2019-04-25

North Devon Marine Pioneer 2: A Natural Capital Asset and Risk Register.

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http://hdl.handle.net/10026.1/14927

North Devon Marine Pioneer
2: A Natural Capital Asset and Risk Register

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Suggested citation for this report:

Rees, S.E., Ashley, M., Cameron, A. 2019. North Devon Marine Pioneer 2: A Natural Capital Asset and Risk Register. A SWEEP/WWF-UK report by research staff the Marine Institute at the University of Plymouth

Acknowledgements:
This report was funded by WWF-UK and SWEEP. The geodatabase had been funded by Natural England. The authors would like to thank staff from the Devon and Severn IFCA, Plymouth Marine Laboratory, The Marine Management Organisation, North Devon Council and North Devon Biosphere for assistance with data and advice.

List of abbreviations

BAC background assessment concentrations

CL Conservation Limit

CPUE Catch per Unit Effort

DAIN Dissolved Available Inorganic Nitrogen

DEFRA Department for Environment, Food & Rural Affairs

EAC Environmental Assessment Criteria

ES Ecosystem Service

EUNIS European Nature Information System

FIPs Fishery Improvement Projects

GES Good Environmental Status

ICES International Council for the Exploration of the Sea

IFCA Inshore Fisheries and Conservation Authority

iVMS Inshore Vessel Monitoring System

JNCC Joint Nature Conservation Committee

LRC Likely Relative Condition

MarESA Marine Evidenced Based Sensitivity Assessment

MCAA Marine and Coastal Access Act 2009

MCZ Marine Conservation Zone

MENE Monitor of Engagement with the Natural Environment

MESH Marine European Seabed Habitats

MPA Marine Protected Area

MSC Marine Stewardship Council

MSFD Marine Strategy Framework Directive

MSY Maximum Sustainable Yield

MWG Marine Working Group

NASCO North Atlantic Salmon Conservation Organization

NCC Natural Capital Committee

NDCC North Devon County Council

NDMP North Devon Marine Pioneer

NTZ No Take Zone

NVZ Nitrate Vulnerable Zone

ORVAL Outdoor Recreation Valuation Tool

SAC Special Area of Conservation

SCC Social Cost Carbon

SSSI Site of Special Scientific Interest

SWEEP South West Partnership for Environment & Economic Prosperity

TAC Total Allowable Catch

VMS Vessel Monitoring System

WFD Water Framework Directive

Executive Summary

To operationalise the Natural Capital Approach the United Kingdom (UK) Government Department for Environment, Food and Rural Affairs (Defra) created four Pioneer projects to inform the development and implementation of the 25 Year Environment Plan (HM Government, 2018b). 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.

This report represents a follow-on from Ashley, Rees et al (2018) to further test the framework for the application of the Natural Capital Approach in the Marine Pioneer. We present:

- A natural capital asset register that considers the extent and condition of the natural capital assets (Part One) and the stocks and flows of ecosystem services in the North Devon Marine Pioneer (Part Two);
- A risk register to identify threats to natural capital in the North Devon Marine Pioneer (Part Three); and
- Recommendations on key natural capital assets on which future management opportunities could be focussed to achieve the greatest gains (Part Four).

A Natural Capital Asset Register

Extent and Condition

To collate evidence of the extent and condition of the natural capital assets and the levels of flow of services and benefits, a range of potential indicator metrics were defined in Ashley et al (2018) and refined for this report. All indicator metrics are assessed for the baseline year (2017 or next closest year data are available) and the trend since 2010 (increase or decrease) is analysed using annual data for 2010-2017 where available.

The **extent** of the natural capital assets in km^2 are calculated for the NDMP. The habitat map created for the NDMP represents 'best available evidence' at the time of writing this report in December 2018. We also calculate the extent of habitats within MPAs and the extent of the habitat that interacts with a management measure to reduce benthic impact. 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. Therefore, any changes in the **extent** of the habitats is only meaningful for habitats where there is high confidence of the habitat feature boundaries. Overall, in the last 5 years there has been an increase in the **extent** of habitats incorporated within designated MPAs. Concurrently, there has been an increase in the **extent** of habitat with management measures to protect benthic features, since the Lundy No Take Zone prohibited all fishing activity within 3.3km^2 of Lundy habitats in 2003.

The assessment of the **condition** of natural capital assets within the NDMP makes use of three sources: The **condition** of habitats and species within designated MPAs; The **condition** of water body assets (including designated bathing waters and shellfish waters); and the **condition** of seabed habitats (modelled approach).

Within MPAs, there is a policy objective, to undertake **condition** assessments for specific habitats every 6 years. The majority of MPA features have a management objective to 'maintain'. Habitats and species with an objective for recovery include spiny lobster (Lundy MCZ), fragile sponge and anthozoan communities on subtidal rocky habitats, moderate energy circalittoral rock, subtidal coarse sediment, Pink Seafan and subtidal sand (Hartland Point to Tintagel MCZ) subtidal sand (Bideford to Foreland Point MCZ).

The **condition** for water body assets is only available for waters that are assessed within the jurisdiction of the Water Framework Directive and the Marine Strategy Framework Directive. There are large tracts of the NDMP water body asset (particularly offshore areas beyond estuarine and coastal water bodies where the **condition** (e.g. ecological and chemical status) is not currently known. Overall, the condition of the NDMP water body asset is limited by upstream effects from farming and water treatment. The Taw Estuary is designated as a Polluted Water [Eutrophic] under the Nitrates Directive and the likelihood of poor water quality has implications on the shellfish waters and bathing waters within the estuary.

To obtain a spatially explicit indication of asset **condition** applicable across the Marine Pioneer area, a proxy approach was applied, based on knowledge of habitat sensitivity to pressures, and activity data (fishing) that may contribute to those pressures. By combining data layers on habitat sensitivity and exposure (to activity) levels we determine the Likely Relative Condition (LRC) of that habitat. The majority of habitats within the NDMP have been impacted by abrasion related to demersal fishing. Just 8.3% of all intertidal (littoral) and subtidal (sublittoral) habitats in NDMP were classified with the highest LRC, suggesting that the structure and function of the ecosystem is (relatively) intact. 45.7% of all littoral and sublittoral habitats were classified with an LRC of 1 to 3 (the lowest 3 categories), suggesting exposure to activities-pressures which were reviewed to negatively impact the structure and functioning of the habitats typical component flora and fauna communities. Contribution to ES provision is likely to be impacted for these habitats. Several limitations exist with the application of this proxy measure to inform future management of natural capital including the temporal and spatial resolution of activity data, the combination of 'uncertainty' measures across methods and the application of sensitivity assessments to broad scale habitat levels.

Ecosystem Service Flows

Food (Wild food)

There are a range of habitats within the North Devon Biosphere reserve that support food production that benefit food provision (fisheries) at both a local and regional scale. Habitats that provide structure, complexity, and niches provide shelter and food resources for fish and shellfish. For example the three dimensional structure of saltmarsh vegetation during high tide, provides significant shelter benefits to juvenile fish species, as well as food resources. Reefs (including biogenic reefs) and kelp communities provide shelter and prey resources for juvenile stages of commercially targeted fishes, crustaceans and bivalve mollusc. Sediment habitats that cover a vast tract of the NDPR are a significant provider of food resources for fish. The water column is a key asset in realising the benefit of food provision from natural assets with currents, the chemical composition, transition zones (nutrient rich mixed water and stratified water) and areas of primary production fuelling life within the ocean (Ashley, Rees & Cameron, 2018).

Two sets of data were available to assess fishing activity: 1) Data on landings of principle species (live weight) were obtained for the years 2010-2017 for a subset of vessels from North Devon ports (Clovelly, Bideford, Appledore, Ilfracombe), that were identified to fish within NDMP. These were vessels that operators had provided consent for their vessel's data to be obtained from MMO; and 2) MMO data of landings by UK and foreign vessels to ports all within NDMP (Boscastle, Bude, Clovelly, Bideford, Appledore, Ilfracombe).

An overall decline in the fishing sector in NDMP is apparent from the indicator data analysed, with number of registered vessels in the region declining from 2010-2017 and also a decline in the number of processers and sellers of local fish. The number of vessels registered to ports within NDMP (Devon and Cornwall), between 2010-2017, peaked in 2012 (58 vessels) and declined to 29 vessels in 2016/17. Landings and associated value trends, for the vessels that fished within the NDMP were negative for all species apart from whelk *B. undatum* and herring *C. harengus* over the time series 2010 to 2017. However, over a shorter time scale, between 2014 and 2017, there has been an increase in landings volume (t) of plaice *P. platessa*, sole *S. solea*, thornback ray *R. clavata* and blonde ray *R. brachyura*. Between 2010 and 2017, of vessels that fished within the NDMP, larger vessels (over 10m) based in larger ports such as Ilfracombe and Bideford have landed >90% of the total volume (t) of fish landed. These trends were also identified in the landings data to all ports within the NDMP (Devon and Cornwall), for all vessels (including visiting vessels and vessels that may have landed catches inside an outside the NDMP).

Increase in stock assessment surveys CPUE (number per km^2) occurred for thornback ray *R. clavata,* squid species and herring *C. harengus* in ICES rectangles interacting with NDMP between 2010-2017. Sole *S. solea* CPUE displayed little change over time. Sole *S. solea* and thornback ray *R. clavata* are high value stocks for the vessels fishing from NDMP ports (*R. clavata* due to high landings volume and *S. solea* due to high value but smaller volume of landings). Herring *C. harengus* represent a stock that have previously supported a historical seasonal fishery. The trends identified in CPUE were reflected in recommendations for TAC for the wider ICEA Area VII f for all species apart from for Thornback ray *R. clavata* and sole *S. solea* (which showed reduced TAC in the wider ICES area but increased CPUE in stock assessment samples in proximity to NDMP). The trends suggest either the wider southern Celtic Sea stocks were assessed to be in poor condition and/or there were larger local populations of species at the time of sampling (annual autumn surveys).

Landings of lobster *H. gammarus* are a high value fishery. Landings have shown a declining trend between 2010 and 2017. South West UK lobster stocks are assessed as being exploited above minimum reference limits and approaching, but not yet at maximum sustainable yield (Cefas, 2017b). However, there is no data on the local levels of lobster abundance for the NDMP. Historical re-stocking with hatchery reared juveniles has occurred in the region. Assessing the benefit of such initiatives would inform future sustainable management options. At a UK level, lobster stocks are part of Project UK (https://www.seafish.org/article/project-uk). Project UK aims to determine the environmental performance of key commercial fisheries, demonstrate how these can move towards sustainability through Fishery Improvement Projects (FIPs) and ultimately achieve MSC certification where possible.

Overall, there has been a decline in catch per unit effort of cod *G. morhua*, plaice *P. platessa,* sole *S. solea*, bass *D. labrax* and small eyed ray *R. microcellata* stocks from stock assessment survey trawls within and adjacent to the NDMP, since 2010. There have also been decreases in stocks, in relation to fishing pressure, in the wider ICES areas the fish stocks inhabit, indicated by reductions in recommended TAC. Declines in vessel numbers and landings of the majority of species may reflect declines in abundance but may also be influenced by social and economic factors that are not quantified by indicator data. Many social and economic factors influence fishing activity such as: fishers reaching retirement and fewer people entering the industry, cost of insuring and running vessels and availability of markets/ processors and prices paid by those markets, reduction in available grounds, competition with visiting vessels, or reduced demand for locally caught fish etc. Management measures (responding to reduction in stocks) may also trigger declines in landings though the implementation of spatial management measures, changes in landing size, TAC etc. Investigating these factors further through interviews or meetings with the local fishing industry members would provide knowledge on the factors influencing the trends observed in this study.

Historical exposure to the pressure 'abrasion' linked to demersal fishing activity has negatively impacted the potential provision to ES 'Food' (wild food) from NDMP habitats (that contribute moderately or significantly to ES 'food'. Management, leading to recovery of habitats, is likely to benefit fish stocks and therefore ES 'Food' benefits available to local fisheries. The saltmarsh within SSSI units and estuary waters are important nursery areas for fish, particularly bass. Estuaries also provide migratory routes for salmon and sea trout. A reduction in the extent and condition of nursery habitats, along with poor water quality, will impact upon the condition of these stocks and the potential flow of benefits. Habitats within designated MPAs, especially estuarine saltmarsh and coastal infralittoral reef, provide important nursery habitat supporting the main commercial fish species such as Thornback ray *R. clavata,* sole *S. solea* and Lobster *H. gammarus.* Ensuring saltmarsh SSSI units currently in unfavourable condition recover and infralittoral reef habitats in coastal MCZs and SACs are maintained in favourable condition will continue to benefit these fisheries.

A Healthy Climate

A healthy climate is dependent on the balance and maintenance of the chemical composition of the atmosphere and the oceans by marine living organisms. The capture and export of carbon is central to this process. Saltmarsh plant communities, algae and kelp communities capture carbon and soft substratum sediments contribute towards storage / sequestration. The water column supports the carbon cycle though oceanic primary production harvesting light to convert inorganic to organic carbon.

A total value of 7275.01 t/C/km^2/yr was calculated to be sequestered by habitats and associated algae and plant species communities within NDMP the annual value of which is between £30,000 and £167,000. This figure however, does not take into account the condition of the saltmarsh. Saltmarsh plant communities capture carbon that is then stored in saltmarsh soils. A healthy saltmarsh plant community will thereby, provide a greater contribution to this internationally important ES benefit. Within the NDMP, an assessment in 2012 (most recent condition assessment at time of writing) reports that 30% of the saltmarsh extent within Taw Torridge Estuary SSSI was in unfavourable condition (due to grazing pressure impacting plant communities) (Natural England, 2012).

Areas of high planktonic productivity (water bodies containing high abundance of phytoplankton) were also reviewed to provide a moderate contribution to the ES benefit 'Healthy Climate'. A future assessment of the role of oceans in supporting a healthy climate would benefit from including the extent of areas of high planktonic productivity. If high planktonic productivity occurred over the entire extent of waterbodies within NDMP an additional 19.90t of carbon is calculated to be sequestered. Although most phytoplankton are consumed by higher trophic level organisms, a small yet important fraction of carbon in phytoplankton (0.1%) have been calculated to sink, and associated carbon to become sequestered long–term in sea floor sediments (Falkowski, 2012; Howard *et al.*, 2017).

Natural Hazard Regulation (Flood Prevention/Sea Defence)

Marine habitats play a valuable role in the defence of coastal regions. The physical structures dampen wave energy from tidal surges, storms (e.g. reefs). The floodwater storage and attenuation of water currents and wave energy provided by habitats such as saltmarsh also delivers significant benefits to natural hazard regulation. Sediment habitats also dissipate wave energy, thus reducing the risk of damaging coastal defences and flooding low-lying land.

Intertidal habitats not only provide sea defence ES benefits in relation to present sea level (and sea conditions), but unlike man made defences, natural intertidal habitats such as saltmarsh will migrate with rising sea levels, predicted under future climate scenarios. The total of value of residential property in NDMP coastal belt, that are within flood risk zone 2 or 3 (medium or high risk of flooding) in 2018 was £694,033,905 (based on average house prices). There is an additional 0.39km^2 of high quality agricultural land (grade 1,2,3a) that overlaps with flood risk zone 2 or 3 in NDMP coastal belt with a sale value of £867,600.

Salt marsh, intertidal sand and coarse sediment (beaches), in particular, support multiple ES benefits in addition to sea defence including food and recreation. Restoring extents of saltmarsh in unfavourable condition and maintaining habitat extents of saltmarsh and intertidal sand and coarse sediment habitats will ensure ES provision is maximised. Habitats with structure and function in favourable condition will adapt (migrate) to sea level rise and continue to provide sea defence benefits under future scenarios. The current assessment is limited as fluvial and tidal models used to assess flood risk focus on hydro-morphology rather than habitat characteristics. Models, applied to specific properties of NDMP intertidal habitats, such as, grain size, slope, water storage and effect of vegetation on attenuation of water currents would increase the accuracy of future assessment.

Clean Water and Sediments

Marine living organisms store, bury and transform waste though assimilation and chemical decomposition and re-composition. 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. 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; Sturdivant & Shimizu, 2017).

Habitats with a moderate contribution of provision to ES clean water and sediments cover a huge proportion of NDMP. A very large proportion of these sublittoral soft substratum habitats are also either in conservation objectives of 'recover' (in coastal MCZs), or received a modelled likely relative condition of moderate or below. The provision of the ES benefit of clean water and sediments is likely to be highly limited in NDMP due to pressures related to historical activities. The moderate proportion of saltmarsh habitat in unfavourable condition is also likely to impact provision of ES benefit.

In an impacted state, these altered habitats reduce resistance and resilience of NDMP as a whole, to absorb and recover from anthropogenic pressures such as input of excess nutrients through agriculture or sewage. A reduction in water quality and ecological status of water body assets would also impact levels of participation in recreational activities, and so related economic benefits to the local community and health benefits to participants.

Tourism and Recreation

Marine natural capital assets provide the basis for a wide range of tourism and recreational activities. Tourism and Recreation opportunities include watersports, wildlife watching, fishing, appreciating scenery (e.g. from a viewpoint), swimming outdoors, visits to a beach (sunbathing or paddling in the sea), walking (e.g. walking the coast path). Saltmarsh (in relation to coastal access points, nature watching, aesthetic interest and supporting species of interest to recreational fishing and foraging) and littoral sand, coarse and mixed sediments (in relation to beaches and coastal access points) were reviewed to provide significant contributions to the provision of the ES of Tourism and Recreation.

According to Visit England statistics, between 2015 and 2017, there were approximately 4,317,000 overnight stays of tourists in the North Devon and Torridge Council districts representing £250m in expenditure. Analysis of the Devon wide Monitor of Engagement with the Natural Environment (MENE) data identified that coastal resorts and towns provide a focal point for people undertaking beach activities and water sports. The importance of coastal towns becomes evident when MENE data is mapped through ORVAL relative to the scale of the NDMP. Visits to paths and beaches are concentrated close to larger coastal towns, as are highest welfare values (such as Appledore, Westward Ho!, Barnstaple, Bideford, Woolacombe, Bude, Ilfracombe, Combe Martin and Minehead). In terms of the local residents, over 70% of respondents to the 2018 North Devon Water Sports Survey stated that they took part in a water sports activity. Surfing (alone and combined with bodyboarding and knee boarding) was by far the most popular activity practised by North Devon residents completing the survey. The scaled up average spend of Marine Pioneer residents of approximately £28m per year on water sports is also likely to be focused in these towns, supporting economic benefits to businesses and communities.

For water sports and recreation activities, the water quality within water body assets is an essential factor to support participation. At the same time, good and excellent water quality supports the condition of species communities and so health of habitats and species of interest to recreational diving, angling and wildlife watching as well as general appreciation of scenery. Failure of Instow and Ilfracombe – Wildersmouth beaches to meet designated bathing water standards and the wider coastal and estuarine water bodies Taw Torridge Estuary, Bristol Channel Inner South and Bridgewater Bay remain a concern for provision of ES benefits at their full potential.

Species assets, protected within NDMP MPAs (grey seal, puffin and other sea birds and spiny lobster) as well as cetaceans support at least 12 wildlife watching tour boats, and provide interest for visitors to Lundy. These are also species of interest to recreational divers. Kittiwake *Rissa tridactyla* populations within Lundy SSSI were reported to have continued a long-term decline and South West UK populations of Spiny lobster *Panulirus argus* are reported to be depleted. Addressing these declines will support provision of benefits to wildlife watching in NDMP.

Recovering and maintaining habitat assets across NDMP to favourable condition will continue to support feeding and nursery areas for larger species of interest to nature watching, as well as juvenile and adult fish and shellfish species supporting recreational fishing and interest to recreational divers. As a region with historically important recreational rod and line salmon and sea trout fishing, ensuring the migratory routes of salmon and sea trout in the Lyn, Taw and Torridge are unaffected by development and poor habitat condition is essential. All rivers are currently classified 'probably at risk' at not meeting conservation objectives.

The link between estuarine habitat, particularly salt marsh and coastal reef habitats is very important for provision of nursery areas for fish and shellfish of interest to commercial and recreational fisheries. Much of the estuary and coastal habitats in NDMP are within MPAs, which provides opportunity for management to ensure habitats are in the best condition for provision of ES benefits. In the most recent conservation assessment 30% of saltmarsh habitat in Taw Torridge SSSI was in unfavourable condition. Large extents of subtidal rock, subtidal coarse sediment and subtidal sand habitats were also assessed to have a conservation objective of 'recover'. Management measures to limit benthic impact from pressures such as abrasion are limited to MPAs around Lundy. Future management to ensure recovery of estuarine and coastal habitats inside and outside MPAs will benefit not only tourism and recreation ES benefits but, multiple key ES benefits including food, sea defence, clean water and sediments and healthy climate.

A Risk Register for the North Devon Marine Pioneer

To inform routes towards sustainable development and to underpin the flow of ecosystem services the purpose of a natural capital risk register is to identify those assets and the linked flows of benefits that are at greatest risk from unsustainable use and gaps in management. A method for developing a risk register was developed by (Mace *et al.*, 2015) as part of the Natural Capital Committee's work. The risk register developed by Mace et al (2015) is a preliminary high-level assessment based on natural capital assets at a national scale. The national scale risk register revealed substantial gaps in knowledge about the marine asset-benefit relationships and therefore the associated risk of loss of ecosystem service benefits. Through the development of the risk register at a case study scale for the North Devon Marine Pioneer we test and refine the application of the Natural Capital Approach suitable for the marine context and develop targeted recommendations to support a 'net gain' approach to marine management in the NDMP.

Asset-benefit relationships represent the relationship between the condition of the natural asset and the benefit provided to people. Three types of natural capital assets were taken forward for this study. These comprise: Habitat assets – All EUNIS level 3 habitats that provide a moderate or significant contribution to an ecosystem service benefit; Species assets – commercial species (fish and shellfish) with and without quota; migratory species (salmon and seatrout); and the water column – water bodies, bathing waters, shellfish waters. To determine the nature and the severity of the risk to the asset-benefit relationship we assess the performance of the asset benefit relationship against UK policy targets. We also integrate a metric for Community Based Knowledge of the Risk developed though participation in a workshop of the members of the North Devon Marine Working Group (MWG).

The greatest risk to the asset-benefit relationships in the NDMP are summarised as:

- Food (wild fish and shellfish) is high risk due to the extent of sublittoral habitat without management objectives and with impaired quality (condition) based on knowledge of previous fishing activity.
- Healthy climate benefits are at risk due to the degraded quality of the saltmarsh and rock/reef habitats.
- Sea defence services provided by saltmarsh, littoral sand and mud sediments are at risk.
- Recreation and tourism is at risk due to degraded habitats and incidences of poor water quality.
- Clean water and sediments supported by the ecological functions and processes in the subtidal sediments are considered to be at risk due to impaired quality (condition) based on knowledge of previous fishing activity.

The severity of risk is largely subjective based on what parameters are used to judge 'severity'. From an ecological perspective the provision of Food (wild fish and shellfish) demonstrates the most asset-benefit relationships. This signals that there is a moderate to high degree of risk that the ecological connections that support fish and shellfish throughout their life history stages may be impaired and there is a broad range of risk to the future delivery of this benefit. If 'severity' is to be judged on the number of high risk (red) asset-benefit relationships as a proportion of the total asset-benefit relationships identified then the future provision of Clean Water and Sediments is the benefit most at risk of loss (with 36% of the total asset-benefit relationships in the 'high risk' category). From an economic perspective the Recreation and Tourist industry is the largest economic driver in the region representing a severe societal risk if the benefit is lost. Climate change will have a greater magnitude of social and economic impact at a global scale. The severity of the risk of loss of the asset-benefit relationships contributing to a Healthy Climate may also be considered within this context.

An overriding feature of the Risk Register is the contribution of the range of habitats to the provision of the range of ES benefits. MPAs and the management of features of conservation interest have long been considered the main policy tool to underpin human wellbeing. Whilst MPAs may play a significant role in achieving this, the risk register demonstrates that this is a limited assumption. ES benefits are linked to habitats and species with and without conservation designations. The risk to the asset-benefit relationship is heightened through the application of thresholds for Good Environmental Status (GES) of seafloor integrity under the Marine Strategy Framework Directive which reveals the impact that some fishing activity may have on the structure and functioning of marine ecosystems and hence the delivery of ecosystem service benefits. Knowledge and access to data on recent levels of fishing pressure would further support this evidence base and help clarify risk in order to target management measures to reduce the risk.

Recommendations

The range of habitats across the NDMP support a valuable flow of ecosystem services that underpin human wellbeing. The following recommendations for management opportunities are suggestions for further discussion with the Marine Pioneer Steering Group.

- To set management priorities that will rapidly enable ‘recovery’ of habitats where this conservation objective exists within MPAs.
- A ‘net gain’ for natural capital may be achieved via MPA management though a more ambitious approach to marine biodiversity conservation that considers the wider ecological structures and processes that have the potential for ‘recovery’ and ‘renewal’ beyond the delineated boundaries of features of conservation interest within an MPA (the whole site approach).
- To support the implementation of management measures that can reduce pressure across subtidal sediments.
- Evaluate the effectiveness of current iVMS trials on all mobile gear in the district as a tool to deliver effective spatial management of natural capital. Consider the roll out of iVMS to all vessels.
- Seek investment in water and sewerage infrastructure and;
- Trial natural capital approaches that support waste remediation (e.g. saltmarsh restoration, mussel beds)

Contents

1 Introduction

To operationalise the Natural Capital Approach the United Kingdom (UK) Government Department for Environment, Food and Rural Affairs (Defra) created four Pioneer projects to inform the development and implementation of the 25 Year Environment Plan (HM Government, 2018b). 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.

In June 2018, Ashley, Rees and Cameron (2018) completed a state of the art report for the Marine Pioneer (Report 1). The purpose of Report 1 was to develop the framework for the application of the Natural Capital Approach in the marine environment. The project objectives were to: 1) To demonstrate the pathways between ecology, ecosystem services and benefits that influence the human wellbeing; 2) Identify how stakeholders are linked (directly or indirectly) to natural capital; and 3) Identify relevant indicators, data sources and potential means for valuing ecosystem service benefits (monetary and non-monetary). Report 1 (Ashley, Rees & Cameron, 2018) identified the range of ecosystem service benefits that are supported by marine habitats in NDMP. Five key ES benefits that where of high relevance to North Devon and for which, natural assets in NDMP provided a moderate or significant contribution for, were taken forward for assessment (Table 1). For example, NDMP habitats such as coastal saltmarsh and intertidal and shallow reefs with seaweed (kelp) communities provide significant contribution to ‘Food’, ‘Sea Defence’, ‘Healthy Climate’ and ‘Tourism and Recreation’(Table 1). Intertidal biogenic reef and sediment habitats provide important contributions to species habitat, protection of coastal land from flooding and extreme weather (sea defence), and tourism/recreation benefits from beaches. Report 1 also identified management measures associated with the NDMP and reviewed the indicators available that could be used to populate a Natural Capital Asset and Risk Register (Ashley, Rees & Cameron, 2018).

Table 1 Habitats providing moderate and/ or significant contribution to multiple ES Goods/Benefits within NDMP

	Natural Capital Asset: Habitats in North Devon Marine Pioneer		Extent (km²) of habitat within NDMP	Contribution to ES Goods/Benefits				
				Food (wild food)	Tourism (incl. nature watching and recreation)	Sea Defence	Healthy climate	Clean water and sediments
Coastal margins	Saltmarsh	A2.5: Saltmarsh	2.8	3	3	3	3	3
Marine	Intertidal reef	A1: Littoral rock and other hard substrata	11.31	3	1	1	2	
	Subtidal reef	A3: Infralittoral rock and other hard substrata	16.61	3	1	1	2	
		A4: Circalittoral rock and other hard substrata	875.9	1	1	1		
	Intertidal sediments	A2.1 Littoral Coarse sediment	0.76	1	1	3		
		A2.2: Littoral sand and muddy sand	14.99	1	1	3	2	
		A2.3: Littoral mud	9.98	3	1	3	3	3
		A2.4: Littoral mixed sediment	0.45	1	1	3	2	
	Biogenic reef	A2.7: Littoral biogenic reefs	0.01	2	1	2	1	2
	Subtidal sediment	A5.1: Sublittoral coarse sediment	2845.22	2		3		3
		A5.2: Sublittoral sand	1690.03	2		3		3
		A5.3: Sublittoral mud	10.85	2		3		3
		A5.4: Sublittoral mixed sediments	48.56	2		3		3

Scale of ecosystem service contribution relative to other features	
#	Significant contribution
#	Moderate
#	Low
#	No or neglibible
[Blank]	Not assessed

Confidence in evidence available to assign ES provision	
3	UK-related, peer-reviewed literature
2	Grey or overseas literature
1	Expert opinion
[Blank]	Not assessed

This report represents a follow-on from Ashley, Rees et al. (2018) to further test the framework for the application of the Natural Capital Approach in the Marine Pioneer. Project objectives are to develop:

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- Recommendations on key natural capital assets on which future management opportunities could be focussed to achieve the greatest gains (Part Four).

2 A Natural Capital Asset Register (Part One)

The Natural Capital Committee (2017) define an asset register as "an inventory of the natural assets in an area and their condition". Ashley, Rees and Cameron (2018) began this process by defining the extent of the natural capital assets of the NDMP and the ecosystem services they provide. The purpose of this next step is to collate evidence of the state and condition of the natural capital assets and the levels of flow of services and benefits. Gathering this detailed information for the NDMP will provide the basis for discussions for a North Devon Marine Natural Capital Plan.

2.1 General Methods

Indicators identified in the review process undertaken in Report 1 by Ashley, Rees and Cameron (2018) were applied to assess extent and condition of natural assets, and flow of ES benefits for each ES within NDMP, for each ES identified in Table *1*. Monetary benefits, where applicable and data were available, were also assessed through relevant indicator metrics.

2.2 Indicators

Ashley, Rees and Cameron (2018) defined a number of indicator metrics that would allow an assessment of the extent and condition of natural capital assets as well as the flows linked to the ES benefits. The indicators presented in this report represent a final sift by the project team to access relevant indicator data within the timescale of the project.

Table 2 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 (Ashley et al 2018)

<table>
<tr><th colspan="9">Indicators Required to Assess Flow of Ecosystem Services from Natural Capital Assets through to Benefits to Individuals and Communities.</th></tr>
<tr><th colspan="5">Physical</th><th colspan="4">Economic</th></tr>
<tr><td colspan="3">Natural Capital Asset Extent and Condition</td><td colspan="2">Physical ES Benefit (Supply-Use)</td><td colspan="4">Economic ES Benefit (Use)</td></tr>
<tr><td rowspan="2">Natural Capital Assets (incl. Habitats, Species, Water bodies)</td><td rowspan="2">Indicators: extent</td><td rowspan="2">Indicators: condition</td><td rowspan="2">Level of provision of ecosystem service goods / benefits</td><td rowspan="2">Indicators: (identified in ecosystem service literature)</td><td>Value</td><td colspan="2">Employment</td><td>Health</td></tr>
<tr><td>Value indicators</td><td>Employment indicators</td><td>Labour market indicators</td><td>Physical and mental health indicators</td></tr>
</table>

Where possible all indicator metrics are assessed for the baseline year (2017 or next closest year data are available) and the trend since 2010 (increase or decrease) is analysed using annual data for 2010-2017 where available. Indicator metric data resources and physical data have been recorded and stored in linked excel spreadsheets provided as supplementary material. Where spatial data exists this has been stored in the geodatabase.

Specific methods for data collection and the original methods used in collection of secondary data are reported in Annexes, separated for each ES benefit (Annex I-IV). Additional data analysis and discussion of options for development of more suitable indicator metrics are also included in each Annex (for each ES benefit).

2.2.1 Trend Analysis

Where data were available for multiple years the trends (positive, negative or no change) between the earliest years data and the baseline year (2017) were assessed. Values such as fisheries landings for a species may rise and fall between years and do not necessarily provide a linear trend over time (increase or decrease concurrently and at a constant rate). Therefore, to visually identify if a trend over time occurred, annual data (e.g. 2010-2017) were first plotted in line charts in excel to observe inter-year changes. To statistically test for the presence of a trend, Kendall's tau-b statistical tests were calculated in SPSS to test for presence of a monotonic relationship between indicator data and time (2010-2017). The test provides a non-parametric form of monotonic trend regression analysis (Meals *et al.*, 2011). Monotonic trends occur when the variables (indicator over time) tend to move in the same relative direction, but not necessarily at a constant rate. A significant positive or negative trend was assessed at the 95% confidence limit (>0.05).

Moving averages (3year) were also compared where possible, to identify a change in average values between the most recent 3 year period and the three year period previous to it (e.g was there an increase, decrease or no change in the moving (3 year average) between 2012-2014, and 2015-2017). This provided a summary of changes in the most recent years data, and provided consideration for inter annual variation which was common in data such as fisheries landings or tourism statistics.

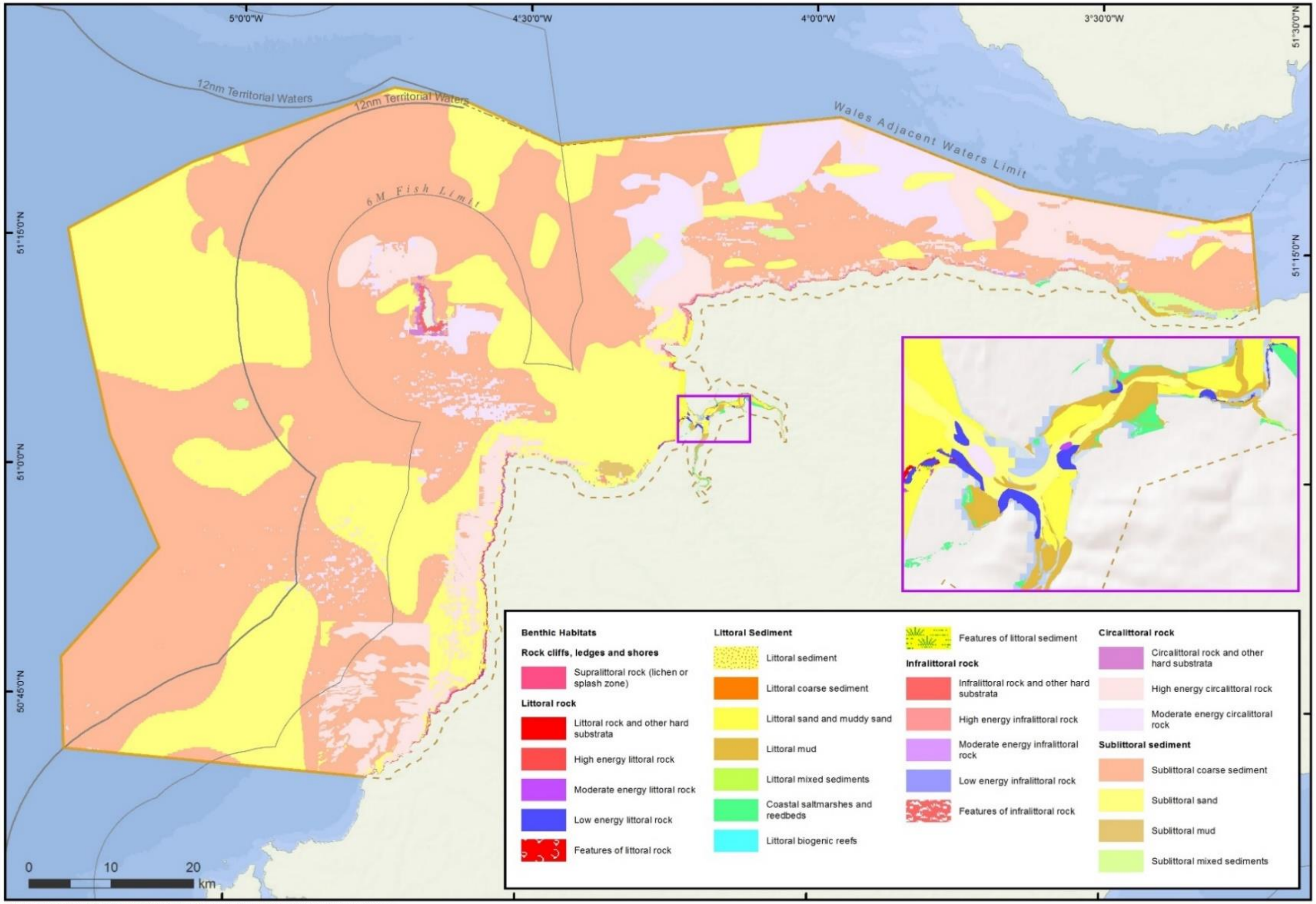
3 Natural Capital Assets: Extent

In this section the extent of marine and intertidal habitat assets are calculated and mapped. All methods are consistent with those presented in Ashley, Rees and Cameron (2018). The results should supersede those presented in Ashley, Rees and Cameron (2018) as new data has become available. Results are updated here:

- The NDMP habitat map;
- The matrix assessment of the provision of intermediate services and goods and benefits from habitats in the NDMP demonstrating the full extent across the NDMP (km^2), the extent of habitats within MPAs (km^2) and the extent of habitats with management measures to reduce benthic impacts (km^2).

3.1.1 NDMP habitat map

Extent of NDMP habitats has been calculated in accordance with the methods presented in Ashley, Rees and Cameron (2018). Any new data on habitat extent that became available over the course of the study were incorporated in Figure 1 NDMP Habitat Map.



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 1 NDMP Habitat Map

Table 3 Extent of NDMP habitats within MPAs and extent of habitats associated with a management measure in November 2018, summarised in relation to contribution to key ES goods/benefits classes identified by Turner et al. (2014) (Table 1)

	Natural Capital Asset: Habitats in North Devon Marine Pioneer		Extent (km²) of habitat within NDMP	Extent (km²) within an MPA	Extent (km²) in MPAs interacting with a manage-ment measure to reduce benthic impact	Contribution to ES Goods/Benefits				
						Food (wild food)	Tourism (incl. nature watching and recreation)	Sea Defence	Healthy climate	Clean water and sediments
Coastal margins	Saltmarsh	A2.5: Saltmarsh	2.8	2.01	0.6	3	3	3	3	3
Marine	Intertidal reef	A1: Littoral rock and other hard substrata	11.31	10.42	1.42	3	1	1	2	
	Subtidal reef	A3: Infralittoral rock and other hard substrata	16.61	12.51	3.9	3	1	1	2	
		A4: Circalittoral rock and other hard substrata	875.9	180.8	9.3	1	1	1		
	Intertidal sediments	A2.1 Littoral Coarse sediment	0.76	0.61	0	1	1	3		
		A2.2: Littoral sand and muddy sand	14.99	14.56	3.8	1	1	3	2	
		A2.3: Littoral mud	9.98	4.27	4.27	3	1	3	3	3
		A2.4: Littoral mixed sediment	0.45	0.33	0.02	1	1	3	2	
	Biogenic reef	A2.7: Littoral biogenic reefs	0.006	0.006	0.001	2	1	2	1	2
	Subtidal sediment	A5.1: Sublittoral coarse sediment	2845.2	175.7	13.23	2		3		3
		A5.2: Sublittoral sand	1690	52.81	16.78	2		3		3
		A5.3: Sublittoral mud	10.85	0.21	0	2		3		3
		A5.4: Sublittoral mixed sediments	48.56	2.04	0	2		3		3

3.1.2 Key Points on the Extent of Natural Capital

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. Therefore, any changes in the extent of the habitats is only meaningful for habitats where there is high confidence of the habitat feature boundaries.

Overall, there has been an increase in extent of habitat within designated MPAs due to the number of recent designations. In 1986, Lundy Voluntary Marine Nature Reserve (a voluntary reserve since 1973), became the UKs first statutory Marine Nature Reserve. Notification of Taw Torridge Estuary SSSI (with marine, intertidal components) occurred in 1988. Lundy 'no take zone' (NTZ) was implemented in 2003, with a larger extent of Lundy coastal waters designated as an SAC in 2005, which further protected subtidal and intertidal habitats around Lundy. Lundy then became the first of the English MCZs in 2010. Lundy MCZ added spiny lobster *Palinurus elephas* as a designated feature within the site (Table 4). Extent of habitats within MPAs in NDMP increased in 2016 with the designation of Hartland Point to Tintagel MCZ, and Bideford to Foreland Point MCZ in Tranche 2 of MCZ process. Over time within designated sites, extent of saltmarsh was assessed to have shown a small increase in the Taw Torridge Estuary SSSI (although 1 unit was assessed in 2012 as unfavourable due to grazing pressure) (Natural England, 2012).

Concurrently, there has been an increase in the extent of habitat within management measures to protect benthic features, since the Lundy No Take Zone prohibited all fishing activity within 3.3km^2 of Lundy habitats in 2003. In 2015 byelaws were introduced in Lundy SAC, by Devon and Severn IFCA, preventing access to vessels using demersal fishing gear.

In 2018, access was authorised for demersal trawl gear in a small area (6.57 km^2) of Lundy SAC (and also Lundy MCZ), and similarly access was authorised for demersal scallop gear in a smaller subsection (1.24 km^2) of this area. These spatial access changes occurred along with the introduction of new permit conditions for the implementation and use of Inshore Vessel Monitoring Systems (I-VMS) and the introduction of the size of a scallop (100mm) a as Permit Condition (Devon and Severn IFCA, 2018a) (Table 4).

Table 4 Habitat and species features within designated MPAs (and SSSIs with intertidal components) in NDMP.

MPA	Feature	Subfeature	EUNIS	Condition	Management
Lundy SAC	Reefs	Intertidal rock	A1	Maintain	D&S IFCA byelaws 2018: Prohibition of the removal of *Palinurus elephas* (Spiny lobster). Mobile Fishing Permit Byelaw 2018 (no access to vessels using demersal gear, except if access is authorised within the permit to an area to the north west of Lundy (iVMS introduction to monitor fishing location) for demersal trawl gear and demersal scallop gear). Potting and Mobile fishing bylaw IFCA 2015. Netting Permit Byelaw 2018.. No take zone since 2003, 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**	Management for Lundy SAC overlaps with Lundy MCZ, specific to Lundy MCZ is also the Diving Permit Byelaw 2018, which limits removal of edible crab, lobster, scallop, spider crab and spiny lobster.
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 D&S IFCA fishing restriction byelaws (prohibition on removal of spiny lobster across the site, Potting Permit Byelaw 2018 and restrictions within the Netting Permit Byelaw 2018)
	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**	
Taw Torridge Estuary SSSI	Saltmarsh		A2.5	Favourable	Interacts with D&S IFCA fishing restriction byelaws (Netting Permit Byelaw 2018, Potting permit byelaw 2018)
	Sheltered muddy shores		A2.3	Favourable	
Lundy SSSI (marine and intertidal features only listed)	Seabirds (5)			Populations of all seabirds expanding, with the exception of kittiwake.	Interacts with D&S IFCA fishing restriction byelaws (see Lundy SAC and MCZ)
	Grey seal			Seal population is stable; ample evidence of continued successful breeding.	
	Littoral sediment		A2	Favourable	

Since 2009, the Marine and Coastal Access Act 2009 has required impacts of activities such as construction, dredging, deposits or removal of an object on all extent of benthic habitat features within NDMP (English inshore and offshore marine area) to be considered as part of the marine license process (MMO, 2018a; MMO, 2018b).

Although not directly related to protection of benthic habitat features (from pressures such as abrasion), no removal of spiny lobster is permitted in Bideford to Foreland Point and Lundy MCZs. No netting is permitted in Taw Torridge unless being used in accordance with Netting Permit Conditions (<20mm seine net for sand eel only). Netting Permit holders are also restricted under byelaw conditions to only use drift or seine nets set at least 3 metres below the surface of the water in 4 separate coastal areas within Bideford to Foreland Point MCZ. Netting is also not permitted within a large extent of Lundy SAC / MCZ (Devon and Severn IFCA, 2018b). All NDMP inshore and offshore areas are also managed in relation to planned activities that may impact the marine environment under the MMO Marine Licensing process (MMO, 2018a). Further management measures are likely to be introduced in the Bideford to Foreland Point and Hartland Point to Tintagel MCZs following further ground truthing surveys (S.Clark pes comment).

3.2 Natural Capital Assets: Condition

Understanding the condition of natural capital assets in relation to the benefits derived from them is an essential step for informing future management options for improving natural capital (Natural Capital Committee, 2017). An assessment of the condition of natural capital assets within the NDMP is tested under the following headings:

- The condition of habitats and species within designated MPAs;
- The condition of water body assets (including designated bathing waters and shellfish waters); and
- The condition of seabed habitats (modelled approach).

3.2.1 The Condition of Habitats and Species within Designated MPAs

Within designated MPAs the condition of habitats are inferred through conservation objectives assigned to each feature (in Conservation Advice packages produced by Natural England for each site) (Natural England, 2017). For MCZs if habitats are considered to be in favourable condition a conservation objective of 'maintain' is applied. If the feature is considered to be in unfavourable condition a conservation objective of 'recover' (to favourable condition) is applied[1]. A 'recover' conservation objective may also be applied in a precautionary manner where there is knowledge of previous bottom towed fishing activity over a highly sensitive habitat.

In regard to SACs condition assessment (of features of Lundy SAC) have been accessed through Natural England's latest Conservation Advice packages (Natural England, 2017). 'Maintain' or 'recover' conservation objectives are applied within conservation assessments for SACs although categories for assessment are slightly different to MCZs. In SACs 'Conservation Status Habitat' (which is aggregated grade for 'restoration possibilities') and 'Global Grade habitat' are applied to assess conservation objectives of 'maintain' or 'recover'. Assessments on the first category 'Conservation Status Habitat' in particular, are of interest to assessment. 'Conservation Status Habitat' cmbines assessment of degree of conservation of structure and function (A = Excellent conservation, B = Good conservation, C = Average or reduced conservation). As an example, Lundy SAC has been assessed as: A for Reefs (1170), B for Sandbanks which are slightly covered by sea water all the time (1110), A for Submerged or partially submerged sea caves (8330). The 'Global grade habitat' (A = Excellent value, B = Good value, C = Significant value) for Lundy has been assessed as 'B'.

Using a literature review of conservation advice packages on Natural England's designated sites online resource, the conservation objectives for designated features within all MPAs within the NDMP were collated (Natural England, 2017) (Table 4). Current management practices to protect or recover features from current or historical unacceptable impact are also summarised in Table 4. Impacts of planned activities on designated features of MPAs within NDMP are also considered (even if activities occur outside MPAs) within in the MMO Marine Licensing process (MMO, 2018a). The MMO must consider whether the act is capable of affecting (other than insignificantly) the protected features or any ecological or geomorphological process on which the conservation of any protected feature is dependant.

[1] Defra, Marine Conservation Zones Designation Explanatory Note, November 2013

3.2.2 The Condition of Water Body Assets in NDMP

In line with UK commitments under the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD) data is collected by government agencies that can be applied in the natural capital context as indicators of the condition of water body assets.

Status of water bodies intersecting NDMP

Water body status, in reference to WFD targets, for water bodies was assessed for each water body in NDMP (Table 5). Data on water body statuses was accessed from HM Government online resources (Environment Agency, 2018a). The overall waterbody status, ecological, chemical and morphological status for water bodies within NDMP are summarised in Table 5. Water bodies are required to have all status categories (ecological, chemical and hydromorphology) classified as 'good' or 'high' to meet WFD requirements. Overall ecological status reflects the lowest classification received across all categories. Three water bodies (Taw/Torridge, Bristol Channel Inner South and Bridgwater Bay) failed to meet WFD standards, receiving a classification of 'Moderate' in 2015. All other water bodies received classifications of 'Good' or 'High'. These classifications were the same as those in the previous 'River Basin Management Plan: South West River Basin District' in 2009 (Environment Agency, 2009) (Table 5, Figure 2).

Table 5 Water body status for WFD estuarine and Coastal water bodies within NDMP (Environment Agency, 2018c)

WFD Estuarine and Coastal Water Body	**2015 status, based on data collected 2009-2014**				
	Overall water body status	**Ecological status**	**Chemical status**	**Target water body status**	**Hydromorpholoy status**
Cornwall North	High	High	Good	High	High
Lundy	Good	Good	Good	Good	High
Taw / Torridge	Moderate	Moderate	Good	Moderate	Supports Good
Barnstaple Bay	Good	Good	Good	Good	High
Bristol Channel Outer South	Good	Good	Good	Good	Supports Good
Bristol Channel Inner South	Moderate	Moderate	Good	Moderate	Supports Good
Bridgwater Bay	Moderate	Moderate	Good	Good	High

It is important to note that the Taw estuary is designated as a Polluted Water [Eutrophic] under the Nitrates Directive. Under the WFD, the Taw Estuary is hyper-nutrified and classified as moderate in respect to dissolved available inorganic nitrogen (DAIN) (Environment Agency, 2016). The main source of the DAIN is from freshwater sources. The Taw Estuary is also classified as moderate with respect to phytoplankton. The River Taw, from Newbridge to the mouth of the Taw Estuary is designated as a Nitrate Vulnerable Zone (NVZ) for the purpose of the Nitrate Pollution Prevention Regulations 2015 (Environment Agency, 2016).

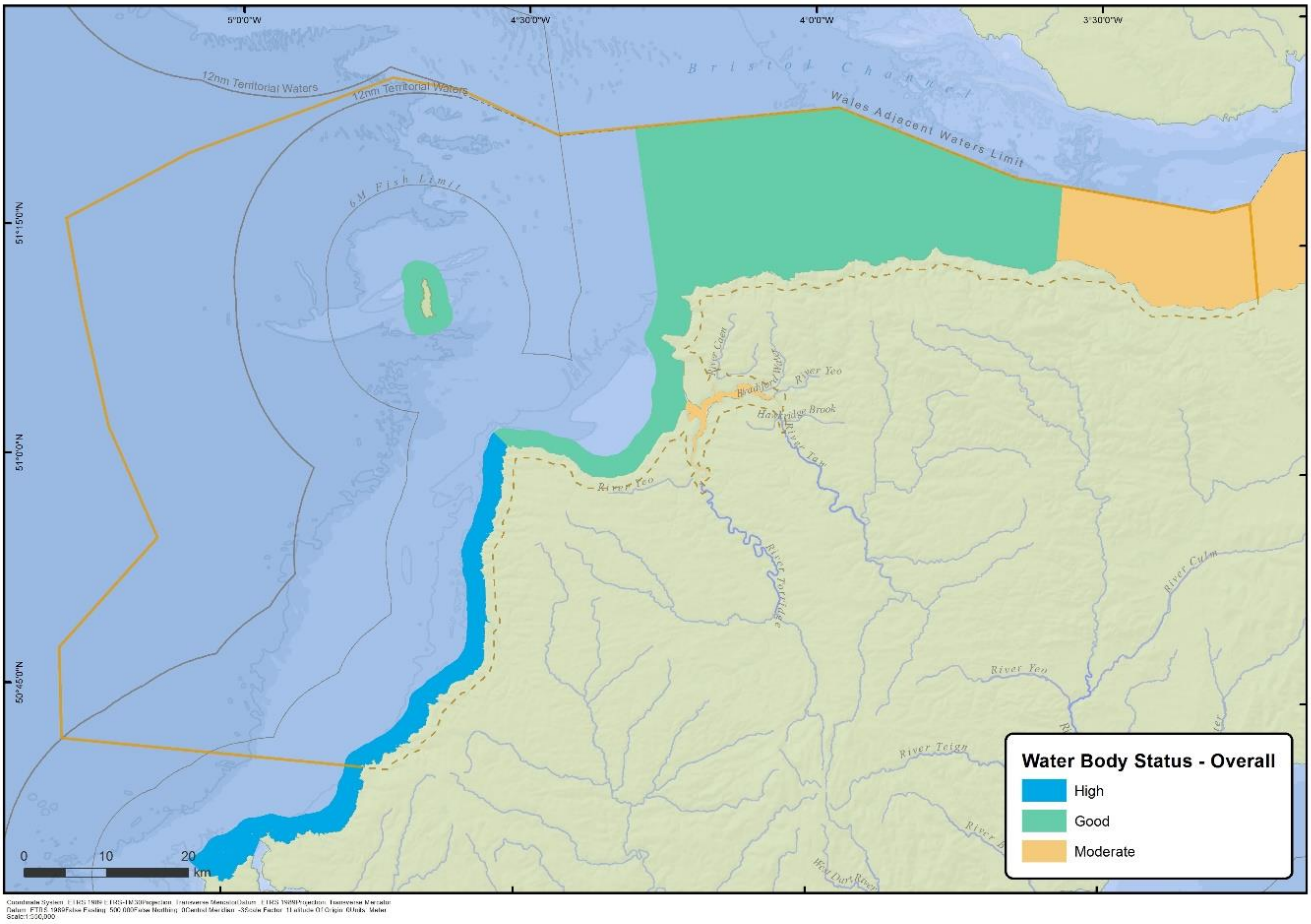


Figure 2 Water Body Statuses for water bodies within NDMP

Condition of Designated Bathing Waters

Annual assessment of bathing water quality for sample sites (beach locations) were accessed from Environment Agency *Bathing Water Data* online resources (Environment Agency, 2018b). The Bathing Water Data reports annual classifications for each beach (sample point) (Environment Agency, 2018b). The Bathing Water Data reports annual classifications for each beach (sample point), the classifications are:

- excellent – the highest cleanest seas
- good – generally good water quality
- sufficient – the water meets minimum standards
- poor – the water has not met the new minimum standards. (The Environment Agency state they plan work to improve bathing waters not yet reaching Sufficient (Environment Agency, 2018b).

The most recent classification (baseline) year for beaches within NDMP was 2017/18. Trends in classification were assessed from 2015, as prior to 2015 different standards for assessing bathing water quality were used. Classifications prior to 2015 use data collected using different analytical methods (as 3 years historical data are analysed to provide a classification and data prior to 2012 were collected and analysed using a different methodology).

An increase was seen in 2017/18 in the total number of beaches receiving ‘poor’ bathing water classification (below WFD requirement), from 2 beaches in previous years to 3 in 2017/18. In 2017/18 , bathing water at 7 beaches was classified as 'Good', and 12 beaches 'Excellent'. Decrease in bathing water classification was seen in 2017/18 from previous years at Combe Martin, and Bude Summerleaze (Table 6, Figure 3). Increases in bathing water classification were seen over a four year period at Ilfracombe Hele Bay (from ‘satisfactory’ to ‘good’). All other remaining beaches showed no change from previous years (Table 6, Figure 3).

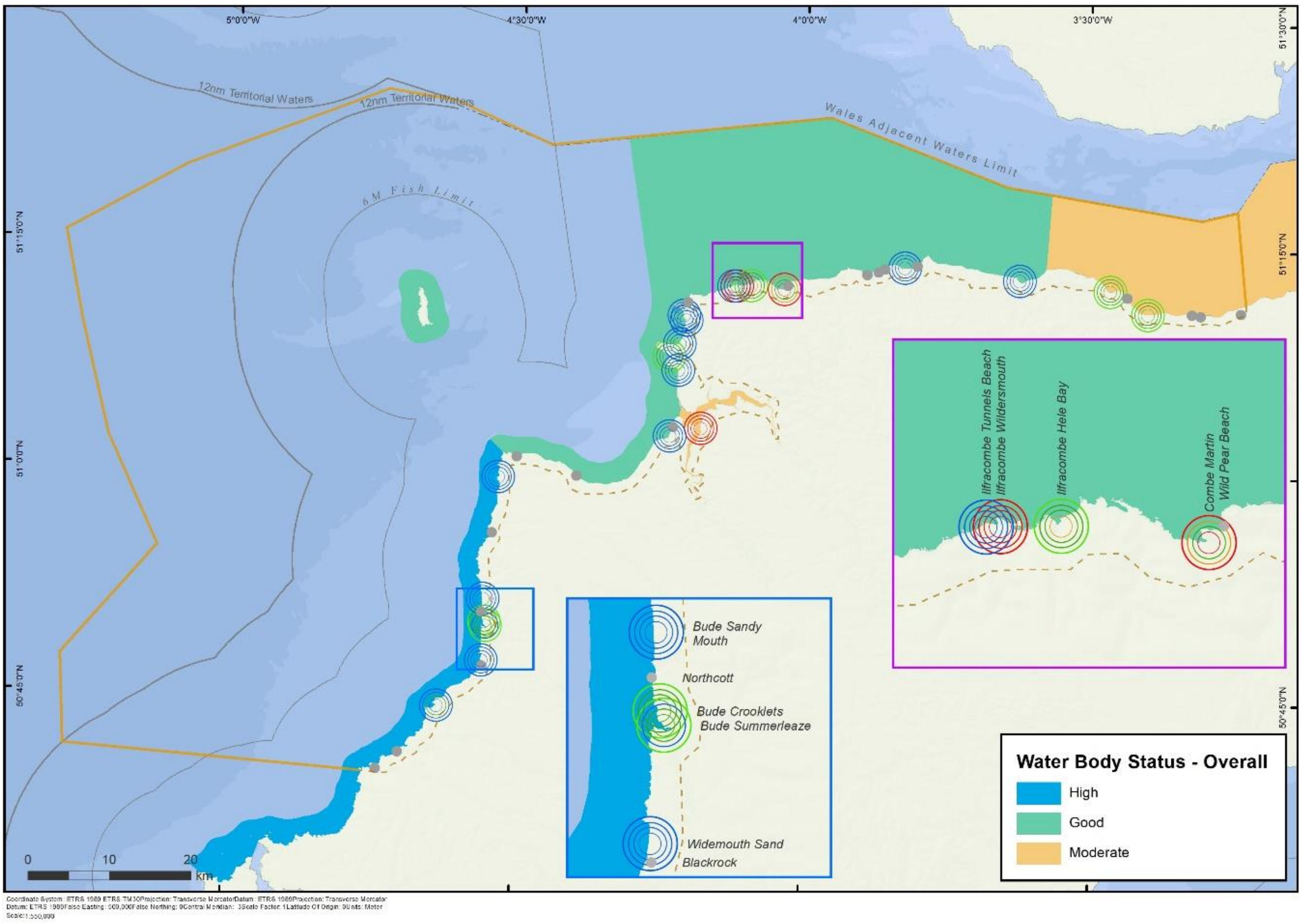


Figure 3 Designated bathing water quality classification for bathing waters within NDMP (innermost circle = 2014/2015, outermost circle = 2017/2018; (blue = excellent, green = good, orange = sufficient, red = poor)

Pollution incidents which cause beaches to be closed for a period (e.g. sewage from overflowing drains, pollution from oil or fuel) are also recorded in Environment Agency Bathing Water Data resources (Environment Agency, 2018b). There were a total of 3 pollution incidents recorded in 2017/2018. There were a total of 3 pollution incidents recorded in 2017/2018 (Table 6) (Environment Agency, 2018).

Table 6 Bathing Water Quality classification for beaches within and adjacent to NDMP. 0 = poor, 1 = satisfactory, 2 = good, 3 = excellent. Trend = increase ↑, decrease ↓ or no change ↔ between 2017/18 and mean of previous assessments 2014/15-2016/17. Pollution incidents are recorded as total over last 2 years.

Beach (Sample Point)	**Bathing Water Quality Classification**				**Trend**	**Pollution incidents 2017-2018**	**No. bathers per 100m, 2017 season (mean)**
	2015	**2016**	**2017**	**2018**			
Somerset beaches							
Blue Anchor West	2	2	2	2	↔	0	no data
Minehead Terminus	2	2	2	2	↔	0	no data
Porlock Weir	3	3	3	3	↔	0	no data
Devon beaches							
Lynmouth	3	3	3	3	↔	0	no data
Combe Martin	0	2	1	0	↓	1	4.91
Ilfracombe Hele Bay	1	2	2	2	↑	0	1.52
Ilfracombe Tunnels Beach	3	3	3	3	↔	0	4.4
Ilfracombe Wildersmouth	0	0	0	0	↔	0	0.73
Woolacombe - Barricane Bay	3	3	3	3	↔	0	5
Woolacombe Village	3	3	3	3	↔	0	24.55
Putsborough	3	3	3	3	↔	0	14.75
Croyde Bay	2	2	2	2	↔	1	35.45
Saunton Sands	3	3	3	3	↔	0	25
Westward Ho!	3	3	3	3	↔	0	15.65
Instow	0	0	0	0	↔	0	1.15
Hartland Quay	3	3	3	3	↔	0	0.55
Cornwall beaches							
Bude Crooklets	2	2	2	2	↔	1	13.7
Bude Sandy Mouth	3	3	3	3	↔	0	11.15
Bude Summerleaze	2	2	3	2	↓	0	42.5
Widemouth Sand	3	3	3	3	↔	0	45
Crackington Haven	3	2	3	3	↑	0	9.2

Water quality indicators in NDMP shellfish waters

Currently the 2018 monitoring of shellfish waters outer estuary (Spratt Ridge East) has identified harmful plankton to be above trigger levels on 6 occasions. Biotoxin monitoring of flesh from the outer estuary (Spratt Ridge East) reports toxin detected/clinical signs observed below action level on 6 occasions (Food Standards Agency, 2018).

3.2.3 Key Points on the Condition of Natural Capital

Condition within MPAs

Condition assessments for MPAs are undertaken every 6 years. The majority of MPAs have a conservation objective for the features being protected to be in 'favourable' condition, with a conservation objective or 'maintain'. General management approaches for the designated features are then determined to achieve the conservation objective. Most management approaches are set to maintain the designation features in question. Habitats and species with an objective for recovery include spiny lobster, fragile sponge and anthozoan communities on subtidal rocky habitats, moderate energy circalittoral rock, subtidal coarse sediment and subtidal sand (Table *4*). It should be noted that there is no historic data included in the condition assessments to provide a long-term trend of the condition of features. Additionally, management approaches for conservation of features are determined in the context of knowledge of activities and pressures at the site. Consequently, whilst they can broadly be considered to infer some form of condition 'state', this is with reference to current levels of activity. Defra's guidance on the MCZ designation process advises that the general management approach can be changed post-designation for three reasons:

1. New scientific evidence on the condition of features
2. New scientific evidence on the sensitivity of features to activities
3. New evidence of changes to the types and levels of human activity at the site (including activities not thought to be present before)

In the case of North Devon for example, much of the dredging fishing fleet has now dissipated, so recovery targets, and their inferred condition status may no longer be appropriate.

Water Quality

The condition for water body assets is only available for waters that are assessed within the jurisdiction of the WFD and the MSFD. There are large tracts of the NDMP water body asset (particularly offshore areas beyond estuarine and coastal water bodies in Figure *2*) where the condition (eg ecological and chemical status) is not currently known.

Wider metrics that may provide an indicator of the provision of ES benefits from the water body asset at a greater spatial scale include data linked to production and hydrographic conditions. 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 from satellite remote sensing data (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 identified as a generic indicator of water column primary productivity. Front frequency map data layers produced by Plymouth Marine Laboratory, available through Defra MB102 provide seasonal indications of broad scale front activity (Miller, 2009; Miller & Christodoulou, 2014; Miller, Christodoulou & Saux Picart, 2010).

The condition of the NDMP water body asset is limited by upstream effects from farming and water treatment. Taw Estuary is designated as a Polluted Water [Eutrophic] under the Nitrates Directive and the likelihood of poor water quality has implications on the shellfish waters and bathing waters within the estuary. The Environment Agency (EA) has assessed that it will be infeasible to deliver the measures that are required to improve water quality at Instow to meet the ‘sufficient’ classification required by the WFD, and that it will therefore continue to receive a ‘Poor’ classification. The EA had advised that permanent advice against bathing should be introduced at an earlier stage, before the 2018 bathing season began (DEFRA, 2017). Poor classification of designated bathing waters, or de-designation, suggests loss of assets supporting recreation benefits. Excess nutrient levels are also likely to impact shellfish harvests (ES benefit ‘Food’) and provision of suitable habit supporting species supporting commercial and recreational fishing as well as wildlife watching activities. Although measures to address ‘poor’ bathing water classification at Instow were assessed as infeasible, addressing measures to improve ‘poor’ bathing water classification at Ilfracombe (Wildersmouth beach) and Combe Martin would improve access to recreational and tourism benefits within NDMP.

3.2.4 The Condition of Seabed Habitats (modelled approach)

The development of an Asset Register for the North Devon Pioneer area requires some assessment of condition that can be applied consistently across the entire area. As described above, MPA assessments of benthic habitats are both limited spatially to the extent of designated sites only, to the designation features of interest within them, and with limitations on the level of activity information and update frequency available. To obtain a spatially explicit indication of condition applicable across the marine Pioneer area, alternative approaches are therefore required. In pursuit of this, a proxy approach was applied, based on knowledge of habitat sensitivity to pressures, and activity data that may contribute to those pressures.

3.2.4.1 Method

Mapped habitats data were compiled according to the European Nature Information System[2] (EUNIS) system through a process to select best-available evidence and resolve ambiguous or conflicting habitat classifications (Ashley, Rees & Cameron, 2018) These were subsequently linked to potential for Ecosystem Service provision from the matrix assessment (Ashley, Rees & Cameron, 2018), primarily through matching at EUNIS level 3, but at more detailed levels where available. Sensitivity information by EUNIS habitat was extracted from the Marine Evidence-based Sensitivity Assessment (MarESA) database (Tyler-Walters *et al.*, 2018). MarESA compiles sensitivity information through a detailed literature review process of available evidence on the effects of pressures arising from human activities on marine habitats. The assessments assign scores for habitat sensitivity as a combination of resistance and resilience to particular pressures. The scores allocated are: Not Sensitive (NS), Low (L), Medium (M), High (H) and Not relevant (NR)[3].

The assessments also include semi-quantitative assessments of the quality of evidence, applicability of evidence and the degree of agreement between evidence sources. These were coded numerically and linked to the North Devon habitat data layer through a series of iterative joins, linking sensitivity information based on the most detailed habitat class information available (EUNIS levels 5 and 6), up to EUNIS level 3. At the higher EUNIS levels (3 and 4), MarESA assessments were aggregated, taking advantage of EUNIS' hierarchical structure and following a precautionary approach to assign the most sensitive score of all 'children' classes from existing MarESA assessments to their 'parent' class.

This habitat-ES-sensitivity data layer was then intersected with data on fishing intensity. The fishing data used was an amalgamated product combining spatial information on smaller fishing vessels,

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[2] https://eunis.eea.europa.eu/
[3] https://www.marlin.ac.uk/sensitivity/sensitivity_rationale

obtained through the participatory mapping exercise FisherMap, with aggregated VMS data for vessels over 15m (Enever *et al.*, 2017). Enever *et al.* (2017) classified their dataset into low, medium or high exposure according to relative levels of fishing effort throughout English waters, based on quartiles of vessel counts per square nautical mile. These exposure levels were coded and combined spatially with the sensitivity information. Combinations of sensitivity and exposure levels (Table 7) were then used to indicate the likely impacts to benthic habitats, and their likely relative condition as a result (LRC). Finally, the LRC layer was intersected with spatial boundaries of management measures (MPAs and fishery byelaws) and areas aggregated by broad ES classes to examine extent and condition under management.

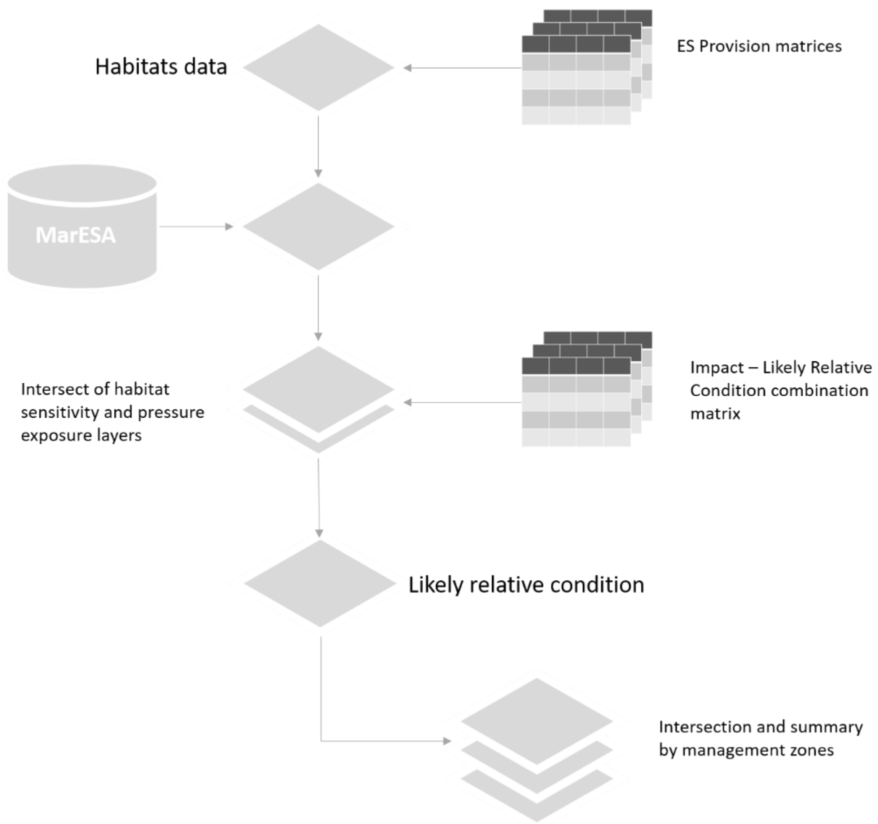


Figure 4 Diagram overview of process to assess Likely Relative Condition on NDMP habitats

Table 7 *Combination matrix for Impacts due to habitats sensitivity and pressure exposure, and inferred Likely Relative Condition (LRC) due to impacts.*

Sensitivity	Exposure			
	None	Low	Moderate	High
NS	None	None	None	None
L	None	Low	Low	Moderate
M	None	Low	Moderate	High
H	None	Moderate	High	Very High

⇒

Sensitivity	Exposure			
	None	Low	Moderate	High
NS	Good	Good	Good	Good
L	Good			↓
M	Good			↓
H	Good	→	→	

3.2.4.2 Results

Across the marine Pioneer area, 141 habitat types were mapped from EUNIS level 6 to level 2. 24 of these were linked directly to their potential ES delivery through the provision matrix, with the remaining summarised by their level 3 or 4 parent. Areas mapped at EUNIS level 2 (Infralittoral and Circalittoral rock) around Lundy were examined and reassigned a level 3 class on the basis of their likely exposure regime and in light of the ES potential across the level 3 options being identical.

Direct links between mapped habitats and MarESA sensitivity information were limited to an area totalling just 17km^2 of the full extent of mapped habitats within the Pioneer of 5,529km^2 (Figure 5). Using the precautionary approach, sensitivity assessment scores are available for mapped habitats across the entire Pioneer area (Figure 6). The results of the condition proxy from the sensitivity-pressure approach for abrasion impacts from demersal fishing are shown in Figure 7 - 7. Table 8 summarises the extent and LRC of habitats aggregated according to potential ES provision knowledge. Figures for Likely Relative Condition for EUNIS habitats based on abrasion impacts are shown in full in Table 8. More detailed breakdowns by ecosystem service are provided in Section 4.

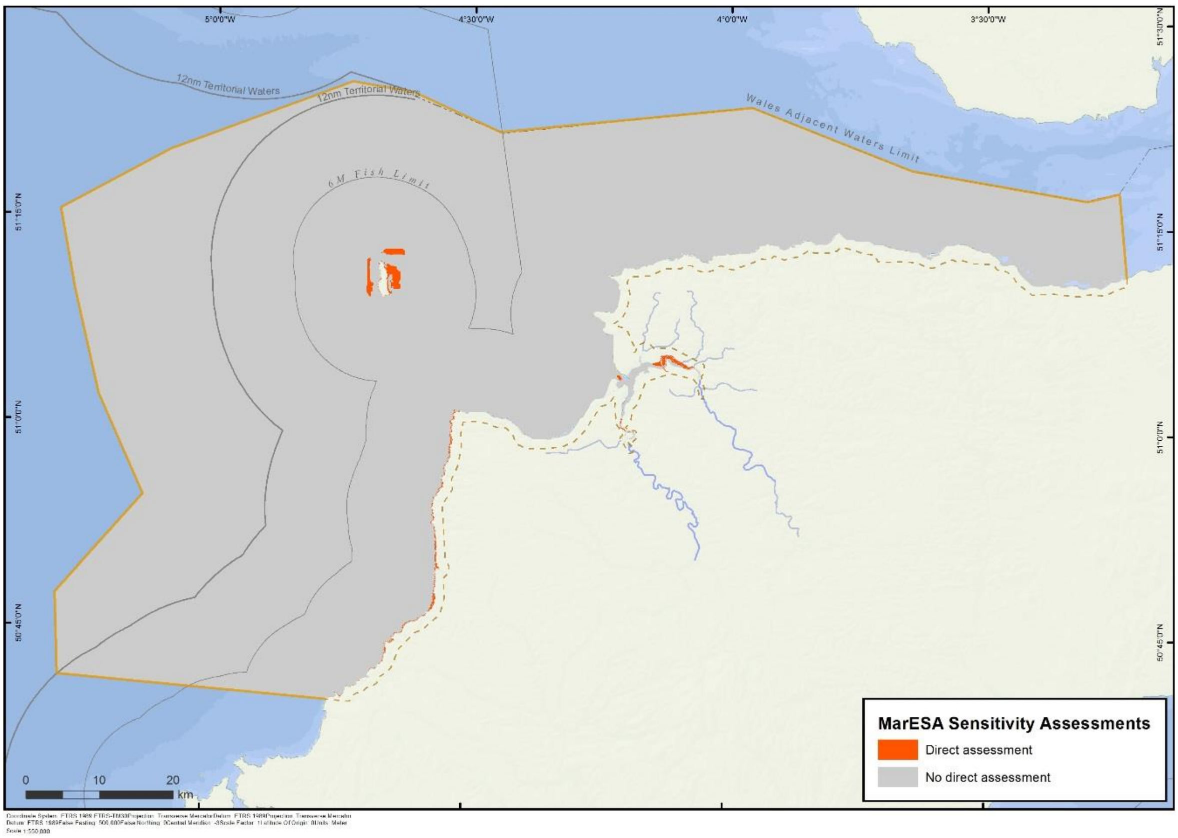


Figure 5 Spatial distribution of habitats with direct links to existing MarESA assessments across the Pioneer area

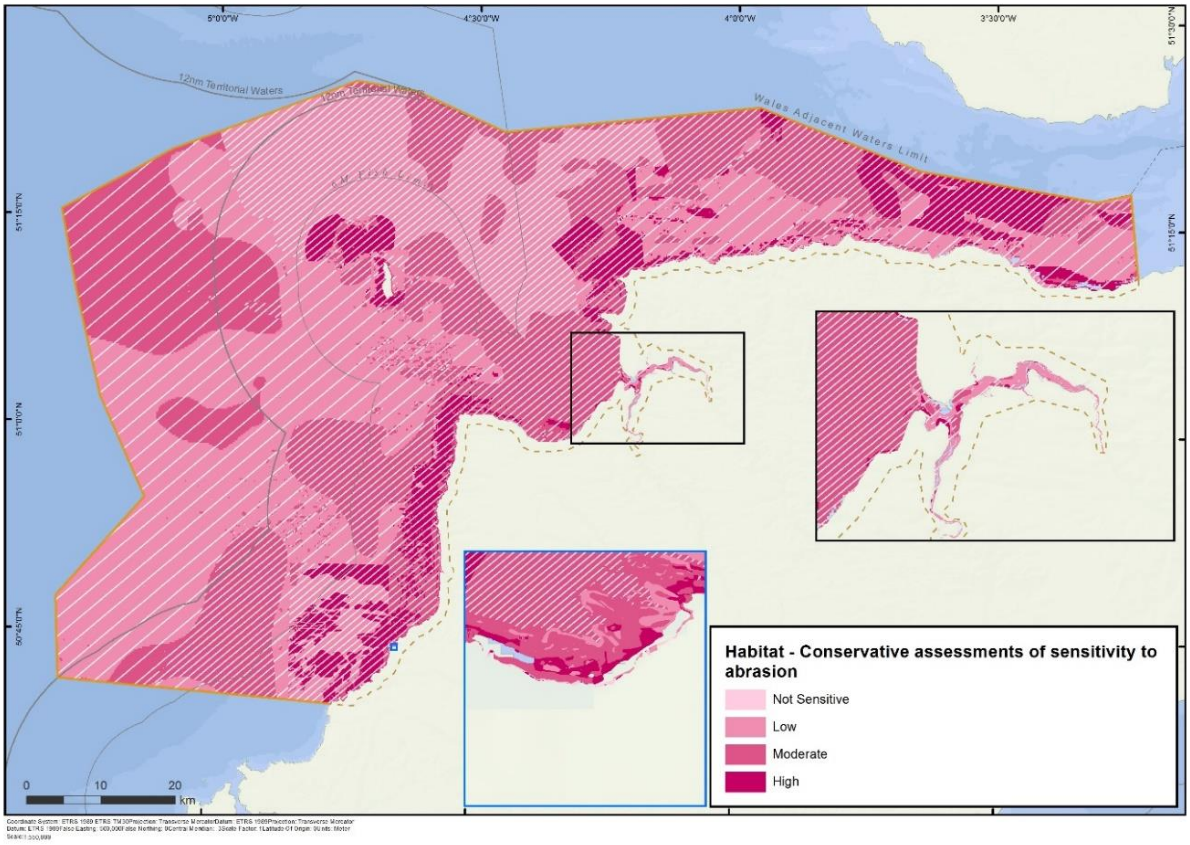


Figure 6 Sensitivity to abrasion across the Pioneer area applying a precautionary approach to link to the MarESA database. Here the more densely-packed lines indicate higher levels of uncertainty (tight hatching indicates having to resort to conservative summary of sensitivity at EUNIS L3; broader hatching indicates summary at L4; no hatching is summary at L5 or direct MarESA assessment)

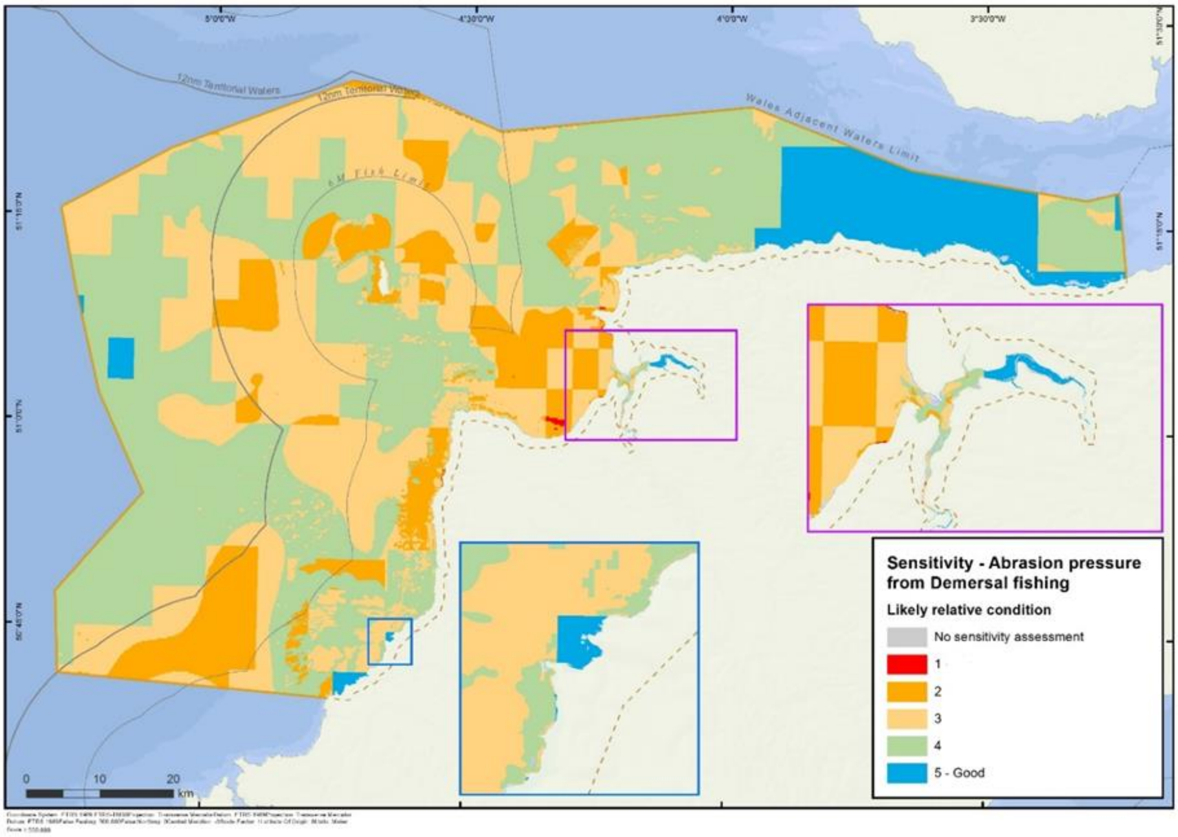


Figure 7 Likely Relative Condition (LRC) due to impacts from abrasion, as inferred from the sensitivity-pressure approach.

Table 8 Summary table of habitats by potential ES provision and LRC (areas are presented in hectares (ha) to convert to km² divide the value by 100)

	Natural Capital Asset: Habitats in North Devon Marine Pioneer (EUNIS level 3)	Area (ha)	Area (% of Pioneer)	Likely Relative Condition (LRC) inferred by sensitivity/pressure information - Full Pioneer					Intermediate services																									
									Supporting services							Regulating services				from Provisioning services (Goods / Benefits)					from Regulating services (Goods / Benefits)					from Cultural services (Goods / Benefits)				
				LRC 1 area, ha (% of Pioneer)	LRC 2 area, ha (% of Pioneer)	LRC 3 area, ha (% of Pioneer)	LRC 4 area, ha (% of Pioneer)	LRC 5 'Good' area, ha (% of Pioneer)	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	References
	Saltmarsh	279.67	0.05						2	3	3		3	3	3		3	3	3	3		3			3	3	3	3	3	3	1	3	1	Potts et al. (2014)
B3.1	B3.1: Supralittoral rock (lichen or splash zone)	85.09	0.02	0.44 (0.00008%)	3.65 (0.00066%)	11.46 (0.00207%)	14.24 (0.00258%)	5.67 (0.00102%)																										
A1	A1: Littoral rock and other hard substrata	52.23	0.01																															
A1.1	A1.1: High energy littoral rock	573.43	0.10	47.42 (0.00858%)	122.43 (0.02214%)	151.15 (0.02734%)	79.03 (0.01429%)	92.05 (0.01665%)	3	2	3		2	1	1		1		2	3					2	1	1			1	1	1	1	Potts et al. (2014)
A1.2	A1.2: Moderate energy littoral rock	297.91	0.05		17.89 (0.00324%)	111.63 (0.02019%)	127.64 (0.02308%)	23.07 (0.00417%)	3	2	3		2	1			1		2	3					2	1	1			1	1	1	1	Potts et al. (2014)
A1.3	A1.3: Low energy littoral rock	168.73	0.03	4.11 (0.00074%)	104.13 (0.01883%)	9.54 (0.00173%)	6.62 (0.0012%)	33.43 (0.00605%)	3	2	3		2	1			1		2	3					2	1	1			1	1	1	1	Potts et al. (2014)
A1.4	A1.4: Features of littoral rock	38.46	0.01		2.72 (0.00049%)	8.38 (0.00152%)	20.02 (0.00362%)	4.39 (0.00079%)																										
A2	A2: Littoral sediment	30.05	0.01																															
A2.1	A2.1: Littoral coarse sediment	75.57	0.01			1.9 (0.00034%)	17.49 (0.00316%)	27.13 (0.00491%)	1	3	1		3	1	1		3			1						3	3			1	1	1	1	Potts et al. (2014)
A2.2	A2.2: Littoral sand and muddy sand	1,498.82	0.27		230.19 (0.04163%)	731.77 (0.13234%)	178.14 (0.03222%)	276.26 (0.04996%)	3	3	3			1	3		3		2	1					2	3	3			1	1	3	1	Potts et al. (2014)
A2.3	A2.3: Littoral mud	997.99	0.18			31.83 (0.00576%)	289.44 (0.05235%)	601.43 (0.10877%)	3	3	3		1		1		3	3	3	3					3	3	3	3	3	1	1	1	1	Potts et al. (2014)
A2.4	A2.4: Littoral mixed sediments	44.77	0.01			5.34 (0.00097%)	33.99 (0.00615%)	3.44 (0.00062%)	3	3	3			1	1		3		2	1					2	3	3			1	1	1	1	Potts et al. (2014)
A2.5	A2.5: Coastal saltmarshes and saline reedbeds	279.67	0.05						2	3	3		3	3	3		3	3	3	3		3			3	3	3	3	3	3	1	3	1	Potts et al. (2014)
A2.7	A2.7: Littoral biogenic reefs	0.60	0.00		0.19 (0.00004%)	0.41 (0.00007%)			1	1	2		3		1		2	1	1	2					1	2	2	2	2	1	1		1	Potts et al. (2014)

	Natural Capital Asset: Habitats in North Devon Marine Pioneer (EUNIS level 3)	Area (ha)	Area (% of Pioneer)	Likely Relative Condition (LRC) inferred by sensitivity/pressure information - Full Pioneer					Intermediate services											Goods / Benefits														References
				LRC 1 area, ha (% of Pioneer)	LRC 2 area, ha (% of Pioneer)	LRC 3 area, ha (% of Pioneer)	LRC 4 area, ha (% of Pioneer)	LRC 5 'Good' area, ha (% of Pioneer)	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	
A2.8	A2.8: Features of littoral sediment	3.03	0.00				2.54 (0.00046%)	0.48 (0.00009%)																										
A3	A3: Infralittoral rock and other hard substrata	389.12	0.07																															
A3.1	A3.1: Atlantic and Mediterranean high energy infralittoral rock	1,119.22	0.20		82.29 (0.01488%)	419.04 (0.07578%)	279.67 (0.05058%)	310.03 (0.05607%)	2	2			2	1			1		2	3					2	1	1			1	1		1	Potts et al. (2014); Fletcher et al (2012)
A3.2	A3.2: Atlantic and Mediterranean moderate energy infralittoral rock	143.98	0.03		1.04 (0.00019%)	22.88 (0.00414%)	30.99 (0.00561%)	87.02 (0.01574%)	2	2			2	1			1		2	3					2	1	1			1	1		1	Potts et al. (2014); Fletcher et al (2012)
A3.3	A3.3: Atlantic and Mediterranean low energy infralittoral rock	6.77	0.00		6.77 (0.00122%)				2	2			2	1			1		2						2	1	1			1	1		1	Potts et al. (2014); Fletcher et al (2012)
A3.7	A3.7: Features of infralittoral rock	0.03	0.00				0.01 (0%)	0.01 (0%)																										
A4	A4: Circalittoral rock and other hard substrata	564.82	0.10		564.14 (0.10203%)	0.48 (0.00009%)																												
A4.1	A4.1: Atlantic and Mediterranean high energy circalittoral rock	47,658.02	8.62	38.77 (0.00701%)	16604.04 (3.00291%)	15041.35 (2.72029%)		15973.49 (2.88888%)	2	2			2	1			1			1						1	1			1	1		1	Potts et al. (2014)
A4.2	A4.2: Atlantic and Mediterranean moderate energy circalittoral rock	39,367.51	7.12		1012.29 (0.18308%)	8569.03 (1.54975%)	21477.47 (3.8843%)	8308.72 (1.50267%)	2	2			2	1			1			1						1	1			1	1		1	Potts et al. (2014)
A5.1	A5.1: Sublittoral coarse sediment	284,521.56	51.46			74212.1 (13.42158%)	195513.21 (35.35942%)	14689.32 (2.65663%)	3	3	3		3				3	1		2	3					3	3	3	1		1		1	Potts et al. (2014)
A5.2	A5.2: Sublittoral sand	169,003.27	30.56		48602.01 (8.78989%)	81902.68 (14.81246%)	34715.5 (6.27845%)	3715.01 (0.67188%)	3	3	3		3				3	1		2	3					3	3	3	1		1		1	Potts et al. (2014)
A5.3	A5.3: Sublittoral mud	1,085.29	0.20	202.96 (0.03671%)	280.74 (0.05077%)	223.92 (0.0405%)	20.26 (0.00366%)	356.7 (0.06451%)	3	3	3		3				3	1		2	3					3	3	3	3		1		1	Potts et al. (2014)

	Natural Capital Asset: Habitats in North Devon Marine Pioneer (EUNIS level 3)	Area (ha)	Area (% of Pioneer)	Likely Relative Condition (LRC) inferred by sensitivity/pressure information - Full Pioneer					**Intermediate services**											**Goods / Benefits**															References
				LRC 1 area, ha (% of Pioneer)	LRC 2 area, ha (% of Pioneer)	LRC 3 area, ha (% of Pioneer)	LRC 4 area, ha (% of Pioneer)	LRC 5 'Good' area, ha (% of Pioneer)	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	
A5.4	A5.4: Sublittoral mixed sediments	4,856.38	0.88		2015.49 (0.36451%)	1547.39 (0.27985%)	20.36 (0.00368%)	1227.63 (0.22202%)	3	3	3		3				3	1		2	3					3	3	3	3		1		1	Potts et al. (2014)
Natural Capital Asset: Habitats in North Devon Marine Pioneer (EUNIS level >3)																																		
A1.2142	A1.2142, A3.2112 Intertidal underboulder communities	2.09	0.00				2.07 (0%)	0.02 (0%)	1	1			2				1			2						1	1			1	1	1	1	Potts et al. (2014)
A3.2112	A1.2142, A3.2112 Intertidal underboulder communities	0.77	0.00				0.77 (0%)		1	1			2				1			2						1	1			1	1	1	1	Potts et al. (2014)
A2.71	A2.71: Honeycomb worm, *Sabellaria alveolata* reef	0.38	0.00			0.02 (0%)	0.36 (0.00007%)			1	1		3	1		1	2	1	1	1					1	1	1	1	1	1	1		1	Potts et al. (2014)
A3.213	A3.126, A3.213: Tide-swept algal communities (L.hyperborea)	67.51	0.01			64.54 (0.01167%)			1	1	1		1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	

3.2.4.3 Key points on the Condition of Seabed Habitats (modelled approach)

In this analysis, we have focused on impacts due to abrasion, using best-available evidence on fishing intensity as the predominant activity causing this pressure across the Pioneer area. There are a number of issues and limitations associated with the current analysis that are important to note.

Applying Sensitivity assessments at broad-scale levels The MarESA sensitivity assessments are conducted on the basis of evidence of biological and ecological responses to pressures. Consequently the assessments apply to the lower levels of the EUNIS hierarchy that pertain to biotopes (those habitats defined by biological communities or assemblages that constitute them). Generally, the best available habitat maps tend to be at the higher EUNIS levels, defined by abiotic parameters (e.g. substrate, light level, exposure regime). This disjoint between the available habitat information and the sensitivity assessments limits the spatial extent over which sensitivity assessments can be directly applied (Figure 5). In this analysis we adopted the precautionary approach of adopting the 'worst-case' sensitivity for any given habitat based on any existing MarESA sensitivity assessments linked to children classes within the EUNIS hierarchy. This potentially overestimates sensitivity in most cases of areas mapped at L3 or L4. However, the evidence base for sensitivity of abiotic habitat types is scarce, and unlikely to change due to the variation of biological responses to pressures within L3 and L4 types. Further application of this approach, and the associated assumptions adopted in this method of aggregating sensitivity information then becomes a conceptual exercise. At the time of writing, the JNCC is developing an automated process to aggregate sensitivity information at all EUNIS levels in accordance with the approach taken here, which should greatly facilitate the compilation of Asset Registers if applied elsewhere.

Temporal resolution The fishing data layer used here covers the period 2007-2010, primarily due to the best-available data on fishing effort of the inshore fleet, gathered through a participatory mapping effort during 2007-2010 (des Clers, 2010). A number of changes in the vessels operating across the North Devon Pioneer since then are known to have occurred, and so the proxy exposure to abrasion pressure will likely have changed in intensity and distribution. For a more relevant assessment of likely condition due to abrasive impacts, more recent data from an appropriate timeframe in relation to habitat recoverability knowledge would be used, both for smaller vessels of the inshore fleet and larger commercial vessels. Whilst there are plans to roll out 'iVMS' technology to smaller vessels across English waters, the implementation programme, starting in April 2019 allows for up to 6 months for the first vessel sector (9-11.99m) to complete installation. Level of spatial accuracy and aggregation of data shared with research projects will influence the effectiveness of iVMS and VMS data to assess change in spatial fishing effort. However, the availability of data from iVMS (and VMS) at aggregation levels and spatial resolutions relevant to a management boundary such as the NDMP, would enable not only more up-to-date information on inshore fishing effort, with greater spatial accuracy, but also with the added benefit of being more readily integrated with VMS data from the industrial fleet. Updates to inshore effort through participatory mapping approaches such as FisherMap are another option, but currently those methods are labour intensive to obtain sufficient representation of the fleet.

Spatial resolution Readily available aggregated fishing activity data based on VMS is published by the MMO at a resolution of 0.05 decimal degrees, approximately 3-5km on average in the Pioneer area. This is coarse relative both to the level of spatial accuracy of much of the available habitats data and to the movements (and subsequent impacts) of individual vessels. At this time, issues around privacy and consent prevent access to more detailed VMS records or data products based on VMS pings, such as interpolated vessel tracks, from being used in this approach. Recent high profile discussions in the literature (Amoroso *et al.*, 2018; Kroodsma, 2018; Kroodsma *et al.*, 2018) have highlighted the wide-ranging interpretations of fishing intensity that arise from the resolution used to report by, and implicitly impacts (and condition) information can be overestimated as a result.

Uncertainty The data used in this analysis all have various sources of uncertainty associated with them, many of which are captured in ways that are appropriate, but specific, to the nature of the information they represent. The habitats data have confidence scores based on the methods of data capture and interpretation that produced them (Cameron, Askew & 2011; Lillis, 2016; MESH, 2015) Potts et al. (2014) provided a simple scoring of evidence for habitat and ES links. In the MarESA assessments, three different measures of certainty summarise the evidence base contributing to each habitat's sensitivity score per pressure. Combining these data compounds these uncertainties and the resulting LRC should be viewed with that in mind. The only way to truly determine the condition of a feature is to carry out direct condition assessments. Interpretation of LRC and appropriate thresholds (to maintain flows of ecosystem services) remains a key point of discussion in the development of this method.

Activities and pressures data Despite data access issues, fishing is one of the better documented activity datasets, especially across UK waters. It is important to recognise there are many other activities that may also cause impacts to the seabed, such as abrasive pressure due to anchoring. In a complete accounting process these additional activities and resulting pressures would also be mapped and integrated into cumulative layers. However, relative to the NDMP area, abrasion due to fishing dominates the spatial distribution of activities that cause pressures that the NDMP habitats have medium to high sensitivity to (at the available mapped habitats resolution).

4 Linking the Natural Capital Assets to Flows of Ecosystem Services in the North Devon Marine Pioneer (Part 2)

The Ecosystem Service (ES) benefits considered in this report are:

- Food (wild food) from NDMP fisheries;
- Sea Defence (natural hazard regulation (specifically flood prevention)); and
- Healthy climate (carbon sequestration).
- Clean Water and Sediments
- Tourism and Recreation (specifically coastal access and beach use, recreational angling, surfing, diving, boating and related on water activities (e.g. kayaking, stand up paddle boarding, water skiing), nature watching (through tour operators and club activities);

The selection of indicators and trend analysis follow the general methods defined in Part 1. A full review of all indicators and a rationale for inclusion in the asset register can be found in Ashley, Rees and Cameron (2018) and revised in Annexes I-IV. Detailed methods and information on secondary data sources for ES good/benefits can be found in Annexes I-IV.

4.1 Food (Wild Food)

Fisheries are a key economic industry in North Devon linked to and dependent upon the natural capital assets. The following indicator metrics have been sourced to define the link between the natural capital assets and the flows of ecosystem services.

Extent (Habitat)

- Area of habitats providing moderate or significant contribution to ES Food (wild food)

Extent (Species)

- CPUE (number per km^2) of species in ICES trawl survey data from sample sites in ICES rectangles overlapping with NDMP.
- CPUE of commercial catches of non-quota species (crab, lobster)
- CPUE of Salmon and sea trout in rivers (and estuaries) supporting migratory fish in NDMP.

Condition (Habitat)

- Area of each habitat providing moderate or significant contribution to ES Food (wild food) within MPAs with conservation objective to maintain or recover
- Area of each habitat providing moderate or significant contribution to ES Food (wild food) and modelled relative ‘condition’

Condition (Water body)

- The condition of water body assets (WFD and MSFD targets, Bathing water quality, Shellfish water quality). Water body condition indicators are summarised in relation to the ES benefit ‘Food’. Section 3 for full analyses of data sets in relation to water quality.

Condition (Species)

- TAC recommendations to ICES for quota species in area 7f.
- Condition of non-quota species assessed from Cefas stock assessment reports.
- Condition of salmon rivers (meeting management objectives).

Ecosystem Service Flows and Benefits

- Annual landings (t) per species by vessels operating from NDMP ports.
- Annual landings value (£) per species to vessels operating from NDMP ports.
- Number of businesses and employment) supported. (Fishing vessel businesses, processors and markets/fish sellers and boat building, engineering).

- Indirect stakeholders and supporting stakeholder businesses related to the fishing industry.

4.1.1 Extent: Area of habitats providing moderate or significant contribution to ES Food (wild food)

There are a range of habitats within the NDMP that support food production that benefit food provision (fisheries) at both a local and regional scale (Table 9 and Figure 9).

Table 9 Habitat assets providing a moderate or significant contribution to provision of ES Food, the extent within NDMP, within MPAs and extent with condition 'recover' in MPAs or modelled LRC of moderate or below.

	Natural Capital Asset: Habitats in North Devon Marine Pioneer		**Level of contribution to delivery of ES 'Food'**	**Area of habitats (km²) providing moderate or significant contribution to ES good/benefit food (wild food)**	**Area within an MPA**	Area in MPAs with condition assessment of 'recover'	Area with modelled relative condition within categories ≤ 3 for interaction with abrasion
Coastal margins	**Saltmarsh**	A2.5: Saltmarsh	3	2.8	2.01	0.6	0
Marine	**Intertidal reef**	A1: Littoral rock and other hard substrata	3	11.31	10.42	0	5.79
Marine	**Subtidal reef**	A3: Infralittoral rock and other hard substrata	3	16.61	12.51	0	5.32
Marine	**Subtidal reef**	A4: Circalittoral rock and other hard substrata	1	875.9	180.76	147.5	418.3
Marine	**Intertidal sediments**	A2.1 Littoral Coarse sediment	1	0.76	0.61	0	0.02
Marine	**Intertidal sediments**	A2.2: Littoral sand and muddy sand	1	14.99	14.56	0	9.61
Marine	**Intertidal sediments**	A2.3: Littoral mud	3	9.98	4.27	0	0.32
Marine	**Intertidal sediments**	A2.4: Littoral mixed sediment	1	0.45	0.33	0	0.05
Marine	**Biogenic reef**	A2.7: Littoral biogenic reefs	2	0.01	0.01	0	0.01
Marine	**Subtidal sediment**	A5.1: Sublittoral coarse sediment	2	2845.22	175.73	119.95	742.121
Marine	**Subtidal sediment**	A5.2: Sublittoral sand	2	1690.03	52.81	47.19	1305.05
Marine	**Subtidal sediment**	A5.3: Sublittoral mud	2	10.85	0.21	0	7.08
Marine	**Subtidal sediment**	A5.4: Sublittoral mixed sediments	2	48.56	2.04	0	35.63
Total extent all habitats providing moderate or significant contribution to the ES				5526.71	455.66	314.78	2529.2787

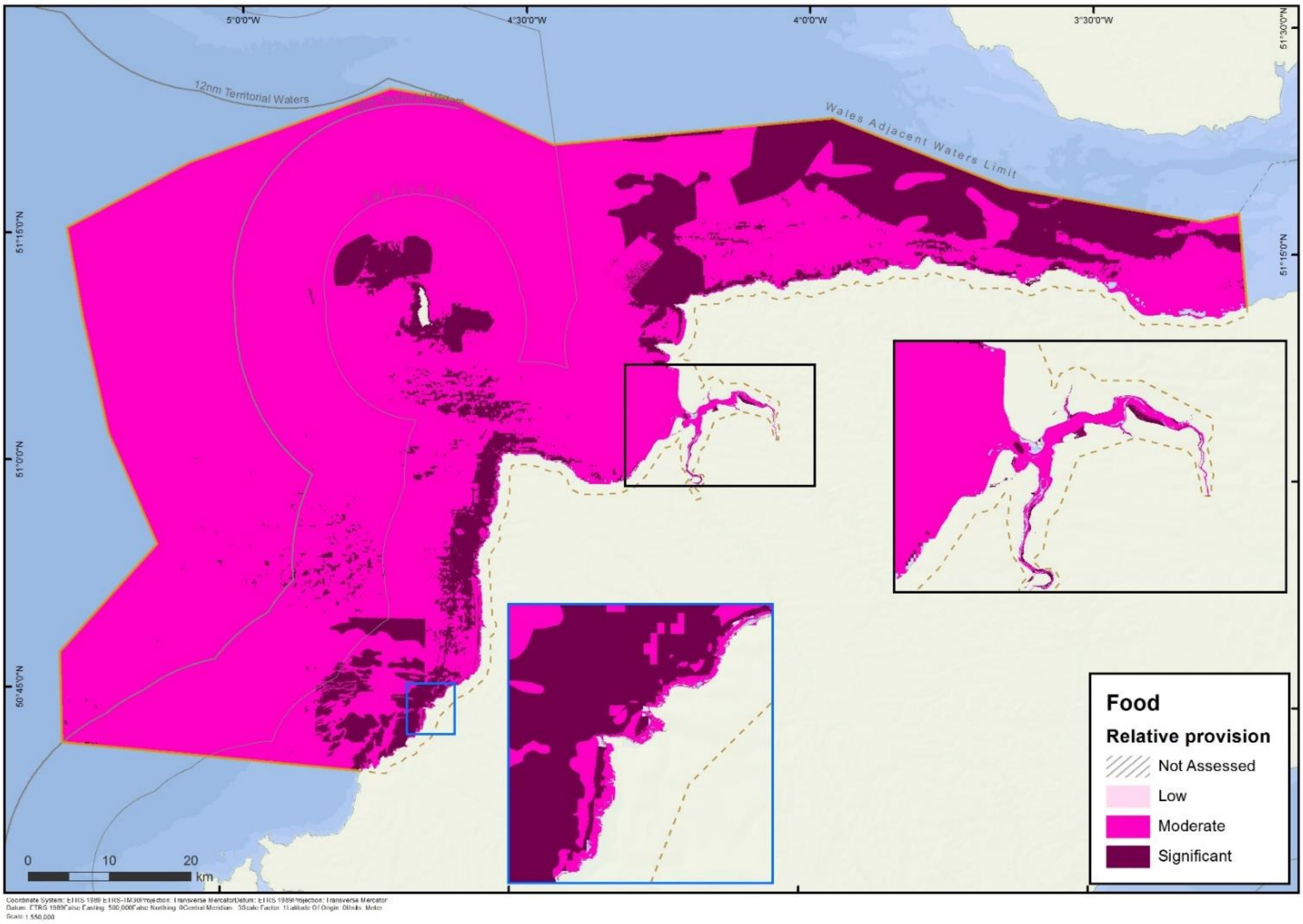


Figure 8 Contribution of NDMP habitat assets to provision of the ES benefit 'Food' (wild food and fisheries)

Data were not present to plot or statistically analyse trends. However, the total extent of habitats providing a moderate or significant contribution to the ES benefit of food (wild food) are not known to have changed within NDMP over the course of data collection apart from a small increase in extent of saltmarsh extent, recorded in the 2012 condition assessment of Taw Torridge Estuary SSSI (Natural England, 2012).

4.1.2 Extent (Species): CPUE (number per km²) of species in ICES trawl survey data from sample sites in ICES rectangles overlapping with NDMP.

Sample data were selected from sample sites within ICES rectangles that intersected with NDMP from UK Irish Sea and Bristol Channel Beam Trawl Survey samples, the annual survey which contributes to ICES stock assessments in area VII f (ICES, 2009) (Figure 9) (Annex II). In a comparison of most recent 3 year periods, comparing moving averages (3yr) between 2012-2014 and 2015-2017 for the 7 quota fish species assessed: there was a decline in CPUE per km² per sample stations for all species, apart from blonde ray *Raja brachyura* and Bass *Dicentrarchus labrax*. Moving averages do not account for abundance of species prior to 2012 and it is important to consider the historical population for commercially targeted species (for instance Bass *Dicentrarchus labrax* have shown a large decline since 2010) which is better represented by analyses of trends since 2010 (or even greater historical time periods).

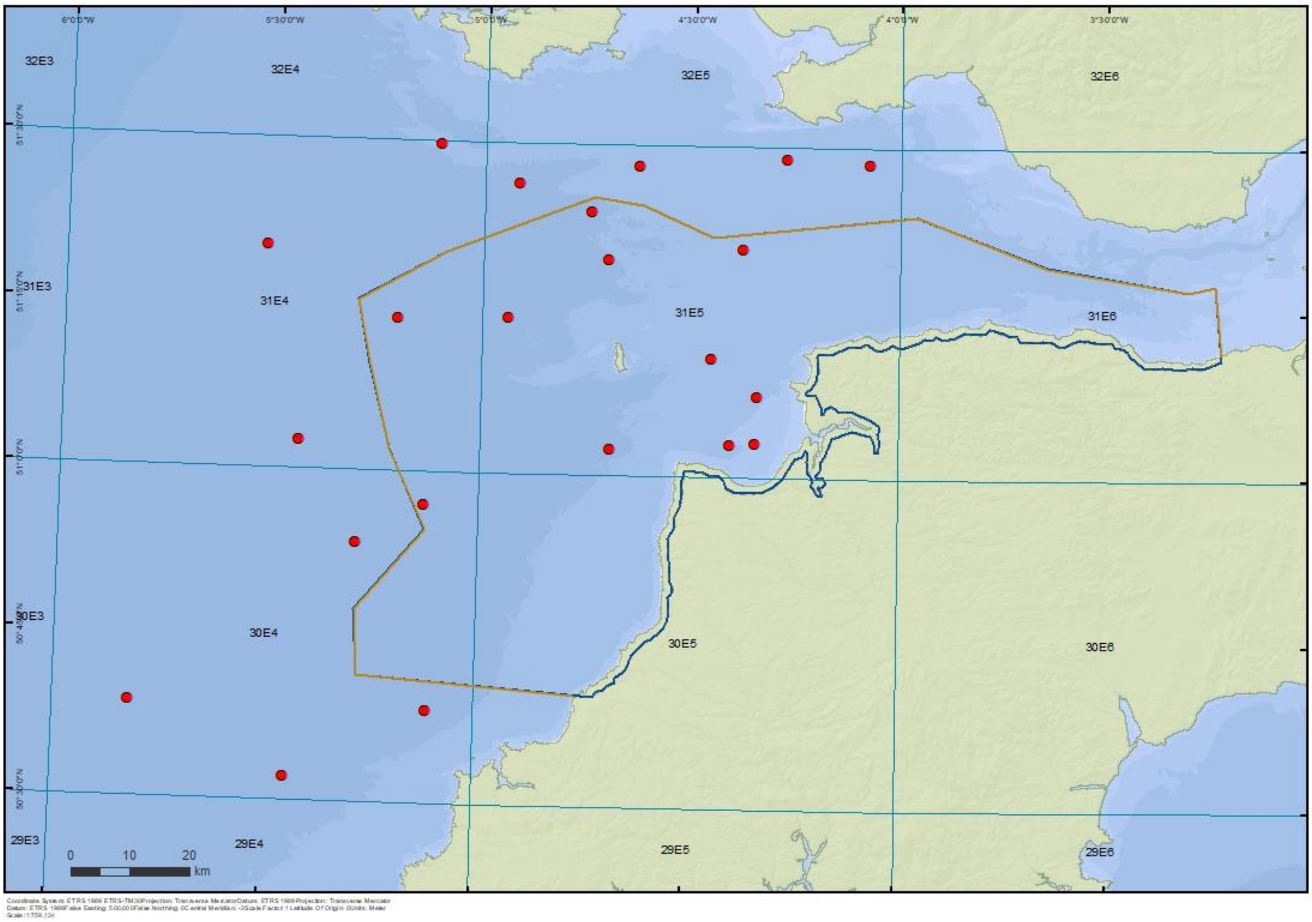


Figure 9 Location of UK Irish Sea and Bristol Channel Beam Trawl Sample Sites (red circles) in ICES rectangles (blue rectangles) intersecting with NDMP (orange border).

Assessment of monotonic trend between 2010-2017 displayed an increase was present in CPUE (number per km²) between 2010 and 2017 for Thornback ray *Raja clavata*, herring *Clupea hareangus* and Squid. The positive trend for squid CPUE was significant (all species, Kendall's tau –b = 0.571, *p*=0.048) however the positive trends for other species were weak (Thornback ray, Kendall's tau –b = 0.286 (*p*=0.322) and Herring, Kendall's tau –b = 0.357 (*p*=0.257)) (Table 10). Blonde ray *Raja brachyura* displayed no change in CPUE (number per km²) (Table 10, Figure 10). Sole *Solea solea*, the principle species the stock assessment survey targeted displayed only a very weak negative trend (Kendall's tau –b = -0.071 (*p*=0.805), suggesting populations were relatively stable across the time series (2010-2017) despite some inter annual variation in abundance (Table 10, **Error! Reference source not found.** 10). The only significant negative trend identified for CPUE (number per km²) 2010-2017 in samples from the Irish Sea and Bristol Channel Beam Trawl Survey for key quota species targeted by NDMP fisheries was a negative trend in CPUE of cod *Gadus morhua* (Kendall's tau –b = -0.786 (p=0.013)). Although change in 3 year moving average was positive for Bass *Dicentrarchus labrax* the trend between 2010-2017 was negative (Kendall's tau –b = -0.286 (p=0.322). Negative trends identified for remaining quota species Small eyed ray *Raja microcellata* and Plaice *Pleuronectes platessa* were weak (Table 10, Figure 10).

The beam trawl sample method used in UK Irish Sea and Bristol Channel Beam Trawl Survey is most applicable to sampling flatfish populations and data for other species should be interpreted with caution. This is particularly true for herring, a mid-water species that is typically targeted by mid water trawls and nets. Squid species are also typically caught by jigging, and landed through beam trawl and other bottom fishing methods as by-catch.

Table 10 CPUE (number per km²) from UK Irish Sea and Bristol Channel Beam Trawl Survey samples. Species include main quota species (by landings weight) for fisheries from NDMP ports.

Natural Capital Assets	Indicator		Unit	Baseline year 2017	Baseline Trend 2010-2017	Correlation coefficient (Kendall's tau-b)	Significance
Species stocks (for each fish and shellfish stock used for food: Quota Species)	Extent: Abundance, CPUE n per km² (average per sample site from ICES rectangles intersecting NDMP: 31E4, 31E5, 31E6, 30E4, 30E5	Cod: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	0	↓	**-0.79**	**0.006**
		Plaice: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	2697.82	↓	-0.214	0.458
		Sole: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	4436.94	↓(↔)	-0.071	0.805
		Herring: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	0	↑	0.357	0.275
		Thornback ray: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	444.33	↑	0.286	0.322
		Small eyed ray: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	67.47	↓	-0.429	0.138
		Blonde ray: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	199.63	↔	0	1
		Bass: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	21.69	↓	-0.286	0.322
		Squid: CPUE	n per km² (per sample site in ICES rectangles intersecting NDMP)	468.79	↑	**0.571**	**0.048**

Figure 10 Trends in CPUE (number per km² per sample site) of key quota species caught by NDMP fishermen (ICES Bottom Trawl Survey Data for sample stations in ICES rectangles intersecting with NDMP).

It is also important to consider the Irish Sea and Bristol Channel beam trawl survey design is also aimed at assessing stocks across much larger ICES areas (e.g. area VII f). The low number of sample sites in ICES rectangles intersecting with the NDMP limits applicability of this data source as an indicator of species biomass or abundance in relation to NDMP. Fish stocks are, however, mobile and the survey data are important to consider in combination with scientific advice on TAC for ICES areas, landings data and where possible juvenile abundance to assess the contribution of NDMP habitats to supporting stocks.

For demersal species that can be accurately sampled through beam trawl surveys, the indicator suggests there is a negative trend in the natural asset (species stocks) for all species apart from Thornback ray, and Blonde ray. It is important to consider the wider population of these species are assessed as 'near threatened' by IUCN (Ellis, 2009) and historical populations, before 2010, should be considered in anlysis of trends by future studies. For instance Mace *et al.* (2015) suggest a target for comparison, of average fish stock levels between 1938 and 1970. Data from the UK Irish Sea and Bristol Channel Beam Trawl Survey are limited to 1988 onwards, limiting longer-term comparison, but enabling trends over 20 years to be analysed.

Current studies of juvenile fish use of habitats in Taw Torridge estuaries and Bideford Bay by, such as *i-bass* will also provide valuable data of stocks of juvenile fish and importance of estuarine NDMP habitats to juvenile fish (including commercially exploited stocks) (Thomas Stamp personal communication, University of Plymouth, 2018, https://www.plymouth.ac.uk/research/i-bass).

4.1.3 CPUE of commercial catches of non-quota species (crab, lobster)

Effort data were unavailable to confidently assess this indicator making the calculation of CPUE impossible. Landings data (live weight and value) and value 201-2017 were assessed for vessels from North Devon ports that were identified to fish within the NDMP. This data set was limited as it did not contain all landings that are likely to relate to catches within NDMP. Consent had to be obtained from each individual vessel and within North Devon ports consent was not obtained from at least 2 vessels. Furthermore, landings from vessels in North Cornwall ports and Welsh ports that relate to catches within NDMP would not be included in this data set. However, this data were used, as, in the absence of landings linked to spatial effort, due to restrictions on provision of fishing activity data, it provided the most confident assessment that the landings analysed were linked to fishing activity within NDMP. Results were also compared to publically available data on landings by UK and foreign vessels to ports within NDMP (all Devon and Cornwall ports). It is important to consider that although landings recorded in second data set were greater, catches may have been taken outside NDMP.

Landings data for North Devon vessels that were identified to fish within NDMP showed a small decline in moving averages (between 2012-2014 and 2015-2017) for both European lobster *H. gammarus* and brown crab *C. pagurus* landings live weight. Trend assessed with Kendall's tau –b between 2010 – 2017 in landings data were negative for both species, the negative trend was significant for crab *C. pagurus (C.pagurus,* Kendall's tau-b = -0.571 p =0.048, *H.gammarus* Kendall's tau-b = -0.357 *p*=0.216). The same trend was identified for landings by UK and foreign vessels to ports within NDMP, and the negative trends were significant for both species *(C.pagurus,* Kendall's tau-b = -0.857 *p* =0.003, *H.gammarus* Kendall's tau-b = -0.571 *p*=0.048). A similar decline in landings of *C. pagurus* and *H. gammurus* by UK and foreign vessels to all UK ports has not occurred. Instead national trends show no large observable change, with landings of *C. pagurus* ~30 000 t between 2013 and 2017 and *H.gammarus* landings have increased from 3000 t in 2013 to 3400 t in 2017 (MMO, 2018).

4.1.4 Condition: CPUE of Salmon and sea trout in rivers (and estuaries) supporting migratory fish in NDMP.

Commercial catches of salmon *Salmo salar* and sea trout *Salmo trutta* in NDMP rivers/estuaries (Taw and Torridge estuaries) are available in relation to fishing effort, calculated as number per license day. Data are published annually by Environment Agency and Natural Resources Wales (Environment Agency & Natural Resources Wales, 2017). The net season is concentrated in summer months (1st June to 31st July). Net CPUE was only available for Taw and Torridge, there was an increase in comparison of 2 year moving averages (2013-2014, and 2015-2016).

Limited change in net CPUE for sea trout and salmon has occurred in Taw/Torridge between 2010-2017, a small decline was observed in salmon CPUE and a small increase in sea trout CPUE, Kendall tau-b correlation coefficient reflected these changes but was not significant for either species (Table 11).

Table 11 Salmon and Sea trout CPUE from net fisheries on NDMP estuaries

Natural Capital: Flow from Assets to Physical Benefits	Indicator	Species	Unit	Port/River	Baseline year 2017	Baseline Trend 2010-2017	Correlation coefficient (Kendall's tau-b)	Signifi-cance
Physical Account: Food (fish and shellfish)								
Species stocks (for each fish and shellfish species used for food)	Env. Agency and Cefas salmon sea trout monitoring (annual catch nets)	Salmon	*n* per license day	Taw/Torridge	0.75	↓(↔)	-0.4	0.327
		Sea trout	*n* per license day	Taw/Torridge	0.95	↑(↔)	0.6	0.142

4.1.5 Condition: Area of each habitat providing moderate or significant contribution to ES Food (wild food) within MPAs with conservation objective to maintain or recover

Of the total extent of habitat in NDMP providing moderate or significant contribution to ES Food (wild food) (5526.71 km²) 455.66 km² are within an MPA, and 314.78 km² within MPAs have a condition assessment of 'recover' (Table 9). Saltmarsh and infralittoral rock habitats, that were assessed to provide a significant contribution to the ES Food (with high confidence in the association), have a high proportion of the habitat contained within MPAs and all extents in MPAs are in favourable condition, apart from 0.6 km² (30%) of saltmarsh habitat (Table 9).

Circalittoral rock habitats were also reviewed to provide a significant contribution to the ES Food, although confidence was limited due to a lack of peer reviewed evidence (Table 9). This habitat covers a large extent of NDMP (875.9 km²). A much lower proportion of the total extent of this deeper subtidal habitat is within an MPA (21%). The extent of circalittoral rock habitat that is within an MPA, has a high proportion with the conservation objective 'recover' (82%).

Sublittoral coarse sediment and sublittoral sand habitats, were reviewed to provide a moderate contribution to the ES Food (with moderate confidence in the evidence). Although providing a lower contribution to provision of the ES than saltmarsh or rock habitats sublittoral coarse sediment and sublittoral sand habitats cover huge extents in NDMP (2845.22 and 1690.03 km² respectively). In comparison to other habitats contribution to the ES Food is likely to be high, however, a very small proportion is within an MPA (6%, and 3% respectively) and of that extent, the conservation objective is 'recover' for a high proportion (68% and 47% respectively).

Provision of the ES Food from habitat assets, and particularly, saltmarsh, circalittoral rock habitats and sublittoral soft substratum habitats within NDMP is thereby, likely to be much lower than it could potentially be.

4.1.6 Condition: Area of each habitat providing moderate or significant contribution to ES Food (wild food) and modelled relative 'condition'

Of the total extent of habitat in NDMP providing moderate or significant contribution to ES Food (wild food) (5526.71 km²), 2529.27 km² (46%) has a modelled relative 'condition' within categories ≤ 3. The habitat therefore, has been exposed to moderate to high exposure to demersal fishing activity and moderate to high sensitivity to the pressure 'abrasion' related to exposure to demersal fishing activity (Table 9).

For habitats providing a significant contribution to the ES Food, historical demersal fishing activity was assessed to have interacted with 5.32km² of infralittoral rock habitat (32% of the total extent). Although there were limitations with the availability of more recent fishing activity data to assess exposure to the pressure 'abrasion' there is potentially a large area where provision of the ES Food is impacted. Sublittoral coarse sediment and sublittoral sand cover huge extents of NDMP, however (as with areas of habitat assessed within MPAs) moderate to large extents of these habitats were modelled to have low relative condition (within categories ≤ 3) (26% and 77% respectively).

Particularly for subtidal sand, contribution to potential ES delivery for the good/benefit 'Food' is likely to be limited due to historical interaction with human activities. It is important however, to consider recovery time (resilience) for typical communities in sand substratum habitats, and the level of exposure to the pressure 'abrasion' in recent years. Current demersal fishing, mooring or anchoring data were unavailable for the modelled LRC analysis and availability of this data would greatly benefit knowledge on current condition of habitats and their contribution to ES benefits.

4.1.7 Condition of Quota Species Stocks: TAC recommendations to ICES for quota species in area VIIf

Comparison of recommended TAC moving averages (3year) (2012-2014, and 2015-2017) showed an increase occurred in recommended TAC for Thornback ray *Raja clavata*. Plaice *Pleuronectes platessa* showed no discernible change. All other species (sole *Solea solea*, smalleyed ray *Raja microocellata*, blonde ray *Raja brachyura*, cod *Gadus morhua* and herring *Clupea harengus*) showed a decline in comparison of recommended TAC moving averages (3year) (2012-2014, and 2015-2017).

The trend over the longer time series, 2010 to 2017, showed recommended TACs for ray species *Raja clavata, Raja brachyura, Raja microocellata,* flatfish species *Solea solea, Pleuronectes platessa*, and cod *Gadus morhua* have shown a negative trend in relation to time (Table 12). Only herring *Clupea harengus* displayed a positive trend for advised TAC between 2010 and 2017. However, the data for herring are from the TAC provided for areas VIIg-h and VII j-k (Irish Sea, Celtic Sea and south west of Ireland) as there was not a recommended TAC for area VIIf, or for VIIe, for 2010-2017. Confidence in the relevance at NDMP scale is limited, as the Celtic Sea population are likely to be a separate stock (D&S IFCA, pers. Comm., January 2019). Advised TAC (t) for Celtic Sea herring also displayed large changes (increases and decreases) between years, from a minimum in 2010 of 13,200 tonnes to a maximum in 2014 of 35,942 tonnes. In 2017 advised TAC for herring in Celtic Sea areas had declined to 16,145 tonnes (Table 12). Significant negative trends were identified for smalleyed ray *Raja microocellata* (Kendall'a tau-b = -0.926 (p=0.002)) and blonde ray *Raja brachyura* (Kendall'a tau-b = -0.926 (p=0.002)).

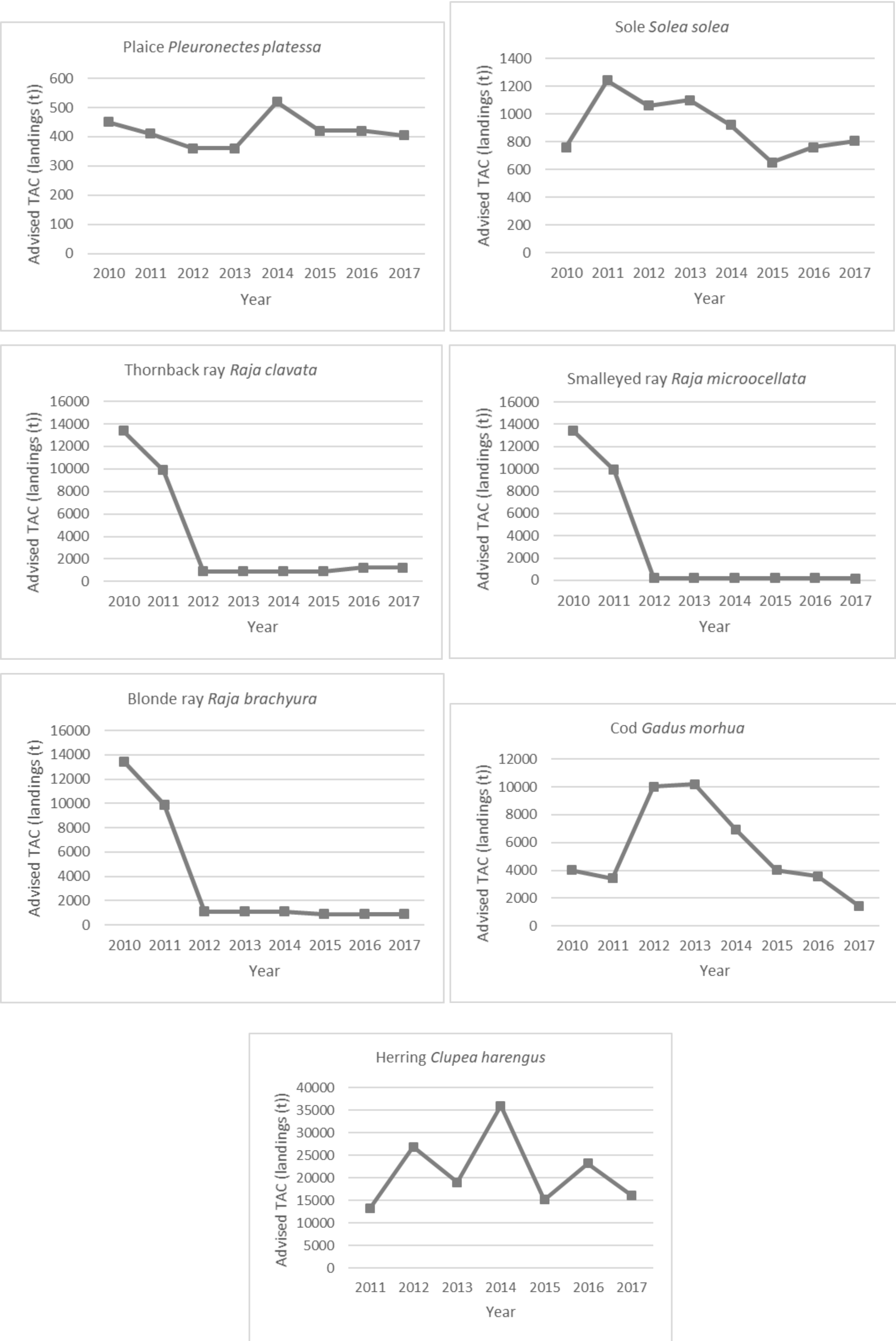
The CPUE of skate and ray species in Irish Sea and Bristol Channel Beam Trawl Survey samples have shown an increase since 2011 (Table 10, Figure 10). However, the decrease in TAC from 9900 tonnes in 2011 to <196 tonnes until 2017 for Smalleyed ray *R. microocellata* and from 9900 tonnes in 2011 to <1196 tonnes until 2017 for blonde ray *R. brachyura* reflects a precautionary approach across ICES area VIIf (Table 12, Figure 11). Prior to 2013 individual skate and ray species were not separated in ladings data and stock assessment trawl surveys are likely to mis-represent actual abundance due to equipment and survey design (ICES, 2018b). It is important to consider too that TAC relates to commitments to maximum sustainable yield (MSY) targets and so stock abundance in relation to fishing pressure, and not a target of restoring populations to specific historical abundances. The TAC figures analysed in this report were the recommended TACs for each species, each year for the relevant ICES area, based on scientific advice in relation to MSY based on stock assessment and landings data.

Increases in CPUE from survey trawls in and adjacent to NDMP for *R.clavata* and *R. brachyura* since 2011 may indicate effectiveness of management (TAC) measures since 2011, or indicate local stocks in NDMP are in good condition compared to the wider population. The difference may also highlight challenges in applying TAC data to assess species population's abundance and condition at NDMP scale. It is also acknowledged in ICES TAC recommendations, that a precautionary reduction in catches should be applied for *R. clavata* and *R.brachyura* populations as ICES did not have sufficient information on abundance or exploitation (ICES, 2018b). Studies to assess local population levels and movement patterns within and outside NDMP would inform the relationship between NDMP stocks and the wider ray populations. Comparison of current stocks to historical abundance over greater timescales, especially before intense fishing activity in the latter 20th century would also be beneficial, to provide an assessment in relation to population size that naturally occur, rather than solely on maximum sustainable yield, which only accounts for maintaining a population in reference to current levels of fishing activity but not restoring a population to historical abundance (Mace *et al*. 2015).

Table 12 Advised TAC for ICES area VII f, based on scientific advice for key NDMP commercial species by weight landed (herring is included as a traditional fishery)

Natural Capital Assets	**Indicator**		**Unit**	**Baseline year 2017**	**Baseline Trend 2010-2017**	**Correlation coefficient (Kendall's tau-b)**	**Significance**
Species stocks (for fish and shellfish stock used for food: Quota Species)	Condition	Cod: Advised TAC for area VIIf	(t)	1447	↓	-0.286	0.322
		Plaice: Advised TAC for area VIIf	(t)	405	(↔)	-0.074	0.802
		Sole: Advised TAC for area VIIf	(t)	806	↓	-0.327	0.262
		Herring: Advised TAC for area VIIg	(t)	16145	(↔)	0.048	0.881
		Thornback ray: Advised TAC for area VIIf	(t)	1235	↓	-0.206	0.503
		Small eyed ray: Advised TAC for area VIIf	(t)	154	**↓**	**-0.926**	**0.002**
		Blond ray: Advised TAC for area VIIf	(t)	895	**↓**	**-0.926**	**0.002**

Figure 11 Trends in advised TAC based on scientific recommendations to ICES for key species in NDMP fisheries



4.1.8 Condition: Non-quota species assessed from Cefas stock assessment reports.

Assessment of crab *Cancer pagurus* and lobster *Homarus gammarus* stocks in relation to NDMP were available only for the wider South West UK region (West Somerset, Dorset, Devon and Cornwall).

The south west region stock of crab *C. pagurus* (from 2016 data) were assessed as likely to be sustainable, as landings (in relation to the stock size) were assessed to be below maximum sustainable yield (MSY) in 2017 (Cefas, 2017a). MSY is defined as '*where the fishery is maximizing the average long-term yield from a given stock while maintaining productive fish stocks within healthy marine ecosystems'* (Cefas, 2017a). *H. gammarus* stocks were above minimum reference point limit but below MSY target (Cefas, 2017a). *H. gammarus* stocks were assessed to be under greater pressure than *C. pagurus* as Cefas (2017) concluded that exploitation was moderate, above rates consistent with MSY but below maximum reference point limit. Exploitation rate for *H.gammarus* was assessed to have decreased between 2013-2016 (Cefas, 2017a). The stock status for both *C.pagurus* and *H. gammarus* have remained unchanged in reports covering years between 2010 and 2017 for the South West UK region (Table 13).

Table 13 Crab and lobster (non quota species) stock assessment, from Cefas stock reports to ICES for south west UK

Natural Capital Assets	**Indicator**		**Unit**	**Baseline year (2017)**	**Trend 2010-2017**
Species stocks (for each fish and shellfish stock used for food: Non-Quota Species)	Condition (Cefas stock status report)	Crab (*Cancer pagurus*)	classification (exploitation level)	Moderate, likely to be sustainable, between minimum reference point and MSY.	↔
		Lobster (*Homarus gammarus*)	classification (exploitation level)	Moderate, above critical levels but not yet at the MSY.	↔

4.1.9 Condition: Salmon Rivers (meeting management objectives).

The proportions (%) of the Conservation Limit (CL) is defined as the reference point to maintain stocks within safe and sustainable biological limits, calculated in reference to *Salmo salar* egg deposition. CL attained between 2010 and 2017 in salmon rivers in NDMP are displayed in Table 15Table 14. Egg deposition estimates may be consistently above the CL but assessed status may still be uncertain. This reflects, in part, the marked year for year variation in egg deposition estimates but also arises due to statistical uncertainty when results from sample sites within a river are extrapolated (Cefas, Environment Agency & Wales, 2017).

Condition of a river's salmon population are classified as i) at risk, ii) probably at risk or iii) probably not at risk, in reference to not achieving compliance with the management objective (of meeting or exceeding their CLs in at least four years out of five). The assessment of compliance of Taw, Torridge and Lyn rivers with management objectives for the baseline year (2017) are provided in Table 15.

Table 14 % of conservation limit (egg deposition levels) attained in salmon rivers in NDMP

Natural Capital Assets	Indicator		Unit	2010	2011	2012	2013	2014	2015	2016	Baseline year (2017)	Trend 2010-2017	Correlation coefficient (Kendall's tau-b)	Signifi-cance
Compliance of salmon and sea trout rivers with conservation limits, as reported in annual ICES reports	Condition % of the percentage of the CL attained (annual)	Taw	% of conser-vation limit attained	134	287	199	52	109	253	139	244	↔	0.071	0.805
		Torridge	% of conser-vation limit attained	80	68	131	58	49	91	83	101	↑↔	0.143	0.621
		Lyn	% of conser-vation limit attained	227	291	166	85	103	95	60	257	↓(↔)	-0.357	0.216

Table 15 Compliance of salmon rivers in NDMP with management objectives

Natural Capital Assets	Indicator		Unit	Baseline year (2017)	Trend 2010-2017
Compliance of salmon rivers with management objectives, as reported in annual ICES reports	Condition (Classification: At Risk, Probably at risk, Probably not at risk)	Taw	classification	Probably at risk	↔
		Torridge	classification	Probably at risk	↔
		Lyn	classification	Probably at risk	↑(↔)

Compliance of salmon rivers (% of conservation limit obtained in relation to egg deposition) provided annual data between 2010-2017. Kendalls tau-*b* correlation coefficient did not identify a significant positive or negative trend at any river (Table 14). The direction of the trend returned showed a small negative trend for the Lyn and small positive trends for the Taw and Torridge % of conservation limit (CL) attained between 2010 and 2017. All rivers were classified as probably at risk of not achieving management objectives (that the river should meet or exceed their CLs in at least four years out of five) in 2017 (Table 15).

4.1.10 Ecosystem Service Flows and Benefits: Annual landings (t) per species by vessels operating from North Devon ports that fish within NDMP.

Data on landings of principle species (live weight) were obtained for the years 2010-2017 for a subset of vessels from North Devon ports (Clovelly, Bideford, Appledore, Ilfracombe), that were identified to fish within NDMP. These were vessels that operators had provided consent for their vessel's data to be obtained from MMO. Although the data set is unlikely to identify all landings from NDMP (as some fishermen did not provide their consent or were not identified) it was intended to provide the best confidence possible that the time series of landings analysed were catches from fish and shellfish populations in NDMP. Analyses of combined landings data for these vessels are presented below.

Comparison is also made with publically available data from landings by UK and foreign vessels to ports all within NDMP (Boscastle, Bude, Clovelly, Bideford, Appledore, Ilfracombe), from MMO data sets. The full analysis for landings by UK and foreign vessels to ports all within NDMP is included in Annex III. It is acknowledged that data from MMO publically available data sets on landings by UK and foreign vessels is likely to include data relating to catches taken outside NDMP. Without availability of data on all landings related to catches in NDMP, and related fishing effort, due to restrictions on data provision and processing resources, analysis of these two data sets provided the best available indicator on changes in landings associated with fish and shellfish populations in NDMP.

Whelk *Buccinum undatum* (117.97t), blonde ray *Raja brachyura* (93.02 t) and thornback ray *Raja clavata* (71.07 t) contribute the highest volume per species to total landings (live weight) in 2017 by vessels that were identified to fish within NDMP. Crab *C. pagurus* (16.18 t) and Lobster *H. gammarus* (14.61 t) contribute the next highest landings volume. Small-eyed ray *Raja microocellata* (7.25 t) and flat fish species (sole *S. solea* (4.75 t), plaice *P. platessa* (3.37 t)) as well as cod *G. morhua* (2.82 t) and bass *D. labrax* (2.46 t), provided much smaller contributions to live weight of species landed in 2017 by vessels that were identified to fish within NDMP. (Table 16, Figure 12). Landings from all UK and foreign vessels to all NDMP ports showed the same species as contributing to the highest landings live weight (Annex III). Landings live weights were similar for demersal and pelagic fish, but much higher, for whelk *B. undatum* (282.05 t), Crab *C. pagurus* (32.16 t) and Lobster *H. gammarus* (23.1 t) in data from all UK and foreign vessels to all NDMP ports (Annex III).

Of species with highest contribution to landings volume, landings of whelk *B. undatum,* by vessels fishing within NDMP, have shown an increasing trend since 2010, from 77 t in 2010 to a peak of 415 t in 2015, although landings had decreased to 118 t in 2017. A very weak positive trend was identified by Kendal's tau-*b* across the entire 2010-2017 time series for vessels that fished within NDMP, for landings of *B. undatum* (Table 16; Figure 12). Landings weight of herring *C.harengus* was small throughout the time series (max 0.25t in 2014), but landings also displayed a positive trend across the time series (Table 16; Figure 12). All other species displayed a negative trend in landings volume between 2010-2017 (Table 16; Figure 12). For flatfish (sole and plaice) and lobster *H. gammarus* negative trends were very weak. Flatfish landings are likely to be dependent on available quota. Lobster *H. gammarus* as a non-quota species have only shown a limited decline in landings over the period 2010-2017. Lobster *H. gammarus* landings initially increased from 10 t in 2010 to a peak of 19 t in 2012. Lobster *H. gammarus* landings volume for vessels that fished within NDMP has since declined from 2012 to 15 t in 2017 (Figure 13).

Table 16 Landings of commerially caught fish by vessels operting in the NDMP (2010-2017) (tonnes per year) and salmon and sea trout catch (n per liecense day) from salmon and sea trout net fishery license holders in NDMP rivers and estuaries.

Natural Capital: Flow from Assets to Physical Benefits	Indicator	Species	Unit	Port/River	Baseline year 2017	Baseline Trend 2010-2017	Correlation coefficient (Kendall's tau-b)	Signifi-cance
Species stocks (for each fish and shellfish species used for food)	MMO Fishing Activity data: Landings, to ports in NDMP from ICES rectangles in NDMP	Cod	t/yr	All North Devon	2.82	**↓**	**-0.571**	**0.048**
		Plaice	t/yr	All North Devon	3.37	↓	-0.429	0.138
		Sole	t/yr	All North Devon	4.75	↓	-0.357	0.216
		Herring	t/yr	All North Devon	0.17	↑(↔)	0.483	0.11
		Thornback ray	t/yr	All North Devon	71.07	↓	-0.286	0.322
		Small eyed ray	t/yr	All North Devon	7.25	**↓**	**-0.857**	**0.003**
		Blonde ray	t/yr	All North Devon	93.02	↓	-0.286	0.322
		Crab	t/yr	All North Devon	16.18	**↓**	**-0.571**	**0.048**
		Lobster	t/yr	All North Devon	14.61	↓	-0.357	0.216
		Whelk	t/yr	All North Devon	117.97	↑(↔)	0.143	0.621
		Squid	t/yr	All North Devon	0.05	↓	-0.429	0.138
		Bass	t/yr	All North Devon	2.46	**↓**	**-0.571**	**0.048**
	Env. Agency and Cefas salmon sea trout monitoring (annual catch nets)	Salmon	*n* per license day	Taw/Torridge	0.75	↓(↔)	-0.4	0.327
		Sea trout	*n* per license day	Taw/Torridge	0.95	↑(↔)	0.6	0.142

As effort data were unavailable it can not be assessed if these trends are due to changes in fishing effort or abundance of local stocks. Negative trends were significant for cod *G. morhua*, crab *C. pagurus* and bass *D. labrax* landings (Kendall's tau-b-0.571, p=0.048) for landings from vessels fishing within NDMP (Table 16). For the quota species cod *G. morhua* and bass *D. labrax,* TAC has decreased or management measures have been introduced to limit targeted fisheries for these species, which will have influenced landings. However, crab *C. pagurus* are non-quota species. Crab *C. pagurus* landings by vessels within the NDMP displayed an increase from 2010-2012 from 26 to 42 tonnes but have since declined to current landings in 2017 of 16 tonnes (Figure 13).

Figure 12 Landings trends for key quota species in NDMP (landed by vessels working within the NDMP)

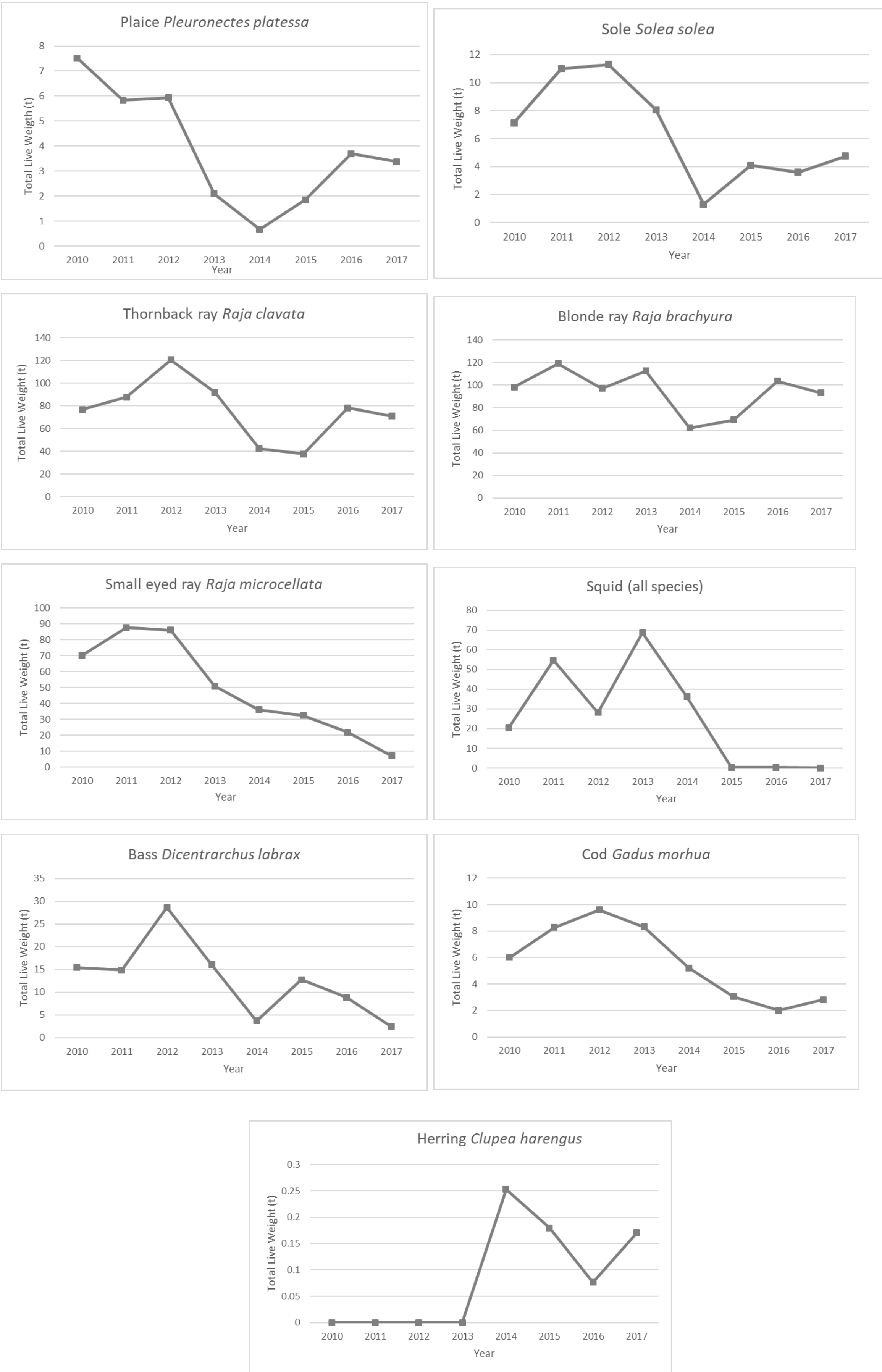
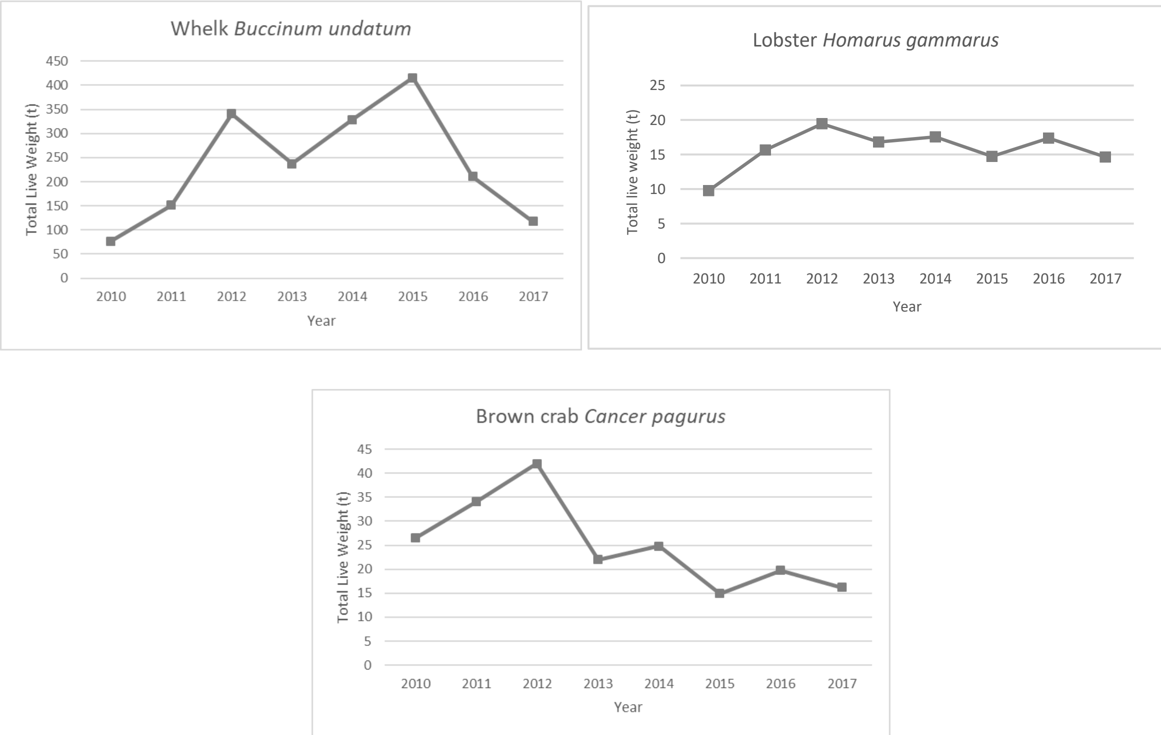


Figure 13 Landings trends for key non-quota species in NDMP (landed by vessels working within the NDMP)



Trends were similar for landings from all UK and foreign vessels to NDMP ports (Annex III). The trend for *C.pagurus* landings to North Devon and all NDMP ports goes against a national trend which shows no change in landings to all UK ports (MMO, 2018).

For flatfish (*S. solea* and *P. platessa*), bass *D. labrax,* squid (all species), crab *C. pagurus and* lobster *H. gammarus* negative trends over the 2010-2017 time series for landings (live weight) from UK and foreign vessels to all NDMP ports were much stronger and all were significant (p=>0.05), in contrast to the weak, not significant negative trend for just landings from vessels that fished within the NDMP (Annex III).

In national data for all landings to all UK ports by UK and foreign vessels declines in landings (weight) are also present between 2013-2017 for bass *D. labrax*, sole *S. solea*, suggesting trends seen in NDMP related data are also occurring across the UK. At a UK scale it is not identified which factor, quota, declines in active vessels, or local populations, has the greatest impact on this trend. Opposed to trends in NDMP, landings of cod *G. morhua* and squid species have increased between 2013-2017 for all UK data, although there has been a large decline in landings (weight) of these species in both data sets related to NDMP (MMO, 2018). This also reflects trends in landings (weight) of *C. pagurus* and *H. gammarus*, which as discussed have not changed or, even, have increased across the UK but declined in NDMP (MMO, 2018).

4.1.11 Economic benefit: Annual landings value (£) per species to vessels operating within the NDMP

Lobster *H. gammarus* (£161,993.60) whelk *B. undatum* (£141,932.10) blonde ray *R. brachyura* (£130,144.30) Thornback ray *R. clavata* (£99,434.04) and Sole *S. solea* (£39,191.92) represented the highest value fisheries in 2017 from landings by vessels that were identified to fish within NDMP (Table 17). Thornback ray *R. clavata*, blonde ray *R. brachyura* and whelk *B. undatum* represent low value species that are landed in relatively high volume (71.07-117.97 tonnes) (Table 16, Table 17). Lobster *H. gammarus* and sole *S. solea* represent higher value species that are landed by vessels (that fish within NDMP) in smaller volumes (4.75 t *S. solea*, 14.61 t lobster *H. gammarus*)..

Table 17 Landings value (estimate) of commercially caught fish by vessels operating in the NDMP (2017)

Natural Capital: Flow from Assets to Economic Benefits	**Indicator**	**Species**	**Unit**	**Port**	**Baseline year (£/yr) 2017**	**Trend (Landings live weight) 2010-2017**	**Correlation coefficient (Kendall's tau-b) (landings live weight)**	**Signifi-cance**
Species stocks (for each fish and shellfish species used for food)	MMO Fishing Activity data: Landings, to ports in NDMP from ICES rectangles in NDMP	Cod	£/yr	All North Devon	6,559.07	↓	**-0.571**	**0.48**
		Plaice	£/yr	All North Devon	3,672.29	↓	-0.429	0.138
		Sole	£/yr	All North Devon	39,191.92	↓	-0.357	0.216
		Herring	£/yr	All North Devon	363.41	↑(↔)	0.483	0.11
		Thornback ray	£/yr	All North Devon	99,434.04	↓	-0.286	0.322
		Small eyed ray	£/yr	All North Devon	10,143.48	↓	**-0.857**	**0.003**
		Blonde ray	£/yr	All North Devon	130,144.28	↓	-0.286	0.322
		Crab	£/yr	All North Devon	19,321.19	↓	**-0.571**	**0.48**
		Lobster	£/yr	All North Devon	161,993.63	↓(↔)	-0.071	0.8
		Whelk	£/yr	All North Devon	141,932.07	↑(↔)	0.143	0.621
		Squid	£/yr	All North Devon	294.13	↓	-0.429	0.138
		Bass	£/yr	All North Devon	19,202.69	↓	**-0.571**	**0.48**

Quotas for sole *S. solea* and ray species will influence annual landings. Lobster *H. gammarus* are non quota and the fishery is likely to be significant for supporting fishing businesses in NDMP. Assessment of effectiveness of re stocking through juveniles from lobster hatchery stocks would benefit ensuring the fishery can continue to provide high monetary benefits. Crab *C. pagurus* landings (live weight and associated value of landings) have decreased between 2010-2017. The recent designation of MCZs in addition to Lundy SAC no take zone increase the extent of infralittoral reef habitats as designated features to 12.51 km². If effectively managed these habitats are likely to support crab *C. pagurus* and lobster *H. gammarus* stocks.

General trends were similar for the data set that included landings by all UK and foreign vessels to NDMP ports. Whelk and lobster fisheries also provide by far the highest value from landings by all UK and foreign vessels to NDMP ports (£339,107.40 and £292, 154.02 respectively), as well as solely the vessels that fish within the NDMP (Annex III).

Over the time series 2010 to 2017, Sole *S. solea*, skate and ray species, squid species and bass *D. labrax* had also contributed to the highest value fisheries, from value of landings to all NDMP ports from all UK and foreign vessels (Annex III). Value from Sole *S. solea* peaked at £151, 690.60 in 2011, and had declined to £46, 536.43 in 2017. In 2013 Thornback ray *R. clavata* landings valued £217,254.30 and were £101,019.80 in 2017 (Annex III). Value of landings of squid species peaked at £386,665.30 in 2013 but had declined to £346.60 in 2017. Value of bass *D. labrax* landings peaked in 2012 at £227,767.60 and were £33, 654.22 in 2017 (Annex III). Similar trends occur in landings volume and value for both data sets, with peaks between 2011-2013, and subsequent declines in value (reflecting declining landings) to 2014/15. In both data sets, sole *S. solea*, plaice *P. platessa*, thornback and blonde ray *R. clavata*, *R. brachyura* landings weight and value show small increases between 2014/15 and 2017, in weight and value. Between 2013 and 2017 *H. gammarus* landings remain more stable in both data sets relating to NDMP, reflecting national trends more closely.

Although there is a negative trend in many species landings and value data between 2010-2017, identified by Kendall's tau *b* in both data sets relating to NDMP (Table, 16, 17, Annex III), there is a stable or positive trend in the more recent years (2014-2017) for flatfish, skate and ray and lobster species (Figure 12, 13, Annex III). The increased landings for flatfish and skate and ray species between 2014 and 2017 in data sets related to NDMP go against the national trend across the UK where a decline in landings weight and value occurs (MMO, 2018). Trends in lobster landings and value related to NDMP show a stable to negative trend compared to the increasing trend seen at a national level (MMO, 2018). Maintaining and recovering habitat quality in MPAs and monitoring benefit to populations of these species would benefit food provision and associated economic and wellbeing benefits to NDMP and surrounding areas. Flatfish and skate and ray species also utilise the large extents of soft substratum habitats outside of MPAs in NDMP. It would be beneficial to improve knowledge of habitat use within NDMP through juvenile and adult life stages of these species to assess effectiveness of MPA designations at benefitting populations, and effectiveness of voluntary measures such as the 'Ray box', North of Lundy, to support sustainability of stocks.

4.1.12 Economic benefit: Number of businesses and employment) supported (Fishing vessel businesses, processors and markets/fish sellers and boat building, engineering)

Total number of vessels registered to all NDMP ports in 2016 was 29, suggesting a minimum estimated employment of 23 fishermen for the 23 under 10m vessels and 12 fishermen for the 6 over 10m vessels (Table 18, Figure 14). In 2016, of the vessels that were identified to fish within NDMP and that landings data were obtained for, 7 were registered as over 10m and 3 under 10m, suggesting a minimum employment of 17 fishermen.

Table 18 Businesses supported by NDMP fisheries

Natural Capital: Flow from Assets to Economic Benefits	Indicator	Business type	Unit	Baseline year 2017	Baseline Trend 2010-2017
Marine and Coastal Margin habitats; Species stocks (all)	Businesses supported	<10m vessels	n	23	↓
		>10m vessels	n	6	↓
		Processors	n	4	↓
		Traders and wholesalers	n	Approx 13	↓
		Vessel, equipment and technical support	n	Approx 3	(unknown)

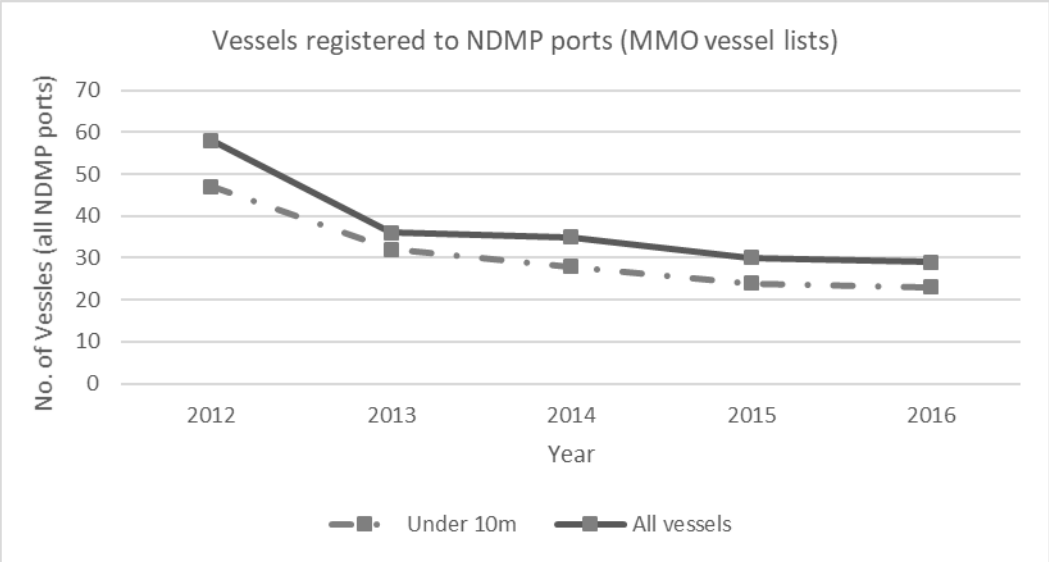


Figure 14 Vessels registered to all NDMP ports (Devon and Cornwall) from MMO vessel lists (under 10m vessels dotted line, over 10m and under 10m vessels solid line)

Total number of vessels registered to all NDMP ports (Devon and Cornwall) has decreased from a total of 58 vessels in 2012 to 29 vessels in 2016. The trend has been for a steady decline of between 1 and 5 registered vessels per year (2013 – 2016) apart from 2012 – 2013 when a decline of 22 vessels occurred (15 under 10 vessels, 7 over 10 metre vessels) (Figure 14). Reasons for the decline in vessels are unknown and would be of interest to further consultation with the local fishing industry (e.g. social or economic reasons and significant policy or management events that influenced vessel owners actions).

4.1.13 Indirect stakeholders and supporting stakeholder businesses related to the fishing industry

In 2017 Indirect stakeholders related to fisheries in NDMP included 4 primary processors, 7 traders and wholesalers (8 including catches sold at Billingsgate fish market, London) and 6 retailers (>7 if supermarket chains that sold NDMP catches were included) (Ashley, Rees & Cameron, 2018). Local catches are also sold infrequently (c2017/2018) at local farmers markets and seasonal fish and seafood festivals. A local fish seller estimated there had been more local shops and market stalls selling local catch in Bideford 10 – 25 years ago (Felicity Sylvester personal communication, September, 2018). Number of people employed by these businesses has not been collected for this report but employment data would benefit future assessment.

4.1.14 Key Points on Food (Wild Food)

There are a range of habitats within the North Devon biosphere reserve that support food production that benefit food provision (fisheries) at both a local and regional scale. Habitats that provides structure, complexity, niches provide shelter, habitat, food for fish and shellfish. For example the three dimensional structure of saltmarsh vegetation and the availability of food during high tide, provides significant benefits to juvenile fish species. Reefs (including biogenic reefs) and kelp communities provide shelter for juvenile stages of commercially targeted fishes, crustaceans and bivalve mollusc, Kelp holdfasts, the attachment between kelp and reef features; provide food resources for flatfish, sea bass. The complexity of structure of a reef habitat, shelter and food resources for commercially targeted fish and shellfish. Sediment habitats that cover a vast tract of the NDPR significant provision of food resources for fish. The water column is a key asset in realising the benefit of food provision from natural assets with currents, the chemical composition, transition zones (nutrient rich mixed water and stratified water) and areas of primary production fuelling life within the ocean (Ashley, Rees & Cameron, 2018).

Historical exposure to the pressure ’abrasion’ linked to demersal fishing activity has negatively impacted the potential provision to ES ‘Food’ (wild food) from NDMP habitats (that contribute a moderately or significantly to ES ‘food’). 32% of infralittoral rock habitats were assessed as being previously exposed to unacceptable impact (LRC moderate or below). For circalittoral rock habitats, 82% of extent in MPAs were assigned a conservation objective ‘recover’ in 2016/17, and 48% of entire NDMP extent was assessed as exposed to an impact where the structure and function of the ecosystem is likely to be imparied (LRC moderate or below). For all subtidal soft substratum (combined EUNIS L3 habitats) 45% of entire NDMP extent were assessed as being exposed to unacceptable impact (LRC moderate or below) (72% of extent in MPAs have a conservation objective: ‘recover’). Fish stocks supporting commercial fisheries benefit from shelter and food resources that are maximised by these habitats being in favourable condition. Effective management, leading to recovery of habitats, is likely to benefit fish stocks and therefore ES ‘Food’ benefits available to local fisheries.

The saltmarsh within SSSI units and estuary waters are important nursery areas for fish, particularly bass. Estuaries also provide migratory routes for salmon and sea trout. A reduction in the extent and condition of nursery habitats, along with poor water quality, will impact upon the condition of these stocks and the potential flow of benefits.

An overall decline in the fishing sector in NDMP is apparent from the indicator data analysed, with number of registered vessels in the region declining from 2010-2017 and also numbers of processers and sellers of local sustainable fish declining. Number of vessels actively fishing from NDMP ports peaked in 2015 (12 vessels) and declined to 9 vessels in 2017. Landings and associated value trends for North Devon vessels identified to fish within NDMP were negative for all species apart from whelk *B. undatum* and herring *C. harengus* over the time series 2010 to 2017. However, over a shorter time scale, between 2014 and 2017, there has been an increase in landings volume (t) of plaice *P. platessa*, sole *S. solea*, thornback ray *R. clavata* and blonde ray *R. brachyura*. Between 2010 and 2017 larger vessels (over 10m) based in larger ports such as Ilfracombe and Bideford have landed >90% of the total volume (t) of fish landed by North Devon vessels which fish within the NDMP.

Increase in stock assessment surveys CPUE (number per km^2) occurred for thornback ray *R. clavata,* squid species and herring *C. harengus* in ICES rectangles interacting with NDMP between 2010-2017. Sole *S. solea* CPUE displayed little change over time. Sole *S. solea* and thornback ray *R. clavata* are high value stocks for the vessels fishing from NDMP ports (*R. clavata* due to high landings volume and *S. solea* due to high value but smaller volume of landings). Herring *C. harengus* represent a stock that have previously supported a historical seasonal fishery.

The trends identified in CPUE were reflected in recommendations for TAC for the wider ICEA Area VII f for all species apart from for Thornback ray *R. clavata* and sole *S. solea* (which showed reduced TAC in the wider ICES area but increased CPUE in stock assessment samples in proximity to NDMP). The trends suggest either the wider southern Celtic Sea stocks were assessed to be in poor condition and/or there were larger local populations of species at the time of sampling (annual autumn surveys). For skate and ray species it is recognised by ICES that sampling methodologies of stock assessment and species records in landings data (before 2013 all skate and ray species were combined in landings data) prevent effective monitoring of populations and exploitation, as a result a precautionary TAC is advised (ICES, 2018b).

Landings of lobster *H. gammarus* are a high value fishery. Landings have shown a declining trend between 2010 and 2017. South West UK lobster stocks are assessed as being exploited above minimum reference limits and approaching, but not yet at maximum sustainable yield (Cefas, 2017b). However, there is no data on the local levels of lobster abundance for the NDMP. Historical re-stocking with hatchery reared juveniles has occurred in the region. Assessing the benefit of such initiatives would inform future sustainable management options. At a UK level, lobster stocks are part of Project UK (https://www.seafish.org/article/project-uk). Project UK aims to determine the environmental performance of key commercial fisheries, demonstrate how these can move towards sustainability through Fishery Improvement Projects (FIPs) and ultimately achieve MSC certification where possible.

Overall there has been a decline in species stocks at a local level (CPUE data from survey trawls) and in the wider ICES areas the fish stocks move within (recommended TAC data). Declines in vessel numbers and landings of the majority of species may reflect declines in abundance but may also be influenced by social and economic factors that are not quantified by indicator data. Many social and economic factors influence fishing activity such as: fishers reaching retirement and fewer people entering the industry, cost of insuring and running vessels and availability of markets/ processors and prices paid by those markets, reduction in available grounds, competition with visiting vessels, or reduced demand for locally caught fish etc. Management measures may also trigger declines in landings though the implementation of spatial management measures, changes in landing size, TAC etc. Investigating these factors further through interviews or meetings with the local fishing industry members would provide knowledge on the factors influencing the trends observed in this study.

Habitats within designated MPAs especially estuarine saltmarsh and coastal infralittoral reef provide important nursery habitat supporting the main commercial fish species such as Thornback ray *R. clavata,* sole *S. solea* and Lobster *H. gammarus.* Ensuring salt marsh SSSI units currently in unfavourable condition recover and infralittoral reef habitats in coastal MCZs and SACs are maintained in favourable condition will continue to benefit these fisheries.

4.2 Healthy Climate (Carbon sequestration)

A healthy climate is dependent on the balance and maintenance of the chemical composition of the atmosphere and the oceans by marine living organisms. The capture and export of carbon is central to this process. The following indicator metrics have been sourced to define the link between the natural capital assets and the flows of ecosystem services.

Extent (Habitat)

- Area of habitats providing moderate or significant contribution to the ES of a Healthy Climate

Condition (Habitat)

- Area of each habitat providing moderate or significant contribution to the ES of a Healthy Climate within MPAs with conservation objective to maintain or recover
- Area of each habitat providing moderate or significant contribution to the ES of a Healthy Climate and modelled relative 'condition'

Ecosystem Service Flows and Benefits

- The value of sequestered carbon

Areas of high planktonic productivity (water bodies containing high abundance of phytoplankton) were also reviewed (Ashley, Rees & Cameron, 2018) to provide a moderate contribution to the ES benefit a Healthy Climate. Data availability and time constraints have meant that this asset has not been reviewed but a short note is provided on the potential.

4.2.1 Extent: Area of habitats providing moderate or significant contribution to the ES of a Healthy Climate

The total area of habitats reviewed to provide a moderate or significant contribution to ES Healthy Climate (carbon sequestration) were calculated to be 29.4km² (Table 19). Saltmarsh provides the strongest contribution, while littoral (intertidal) mud and infralittoral rock (with algae and particularly kelp communities) provide moderate contributions (Table 19).

Table 19 Habitat assets providing a moderate or significant contribution to provision of ES benefit Healthy Climate the extent within NDMP, within MPAs and extent with condition 'recover' in MPAs or modelled LRC of moderate or below.

	Natural Capital Asset: Habitats in North Devon Marine Pioneer		**Level of contribution to delivery of ES 'Healthy climate'**	**Area of habitats (km²) providing moderate or significant contribution to ES good/benefit food (Healthy climate)**	**Area within an MPA**	Area with condition recover	Area within NDMP with modelled relative condition within categories ≤ 3 for interaction with abrasion
Coastal margins	**Saltmarsh**	A2.5: Saltmarsh	3	2.8	2.01	0.6	0
Marine	**Intertidal reef**	A1: Littoral rock and other hard substrata	2	11.31	10.42		5.79
	Subtidal reef	A3: Infralittoral rock and other hard substrata	2	16.61	12.51		5.32
		A4: Circalittoral rock and other hard substrata		875.9	180.76	147.5	418.3
	Intertidal sediments	A2.1 Littoral Coarse sediment		0.76	0.61		0.02
		A2.2: Littoral sand and muddy sand	2	14.99	14.56		9.61
		A2.3: Littoral mud	3	9.98	4.27		0.32
		A2.4: Littoral mixed sediment	2	0.45	0.33		0.05
	Biogenic reef	A2.7: Littoral biogenic reefs	1	0.01	0.01		0.01
	Subtidal sediment	A5.1: Sublittoral coarse sediment		2845.22	175.73	119.95	742.121
		A5.2: Sublittoral sand		1690.03	52.81	47.19	1305.05
		A5.3: Sublittoral mud		10.85	0.21		7.08
		A5.4: Sublittoral mixed sediments		48.56	2.04		35.63
Total extent all habitats providing moderate or significant contribution to the ES				29.4	18.8	0.14	5.6443

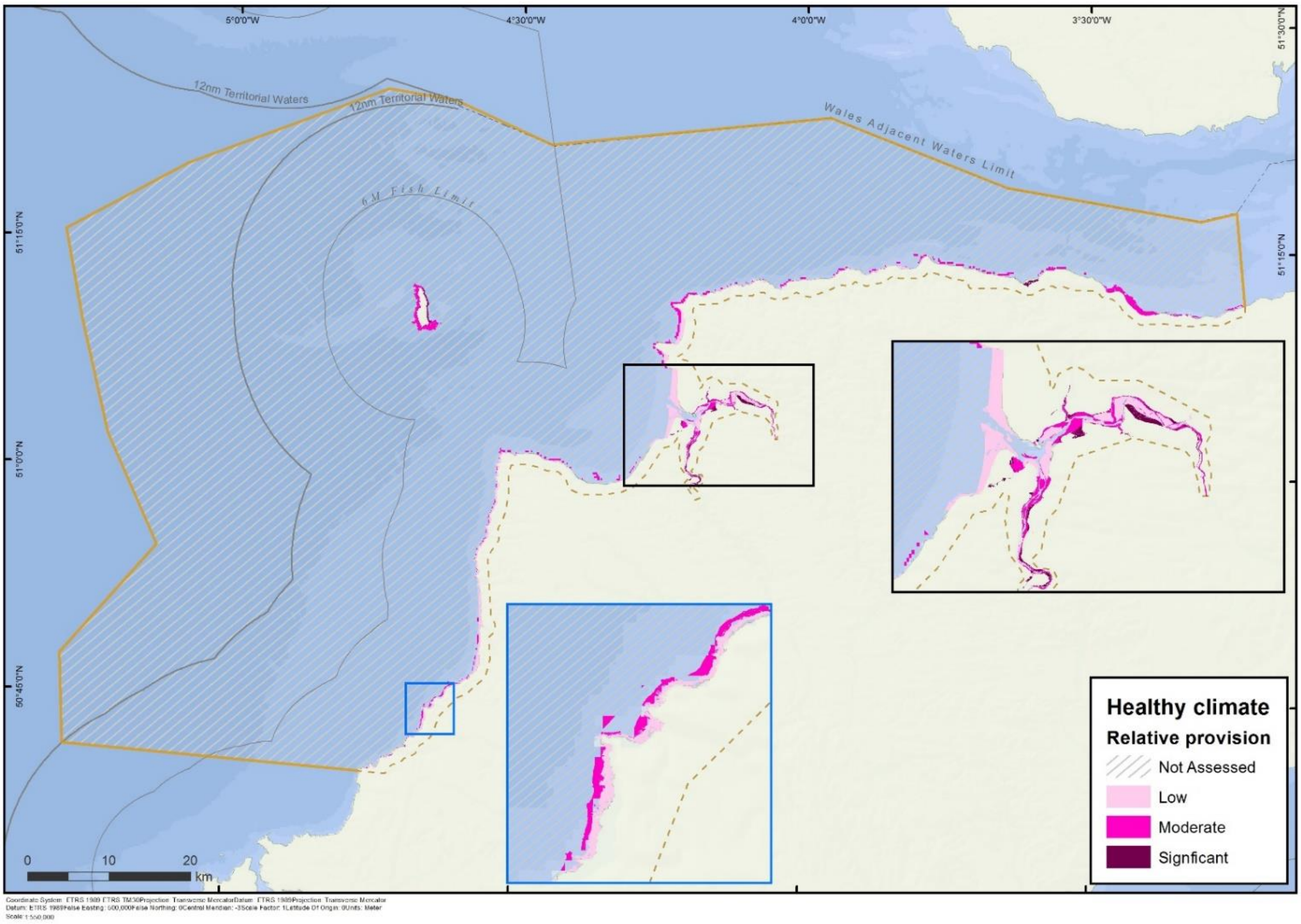


Figure 15 Map of contribution of habitats within NDMP to provision of ES benefit 'Healthy Climate'

4.2.2 Condition: Area of each habitat providing moderate or significant contribution to the ES of a Healthy Climate within MPAs with conservation objective to maintain or recover

Of the total extent of habitats in NDMP providing moderate or significant contribution to the ES benefit 'Healthy Climate' (29.4 km²), 18.8 km² are within an MPA, and 0.14 km² within MPAs have a condition assessment of 'recover' (Table 19).Table 9 Saltmarsh and infralittoral rock (with kelp communities) that were assessed to provide a moderate to significant contribution to the ES 'Healthy Climate' (with confidence in the association ranging from moderate to high), have a high proportion of the habitat contained within MPAs. Littoral mud habitats, also provide a moderate contribution to ES Healthy Climate, although only 43% of the extent is contained within an MPA (Table 19). In 2012, 30% of saltmarsh extent within an MPA (Taw Torridge SSSI) was assessed as being in unfavourable condition. Contribution to ES benefit Healthy Climate from the saltmarsh habitat within NDMP is thereby, likely to be much lower than it could potentially be, given the significant contribution of saltmarsh habitats when in favourable condition.

4.2.3 Condition: Area of each habitat providing moderate or significant contribution to the ES of a Healthy Climate and modelled relative 'condition'

Of the total extent of habitat in NDMP providing moderate or significant contribution to ES Healthy Climate (29.4 km^2) 5.64 km^2 has a modelled relative 'condition' within categories ≤ 3 at present LRC has only been assessed in relation to moderate to high sensitivity to the pressure 'abrasion' related to exposure to demersal fishing activity) (Table 19, Table 9).

For habitats providing a significant contribution to the ES Healthy Climate, historical demersal fishing activity was assessed to have interacted with 5.32km^2 of infralittoral rock habitat, 32% of the total extent. Although there were limitations with the availability of more recent fishing activity data to assess exposure to the pressure 'abrasion,' the assessment indicates there is a moderate area (32%) of infralittoral rock habitat where provision of the ES Healthy Climate is impacted.

4.2.4 Ecosystem Service Flows and Benefits: The value of sequestered carbon

Values of carbon sequestered by habitats (t/C/km^2/yr) in NDMP were assessed from reviewed data (ANNEX IV). The value per km^2 was then multiplied by the extent (km^2) of that habitat present in NDMP. The values provided assume the habitat is in favourable condition and ecological structures and functions are healthy. A total value of 7275.01 t/C/km^2/yr was calculated to be sequestered by habitats and associated algae and plant species communities within NDMP (Table 20).

Saltmarsh, intertidal reef communities (with algae communities) and shallow subtidal (infralittoral) reef communities provide the greatest contribution to carbon sequestration within NDMP (2270.55, 1838.49 and 2808.59 t/C/km^2/yr respectively). Confidence is far greater for the contribution of saltmarsh habitat than reef habitat with algae (and particularly kelp) communities (Howard *et al.*, 2017). Saltmarsh plants can capture carbon and store a small proportion (that is not released back into the atmosphere through plant and microbe respiration or stored temporarily in plant foliage) in woody biomass and soil (Howard *et al.*, 2017). As kelp are often free floating or attached to rocky substrates, an extensive root systems is not developed for trapping detritus and sediment such as coastal wetlands and, therefore, do not have a soil carbon pool (Howard *et al.*, 2017). Confidence in the high value for kelp communities returned in previous reviews (Alonso *et al.*, 2012) requires further research to examine actual sequestration levels. This is particularly important to verify for NDMP, as it would influence potential decisions regarding payment for ecosystem services as mitigation for developments (if payment for ecosystem services was applied as a financing/management option).

Economic benefits associated with carbon sequestered by natural capital habitat and associated species community assets were calculated using UK Government current traded carbon values and also the social cost of carbon method previously used by the UK Government. Traded carbon values provide an assessment of the cost avoided of mitigating equivalent emissions to the carbon sequestered by habitats. Social Cost of Carbon metrics provide an assessment of the cost avoided of long-term damage from the sequestering of carbon by natural habits/species (HM Government, 2018a; Watkiss. *et al.*, 2005) For the total carbon sequestered (t) by natural capital assets in NDMP (2017 extent) the UK Government 2017 traded carbon values (central value) was £30,045.81. For the same total carbon sequestered (t) the cost avoided value using Social Cost of Carbon was £167,688.98. The estimated social cost of carbon was suggested as £19/tCO_2 in 2002, with an increase of £0.27/ tCO_2 per year to reflect the increasing marginal cost of emissions (HM Government, 2018a). A figure of £23.05/tCO_2 was, therefore used to calculate SCC for the baseline year of 2017.

Table 20 Values of carbon sequestered by habitats (total t/C/km²/yr) in NDMP

Natural Capital Asset	Benefit (Flow) (2017)		Monetary Benefit (2017)	
	Carbon sequestered (t)	**Trend** (2010-2017)	**Cost avoided of mitigating emissions** (UKGOV 2017 traded carbon value (central))	**Cost avoided of long term damage by carbon** (total sequestered) (SCC)
			Value (£)	Value (£)
Habitats reviewed to provide significant or moderate contribution to the Benefit 'Healthy Climate'	**7275.01**	↔	**£30,045.81**	**£167,688.98**

4.2.5 The role of the water column

Chlorophyll-a concentrations provide a proxy for the amount of photosynthetic plankton, or phytoplankton, present in the ocean and can be assessed through satellite remote sensing. Phytoplankton populations change temporally due to climatic factors such as sea surface temperatures and winds, but review of data products provided by the Ocean Colour Climate Change Initiative Project indicate that water bodies in NDMP support high levels of plankton primary productivity (Valente *et al.*, 2016). Analysis of annual mean chlorophyll-a concentrations across NDMP would produce a proxy for planktonic productivity and potentially increase extent of habitats contributing to Healthy Climate ES benefit to 5526.93 km². Carbon sequestered by areas of high planktonic productivity are estimated to be much lower than habitats providing significant contributions to carbon sequestration such as saltmarsh (0.004 t/C/km²/yr for plankton communities, compared to 206.68 t/C/km²/yr for saltmarsh) (ANNEX IV). However, spatial extent of plankton communities in the water column is much greater and thus, overall contribution to ES benefit of Healthy Climate are likely to be significant over large spatial scales (Howard *et al.*, 2017).

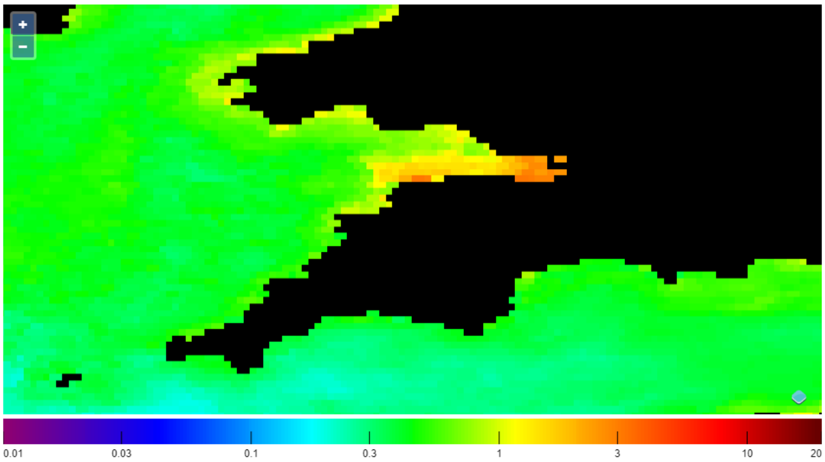


Figure 16 Chlorophyll-a concentration in seawater (mg m^3) August 2018, Bristol Channel and Southern Celtic Sea, Ocean Colour-CCI (Plymouth Marine Laboratory)

4.2.6 Key Points on the ES of a Healthy Climate

A healthy climate is dependent on the balance and maintenance of the chemical composition of the atmosphere and the oceans by marine living organisms. The capture and export of carbon is central to this process. Saltmarsh plant communities, algae and kelp communities capture carbon and soft substratum sediments contribute towards storage / sequestration. The water column supports the carbon cycle though oceanic primary production harvesting light to convert inorganic to organic carbon.

The assessment in 2012 (most recent condition assessment at time of writing) that 30% of saltmarsh extent within Taw Torridge Estuary SSSI was in unfavourable condition (due to grazing pressure impacting plant communities) is of concern to provision of ES Healthy Climate (Natural England, 2012). The plant communities capture carbon that is then stored in saltmarsh soils, and a healthy plant community will thereby, provide a greater contribution to this internationally important ES benefit (Howard *et al.*, 2017).

A total value of 7275.01 t/C/km^2/yr was calculated to be sequestered by habitats and associated algae and plant species communities within NDMP the annual value of which is between £30,000 and £167,000.

Areas of high planktonic productivity (water bodies containing high abundance of phytoplankton) were also reviewed to provide a moderate contribution to the ES benefit 'Healthy Climate'. Future assessment would benefit from including extent of areas of high planktonic productivity. If high planktonic productivity occurred over the entire extent of waterbodies within NDMP an additional 19.90t of carbon is calculated to be sequestered. Although most phytoplankton are consumed by higher trophic level organisms, a small yet important fraction of carbon in phytoplankton (0.1%)

have been calculated to sink, and associated carbon to become sequestered long–term in sea floor sediments (Falkowski, 2012; Howard *et al.*, 2017).

Sequestration of carbon from areas of high planktonic productivity is likely to occur thorough burial in offshore soft substratum. Offshore soft substratum, such as the large extents present in NDMP, also contribute to the burial of organic carbon that is eroded from the terrestrial biosphere and been transported to NDMP habitats through river and estuary systems (Burdige, 2005; Kao et al. 2014). Although the level of contribution to the ES benefit is likely to be small in comparison with habitats such as saltmarsh, as with areas of high plankton productivity, the large extent of offshore soft substratum habitats in NDMP, means as a whole the habitat may provide a larger contribution to the ES benefit 'Healthy Climate'. It is important to consider the extent of habitats, as well as level of ES provision, when interpreting the assessment of provision of ES benefits from NDMP habitat assets.

4.3 Natural Hazard Regulation (Flood prevention/Sea defence)

Marine habitats play a valuable role in the defence of coastal regions. The following indicator metrics have been sourced to define the link between the natural capital assets and the flows of ecosystem services.

Extent (Habitat)

- Area of habitats providing moderate or significant contribution to the ES Natural Hazard Regulation

Condition (Habitat)

- Area of each habitat providing moderate or significant contribution to the ES of ES Natural Hazard Regulation within MPAs with conservation objective to maintain or recover
- Area of each habitat providing moderate or significant contribution to the ES of Natural Hazard Regulation and modelled relative ‘condition’

Ecosystem Service Flows and Benefits

- Area of coastal land at risk from flooding
- Area of high quality agricultural land that overlaps with flood risk zone
- Value of property interacting with high flood risk areas
- Value of agricultural land interacting with medium to high-risk flood zones.

4.3.1 Extent Area of habitats providing moderate or significant contribution to the ES Natural Hazard Regulation

Extent of habitat assets providing moderate or significant contribution of the ES Benefit 'Sea defence' in NDMP were assessed to be 46.72km^2 (Table 21). Habitats in NDMP such as saltmarsh and littoral sediments provide benefits due to attenuation of currents, wave action and storage of flood waters (due to storms or tides). Littoral sand and muddy sand, due to the greater extent of the habitat in NDMP (compared to saltmarsh and other littoral sediments) provides the greatest benefit overall (Table 21, Figure 17). The capacity of deep estuaries in NDMP, to aid drainage of flood water was not assessed in this study but is important to consider.

Table 21 Habitat assets providing a moderate or significant contribution to provision of ES benefit Sea Defence, including the extent within NDMP, within MPAs and extent with condition 'recover' in MPAs or with a modelled LRC of moderate or below.

Natural Capital Asset: Habitats in North Devon Marine Pioneer			**Level of contribution to delivery of ES 'Sea Defence'**	**Area of habitats (km²) providing moderate or significant contribution to ES good/benefit food (sea defence)**	**Area within an MPA**	Area with condition recover	Area within NDMP with modelled relative condition within categories ≤ 3 for interaction with abrasion
Coastal margins	**Saltmarsh**	A2.5: Saltmarsh	3	2.8	2.01	0.6	0
Marine	**Intertidal reef**	A1: Littoral rock and other hard substrata	1	11.31	10.42		5.79
	Subtidal reef	A3: Infralittoral rock and other hard substrata	1	16.61	12.51		5.32
		A4: Circalittoral rock and other hard substrata	1	875.9	180.76	147.5	418.3
	Intertidal sediments	A2.1 Littoral Coarse sediment	3	0.76	0.61		0.02
		A2.2: Littoral sand and muddy sand	3	14.99	14.56		9.61
		A2.3: Littoral mud	3	9.98	4.27		0.32
		A2.4: Littoral mixed sediment	3	0.45	0.33		0.05
	Biogenic reef	A2.7: Littoral biogenic reefs	2	0.01	0.01		0.01
	Subtidal sediment	A5.1: Sublittoral coarse sediment	3	2845.22	175.73	119.95	742.121
		A5.2: Sublittoral sand	3	1690.03	52.81	47.19	1305.05
		A5.3: Sublittoral mud	3	10.85	0.21		7.08
		A5.4: Sublittoral mixed sediments	3	48.56	2.04		35.63
Total extent all habitats providing moderate or significant contribution to the ES				46.17	39.51	0.14	20.726

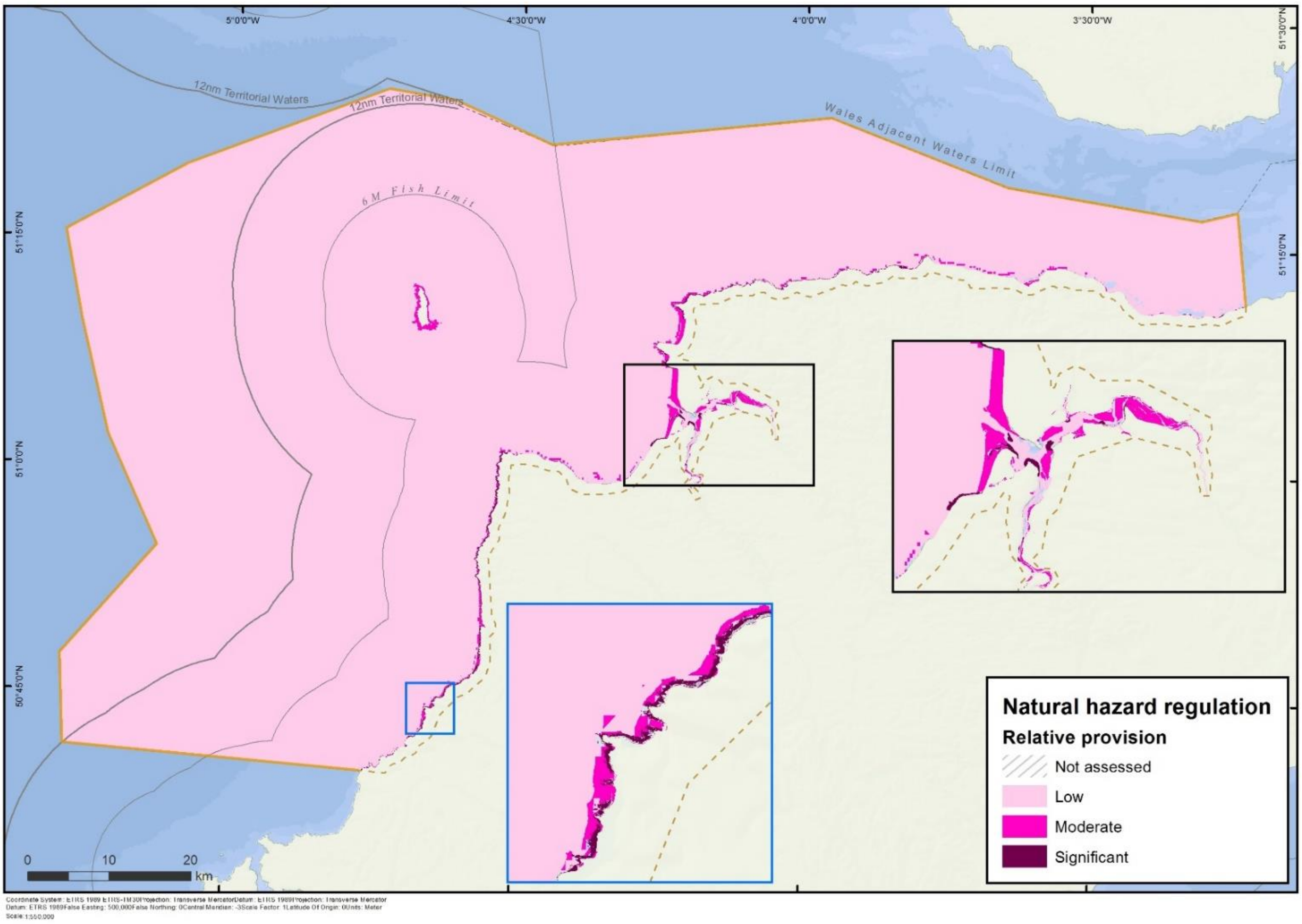


Figure 17 Map of contribution of NDMP habitats to ES benefit 'Sea Defence' (in relation to the 'intermediate' ES 'natural hazard regulation').

Although existing man-made sea defences were assessed by the Environment Agency (2011) to present a viable benefit for over 1200 properties (in 2011) in Taw Torridge estuary, there is increasing input of public money to maintain them, and benefits were predicted to be limited under future sea level rise predictions (Environment Agency, 2011). Sea defence ES benefits from habitat assets (relating to coastal and tidal flooding) provide a more cost effective long term solution, as habitats such as saltmarsh naturally migrate in response to changing sea levels.

Protection due to natural habitats (in 2011 extent and condition) from tidal flooding during a 1 in 200 probability tidal event in Taw Torridge estuary was assessed to still result in 1,517 properties (1271 residential) being at risk of tidal flooding (Environment Agency 2011). Man – made flood defences installed in the estuary were assessed to reduce the properties impacted during a 0.5% AEP (1 in 200 probability) tidal event in Taw Torridge estuary to 57 (of which 52 are residential) (Environment Agency 2011). Although habitat loss was not a key concern in 2011, it was predicted to become an issue in the future, as there will be insufficient sediment accretion to keep pace with rising water levels due to sea level rise (Environment Agency 2011). Risks were identified under sea level rise predictions, whereby, coastal squeeze would occur due to fixed sea defences becoming ineffective but also preventing the natural migration of saltmarsh inland. Assessing the current and future benefits provided by habitats, particularly extent and condition of salt marsh and intertidal (littoral) habitats will be extremely important in ensuring sea defence benefits from natural assets under future sea level conditions are maintained.

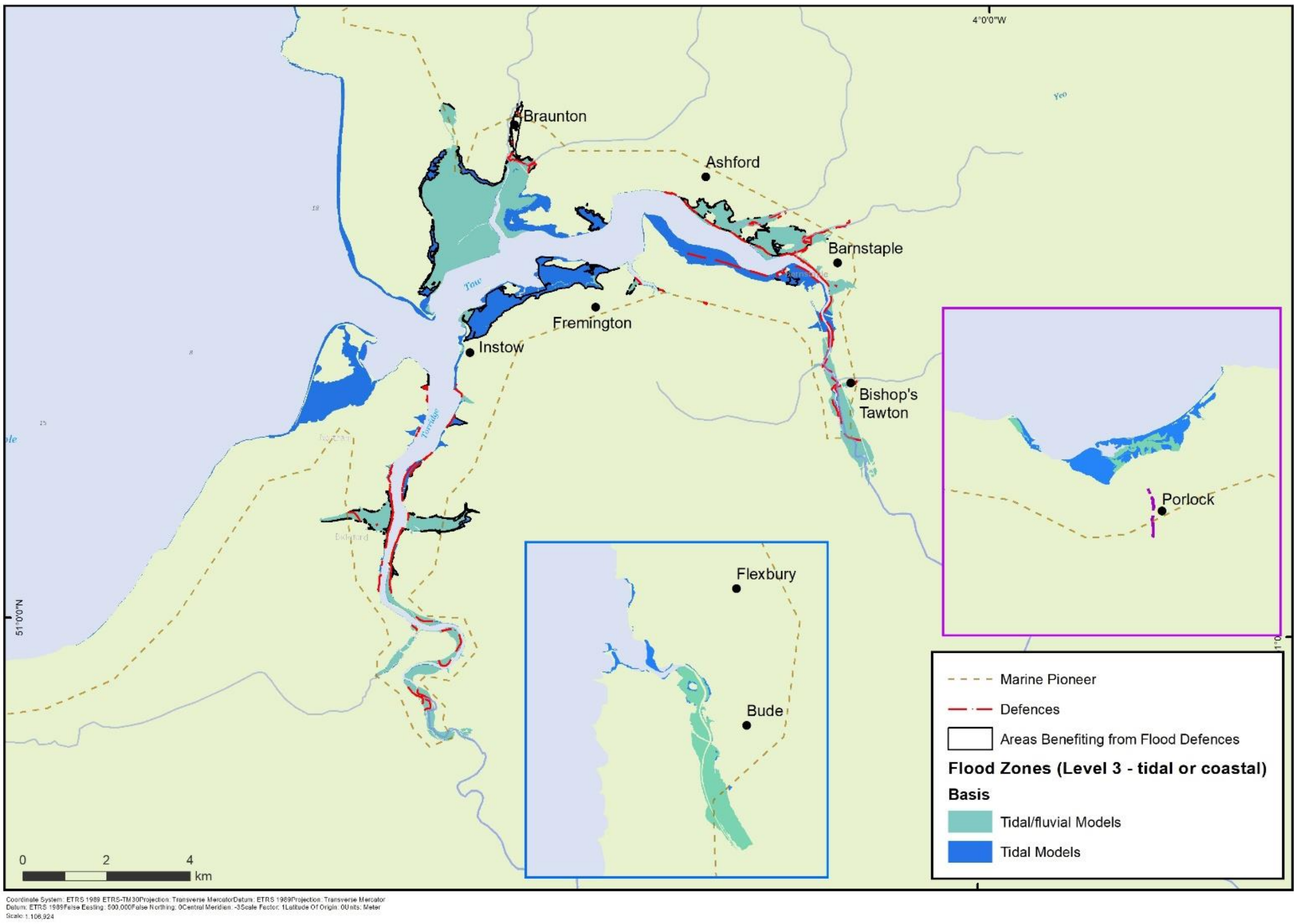


Figure 18 Map of flood zones 2 and 3 (all zone 2 is category 3 also in NDMP), areas with coastal defences and areas benefitting from coastal defences

4.3.2 Condition: Area of each habitat providing moderate or significant contribution to the ES of ES Natural Hazard Regulation within MPAs with conservation objective to maintain or recover

Of the total extent of habitat in NDMP providing moderate or significant contribution to ES benefit Sea Defence (46.17km²) 39.51 km² are within an MPA, and 0.6 km² within MPAs have a condition assessment of 'recover' (Table 21Table 9littoral rock and littoral sediments and biogenic reefs that were assessed to provide a moderate to significant contribution to the ES benefit Sea Defence have a high proportion of the habitat contained within MPAs (Table 21. In 2012, 30% of saltmarsh extent within an MPA (Taw Torridge SSSI) was assessed as being in unfavourable condition. All other habitat extents that provide a moderate to significant contribution to the ES Sea Defence had conservation objectives of ‘maintain’. had conservation objectives of ‘maintain’.

Contribution to ES benefit Sea Defence from the saltmarsh habitat within NDMP is thereby, likely to be lower than it could potentially be. To be able to migrate as effectively as possible under future sea level conditions, to provide future benefits, entire extent of salt marsh in NDMP would be required to be in favourable condition.

4.3.3 Condition: Area of each habitat providing moderate or significant contribution to the ES of Natural Hazard Regulation and modelled relative ‘condition’

Of the total extent of habitat in NDMP providing moderate or significant contribution to ES Sea Defence (46.17 km^2) 6.66 km^2 are outside an MPA (Table 21Table 19Table 9). Saltmarsh, littoral rock and littoral sediments that were assessed to provide a moderate to significant contribution to the ES benefit Sea Defence are unlikely to interact with demersal fishing activity. Therefore, calculation of LRC based on pressures associated with this activity should be treated with caution. 5.79km^2 of littoral rock extent, 0.01km^2 of biogenic reef, 9.67 km^2 of littoral sand and muddy sand, 0.02 km^2 coarse sediment and 0.05 km^2 of mixed sediment extents were assessed to interact with demersal fishing activity. It is likely that this is due to the coarse spatial resolution of fishing activity data sets available for assessment and research. Other activities such as bait digging, launching and retrieving recreation vessels and anchoring and mooring of small recreation craft are more likely to cause the pressure abrasion and impact ES provision form these habitats.

4.3.4 Ecosystem Service Flows and Benefits: Area of coastal land at risk from flooding and the value of property interacting with high flood risk areas

4.3.4.1 Area of coastal land at risk

Population of the coastal belt overlapped by NDMP is 85176 (Table 23). Environment Agency flood risk maps provide modelled data on flooding from fluvial events (from rivers), tidal events (from sea/estuary) and coastal event models as well as combined fluvial and tidal events (Environment Agency, 2018e) (Figure 18). Extent of coastal land at risk from flooding (within modelled flood risk zone 2 (medium) or zone 3 (high) in 2018 from tidal events, coastal events and combined fluvial and tidal events was 49.47km^2 (Environment Agency, 2018e) (Table 23).

Flood models principally assess hydrodynamic response to land elevation, water volume, water storage (area and depth) and drainage capacities of water bodies to calculate flood extents/risk (Teng *et al.*, 2017). It is, therefore challenging to separate contribution of specific habitats/assets to the results of models used to assess flood risk. Without detailed modelling of contribution of flood prevention benefits of NDMP habitats (water storage of habitats, and hydrodynamic responses due to attenuation of currents or wave actions due to vegetation), a specific number of population, properties and area of land benefitting from flood protection provided by habitats can not be provided.

Projects are currently underway as part of the SWEEP project to address this. Contribution of beach profile, slope and substratum grain size to protection from coastal storms and tidal flooding has been modelled to provide an early warning system for coastal storm impacts (Dr Christopher Stokes, University of Plymouth, personal communication, June 2018).

4.3.4.2 Value of property interacting with high flood risk areas

To assess baseline economic risk from flooding in NDMP, the number of residential properties in medium or high flood risk zones (flood risk zones 2 and 3) in the NDMP were assessed for postcode districts intersecting the NDMP coastal belt (Figure 19,

). The National Flood Risk Assessment, Risk of Flooding from Rivers and Sea database, was used to calculate the number of properties in post code districts in flood zone 2 or 3, that intersect with NDMP coastal belt (Environment Agency, 2018f). It is recognised that the Risk of Flooding from Rivers and Sea database returns an overestimate of properties affected: (i) because the post code districts also identify properties inland of the NDMP coastal belt and, (ii) because the database does not separate flood risk zones that are modelled from fluvial data and those that are modelled from tidal/coastal data.

However, as an indicator metric it can be used at different spatial scales (for instance around an area of habitat creation or loss) to assess change in number of properties at risk in: i) postcode area, ii) postcode area + districts II) postcode areas + districts + sectors, following the intervention (Davis et al., 2018).

Total number of residential properties in medium or high flood risk zones (flood risk zones 2 and 3) in the NDMP coastal belt in 2018 was 4532 (Table 22). Total of mean values of residential property in NDMP coastal belt, that are within flood risk zone 2 or 3 (medium or high risk of flooding) in 2018 was £694,033,905.00 (Table 19). Individual property values range from £146,479.00-£336,500.00 (Table 22 and Table 23). The analysis is limited to assessing interaction with all flood models including fluvial models, fluvial/tidal models and tidal models, therefore results in Table 22 are an over estimate of properties affected by just coastal and tidal flood events alone.

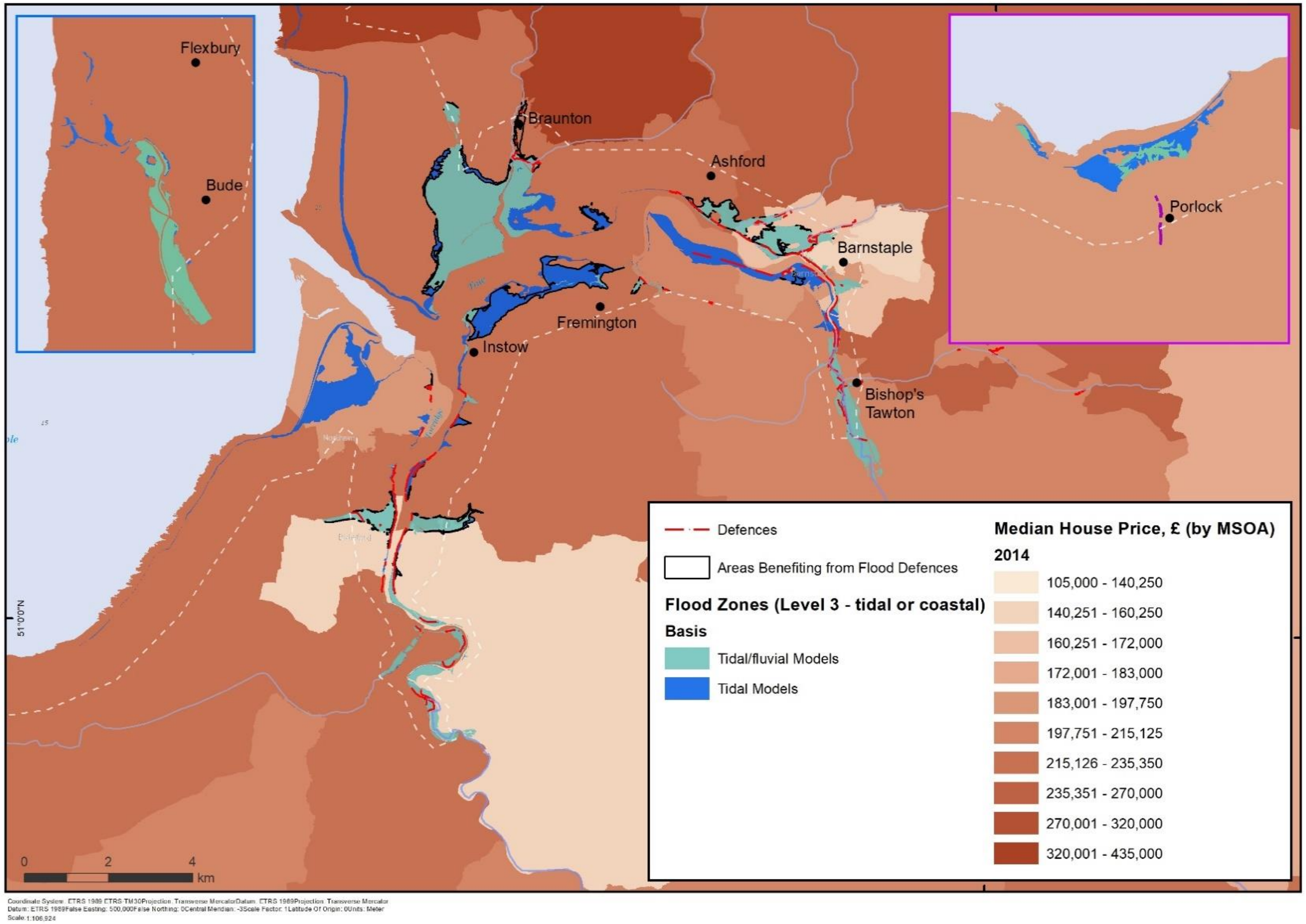


Figure 19 Map of property values median by MSOA (within Local Authority Areas) and extent of overlap with flood zones 2 and 3. White dotted line is the NDMP boundary.

Table 22 Value of properties within post codes (sorting office areas) interacting with flood risk zones within NDMP coastal belt (total value = average house price within LAA multiplied by No. of properties within post code area).

Local Authority	Average House Price £ (2018)	Post code	Number of residential properties in flood zone 2	Number of residential properties in flood zone 3	Total number of residential property in flood zone 2+3	Total value of residential property in flood zones (medium to high flood risk)
Cornwall	234,128	PL35	57	1	58	13579424
		EX23	205	38	243	£55,201,338.00
Torridge	227,166	EX39	426	141	567	£128,803,122.00
North Devon	214,647	EX31	251	67	318	£68,257,746.00
		EX32	290	295	585	£125,568,495.00
		EX33	489	69	558	£119,773,026.00
		EX34	146	698	844	£181,162,068.00
West Somerset	234,894	EX35	9	56	65	£15,268,110.00
		TA24	1080	87	1167	£1,260,360.00
		TA23	100	27	127	£12,700.00
TOTAL						£694,033,905.00

Assessment of sea defence ES benefits from habitat assets as well as drainage and hydromorphological characteristics of environmental features and separating benefits based on existing flood risk models is challenging. Greater understanding (modelling) of land area, properties, businesses and infrastructure protected from flooding by habitat assets in NDMP is required to confidently assess flow of benefits from natural assets.

Davis et al. (2018) have also applied natural capital assessment approaches to identify benefits that new saltmarsh provides to society, relative to the costs of removing land from its current use, including property damage from realignment and flood prevention benefits. Understanding how flood risk is affected (either increased or decreased) in properties neighbouring candidate realignment sites (due to change in land use to increase saltmarsh extent) is also identified by Davis *et al.* (2018) as an important area for further research (Davis *et al.*, 2018).

Table 23 Flow of benefit 'Sea defence' from natural assets to physical and economic benefits

Natural Capital Asset	**Indicator**	**ES Flow - Benefit** (2017)	**Trend** (2010-2017)
Habitats reviewed to provide significant or moderate contribution to the Benefit 'Natural Hazard Regulation (sea defence).'	**Habitats** reviewed to provide significant or moderate contribution to the Benefit 'Sea Defence' (km²)	5505.23 km²	↔
	Area of coastal land at risk of flooding (area in flood risk 2 and 3 (medium and high)	25.62 km² (Zone2) 23.85 km² (Zone 3)	
	Area of high quality agricultural land (grade 1,2,3a) that overlaps with flood risk zone 2 or 3 in NDMP coastal belt	0.39 km²	
	Value of high quality agricultural land (grade 1,2,3a) that overlaps with flood risk zone 2 or 3 in NDMP coastal belt	£867,600	
	Number of people that live in the coastal belt overlapped by NDMP	85176	
	Total value of property interacting with medium to high flood risk areas in post code sectors interacting with NDMP. (based on average property value for the Local Authority Area and number of properties in post code sector).	£694,033,905.33	

4.3.5 Ecosystem Service Flows and Benefits: Area and value of high quality agricultural land that overlaps with flood risk zone

Extent of high quality agricultural land (grade 1 to 3a) interacting with medium and high risk flood zones in NDMP in 2018 was 0.39km² (Environment Agency, 2018e). Following methods of Davis *et al.* (2018) we multiplied the extent of land (grade 1 to 3a) interacting with medium and high risk flood zones in NDMP in 2018 by sale price data specific to the land grade (using 2018 review of land prices for prime arable land of £9,000 per acre (Savills, 2018). As 0.39 km² relates to 96.4 acres, the value of high quality agricultural land in NDMP, interacting with medium to high risk flood zones was calculated to be £867,600.

4.3.6 Key points on the ES of Natural Hazard Regulation (Flood prevention/Sea defence)

Marine habitats play a valuable role in the defence of coastal regions. The physical structures dampen wave energy from tidal surges, storms (e.g. reefs). The floodwater storage and attenuation of water currents and wave energy provided by habitats such as saltmarsh also delivers significant benefits to natural hazard regulation. Sediment habitats also dissipate wave energy, thus reducing the risk of damaging coastal defences and flooding low-lying land.

Intertidal habitats not only provide sea defence ES benefits in relation to present sea level (and sea conditions), but unlike man made defences, natural intertidal habitats such as saltmarsh will migrate with rising sea levels, predicted under future climate scenarios.

The physical barrier provided by intertidal rock habitats and the dampening of wave energy of intertidal soft substratum (beaches and mud flats) and water storage benefits of saltmarsh are well documented (Ashley, Rees & Cameron, 2018). Models, applied to specific properties of NDMP intertidal habitats, such as, grain size, slope, water storage and effect of vegetation on attenuation of water currents would increase the accuracy of future assessment. Current assessment is limited as fluvial and tidal models used to assess flood risk focus on hydro-morphology rather than habitat characteristics.

Salt marsh, intertidal sand and coarse sediment (beaches), in particular, support multiple ES benefits in addition to sea defence including food and recreation. Restoring extents of saltmarsh in unfavourable condition and maintaining habitat extents of saltmarsh and intertidal sand and coarse sediment habitats will ensure ES provision is maximised. Habitats with structure and function in favourable condition will adapt (migrate) to sea level rise and continue to provide sea defence benefits under future scenarios.

4.4 Clean Water and Sediments

A significant amount of human waste is released into the oceans comprising of both organic (oil and sewerage) as well as inorganic (chemical) pollution. Marine habitats and species have a role in ecosystem processes that deliver the benefits of clean water and sediments. The following indicator metrics have been sourced to define the link between the natural capital assets and the flows of ecosystem services.

Extent (Habitat)

- Area of habitats providing moderate or significant contribution to the ES of clean water and sediments

Condition (Habitat)

- Area of each habitat providing moderate or significant contribution to the ES clean water and sediments within MPAs with conservation objective to maintain or recover
- Area of each habitat providing moderate or significant contribution to the ES of clean water and sediments and modelled relative ‘condition’

Ecosystem Service Flows and Benefits: Condition (Water body)

- The condition of water body assets (WFD and MSFD targets, Bathing water quality, Shell fish water quality).These indicator metrics are reviewed in full in Section 3

4.4.1 Extent: Area of habitats providing moderate or significant contribution to the ES of clean water and sediments

Saltmarsh habitats, littoral mud and subtidal soft substratum habitats provide moderate to significant contribution to the ES benefit clean water and sediments. Within NDMP, these habitats cover a combined extent of 4607.45 km² (Table 24). The large extent of sublittoral coarse and sublittoral sand sediment habitat, which provides a moderate contribution to the ES benefit clean water and sediments, is responsible for the large overall extent (sublittoral coarse sediment, 2845 km² and sublittoral sand 1690 km²) of habitat contributing to this ES benefit (Table 24).

Data were not present to plot or statistically analyse trends. However, the total extent of habitats providing a moderate or significant contribution to the ES benefit of clean water and sediments are not known to have changed within NDMP over the course of data collection (although a small increase in extent of saltmarsh extent is recorded in 2012 condition assessments of Taw Torridge estuary SSSI (Natural England, 2012)). It is important to consider that confidence in habitat extent calculations is low as large areas of sublittoral sediment extents were based on modelled data.

Table 24 Habitat assets providing a moderate or significant contribution to provision of ES benefit Clean Water and sediments including the extent within NDMP, within MPAs and extent with condition 'recover' in MPAs or with a modelled LRC of moderate or below.

	Natural Capital Asset: Habitats in North Devon Marine Pioneer		**Level of contribution to delivery of ES 'Clean water and sediments'**	**Area of habitats (km²) providing moderate or significant contribution to ES good/benefit food (Clean water and sediments)**	**Area within an MPA**	**Area with condition recover**	Area within NDMP with modelled relative condition within categories ≤ 3 for interaction with abrasion
Coastal margins	**Saltmarsh**	A2.5: Saltmarsh	3	2.8	2.01	0.6	0
Marine	**Intertidal reef**	A1: Littoral rock and other hard substrata		11.31	10.42		5.79
	Subtidal reef	A3: Infralittoral rock and other hard substrata		16.61	12.51		5.32
		A4: Circalittoral rock and other hard substrata		875.9	180.76	147.5	418.3
	Intertidal sediments	A2.1 Littoral Coarse sediment		0.76	0.61		0.02
		A2.2: Littoral sand and muddy sand		14.99	14.56		9.61
		A2.3: Littoral mud	3	9.98	4.27		0.32
		A2.4: Littoral mixed sediment		0.45	0.33		0.05
	Biogenic reef	A2.7: Littoral biogenic reefs	2	0.01	0.01		0.01
	Subtidal sediment	A5.1: Sublittoral coarse sediment	3	2845.22	175.73	119.95	742.121
		A5.2: Sublittoral sand	3	1690.03	52.81	47.19	1305.05
		A5.3: Sublittoral mud	3	10.85	0.21		7.08
		A5.4: Sublittoral mixed sediments	3	48.56	2.04		35.63
Total extent all habitats providing moderate or significant contribution to the ES				4607.45	237.08	167.28	2090.2053

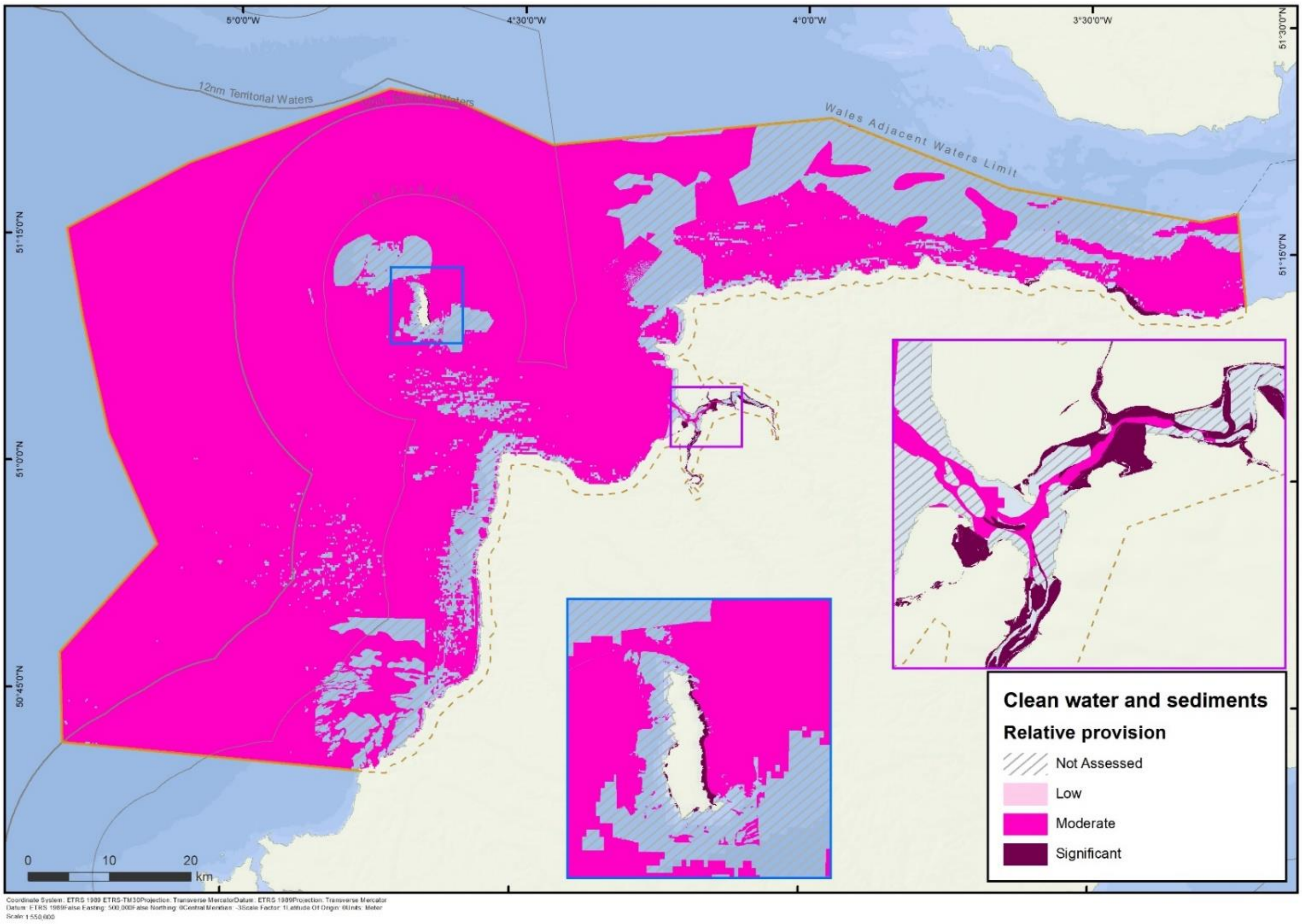


Figure 20 Map of contribution of NDMP habitats to ES benefit 'Clean Water and Sediments'.

4.4.2 Condition: Area of each habitat providing moderate or significant contribution to the ES of ES Clean Water and Sediments within MPAs with conservation objective to maintain or recover

Of the habitats providing a moderate or significant contribution to ES 'Clean water and sediments' only saltmarsh has a large proportion of the total extent within an MPA (72% within Taw Torridge Estuary SSSI). Of this extent 0.6 km² (30%) was in unfavourable condition in condition assessments in 2012 (Natural England, 2012). A moderate extent 4.27 km² (43%) of littoral mud habitat is within an MPA and has a conservation objective or recover. Although 100% of biogenic reef habitat is within an MPA, with a conservation objective of maintain, the total extent of this habitat is very low (below 0.01 km²) (Table 24). Overall contribution to the ES benefit from biogenic reef habitat within NDMP is, thereby, likely to be low in comparison to other habitats. ES provision from these habitats is limited by the moderate to large proportions with conservation objectives of 'recover'.

Sublittoral coarse sediment and sublittoral sand habitats cover huge extents of NDMP. Although extents of these habitats in MPAs are large compared to any other habitats, the proportion of the extent in an MPA is very low (sublittoral coarse sediment 6%, sublittoral sand 3%) (Table 24). Almost the entire extent within an MPA has a conservation objective 'recover' suggesting the structure and function of the component habitats and communities are negatively impacted. This will limit ES provision as, the provision of the ES benefit 'clean water and sediments', relies on favourable structure and functioning of biological communities to aid biogeochemical cycling processes (e.g. role of macrofauna bioturbation in the degradation of organic matter) (Queirós *et al.*, 2013; Sturdivant & Shimizu, 2017).

4.4.3 Condition: Area of each habitat providing moderate or significant contribution to the ES of Natural Hazard Regulation and modelled relative 'condition'

Modelled relative condition, in relation to exposure to the pressure abrasion, associated with demersal fishing activity, indicates very large proportion of NDMP sublittoral soft substratum habitats are in an impacted condition (LRC ≤3) (Table 24). As with extents of habitats in MPAs with conservation objectives of 'recover', the biological communities in habitats with moderate or worse modelled relative condition are likely to be impacted and, therefore, processes such as macrofauna bioturbation also limited. As very large extents of sublittoral sediment habitats were assessed to be in LRC of 1 to 3 (2090 km^2), provision of the ES benefit 'clean water and sediments' is severely limited in NDMP. Confidence in LRC calculations in offshore areas is impeded by the data on interaction of habitats with the pressure abrasion (from demersal fishing activity) being limited to historical data. The resilience (recovery time) of species communities within the soft stratum habitats impacted needs to be considered in relation to data from 2008 up to the present day on spatial distribution and intensity of demersal fishing activity, anchoring and mooring to confidently assess LRC.

4.4.4 Ecosystem Service Flows and Benefits: The condition of water body assets (WFD and MSFD targets, bathing water quality, shellfish water quality).

Biological processes performed within NDMP habitats enable provision of moderate to significant contribution to the ES benefit 'clean water and sediments'. The biological processes also contribute to estuarine and coastal water bodies achieving ecological water body status WFD targets (Section 3). Without efficient degradation of organic matter, bathing water quality and shellfish water quality would also be impaired.

It must also be acknowledged that estuarine and coastal water body status and water quality are also related to direct impacts of human activities such as increased nutrients from sewage or agricultural run-off. Without the biological processes provided by habitats within NDMP, no water body would achieve good or higher condition and bathing water would not meet 'satisfactory' or above classification targets. The need to improve and maintain condition of water body assets in NDMP (3 in moderate condition (fail), and 4 in good or high classification in 2015), and bathing water quality in designated bathing waters in NDMP (3 classified as poor, 18 classified as satisfactory or higher in 2017/18), relies, in part, on maximising contribution of habitats to the ES benefit clean water and sediments.

As water quality is vital to enabling participation in marine based recreational activities, reduction in clean water and sediment ES benefits are also likely to impact economic benefits to local communities from visiting water sport enthusiasts. Health impacts are also likely for local and visiting participants. Wildlife watching and recreational fishing will also be impacted if water quality can not support species of interest.

4.4.5 Key points on the ES of Clean Water and Sediments

Marine living organisms store, bury and transform waste though assimilation and chemical decomposition and re-composition. 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. 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; Sturdivant & Shimizu, 2017).

Habitats with a moderate contribution of provision to ES clean water and sediments cover a huge proportion of NDMP. A very large proportion of these sublittoral soft substratum habitats are also either in conservation objectives of 'recover' (in coastal MCZs), or received a modelled likely relative condition of moderate or below. The provision of ES benefit clean water and sediments is likely to be highly limited in NDMP due to pressures related to historical activities. The moderate proportion of saltmarsh habitat in unfavourable condition is also likely to impact provision of ES benefit.

In an impacted state, these habitats reduce resistance and resilience of NDMP as a whole, to absorb and recover from anthropogenic pressures such as input of excess nutrients through agriculture or sewage. Management is required to address water quality issues, and support processes enabling maintenance of water quality, to enable long-term benefits from NDMP, and to support economic and health benefits to local populations and visitors. Reduction in water quality and ecological status of water body assets would impact levels of participation in recreational activities, and so related economic benefits to the local community and health benefits to participants.

4.5 Tourism and Recreation

Marine Natural Capital Assets provide the basis for a wide range of tourism and recreational activities. Examples from the Monitor of Engagement with the Natural Environment (MENE) survey include: watersports, wildlife watching, fishing, appreciating scenery (e.g. from a viewpoint), swimming outdoors, visits to a beach (sunbathing or paddling in the sea), walking with a dog or without a dog (e.g. walking the coast path) (Natural England, 2018). The following indicator metrics have been sourced to define the link between the natural capital assets and the flows of ecosystem services.

Extent (Habitat)

- Area of habitats providing moderate or significant contribution to the ES of Tourism and Recreation
- Extent of water bodies and features supporting tourism and recreation activities

Condition (Habitat)

- Area of each habitat providing moderate or significant contribution to the ES of Tourism and Recreation within MPAs with conservation objective to maintain or recover
- Area of each habitat providing moderate or significant contribution to the ES of Tourism and Recreation and modelled relative ‘condition’

Condition (Water body)

- The condition of water body assets (WFD and MSFD targets, Bathing water quality, Shell fish water quality). See Section 3
- Bathing water quality

Condition: (Species)

- Fish Stocks: Advised Total Allowable Catch

Ecosystem Service Flows and Benefits

- Length of accessible coast path
- Number of designated bathing waters
- Number of surfing beaches suitable for all ability levels
- Visitor numbers and Overnight Stays
- Monitor of Engagement with the Natural Environment data and modelling by ORVAL

- Number of North Devon Residents undertaking recreation (watersports) activities
- Spend of North Devon residents undertaking recreation watersports activity

4.5.1 Extent (Habitat): Area of habitats providing moderate or significant contribution to the ES of Tourism and Recreation

Saltmarsh (in relation to coastal access points, nature watching, aesthetic interest and supporting species of interest to recreational fishing and foraging) and littoral sand, coarse and mixed sediments (in relation to beaches and coastal access points) were reviewed to provide significant contributions to the provision of the ES of Tourism and Recreation (Table 25, Figure 21). Saltmarsh habitats cover a smaller extent (2.8 km^2) while littoral sand, coarse and mixed sediments provide a greater accessible area for tourism and recreation activities (16.2 km^2).

Table 25 Habitat assets providing a moderate or significant contribution to provision of ES benefit Tourism and Recreation including the extent within NDMP, within MPAs and extent with condition 'recover' in MPAs or with a modelled LRC of moderate or below.

	Natural Capital Asset: Habitats in North Devon Marine Pioneer		**Level of contribution to delivery of ES 'Tourism (incl. nature watching and recreation)'**	**Area of habitats (km²) providing moderate or significant contribution to ES good/benefit food (wild food)**	**Area within an MPA**	Area within MPA with condition recover	Area within NDMP with modelled relative condition within categories ≤ 3 for interaction with abrasion
Coastal margins	**Saltmarsh**	A2.5: Saltmarsh	3	2.8	2.01	0.14	0
Marine	**Intertidal reef**	A1: Littoral rock and other hard substrata	1	11.31	10.42		5.79
	Subtidal reef	A3: Infralittoral rock and other hard substrata	1	16.61	12.51		5.32
		A4: Circalittoral rock and other hard substrata	1	875.9	180.76	147.5	418.3
	Intertidal sediments	A2.1 Littoral Coarse sediment	1	0.76	0.61		0.02
		A2.2: Littoral sand and muddy sand	1	14.99	14.56		9.61
		A2.3: Littoral mud	1	9.98	4.27		0.32
		A2.4: Littoral mixed sediment	1	0.45	0.33		0.05
	Biogenic reef	A2.7: Littoral biogenic reefs	1	0.01	0.01		0.01
	Subtidal sediment	A5.1: Sublittoral coarse sediment		2845.22	175.73	119.95	742.121
		A5.2: Sublittoral sand		1690.03	52.81	47.19	1305.05
		A5.3: Sublittoral mud		10.85	0.21		7.08
		A5.4: Sublittoral mixed sediments		48.56	2.04		35.63
Total extent all habitats providing moderate or significant contribution to the ES				911.51	210.78	147.64	433.30

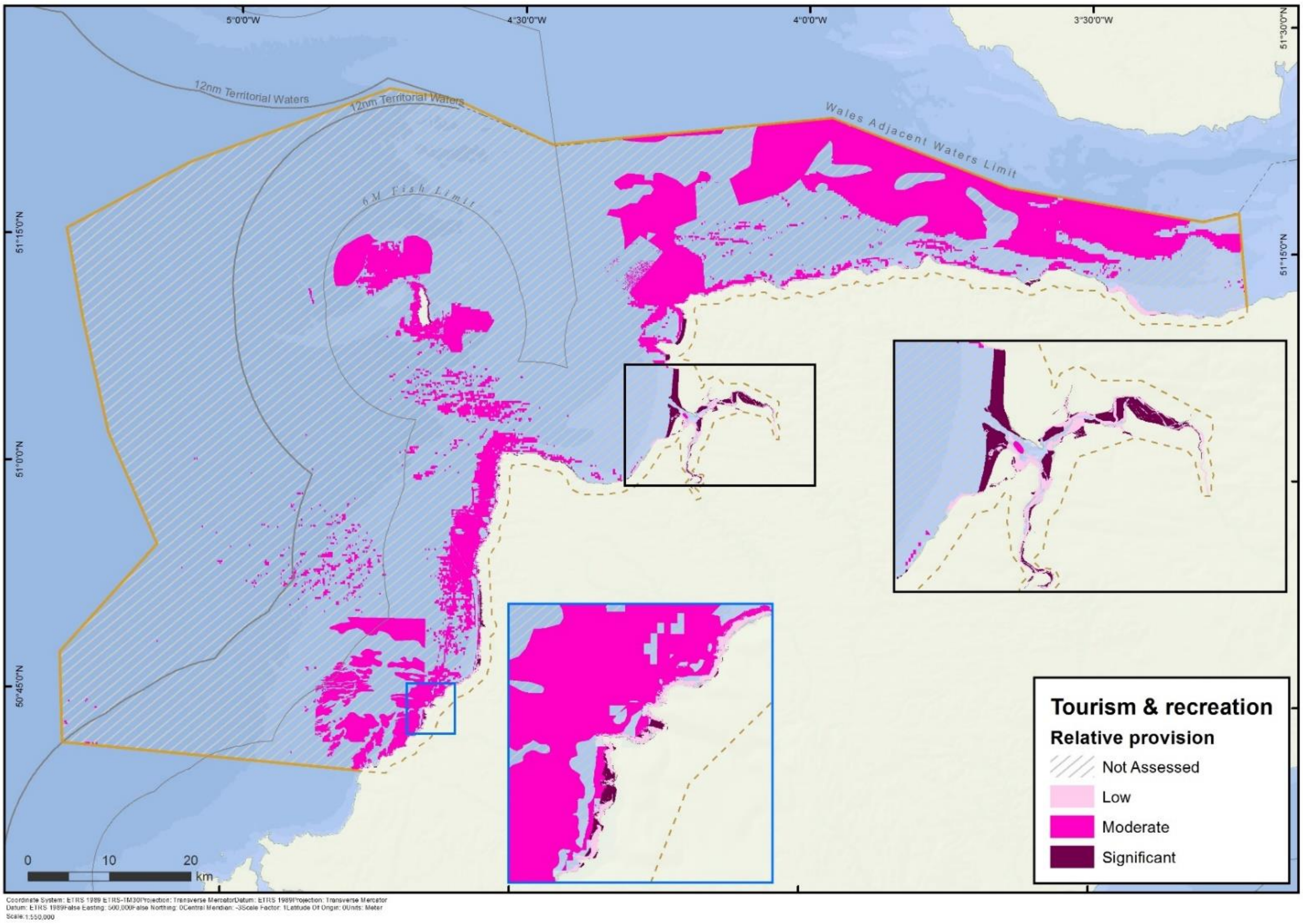


Figure 21 Map of contribution of NDMP habitats to ES benefit 'Tourism and Recreation'.

Infralittoral and circalittoral rock habitats were reviewed to provide a moderate contribution to the provision of the ES Tourism and Recreation. These subtidal rock habitats extend over a large area of NDMP (16.61 km² and 875.9 km²) providing a significant resource for specific recreation activities (angling and snorkelling/diving), as well as providing habitat for species of interest to wildlife watching such as the Atlantic grey seal *Halichoerus grypus* (Table 25, Figure 21). Extent of saltmarsh was reported to have increased over a small area in Taw Torridge Estuary SSSI in the most recent monitoring report (Natural England, 2012). No change in extent of habitats in Lundy SAC has been reported in most recent monitoring of designated features at the site (Natural England, 2017). As MCZs protecting littoral sediments and subtidal rock habitats have only recently been designated (2016) there were no historical records to assess trend at the time of writing.

4.5.2 Extent: Water bodies supporting tourism and recreation activities.

The water column of the outer Bristol Channel and eastern Celtic Sea interacts with almost the entire extent of NDMP. Within NDMP there are 6 estuarine and coastal water bodies. The ~200km of coastline is accessible through the South West Coast Path. Although not all beaches and coves can be accessed from land due to steep cliffs, NDMP contains 21 designated bathing waters.

4.5.3 Condition (Habitat): Area of each habitat providing moderate or significant contribution to the ES of Tourism and Recreation within MPAs with conservation objective to maintain or recover

Over 70% of the extent of saltmarsh habitat in NDMP is within a designated site (Taw Torridge Estuary SSSI), in the most recent available assessment (2012) 0.14 km² of 2.01 km² was assessed as to be in unfavourable condition due to grazing pressure (Natural England, 2012). A larger proportion of infralittoral rock habitat is within an MPA (75%) compared to the deeper circalittoral rock habitat (21%) (Table 25). All infralittoral reef habitat within MPAs in NDMP was assessed to be in favourable condition, while 147.5 km² was assessed to require a conservation objective of 'recover' (Table 25). A high proportion of the extent of littoral sand, coarse and mixed sediments within NDMP is contained within designated MPAs (>70% for each habitat feature) and assessed to be in favourable condition (Table 25). The high proportion of circalittoral rock habitat within MPAs, assessed to require a conservation objective of 'recover' (82%), is likely to be limiting the provision of benefits to recreational anglers, divers and wildlife watching benefits in relation to the potential of NDMP.

4.5.4 Condition (Habitat): Area of each habitat providing moderate or significant contribution to the ES of Tourism and Recreation and modelled relative 'condition'

Modelled relative condition (in relation to the pressure 'abrasion') provides a proxy for assessing condition of habitats in relation to impact on the reviewed level of provision of ES goods/benefits. Across the entire extent of circalittoral rock habitat within NDMP (875.9 km²), 418.3 km² (48%) was assessed to likely be in moderate or lower condition, due to historical interaction with activities causing the pressure 'abrasion' (Table 25). As with habitat extent within MPAs, the historical impact to condition of circalittoral reef is likely to negatively affect the level of contribution of the impacted area of habitat to provision of tourism and recreation ES benefits (such as, wildlife watching, recreational fishing and diving).

4.5.5 Condition water bodies: Water body status

The maintenance of high condition for water bodies within NDMP is essential to maximise tourism and recreation ES benefits (water body status, assessed in relation to WFD targets (Annex I)). Condition of water body assets in NDMP are assessed in Section 3.2.2. The failure of 3 of the 7 water bodies within NDMP to receive an overall classification above 'moderate' (failure to meet minimum WFD target) was due to ecological status failing to meet 'good' or 'high' target levels in the most recent assessment (2015). The Taw/Torridge Estuary waterbody was impacted due to the River Taw, from Newbridge to the mouth of the Taw Estuary being designated as a Nitrate Vulnerable Zone (NVZ) for the purpose of the Nitrate Pollution Prevention Regulations 2015 (Environment Agency, 2016). The Taw Estuary is also classified as moderate with respect to phytoplankton. The waterbodies to the eastern extent of NDMP, Bristol Channel Inner South and Bridgewater Bay also failed due to ecological status being classified as 'moderate'.

Failure to meet ecological status targets is likely to impact potential level of contribution of natural assets to provision of tourism and recreation ES benefits. High nitrate levels from freshwater sources increase the risk of eutrophication and occurrence of harmful plankton that impact species of interest to recreational fishing and foraging and also increases health risks to bathers. As identified in Section 3.2.2, monitoring of shellfish waters in Taw Torridge Estuary (outer estuary (Spratt Ridge East)) in 2018 identified harmful plankton to be above trigger levels on 6 occasions. Biotoxin monitoring of flesh from bivalve shellfish in the outer estuary (Spratt Ridge East) reported toxins were detected but clinical signs were observed to be below action level on 6 occasions (Food Standards Agency, 2018).

4.5.6 Condition water bodies: Bathing water quality

Bathing water quality supports the level of tourism and recreation ES benefit that can be provided in relation to the 21 designated bathing waters within NDMP (*Figure 3*). An increase was seen in 2017/18 in the total number of beaches receiving 'poor' bathing water classification (below WFD requirement), from 2 beaches in previous years to 3 in 2017/18 (

Table 26). For beaches with the classification 'poor' (Combe Martin, Ilfracombe Wildersmouth and Instow) (Table 26 (Figure *3*, Section 3.2.2)) bathing is not advised, due to greater health risks to bathers due to levels of bacterial or other pollution (Environment Agency, 2018d). This severely limits the provision of tourism and recreation ES benefits such as any in water activities at these locations. Three short-term pollution incidents (e.g. sewage contamination from overflowing drains, pollution from oil or fuel spillage) were recorded at separate designated bathing water beaches in 2017-2018 (Croyde Bay, Combe Martin and Bude Crooklets) limiting the provision of recreation and tourism ES benefits at these sites for shorter periods (hours to days).

Table 26 No. bathers per 100m (mean 2017 season) and Bathing Water Quality classification for beaches within and adjacent to NDMP. 0 = poor, 1 = satisfactory, 2 = good, 3 = excellent. Trend = increase ↑, decrease ↓ or no change ↔ between 2017/18 and mean of previous assessments 2014/15-2016/17. Pollution incidents are recorded as total over last 2 years.

Beach (Sample Point)	**Bathing Water Quality Classification**				**Trend**	**Pollution incidents 2017-2018**	**No. bathers per 100m, 2017 season (mean)**
	2015	**2016**	**2017**	**2018**			
Somerset beaches							
Blue Anchor West	2	2	2	2	↔	0	no data
Minehead Terminus	2	2	2	2	↔	0	no data
Porlock Weir	3	3	3	3	↔	0	no data
Devon beaches							
Lynmouth	3	3	3	3	↔	0	no data
Combe Martin	0	2	1	0	↓	1	4.91
Ilfracombe Hele Bay	1	2	2	2	↑	0	1.52
Ilfracombe Tunnels Beach	3	3	3	3	↔	0	4.4
Ilfracombe Wildersmouth	0	0	0	0	↔	0	0.73
Woolacombe - Barricane Bay	3	3	3	3	↔	0	5
Woolacombe Village	3	3	3	3	↔	0	24.55
Putsborough	3	3	3	3	↔	0	14.75
Croyde Bay	2	2	2	2	↔	1	35.45
Saunton Sands	3	3	3	3	↔	0	25
Westward Ho!	3	3	3	3	↔	0	15.65
Instow	0	0	0	0	↔	0	1.15
Hartland Quay	3	3	3	3	↔	0	0.55
Cornwall beaches							
Bude Crooklets	2	2	2	2	↔	1	13.7
Bude Sandy Mouth	3	3	3	3	↔	0	11.15
Bude Summerleaze	2	2	3	2	↓	0	42.5
Widemouth Sand	3	3	3	3	↔	0	45
Crackington Haven	3	2	3	3	↑	0	9.2

4.5.7 Condition: (Species): Fish Stocks: Advised Total Allowable Catch

Fish stocks supporting commercial fisheries are also of interest to recreational anglers (Section 4.1). Healthy fish populations also provide wildlife watching interest to recreational divers and increase the quality of dive sites and diving experiences. CPUE (number per km^2) from UK Irish Sea and Bristol Channel Beam Trawl Survey samples displayed a negative trend between 2010-2017 for most species, apart from for Herring *C. harengus* and Thornback ray *R. clavata* (which displayed a positive trend in CPUE). Sole *S.solea* displayed a very weak negative trend and Blonde ray *R. brachyura* displayed no change in CPUE. The trends identified in CPUE were reflected in recommendations for TAC for the wider ICES Area VII f for all species apart from for Thornback ray *R. clavata* (which showed reduced TAC but increased CPUE in stock assessment samples in proximity to NDMP) and herring which showed increased CPUE but no change in recommended TAC. In respect to CPUE values the surveys were designed to assess sole *S.solea* and plaice *P.platessa* populations and confidence is low in assessments of other species. The decrease or no change observed in TAC for ICES area VII f suggests populations are currently fished at maximum sustainable yield or above, as stocks have not increased to support higher TAC.

4.5.8 Condition species: Environment Agency and Cefas Salmon and Seatrout Monitoring (Annual Catch Records)

Although recreational fishing for salmon and sea trout often takes place upstream of the NDMP these species are migratory and spend adult life stages on a migratory route into the northwest Atlantic to western Greenland (although some sea trout remain in freshwater habitats (brown trout) and may only move into seas if there are limited food resources). The hydromorphological, chemical and ecological status of the estuaries and rivers in NDMP are important in maintaining stocks (Table *5*). The Atlantic salmon *Salmo salar* is in Annexes II and V of the European Union's Habitats Directive as a species of European importance. Populations in many European rivers are at risk due to man-made barriers to movement, and deterioration in water quality due to urban expansion and changes in agricultural practices (Hendry & Cragg-Hine, 2003). Recreational fishing for salmon and sea trout has a long history, especially on the Taw and Torridge rivers (National Rivers Authority, 1995).

Since 2010 % of conservation limit (egg deposition levels) attained in salmon rivers in NDMP have shown very weak positive trends for Taw and Torridge rivers and a declining trend in the Lyn (Section 4.1.9, Table 14). Mean CPUE (rod fishing) has shown a 19% increase in the wider south west region in 2017 compared to the 5 year mean (2012-2016) (Environment Agency & Natural Resources Wales, 2017). For rivers (estuaries) within NDMP, CPUE (number per license day) for rod and line fishing for salmon has shown a weak positive trend in the Taw (2012-2016) (Kendall's tau-b =0.2, p=0.6), but weak or very weak negative trends in the Torridge and Lyn (Kendall's tau-b = -0.32, p=0.5, kendall's tau-b = -0.1, p=0.8 respectively) (Table 27). Salmon CPUE (number per licence day) is greatest in the Lyn (0.14 per license day), compared to the Taw and Torridge (0.09 and 0.06 per license day respectively) (Table 27). All salmon rivers supporting salmon stocks in NDMP are considered 'probably at risk' in relation to meeting management objectives (management objectives relate to meeting conservation limits (egg deposition) in 4 out of 5 years) (Section 4.1.9,Table 15).

Despite the weak positive trend in rod CPUE in the Taw, the 'probably at risk' status of salmon rivers in NDMP, suggests salmon stocks are not supporting the potential level of contribution to provision of the ES benefit tourism and recreation related to recreational fishing that is possible. Sea trout stocks appear healthier in the Taw and Torridge (with a positive trend in CPUE 2012-2016). With successful management (maintaining access to spawning grounds and water and habitat quality in rivers) continued positive trend in abundance will help contribute to recreational fishing benefits (Table 27).

Table 27 Mean CPUE (rod fishing) for salmon and sea trout in NDMP rivers/estuaries

Natural Capital: Flow from Assets to Physical Benefits	**Indicator**	**Species**	**Unit**	**Estuary / River**	**Baseline year 2016**	**Baseline Trend 2012-2016**	**Correlation coefficient (Kendall's tau-b)**	**Signifi-cance**
Species stocks supporting recreational fishing for salmon and sea trout	Environment Agency and Cefas salmon and sea trout monitoring (annual catch rods)	Salmon	*n* per license day	Taw	0.09	↑	0.2	0.624
			n per license day	Torridge	0.06	↓	-0.316	0.448
			n per license day	Lyn	0.14	↓(↔)	-0.105	0.801
		Sea trout	*n* per license day	Taw	0.19	↑	0.6	0.142
			n per license day	Torridge	0.23	↑	0.527	0.207
			n per license day	Lyn	0.06	↓	-0.6	0.142

4.5.9 Condition species: Fauna of interest to wildlife watching from land, sea or recreational snorkelling and diving.

Species protected as designated features of MPAs (including notified features of SSSIs) support provision of benefits to nature watching activities and residents and visitors' enjoyment of the natural environment in NDMP (Table 28).

Table 28 Species protected as designated features of MPAs

Natural Capital Asset	Indicator	Species	Baseline (2017 or closest year)	Trend
Species populations: Fauna of interest to wildlife watching	Population within NDMP (no. of individuals)	Grey seal *Halichoerus grypus*	Average 2006-2013 Lundy SSSI/SAC: 81 individuals	Population is stable (assessed in 2015)
		Kittiwake *Rissa tridactyla*	Lundy SSSI (no abundance data provided in condition assessment)	continued long-term decline
		Manx shearwater *Puffinus puffinus*	As above	Population expanding (2015 assessment)
		Puffin *Fratercula arctica*	As above	Population expanding (2015 assessment)
		Razorbill *Alca torda*	As above	Population expanding (2015 assessment)
		Guillemot *Uria aalge*	As above	Population expanding (2015 assessment)
		Spiny lobster *Palinurus elephas*	No data	Population in South West UK waters depleted
		Harbour porpoise *Phocoena phocoena*	Bristol Channel Approaches / Dynesfeydd Môr Hafren candidate SAC site supports approximately 2,147 individuals.	unknown

Grey seal *Halichoerus grypus* are a key attraction for wildlife watching activities in NDMP and are also a species of high interest to divers and snorkelers. Grey seal *Halichoerus grypus* are a notified feature of Lundy SSSI. The grey seal population was recorded as stable in the most recent condition assessment (2015) with ample evidence of continued successful breeding. Grey seal *Halichoerus grypus* are also a designated feature within Lundy SAC and the population is assessed to be stable with a conservation objective of maintain. Conservation advice for Lundy SAC records that whilst abundance in the site may vary spatially and temporally, the average number of seals counted per survey between 2006 and 2013 is 81 individuals (Natural England, 2017). The highest number of seals ever recorded in one survey at Lundy was 239 (Aug 2011) (Natural England, 2017).

Guillemot *Uria aalge,* Kittiwake *Rissa tridactyla,* Manx shearwater *Puffinus puffinus,* Puffin *Fratercula arctica,* Razorbill *Alca torda* are also notified features of Lundy SSSI and species of high interest to nature watching activities. Populations of all seabird species were assessed to be expanding in 2015, with the exception of Kittiwake, which was assessed to be following a continued long-term decline. Research suggests that the causes of this decline are likely to lie off-site, with weather conditions over both winter and summer implicated.

Spiny lobster *Palinurus elephas* is a designated feature of Lundy and Bideford to Foreland Point MCZs in NDMP and a species of interest to recreational divers and snorkelers. Data from current population assessments e.g. from surveys, are not provided in supplementary advice for the feature in conservation advice packages provided by Natural England (Natural England, 2017). The 'recover' conservation objective in all sites is based on evidence that spiny lobster is in unfavourable condition in all South West England waters as stocks are depleted (Goni & Latrouite, 2005). The recruitment and reproductive capability of spiny lobster within Lundy and Bideford to Foreland Point MCZs is therefore judged to be reduced and in need of recovery (Natural England, 2017). There is sightings evidence of an increase in the numbers of juvenile spiny lobster in the Southwest and particularly in the Lundy MCZ, indicating the possibility of recovery (S. Clark pers comment)

Tour operators advertise opportunities to site dolphins, porpoises and occasional basking sharks within NDMP (e.g. between Lundy and Ilfracombe). The harbour porpoise population within the Bristol Channel Approaches / Dynesfeydd Môr Hafren candidate SAC site, which overlaps with the western extent of NDMP, was identified as being within the top 10% of persistent high-density areas for harbour porpoise in UK waters for both winter and summer seasons (Heinanen & Skov, 2015). However, model confidence in summer was low. The site supports approximately 2,147 individuals (95% Confidence Interval: 810 – 5,693) for at least part of the year, as seasonal differences are likely to occur, and represents approximately 4.7% of the population within the UK part of the Celtic and Irish Seas management unit (JNCC, 2017).

NDMP contains nationally important harbour porpoise populations, sea bird and seal populations that provide features of interest to wildlife watching activities. The stable or increasing populations within Lundy SAC and SSSI and the wider NDMP (harbour porpoise) contribute significantly to the nature watching ES benefits provided in the region. Recovery of spiny lobster populations would further increase the occurrence of species of interest to divers and snorkelers.

4.5.10 Ecosystem Service Flows and Benefits: Number of sites supporting activities and length of accessible coast path

Natural assets including habitats, species stocks and estuarine and coastal water bodies within NDMP contribute to the provision of Tourism and recreation ES benefits. Multiple sites are accessed by people from the local community and visitors to NDMP for the activities identified in the Monitor of Engagement with the Natural Environment survey (Natural England, 2018). The number or extent of sites providing these opportunities were recorded to record sites where flow from natural assets to tourism and recreation benefits are possible and likely to occur. Watersports (e.g. surfing and diving) and recreational fishing sites were identified from guide books and also included sites identified by participants in North Devon Council's Watersports Survey (NDCC report 2018 in prep). Number of designated bathing waters in NDMP were recorded in relation to sites supporting swimming outdoors and visits to a beach (sunbathing or paddling in the sea). Length of accessible coast path was included as a very broad level indicator of accessible areas or sites where interaction with the NDMP environment is possible when walking. Length of accessible coast path and number of beaches also relates to opportunities for wildlife watching and appreciating scenery (e.g. from a viewpoint) (Table 29).

Table 29 Accessible sites where interaction with the NDMP environment is possible, including specific recreation activities

Natural Capital Asset	Indicator (sites enabling flow from asset – benefit)	Baseline (2017/18)	Trend or known change in *n* of sites
Habitats reviewed to provide moderate or significant contribution to ES benefit Tourism and Recreation. Species stocks supporting wildlife watching and recreational activities. Water Quality of water bodies accessed for recreation.	Number of fishing marks (regularly accessed and safe to access)	23	No known change
	Number of surfing locations (suitable for all levels)	14	No known change
	Number of diving locations (<40m recognised in local guides)	22	No known change
	Number of designated bathing waters	21	No known change
	Length of accessible coast path	all NDMP coast path sections accessible in 2017/18	Storm damage in 2014 at Inkerman Bridge (Woody Bay) and Mouth Mill (Clovelly) in North Devon repaired and access provided.

4.5.11 Ecosystem Service Flows and Benefits: Visitor numbers and Overnight Stays

Data on overall tourism visitors to NDMP were gathered from Visit England statistics for Local County Council regions (Table 30). These display a total number of overnight stays of 5,945,333 for North Devon, Torridge and West Somerset, and 4,317,333 overnight stays for just North Devon and Torridge in 2015-17 (Table 30).

There has been a small decrease since 2010-2012 in visitor overnight stays in North Devon, (from 6,848,000 in 2010-2012) however these data cover both the NDMP coastal region and all inland areas for local county council areas and therefore changes are difficult to attribute to the marine tourism and recreation opportunities. Cornwall Council region overlaps with NDMP, however figures are not presented for Cornwall as the extent outside the NDMP boundary is much larger. Therefore, only a very small proportion of the total figures are likely to relate to visits within NDMP. It is recognised that this limitation also exists, to a lesser extent for other County Council regions.

Table 30 Average values for total number of overnight stays in NDMP Local council areas, and total spend in council areas from Visit England statistics.

	Total nights 000s		
	Average values		
	2010-2012	**2013-2015**	**2015-2017**
West Somerset	1666	1601	1628
North Devon	3996	2896	2918
Torridge	1186	1337	1399
Total	**6848**	**5834**	**5945**

	Total average annual spend millions (£)		
	Average values (based on 3 year average)		
	2010-2012	**2013-2015**	**2015-2017**
West Somerset	76	95	98
North Devon	186	155	173
Torridge	61	64	77
Total	**323**	**314**	**348**

4.5.12 Ecosystem Service Flows and Benefits: Number of participants undertaking recreation (watersports) activities

4.5.12.1 Summary of region wide visits and activities in Devon and NDMP: The Monitor of Engagement with the Natural Environment (MENE) survey and data processed by the Outdoor Recreation Value Tool (ORVAL).

Analysis of data on coastal activities from Monitor of Engagement with the Natural Environment (MENE) survey, from the most recent baseline year available (March 2015-Feb 2016) identified the most popular activities undertaken in coastal resorts or towns in Devon were: visits to a beach (sunbathing or paddling in the sea) (87% of respondents) and watersports (54%) (Natural England, 2016b). For other seaside and seaside coastline areas (beaches and cliffs) the most popular activity was fishing (25%) (Table 31). Across Devon (coastal and inland) walking (with or without a dog), wildlife watching and appreciating scenery from a car were the most common activities undertaken as the main purpose of a visit to the natural environment (Natural England, 2016b).

Table 31 Analysis of data on coastal activities from Monitor of Engagement with the Natural Environment (MENE) survey, accessed through the online 'cross tabulation viewer' (Natural England, 2016b).

	Activities undertaken on visit (relating to NDMP recreation and wildlife watching in NDMP)							
Where participant spent most of their time on their visit to the outdoors in the natural environment, away from home (at the time of surveying)	**Fishing**	**Appreciating scenery from your car (e.g. a viewpoint)**	**Swimming outdoors**	**Visits to a beach (sunbathing or paddling in the sea)**	**Walking (not with a dog)- including short walks / rambling / hill walking**	**Walking (with a dog)- including short walks / rambling / hill walking**	**Water-sports**	**Wildlife watching**
Weighted base	286	1058	1172	4619	46877	103968	649	3048
In a seaside resort or town	150	357	137	4030	11955	9832	348	173
	30%	34%	12%	87%	26%	9%	54%	6%
Other seaside coastline (including beaches and cliffs)	125	53	154	401	3374	2674	0	371
	25%	5%	13%	9%	7%	3%	0%	12%
In the countryside (including areas around towns and cities)	176	479	437	152	13157	46526	171	1721
	35%	45%	37%	3%	28%	45%	26%	56%

As the data accessed from the MENE Online Cross Tabulation Viewer can not be broken down to the scale of NDMP (the smallest relevant geographic area is 'Devon') there is limited confidence in applicability of the data accessed through the cross tabulation viewer.

To investigate intensity of visits to paths and beaches at NDMP scale, data layers from the Outdoor Recreation Value Tool (ORval) were applied. ORval outputs are based on statistical models of recreational demand derived from MENE data (Day & Smith, 2018). The number of trips to each site or path segment is estimated via an econometric model based on data from the MENE (monitor of engagement with the natural environment) survey, taking into account socioeconomic characteristics, location, size, land covers, water margins, designations and points of interest (Day & Smith, 2018). The Data on visitation to beaches and coastal paths in NDMP were available as an ARC GIS data layer from the Outdoor Recreation Value Tool (ORval). Data are presented as mapped layers of estimated visits (to a beach or path segment) per year (Figure 22, Figure 23).

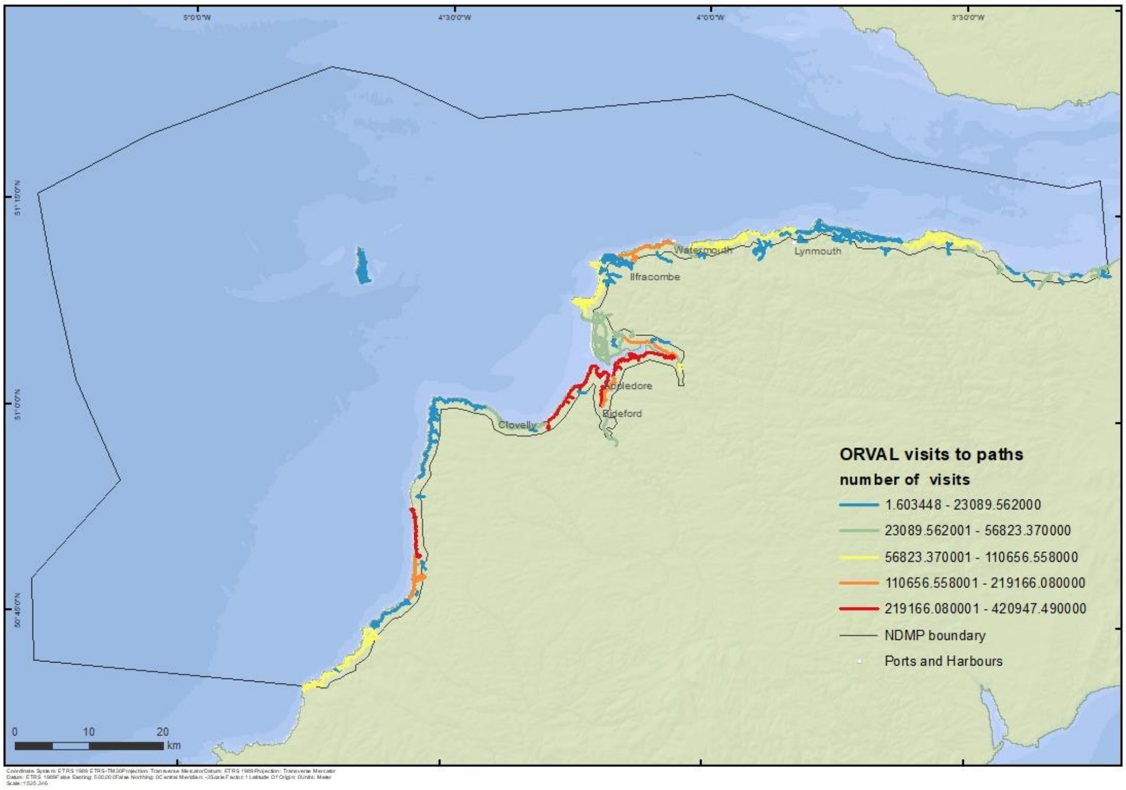


Figure 22 Visits to paths per year, in NDMP estimated via the ORVAL econometric model based on data from the MENE survey.

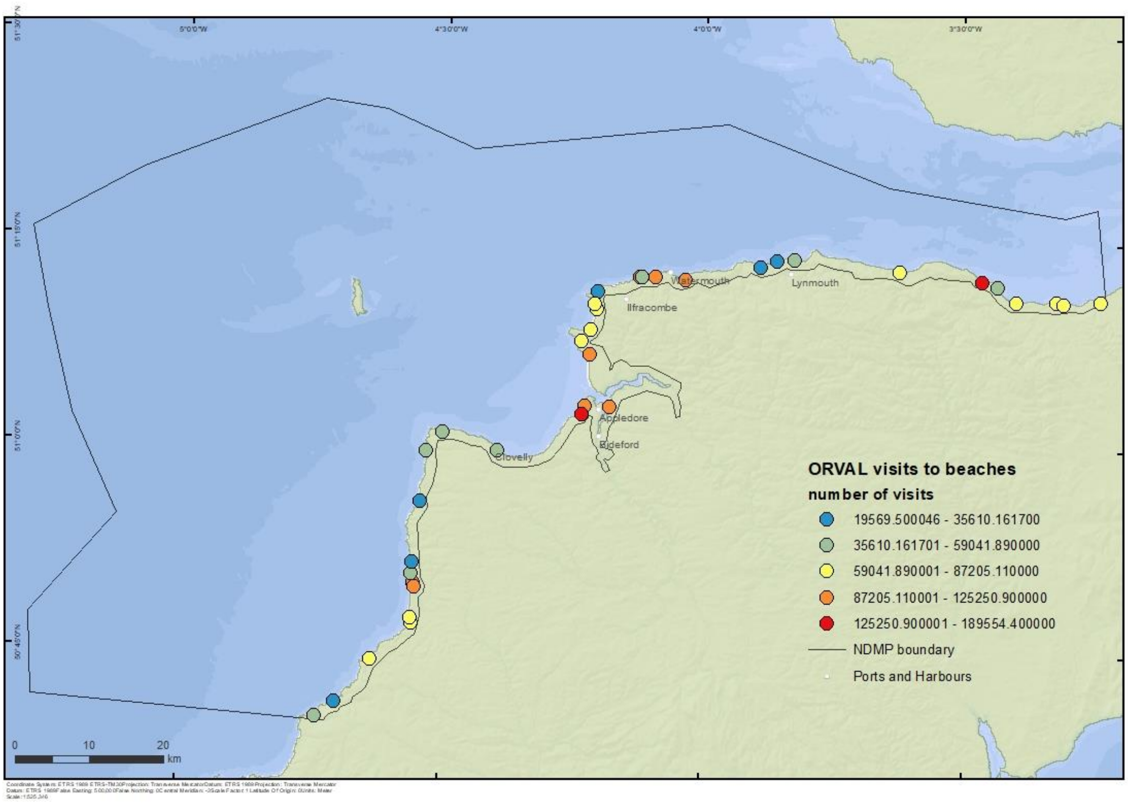


Figure 23 Visits to beaches per year, in NDMP estimated via the ORVAL econometric model based on data from the MENE survey.

Mapping of ‘visits to paths’ and ‘visits to beaches’, display the high frequency of visits to path sections and beaches close to urban (seaside resorts or towns) in NDMP. Number of visits were divided into 5 categories using ‘Jenks breaks’ procedures to display lowest (category 1) and highest frequency of visits (category 5) (Figure 22). Highest number of visits for both visits to paths and visits to beaches were for locations close to towns or sea side resorts such as Bude, Bideford, Appledore, Westward Ho! and Ilfracombe. Number of visits to beaches were also high at locations in proximity to those with bathing water classifications of ‘poor’ in Ilfracombe (Wildersmouth Beach) and Bideford (Instow). Visitors to these locations are either at greater health risk or are likely to be deterred from bathing due to the poor water quality at these locations, impacting health benefits available from visits.

Use of designated bathing waters

As part of regular designated bathing water monitoring during May to September, Environment Agency staff record the number of bathers per 100m at each beach site. These data provide an additional indicator of intensity of frequency of bathing and swimming in the sea activities. Highest mean number of bathers from May to September 2017 was recorded at beaches surrounding the resort town of Bude, the beaches of Saunton and Woolacombe also recorded comparably high mean no. of bathers per 100m (Figure 24).

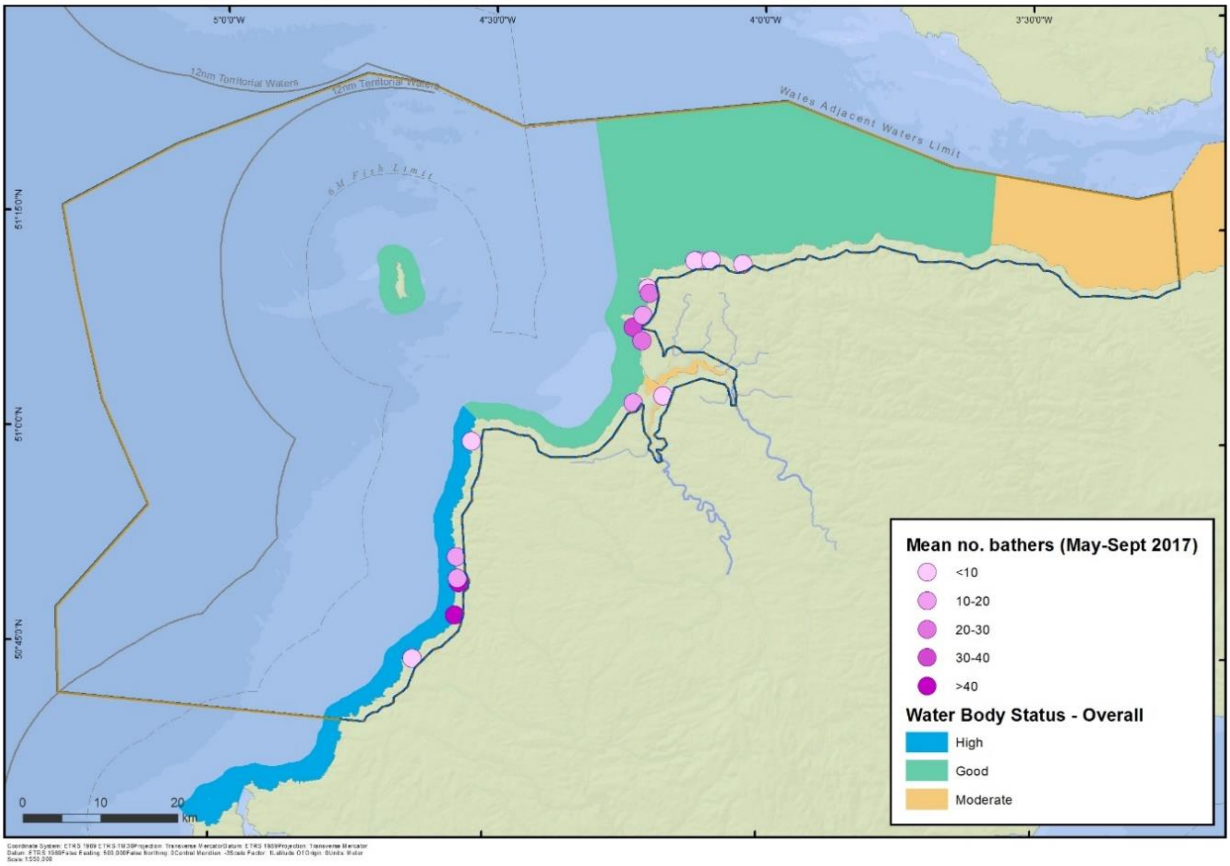


Figure 24 Average number of bathers per 100m recorded during bathing water quality sampling conducted by the Environemnt Agency in 2017.

Visits to a seaside resort or town to undertake 'visits to a beach (sunbathing or paddling in the sea)' (4030 respondents) and all walking activities (21787 respondents) provided the greatest frequency of interaction with marine environments (in North and South Devon) (Natural England, 2016a). Maintaining water quality and condition of habitat and species assets supporting these visits will provide long-term economic benefits to local businesses and health and other wellbeing benefits to visitors and local participants in NDMP.

4.5.12.2 North Devon Council (NDC) Watersports Survey

Between March 2018 and September 2018, NDC undertook a survey with local residents to gain an insight into their frequency of participation in different activities, the money spent on daily undertaking of the activity and spend on equipment (NDCC report 2018 in prep). The results of the survey provided a much greater level of detail on participation in specific water sports activities than the MENE survey. The spatial (site specific detail within North Devon) and temporal detail (annual frequency of activity) available for each activity were also much greater compared to MENE survey results (NDCC report 2018 in prep).

NDC watersports survey was distributed to local residents in NDC area using the North Devon CC communications network (press releases, web links) and was completed by 1193 respondents. Of these respondents, 883 (70%) stated that they took part in a watersport in North Devon and 360 respondents (30% of the sample group) responded that they did not take part in a water sport. Figure 25 provides a breakdown of watersports activity (NDCC report 2018 in prep).

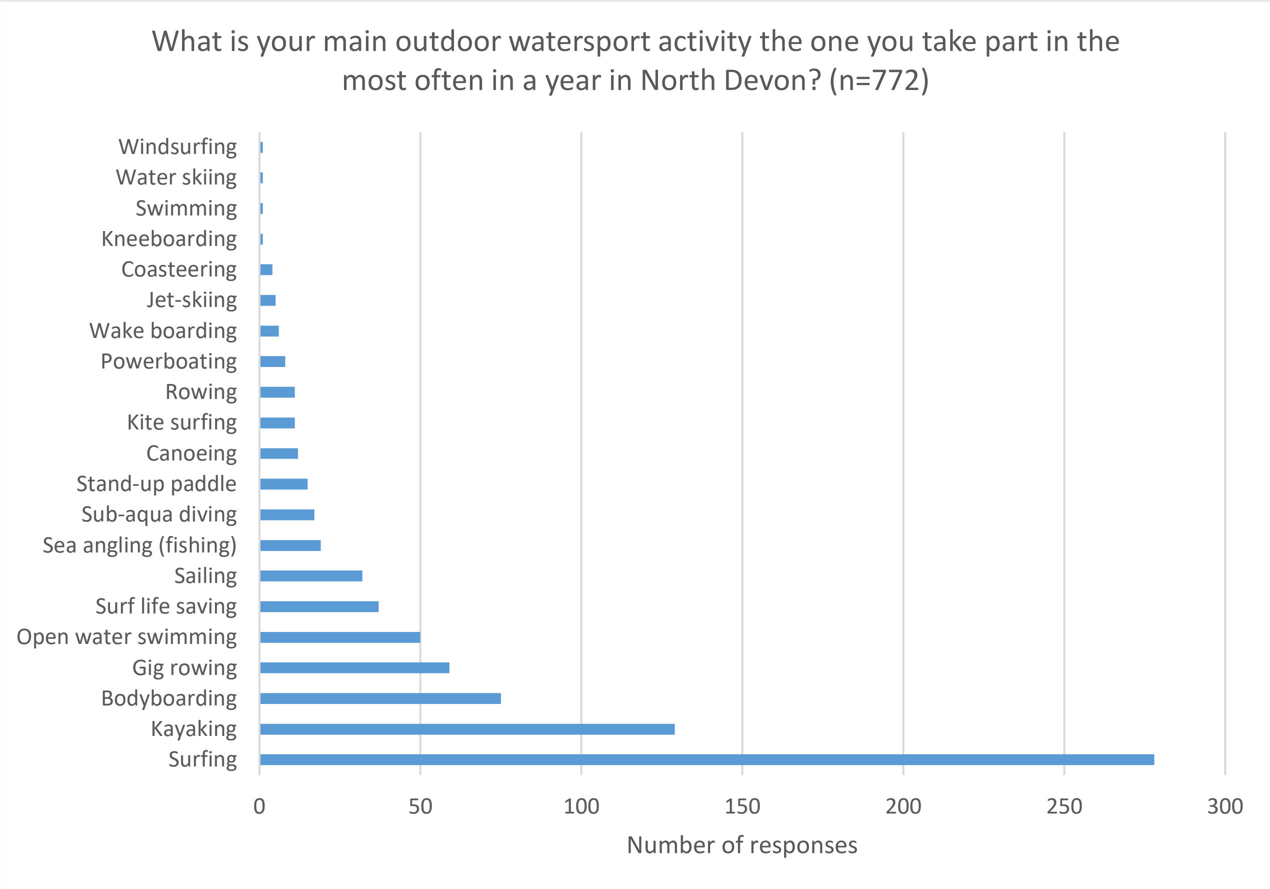


Figure 25 No. of respondents to NDCC watersports survey participating in each activity as their 'main outdoor watersport activity'

Surfing (alone and combined with bodyboarding and knee boarding) was by far the most popular activity practised by North Devon residents completing the survey. As the survey was targeting watersports enthusiasts and was sent to many local clubs, as well as the general population, it is important to consider there is potential bias towards activities with a strong club representation in North Devon receiving greater response rates.

4.5.13 Ecosystem Service Flows and Benefits: Spend of participants undertaking recreation watersports activity

ORVAL welfare value of interaction with natural environment in NDMP

The visitation to each beach or path segment is estimated within ORval via an econometric model based on MENE survey data. Welfare values are calculated for each recreational site using a Recreation Demand Model. The model provides estimates of the recreational behaviour of a person with particular characteristics living in a particular location. The model can be used to predict which greenspaces an individual might visit over the course of a year and how much welfare value they get from each of the greenspaces available for them to visit (Day & Smith, 2018).

The value of the trips are based on the travel cost, in terms of vehicle fuel and travel time. The welfare value estimates the welfare derived from a good in relation to how demand for that good changes as its price changes. The relationship traces out how much money individuals are willing to give up (in relation to fuel, other travel costs and travel time) in order to enjoy that good. The travel cost provides a quantity that (roughly speaking) defines the measure of welfare the beach or path segment visited provides (expressed as: economic value, £) (Day & Smith, 2018).

The welfare value of a site is, thereby, a monetary estimate of the extra welfare enjoyed by adult residents of England and Wales from being able to access that site (Day & Smith, 2018). Welfare values for an existing site are estimated by calculating how much each individual's welfare would fall if they were no longer able to access that site and then converting that welfare quantity into an equivalent monetary amount (Day & Smith, 2018). Those welfare values were then aggregated over the adult population of England and Wales for an entire year (Day & Smith, 2018). Welfare values, calculated for NDMP path segments and beaches are mapped below (Figure 26, Figure 27).

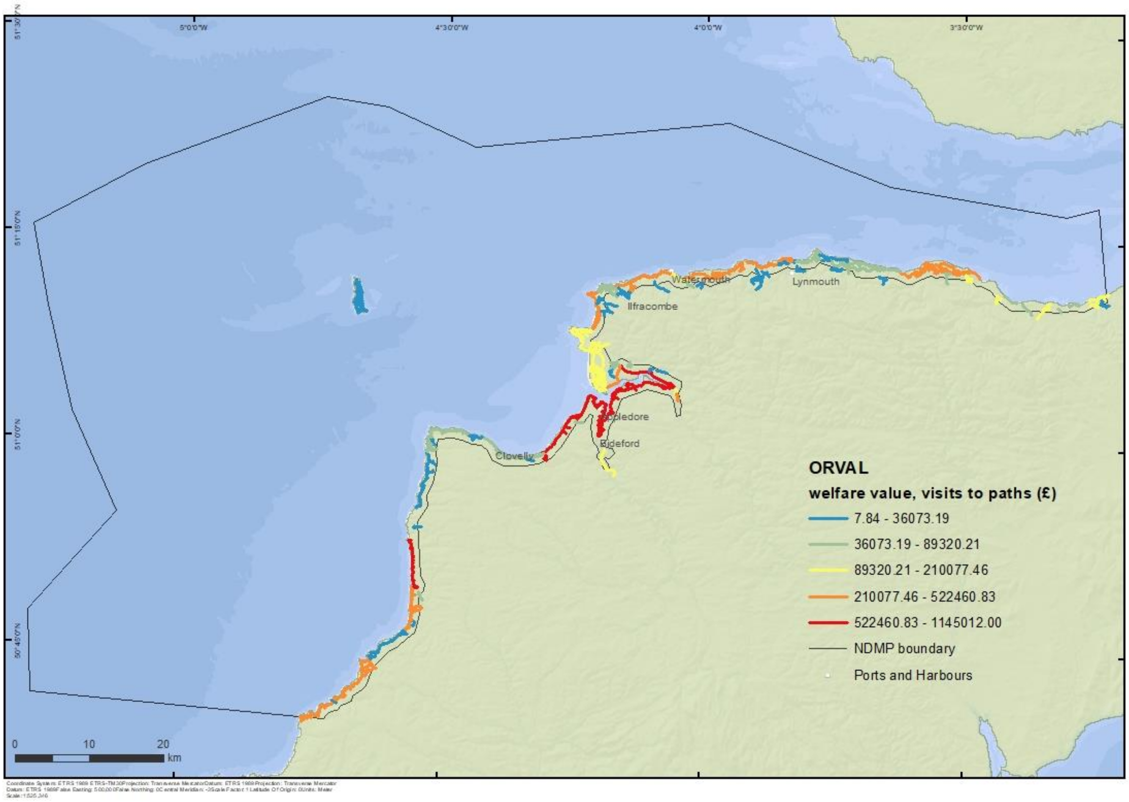


Figure 26 Welfare value (per year, £) related to visits to NDMP path sections

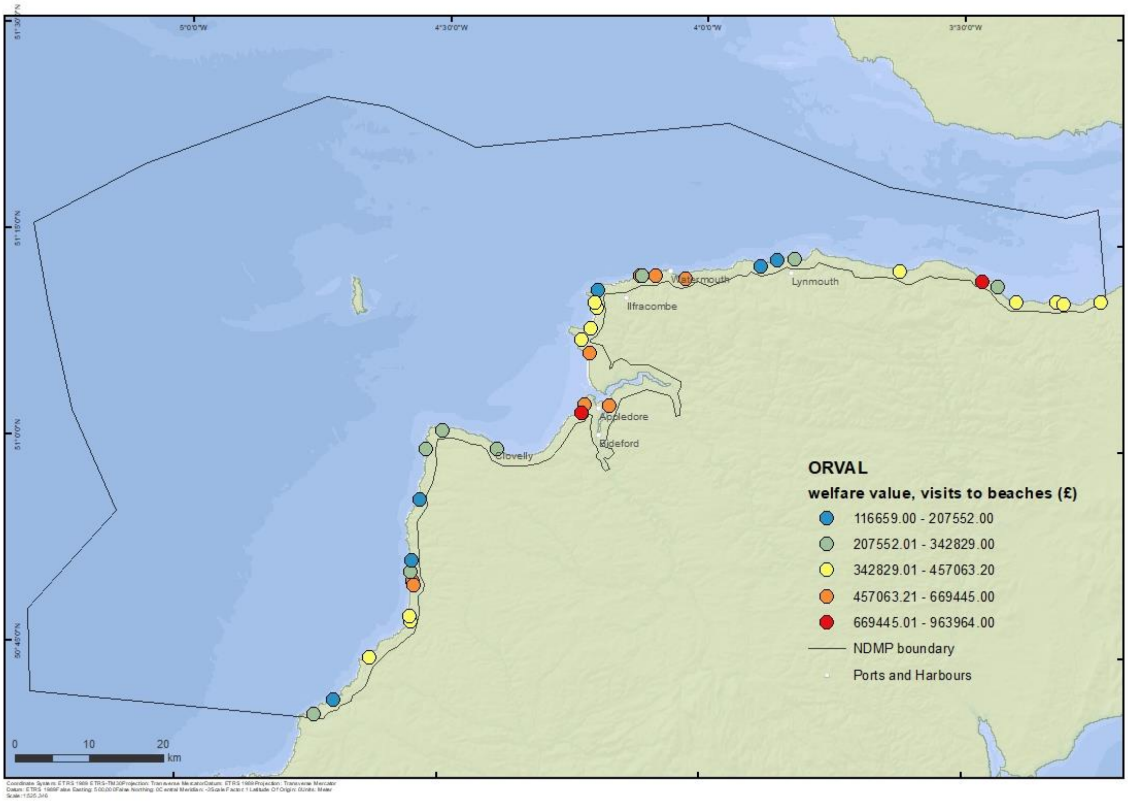


Figure 27 Welfare value (per year, £) related to visits to NDMP beaches

Welfare values for both coasts and paths indicate the importance of access from coastal resorts and towns as areas that provide a link for residents and visitors to the natural assets of NDMP. All welfare values in the highest 2 categories identified in 'Jenks breaks' are adjacent to coastal resorts or seaside towns (Figure 26, Figure 27). It should be considered that locations with greater survey effort and or responses are likely to be near urban areas. Urban areas also, however provide the greatest range of amenities and access to the most popular activities identified in the MENE survey (2015-2016 results): visits to a beach (sunbathing or paddling in the sea) (87% of respondents), watersports (54%) (Natural England, 2016b) (Table 31) . Popular activities undertaken at other seaside and seaside coastline areas (beaches and cliffs) fishing (25%) and across Devon (coastal and inland) walking (with or without a dog), wildlife watching and appreciating scenery from a car appear to be most popular at coastline areas a short distance from a seaside resort or town (Figure 22, Figure 26).

North Devon Council (NDC)l 2018 watersports survey

Over half of the respondents who stated that they undertook a water sport in North Devon provided economic details on average spend per day, number of trips per year and annual spend on water sports equipment. The overall average spend is presented as well as low and high estimates based on the standard error of the mean. Overall, the sample population of North Devon spend between £257k and £1.4million on their water sports activity. It is of note that the sample population stated that 80% of their annual spend on water sports equipment was purchased from North Devon suppliers Table 32.

Table 32 Spend per day per trip, spend on equipment and overall spend per year, low, average and high values calculated for across all water sports activites as a whole.

	low	average	high
Average spend per day/trip on watersports (excluding equipment) n=456	£0.37	£11.36	£22.35
Trips per year (n=478)	44355	44355	44355
Overall spend per year (excluding equipment)	£16,411	£503,873	£991,334
Annual spend on watersports hardware and equipment (n=467)	£241,057	£321,194	£414,800
Total annual spend (n=1193)	£257,468	£825,067	£1,406,134

Based on this sample group is possible to scale up the spend of this sample group to the residents of the North Devon Marine Pioneer. Based on the 1km gridded population 2011 census data 85,176 people live in the coastal belt overlapped by the Marine Pioneer. Noting that 70% of the survey respondents stated that that undertook a water sport on the Marine Pioneer is possible to scale up the sample group spend to 70% of the total number of residents living in the Marine Pioneer coastal belt. However, as the survey was not completely random and may have been 'picked up' by water sports enthusiasts there may be some bias. Therefore, when a more conservative estimate of 40% (representing 34,070 residents living in the Marine Pioneer coastal belt) is applied, the scaled up average spend of Marine Pioneer residents is approximately £28m per year on water sports (NDCC report 2018 in prep).

4.5.14 Key Points

High interest in activities that utilise beaches (surfing, bodyboarding, surf life saving and swimming), and activities that access Taw Torridge estuary, coastal harbours and water bodies (kayaking, gig rowing, sea angling, sailing, sub aqua diving) illustrates the importance of these activities and the waterbodies and natural assets that support them to residents of NDMP. There is also considerable spend associated with these activities which supports businesses and communities within NDMP coastal belt.

Analysis of Devon wide MENE data identified coastal resorts and towns provide a focal point for people undertaking beach activities and water sports (Natural England, 2016b). The importance of coastal towns becomes evident when MENE data is mapped through ORVAL map outputs. Visits to paths and beaches are concentrated close to larger coastal towns, as are highest welfare values (such as Appledore, Westward Ho!, Barnstaple, Bideford, Woolacombe, Bude, Ilfracombe, Combe Martin and Minehead). The scaled up average spend of Marine Pioneer residents of approximately £28m per year on water sports is also likely to be focused in these towns, supporting economic benefits to businesses and communities.

For water sports and recreation activities the water quality within water body assets is an essential factor to support participation. At the same time, good and excellent water quality supports condition of species communities and so health of habitats and species of interest to recreational diving, angling and wildlife watching as well as general appreciation of scenery. Failure of Instow and Ilfracombe – Wildersmouth beaches to meet designated bathing water standards and the wider coastal and estuarine water bodies Taw Torridge Estuary, Bristol Channel Inner South and Bridgewater Bay remain a concern for provision of ES benefits at their full potential.

The high occurrence of visits to conduct watersports activities close to towns and urban areas highlights the importance of these locations to provide the link, or access to NDMP natural assets for residents and visitors alike. The shores of the Taw Torridge in particular as well as coastal cliffs and beaches adjacent to sea side towns and resorts such as Bude, Westward Ho! and Ilfracombe received the highest estimated number of visits from ORval models. Undertaking paddling and bathing at beaches and watersports were the principle activity in these urban areas. Fishing was the most popular reason for a visit to coasts outside of resorts and sea side towns in MENE data.

Data on frequency of visits to fishing sites from NDCC Watersports Survey shows that NDMP residents undertook fishing activity more frequently in coasts in close proximity to towns. Moderate activity also occurred between between Saunton and Woolacombe, an area dominated by wide open beaches, with car parking access (Figure 28).

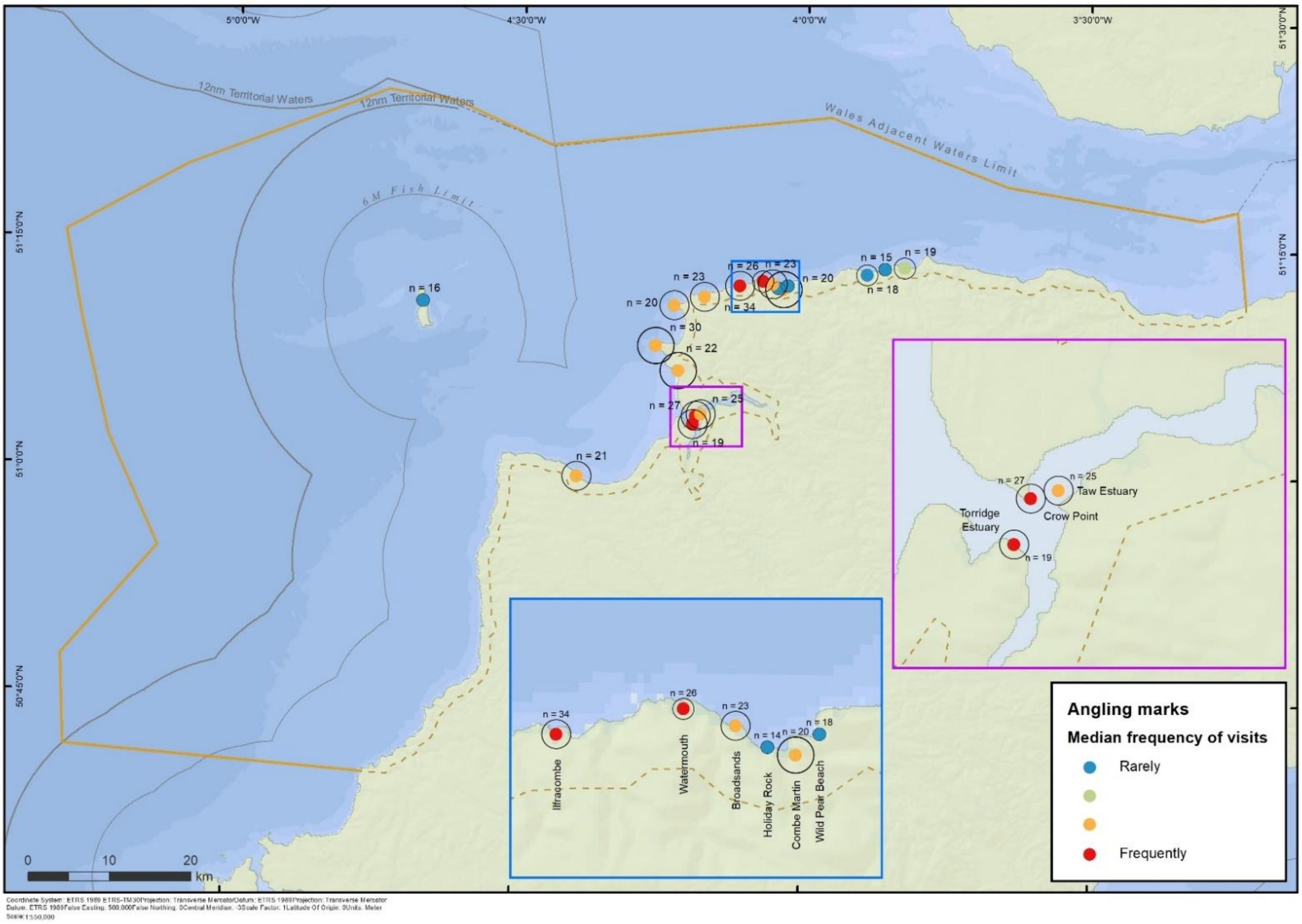


Figure 28 Frequency of visits to angling marks, calculated form NDCC Water sports survey responses

If visitors to NDMP are considered as well as the NDMP residents, participation in recreational angling is likely to be higher than suggested in Figure 25, as Defra (2013) surveys reported that 5.6% of the wider South West region are anglers.

As with commercial fish stocks, recreational angling is an ES benefit that would be supported by better understanding of habitat use within NDMP MPAs by juvenile and adult populations of species of interest. Data gathered from anglers catches, can provide an important contributors to data collection on abundance of stocks and habitat use (Environment Agency & Natural Resources Wales, 2017) (and is being undertaken within the ibass project, Thomas Stamp, Plymouth University, personal communication, 2018).

In comparison to other activities, the age range of participants responding that sea angling was their principal activity in the NDCC Water sports Survey was older (the highest proportion (33%) of respondents that recognised angling was their primary activity were in the 45-64 age category). As with other water sports activities recreational fishing is a direct means that participants experience the environment. Recreational angling enhances social capital, promotes respect for nature and provides health benefits (Defra, 2013; McPhee, 2017). McPhee (2017) state that, in contrast to many water sports that require certain levels of fitness, or specialised equipment, recreational angling is accessible across demographic groups and economic backgrounds.

Accessibility of other coastal recreation activities undertaken in NDMP to people of all ages, economic backgrounds and fitness levels is also important to take into account. Swimming or bathing, walking and viewing scenery were all popular activities undertaken at the coast in MENE survey data. High visitation close to seaside resorts and towns, shown in mapped ORval data may relate to these activities which include vital ways for the very young, or old, or people with low disposable income to interact with natural assets within NDMP.

The economic importance of residents and visitors interest in undertaking surfing, kayaking and various on water activities within NDMP is evident in the results of NDC's water sports survey. Surfing and on water boating activities accounted for the highest proportion of participation in watersport activities by residents (Figure 25, Table 32). Interest in visiting coastal resorts and towns to undertake watersports in the MENE survey data, and high visits to beaches with surfing condition close to urban centres, suggest a high proportion of watersports related spend (in addition to solely the travel cost modelled by ORval) is likely to support businesses and communities on the NDMP coast.

Participation and associated economic benefits to communities related to surfing and boating/on water activities, undertaken by NDMP residents are likely to be comparable to figures for all North Devon residents and visitors presented in national studies. Gibson (2017) showed that nationally (UK) participation in any water sport has increased 2016-2017 by 3.4% and the category of 'any boating activity' by 0.8% 2016-2017. In 2008, a study of value of surfing to North Devon indicated a total surfing population of 42,000 (including visitors to the region as well as residents) and a total spend (equipment spend and spend in shops and cafes) of £52.1 million (Abell & Mallett, 2008). A 2012 study of the economic impact of domestic surfing in the UK estimated the number of surfers amongst local residents in North Devon to be 23,923 (Mills, 2013). Regional spend by resident surfers across North Devon (total related to participation, including equipment, as well as spend on car parking and in shops and cafes) was calculated by Mills (2013) to be £42 million (Mills, 2013) (£75.6million including fuel expenditure). When comparing the data, it is recognised by Mills (2013) that TRISURF's study of North Devon (Abell and Mallett, 2008) included both resident and visiting surfers. Surfing, therefore has been popular and supported a high spend in the NDMP region for a considerable time, from local residents and visitors. Participants are attracted to NDMP by multiple surf spots that provide a range of wave conditions suitable for different ability levels (Scott, Masselink & Russell, 2011), including Croyde Bay, a bar-rip morphology beach, described in surf guides as 'world class' (Sutherland, 2012).

Wildlife watching accounts for a moderate proportion of people's reason for visiting the coast in Devon (Natural England, 2016). Species assets, protected within NDMP MPAs (grey seal, puffin and other sea birds and spiny lobster as well as cetaceans) support at least 12 wildlife watching tour boats, and provide interest for visitors to Lundy. These are also species of interest to recreational divers. Kittiwake *Rissa tridactyla* populations within Lundy SSSI were reported to have continued a long term decline and South West UK populations of Spiny lobster *Panulirus argus* are reported to be depleted. Addressing these declines will support provision of benefits to wildlife watching in NDMP.

Recovering and maintaining habitat assets across NDMP to favourable condition will continue to support feeding and nursery areas for larger species of interest to nature watching, as well as juvenile and adult fish and shellfish species supporting recreational fishing and interest to recreational divers.

NDMP and the rivers Taw, Torridge and Lyn support historically important recreational rod and line salmon and sea trout fishing. To enable this ES benefit, it is essential the migratory routes of salmon and sea trout in the Lyn, Taw and Torridge rivers and estuaries are not negatively impacted by development and poor habitat condition. All rivers are currently classified 'probably at risk' at not meeting conservation objectives.

The link between estuarine habitat, particularly salt marsh and coastal reef habitats is very important for provision of nursery areas for fish and shellfish of interest to commercial and recreational fisheries, sub aqua diving and snorkelling and wildlife watching. Much of the estuary and coastal habitats in NDMP are within MPAs, which provides opportunity for management to ensure habitats are in the best condition for provision of ES benefits. In the most recent conservation assessment 30% of saltmarsh habitat in Taw Torridge SSSI was in unfavourable condition. Large extents of subtidal rock, subtidal coarse sediment and subtidal sand habitats were also assessed to have a conservation objective of ‘recover’. Management measures to limit benthic impact from pressures such as abrasion are limited to MPAs around Lundy. Future management to ensure recovery of estuarine and coastal habitats inside and outside MPAs will benefit not only tourism and recreation ES benefits but multiple key ES benefits including food, sea defence, clean water and sediments and healthy climate.

5 Risk Register (Part Three)

5.1 Introduction

Risk registers were first developed as a tool for businesses to identify risk to business operations by combining metrics for plausible risk, probability, future impacts and managerial responsibility. The tool has been adapted for environmental management. To inform routes towards sustainable development and to underpin the flow of ecosystem services the purpose of a natural capital risk register is to identify those assets and the linked flows of benefits that are at greatest risk from unsustainable use and gaps in management (Natural Capital Committee, 2013). A method for developing a risk register was developed by (Mace *et al.*, 2015) as part of the Natural Capital Committee's work. The risk register developed by Mace et al (2015) is a preliminary high-level assessment based on natural capital assets at a national scale. The national scale risk register revealed substantial gaps in knowledge about the marine asset-benefit relationships and therefore the associated risk of loss of ecosystem service benefits. Through the development of the risk register at a case study scale for the North Devon Marine Pioneer we aim to test and refine the application of the Natural Capital Approach suitable for the marine context and develop targeted recommendations to support a 'net gain' approach to marine management in the NDMP.

5.2 Method

5.2.1 The Asset-Benefit Relationship

Asset-benefit relationships represent the relationship between the condition of the natural asset and the benefit provided to people. Three types of natural capital assets have been taken forward for this study. These comprise:

1. Habitat assets – All EUNIS level 3 habitats that provide a moderate or significant contribution to an ecosystem service benefit;
2. Species assets – commercial species (fish and shellfish) with and without quota; migratory species (salmon and seatrout); and
3. The water column – water bodies, bathing waters, shellfish waters.

In total 285 asset-benefit relationships were reviewed (see: Supplementary material, Risk Register Table 1)

5.2.2 Asset Status

Mace *et al.* (2015) record degradation of natural capital in the risk register in relation to the degree to which it will lead to loss of well-being in present and future generations (Asset Status). Three dimensions of asset status are identified that help resolve how much benefits are affected by deterioration in the condition of assets. These measure the: i) quantity (extent), ii) quality (condition) and iii) spatial configuration of the assets in relation to the benefits (links to extent and condition) (Table 33).

Table 33 Definition and example of 'quantity', 'quality' and 'spatial configuration' in relation to natural assets and provision of goods/benefits (as defined by Mace et al. (2015)).

Asset Status Category	**Definition (asset)**	**Example (relationship to provision of goods/benefits)**
Quantity	Amount of asset (its area, volume or mass) (e.g. abundance or biomass of species).	Food from species associated with reef habitat.
Quality	Specific conditions of the natural asset ('quality' is critical where the nature of habitat management or the presence of certain components or processes affects benefits).	Provision of recreation benefits from a beach or dive site may rely just as much, or even more on the quality of the water or species communities (biodiversity) than merely amount or extent of an environmental feature (such as intertidal sand or subtidal reef).
Spatial configuration	The location of the asset and/or its spatial patterning or fragmentation.	Mace et al. (2015) suggest spatial configuration is critical for recreation benefits, but also productive and regulatory benefits. For example, the spatial configuration of saltmarsh habitat will influence the benefit to the ES benefit 'sea defence' and the contribution to nursery habitat for juvenile fish (food provision).

5.2.3 Policy Targets

Within a risk register, it is necessary to define the nature and the severity of the risk to the asset-benefit relationship. Mace et al (2015) categorise risk according to the performance of the asset-benefit relationship to relevant policy targets. Policy targets in this context are considered to be societal aspirations for the asset-benefit relationship and, as such, form a threshold target against which risk can be defined. Table *34* identifies the policy targets applied within this framework.

Within the marine environment, the long-term sustainability of the habitat asset-benefit relationship largely sits within policy that is linked to Marine Protected Areas (MPAs). MPAs are regarded as an important tool for the maintenance of marine ecosystem functionality, health, and ecosystem integrity through the conservation of significant species, habitats, or entire ecosystems (Sobel & Dahlgren, 2004). As such, they have an important role in supporting the benefits that underpin human wellbeing. In recognition of the crucial interdependencies between the natural and the human system, targets to sustainably manage marine ecosystems though establishing ecologically coherent networks of MPAs are embedded in international policy (CBD, 1992; CBD, 2010; OSPAR Convention, 2002; United Nations, 2014). Therefore, within this risk register the extent and condition of the asset benefit relationship is assessed against targets for MPAs across a range of policies (Table 34).

For the condition of habitats within MPAs this risk register method relies on an interpretation of the management objectives for each MPA as a proxy metric for condition. It is noted that the statutory agencies use field assessment and/or risk based assessment to trigger management objectives therefore the confidence in 'actual' condition will vary. MPA management objectives remain the best available evidence for the condition of MPA habitat features.

Outside of MPAs there is very limited evidence of the condition of habitats. This exposes two avenues of thought in terms of assumptions of the risk posed to the asset-benefit relationship. The first assumption is that MPAs and the management objectives for each site are sufficient to underpin the flow of benefits. The second assumption is based on an understanding that the asset-benefit relationships are non-linear and reliant on a range of habitat assets to support a final benefit. Within this context, it must therefore be considered that, the flows of benefits are supported by habitats both inside and outside MPAs. Securing these benefits requires an assessment of the condition of the habitats at a broader scale than the MPA boundary and a management response triggered that can lead to a net-gain for biodiversity and ecosystem services.

In developing the second assumption (that the flow of benefits is dependent on the condition of the habitats both inside and outside MPAs) we test the MSFD GES Descriptor 6 in that 'Sea floor integrity is at a level that ensures that the structure and function of the ecosystem are safeguarded and benthic ecosystems in particular are not adversely affected.' At a scale relative to the NDMP a proxy layer of condition is used that depicts the Likely Relative Condition (LRC) of the habitat based on known previous levels of physical abrasion from fishing activity (Section 3.2.4). Interaction with the pressure abrasion (related to demersal fishing activity) is assessed for each habitat. Where an interaction occurs, the sensitivity of that habitat to the pressure (as reviewed by Marine Evidence Based Sensitivity Assessments (Tyler-Walters *et al.*, 2017)) is used to indicate an LRC score between 1 and 5. If the LRC is 4 or above then the habitat can be considered structurally sound and ecological function has not been impaired by pressure from fishing abrasion.

In lieu of any policy targets that can serve to recognise the role of marine habitats, beyond features of conservation interest in supporting ecosystem service benefits we apply proposed UK targets for achieving Good Environmental Status under Descriptor 6 - Sea floor integrity (Cefas, 2012) (Table *34*). Condition assessments of features within MPAs (Natural England, 2017), and extent of each habitat within NDMP that is in an impacted state (in relation to the pressure 'abrasion' from interaction with demersal fishing activity) were assessed against targets on the quality and quantity of benthic habitats (% of habit in a state unimpacted by human activities) (Supplementary material, Risk Register Table 1).

It is recognised that proposed targets may be contentious as there are limited examples of comparable baseline or reference conditions within NDMP (as with many European coastal areas) where human impacts are negligible. As discussed by Hopkins and Bailey (2018) it is not possible to determine indisputably 'unimpacted' reference conditions either through modelling/historic data or through marine areas where human effects are currently minimal. Likely Relative Condition (LRC), in relation to sensitivity of habitats to pressures (abrasion) was therefore applied as an assessment of proportion of habitat that has historically received acceptable (sustainable use) or unacceptable impact (unsustainable use). The LRC score provides a proxy assessment for whether the habitat state (structure and function of habitat and constituent communities) can provide expected contribution to an ES (good LRC, acceptable use) or contribution to provision of an ES is impaired (moderate – very low LRC, unacceptable use).

For rock/reef habitats and saltmarsh habitats the significant contribution of these habitats to multiple ES was recognised and a target of >95% of the extent of these habitats were required to have a condition assessment of 'maintain' in MPAs and a good – very good LRC across the entire extent of NDMP. Outside MPAs targets applied to soft substratum habitats (intertidal and subtidal) were assessed based on the extent of the habitat within NDMP. If the extent of the habitat (EUNIS L3) was less than 50% of the area of NDMP, a more conservative option was applied, >95% of the extent of these habitats were required to be have a condition assessment of 'maintain' in MPAs and >90% of extent with a good – very good LRC (acceptable use) across the entire extent of NDMP. If the extent of the habitat (EUNIS L3) was greater than 50% of the area of NDMP, a less conservative option was applied. Greater than 95% of the extent of these habitats were required to have a condition assessment of 'maintain' in MPAs, and >85% of extent was required to have a good – very good LRC (acceptable use) across the entire extent of NDMP (Table *34*).

For commercial species extent and condition policy targets are linked to the Marine Strategy Framework Directive (Descriptor 3) and the Common Fisheries Policy, recommended TAC and stock assessment of non-quota species are applied as indicators of quantity and quality in relation to exploitation below maximum sustainable yield (Table *34*). For the water column as an asset, only condition is assessed in relation to WFD targets for coastal and estuarine water bodies and designated bathing waters (Table *34*).

Table 34 Targets for natural assets within MPAs and outside MPAs, across national and international policies.

Natural Capital Asset	Policy	Target
Habitat Extent	Convention on Biological Diversity Aichi target 11 Sustainable Development Goa1 14.5	By 2020, conserve at least **10 per cent of coastal and marine areas**, consistent with national and international law and based on the best available scientific information
	Marine Strategy Framework Directive - Biodiversity	**Good Environmental Status is reached when 'The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions."** *Target for rock/reef habitats and saltmarsh* **Extent: (Inside MPAs):** extent is stable or increasing (>95% conservation objective 'maintain') **Extent: (outside MPAs)**: For 95% extent in NDMP assessed to be unimpacted by anthropogenic activites (in LRC >3). *Target for all soft substratum habitats (where extent of the habitat is less than 50% of all NDMP)* **Extent: (Inside MPAs):** extent is stable or increasing (>95% conservation objective 'maintain') **Extent: (outside MPAs)** area of habitat lost + area of habitat below GES (in condition recover or impacted by unacceptable impact (LRC 3 or below) ≤ 10% for entire NDMP. *Target for all soft substratum habitats (where extent of the habitat is above 50% of all NDMP):* **Extent: (Inside MPAs):** extent is stable or increasing (>95% conservation objective 'maintain'). **Extent: (outside MPAs)** area of habitat lost + area of habitat below

		GES (in condition recover or impacted by unacceptable impact (LRC 3 or below) ≤ 15% for entire NDMP.
Habitat Condition	Biodiversity Strategy 2020	≥95% **SSSI** favourable/ recovering by 2020
	Marine and Coastal Access Act	features of **MCZs** to have conservation objective: 'maintain'
	EU Habitats Directive	Features of **SACs** to be in 'favourable' condition (excellent or good conservation).
	Marine Strategy Framework Directive : Sea floor integrity	GES is achieved when 'Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected". *Target for rock/reef habitats and saltmarsh* **Extent: (Inside MPAs):** >95% conservation objective 'maintain' (e.g. biological communities are present that provide a key role in the structure and functioning of the habitat) **Extent: (outside MPAs)**: For 95% extent in NDMP assessed to be unimpacted by anthropogenic activites (in LRC >3). *Target for all soft substratum habitats (where extent of the habitat is below 50% of all NDMP)* **Extent: (Inside MPAs):** >95% conservation objective 'maintain' (e.g. biological communities are present that provide a key role in the structure and functioning of the habitat) **Extent: (outside MPAs)** area of habitat lost + area of habitat below GES (in condition recover or impacted by unacceptable impact (LRC 3 or below) ≤ 10% for entire NDMP. *Target for all soft substratum habitats (where extent of the habitat is above 50% of all NDMP):* **Extent: (Inside MPAs):** >95% conservation objective 'maintain' (e.g. biological communities are present that provide a key role in the structure and functioning of the habitat).

		Extent: (outside MPAs) area of habitat lost + area of habitat below GES (in condition recover or impacted by unacceptable impact (LRC 3 or below) ≤ 15% for entire NDMP.
Species (Commercial) Extent	SDG 14.4.1	Proportion of fish stocks within biologically sustainable levels
	MSDF, GES, Descriptor 3	Healthy age and size structure is a recognised criteria for assessing GES of fish stocks, but it is not currently included by the EC as it is 'not sufficiently developed and no threshold for GES is known for this criterion.' Reproductive capacity (spawning stock biomass) provides a key indicator of healthy stocks. However, this criterion is not sufficiently developed and no threshold for GES is known for this criterion. The trend in biomass/abundance (CPUE per km²) has been used as a proxy for SSB and abundance of older/larger fish.
	Common Fisheries Policy	Spawning stock biomass also indicates the extent of the population in relation to assessment of maximum sustainable yield of stocks in ICES areas, to assess sustainable levels of fishing pressure, TAC and quota under the common fisheries policy.
Species (Commercial) Condition	MSDF, GES, Descriptor 3, Common Fisheries Policy	Scientific advice on recommended TAC provides the closest proxy for the health (and thereby condition or quality) of a stock (in relation to the fishing effort it can support). TAC recommendations are calculated from data on spawning stock biomass, recruitment and fishing pressure. Spatial scale is, however, much greater for TAC assessments (ICES areas) than NDMP extent.
The water column condition	WFD	WFD targets for overall status of coastal and estuarine water bodies to be assessed as ‘good’ or ‘high.’
Bathing waters condition	EU Bathing Waters Directive	Designated bathing waters classification to be ‘satisfactory’ or above.

5.2.4 Assessment

Each asset –benefit relationship was assessed against the evidence in the asset register (Section 3). The risk matrix (Figure 29) shows the risk scoring as high (red), medium (orange) or low (green) based on whether the benefit level is currently above or below target and whether the asset is deteriorating and how rapidly (Figure 30b and supplementary material).

		Status		
		Above, at or just below target	Below target	Substantially below target
Trend in Status	Positive or not discernible	*A*	*B*	*B*
	Negative	*B*	*C*	*C*
	Strongly negative	*C*	*C*	*C*

Figure 29

Each risk scoring was assessed for the strength of evidence and agreement between evidence sources. The confidence score (2c) is the sum of confidence scores for 'status' and 'trend', if both scores are assessed from limited evidence (confidence score 4) and low agreement between sources (confidence score 4) the total score presented in the risk assessment was 8.

		Agreement	
		High	Low
Robustness	*Significant evidence*	**1**	**3**
	Limited evidence	**2**	**4**

	High confidence	Low confidence
Low risk	*A*	*A*
High risk (or risk unknown)	*B*	*B - C*
Very high risk	*C*	*C*

Figure 30b Risk register confidence assessment in relation to robustness and agreement of evidence (confidence was assessed for status and trend and therefore confidence is sum of both)

5.2.5 Integrating Community Based Knowledge of the Risk to the Asset-Benefit Relationship

Community Based Risk = Risk Exposure * Sensitivity to change

Societal aspirations set at a national policy level may not reflect perceived and actual risk at a local level. Finding synergies where the risk to asset-benefit relationships is relevant and realised at both a national and a local scale is a crucial next step for developing a 'net gain' management approach. To incorporate community based knowledge into the risk register we adapted the Ecosystem Service Assessment methods developed by Pendleton et al (2015) and the Sustainable Development Vulnerability Index (Rees *et al*. 2018).

Community based knowledge of risk was developed though participation in a workshop of the members of the North Devon Marine Working Group (MWG) which convened on the 17th September 2018 in Ilfracombe, North Devon. During the working group four groups were formed to consider the following questions linked to the ecosystem service benefits of 1) Food provision 2) Recreation and tourism 3 and 4) Healthy climate and clean water and sediments and; 5) Natural hazard protection. A facilitator led each group and a scribe nominated to take detailed notes of the discussion. Groups were provided with an A2 table to fill in to capture the quantitative and qualitative outputs and any key discussion points around the benefit-asset relationship. The key questions were:

- What is the importance of the benefit-asset relationship? (Risk exposure). 3= high importance; 2= medium importance; 1= low importance;
- What is the likelihood that the benefit will change if the quality or quantity of the asset is reduced? (Sensitivity). 3= high; 2= medium, 1= low; and
- What are the warning signals, thresholds, red flags that the benefit –asset relationship is at risk? (Thresholds, community-defined criteria for sustainability). Group were encouraged to quantify their statement (an increase in, a reduction of, more, less, fewer etc.)

The Community Based Knowledge of Risk was calculated as:

Community Based Risk = Risk Exposure * Sensitivity to change

5.3 Results

Of the initial 285 potential relationships between the 5 ES Benefits and the quantity, quality and spatial configuration of 13 EUNIS level 3 habitats, as well as water bodies, bathing waters and stocks of quota fish species, non-quota fish species and migratory salmon and sea trout, 136 priority relationships were assessed in the risk register (Table 35) (Supplementary Table 1). 149 relationships were judged to be of lower significance for either ecological function or management reasons, or could not be assessed due to lack of available data to assess status or trend (Supplementary Table 1). As examples, the quantity or spatial configuration of water bodies within NDMP could not be altered, or managed, to enhance or reduce benefits derived from the marine and coastal environment. For fish species, there was limited data available on spatial abundance and also spatial configuration of populations in relation to NDMP habitats. 15 asset-benefit relationships were allocated to the highest risk category (red cells, category 'C' where status is substantially below the policy target and or trend is strongly negative (Table 36). The community based knowledge identified 29 high risk asset benefit relationships. These risks are summarised as:

- Food (wild food fish and shellfish) is high risk due to the extent of sublittoral habitat without management objectives and with impaired quality (condition) based on knowledge of previous fishing activity.
- A healthy climate is at risk due to the degraded quality of the saltmarsh and rock/reef habitats.
- Sea defence services provided by saltmarsh, littoral sand and mud sediments are at risk
- Recreation and tourism is at risk due to degraded habitats and incidences of poor water quality.
- Clean water and sediments supported by the ecological functions and processes in the subtidal sediments are considered to be at risk due to impaired quality (condition) based on knowledge of previous fishing activity.

Table 35 Priority relationships assessed in the risk register. For each ES the top row is risk assessed in relation to analysis of indicator data in relation to policy targets, the lower row for each ES is risk assessed in relation to (local) community based knowledge of risk. Red, amber green shading and confidence scores were assessed in relation to the key in figure 30b.

Asset	**Saltmarsh**			**Littoral rock**			**Littoral coarse sediments**			**Littoral sand and muddy sand**			**Littoral mud**		
Risk category policy	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**
Risk cat. Community	**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**		
Food (Wild Food - fish and shellfish).	B (4)	C (4)	C (8)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	C (4)	C (4)	C (8)
Food - local															
Healthy climate (carbon sequestration).	B (4)	C (4)	C (8)										C (4)	C (4)	C (8)
Climate -local															
Sea defence. (natural hazard regulation / flood prevention).	B (4)	C (4)	C (8)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)			
Sea defence - local															
Recreation and Tourism	B (4)	C (4)	C (8)				B (4)	B (4)	B (4)	B (4)	B (4)	B (4)			
Recreation and Tourism - local															
Clean water and sediments.	B (4)	C (4)	C (8)										C (4)	C (4)	C (8)
Clean water -local															

Asset	**Littoral mixed sediments**			**Littoral biogenic reefs**			**Infralittoral rock**			**Circalittoral rock**			**Sublittoral coarse sediment**		
Risk category policy	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**
Risk cat. Community	**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**		
Food (Wild Food - fish and shellfish).	B (4)	B (4)	C (8)	B (4)	B (4)	C (8)	C (4)	C (4)	B (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)
Food - local															
Healthy climate (carbon sequestration).				B (4)	B (4)	C (8)	C (4)	C (4)	B (4)						
Climate -local															
Sea defence. (natural hazard regulation / flood prevention).	B (4)	B (4)	B (4)	B (4)	B (4)	C (8)	C (4)	C (4)	B (4)						
Sea defence - local															
Recreation and Tourism							C (4)	C (4)	B (4)	C (4)	C (4)	C (4)			
Recreation and Tourism - local															
Clean water and sediments.				B (4)	B (4)	C (8)							C (4)	C (4)	C (4)
Clean water -local															

Asset	**Sublittoral sand**			**Sublittoral mud**			**Sublittoral mixed sediments**			**Water bodies**			**Bathing waters**		
Risk category policy	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**
Risk cat. Community	**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**		
Food (Wild Food - fish and shellfish).	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)		B (2)		C (2)	C (2)	
Food - local															
Healthy climate (carbon sequestration).											B (2)				
Climate -local															
Sea defence. (natural hazard regulation / flood prevention).											B (2)				
Sea defence - local															
Recreation and Tourism											B (2)		C (2)	C (2)	
Recreation and Tourism - local															
Clean water and sediments.	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)	C (4)		B (2)		C (2)	C (2)	
Clean water -local															

Asset	**Shellfish waters**			**Fish (quota species)**			**Fish (non-quota species)**			**Fish (migratory species (salmon and sea trout)**		
Risk category policy	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**	**Qun**	**Qal**	**Sp.**
Risk cat. Community	**Risk: Local community**			**Risk: Local community**			**Risk: Local community**			**Risk: Local community**		
Food (Wild Food - fish and shellfish).		B (2)		C (4)	C (4)		C (8)	Lob B (4) Crab A (4)		C (4)	B (4)	C (4)
Food - local												
Healthy climate (carbon sequestration).												
Climate -local												
Sea defence. (natural hazard regulation / flood prevention).												
Sea defence - local												
Recreation and Tourism		B (2)		C (4)	C (4)		C (8)	Lob B (4) Crab A (4)		C (4)	B (4)	C (4)
Recreation and Tourism - local												
Clean water and sediments.		B (2)										
Clean water -local												

In terms of the Community Based Knowledge of the risk to the asset-benefit relationship, the participants of the North Devon Marine Working Group discussed the risk relationship within the context of the North Devon Marine Pioneer. The benefits considered to be most at risk were Clean Water and Sediments, Food (wild food fish and shellfish) and Recreation and Tourism. Community Based Knowledge highlights saltmarsh, intertidal sediments (mud) and intertidal sediments (mud and sand), and subtidal sediments as the habitat assets subject to the most risk (

Table 35). However, it must be noted that all habitats were assigned a degree of risk with the least risk assigned to biogenic *Saballaria* reefs. This low risk was attributed to the small patches of biogenic reef in North Devon and this score does not downgrade their status as an ecologically important habitat.

The MWG identified a range of ecological, economic and social thresholds where they consider that the asset-benefit relationship is at risk (S2). For the majority of thresholds identified there is no data to assess change over time. The thresholds which standout are:

- Ecological thresholds linked to changes (reduction) in the physical extent or changes in species composition/diversity. The risk was most strongly associated with biogenic and vegetated habitats. It was noted for some habitat assets that there is natural variation in extent e.g. subtidal sandy sediments. Therefore, changes in extent may not meaningfully reflect any loss or gain in natural capital assets.
- Economic thresholds linked to a decline in fisheries yield and landing values. Whilst the relationship between essential fish habitat, fish stocks, yields and value is difficult to prove there has been a decline in fish landings and changes in market demand in North Devon.
- Economic and social thresholds linked to the number of designated bathing waters, healthy marketable shellfish and the number of public health incidents arising from poor water quality.

5.4 Discussion

The highest number of asset benefit relationships at risk from not meeting a defined policy target, and or trend is strongly negative, are associated with the degradation and loss of the ecosystem service benefits of Food (wild food fish and shellfish) and Clean Water and Sediments. If it is considered that Recreation and Tourism also rely on clean water to underpin the benefit, then there is also an associated risk in the reduction of this benefit. Therefore, Recreation and Tourism should be considered within the high-risk category. Community based knowledge also supports this finding, signalling that more targeted local management is required with community set thresholds.

The highest risk to these asset-benefit relationships is highlighted in the sublittoral sediment habitats where fishing pressure is potentially limiting the ecological structure and function of the benthic habitats that support the flow of benefits of food and clean water and sediments. Only small proportions of subtidal sediments are within MPAs, with the majority of the extent of subtidal habitats designated with conservation objectives of ‘recover’. In terms of the extent of sublittoral sediment across all NDMP, large proportion were assessed to have an LRC of 3 (moderate) or below. The large extent of these habitats exposed to unacceptable impacts is expected to significantly reduce their contribution to the ecosystem service benefit of Food (Wild food, fish and shellfish) and Clean Water and Sediments. However, there is a lack of confidence in this finding due to the reliance on modelled data to assess extent of habitats and the lack of survey data to assess condition of habitats and species communities. Community based knowledge also assigns a high degree of risk to the relationship between subtidal sediments and the realisation of ES benefits. This indicates a high degree of awareness from the community with regard to the role of marine habitats (inside and outside of MPAs) in supporting a range of benefits.

Knowledge and access to data on recent levels of fishing pressure would support the evidence base and help target management measures to reduce the risk. Risk to the asset-benefit relationship within this context was also tested against proposed UK targets for achieving GES under the MSFD Descriptor 6 - Sea floor integrity (Cefas, 2012). Targets for the proportion of habitat extent within NDMP exposed to unacceptable/acceptable impacts were assessed for each habitat in relation to contribution to ES benefits. Rock habitats and saltmarsh, that contribute significantly to multiple ES required <5% exposed to unacceptable impacts. Soft substratum habitats with limited extent in NDMP (that have a moderate to significant contribution to multiple ES) required <10% exposed to unacceptable impacts. Soft substratum habitats with large extents within NDMP (greater than 50% of the NDMP area) required <15% exposed to unacceptable impacts. These targets have been applied as a placeholder until a more locally specific policy threshold are designed that can support a 'net gain' for marine systems.

A medium degree of risk in the degradation and loss of the benefits of food (wild food fish and shellfish), clean water and sediments and recreation and tourism is associated with policy targets set out within the Water Framework Directive and Bathing Water Directive. Confidence is high in the assigned level of risk as there is data for both current status and historical status in relation to monitoring objectives. Three of seven waterbodies intersecting with NDMP failed to receive 'good' overall status in 2015. Between 2015 and 2018 two bathing waters classification decreased from 'good' to 'poor' and one decreased from 'excellent' to 'good'. For shellfish waters all Taw Torridge sites classed as 'B' or below (A Class is the highest standard). There were 3 pollution incidents recorded in 2017/2018 across sites in NDMP, which caused beaches or coastal access points to be closed for a period (e.g. sewage from overflowing drains, pollution from oil or fuel) (Environment Agency, 2018b). Monitoring of shellfish waters in Taw Torridge outer estuary (Spratt Ridge East) has identified harmful plankton to be above trigger levels on 6 occasions. Biotoxin monitoring of flesh from the outer estuary (Spratt Ridge East) reports toxin detected/clinical signs observed, but below action level on 6 occasions (Food Standards Agency, 2018).

Whilst there is progress, towards national policy targets the community based knowledge highlighted economic and social thresholds linked to water quality. Recreation and Tourism as an ecosystem service benefit is a major economic driver in the region and an economic sector linked to future economic growth strategies for the region. Spend related to tourism visits and overnight stays in the North Devon Local Authority Area represented £173 million of expenditure per year (3 year moving average 2014-2017) (Visit England, 2018). Watersports recreation activities are very popular amongst local residents and visitors alike. A 2012 study of the economic impact of domestic surfing in the UK estimated that there were 23,923 local residents in North Devon (beyond just the NDMP coastal belt) who surf (Mills, 2013). Regional spend by resident surfers across North Devon (total related to participation, including equipment, as well as spend on car parking and in shops and cafes) was calculated by Mills (2013) to be £42 million (Mills, 2013) (£75.6million including fuel expenditure). Other on water activities (such as boating, sailing, kayaking, water skiing, gig rowing and stand up paddleboarding) were estimated from surveys conducted by North Devon Council in 2018 to also be popular with residents of the NDMP. Many of these activities are supported by the natural environment in the Taw Torridge estuary and sheltered harbours such as Combe Martin, Ilfracombe, Boscastle and Bude. The evidence of water quality failures within the NDMP signals that the community defined threshold has been exceeded and that the risk of the degradation and loss of the benefits should be upgraded to high risk to meet community needs and expectations.

A low degree of risk to the asset-benefit relationship was assigned to crab *C.pagurus* stocks in relation to non-quota species assets supporting delivery of the ES benefit 'Food'. Stock assessments suggest exploitation is below MSY (the target above which exploitation would reduce stocks and so the asset providing the benefit) and this assessment has not changed from previous assessments. As assessment data were only available for the entire south west UK region and not at a relevant spatial scale to confidently assess risk for NDMP, confidence in the allocation is low. A large extent of infralittoral reef and shallow subtidal sediments are within MPAs in NDMP. These habitats provide important shelter and food resources for shellfish species including *C.pagurus.* Management within Lundy SAC restricts fishing practices such as mobile demersal trawls and dredges that are likely to impact condition *C.pagurus* habitat. The Lundy NTZ also provides an area where all fishing pressure on shellfish species is reduced and is likely to contribute to maintenance of sustainable *C.pagurus* and *H.gammarus* stocks.

From a community knowledge perspective, a high degree of risk was assigned to the loss and degradation of saltmarsh habitat. The large proportion of saltmarsh (30% of the NDMP total saltmarsh extent) assessed as unfavourable (due to grazing pressure) in 2012 also highlighted this asset as 'high risk' and a priority for further monitoring and management. The fact that the community have highlighted saltmarsh as an asset that is at risk potentially signals an 'experienced' visual loss of the benefits of saltmarsh habitat and/or a heightened recognition of the contribution of saltmarsh to the provision of multiple ecosystem services.

The loss or degradation of the asset-benefit relationships for sea defence and a healthy climate also pose a medium risk. Both benefits are supported by shallow rock and soft substratum habitats (vegetated habitats provide greater contribution, and solely for 'Healthy Climate' benefits). The risk is reduced as a large extent of NDMP littoral habitats are within MPAs and have been assessed to have the conservation objective 'maintain' in 2016-2017. However, there is no data to assess trends as the coastal MCZs have only been recently designated in 2016 and there is no monitoring data predating the designation. The high risk identified for saltmarsh quality is likely to significantly negatively impact provision of sea defence and healthy climate ES benefits. Especially due to grazing pressure impacting the plant communities that capture carbon and also attenuate currents and wave energy to aid reduction of flooding and storm damage.

5.5 Conclusion

Through the application of the Risk Resister approach (Mace *et al.*, 2015) it has been possible to identify those assets and the linked flows of benefits that are at greatest risk in the NDMP. Through the inclusion of a method to identify Community Based Knowledge of risk it is possible to prioritise action at a scale relevant to the NDMP to maintain the flow of benefits.

The majority of asset-benefit relationships are at a medium to high risk of loss. There are particular risks to the future delivery of benefits from Food (wild food fish and shellfish), Clean Water and Sediments and Recreation and Tourism. Sectors of the North Devon economy are heavily dependent on the maintenance and/or restoration of these asset-benefit relationships, which poses a challenge to the NDMP community, managers and policy makers as to how to underpin these benefits.

An overriding feature of the Risk Register is the contribution of the range of habitats to the provision of the range of ES benefits. MPA and the management of features of conservation interest have long been considered the main policy tool to underpin human wellbeing. Whilst MPAs may play a significant role in achieving this, the risk register demonstrates that this is a limited assumption. ES benefits are linked to habitats and species with and without conservation designations for management.

In this study, we tested at application of thresholds for GES for seafloor integrity under the MSFD as a proxy measure to determine risk to the wider asset-benefit relationship and the flow of ES outside of MPAs. It is fully acknowledged that confidence in the 'likely relative condition' (LRC) of habitats is limited until there is more access and more up to date data on spatial intensity of fishing activity (eg iVMS and VMS at relevant scales). Greater confidence in this approach would be further supported by targeted assessments of 'recovery' of habitats and species to dominant physical pressures (dredging, static gear, anchoring etc.). Current thresholds for GES of seafloor integrity are largely precautionary as there is limited evidence or threshold for a baseline state (what to recover to). Additionally, it is not possible to determine indisputably 'un-impacted' conditions either through modelling/historic data or through marine areas where human effects are currently minimal. Also, if GES for seafloor integrity is defined as 'no human impact' for 85% -95% of a habitat extent outside an MPA (as demonstrated by the precautionary approach taken in this analysis) then it is possible that targets or thresholds become unobtainable. Understanding 'acceptable impact' and sustainable use based on the LRC approach is a key first step. Revisiting proposals for 'Reference Areas' under the Marine and Coastal Access Act to support robust experimental design and inform rational and targeted approaches for recovery of marine systems.

6 Recommendations on key natural capital assets on which future management opportunities could be focussed (Part Four).

The range of habitats across the NDMP support a valuable flow of ecosystem services that underpin human wellbeing. The following recommendations for management opportunities are suggestions for further discussion with the Marine Pioneer Steering Group.

MPAs and the associated management measures cover a relatively small proportion of the NDMP. The ES benefits of Food, Sea Defence, Healthy Climate and Tourism and Recreation are largely supported by MPA management measures for estuarine and coastal intertidal habitats, particularly saltmarsh as well as shallow subtidal reefs and sediments. Given the importance of these habitats to multiple ES, it is necessary to set management priorities that will rapidly enable 'recovery' of habitats where this conservation objective exists. For example, the restoration (extent and condition) of saltmarsh in the NDMP with consideration of the ecological function and connectivity of saltmarshes in the wider Bristol Channel region would benefit multiple ES benefits.

A 'net gain' for natural capital may be achieved via MPA management though a more ambitious approach to marine biodiversity conservation that considers the wider ecological structures and processes that have the potential for 'recovery' and 'renewal' beyond the delineated boundaries of features of conservation interest within an MPA (the whole site approach). ES benefits may be linked to management that seeks a reduction in pressures across the 'whole site' along with the identification of thresholds for sustainable use. For instance, reduction of pressures on intertidal saltmarsh extents (e.g. managing grazing and construction activities on or near saltmarsh in Taw Torridge SSSI) and reduction of pressures negatively impacting sublittoral rock and soft substratum habitats further offshore (e.g. abrasion related to demersal fishing, anchoring and mooring in coastal MCZs), will benefit fish and shellfish populations that utilize multiple habitats as nursery areas or across different life stages.

Identifying habitat extents outside MPAs, that enhance ecological connectivity, would benefit site level management approaches to underpin flows of ES benefits. Studies, currently underway in the Taw Torridge Estuary, to understand the role of estuarine habitats as fish nursery grounds, could be extended to understand use of habitats, and influence of habitat condition, inside and outside coastal MCZs (Hartland Point to Tintagel and Bideford to Foreland Point MCZs) to inform management. Such monitoring would also extend existing knowledge being gathered on the suitability of saltmarsh as bass nursery areas. Fisher-science partnerships could also be developed to assess effectiveness of mitigation projects such as seeding juvenile lobsters within subtidal coarse sediment and reef habitats that have high level of protection from human impacts.

Beyond MPAs, deeper subtidal habitats provided a moderate to significant contribution to the ES benefits 'food' and clean water and sediments'. These habitat assets make up a significant proportion of NDMP. Very large extents of these deeper offshore habitats are in an impacted condition, assessed to have a conservation objective of 'recover', or to be in an impacted 'likely relative condition' (outside of MPAs) due to previous interactions with abrasive pressure from demersal fishing activities. Management must consider increasing both the extent and condition of this habitat under management measures. To support the implementation of management measures that can reduce pressure across subtidal sediments. It is necessary to trial management measures that improve spatial knowledge of fishing and levels of impact across sediment habitats (iVMS).

The natural capital assets and the flow of ES benefits in the NDMP are impacted by diffuse pollution from agriculture (mainly nitrate levels) and acute pollution incidents from the failure of water and sewerage infrastructure. A management goal could be to trial the use of mussels in the Estuary to support Clean Water and Sediments along with seeking investment in water and sewerage infrastructure.

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ANNEXES

ANNEX I Methods to assess water quality status

Additional information on assessment of water body status

Indicator data on the condition of water bodies within NDMP were applied as identified in the review. The indicator for condition for individual sample sites in relation to bathing water quality was altered, as annual assessments of bathing water quality provided more robust analysis of multiple years data to provide water quality assessment (Table 36).

Table 36 Indicators applied in the assessment of Natural Capital Asset Condition for water bodies/water column in NDMP

Indicator Identified in Review		Indicator applied in the study (Yes/No or details of indicator used)
Natural Capital Asset: Condition	Condition (water body): WFD assessment (overall, general, ecological, chemical)	Yes: Condition (water body): WFD assessment (overall, general, ecological, chemical)
	Condition (sample site): n of incidences per year above threshold	Condition (sample site): annual assessment of bathing water quality
		Condition: Shellfish water n of incidences of toxic phytoplankton concentrations above threshold
		Condition: Shellfish water n of incidences of shellfish flesh sample toxins above threshold levels

The main aim of EU water policy and thereby the WFD, is to ensure that a sufficient quantity of good-quality water is available for both people's needs and the environment. The Water Framework

Directive (WFD), which came into force in 2000, established a framework for the assessment, management, protection and improvement of the quality of water resources across the EU, to ensure 'good status' for all water bodies. Water bodies across Europe were identified as ground waters and surface waters (rivers, lakes, transitional (e.g. estuaries) and coastal waters) (European Environment Agency, 2018). Within the NDMP, there are 3 coastal water bodies and 1 transitional water body. The Environment Agency have assessed ecological, chemical, and hydro-morphological status and summarised general status for these water bodies. Water body status data were last assessed in 2015, the assessment published in 2015 relies on data analysed from 2009-2014 (Environment Agency, 2018a).

Status is expressed in terms of five classes (high, good, moderate, poor or bad). These classes are established on the basis of specific criteria and boundaries defined against biological, physico-chemical and hydro-morphological elements. Biological assessment uses numeric measures of communities of plants and animals (for example, fish and rooted plants). Physico-chemical assessment looks at elements such as temperature and the level of nutrients, which support the biology. Hydro-morphological quality looks at water flow, sediment composition and movement, continuity (in rivers) and the structure of physical habitat.

The overall Ecological Status of a water body is determined by whichever of these assessments is the poorer. For example, a water body might pass 'Good Status' for chemical and physico-chemical assessments, but be classed as 'Moderate Status' for the biological assessment: In this case it would be classed overall as 'Moderate Ecological Status' (Environment Agency, 2010). Overall waterbody status, ecological, chemical and morphological status for water bodies within NDMP are summarised in **Table 5**.

Additional information on assessment of bathing water quality

Annual classifications are based on statistical analysis of the previous four years of samples collected between May and September each year. Each sample is tested for bacteria which indicate whether there is faecal matter in the water (Escherichia coli (EC) and Intestinal enterococci (IE)) (Environment Agency, 2018b). Standards used in the assessment are those specified in the Bathing Waters Directive [Bathing Water Directive (2006/7/EC)]. Statistical analysis assesses the probability that in the bathing water season (May to September) most of the time concentrations of Escherichia coli (EC) or Intestinal enterococci (IE) will be below classification thresholds (Environment Agency, 2018b). The classification thresholds for the four classifications are displayed in Table 37.

Table 37 Classification thresholds for predicted Escherichia (EC) or Intestinal enterococci (IE) concentration (colony forming units/100ml).

Coastal Bathing Waters (Environment Agency, 2018b)	
Classification	**Classification threshold: Predicted Escherichia coli (EC) or Intestinal enterococci (IE) concentration (colony forming units/100ml)**
Excellent	EC: ≤250 cfu/100ml ; IE: ≤100 cfu/100ml
Good	EC: ≤500 cfu/100ml ; IE: ≤200 cfu/100ml
Sufficient	EC: ≤500 cfu/100ml ; IE: ≤185 cfu/100ml
Poor	means that the values are worse than the sufficient

Comments on changes in indicators applied

The Bathing Water Data reports annual classifications for each beach (sample point) were used as an indicator in the study, as opposed to n of incidences per year above threshold levels as more comprehensive statistical analysis was used to produce the annual classifications. Data is also not collected all day every day at each sample location and therefore applying the sample data results (Escherichia coli (EC) or Intestinal enterococci (IE) concentration (colony forming units/100ml)) would only record concentrations on a given day and time. The statistical techniques, used to produce annual classifications, using four years data provide a more robust means of assessing water quality for each year.

The no. of incidences of heavy metal and DAIN levels above threshold levels were not recorded in bathing water assessment. Sample data from rivers, estuary and offshore water bodies does record heavy metals and DAIN levels and are available through the Environment Agency Water Quality Data Archive (Environment Agency, 2018c). All mean DAIN levels from sample points in Taw estuary sample points were above threshold levels (hyper-nutrified) in 2017. Heavy metal levels were not compared to a threshold level in available reports. For future assessment heavy metal concentrations can be compared to background assessment concentrations (BAC) (background assessment levels are those levels that would be expected in coastal sediments where there is no anthropogenic impacts), and ecological significance of contaminant concentration values that represent concentration values below those that rarely cause adverse effects in marine organisms.

Such values are provided by Effects Range-Low; ERL, calculated by O’Conner (2004). OSPAR (2017) provide guidelines for assessing the ecological significance of contaminant concentrations in sediment (Effects Range-Low; ERL) as proxy for Environmental Assessment Criteria (EAC), based on United States National Oceanic and Atmospheric Administration guidelines (O'Conner, 2004; OSPAR,

2017) (Table 37). The BAC and ERL concentrations provide potential threshold levels if heavy metal concentrations in sediment are sampled in NDMP.

Table 37 Assessment criteria used for heavy metals in sediment. BAC, Background Assessment Concentrations (normalised to 5%), ERL, Effects Range-Low (O'Conner, 2004); dw, dry weight

	BAC	**ERL**
mg/kg dw	All OSPAR assessment areas except Iberian Sea and Gulf of Cadiz	All OSPAR assessment areas
Cadmium	0.31	1.2
Mercury	0.07	0.15
Lead	38	47

Suggestions for development of Natural Capital assessment indicators to assess water quality

Although not assessed in this report, use of the heavy metal and DAIN records (available in monitoring of coastal water bodies) would provide a useful addition to quality and condition assessment in future natural capital studies.

Terrestrial management practices to increase water quality and meet WFD targets are applied in North Devon, such as catchment sensitive farming (Taw Torridge and North Devon Streams Catchment Sensitive Farming Partnership) (Environment Agency, 2016). Recording area of farmland within catchment sensitive farming schemes and recording other pollution reduction measures within the catchment would be useful for future assessments. Pollution sources affecting Instow have been assessed as 65% from agriculture and 35% from farming. Since the 1980s improvements have been made to the sewerage system, including the installation of secondary treatment and ultraviolet disinfection at the sewage treatment works and correction of misconnections to the surface water system (DEFRA, 2017). Further improvements to 14 combined sewer overflows have been included in the National Environment Plan which runs until 2020 (DEFRA, 2017). Recording all actions and improvements (including costs) would be of use for future assessment.

ANNEX II Assessment of ES benefit Wild Food

Indicators applied in the assessment of extent and condition of natural capital assets providing the ecosystem service benefit Food (wild food)

There were limited changes to the indicators identified in review of ecosystem service literature and existing studies of natural capital assets and provision of ecosystem service benefits (flow of ecosystem services from natural capital assets and economic (monetary) benefits (

Table 38). Limitations were identified in assessment of extent/abundance of species and condition, as available data are limited to beam trawl survey data from sample sites within and adjacent to NDMP and recommendations for TACs for ICES area VII f. The UK Irish Sea and Bristol Channel beam trawl survey design is aimed at assessing stocks at greater spatial scales than NDMP. It is important to consider that stocks of many commercially targeted species also move over greater spatial scales than NDMP. The NDMP is however important to many of these species during important life stages, supporting spawning and nursery grounds (Ellis *et al.*, 2012). In addition to indicators applied in this study, detailed assessments of biomass tonnes/km^2 and/or abundance km^2 of adult and juvenile populations of commercially targeted species, utilising habitats within NDMP would aid future assessment.

Table 38 Summary of the indicators identified in review (Report I) and the indicators applied in the study to assess extent and condition of the extent and condition of natural capital assets supporting the ES Food (wild food)

Indicator Identified in Review		Indicator applied in the study (Yes/No or details of indicator used)
Extent (habitat)	Area of habitats providing moderate or significant contribution to ES Food (wild food)	Yes
Extent (species)	Biomass tonnes/km^2 and/or abundance km^2	**CPUE quota species** (number per hour (per haul)) of species in ICES trawl survey data from sample sites in ICES rectangles intersecting with NDMP
		CPUE of salmon and sea trout in each estuary in NDMP (commercial nets)
Condition (species)	Species diversity, reproduction success (abundance/biomass of year 1 juveniles), TAC of each species, quota for each species.	**Quota species** stocks assessed based on Total Allowable Catch (TAC) scientific recommendations from ICES for area 7f.
		Non-quota species assessed from Cefas stock assessment reports.
		Salmon rivers: assessment in relation to conservation limits (salmon egg deposition)
		Salmon rivers: assessment in relation to management objectives

Methods related to secondary data: Fish and Shellfish Extent and Condition Assessment

<u>Stocks supporting commercial and recreational fisheries</u>

1. **Extent: CPUE (number per haul per hour) of species in ICES trawl survey data from sample sites in ICES rectangles overlapping with NDMP.**

Data on CPUE (number per haul per hour) were accessed through ICES Database of Trawl Surveys (DATRAS) (ICES, 2018). Data for key species for commercial fisheries in North Devon were extracted for years 2010-2017, within the ICES rectangles that overlap NDMP (30E5, 31E5, 31E6). Trawl surveys for stock assessment within ICES area VII f which overlaps with NDMP are conducted by Cefas as part of the UK Irish Sea and Bristol Channel Beam Trawl Survey (ICES, 2009). Surveys are conducted annually over September and October. The surveys consist of a 30 minute tow of a 4m beam trawl with 40mm mesh. The surveys principally target plaice and sole but all species caught are recorded. Species, length, sex and environmental conditions are recorded by surveys (ICES, 2009, 2010). Between 2010 and 2016 hauls were undertaken annually at 22 sample sites in ICES rectangles 30E5, 31E5, 31E6 and in 2017 hauls were undertaken at 17 sites. CPUE (number per haul per hour) data were extracted for each year for the quota species that contribute highest to landings in NDMP (ray species *Raja clavata, Raja brachyura, Raja microocellata,* flatfish species *Solea solea, Pleuronectes platessa*, cod *Gadus morhua* and combined squid species). Data for each species were plotted in line charts and Kendall's tau-b statistical tests of trend strength and direction were undertaken in SPSS.

Condition of species stocks

1. **TAC recommendations to ICES for quota species in ICES area 7f.**

As part of the EU Common Fisheries Policy total allowable catches (TACs), are catch limits (expressed in tonnes or numbers) that are set for most commercial fish stocks. TACs are set based on scientific assessments of the state of fish stocks. They are based on the tonnage of that stock that could be caught while ensuring the supply of fish in the future.

The European Commission set their EU TAC per quota species on the scientific evidence relating to the health of that species. Scientific advice used in setting quota comes from The International Council for the Exploration of the Seas (ICES), which makes recommendations on how fisheries should be managed in future for conservation of the species (EU, 2018; ICES, 2018b).

ICES advise on TAC for each species is based on 3 main indicators, the reproductive biomass of the stock (spawning stock biomass), the mortality of the species stock related to fishing mortality (landings and discards) and recruitment of age 1 fish (number (in millions)). The relationship of these factors is considered in relation to precautionary limits (such as existing management measures) and maximum sustainable yield. Maximum sustainable yield (MSY) is interpreted by ICES as: '*maximizing the average long-term yield from a given stock while maintaining productive fish stocks within healthy marine ecosystems*' (ICES, 2018b; Lart & Caveen, 2016).

Reproductive biomass (spawning stock biomass) and recruitment of age 1 fish are assessed from ICES trawl survey data. Surveys for ICES area VII f which overlap with NDMP are conducted by Cefas as part of the UK Irish Sea and Bristol Channel Beam Trawl Survey (ICES, 2009). The French Groundfish Survey in the Celtic Sea and Bay of Biscay sample sites also provide data as part of the International Bottom Trawl Survey for assessment of species in area VII f (ICES, 2010).

Fishing mortality is calculated from landings data and discard estimates (ICES, 2018b). Discard estimates are based on data from observer schemes and discards which in accordance with landings obligations should be landed (ICES, 2018b). Landings obligations been phased in under the reformed Common Fisheries Policy of 2013 since 2015 and are intended to cover all fisheries by 2019 and previous discard estimates were based on observer and log book data (European Commission, 2018).

The recommended TAC, based on scientific advice for each year 2010-2017 for the species with the greatest contribution to landings by vessels from NDMP ports were accessed from ICES online resources ((ICES, 2018a)). Line charts were produced for recommended TAC (t) for each species between 2010-2017 and Kendall's tau-b statistical tests of trend strength and direction were undertaken in SPSS.

2. **Condition of non-quota species assessed from Cefas stock assessment reports.**

Assessment of crab and lobster stocks in relation to NDMP were available only for the wider south west (West Somerset, Devon and Cornwall) region. Assessment is undertaken by Cefas and status of stocks are reported every 2-3 years. Landings data were analysed from MMO data, in relation to fishing effort (Fishing effort is derived by the MMO from Monthly Shellfish Activity Returns for <=10m vessels or EU logbooks for >10m vessels). Scientific officers undertaking port visits also measure individual animals and determine ratio of landings by sex. Samples are also received from IFCA's in some regions, and these length samples are combined with Cefas' and scaled up to represent the total landings of crab and lobster (Cefas, 2017).

The status of stocks are assessed by plotting the length frequency numbers from one year to the next (numbers at each length). Growth rates and life expectancy of crab or lobster dictates how many animals at a given size there are in a population. The shape of the length frequency plot is used to infer the rate at which the fishery is removing individuals. The level of exploitation of the fishery (effort and landings data) and the sustainability of the fishery (from assessing length frequency plots) are provided in each stock status report (Cefas, 2017a).

3. **CPUE of Salmon and sea trout in each river in NDMP .**

Commercial catches of salmon and sea trout in NDMP rivers/estuaries (Taw and Torridge estuaries) are available in relation to fishing effort, calculated as number per license day. Data are published annually by Environment Agency and Natural Resources Wales (Environment Agency & Natural Resources Wales, 2017). The net season is concentrated in summer months (1 June to 31st July).

4. Condition of salmon and sea trout rivers (meeting management objectives).

ICES provides scientific advice to the North Atlantic Salmon Conservation Organization (NASCO). NASCO support activities under the Convention for the Conservation of Atlantic Salmon (1983). NASCO require contracting parties to set conservation limits and management targets for all river stocks of salmon in NE Atlantic. Advice is provided to ICES for salmon stocks in the NDMP estuaries/rivers (Taw, Torridge, Lyn) within annual reports by Cefas, Environment Agency and Natural Resources Wales (Cefas, Evironment Agency & Natural Resources Wales, 2018).

Stock conservation limits are the reference point to maintain stocks within safe and sustainable biological limits. The Environment Agency and Natural Resources Wales monitor both stocks and fishery performance in most rivers supporting salmon stocks in England and Wales. This includes operating counters, undertaking surveys of juvenile fish and collecting fishery statistics. These data provide the basis for assessing stock status against conservation limits and informing management decisions (Cefas, Evironment Agency & Natural Resources Wales, 2018).

The ‘management objective’ for salmon stocks in England and Wales is that they should meet or exceed their CLs in at least four years out of five. Compliance with this objective takes into account stock size (defined in terms of eggs deposited) below which further reductions in numbers of spawning adults are likely to result in significant reductions in the number of juvenile fish produced in the next generation. Egg deposition estimates for 2017 have been calculated for each of the 64 main salmon rivers in England and Wales (Cefas, Evironment Agency & Natural Resources Wales, 2018). Further information on methods to assess salmon stocks and fisheries are provided in background reports to the annual assessment of salmon stocks (Cefas, Environment Agency & Wales, 2017). Main salmon rivers in NDMP, assessed in this report include the Taw, Torridge and Lyn.

5. Landings volume (t) species supporting NDMP fisheries

MMO fishing activity data

Data on the volume of species landed by vessels fishing from NDMP ports were obtained from the Marine Management Organisation (MMO) for each vessel that has fished from ports within NDMP

2012-2016. Individual fishermen from each NDMP port were invited to agree to share individual vessel data for use in data collection, to provide a data set of fishing activity (landings volume by species) of vessels operating form NDMP ports (2012-2016).

The catch data included the wet weight reported by fishermen and fish merchants to the MMO, landed at ports within NDMP by local vessels. The data set included the total annual wet weight landed for each species, for each vessel that fishermen had provided agreement for data to be used in the study. We understand that these data could be underestimating the actual landings and fishing effort as not all vessels that fish in NDMP (from ports outside of the NDMP boundary) are included. For those vessels included, there is no statutory requirement for fishermen to declare their catches for 10 metre and under vessels. Landings records for 10 metre and under vessels are therefore collated from log sheets and landings declarations supplied by fishermen and sales notes from buyers and sellers (MMO, 2016). We have, however, used this data set as it presents the official landings and provides a proxy indicator for fishing activity of vessels operating form NDMP ports.

6. **Landings value (£) from NDMP fisheries**

To provide landings value, value per tonne for each species in 2017, from figures obtained in report 1 (Ashley, Rees & Cameron, 2018) were used to calculate the value per tonne of each key commercial species, by vessels fishing from NDMP ports. As a single years value per tonne data were used, trends in value have limited confidence as these are estimated based on landings volume data, and changes between years in value of each species are not accounted for.

Data were requested on value of landings for each key commercial species, for each year 2010-2017 from the Marine Management Organisation (MMO) (as well as landings volume (t)) for ICES rectangles that intersect with NDMP (30E4, 30E5, 31E4, 31E5, 31E6). The data request was not processed in the timespan of the project.

Indicators applied in the assessment of flow from natural capital assets to ecosystem service benefit and economic benefits for the ES Food (wild food)

Although landings volume data were applied in the study indicators for landings volume per unit effort and spatial fishing effort were unavailable due to economic sensitivity restrictions on the fishing activity data that can be provided from the UK fishing activity database by MMO. Proxies for spatial effort were applied through face to face interview and mapping exercises with fishermen in

NDMP ports. Fishermen were provided the opportunity to comment and update spatial activity data gathered during the Finding Sanctuary 2009-2012 Marine Conservation Zone project FisherMap process (des Clers, 2010). This work is ongoing but results were insufficient to confidently associate annual landings data for vessels fishing in NDMP ports with fishing spatial effort. Landings value per species per year were not available in MMO data sets accessed for the study. Value was therefore calculated for each year based on 2016/17 values for each species (Table 39).

Table 39 Summary of the indicators identified in review and those applied in the study to assess physical flow and economic benefits relating to the ES Food.

Indicator Identified in Review		Indicator applied in the study (Yes/No or details of indicator used)
Ecosystem service flow	Landings (per unit effort) kg	**Annual total landings (t**) for all species between 2010-2017 were accessed from the MMO. The data were for a subset of vessels that fished from NDMP ports (annual minimum 7 vessels (2010) and maximum 12 vessels (2015)). Landings per unit effort could not be calculated from this data set.
	Landings spatial effort	**High priority grounds and seasonal use for each fishery** were identified in interviews and face to face mapping with fishermen in NDMP ports. The mapping exercise updated 2010-2012 Finding Sanctuary Fishermap maps.
	Nutrition from seafood harvested	Not calculated in this study
	Rod and net catch for salmon rivers/estuaries	**Environment Agency annual data from salmon and sea trout assessments** provided rod and net catch per license day for salmon and sea trout, for NDMP rivers/estuaries. Net catch was applied as an indicator for the ES Food, rod catch was applied under the ES Tourism/recreation.
Economic benefit	Landings (per unit effort) £	Landings value per species per year was not provided in MMO data sets available for the study. **Value was calculated for each year based on 2016/17 values for each species.**
	Number of businesses supported (vessel numbers)	**Registered under 10m and over 10m vessel numbers for NDMP ports 2010-2017** were accessed from MMO vessel lists. Number of known active vessels numbers for NDMP ports were calculated for 2010-2017 from MMO fishing activity data.
	Number of businesses supported (processors and markets/fish sellers)	Number of businesses 2016/17 were accessed from North Devon FLAG data.
	Number of businesses supported (boat building, engineering)	Number of businesses 2016/17 were accessed from North Devon FLAG data.

Suggestions for development of Natural Capital assessment indicators relating to the ES benefit 'Food'

Data on biomass or abundance of commercially targeted species within NDMP are limited to advised TAC from scientific recommendations based on spawning stock, mortality (landings and discards) and recruitment over large scale areas. These measures are suitable for very mobile stocks but may under estimate (or over estimate) populations of species that do not have a great spatial range. There is uncertainty of migration patterns and home range of some species such as smalleyed ray *R. microocellata* (Ellis, 2009). Further study of quota species abundance and range in relation to NDMP would inform future manage decisions regarding management of fisheries and quota provision on smaller spatial scales. Likewise, data on crab *C. pagarus* and lobster *H. gammarus* abundance and habitat use within NDMP would aid conservation and management, as well as assessment of effectiveness of lobster hatchery restocking schemes that have historically been used in the region.

Sample sites of CPUE from annual Irish Sea and Bristol Channel Beam Trawl Data are limited within NDMP and limited confidence can be attributed to the data at small spatial scales. Fishermen-science partnerships are likely to provide a cost effective means of informing smaller scale stock assessment to ensure fisheries are sustainable.

NDMP contains spawning grounds for herring *C. harengus* (cod *G. morhua*, sole *S. solea*, plaice *P. platessa*, and thornback ray *R. clavata*) and nursery grounds for herring *C. harengus*, bass *D. labrax*, cod *G. morhua*, sole *S. solea*, plaice *P. platessa* and thornback ray *R. clavata* (Ellis, 2012). Saltmarsh and infralittoral reef habitats were reviewed to provide the greatest importance as nursery habitat for these species (Report 1) (Ashley, Rees & Cameron, 2018). Use of saltmarsh habitats is currently being investigated by the ibass project (Thomas Stamp, University of Plymouth personal communication, 2018). However, there are limited data available for NDMP on use of infralittoral reef habitats by juvenile fish and shellfish species and links to adult population (stocks) in the regional seas.

Results from current studies in 2017/18 and future research on this topic will benefit assessment of flow of ES benefits from natural assets. Studies of use of habitats, particularly estuarine and inshore habitats and population abundance within Taw Torridge SSSI, Lundy SAC, Hartland Point to Tintagel MCZ and Bideford to Foreland Point MCZ, for juvenile and adult populations of commercial stocks will be of benefit to managing activities to support sustainable fisheries. This will inform options to ensure species benefit from management targeted at important life stages to support harvestable stocks (such as protecting nursery areas).

Studies of use of nursery areas would also inform knowledge on range and condition of ray species (such as smalleyed ray *R. microocellata*) that potentially do not move over the entire VII f ICES area that TAC and quota are assessed for. Evidence on habitat use in NDMP, over life history stages, may inform population assessment and sustainable fisheries management of these species. It is important to consider that International Conservation Union (IUCN) have rated the thornback ray *R. clavata*, blond ray *R. brachyura* and smalleyed ray *R. microocellata* as "Near Threatened" in the northeast Atlantic (Ellis, 2009).

ANNEX III Trends in landings (live weight and value) for landings of fish and shellfish by all UK and foreign vessels to all NDMP ports

Trends in landings to all NDMP ports (Devon and Cornwall), from MMO data on UK fleet and foreign fleet landings, are similar to trends in landings recorded only for vessels that were identified to fish within the NDMP. The landings live weight and value data reported below were similar across both data sets for demersal and pelagic fish species. Although trends were similar, there were, however, greater landings weights and values recorded for shellfish species. This may be due to additional landings included in the MMO data set for all landings to ports (including landings from outside NDMP), from visiting vessels, or landings from the ~2 vessels from North Devon ports that consent was not provided for to access individual vessels data (or a combination of both).

As with data for vessels that fish within NDMP, whelk *Buccinum undatum* (282.05 t), blonde ray *Raja brachyura* (114.59 t) and thornback ray *Raja clavata* (75.38 t) also contributed the highest volume per species to total landings (live weight) to all NDMP ports in 2017. Crab *C. pagurus* (32.16 t) and Lobster *H. gammarus* (23.1 t) contributed the next highest landings volume. Small-eyed ray *Raja microocellata* (7.55 t) and flat fish species (sole *S. solea* (4.88 t), plaice *P. platessa* (3.74 t)) as well as cod *G. morhua* (2.82 t) and bass *D. labrax* (3.89 t), provided much smaller contributions to live weight of species landed by vessels fishing from NDMP ports in 2017 (Table 16, Figure 12).

Of species with highest contribution to landings volume for all NDMP ports, only landings of whelk *B. undatum* and herring *C. harengus* have shown an increasing trend since 2010. Whelk landings increased from 486.93 t in 2010 to a peak of 2069.66 t in 2013, although landings had decreased to 282.05 t in 2017. The very large peak in *B. undatum* landings were due to a landing to one port of 1476 t in 2013, an anomaly that wasn't repeated in other years in the time series and so may also be an error in the MMO landings data set. A very weak positive trend in *B. undatum* and herring *C. harengus* landings was identified by Kendal's tau-*b* across the entire 2010-2017 time series (Kendall's tau-b 0.07, *p*=0.8). All other species displayed a negative trend in landings volume between 2010-2017 (Table 16, Figure 31, 32).

For flatfish (*S. solea* and *P. platessa*), crab *C. pagurus and* lobster *H. gammarus* negative trends were much stronger (all significant (p=>0.05) for all landings to NDMP ports, in contrast to the weak, not significant negative trend for vessels that fished within the NDMP (Table 41, Table 16). Flatfish landings are likely to be dependent on available quota, but crab and lobster landings are not limited by quota. Lobster *H. gammarus* landings initially increased from 32.2 t in 2010 to a peak of 39 t in 2013. Lobster *H. gammarus* landings to all NDMP ports has since declined from 2013, to 23.1 t in 2017 (Figure 32). Brown crab *C. pagurus* landings to all NDMP ports were at their highest in 2010

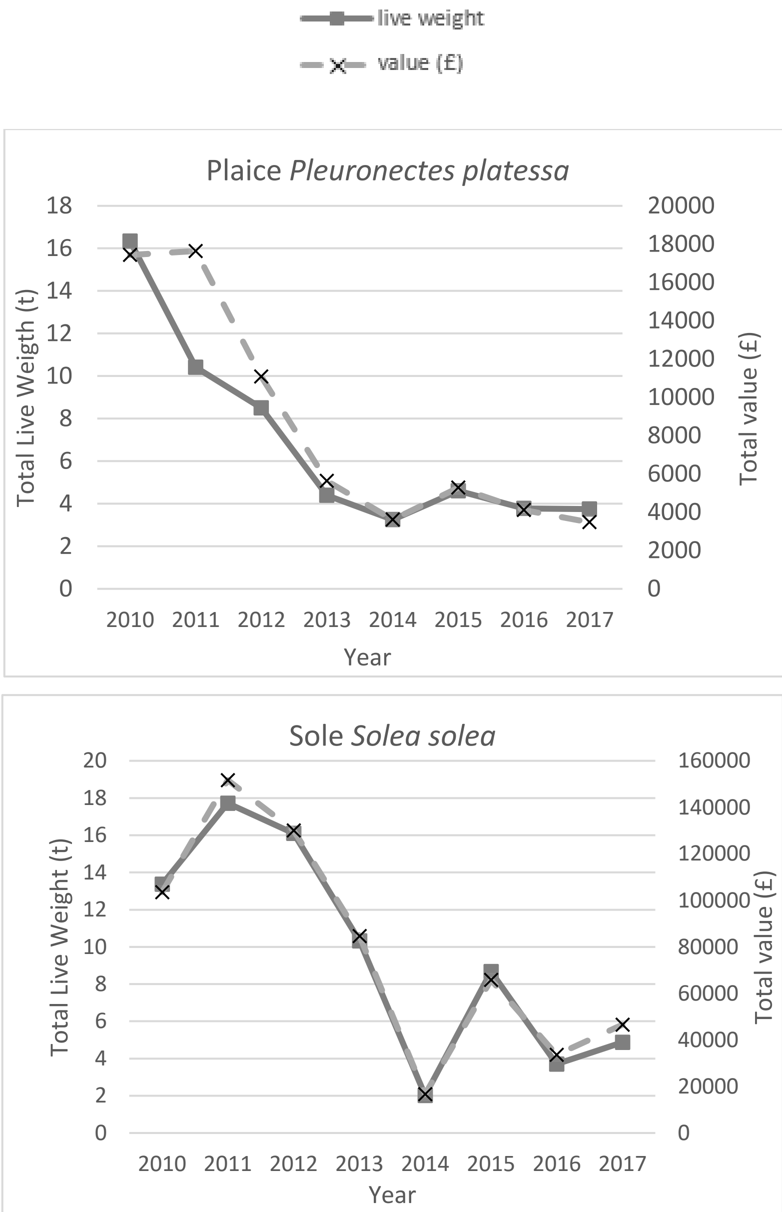
(130 t) and have since declined to 32 tonnes in 2017, the largest annual decline was from 85 t in 2014 to 46.7 t in 2015 (Figure 31).

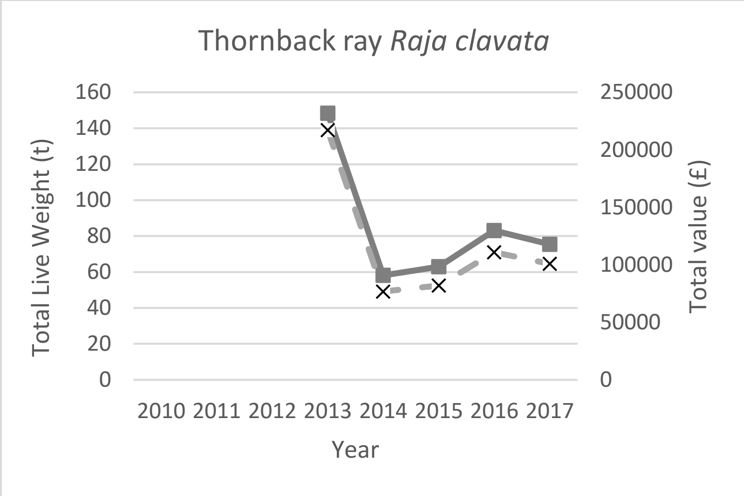
Negative trends in landings data to all NDMP ports were also significant for bass *D. labrax,* and squid (all species) (Table 41). As with landings from vessels that only fished within the NDMP, landings to all ports from all vessels of small eyed ray *R. microcellata*, also displayed a significant negative trend between 2010-2017 (Table 16). Landings for all these species are limited by quota, TAC has decreased or management measures have been introduced to limit targeted fisheries for these species and as such changes in quota for the wider ICES area are likely to effect landings as well as local abundance. Also, as effort data were unavailable it can not be assessed confidently if these trends are due to changes in fishing effort, changes in quota or management or abundance of local stocks.

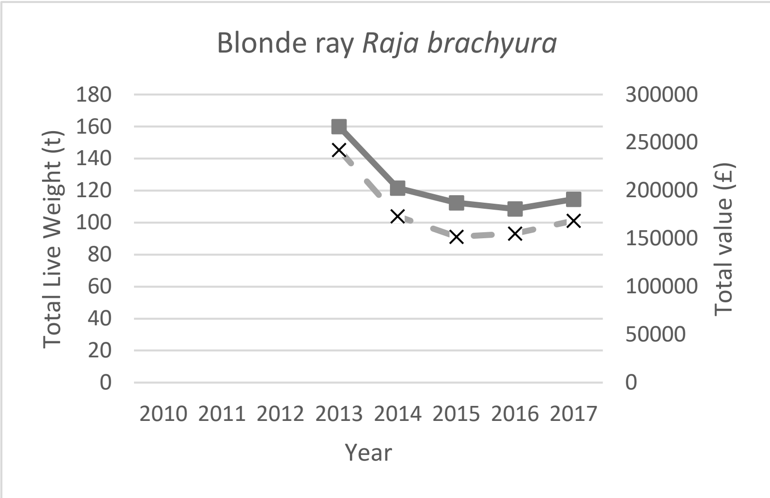
Table 40 Landings of commerially caught fish by vessels based in NDMP ports (2010-2017) (tonnes per year) and salmon and sea trout catch (n per liecense day) from salmon and sea trout net fishery license holders in NDMP rivers and estuaries.

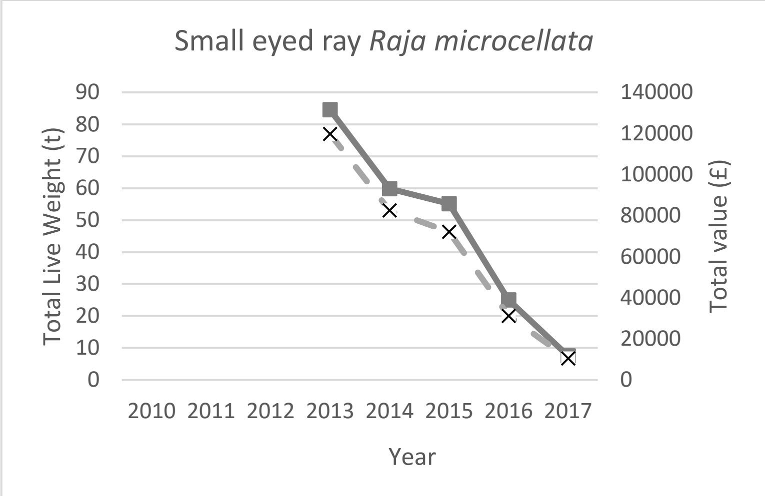
Natural Capital: Flow from Assets to Physical Benefits	Indicator	Species	Unit	Port/River	Baseline year 2017	Baseline Trend 2010-2017	Correlation coefficient (Kendall's tau-b)	Signifi-cance
Species stocks (for each fish and shellfish species used for food)	MMO Fishing Activity data: Landings, to ports in NDMP	Cod	t/yr	All NDMP	2.9	↓	-0.357	0.216
		Plaice	t/yr	All NDMP	3.74	↓	**-0.714**	**0.013**
		Sole	t/yr	All NDMP	4.88	↓	**-0.571**	**0.048**
		Herring	t/yr	All NDMP	0.18	↑(↔)	0.071	0.805
		Thornback ray	t/yr	All NDMP	75.38	↓	-0.525	0.364
		Small eyed ray	t/yr	All NDMP	7.55	↓	**-0.98**	**0.002**
		Blonde ray	t/yr	All NDMP	114.59	↓	-0.6	0.142
		Crab	t/yr	All NDMP	32.16	↓	**-0.857**	**0.003**
		Lobster	t/yr	All NDMP	23.1	↓	**-0.571**	**0.048**
		Whelk	t/yr	All NDMP	282.05	↑(↔)	0.071	0.805
		Squid	t/yr	All NDMP	0.05	↓	**-0.643**	**0.026**
		Bass	t/yr	All NDMP	3.89	↓	**-0.571**	**0.048**

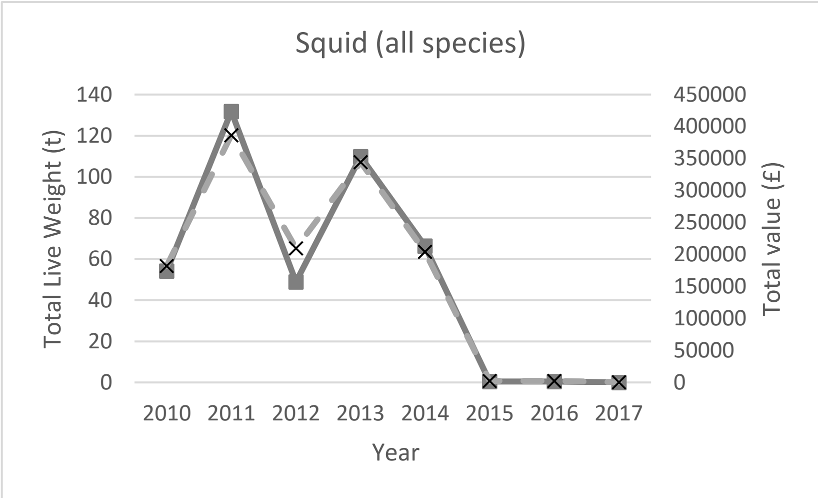
Figure 30 Landings trends for key quota species in NDMP fisheries (landings by UK vessels and foreign vessels to all NDMP ports) live weight (t) is indicated by a solid line and solid square, value (£) is indicated by a dashed line and a cross.

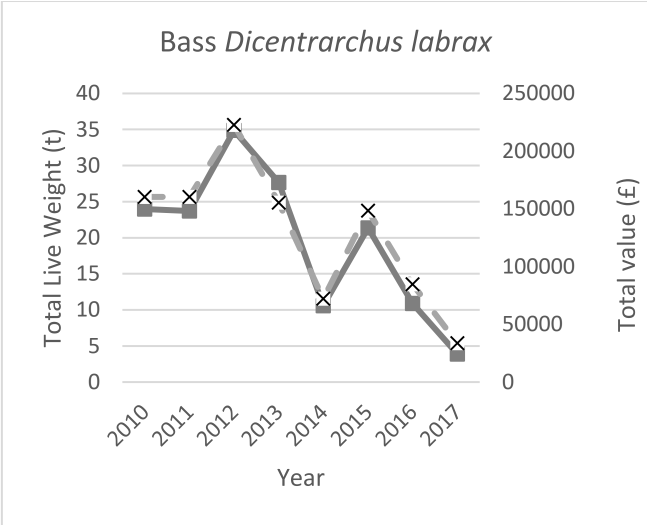


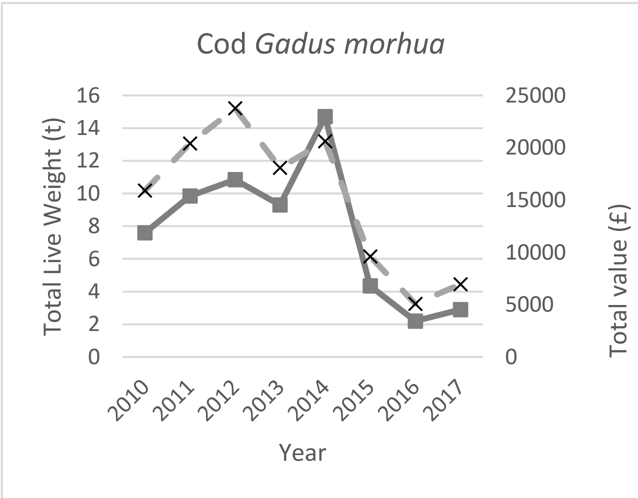

Thornback ray *Raja clavata*
Total Live Weight (t)
Total value (£)
160
140
120
100
80
60
40
20
0
250000
200000
150000
100000
50000
0
2010 2011 2012 2013 2014 2015 2016 2017
Year


Blonde ray *Raja brachyura*
Total Live Weight (t)
Total value (£)
180
160
140
120
100
80
60
40
20
0
300000
250000
200000
150000
100000
50000
0
2010 2011 2012 2013 2014 2015 2016 2017
Year


Small eyed ray *Raja microcellata*
Total Live Weight (t)
Total value (£)
90
80
70
60
50
40
30
20
10
0
140000
120000
100000
80000
60000
40000
20000
0
2010 2011 2012 2013 2014 2015 2016 2017
Year


Squid (all species)
Total Live Weight (t)
Total value (£)
140
120
100
80
60
40
20
0
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
2010 2011 2012 2013 2014 2015 2016 2017
Year


Bass *Dicentrarchus labrax*
40
35
30
25
20
15
10
5
0
250000
200000
150000
100000
50000
0
Total Live Weight (t)
Total value (£)
2010
2011
2012
2013
2014
2015
2016
2017
Year


Cod *Gadus morhua*
16
14
12
10
8
6
4
2
0
25000
20000
15000
10000
5000
0
Total Live Weight (t)
Total value (£)
2010
2011
2012
2013
2014
2015
2016
2017
Year

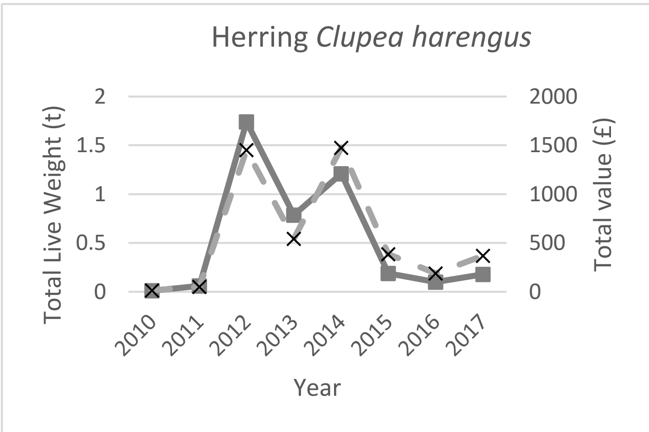
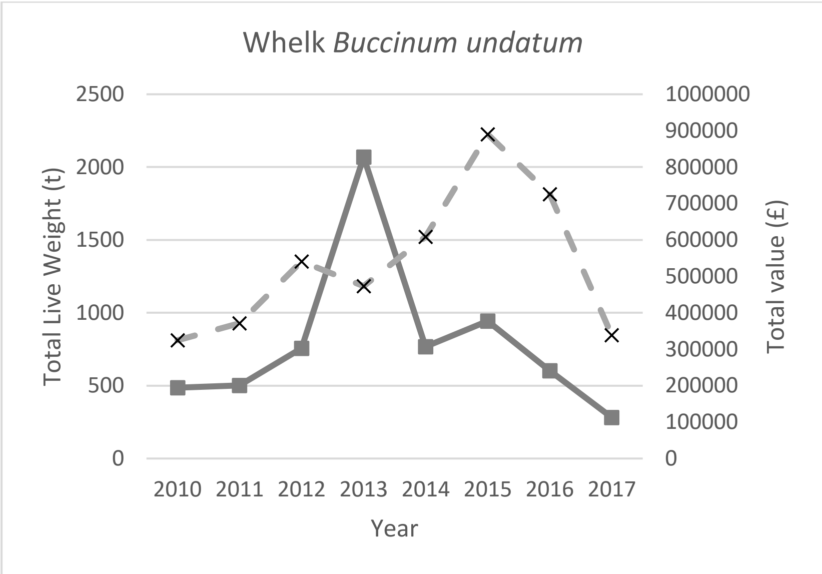
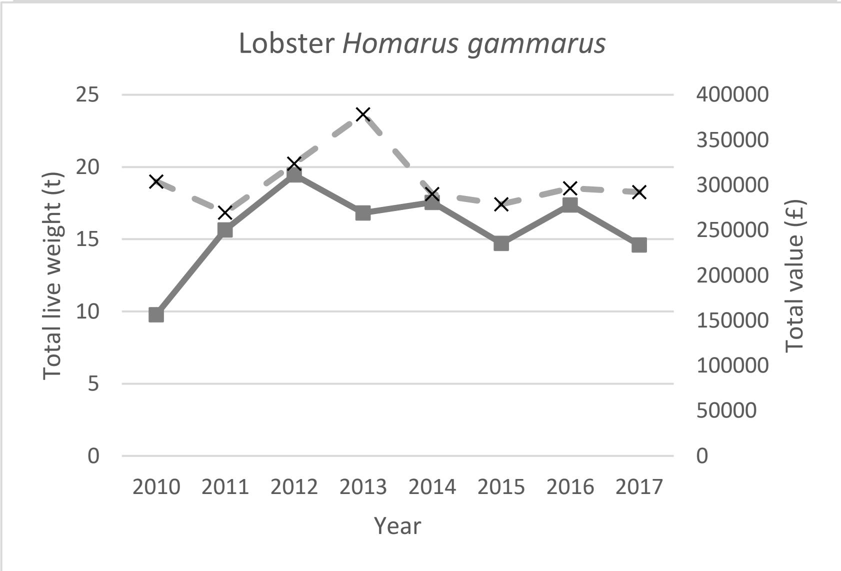
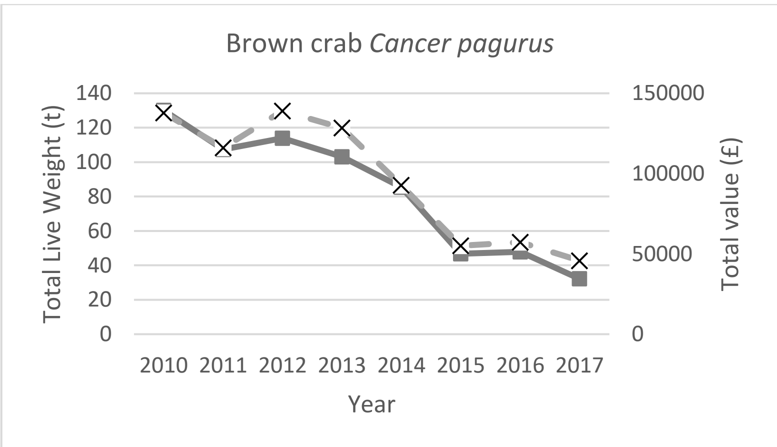

Herring *Clupea harengus*
2
1.5
1
0.5
0
2000
1500
1000
500
0
Total Live Weight (t)
Total value (£)
2010
2011
2012
2013
2014
2015
2016
2017
Year

Figure 31 Landings trends for key non-quota species in NDMP fisheries (landings by UK vessels and foreign vessels to all NDMP ports) live weight (t) is indicated by a solid line and solid square, value (£) is indicated by a dashed line and a cross.







Economic benefit: Annual landings value (£) per species to vessels operating from NDMP ports

Landings value recorded in MMO fishing activity data for landings to all NDMP ports from all UK and foreign vessels were highest in 2017 for lobster *H. gammarus* (£292,154.02) whelk *B. undatum* (£339,107.40) blonde ray *R. brachyura* (£130,144.30) thornback ray *R. clavata* (£99,434.04) and sole *S. solea* (£46,536.43) (Table 42). As with the data set for vessels that were identified to fish within NDMP, thornback ray *R. clavata*, blonde ray *R. brachyura* and whelk *B. undatum* represent low value species that are landed in relatively high volume (75-282 tonnes) (Table 41, Table 17). Lobster *H. gammarus* and sole *S. solea* represent higher value species that are landed in smaller volumes (4.9 t *S. solea*, 23.1 t lobster *H. gammarus*).

Table 41 Landings value (estimate) of commercially caught fish by vessels based in NDMP ports (2017)

Natural Capital: Flow from Assets to Economic Benefits	Indicator	Species	Unit	Port	Baseline year (£/yr) 2017	Trend (Landings live weight) 2010-2017	Correlation coefficient (Kendall's tau-b) (landings live weight)	Signifi-cance
Species stocks (for each fish and shellfish species used for food)	MMO Fishing Activity data: Landings, to ports in NDMP from ICES rectangles in NDMP	Cod	£/yr	All North Devon	6,943.03	↓	-0.429	0.138
		Plaice	£/yr	All North Devon	3,472.12	↓	**-0.786**	**0.006**
		Sole	£/yr	All North Devon	46,536.43	↓	**-0.571**	**0.048**
		Herring	£/yr	All North Devon	370.57	↑(↔)	0.143	0.621
		Thornback ray	£/yr	All North Devon	101,019.80	↓	-0.546	0.341
		Small eyed ray	£/yr	All North Devon	10,530.46	↓	**-0.99**	**0.001**
		Blonde ray	£/yr	All North Devon	130,144.28	↓	-0.4	0.327
		Crab	£/yr	All North Devon	45,798.33	↓	**-0.714**	**0.013**
		Lobster	£/yr	All North Devon	292,154.02	↓(↔)	-0.071	0.8
		Whelk	£/yr	All North Devon	339,107.40	↑(↔)	0.429	0.138
		Squid	£/yr	All North Devon	346.60	↓	**-0.543**	**0.026**
		Bass	£/yr	All North Devon	33,654.22	↓	**-0.543**	**0.026**

Quotas for sole *S. solea* and ray species will influence annual landings. Lobster *H. gammarus* and *C. pagarus* are non quota and the fishery is likely to be significant for supporting fishing businesses in NDMP. Crab *C. pagurus* landings and associated value have decreased between 2010-2017, lobster *H. gammarus* landings by weight have decreased between 2010-2017 but increase in value have led to a smaller decline in value for the landings between 2010-2017 (Figure 13).

ANNEX IV Healthy Climate

The data and literature resources applied to assess contribution of natural assets to the ES benefit ‘Healthy Climate’ are summarised in Table 42.

Table 42 Carbon sequestration values t/C/km2/yr presented in literature reviewed for each habitat asset presented in NDMP. Confidence in the assessment based on review by Howard et al. 2017 and corresponding carbon value (£/t).

Habitat		Area	Carbon sequestered t/C/km²/yr	Confidence (1=poor, 2=moderate, 3=high)	Reference	Benefit (Flow) (adjustred for presence of required L4 habitat) carbon sequestered (t)	Carbon value (£/t CO_2e) value given to the cost of mitigating emissions (central)	Carbon value (£/t CO_2e) value given to measure the long term damage by a tonne of carbon
Saltmarsh	A2.5: Saltmarsh	2.80	206.68	2 (likely underestimate (Howard et al. 2017))	(Scott et al. 2013; Chumara et al. 2003) (Mcleod et al. 2011; Duarte et al. 2013; Howard et al. 2017)	549.77	2270.55	12672.17
Intertidal rock	A1: Littoral rock and other hard substrata **(with seaweed and plant communities)**	11.31	393.68	1	(Trevathan-Tackett et al. 2015; Gevaert et al. 2008; Alonso et al. 2012)	445.15	1838.49	10260.80
Intertidal sediments	A2.2: Littoral sand and muddy sand	14.99				0.00	0.00	0.00
	A2.3: Littoral mud	9.98	16.00	1	(Andrews et al. 2006; Alonso et al. 2012)	159.68	659.47	3680.60
Biogenic reef	A2.7: Littoral biogenic reefs	0.01				0.00	0.00	0.00
Subtidal reef	A3: Infralittoral rock and other hard substrata **(with seaweed and particularly kelp communities)**	17.27	393.68	1 Must Contain Kelp communties (A3.11, A3.12) (Sequestration less likely as no root system in soft substratum (Howard et al. 2017))	(Gevaert et al. 2008; Alonso et al. 2012)	680.05	2808.59	15675.06
	A4: Circalittoral rock and other hard substrata	875.90	unknown / 0			0.00	0.00	0.00
Subtidal sediment to 50m	A5.1: Sublittoral coarse sediment	2,845.22	9.84	1	(Painting et al. 2010; Alonso et al. 2012)	26597.08	109845.92	613062.59
	A5.2: Sublittoral sand	1,690.03	9.84	1	(Painting et al. 2010; Alonso et al. 2012)	15798.43	65247.50	364153.72
	A5.3: Sublittoral mud	10.85	9.84	1	(Painting et al. 2010; Alonso et al. 2012)	101.45	419.00	2338.48
	A5.4: Sublittoral mixed sediments	48.56	9.84	1	(Painting et al. 2010; Alonso et al. 2012)	453.97	1874.92	10464.12
Subtidal sediment >50m to <200m	A5.1: Sublittoral coarse sediment	2,845.22	0.00	1	Thomas et al. 2005	0.00	0.00	0.01
	A5.2: Sublittoral sand	1,690.03	0.00	1	Thomas et al. 2005	0.00	0.00	0.01
	A5.3: Sublittoral mud	10.85	0.00	1	Thomas et al. 2005	0.00	0.00	0.00
	A5.4: Sublittoral mixed sediments	48.56	0.00	1	Thomas et al. 2005	0.00	0.00	0.00
Phytoplankton	Water column	5526.93	0.004	1	(Falkowski 2012; Howard et al. 2017)	19.90	82.17	458.62
TOTAL						44805.47	185046.61	1032766.19

ANNEX IV Assessment of ES benefit Tourism and Recreation

Indicators applied in the assessment of extent and condition of natural capital assets for the ES Tourism and Recreation.

Indicators remained unchanged from those identified in reviews (Report 1) (Ashley, Rees & Cameron, 2018) for assessing natural capital assets and flow from assets to physical benefits relating to the ES Tourism and Recreation (Table 43, Table 44). Assessment of indicators relating to economic benefits from the flow from natural assets to ES benefits for the ES Tourism and Recreation relied solely on calculation of spend per day of participants boating and on water activities (total and n per site), with annual spend on equipment also accounted for. Details of businesses supported will be reported within upcoming reports from NDC.

Table 43 Summary of the indicators identified in review and those applied in the study to assess extent and condition of natural assets contributing to the ES Tourism and Recreation

Indicator Identified in Review		Indicator applied in the study (Yes/No or details of indicator used)
Natural Capital Assets: Extent and Condition	Extent of habitats providing moderate or significant contribution to ES 'Tourism/Recreation'	Yes
	Extent of waterbody supporting recreational activities	Yes
	Water quality – Water body status	Yes (see 'Water Quality' section)
	Water quality – bathing water quality	Yes (see 'Water Quality' section)
	Fish Stocks (TAC for species targeted by recreational anglers)	Yes (see species stocks supporting ES Fish (wild food)
	Condition of salmon rivers (egg deposition estimates related to Conservation Limits)	Yes, **Cefas and Environment Agency annual data from salmon and sea trout assessments** (see species stocks supporting Fish (wild food)
	Stocks of salmon and sea trout (CPUE net fisheries and catch per license day for rod fishery)	Yes, **Environment Agency annual data from salmon and sea trout assessments** provided rod and net catch per license day for salmon and sea trout, for NDMP rivers/estuaries.
	Presence and spatial abundance of species of interest to nature watching	Completed for limited species
	Biodiversity index for species communities of reef habitats and other features of interest to nature watching (scuba diving/snorkelling)	Not available
	Coastal access (length of coast path, number of access points and designated bathing water beaches)	All except number of access points are included
	Number of diving sites	Yes (North Devon Council Participant Survey)
	Participant reported quality of sites	Yes (North Devon Council Participant Survey)
	Number of recreational fishing 'marks'	Yes (North Devon Council Participant Survey)
	Participant reported quality of fishing 'marks'	Yes (North Devon Council Participant Survey)
	Number of surfing locations (suitable for all levels)	Yes (North Devon Council Participant Survey, and review of guide books)

	Participant reported quality of surfing sites	Yes (North Devon Council Participant Survey)
	Number of sites visited for wildlife watching	Yes (Consultation with tour operators)
	Participant reported quality of wildlife watching sites	Yes (Consultation with tour operators)

Table 44 Summary of the indicators identified in review and those applied in the study to assess physical flow from assets to benefits relating to the ES benefit Tourism and Recreation.

Indicator Identified in Review		Indicator applied in the study (Yes/No or details of indicator used)
Ecosystem service flow	Visitor numbers (overnight stays)	Yes (Visit England data)
	Number of participants (beach visits/swimming)	Yes (no of bathers per 100m for each designated bathing water beach)
	Number of participants diving (total and n per site)	Yes (North Devon Council participant survey)
	Number of participants angling (total and n per site)	Yes (North Devon Council participant survey)
	Rod catch per license day for salmon rivers/estuaries	**Environment Agency annual data from salmon and sea trout assessments** provided rod catch per license day for salmon and sea trout, for NDMP rivers/estuaries.
	Number of participants surfing (total and n per site)	Yes (North Devon Council participant survey)
	Number of participants (wildlife watching)	Yes (North Devon Council participant survey)
	Number of participants boating and on water activities (total and n per site)	Yes (North Devon Council participant survey)

Table 45 Summary of the indicators identified in review and those applied in the study to assess economic benefits from the flow from natural assets to ES benefits for the ES Tourism and Recreation.

Indicator Identified in Review		Indicator applied in the study (Yes/No or details of indicator used)
Economic Benefit	Visitor numbers (overnight stays) spend/value of visits	Yes (Visit England data)
	Businesses supported (accommodation)	NO (North Devon Council business survey results were not reported within the timescale of the project)
	Spend per day of participants (beach visits/swimming)	Yes (no of bathers per 100m for each designated bathing water beach)
	Businesses supported (beach and swimming)	NO (North Devon Council business survey results were not reported within the timescale of the project)
	Spend per day of participants diving (total and n per site)	Yes (North Devon Council participant survey)
	Businesses supported (diving equipment and charter vessels)	NO (North Devon Council business survey results were not reported within the timescale of the project)
	Spend per day of participants angling (total and n per site)	Yes (North Devon Council participant survey)
	Businesses supported (angling equipment and charter vessels)	NO (North Devon Council business survey results were not reported within the timescale of the project)
	Spend per day of participants surfing (total and n per site)	Yes (North Devon Council participant survey)
	Businesses supported (surfing equipment rentals, sales and schools)	NO (North Devon Council business survey results were not reported within the timescale of the project)
	Spend per day of participants (wildlife watching)	Yes (North Devon Council participant survey)
	Businesses supported (tour operators and charter vessels)	NO (North Devon Council business survey results were not reported within the timescale of the project)

	Spend per day of participants boating and on water activities (total and n per site)	Yes (North Devon Council participant survey)
	Businesses supported (equipment and schools)	NO (North Devon Council business survey results were not reported within the timescale of the project)

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