

# NATURAL CAPITAL ASSET AND RISK REGISTER TO INFORM THE TAMAR ESTUARIES MANAGEMENT PLAN AND IMPLEMENTATION OF PLYMOUTH NATIONAL MARINE PARK



**PART ONE: INTRODUCTION TO NATURAL CAPITAL ASSETS AND ECOSYSTEM SERVICE BENEFITS WITHIN PLYMOUTH SOUND, ESTUARIES AND COASTAL AREA.**

*Suggested citation for this report:*

Ashley, M., Rees, S., Mullier, T., 2021 Natural Capital Asset and Risk Register to Inform Marine Site Management Plans and Implementation of Plymouth National Marine Park. Part One: Introduction to Natural Capital Assets and Ecosystem Service Benefits within Plymouth Sound, Estuaries and Coastal Area. Report compiled by staff at the University of Plymouth.

Author and affiliation: Matthew Ashley<sup>1</sup>, Siân Rees<sup>1</sup>, Tom Mullier<sup>1</sup>

<sup>1</sup> School of Biological and Marine Science, University of Plymouth.

This report has been compiled by staff at The Marine Institute, School of Biological and Marine Science, University of Plymouth.

Contact Details:

Dr Matthew Ashley / Dr Siân Rees  
School of Biological and Marine Science,  
Marine Institute  
Marine Building  
Level 3  
University of Plymouth.  
Drake Circus  
Plymouth  
PL4 8AA  
Tel 00 44 (0) 1752 584732  
Web: <http://www.plymouth.ac.uk/marine>

Acknowledgements:

This report was funded by NERC- SWEEP [NE/P011217/1](#). The authors would like to thank staff from the Devon and Severn IFCA, Cornwall IFCA, Plymouth Marine Laboratory, The Marine Management Organisation, Environment Agency, Natural England, Plymouth City Council for assistance with data and advice and all who contributed their time and knowledge.

Image: *Siege of Plymouth*, Wenceslaus Hollar 1607-1677, University of Toronto, Public domain

## LIST OF ABBREVIATIONS

- CPUE** Catch per Unit Effort
- DEFRA** Department for Environment, Food & Rural Affairs
- ES** Ecosystem Service
- EUNIS** European Nature Information System
- 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
- MESH** Marine European Seabed Habitats
- MPA** Marine Protected Area
- MSC** Marine Stewardship Council
- MSFD** Marine Strategy Framework Directive
- MSY** Maximum Sustainable Yield
- NCC** Natural Capital Committee
- NMP** National Marine Park
- SAC** Special Area of Conservation
- SSB** Spawning Stock Biomass
- TAC** Total Allowable Catch
- TEMP** Tamar Estuaries Management Plan
- iVMS** Inshore Vessel Monitoring System
- WFD** Water Framework Directive

## SUMMARY

The Plymouth Sound, Estuaries and Coast to Eddystone reefs (PSEC) area contains habitats and species populations of national and international importance. These lie adjacent to a busy urban centre, international port and cargo handling facilities, as well as western Europe's largest naval base. The site also provides marine cultural heritage assets stretching over human history from prehistoric settlements to embarkation points of major historical maritime voyages, including naval battles, expeditions and human migrations. The habitats and species populations provide 'natural capital' that supports multiple ecosystem services (ES), defined as the 'the benefits provided by ecosystems that contribute to making human life both possible and worth living' (UK National Ecosystem Assessment, 2011). Associated marine cultural heritage assets represent interaction between people and the marine environment in the PSEC area through time.

The purpose of reports in this project (reports 1-3) is to develop Natural Capital Assessment tools, to provide the underpinning ecological and socio-economic evidence informing MPA Site Management Plans and management of coastal regions with multiple economic and recreational uses. By undertaking natural capital and ecosystem service perspectives the maintenance of biodiversity is supported side by side with the social and economic benefits the natural environment provides.

The Natural Capital Approach (NCA) is a tool to assess and identify where and how to improve the natural environment and maintain flows of ES benefits. The Natural Capital Approach provides a means to achieve the UK government's vision to 'to be the first generation to leave the natural environment in a better state than it inherited' (HM Government, 2018a; Natural Capital Committee, 2015). The Natural Capital Approach relates the state of natural capital stocks (elements of nature that have value to society, such as forests, fisheries, rivers, biodiversity, land and minerals) to the flow of environmental or 'ecosystem' services over time (Natural Capital Committee, 2013; Natural Capital Committee, 2017b; ONS, 2017).

In Part One of this study we provide an introduction to natural capital assets and ecosystem service benefits within Plymouth Sound, Estuaries and Coastal Area. We identify the links between habitats and species populations within the PSEC area and ecosystem service benefits, as well as identifying the risk to those benefits in relation to the state of the natural environment in the site.

Five key ecosystem service benefits were considered in the study:

From the provisioning services category, the ES benefit 'Wild Food'. From the regulating services category, 'Healthy Climate' benefits, 'Sea Defence' benefits and 'Clean water and Sediment' benefits. From cultural services the benefit, 'Recreation and Tourism'.

We demonstrate from the reviewed evidence that the level of contribution to all ES benefits was greatest for saltmarsh habitats, with a significant level of contribution to all 5 key ES benefits present, supported by high agreement from peer reviewed literature. Littoral and sublittoral seagrass habitats were also reviewed to provide moderate or significant contribution to all 5 key ES benefits. Sublittoral seagrass provide significant contribution to 'Wild Food' benefits, as fish and shellfish species nursery habitats and significant contribution to capture and storage of carbon. However, saltmarsh and seagrass habitats cover comparatively smaller extents (0.83km<sup>2</sup>, 0.4km<sup>2</sup> respectively) to many other marine habitats in the PSEC area.

Sublittoral soft substratum habitats cover much larger extents (14.3km<sup>2</sup> to 84.5km<sup>2</sup>), as do littoral sand and muddy sand and littoral mud habitats (6km<sup>2</sup> and 20.9km<sup>2</sup>) and all rock habitats (2.1 km<sup>2</sup> to 15.3 km<sup>2</sup>). These habitat assets were not reviewed to provide significant contributions to ES benefits over comparable unit areas as saltmarsh and seagrass. However the moderate contributions to Food (wild food), Clean Water and Sediments and low contributions to Sea Defence and Healthy Climate ES benefits, are provided over much larger extents/spatial scales within the PSEC area. It was also identified that full potential contribution to ES

benefits requires interrelationship of processes between habitats. For expected processes such as capture of carbon in algae and burial in soft substratum offshore requires intertidal, infralittoral and deeper circalittoral habitats and related species assets being in an ecological condition to support expected functions and processes within habitats and between habitats, water bodies and species populations, to achieve reviewed contribution to Healthy Climate ES benefits .

Similarly, wild food benefits related to availability of fish and shellfish populations requires nursery habitats such as saltmarsh, seagrass beds, littoral and shallow infralittoral soft substratum and rock habitats to be in a condition to provide expected functions, as well as deeper infralittoral and circalittoral soft substratum and rock habitats that support adult life stages of commercially targeted species to be in condition required to support required habitat and prey resources. Water quality across these habitats is also required to be in condition to support habitat and species contribution to ES benefits, and not be adversely impacted by ecological and chemical contamination.

Reducing adverse impacts and maintaining the condition of all habitats and water bodies across the PSEC site is, thereby, considered vital to achieve the expected contribution to ES benefits. 37% of habitats within the PSEC area are within designated MPAs. Selected habitat features within these MPAs are monitored on a 5-6 year cycle to assess the condition of the habitats and review management needs. Across the PSEC area 36% of habitats are currently protected by management measures to reduce benthic impact. Within MPAs this figure is >90% for physical pressures related to interaction of bottom towed fishing activities with benthic habitats. 63% of habitats in the PSEC area are outside MPAs (with no bylaw to protect benthic features from physical impacts), including large proportions of sublittoral soft substratum habitats that provide important contributions to food, clean water and sediment, healthy climate and sea defence ES benefits. Although adverse impacts of activities on coastal sublittoral sediments are considered in marine licensing processes, there remains less evidence of habitat extent, condition and assessment of adverse impacts of activities of habitats outside MPAs. Part One of the study identifies that greater acknowledgement of the contribution of multiple habitats and species assets to ES benefits, across an estuarine and coastal area, inside and outside MPAs is required in monitoring and management processes to enable implications of habitat and species population extent and condition on provision of ES benefits to be assessed.

Implications of historic and current activities and pressures on water body, habitat and species assets and flow of ES benefits is considered in more detail in Part Two of this study, the Asset and Risk Register.

Part Three considers the evidence in relation to completed ongoing and future Tamar Estuary Plan Actions and how those actions and achieving aims to support flow of ES benefits supports the goals of the Plymouth National Marine Park.

## CONTENTS

List of abbreviations .....	3
Summary.....	4
Introduction.....	7
Plymouth sound, estuaries and coast to eddystone reefs (PSEC) area .....	9
summary of natural capital assets AND flow of ecosystem services .....	12
Contribution of Natural capital Assets to Provision of key Ecosystem service benefits.....	12
Proportion of habitat extents within designated MPAs and proportion interacting with management	
Measures to reduce adverse impacts on benthic habitats.....	18
Main activities presenting risk to Es contribution .....	19
References .....	21
Annex I .....	25

## INTRODUCTION

Undertaking this study is intended to provide evidence to inform management within an estuarine and coastal site. The study is aligned with the management of MPAs and the coastal region within the Plymouth Sound, Estuaries and Coast to Eddystone reefs (PSEC) area.

Management of MPAs within the Plymouth Sound and estuaries area of the site, principally Plymouth Sound and Estuaries Special Area of Conservation (SAC) and Tamar Estuaries Complex Special Protection Area (SPA), European Marine Sites (EMS) is coordinated by the Tamar Estuaries Management Plan (TEMP), developed by Tamar Estuaries Consultative Forum (TECF) (TECF, 2012). TECF is chaired by the Queen's Harbour Master (QHM) for the Dockyard Port of Plymouth, and hosted by Plymouth City Council. The Forum is made up of Relevant Authorities – government departments and public or statutory bodies with local powers or functions that have, or could have, an impact over the marine environment of the Marine Protected Areas (MPAs) (TECF, 2014).

TECF (2014) identifies that such partnership is required due to the complexities of the site, containing large urban centres and important naval docks as well as commercial and passenger ports. The TEMP serves a dual purpose of addressing joint delivery of statutory duties by addressing risks in relation to the European Marine Sites (EMS), as well as providing a joint approach, to delivering a wider range of partnership projects that aim to deliver wider social and economic gains (TECF, 2012). This approach fits directly within the concept of managing natural capital assets to enhance provision of ecosystem services and related benefits to people and society.

Monitoring of designated habitats, water bodies and species features within MPAs across the PSEC area, as well as advising and ensuring management meets targets within national and international legislation is undertaken by Natural England, Environment Agency and Marine Management Organisation in coordination with Inshore Fisheries and Conservation Authorities and landowners. Condition of estuarine and coastal water bodies in relation to policy targets is monitored by Environment Agency. Impacts of activities on marine environments outside of MPAs in the PSEC area is considered within the MMO marine licensing process.

The Natural Capital Approach provides a foundational framework of the United Kingdom's 25 Year Plan to Improve the Environment (HM Government, 2018b). As such, consideration of impact of management actions on extent (quantity) and condition (quality) of habitat and species assets and the resulting relationship to provision of ES benefits provided to society, is central to monitoring and management actions undertaken by resource managers.

Four key definitions are central to the Natural Capital Approach (Natural Capital Committee, 2017a; Natural Capital Committee, 2017b).

- **Natural capital:** The elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions.
- **Assets:** a distinctive component of natural capital as determined by the functions it performs, e.g. soils, freshwater, species.
- **Ecosystem services (ES):** Functions and products from nature that can be turned into benefits with varying degrees of human input.
- **Benefits:** Changes in human welfare (or well-being) that result from the use or consumption of goods, or from the knowledge that something exists.

The application of Natural Capital and ES assessment tools to review impact of existing monitoring and management actions in the PSEC area, and identify priorities for future actions, is undertaken to continue to

test, and enable future refinement of the approach developed under the NERC SWEEP programme and Defra Marine Pioneer (Ashley *et al.*, 2020; Ashley, Rees & Cameron, 2018; Hooper *et al.*, 2018; Hooper *et al.*, 2020; Hooper & Austen, 2020; Rees, Ashley & Cameron, 2019).

Applying Natural Capital and ES assessment tools at this stage provides the opportunity to:

1. Identify the ES supported by natural capital assets within the PSEC area.
2. Assess the state (extent and condition) of habitat and species assets and activities creating adverse impacts.
3. Review impacts of actions taken under the 2012-2018 TEMP, within Plymouth Sound and estuaries EMSs and actions of NE, EA, IFCA, MMO across the wider PSEC area and provide guidance on priorities for management and non-statutory partnership actions to address within the future TEMP process.

This Part One study identifies the natural capital assets and cultural heritage assets within the site, the ES supported by these assets and summarises the main risks to provision of ES in the PSEC area.

In Part Two of this study we provide a Natural Capital Asset and Risk Register for the PSEC area to assess the current state and risk to contribution to ES benefits, in relation to the state (extent and condition) of the habitat and species features.

In, Part Three, we identify the implications of current, ongoing and future, proposed management actions on the asset and risk register.

Within this project, synergies between impacts of the actions undertaken within the TEMP 'sustainable management agenda' and benefits that can enhance environment and community health and wellbeing, under the aims of the proposed Plymouth National Marine Park, are also considered and summarised (Pittman *et al.*, 2019; Plymouth City Council, 2019).



## PLYMOUTH SOUND, ESTUARIES AND COAST TO EDDYSTONE REEFS (PSEC) AREA

This assessment considered the area of the Plymouth Sound and Estuaries Special Area of Conservation (SAC), from the tidal limits of estuaries to the mouth of Plymouth Sound and also the coastal region outside the SAC within the first stage of the proposed Plymouth National Marine Park (Figure 1). The offshore area assessed includes sections of the Start Point to Plymouth Sound and Eddystone SAC. The site assessed also contains the Tamar Estuaries Complex Special Protection Area (SPA), the Tamar Estuary Sites Marine Conservation Zone (MCZ) and estuarine and coastal Sites of Special Scientific Interest (SSSI) (Figure 1).

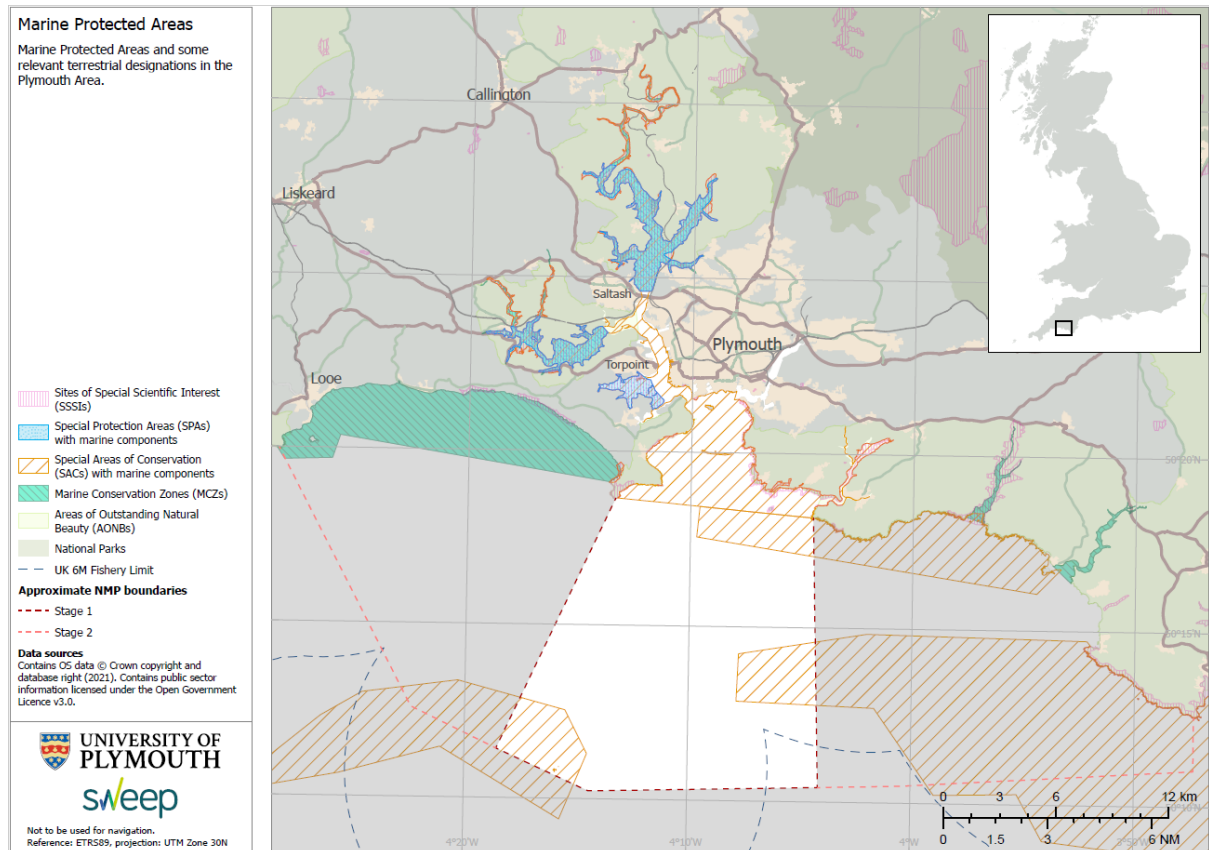


Figure 1 The study site including the Plymouth Sound and Estuaries SAC, from the tidal limits of estuaries to the mouth of Plymouth Sound and also the coastal region outside the SAC within the first stage of the proposed Plymouth National Marine Park (white area). Neighbouring MPA designations are shown for context.

## SPECIAL FEATURES OF PLYMOUTH SOUND, ESTUARIES AND COAST TO EDDYSTONE REEFS AREA

### Diverse wildlife and landscapes

Marine Protected Areas (MPAs) within the area include European Marine Sites (EMS) designated under European Law (EC Habitats Directive 1992), such as Plymouth Sound and Tamar Estuaries Special Area of Conservation (SAC). SACs represent one form of a suite of MPAs in UK waters that protect some of our most important marine and coastal habitats and species of European and national importance. Other MPA sites designated under the Habitats Directive include Special Protection Areas (SPAs) covered by tidal waters. Further MPA sites include those designated under UK law: Marine Conservation Zones (MCZs), (Marine and Coastal Access Act 2010) and marine and intertidal components of Sites of Special Scientific Interest (SSSIs) (The Wildlife & Countryside Act 1981).

In terms of natural capital habitat assets, the PSEC marine area is dominated by sedimentary habitats, particularly subtidal coarse, mixed and sand substratum (Figure 2; Table 1). There are also infralittoral and circalittoral rock reef habitats within Plymouth Sound, in the coastal region and offshore at Eddystone reefs (Figure 2; Table 1). Shallow subtidal and intertidal regions of Plymouth Sound and Estuaries SAC provide seagrass beds, saltmarsh, rocky reef and coarse, sand, mixed and mud soft substratum habitats (Figure 2; Table 1). Mussel beds also provide biogenic reef habitats (Figure 2; Table 1).

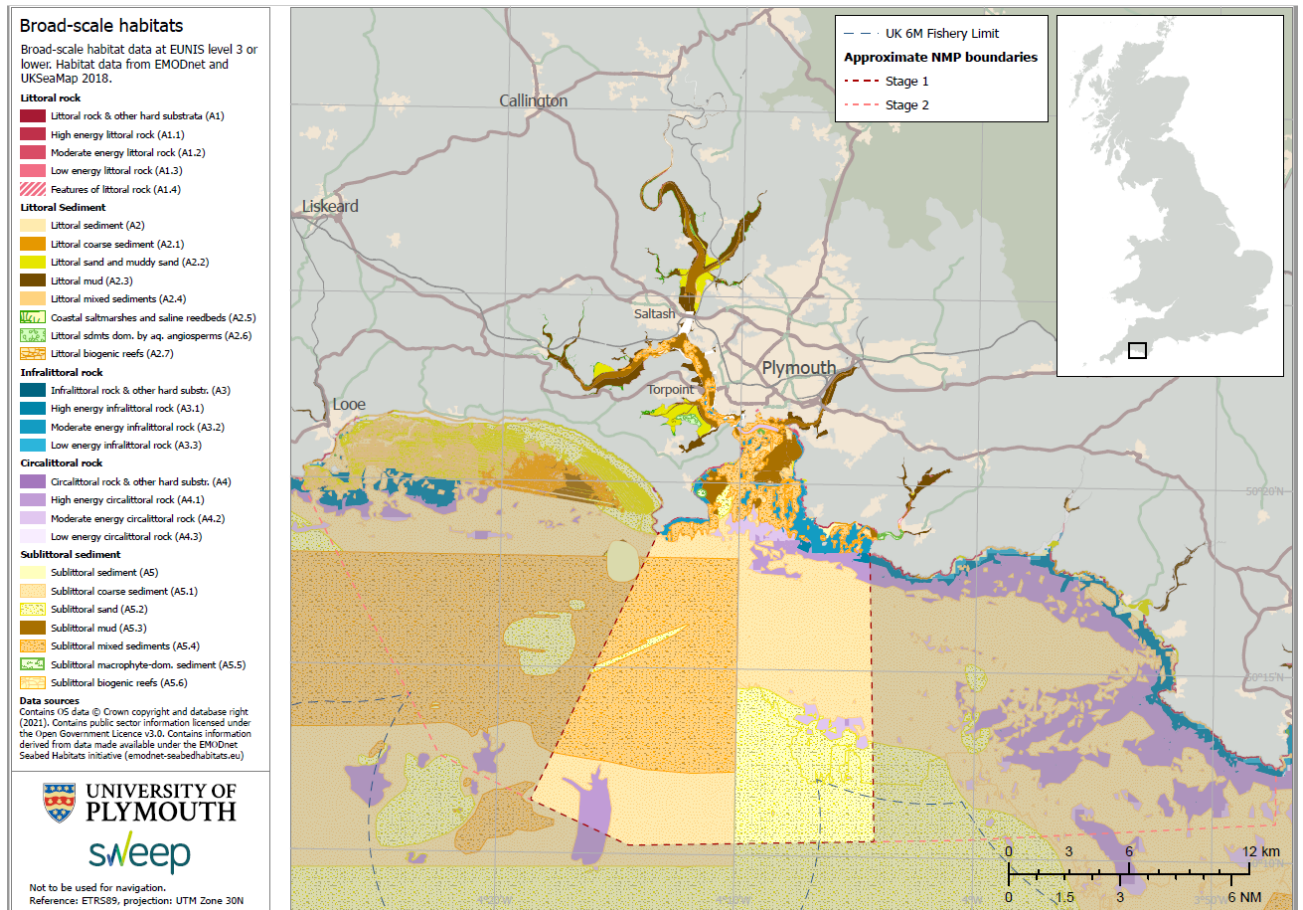


Figure 2 Habitats present in the area, Plymouth Sound, Estuaries and Coastal area within the lighter highlighted offshore area, which overlaps stage 1 of the NMP out to Eddystone reefs. The PSEC study area is highlighted within the red dotted boundary and extends within Plymouth Sound and associated estuaries.

Table 1 Extent of habitat assets present within Plymouth Sound, Estuaries and Coast to Eddystone Reefs (PSEC) area.

Broad scale habitat	Natural Capital Asset: Habitats in Plymouth Sound Estuaries and Coastal area		Extent (km <sup>2</sup> )
Marine	<b>Intertidal reef</b>	A1: Littoral rock and other hard substrata	2.12
	<b>Subtidal reef</b>	A3: Infralittoral rock and other hard substrata	9.24
		A4: Circalittoral rock and other hard substrata	15.32
	<b>Intertidal sediments</b>	A2.1 Littoral Coarse sediment	0.16
		A2.2: Littoral sand and muddy sand	5.98
		A2.3: Littoral mud	20.85
		A2.4: Littoral mixed sediment	0.52
		A2.5 Coastal saltmarshes and saline reedbeds	0.4
		A2.6 Littoral sediments dominated by aquatic angiosperms (seagrass bed)	0.43
		A2.7 Littoral biogenic reefs (A2.72 Blue mussel beds)	0.2
	<b>Subtidal sediment</b>	A5.1: Sublittoral coarse sediment	84.54
		A5.2: Sublittoral sand	45.97
		A5.3: Sublittoral mud	14.27
		A5.4: Sublittoral mixed sediments	83.87
		A5.5: Sublittoral macrophyte dominated sediment	0.4
A5.6 Sublittoral biogenic reefs (A5.62 Mussel beds)		0.02	
<b>Water column</b>	N/A Areas of high planktonic primary productivity		
	N/A Tide swept channels		

The estuaries support regionally and nationally important bird populations including little egret and avocet, designated within the Tamar Estuaries Complex SPA (Annex I). Migratory fish include Allis shad, protected within the SAC, and stocks of Atlantic salmon, migratory brown trout, European eel, lamprey species and smelt (Murrillas et al., 2020). Sub-tidally, demersal fish species, scallops, cuttlefish, crab and European lobster are important for commercial fisheries (MMO, 2020). Species interacting with the site, supporting wildlife watching, include: seals, porpoise, minke whale, dolphins, blue fin tuna (Hiscock & Earll, 2015; ORCA, 2021), basking shark (Sims, Fox & Merrett, 1997), and fish, shellfish, cup coral, anenome and sponge communities of interest to scuba divers (MBA, 1957; Tyler-Walters *et al.*, 2018).

Smelt, native oyster populations, blue mussel beds and intertidal sediment habitats are designated features within the Tamar Estuary Sites MCZ (Annex I). The Tamar-Tavy, Yealm and Lynher estuaries all contain designated Sites of Special Scientific Interest (SSSI) due to species and natural features of national importance, including varying habitats for marine birds. Sites on the lower Tamar valley and the Yealm estuary, totalling about 195km<sup>2</sup> are registered as Areas of Outstanding Natural Beauty (AONB).

#### Culture and heritage

Plymouth Sound and its estuaries provide a significant natural harbour, which has supported human activities throughout European human history (Knights *et al.*, 2016). Earliest records of human habitation within the site include Cattedown bone cave, 150m north of Cattedown Wharves, where remains of at least 15 individual hominids of both sexes were recovered, including children and adults, and dated to 60,000-10,000 years before present (Historic England, 2007). Historically the Tamar valley and surrounding area has evidence of mining since the Bronze Age, for copper and tin, and, in more recent times for tungsten, lead and silver. Due to the historic mining activity, in particular in the valley of Tavistock, the Tamar valley is registered within The Cornwall and West Devon Mining Landscape UNESCO World Heritage Site.

Plymouth has been a major port throughout history. Related heritage assets include the Cattlewater Wreck dated to 1530 and protected under the Protection of Wrecks Act 1973. Plymouth is linked to major naval

battles since the 16<sup>th</sup> century and Plymouth Sound has been the departure point for significant voyages, from Drake's 1577 circumnavigation, to that of the pilgrim's aboard the Mayflower in 1620 and Darwin's voyage on the HMS Beagle in 1831 (Knights *et al.*, 2016). Historic military infrastructure surrounds Plymouth Sound. To this day, Devonport on the Tamar estuary contains western Europe's largest naval base. Devonport and Sutton Harbour contain over 20 scheduled ancient monuments (Historic England, 2021). The wider PSEC coastal fringe contains over 1000 National Heritage Listings for England Heritage assets (Historic England, 2021). Maritime links include war memorials and Drake's circumnavigation memorial on Plymouth Hoe, memorials on the Barbican's Mayflower steps to the Mayflower voyage. While, the wall of Commercial Road opposite the Mayflower steps contains the memorials to fishers and sailors from the port.

The unique combination, of biodiversity importance and cultural importance within Plymouth Sound, estuaries and coast has led to the drive to create the UK's first national marine park, centred on Plymouth Sound (Plymouth City Council, 2019).

#### Diverse economy

Plymouth contains important current day marine industry and economic links. These include, passenger handling facilities for international ferry services and the cruise industry, port facilities for dry cargo, bulk liquid products and cement as well as England's 3<sup>rd</sup> largest fishing port by value of landings (Cattewater Harbour Commissioners, 2020; MMO, 2019). In 2019, over 80 fish and shellfish species, utilising habitats within Plymouth Sound, estuaries and coast, were landed to Plymouth ports, of which scallops and cuttlefish provided the highest contribution to value (MMO, 2019). Pacific oyster are also cultivated commercially in the Yealm estuary and bait digging and crab tiling are undertaken frequently on mudflats in Tamar, Lynher and Plym estuaries (Jenkin *et al.*, 2017 ; Natural England, 2021). Much of the watershed beyond the city of Plymouth is agricultural land with pockets of ancient woodland and the moorland expanses of Dartmoor National Park. The main urban centre is the city of Plymouth with a population of 256,400 that also attracts 5.5 million visitors (2019) for day or overnight trips and 440,000 passengers passing through the port on Brittany Ferries service from Spain and France (Visit Plymouth, 2019).

## SUMMARY OF NATURAL CAPITAL ASSETS AND FLOW OF ECOSYSTEM SERVICES

In this section we review the contribution of habitat and species natural capital assets in the PSEC area to ES provision and provide a summary of the key ES benefits.

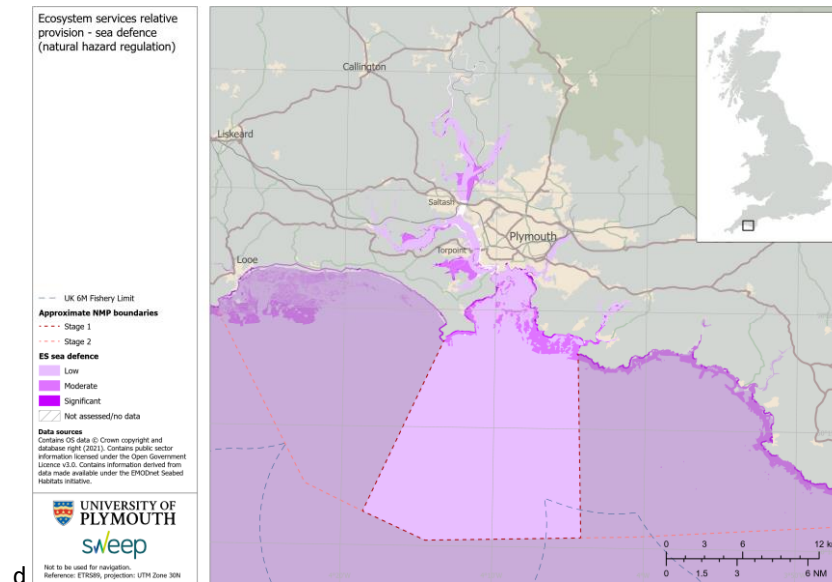
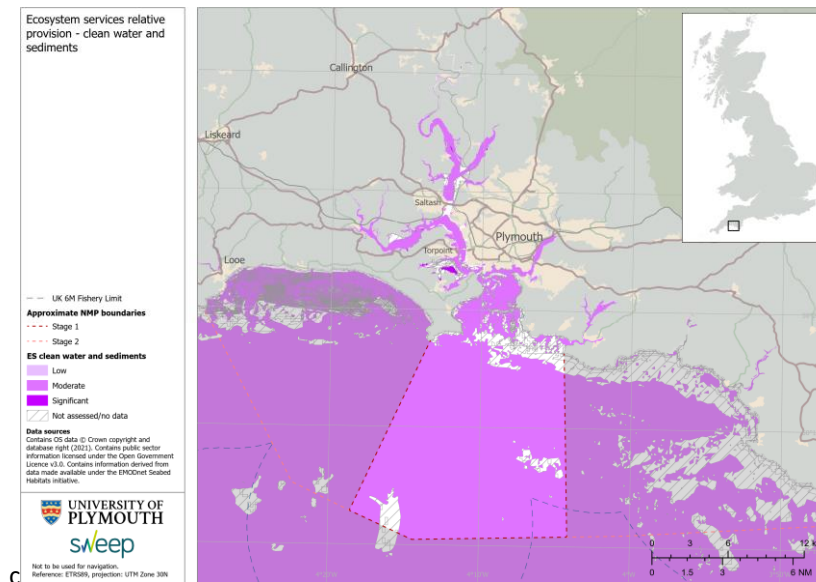
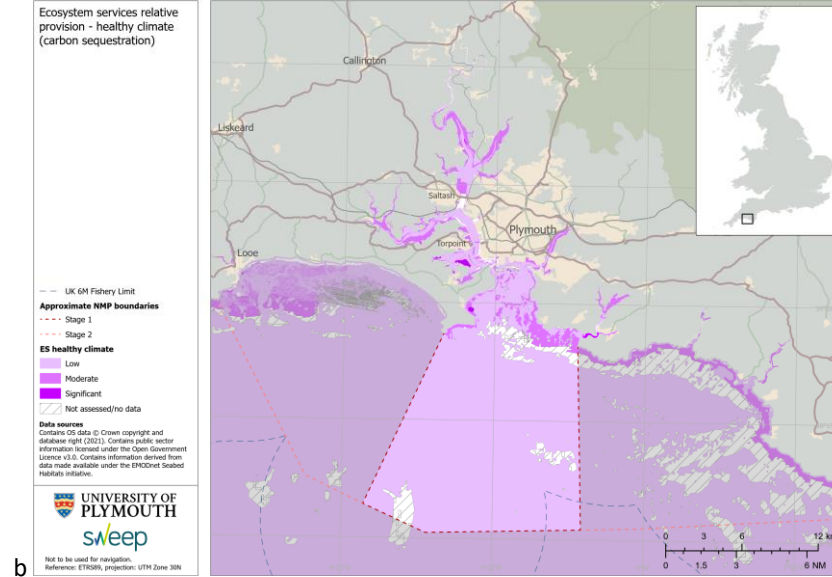
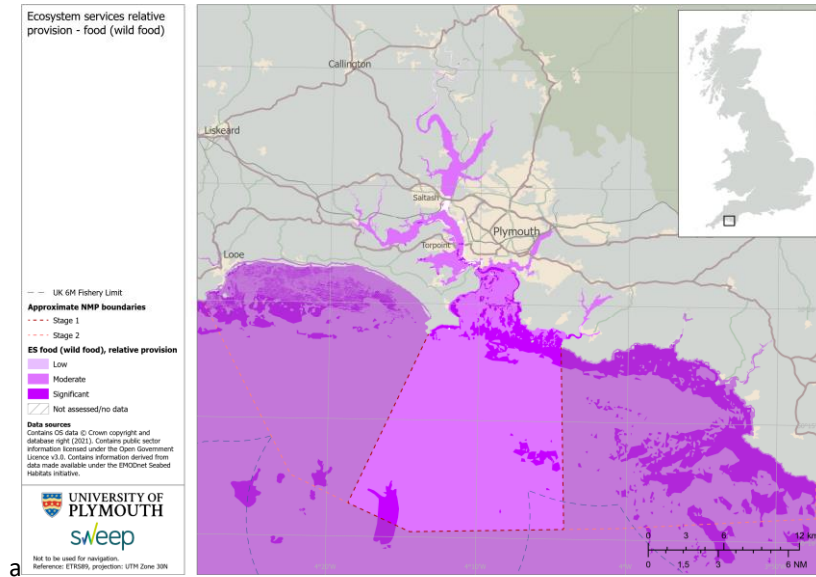
### CONTRIBUTION OF NATURAL CAPITAL ASSETS TO PROVISION OF KEY ECOSYSTEM SERVICE BENEFITS

The natural environment, seascape and cultural heritage are important resources, contributing to ES benefits supporting health and wellbeing of local communities and visitors interacting with the PSEC area. The habitat and associated species community assets within the site were reviewed to provide moderate or significant contributions to all of the 5 key ES benefits selected for the study: wild food, sea defence, clean water and sediments, healthy climate, tourism including recreation and nature watching. The results of literature reviews are summarised in Table 2, spatial contributions of habitats to each key ES are provided in Figure 3. Literature supporting assessments are provided in Supplementary Material 1, Tab 1 and detailed methods applied in reviews and to map ES spatial contribution are provided in the (Technical Methods Report).

Table 2 Contribution of habitat features (aggregated to Eunis level 3) and associated species communities to 5 key ES benefits: wild food, sea defence, clean water and sediments, healthy climate, tourism including recreation and nature watching in the PSEC area (ES contributions reviewed from existing studies (Potts et al, 2014; Rees, Ashley & Cameron, 2019; Saunders *et al.*, 2015).

Scale of ecosystem service contribution relative to other features		Confidence in evidence available to assign ES provision	
#	Significant contribution	3	UK-related, peer-reviewed literature
#	Moderate	2	Grey or overseas literature
#	Low	1	Expert opinion
#	No or negligible	[Blank]	Not assessed
[Blank]	Not assessed	[Blank]	Not assessed

Broad scale habitat	Natural Capital Asset: Habitats in Plymouth Sound Estuaries and Coastal area		Extent (km <sup>2</sup> )	Contribution to ES Goods/Benefits				
				Food (wild food)	Tourism, nature watching and recreation	Sea Defence	Healthy climate	Clean water and sediments
Marine	Intertidal reef	A1: Littoral rock and other hard substrata	2.12	3	1	1	2	
		A3: Infralittoral rock and other hard substrata	9.24	3	1	1	2	
	Subtidal reef	A4: Circalittoral rock and other hard substrata	15.32	1	1	1		
		A2.1 Littoral Coarse sediment	0.16	1	1	3		
	Intertidal sediments	A2.2: Littoral sand and muddy sand	5.98	1	1	3	2	
		A2.3: Littoral mud	20.85	3	1	3	3	3
		A2.4: Littoral mixed sediment	0.52	1	1	3	2	
		A2.5 Coastal saltmarshes and saline reedbeds	0.4	3	3	3	3	3
		A2.6 Littoral sediments dominated by aquatic angiosperms (seagrass bed)	0.43	3	1	1	1	1
		A2.7 Littoral biogenic reefs (A2.72 Blue mussel beds)	0.2	2	1	1	1	1
		Subtidal sediment	A5.1: Sublittoral coarse sediment	84.54	2		3	2
	A5.2: Sublittoral sand		45.97	2		3	2	3
	A5.3: Sublittoral mud		14.27	2		3	2	3
	A5.4: Sublittoral mixed sediments		83.87	2		3	2	3
	A5.5: Sublittoral macrophyte dominated sediment		0.4	3	1	1	2	2
	A5.6 Sublittoral biogenic reefs (A5.62 Mussel beds)		0.02	1	1	1	1	1
Water column	N/A Areas of high planktonic primary productivity		2	1	1	2	1	
	N/A Tide swept channels			1				



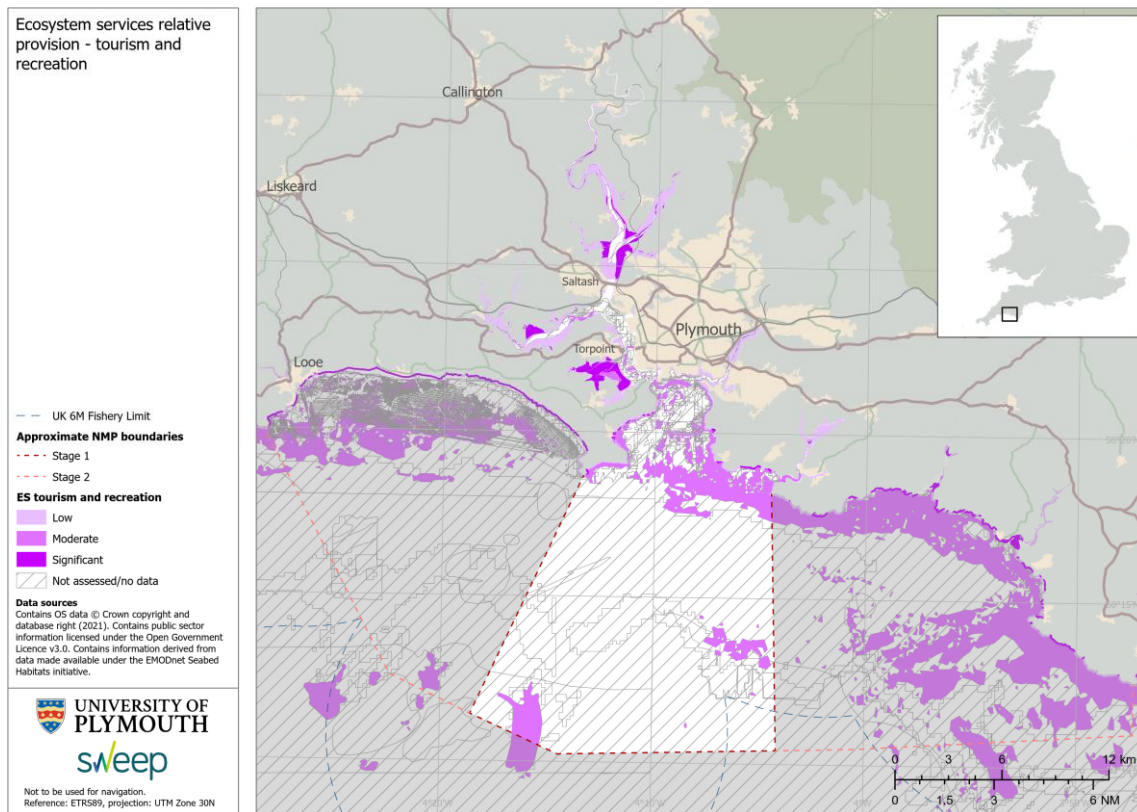


Figure 3 Spatial distribution of habitats in the PSEC area providing significant, moderate and low contributions to 5 key ES benefits a) Wild Food, b) Healthy Climate, c) Clean water and Sediments, d) Sea Defence/Natural Hazard Regulation, e) Recreation and Tourism

In the evidence identified from literature review the level of contribution to all benefits was greatest for saltmarsh habitats, with a significant level of contribution to all 5 key ES benefits present, supported by high agreement from peer reviewed literature (Table 2). Littoral and sublittoral seagrass habitats were also reviewed to provide moderate or significant contribution to all 5 key ES benefits (Table 2). Sublittoral seagrass provide significant contribution to 'Wild Food' benefits, as fish and shellfish species nursery habitats and significant contribution to capture and storage of carbon. However, saltmarsh and seagrass habitats cover comparatively smaller extents (0.83km<sup>2</sup>, 0.4km<sup>2</sup> respectively) to many other marine habitats in the PSEC area (Table 2).

Sublittoral soft substratum habitats cover much larger extents (14.3km<sup>2</sup> to 84.5km<sup>2</sup>), as do littoral sand and muddy sand and littoral mud habitats (6km<sup>2</sup> and 20.9km<sup>2</sup>) and all rock habitats (2.1 km<sup>2</sup> to 15.3 km<sup>2</sup>) (Table 2). These habitat assets were not identified as providing significant contributions to ES benefits over comparable unit areas as saltmarsh and seagrass (Table 2). However, the moderate contributions to Food (wild food), Clean Water and Sediments and low contributions to Sea Defence and Healthy Climate ES benefits, are provided over much larger extents/spatial scales within the PSEC area (Table 2, Figure 3), and so their role in supporting the supply of ES benefits should not be downgraded. It was also identified that the full potential contribution to ES benefits requires interrelationship of processes between habitats. For example, processes such as capture of carbon in algae and burial in soft substratum offshore requires intertidal, infralittoral and deeper circalittoral habitats and related species assets being in condition to support expected functions and processes within habitats and between habitats, water bodies and species populations, to achieve reviewed contribution to Healthy Climate ES benefits. Similarly, wild food benefits related to availability of fish and shellfish populations requires nursery habitats such as saltmarsh, seagrass beds, littoral and shallow infralittoral soft substratum and rock habitats to be in a condition to provide expected functions, as well as deeper infralittoral and circalittoral soft substratum and rock habitats that support adult life stages of commercially targeted species to be in condition required to support required habitat and prey resources.

Water quality across these habitats is also required to be in condition to support habitat and species contribution to ES benefits, and not be adversely impacted by ecological and chemical contamination

Within the PSEC area the habitat and species assets, including the water column provide an array of structures and functions that, when combined, provide the overall contribution to each key ES benefit:



#### PROVISIONING SERVICES: WILD FOOD

---

Commercial fisheries, aquaculture and hand gathering directly benefit from flow of 'wild food' ecosystem service benefits, related to stocks of fish and shellfish species within the study site. Habitats within PSEC area designated MPAs, especially estuarine saltmarsh, sublittoral seagrass beds and coastal infralittoral rock habitats, and also littoral sediments, provide important nursery habitat, supporting shelter and food resources for the main commercial fish species such as, bass *D. labrax*, as well as Thornback ray *R. clavata*, sole *S. solea*, plaice *P. platessa*, pollack *P. pollachius*, whiting *M. merlangus*, Brown crab *C. pagurus* and lobster *H. gammarus* (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021b). (Deeper circalittoral rock habitats support adult life stages of shellfish species and pollack *P. pollachius* (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021b). Outside MPAs sublittoral soft substratum habitats provide important habitats supporting adult life stages of all commercially targeted species. Water quality within the site is essential to supporting aquaculture resources and availability of blue mussel *M. edulis* for hand gathering, as well as supporting healthy fish and shellfish populations.



#### REGULATING SERVICES: 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. Within the PSEC area, saltmarsh and seagrass plant communities with root systems capture and store carbon in situ. Algae and kelp communities on intertidal habitats and circalittoral rock habitats capture carbon which is exported in detritus, and a proportion stored/sequestered in offshore soft substratum sediments (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021b).. The water column supports the carbon cycle through oceanic primary production harvesting light to convert inorganic to organic carbon (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021b). River and estuaries provide relatively large C efflux through terrestrial detritus and sewage inputs to the coastal zone coastal ocean (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021).



#### REGULATING SERVICES: SEA DEFENCE (FLOOD PREVENTION, STORM DEFENCE AND ALLEVIATION OF COASTAL EROSION)

---

Marine habitats within the PSEC area play a valuable role in the defence of coastal regions. Physical barriers such as those provided by littoral rock habitats dampen wave energy and contain rising water (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021). Saltmarsh habitats dampen wave energy, store large volumes of water and saltmarsh vegetation attenuates currents (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021). Soft substratum habitats dissipate wave energy and provide barriers reducing risk of damage to coastal defences and low lying land and infrastructure (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021). Intertidal habitats not only provide sea defence ES benefits in relation to present sea level (and sea conditions), but unlike man made defences, if unimpeded by coastal development, natural intertidal habitats such as saltmarsh will migrate with rising sea levels, predicted under future climate scenarios.





## REGULATING SERVICES: CLEAN WATER AND SEDIMENTS

---

Marine living organisms store, bury and transform waste through assimilation and chemical decomposition and re-composition. Vegetation within saltmarsh and seagrass habitats within PSEC the area have 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 (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021). 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) (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021). Filter feeding bivalves, such as mussels pump water and contaminants such as bacteria, algae, microplastics and detritus into their gill chambers, as they feed, effectively reducing concentrations within the water column (Scott *et al.*, 2019; Viarengo & Canesi, 1991) (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021).



## CULTURAL SERVICES: RECREATION AND TOURISM

---

Marine natural capital assets provide the basis for a wide range of recreation and tourism activities. Recreation and tourism opportunities include watersports, wildlife watching, recreational 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) (Natural England, 2016; Natural England., 2020) (Table 2; Figure 3) (Ashley, Rees & Mullier, 2021). 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) within the PSEC area were reviewed to provide significant contributions to the provision of the ES benefits of Recreation and Tourism.

PROPORTION OF HABITAT EXTENTS WITHIN DESIGNATED MPAS AND PROPORTION INTERACTING WITH MANAGEMENT MEASURES TO REDUCE ADVERSE IMPACTS ON BENTHIC HABITATS

Reducing adverse impacts and maintaining condition of all habitats and water bodies across the site is vital to achieve expected contribution to ES benefits. Of total extent of marine habitats within the Plymouth Sound and Estuaries SAC and Plymouth NMP stage 1 site, 37% are contained within designated MPAs and 36% interact with management measures to reduce human impacts on benthic habitats (Table 4).

Table 3 Extent of each habitat asset within the PSEC area and extent of each habitat within MPAs including extent in favourable / unfavourable condition and extent across the whole site in modelled LRC of moderate or below. Extent within a management measure is also provided.

Broad Habitat	Detail (with Eunis code)	Extent (km <sup>2</sup> )	Extent within MPAs	Extent in MPAs in 'unfavourable / recover'	Extent in MPA within a management measure
<b>Marine inlets and transitional waters</b>					
Intertidal reef	Littoral rock and other hard substrata (A1)	2.12	1.75	0.02	1.53
Intertidal sediments	Littoral coarse sediment (A2.1)	0.16	0.16	0	0.16
	Littoral sand and muddy sand (A2.2)	5.98	5.92	0.65	5.92
	Littoral mud (A2.3)	20.85	17.81	2	17.81
	Littoral mixed sediment (A2.4)	0.52	0.49	0.49	0.49
	Coastal saltmarshes and saline reedbeds (A2.5)	0.40	0.39	0	0.39
	Littoral sediments dominated by aquatic angiosperms (seagrass bed) (A2.6)	0.43	0.4	0.4	0.4
	Littoral biogenic reefs (Blue mussel beds) (A2.7)	0.2	0.1	0	0.1
<b>Sublittoral habitats</b>					
Subtidal reef	Infralittoral rock and other hard substrata (A3)	9.24	8.97	0	8.97
	Circalittoral rock and other hard substrata (A4)	15.32	15.17	0	15.17
Subtidal sediment	Sublittoral coarse sediment (A5.1)	84.54	22.23	22.23	22.23
	Sublittoral sand (A5.2)	45.97	5.33	0	5.33
	Sublittoral mud (A5.3)	14.27	10.32	10.32	10.32
	Sublittoral mixed sediments (A5.4)	83.87	12.77	12.77	12.77
	Sublittoral macrophyte dominated sediment (A5.5)	0.4	0.4	0.4	0.4
	Sublittoral biogenic reefs (Mussel beds) (A5.6)	0.02	0.02	0	0.02
<b>Totals</b>	All habitats	284.29	102.23	47.26	102.01

63% of habitats in the PSEC area remain outside MPAs, including large proportions of sublittoral soft substratum habitats that provide important contributions to food, clean water and sediment, healthy climate and sea defence ES benefits. Although adverse impacts of activities on coastal sublittoral sediments are considered in marine licensing processes, there remains less evidence of habitat extent, condition and assessment of adverse impacts of activities of habitats outside MPAs. Large extents of sublittoral sediment habitats outside MPAs are exposed to demersal towed fishing activities and anchoring and mooring activity

that exert physical pressures that habitats are sensitive to, impacting condition, and thus, functioning and ecological processes contributing to ES and ES benefits (Table 4).

#### MAIN ACTIVITIES PRESENTING RISK TO ES CONTRIBUTION

Activities and pressures presenting risk to the condition of habitat features within the PSEC area are principally assessed for habitat extents within MPAs. Natural England condition Assessments assess condition of habitats in relation to physical, chemical and ecological pressures, related to historical and current activities within the site. The Tamar Estuaries Management Plan (TECF, 2012) assesses challenges and risk to features within the European Marine Sites (EMS) within the PSEC area. Plymouth and South West Devon Local Plan (2014) also contains Habitat Regulations Assessments (HRAs) relating risk from damaging activities to the condition of European Marine Site features. Regional IFCA's have also completed HRAs assessing the level of adverse impact from each fishing activity on EMS present in the PSEC area.

Activities and pressures impacting the PSEC area natural capital assets, summarised from the various asset condition assessments and HRAs are:

- Intertidal habitats within Yealm, Tamar and Lyhner estuaries are adversely impacted by spread of non-native pacific oyster (*Magallana gigas*) populations (Curry, Sabel & Sekula, 2017; Curtis, 2018; Natural England, 2021).
- Littoral rock habitats, littoral mud and sand and muddy sand habitats in the Yealm were assessed as unfavourable due to historical Tributyltin contamination (TBT) (Curry, Sabel & Sekula, 2017; Curtis, 2018; Natural England, 2021).
- Littoral mixed sediments were assessed as unfavourable due to low infaunal quality index in Tamar estuary sites and wider littoral areas of mud and sand flats in MPAs (Curry, Sabel & Sekula, 2017; Curtis, 2018; Natural England, 2021).
- Intertidal seagrass habitats are considered to be in unfavourable condition, due to the presence of opportunistic macroalgae, related to nutrient enrichment. Macroalgae overlies the seagrass and prevents primary production (Bunker & Green, 2020; Curry, Sabel & Sekula, 2017; Curtis, 2018; Natural England, 2021).
- Subtidal seagrass beds were assessed as unfavourable due to interaction with abrasion pressure from anchoring and mooring activities (Bunker & Green, 2020; Curry, Sabel & Sekula, 2017; Curtis, 2018; Natural England, 2021).
- Subtidal habitats in the Tamar estuary were assessed as adversely impacted by historical mining and current industrial contaminants. Subtidal mixed sediments and subtidal mud habitats were assessed as unfavourable due to elevated levels of heavy metals (Mercury, Copper, Lead and Zinc), poly-aromatic hydrocarbons (PAHs) and poly-chlorinated biphenyls (PCBs) within the sediments (Curry, Sabel & Sekula, 2017; Natural England, 2021)
- In the Yealm estuary, subtidal mixed sediments and subtidal mud habitats are also assessed as unfavourable due to elevated sediment contamination levels, but also, elevated aqueous contaminants, primarily Tributyltin (TBT) and presence of the INNS, slipper limpet *Crepidula fornicate*. (Curry, Sabel & Sekula, 2017; Natural England, 2021)
- Presence of the INNS, slipper limpet *Crepidula fornicate* and elevated sediment contaminant levels were assessed to be adversely impacting subtidal soft substratum habitats in shallow inlets and bays within MPAs across the wider site (Curry, Sabel & Sekula, 2017; Natural England, 2021).

Water Quality is identified to be impacted throughout the site from a range of sources, leading to failure to meet overall WFD targets in all water bodies in the site (Curry, Sabel & Sekula, 2017; Environment Agency, 2020; Tamar Catchment Partnership, 2012; TECF, 2012).

- Chemical status targets were failed in assessments for all water bodies due to contamination from historic mining sites and major pollution incidents from industry within the estuarine and river catchments (Curry, Sabel & Sekula, 2017; Environment Agency, 2020; Tamar Catchment Partnership, 2012; TECF, 2012).
- Contaminants are also locked into sediments within the estuary that if disturbed can be released into the water column, such as through dredging of shipping channels (TECF, 2012).
- Ecological status targets in Plymouth Sound and Tamar estuaries were failed in assessments due to diffuse pollution from agriculture practices occurring around the estuaries, the addition of sewage inputs from water treatment works infrastructure and run off from combined sewer overflows (Curry, Sabel & Sekula, 2017; Environment Agency, 2020; Tamar Catchment Partnership, 2012; TECF, 2012).

Impact of these pressures on extent and condition of habitat and species assets are considered in greater detail in Part Two of this study (Ashley, Rees & Mullier, 2021b). Part Three of the study (Ashley, Rees & Mullier, 2021a) considers prioritisation of management measures to enable greatest contribution of natural capital assets to expected level of provision of ES and ES benefits.

In conclusion, in Part One of the study we identify those habitats that support the supply of ecosystem services and the linked benefits. We note that maintaining or recovering the healthy condition of all habitats (including water bodies) and species assets within the PSEC area is important to enabling the expected contribution of the natural capital assets within the PSEC area to deliver ES benefits, both locally and internationally. We find that 37% of the mosaic of habitats that support ES benefits are included for specific management within MPAs. These habitat extents are directly protected from degradation caused by interaction bottom towed fishing activity by fisheries bylaws or anchoring and mooring impacts through placement of trial eco-moorings.

Within MPAs multiple intertidal and subtidal habitat features have extents assessed in unfavourable condition. This represents approximately 46% of the total habitat extent in MPAs. There is also limited applied management to reduce benthic habitats outside MPAs. There remain a number of pressures from human activities that negatively impact water quality, habitat condition and species populations in the PSEC area. A large proportion of functional habitats that support key ecosystems services such as carbon sequestration - climate regulation and formation of habitat - fish and shellfish populations are, thereby, not managed in a way to protect ES benefits, such as healthy climate and food provision at the time of writing.

## REFERENCES

Ashley, M., Rees, S. & Mullier, T. (2021a) *Natural Capital Asset and Risk Register to Inform Marine Site Management Plans and Implementation of Plymouth National Marine Park. Part Three: Implications of Tamar Estuary Management Plan Actions on the State of Natural Capital Assets and Risk to Flow of Ecosystem Services*. The Marine Institute, School of Biological and Marine Science, University of Plymouth. Available.

Ashley, M., Rees, S. & Mullier, T. (2021b) 'Natural Capital Asset and Risk Register to Inform Marine Site Management Plans and Implementation of Plymouth National Marine Park. Part Two: Baseline Asset and Risk Register. A report by research staff at the University of Plymouth'.

Ashley, M., Rees, S., Mullier, T., Reed, B., Cartwright, A., Holmes, L. & Sheehan, E. (2020) *Isles of Scilly Natural Capital Asset and Risk Register to Inform Management of Isles of Scilly Fisheries Resources*. . Plymouth. Available.

Ashley, M., Rees, S. E. & Cameron, A. (2018) *North Devon Marine Pioneer Part 1: State of the art report of the links between the ecosystem and ecosystem services in the North Devon Marine Pioneer*. Available.

Bunker, F. & Green, B. (2020) *Seagrass condition monitoring in Plymouth Sound and Estuaries SAC 2018*. A report to Natural England by Menia Ltd. Available.

Cattewater Harbour Commissioners (2020) 'Plymouth Port: Commercial'. Plymouth Port. [Online]. Available at: <https://plymouthport.org.uk/commercial/> (Accessed: March 2021).

Curry, K., Sabel, J. & Sekula, R. (2017) *Habitat Regulations Assessment: Plymouth & South West Devon Joint Local Plan*. Plymouth, UK: Plymouth City Council. Available at: <https://www.plymouth.gov.uk/sites/default/files/HabitatRegulationsAssessment.pdf>.

Curtis, L. A. (2018) *Plymouth Sound and Estuaries SAC Littoral Habitats Condition Monitoring 2017: Report Number: ER17-348*. Ecospan Environmental Ltd. Available at: [www.ecospan.co.uk](http://www.ecospan.co.uk).

Environment Agency (2020) 'Catchment Data Explorer: Tamar Management Catchment'. [Online]. Available at: <https://environment.data.gov.uk/catchment-planning/ManagementCatchment/3089> (Accessed: June 2021).

Hiscock, K. & Earll, B. (2015) *South-West Marine Ecosystems in 2014: Observations reported at the South-West Marine Ecosystems meeting 2015 and other sources*. Available at: <https://swmecosystems.co.uk/wp-content/uploads/2016/02/21.-SWME-REPORT-on-2014-Autumn-2015.compressed-1.pdf>.

Historic England (2007) 'Worth's Cattedown Bone Cave 150m north of Cattedown Wharves'. [Online]. Available at: <https://historicengland.org.uk/listing/the-list/list-entry/1021406> (Accessed: March 2021).

Historic England (2021) 'The National Heritage List for England'. [Online]. Available at: <https://historicengland.org.uk/listing/the-list/> (Accessed: March 2021).

HM Government (2018a) *A Green Future: Our 25 Year Plan to Improve the Environment*. London: Defra. Available.

HM Government (2018b) *A Green Future: Our 25 Year Plan to Improve the Environment*. London: Department for the Environment Food and Rural Affairs. Available.

Hooper, T., Ashley, M., Börger, T., Langmead, O., Marcone, O., Rees, S., Rendon, O., Beaumont, N., Attrill, M. & Austen, M. (2018) *Application of the natural capital approach to the marine environment to aid decision-making. Report prepared for the Department for Environment Food and Rural Affairs (project code ME5115)*. 109 pp. Available.

Hooper, T., Ashley, M., Mullier, T. & Rees, S. (2020) *North Devon Marine Natural Capital Plan. Sustainability Assessment*. Available.

Hooper, T. & Austen, M. (2020) *Application of the natural capital approach to Sustainability Appraisal. Final Report. October 2020*. Available.

Jenkin, A., Davies, S., Trundle, C., Street, K. & Naylor, H. (2017) *Cornwall IFCA Crab Tiling Survey Tamar Estuaries*. Hayle, Cornwall, UK: Cornwall Inshore Fisheries and Conservation Authority (Cornwall IFCA). Available at: [https://secure.toolkitfiles.co.uk/clients/17099/sitedata/Research\\_Reports/Tamar-Estuaries-crab-tiling-survey-2017.pdf](https://secure.toolkitfiles.co.uk/clients/17099/sitedata/Research_Reports/Tamar-Estuaries-crab-tiling-survey-2017.pdf).

Knights, A. M., Firth, L. B., Thompson, R. C., Yunnice, A. L. E., Hiscock, K. & Hawkins, S. J. (2016) 'Plymouth — A World Harbour through the ages'. *Regional Studies in Marine Science*, 8 pp. 297-307.

MBA (1957) *Plymouth Marine Fauna: Being Notes on Local Distribution of Species* Plymouth, UK: Published by Marine Biological Association of the United Kingdom.

MMO (2019) *UK Sea Fisheries statistics 2019*. Available at: <https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2019> (Accessed: March 2021).

MMO (2020) 'Statistical data set: Latest provisional dataset - UK and foreign vessels landings by UK port and UK vessel landings abroad: 2020 (year to date)'. [Online]. Available at: <https://www.gov.uk/government/statistical-data-sets/uk-and-foreign-vessels-landings-by-uk-port-and-uk-vessel-landings-abroad> (Accessed: March 2021).

Murrillas et al. (2020) *The full list of ecosystem services provided by diadromous fish Deliverable reference: WP 4 – Action nr.1*. Available at: [www.diades.eu](http://www.diades.eu).

Natural Capital Committee (2013) *The State of Natural Capital: Towards a framework for measurement and valuation. A report from the Natural Capital Committee*. 57 pp. Available.

Natural Capital Committee (2015) *The State of Natural Capital Protecting and Improving Natural Capital for Prosperity and Wellbeing*. Third report to the Economic Affairs Committee. 73 pp. Available.

Natural Capital Committee (2017a) *How to do it: a natural capital workbook*. 31 pp. Available.

Natural Capital Committee (2017b) *Natural Capital Committee: How to do it: a natural capital workbook, Version 1*. London: Defra. Available.

Natural England (2016) *Monitor of Engagement with the Natural Environment: The national survey on people and the natural environment: Headline Report from the 2015-16 survey*. Natural England. Available.

Natural England (2021) 'Natural England Conservation Advice for Marine Protected Areas'. [Online]. Available at: <https://designatedsites.naturalengland.org.uk/> (Accessed: March 2021).

Natural England. (2020) 'Monitoring Engagement in the Natural Environment Survey (2009-2019): Welcome to the MENE Dashboard'. [Online]. Available at: <https://defra.maps.arcgis.com/apps/MapSeries/index.html?appid=2f24d6c942d44e81821c3ed2d4ab2ada>.

ONS (2017) 'Office for National Statistics, Principles of Natural Capital Accounting'. [Online]. Available at: <https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting>.

ORCA (2021) 'Species sightings'. [Online]. Available at: <https://www.orcaweb.org.uk/species-sightings/sightings-map> (Accessed: March 2021).

Pittman, S. J., Rodwell, L. D., Shellock, R. J., Williams, M., Attrill, M. J., Bedford, J., Curry, K., Fletcher, S., Gall, S. C., Lowther, J., McQuatters-Gollop, A., Moseley, K. L. & Rees, S. E. (2019) 'Marine parks for coastal cities: A concept for enhanced community well-being, prosperity and sustainable city living'. *Marine Policy*, 103 pp. 160-171.

Plymouth City Council (2019) *Plymouth Sound National Marine Park: Creating The UK's First National Marine Park: Engagement Document*. Available at: <https://www.plymouth.gov.uk/sites/default/files/PlymouthSoundNationalMarineParkDocument.pdf> (Accessed: March 2021).

Potts et al, B., D., Jackson, E., Atkins, J., Saunders, J., Hastings, E, Langmead, O (2014) 'Do marine protected areas deliver flows of ecosystem services to support human welfare? '. *Marine Policy*, 44 pp. 139-148.

Queirós, A. M., Birchenough, S. N. R., Bremner, J., Godbold, J. A., Parker, R. E., Romero-Ramirez, A., Reiss, H., Solan, M., Somerfield, P. J., Van Colen, C., Van Hoey, G. & Widdicombe, S. (2013) 'A bioturbation classification of European marine infaunal invertebrates'. *Ecology and Evolution*, 3 (11), pp. 3958-3985.

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

Saunders, J., Potts, T., Jackson, E., Burdon, D., Atkins, J. P., Hastings, E., Langmead, O. & Fletcher, S. (2015) 'Linking Ecosystem Services of Marine Protected Areas to Benefits in Human Wellbeing?', in Turner, R.K. and Schaafsma, M. (eds.) *Coastal Zones Ecosystem Services: From Science to Values and Decision Making*. Cham: Springer International Publishing, pp. 167-190.

Scott, N., Porter, A., Santillo, D., Simpson, H., Lloyd-Williams, S. & Lewis, C. (2019) 'Particle characteristics of microplastics contaminating the mussel *Mytilus edulis* and their surrounding environments'. *Marine Pollution Bulletin*, 146 pp. 125-133.

Sims, D. W., Fox, A. M. & Merrett, D. A. (1997) 'Basking shark occurrence off south-west England in relation to zooplankton abundance'. *Journal of Fish Biology*, 51 (2), pp. 436-440.

Sturdivant, S. K. & Shimizu, M. S. (2017) 'In situ organism-sediment interactions: Bioturbation and biogeochemistry in a highly depositional estuary'. *PLOS ONE*, 12 (11), pp. e0187800.

Tamar Catchment Partnership (2012) *The Tamar Plan*. Westcountry Rivers Trust. Available at: <http://my-tamar.org/wp-content/uploads/2020/01/The-Tamar-Plan-Summary-lowres.pdf>.

TECF (2012) *Tamar Estuaries Management Plan*. Plymouth, UK: Planning Services, Plymouth City Council. Available at: [www.plymouth.gov.uk/tecf](http://www.plymouth.gov.uk/tecf) (Accessed: March 2020).

TECF (2014) 'The Tamar Estuaries Consultative Forum'. [Online]. Available at: <http://www.plymouth-mpa.uk/home/managing-the-mpa/tamar-estuaries-consultative-forum/> (Accessed: March 2021).

Tyler-Walters, H., Hiscock K. (eds), Tillin, H. M., Stamp, T., Readman, J. A. J., Perry, F., Ashley, M., De-Bastos, E. S. R., D'Avack, E. A. S., Jasper, C., Gibb, N., Mainwaring, K., McQuillan, R. M., Wilson, C. M., Roche, C., Budd, G. C., Hill, J. M., Jackson, A., White, N., Rayment, W. J., Wilding, C. M., Marshall, C. E., Wilson, E., Riley, K., Neal, K. J., Sabatini, M., Durkin, O. C., Ager, O. E. D., Bilewitch, J., Carter, M., Hosie, A. M., Mieszkowska, N. & Lear, D. B. (2018) 'Marine Life Information Network: Biology and Sensitivity Key Information Review Database [on-line]'. Marine Biological Association of the United Kingdom. [Online]. Available at: [www.marlin.ac.uk](http://www.marlin.ac.uk) (Accessed: August 2018).

UK National Ecosystem Assessment (2011) *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC, Cambridge. Available.

Viarengo, A. & Canesi, L. (1991) 'Mussels as biological indicators of pollution'. *Aquaculture*, 94 (2), pp. 225-243.



Visit Plymouth (2019) *Tourism and Leisure Fact Sheet*. Available at:  
<https://www.visitplymouth.co.uk/dbimgs/Tourism%20Sector%20Sheet.pdf> (Accessed: March 2021,).

## ANNEX I

### Habitats and species features of designated sites within the study site

Habitat or species feature/subfeature (Eunis code)	Designated site	Condition (X = unfavourable or recover) (Curry et al., 2017; Natural England, 2021)	Management
Littoral rock (high A1.1, moderate A1.2 and low energy A1.3, and features of littoral rock A1.4)	Plymouth Sound and Estuaries SAC	<b>X – Yealm: presence of invasive non-native <i>Magallana gigas</i> (formerly <i>Crassostrea gigas</i>) and contaminants including TBT.</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Littoral coarse sediment (A2.1)	Plymouth Sound and Estuaries SAC, Tamar Estuary Sites MCZ	Maintain	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Littoral sand and muddy sand (A2.2)	Plymouth Sound and Estuaries SAC	<b>X – Tamar, Mudflats and sand flats not covered by seawater at low tide: not stated</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Littoral mud (A2.3)	Plymouth Sound and Estuaries SAC	<b>X – Tamar: not stated</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Littoral mixed sediments (A2.4)	Plymouth Sound and Estuaries SAC	<b>X – Yealm or Tamar estuary Mudflats and sand flats not covered by seawater at low tide: poor condition of infauna communities (IQI)</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Littoral saltmarsh and saline reed beds (A2.5)	Plymouth Sound and Estuaries SAC,	Maintain	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.

Littoral seagrass beds (A2.6)	Plymouth Sound and Estuaries SAC	<b>X – Yealm or Tamar estuary Mudflats and sand flats not covered by seawater at low tide: opportunistic macroalgae which overlies the seagrass</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Littoral biogenic reefs (A2.7)	Tamar Estuary Sites MCZ	Maintain (Pacific oysters <i>C. gigas</i> are present on mussel beds)	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Infralittoral rock (high A3.1, moderate A3.2 and low energy A3.3)	Plymouth Sound and Estuaries SAC, Start Point to Plymouth Sound & Eddystone SAC	Maintain	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Circalittoral rock (high A4.1, moderate A4.2 and low energy A4.3)	Plymouth Sound and Estuaries SAC, Start Point to Plymouth Sound & Eddystone SAC	Maintain	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Subtidal coarse sediment (A5.1)	Plymouth Sound and Estuaries SAC	<b>X – Shallow inlets and bays: spread of non-native <i>Crepidula fornicata</i> and elevated sediment contaminant levels. Sandbanks which are slightly covered by seawater all the time: elevated contaminant levels and low infauna condition (IQI score, north of breakwater)</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Subtidal sand and muddy sand (A5.2)	Plymouth Sound and Estuaries SAC	Maintain	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Subtidal mud (A5.3)	Plymouth Sound and Estuaries SAC	<b>X – Tamar, Yealm, Shallow inlets and bays: spread of non-native <i>Crepidula fornicata</i> and elevated sediment contaminant levels.</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Subtidal mixed sediments (A5.4)	Plymouth Sound and Estuaries SAC	<b>X – Tamar, Yealm, Shallow inlets and bays: spread of non-native <i>Crepidula fornicata</i> and elevated sediment contaminant levels.</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.

Subtidal seagrass bed (A5.5)	Plymouth Sound and Estuaries SAC	<b>X – Plymouth Sound and Yealm: exposure to anchoring and mooring.</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Subtidal biogenic reefs (A5.6)	Tamar Estuary Sites MCZ (Mussel beds)	(Pacific oysters <i>C. gigas</i> are present on mussel beds)	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Shore dock ( <i>Rumex rupestris</i> )	Plymouth Sound and Estuaries SAC	Maintain	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Allis shad ( <i>Alosa alosa</i> )	Plymouth Sound and Estuaries SAC	<b>X – Gunnislake weir acts as a barrier to migratory fish</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. River and Estuarine Fishing Nets Byelaw 2017. Devon and Severn IFCA: Mobile Fishing Permit Byelaw, Netting Permit Byelaw.
Smelt ( <i>Osmerus eperlanus</i> )	Tamar Estuary Sites MCZ	<b>X – Gunnislake weir acts as a barrier to migratory fish</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. River and Estuarine Fishing Nets Byelaw 2017. Devon and Severn IFCA: Mobile Fishing Permit Byelaw, Netting Permit Byelaw.
Native oyster ( <i>Ostrea edulis</i> )	Tamar Estuary Sites MCZ	<b>X - Nationwide population declines, with the native oyster population considered to be depleted</b>	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Blue mussel ( <i>Mytilus edulis</i> ) beds	Tamar Estuary Sites MCZ	(Pacific oysters <i>C. gigas</i> are present on mussel beds)	Cornwall IFCA: Closed areas (European Marine Sites) No. 2. Devon and Severn IFCA: Mobile Fishing Permit Byelaw.
Avocet ( <i>Recurvirostra avosetta</i> )	Tamar Estuaries Complex SPA	Maintain	
Little egret ( <i>Egretta garzetta</i> )	Tamar Estuaries Complex SPA	Maintain	