quality and delivery of target species (Blyth-Skyrme et al. 2010). Environment Agency records of rod and line caught salmon and rod effort are available in annual reports for Taw Torridge and Lyn rivers. This provides a data set that can be compared over multiple years.

Surfing: as with angling national reports on the activity, such as SAS (2013) provide transferable data on broad scale activity, which can be sense checked with local clubs. As above, more reliable data would be provided through surveys with participants.

Boating, kayaking, stand up paddle boarding: Data on spatial boating activity are available at a broad scale through marine planning data layers provided by the Royal Yachting Association. Analysis of online AIS data sets on vessel tracks/position is possible for larger vessels. As above surveys with participants would provide more reliable data on use of different sites and time spent participating in activities.

Wildlife watching, including tours and Lundy activities: Frequency or level of use of access points, identified above, in relation to 'walking and coastal access (including beach use)' also provides a relevant indicator for wildlife watching. In relation to specific wildlife, such as birds, the number of clubs/organisations and participants gathered from local expert opinion (contact with local clubs) and records of charities such as RSPB provide a more accurate indicator for NDMP. Passenger numbers for the Lundy ferry provide reliable data on visitor numbers to Lundy.

Economic benefits (including employment) Indicators identified by Bohnke-Henrichs et al. (2013) and MMO (2014) in relation to ES of Tourism and nature watching/recreational activities include: employment and employment by sector. MMO (2014) suggest use of employment by sector data available in national and local government statistics. The employment sectors in these data sets do not provide detail of individual marine employment sectors, therefore, assessment of employment numbers related to tourism and recreation businesses is preferred. Assessment would need to be sense checked with local businesses to ensure estimates were realistic. Surveys of local businesses would provide the most accurate data.

Spend per day provides an indicator of value to local businesses in relation to activities and number of participants (Rees *et al.*, 2010). This indicator is applicable across activities, although examples of values that can be transferred to NDMP are only available for certain activities (SAS, 2013; Defra, 2013).

Social benefits (health and recreation). Indicators identified in literature include: relaxation, happiness, and rejuvenation (Bohnke-Henrichs *et al.* 2013) and unemployment levels, deprivation levels and number of recreational visits (in relation to associated health benefits) (MMO, 2014).

Employment/unemployment levels and deprivation levels of communities bordering the NDMP, are available from national and local government statistics, however, as discussed these data only provide a broad level data set, beneficial in multiple year comparisons. In relation to wellbeing indicators such as relaxation and rejuvenation (stress levels), MENE survey data provides responses to these indicators that can be applied in this study. However, data can only be separated to the broader NDMP region. To assess these indicators in relation to specific recreational activities and participants, or employees in the marine recreation sector, surveys would be required such as those undertaken by Rees *et al*. (2016).

6.3 Key findings

Data on extent and condition of natural capital assets are central to assessing the flow of ecosystem services and associated benefits from natural capital, and data sets for habitats, species and water column natural capital assets are relevant to all the ES reviewed.

Within designated MPA sites, where extent of features have been assessed by survey and condition assessments undertaken, detailed data sources are available on the extent and condition of designated habitat features and species features. **Outside of designated sites there is limited confidence in the extent and condition of natural capital assets as the only available data are modelled predictions, or stock assessment surveys designed to provide data on fish stocks over European spatial scales.** Condition of habitat features are not provided by modelled seabed habitat data. Therefore, precautionary approaches, based on level of interaction of habitats with activities that are likely to have an adverse effect, or mapping sensitivity of ES provision to activities are required (Langmead *et al.* 2017; Hooper *et al.* 2017). **Detailed survey work to identify habitat extent and condition of habitats and species communities is costly. Sensitivity mapping approaches, thereby, offer a less costly means to identify areas of high risk to adverse impact on provision of ES, and so areas of management priority inside and outside MPAs.** An opportunity can be identified for greater link up of stakeholders knowledge, such as the local ecological knowledge of fishermen and recreational anglers, for instance, to identify habitat extents and verify modelled data. **Commercial and recreational fishermen may also provide more accurate stock assessment data than broad scale surveys, to inform sustainable use of resources, if involved in well designed fisher-science partnerships.**

Indicators for monitoring Good Environmental Status in relation to MSFD and WFD are highly relevant to the assessment of extent and condition of natural capital assets. Indicators are assessed in relation to habitat and species features within designated sites and water body monitoring, with greater detail in relation to bathing waters over spring and summer months. **Within the NDMP there would be benefits from continuing bathing water monitoring throughout the year (as many recreational activities are year round and a greater data resource would be available) and to monitor MSFD indicators inside and outside of designated sites.**

MMO social impact of marine plan indicators are relevant at marine plan spatial scales, but can only provide a broad scale summary across industry and employment sectors at finer spatial scales, and do not represent specific tourism and marine recreation industries within the NDMP. Unemployment and social deprivation indicators can be assessed to provide a baseline, but **more**

detailed assessment of employment, value of businesses and spend per day of tourists and participants in recreational activities require surveys or site-specific data within NDMP. Survey approaches would also allow further health and social wellbeing indicators to be recorded in relation to provision of ES (Rees *et al.* 2016).

7 Next Steps

The aim of the Pioneer projects are to inform the development and implementation of the Governments 25 Year Environment Plan. The North Devon Marine Pioneer (NDMP) is intended to test, at a local scale, how marine natural capital can be effectively managed to deliver benefits to the environment, economy and people, and identify how best to share and scale up this learning. Based on this initial review the following "next steps" are recommended to maintain progress towards these aims:

Understanding the extent and condition of natural capital assets

The creation of an up to date habitat map based on 'best available evidence' and the translation of MESH confidence scores demonstrates that there remains a lack of confidence in the baseline data that can inform on the 'extent' of the habitat natural capital assets. Within MPAs where the extent of features have been assessed by survey and condition assessments undertaken by the statutory agencies, detailed data sources are available on the extent and condition of designated habitat features and species features. Outside of designated sites there is limited confidence in the extent and condition of natural capital assets as the only available data are modelled predictions, or stock assessment surveys designed to provide data on fish stocks.

To reduce the burden of extensive habitat surveys to verify extent of marine habitat and species it is recommended that site-specific habitat surveys are undertaken in 'contentious areas' proposed for new management measures. There is an opportunity to develop fisher-science partnerships (commercial and recreational) to verify habitat (and species) data in specific areas.

To improve information on the condition status of habitats, a next step is to undertake a 'sensitivity assessment' which maps the sensitivity of habitats to pressures from activities (such as abrasion form bottom towed fishing or anchoring and mooring). A spatial data layer which demonstrates historic pressures from activities and the sensitivity/recoverability of that habitat to physical disturbance can provide a proxy measure for the level of ecosystem service provision from a habitat. Visual tools provide can an effective for managers to communicate with stakeholders and prioritise actions for risk management (Cabral *et al.*, 2015). As such, pressure maps are likely to aid identification of issues and spatial locations where shared responsibility is present and solutions are required for sustainable use.

Establishing baseline natural capital accounts

A full baseline natural capital account at a scale relevant to North Devon that considers the extent and condition of the natural capital assets and the stocks and flows of ecosystem services (jobs, values) is essential. Such evidence will support the identification of actions required to achieve a 'net gain' for biodiversity.

Indicators for monitoring Good Environmental Status in relation to MSFD and WFD are highly relevant to assessment of extent and condition of natural capital assets. MMO marine plan indicators (social impact) are relevant at marine plan spatial scales but cannot be disaggregated to a fine spatial scale relevant to the NDMP.

A key next step is to establish a baseline natural capital account for NDMP, to enable an understanding of level of provision of ecosystem services based on the current extent and condition of marine habitats and species. Where possible, indicator data can be gathered from established sources. For a more detailed assessment, relevant to NDMP, primary data collection (e.g. questionnaires) will be required.

Underpinning ecosystem service delivery via management measures

Analysis of the flow of ES from assets within NDMP, showed a high proportion of the extent of habitats that provide a significant contribution to multiple ES (saltmarsh, littoral sediments, tide swept algal communities and infralittoral reef features), are currently contained in MPAs (>70%) within NDMP. Within these MPAs 30-40% of these habitats intact with a management measure to reduce impact on the benthic habitats. Subtidal sediments which are important for the ES of food provision and supporting/regulating services are within voluntary, seasonal fishing activity closures, but only a low percentage (5%) of these habitats interact with management measures to reduce benthic disturbance (Table 2, Figure 7, Figure 3, Figure 4). A key next step is to review current and future 'risk' to ecosystem service delivery and explore possibilities for more extensive management measures to underpin ES delivery.

Performance management

There is a need to understand changes that are associated with both the demand for ecosystem services and management interventions (e.g. the actions of the Marine Pioneer) in order to determine whether management measures are effective or not in supporting sustainable development and achieving a net gain for biodiversity – performance management.

A range of socio-economic indicators have been proposed within this review which may be useful to evaluate the ‘performance’ of management interventions and the impact of the NDMP over time.

A key next step is to develop an evaluation framework for the NDMP. Applying an evaluation framework to assess impact (or performance) is the systematic process of assessing the causal effects of a project policy or programme (Gertler *et al.*, 2011; Rosenbaum, 2010). An evaluation framework provides evidence on if and how an intervention affects (or has an impact upon) variables of interest, allowing statistical or observational analysis of ‘change’ that underlies an intervention. Evaluation of ES indicators to determine the “performance” of management interventions (including sustainable finance) within the continually evolving marine and coastal policy context the NDMP is vital to identify learning and good practice to support improved marine management and sustainable development. Such evidence may also provide ‘confidence’ to investors under the development of opportunities for sustainable finance.

Who benefits?

This review demonstrates that there is a wide range of stakeholders who can potentially exert influence over natural capital in North Devon. Traditional approaches to marine management have often focussed on the economic sectors that directly benefit from the natural assets and the governance actors who manage the natural asset and levels of exploitation. A key next step is to focus on segments of the value chain to link those ‘less addressed’ stakeholders more strongly to natural capital. Opportunities for future change may be explored though a process to establish a hierarchy of stakeholders’ impact/proximity and influence/power on natural capital to facilitate actions towards shared responsibilities and solutions for sustainable use.

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Annexes.

Annex I: Designated MPAs (and SSSIs with intertidal components) in NDMP.

MPA	Feature	Subfeature	EUNIS	Condition	Management
Lundy SAC	Reefs	Intertidal rock	A1	Maintain	IFCA byelaw 2015. Prohibition of the removal of *Palinurus elephas* (Spiny lobster). D&S IFCA, byelaw, 2015 Potting and Mobile fishing bylaw IFCA 2015. Diving permit byelaw, 2015. No take zone, small area off the east coast of Lundy (2003)
	Reefs	Infralittoral rock	A3	Maintain	
	Reefs	Circalittoral rock	A4	Maintain	
	Sandbanks which are slightly covered by sea water all the time	Subtidal coarse sediment	A5.1	Maintain	
	Sandbanks which are slightly covered by sea water all the time	Subtidal sand	A5.2	Maintain	
	Submerged or partially submerged sea caves	See Annex I relations	A4.71	Maintain	
	Communities of littoral caves and overhangs		A1.44	Maintain	
	Grey seal (Halichoerus grypus)			Maintain	
Lundy MCZ	Spiny lobster (Palinurus elephas)			**Recover**	IFCA byelaw 2015. Prohibition of the removal of *Palinurus elephas* (Spiny lobster). D&S IFCA, byelaw, 2015 Potting and Mobile fishing bylaw IFCA 2015. Diving permit byelaw, 2015.
Hartland Point to Tintagel MCZ	Coastal saltmarshes and saline reed beds		A2.5	Maintain	Impact assessments (Habitats Regulation Assessment) have been undertaken by Cornwall IFCA, to identify impact of each fishing activity on MCZ features and inform byelaws.
	Fragile sponge and anthozoan communities on subtidal rocky habitats		A4.12	**Recover (previous bottom towed fishing gear activity)**	
	High energy circalittoral rock		A4.1	**Recover**	
	High energy infralittoral rock		A3.1	Maintain	
	High energy intertidal rock		A1.1	Maintain	
	Honeycomb worm (Sabellaria alveolata) reef		A2.71	Maintain	
	Intertidal coarse sediment		A2.1	Maintain	
	Intertidal sand and muddy sand		A2.2	Maintain	
	Low energy intertidal rock		A1.3	Maintain	
	Moderate energy circalittoral rock		A4.2	**Recover (see high energy)**	
	Moderate energy infralittoral rock		A3.2	Maintain	
	Moderate energy intertidal rock		A1.2	Maintain	
	Pink sea-fan (Eunicella verrucosa)		SOCI 8	**Recover**	
	Subtidal coarse sediment		A5.1	**Recover (see high energy rock)**	
	Subtidal sand		A5.2	**Recover (see high energy rock)**	
Bideford to Foreland Point MCZ	Low energy intertidal rock		A1.3	Maintain	Interacts with IFCA fishing restriction byelaws (prohibition on removal of spiny lobster and netting permit byelaw)
	Moderate energy intertidal rock		A1.2	Maintain	
	High energy intertidal rock		A1.1	Maintain	
	Intertidal coarse sediment		A2.1	Maintain	
	Intertidal mixed sediment		A2.4	Maintain	
	Intertidal sand and muddy sand		A2.2	Maintain	
	Intertidal underboulder communities		A1.21	Maintain	
	Littoral chalk communities		A1.441	Maintain	
	Low energy infralittoral rock		A3.3	Maintain	
	Moderate energy infralittoral rock		A3.2	Maintain	
	High energy infralittoral rock		A3.1	Maintain	
	Moderate energy circalittoral rock		A4.2	Maintain	
	High energy circalittoral rock		A4.1	Maintain	
	Subtidal coarse sediment		A5.1	Maintain	
	Subtidal mixed sediment		A5.4	Maintain	
	Subtidal sand		A5.2	**Recover**	
	Fragile sponge and anthozoan communities on subtidal rocky habitats		A4.12	Maintain	
	Honeycomb worm (Sabellaria alveolata) reef		A2.71	Maintain	
	Pink sea-fan (Eunicella verrucosa)		SOCI 8	Maintain	
	Spiny lobster (Palinurus elephas)		SOCI 24	**Recover**	

MPA	Feature	Subfeature	EUNIS	Condition	Management
Bristol Channel Approaches SAC	Harbour Porpoise			Maintain	Interacts with seasonal closures and voluntary fisheries management measures
Lundy SSSI (marine and intertidal features only listed)	Seabirds (5)			Populations of all seabirds expanding, with the exception of kittiwake.	Interacts with IFCA fishing restriction byelaws
	Grey seal			Seal population is stable; ample evidence of continued successful breeding.	
	Littoral sediment		A2	Favourable	
Taw Torridge estuary SSSI	Saltmarsh		A2.5	Favourable	Interacts with IFCA fishing restriction byelaws
	Sheltered muddy shores		A2.3	Favourable	

Annex II Methodology to produce composite habitat map for NDMP.

A composite habitat map was generated for the Marine Pioneer study area from existing, best-available spatial datasets. Natural England (NE) made available to the Pioneer project an internally compiled habitats dataset, drawing on best available survey maps (where survey data was not available modelled data from EUSeaMap was used). These survey maps were collated from publically available datasets (available for download from the EMODnet habitats portal[2]) in addition to survey data available only to the partnership as an NE contractor/partner.

The habitat datasets were initially collated hierarchically on the basis of MESH confidence scores[3], with the aim that one single habitat polygon is presented for any given area. Whilst the use of this dataset is preferable to ensure the Pioneer is as aligned with NE (and other national marine initiatives) as possible, two particular issues needed to be resolved prior to use by the partnership:

- Habitat conflicts, i.e. instances where multiple EUNIS types are given for some areas, either through:
    a. overlapping polygons, i.e. spatial conflict, or
    b. ambiguous classification by map creators/intepreters (e.g. 'A2.5 or A2.6')
- Areas where habitat types were given only to EUNIS level 1 or 2

The processing steps taken to resolve these were as follows:

1. Extract those habitat polygons that intersect the ND Marine Pioneer area (NB <u>not</u> clip) [26,215 polygons retained]
2. Create new attribute field, '*HabType_Full*' and assign most detailed EUNIS class available per polygon (from field '*MCZ additional info*' where available, '*HAB_TYPE*' otherwise).
   [Note: 407 polygons were classified as H1320 saltmarsh unidentified, reassigned to A2.5]
3. Append EUNIS L3, 4 and 5 attributes and associate Annex I, OSPAR, MCZ HOCI, and BAP HPI correlations
4. Discard areas of EUNIS level 1
   [26,208 polygons retained[4]]
5. Identify 'overlap' habitat type conflicts (203 instances for intersections with ND Pioneer area), resolving iteratively as follows:
    a. Higher map confidence and non-modelled preferred
    b. Non-ambiguous preferred
    c. Higher detail preferred (implicit more confidence)
    d. Higher combined ES provision preferred
    e. Stronger policy links preferred (i.e. '=' better than '<' relational links to Annex I, OSPAR, HOCI, HPI)
    f. More policy links preferred (i.e. more relational links to Annex I, OSPAR, HOCI, HPI)
    g. Common parent habitat (up to L3)
    h. Arbitrary (where the above criteria did not resolve the conflict)
    i. Conflicts of polygons with area <5m^2 (88 polygons) were resolved arbitrarily

[2] http://www.emodnet.eu/seabed-habitats
[3] http://www.emodnet-seabedhabitats.eu/default.aspx?page=1635
[4] 7 polygons, largest ~150m^2, all from 2014 ERCCIS North Cornwall Biotope Mapping – Tintagel to Hartland Point

[26,106 polygons retained[5]]

6. Identify any remaining ambiguous habitat type conflicts (1,740 polygons, see Figure 12), resolve by comparing conflicting habitats and resolving on the basis of:
    a. Common parent habitat types (to no higher than EUNIS Level 3)
    b. Expert judgement of potential for ES provision, with higher provision preferred (see Table 1).
    c. Precautionary principle for remaining habitat conflicts

[26,106 polygons]

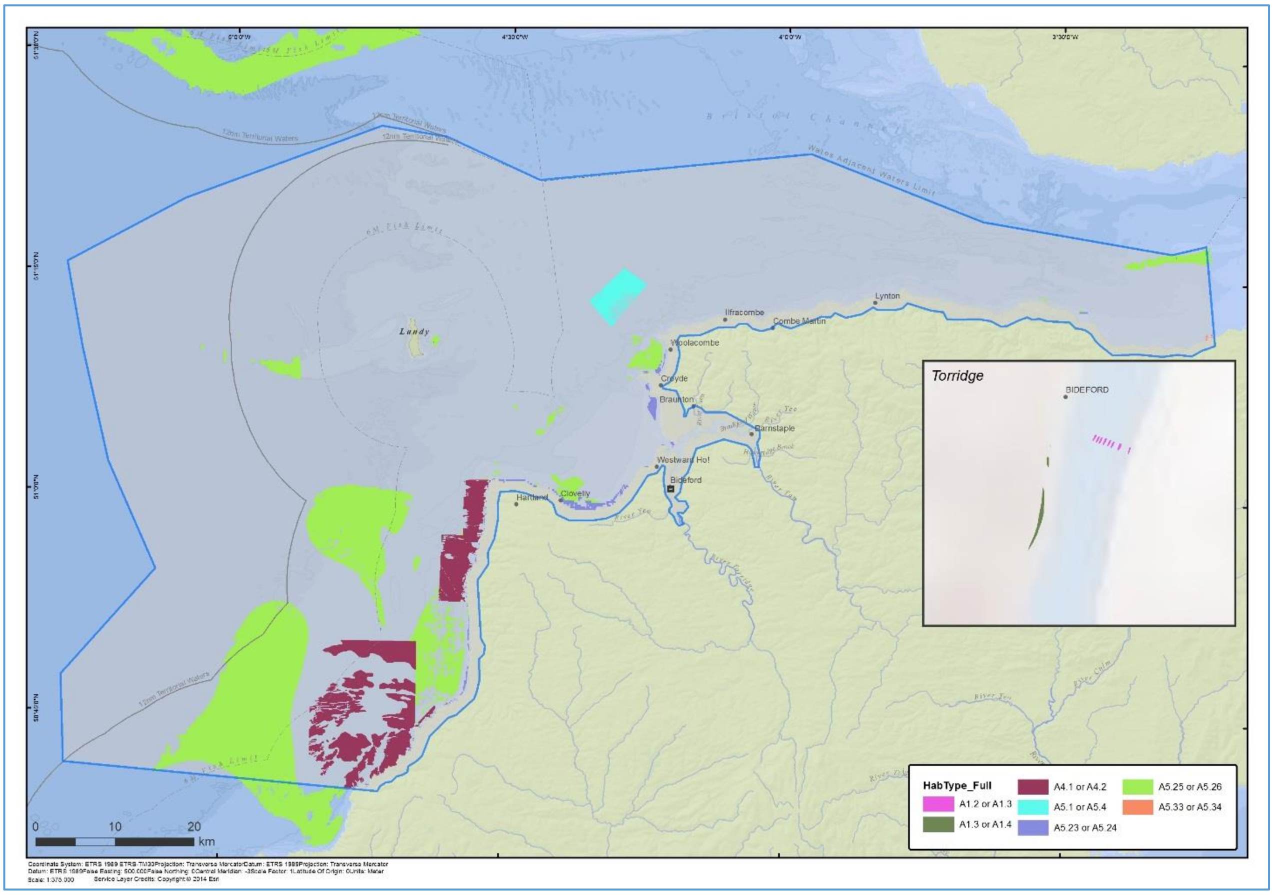

Figure 12 Resolved areas of remaining ambiguous habitat classification.

The resulting composite map depicts 142 distinct EUNIS habitat types (26 types at EUNIS L2/3).

Table 1 Resolving ambiguous habitat classifications for North Devon

Original	Habitat 1	Habitat 2	Parent Habitat	Decision
A4.1 or A4.2	A4.1: Atlantic and Mediterranean high energy circalittoral rock	A4.2: Atlantic and Mediterranean moderate energy circalittoral rock	A4: Circalittoral rock and other hard substrata	No difference in ES provision? Use A4.2 to err on side of moderate/conservative decision. No strong justification for either.

[5] 102 polygons dropped (5 by using common parent class)

A5.25 or A5.26	A5.25: Circalittoral fine sand	A5.26: Circalittoral muddy sand	A5.2: Sublittoral sand	Use L3 Parent.
A5.23 or A5.24	A5.23: Infralittoral fine sand	A5.24: Infralittoral muddy sand	A5.2: Sublittoral sand	Use L3 Parent.
A1.2 or A1.3	A1.2: Moderate energy littoral rock	A1.3: Low energy littoral rock	A1: Littoral rock and other hard substrata	No difference in ES provision? Use A1.2 to err on side of moderate/conservative decision. No strong justification for either.
A1.3 or A1.4	A1.3: Low energy littoral rock	A1.4: Features of littoral rock	A1: Littoral rock and other hard substrata	No difference in ES provision, use A1.4 (potential for features) – v small extent in Torridge only.
A5.1 or A5.4	A5.1 Sublittoral coarse sediment	A5.4: Sublittoral mixed sediments	A5: Sublittoral sediment	Use A5.4. for higher ES provision potential of muddy habitats, e.g. juvenile lobster habitat
A5.33 or A5.34	A5.33: Infralittoral sandy mud	A5.34: Infralittoral fine mud	A5.3: Sublittoral mud	Use A5.34 as more potential for Carbon seq, saltmarsh suitable hab etc.

Annex III Reviewed evidence supporting association of fish and shellfish species of commercial or conservation interest, with natural capital assets in NDMP.

At a regional scale habitats across NDMP, associated with fisheries and wild food benefits, identified by Fletcher et al. (2012a, 2012b) and Potts et al. (2014) are important to the adult and juvenile stages of species supporting commercial and recreational activities (Fletcher, 2012; Fletcher *et al.*, 2012; Potts et al, 2014). All broadscale habitats have a moderate or significant contribution towards this beneficial ecosystem service. Each fishery in NDMP is considered here in more detail.

Static trap fisheries are supported by brown crab *Cancer pagarus*, spider crab *Maja squinado*, European lobster *Homarus gammarus*, whelk *Buccinum undatum* and cuttlefish *Sepia officinalis.* The commercial shellfish species supporting activities in NDMP have similar, broad habitat and prey preferences. The diversity of habitats found in NDMP with reef habitats, coarse substratum and mixed substrata benefits these crustacean species while *B.undatum* prefer sand and mud habitats (Freire *et al.*, 2009; Galparsoro *et al.*, 2009; Gonzalezgurriaran & Freire, 1994; Hancock, 1967; Hayward, 1998; Lawton, 1989).

Static net, line and mobile trawl fisheries are supported by regionally important skate and ray populations, which utilise the coarse, mixed, sand and mud substratum, depending on species preference. Herring *Clupea harengus* utilise coarse substratum in the inshore area of Bideford and Barnstaple Bay, and support a traditional, culturally important, oar and sail fishery in Clovelly.

The North Devon area also supplies flatfish including: Plaice, Sole and Turbot and other demersal species including cod and bass. Sea Bass are caught year round with abundance changing through the year. During the winter months Cod, Haddock and Whiting are reported to be often abundant. Of the seasonal fisheries, the largest is the summer squid *Loligo vulgaris* and *Loligo forbesii* season.

Species of conservation importance that have previously supported commercial fisheries are also supported by the habitat features within the NDMP. Spiny Lobster *P.elephans* is a species of conservation importance (feature) within Lundy MCZ and Bideford to Foreland Point MCZ. Common skate *Dipturus batis,* which is a ‘critically endangered’ ICUN red list species, maintains a population within the western Bristol Channel sea area, which incorporates NDMP (IUCN red list).

The habitat preference, seasonal occurrence in NDMP and preferred food sources of fish species supporting commercial fisheries, or of conservation importance in NDMP are summarised in text below and in table X. Shallow subtidal and intertidal habitats within NDMP are utilised by juvenile

Thornback ray, Herring, Cod, Whiting, Sandeels, Plaice, Sole and Turbot as nursery areas (Ellis et al. 2010; Tyler-Walters, 2008).

Shell fish

Common Whelk *(Buccinum undatum)* naturally occur on all broadscale habitats present in NDMP throughout the year *B. undatum* are scavengers and carnivorous predators feeding on polychaetes, bivalves and carrion, feeding across the range of habitats present in NDMP (Hancock, 1967; Scolding, Richardson & Luckenbach, 2007). *B. undatum* may also bury in soft substrate with their siphon protruding (Hancock, 1967; Scolding, Richardson & Luckenbach, 2007).

Edible Crab *(Cancer pagarus)* occur year round and utilise the range of broadscale habitats found in NDMP. This species makes use of crevices in reefs and space under boulders to shelter, whilst also utilising mixed coarse ground and muddy sand habitats where individuals dig into the sediment (Hayward, 1998; Pawson, 1995). Larger adults utilise offshore muddy sand habitats as well as mixed coarse ground and reefs, whilst juveniles predominantly occur in sublittoral rocky habitats. Habitat utilisation patterns are noted to be different between sexes, larger males are often caught on rocky substrates whilst females are more abundant on sand and gravel (Hayward, 1998; Pawson, 1995). Brown crab tend to move into shallower water at night to feed, scavenging on carrion and predating on molluscs such as whelks, mussels and cockles (Lawton, 1989; Neal, 2008).

Common lobster *(Homarus gammarus)* occur year round and utilise similar habitats and food resources as *Maja squinado* and *Cancer pagarus*, displaying preference for the boundary between sedimentary and rock habitats with medium to high wave conditions (Galparsoro *et al.*, 2009). Juveniles burrow into fine sediments and mud (associated with broadscale habitats 5.1, 5.2, 5.3) while adults will form tunnels under boulders to avoid predation in sedimentary habitats (Galparsoro et al*.* 2009). Both juveniles and adults utilise crevices and holes to shelter in rock habitats (Linnane, Mazzoni & Mercer, 2000). *H.gammarus* feed on annelids, echinoderms and molluscs while juveniles. As adults, *H.gammarus* feed on smaller lobsters, crabs and larger molluscs (Hayward, 1998; Van der Meeren, 2005).

Spider Crab *(Maja squinado)* are a less important commercial species and utilise reef habitats, coarse sand and mixed gravel but utilise seaweeds and sponges for shelter rather than crevices or boulders favoured by *Cancer pagarus* (Freire *et al.*, 2009; Gonzalezgurriaran & Freire, 1994). Juveniles display habitat preference for kelp communities (associated with broadscale habitats A3.1 and A3.2) (Freire *et al.*, 2009; Gonzalezgurriaran & Freire, 1994). Spider crab feed on a range of prey, including seaweeds, molluscs and echinoderms (Freire *et al.*, 2009; Gonzalezgurriaran & Freire, 1994). Tracking of *Maja* spp. in North Western Spain revealed individuals spent a greater proportion of time in coarse sand substrates but isotope analyses showed that over 60% of diet originated from rocky substrates (Freire *et al.*, 2009). In the south west UK and Ireland *M.squinado* move inshore in spring and summer and move offshore in winter (Fahy & Carroll, 2009).

Spiny lobster (*Palinurus elephas)* is a species of conservation importance (SOCI). Abundance of *P.elephas* is higher in spring and summer within NDMP although a small population is present in winter months. Adult *P.elephas* favour reef habitat (A3, A4) or coarse sediment with boulders that provide shelter (A5.1). *P. elephas* preys on a variety of benthic organisms, studies of their natural diet off Ireland revealed the diet is highly omnivorous, including hard–shelled bottom dwelling organisms, principally molluscs, echinoderms and crustaceans. Mating is reported to occur between June and October (De Vascondellos,1960; Gibson & O'Riordan, 1965; Mercer, 1973; Hunter et al., 1996). In the Atlantic *P. elephas* undertakes a pre-reproductive spring onshore migration and a reverse post-reproductive offshore migration in late autumn (Mercer, 1973; Ansell & Robb, 1977). In the 1970s the spiny lobster was a fairly common inhabitant of deep rocky habitats in NDMP, in particular around Lundy (Atkinson and Schembir, 1981). However their numbers appear to have declined since then (Hiscock, 2003; Irving and Northen, 2004; Natural England, 2018). Spiny lobster have also been recorded along the NDMP coast in the Lynmouth area (Defra 2015). A no–take zone in Lundy enforced by D&S IFCA bye laws protects the species from harvesting in a portion of the NDMP.

Scallops

Primarily king scallop *Pecten maximus*. Queen scallops *Aequipecten opercularis*, are a less important commercial species although fisheries exist in UK regions (Howarth *et al.*, 2011).

Adult scallops generally prefer clean, full salinity sea water. They are found on a variety of bottom substrates including rock, stones and mixed sand and gravel substrata. The highest abundance has been noted where rocky outcrops or boulders occur on a substrate of mixed silty sand with gravel or shell (Franklin, 1980). *P. maximus* are often found in shallow depressions in the sea bed and commonly bury into the substratum. *A. opercularis* are commonly more mobile and found above the substratum (Marshall, 2009). Juvenile. Greater habitat complexity, through higher presence of macro algae was also related to increased abundance of juvenile *A. opercularis* within a Scottish marine reserve (Howarth *et al.*, 2011). Complexity provided by areas of sessile epifauna such as ross coral *Pentapora fascialis,* dead man's fingers *A.digitatum*, pink sea fan *E.verrucosa* and presence of mussel beds also provide shelter and resources benefitting juvenile scallops (Howarth *et al.*, 2011;

Sheehan *et al.*, 2013). Fragile sponge and anthozoan communtiies and pink sea fan are designated features in Hartland point to Tintagel and Bideford to North Foreland MCZs.

Cephalopods

Squid *Alloteuthis subulata* and *Loligo vulgaris* move to inshore grounds in NDMP in summer and autumn and support a seasonal fishery. *Allotehis subulata* are smaller (<20cm), the larger European squid species *Loligo vulgaris* reaches >20cm. Both squid species are short lived and abundance depends on success or failure of a particular breeding season. Monthly changes in distribution patterns are consistent with squid undertaking seasonal migrations around the coast of the U.K. (Waluda and Pierce 1998). The population in the north-eastern Atlantic spends the winter in deeper waters off Portugal, then moves towards the coast of France in spring, before migrating farther north. Squid species are described as having no preference for a particular bottom type, the only requirement seems to be the presence of substrata for the attachment of egg strings during the spawning period (Wilson, 2008). Both squid species prey on fish and crustaceans, although fish are the most important prey resource for larger squid (Pierce et al. 1994).

Skates and Rays

Elasmobranchii species, principally thornback ray *Raja clavata* and small-eyed ray *Raja microocellata* are caught by net fisheries.

Thornback Ray *Raja clavata* contribute greatest landings and migrate to inshore coastal waters in spring. Shallow regions are used as nursery areas (including low usage in Lyme Bay) (Ellis *et al.*, 2012). Both ray species prefer sand or mud although *Raja clavata* will occur over rock and gravel (Ellis, Pawson & Shackley, 1996; Holden, 1974; Rae, 1982). *Raja microocellata* prefer softer sand substratum, in which to bury (Kaiser et al. 2004). *Raja clavata* and *Raja microcellata* feed on a range of species, including crustaceans, shrimp and smaller fish including sand eels (Ellis, Pawson & Shackley, 1996; Holden, 1974; Kaiser *et al.*, 2004; Rae, 1982).

Small eyed ray *Raja microocellata* are only abundant in a few sites such as the Bristol Channel in the UK and Bertheaume Bay in France (Ellis, 2000). *R. microocellata* occur in NDMP year round and are found on soft substrates favouring sandy bays and sand banks to which its camouflage is perfectly suited (Kaiser et al., 2004). Very little is known about the diet of the Small-eyed Ray, though it most likely feeds on a variety of bottom dwelling invertebrates such as crustaceans and teleost fish (Whitehead et al., 1986). Studies from Bertheaume Bay, France have shown that it feeds almost exclusively on fast, teleost fish such as sandeels, particularly *Ammodytes tobianus* (Rousset, 1987). Ambush predators, once buried only their eyes and spiracles are visible.

Blonde ray *Raja brachyura* is present year round, most common on sandy sediments (Ellis et al. 2005a). Juvenile *R.brachyura* feed on small crustaceans (amphipods, shrimp, crabs), adults feed more on cephalopods and small fish (sandeels).

Common Skate *Dipturis batis* occur in all seasons in NDMP. The Bristol Channel, along with the Irish Sea and central North sea are the only inshore regions where this once very common skate species still occur, all be it in small numbers. Sandy and muddy substratum in NDMP is therefore important for supporting this species which is listed as critically endangered on the IUCN red list. *D. batis* also occupy the deeper waters off northwestern Scotland and in Celtic Sea, and along the edge of the continental shelf. As *D. batis* are large when juveniles, they may not escape fishing nets. The species is also slow growing and has late sexual maturity which increases survival risk of populations. It hunts actively, enveloping prey before consuming it (Dulvy et al., 2006). Mid-water species are captured by the skate propelling itself rapidly upward, enveloping and gripping the fish before returning to the seabed to consume it (Wheeler, 1969). Fish, larger crustaceans and squid are preferred prey resources (Wheeler, 1969).

Flatfish species, plaice *Pleuronectes platessa* and sole *Solea solea* are the principal flatfish species targeted by fisheries and share similar habitat preferences. Soft substratum with bottom living prey animals, such as, shellfish, cockles, razor shells, polycheates, crustaceans and sand eels is required by both species (Hinz *et al.*, 2006; Reeve, 2007; Ruiz, 2007). Plaice use sight to hunt and utilise clearer habitat with less disturbance, with a preference for sandy patches in rocky areas, such as the soft substratum in between reef features (Hinz *et al.* 2006). *S. solea* have a broader prey preference than plaice; like *P. platessa*, *S. solea* avoid gravelly sediment but use tactile and chemo sensory senses to hunt and so occur in muddier sediments or regions with greater disturbance (Hinz *et al.* 2006). Turbot *Scophthalmus maximus* occur on sand and coarse substratum from about 20 m to a depth of 80 m but occasionally on mud habitats or areas of mixed sand and rock. Juvenile *S. maximus* may be found inshore in the breaker zone or in shore pools and may also occur in brackish waters (Tyler-Walters, 2008).

Demersal fish species, principally cod *Gadus morhua* and bass *Dicentrarchus labrax* are also targeted by static net fisheries (Pearce, 2014). *D. labrax* occur in a range of habitats from rock to soft sediments, including sand, shingle and mud, migrating into south western UK coastal regions in spring and often displaying site fidelity for long periods (Pawson *et al.*, 2008; Pawson *et al.*, 2007). A carnivorous species, *D. labrax* require smaller fish, crustaceans, squid and polychaete prey to be present (Miller, 1997).

G. morhua range to a depth of 600m. Juvenile (up to 5 years) *G. morhua* prefer coarser or rocky ground (Table 3). As shown by Lindholm et al. (1999) the complex habitats provided by reefs and sessile epifauna reduce predation rates of juvenile *G. morhua. G. morhua* feed on crustaceans and other fish as adults and during juvenile stages will eat zooplankton, particularly copepods (Frose, 2015). As adults and juveniles *G. morhua* are present close to the shore in autumn and winter while adults move offshore in early spring (Righton *et al.*, 2007).

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Annex IV

Review of indicators identified in existing literature and NDMP workshops, for classes within CICES ES classification framework.

Due to the size of the CICES classification spreadsheet review of multiple studies this Annex is presented as a table/spreadsheet available in a separate document.

'ANNEX IV_ Review of indicators relevant to NDMP within CICES'

Annex V

a) MSFD and WFD monitoring indicators, in relation to extent and condition of natural capital assets in NDMP

Natural Capital Assets	**Indicators: extent**	Data source	**Indicators: condition**	Data source	**Relevant MSFD indicators**	**Relevant WFD indicators**
● Habitats	Extent (km²/ha)	EMODnet	Condition assessment for features of designated sites.	e.g. Natural England Designated Sites System.	*MSFD Indicator 1.5.1:* Habitat area. *MSFD Indicator 1.6.1:* Condition of the typical species and communities. *MSFD Indicator 1.6.2:* Relative abundance and biomass. *MSFD Indicator 6.1.1:* Type, abundance, biomass and area-extent of relevant biogenic substrate. *MSFD Indicator 6.2.1:* condition of the typical species and communities	Presence of 1. Higher sensitivity habitats, 2. Lower sensitvity habitats.
			Exposure to activities for which the habitat is sensitive to pressures from that activity.	e.g. Natural England Conservation Advice, 'Advice on operations.' Relevant spatial actvity data.	*MSFD Indicator 1.6.3:* physical, hydrological & chemical conditions. *MSFD Indicator 6.1.2:* Extent of the seabed significantly affected by human activities for the different substrate types.	
● Species	Abundance/ biomass	Environment Agency & NRW fish surveys	Population assessment	e.g. Environment agency & NRW fish surveys.	*MSFD Indicator 1.2.1:* Population abundance. *MSFD Indicator 1.2.1:* Population biomass based on Fish population biomass. *MSFD Indicator 1.3.1:* Populations demographic characteristics. MSFD *indicator 3.1.1:* Fishing mortality *MSFD indicator 3.1.2:* Ratio between catch and biomass index. *MSFD indicator 3.2.1:* Spawning Stock Biomass (SSB) *MSFD indicator 3.2.2:* Biomass indices	Presence: 1. Bivalve mollusc production areas, 2. Invasive species.
● Water bodies	Extent (km²/ha)	EMODnet	Water quality	e.g. Environment agency & NRW water body monitoring.	*MSFD Indicator 1.6.3:* physical, hydrological & chemical conditions. *MSFD Indicator 5.2.1:* Chlorophyll concentration in the water column. *MSFD Indicator 5.2.2:* Water transparency related to increase in suspended algae, where relevant. *MSFD Indicator 5.2.3:* Abundance of opportunistic macroalgae. *MSFD Indicator 5.2.4:* Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities. *MSFD Indicator 5.3.2 -* Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned. *MSFD Indicator 8.1.1:* Concentrations of the contaminants mentioned in the COM DECISION, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC. *MSFD Indicator 8.2.1* Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored. *MSFD Indicator 8.2.2:* Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution. *MSFD Indicator 9.1.1* Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels. *MSFD Indicator 9.1.2* Frequency of regulatory levels being exceeded. *MSFD Indicator 10.1.1:* Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source. *MSFD Indicator 10.1.2:* Trends in the amount of litter in the water column (including floating at surface) and deposited on the sea floor, including analysis of its composition, spatial distribution and, where possible, source. *MSFD Indicator 10.1.2:* Trends in the amount of litter in the water column (including floating at surface) and deposited on the sea floor, including analysis of its composition, spatial distribution and, where possible, source.	Water Body: ecological status, chemical status, water quality (phytoplankton and harmful algae).
	Depth (bathymetry)	Hydrographic charts	Modification of water body.	e.g. Environment agency monitoring.	*MSFD Indicator 7.1.1:* Extent of area affected by permanent alterations. *MSFD Indicator 7.2.1:* Spatial extent of habitat affected by the permanent alteration	Water Body: Hydromor-phology (modifica-tion)

b) MMO social an economic impact of marine plan indicators, in relation to assessing economic and social benefit of flow of ES from natural capital assets in NDMP

Level of delivery of ecosystem service (goods/ benefit)	**Indicators**	**Well-being (social impact) related to level of delivery** of ecosystem service (goods/ benefit) (linked to marine plan social impact indicators)				
		Well-being (Value)			**Well-being (Health and Social)**	
		Value	Employment		Health	
		Value indicators	Employment indicators	Labour market indicators	Recreation, coastal visit indicators	Physical and mental health indicators
As identified for individual ES from reviews of recent studies and expert knowledge.	As identified for individual ES from reviews of recent studies and expert knowledge.	As identified for individual ES from reviews of recent studies and expert knowledge.	1. Most accurate industry specific data, 2. ONS Business Register and Employment Survey data are analysed. 3. ONS Annual population survey to assess jobs in coastal communities.	1. Marine sector employment as proportion of total coastal community employment (ONS Business Register and Employment Survey). 2. Number of coastal Lower Super Output Areas (LSOAs) that are amongst the 10 per cent most employment deprived in England. (Indices of Multiple Deprivation (IMD), Department for Communities and Local Government (DCLG)). 3. Unemployment IMD DCLG	1. The volume of visits to marine and coastal areas (Natural England Monitoring Engagement with the Natural Environment (MENE))	1. ONS Annual Survey of Hours and Earnings (ASHE). 2. Number of coastal Lower Super Output Areas (LSOAs) that are amongst the 10 per cent most employment deprived in England. (Indices of Multiple Deprivation (IMD), Department for Communities and Local Government (DCLG)). 3. Unemployment IMD DCLG. 4. Number of physically active visits occurring in the marine and coastal area (Natural England Monitoring Engagement with the Natural Environment (MENE)). 5. Average rank (1 to 5) of mental health benefits of coastal visit (whether the visit made the person (i) feel calm and relaxed, and (ii) feel refreshed and revitalised. As such it indicates the mental health benefits of physical activity) (MENE). 6. Average ranking of 'life satisfaction' for the population of a given are, (ONS Subjective Wellbeing Annual Population Survey). 7. Subjective ranking of satisfaction with health (1 completely dissatisfied to 7 completely satisfied) (Understanding Society, Institute for Social and Economic Research (ISER), at the University of Essex). 8. Average rank (1 to 5) of whether learning about the natural world took place during the visit (MENE). 9. Number of people receiving job related training in the last 13 weeks (ONS Annual population Survey).