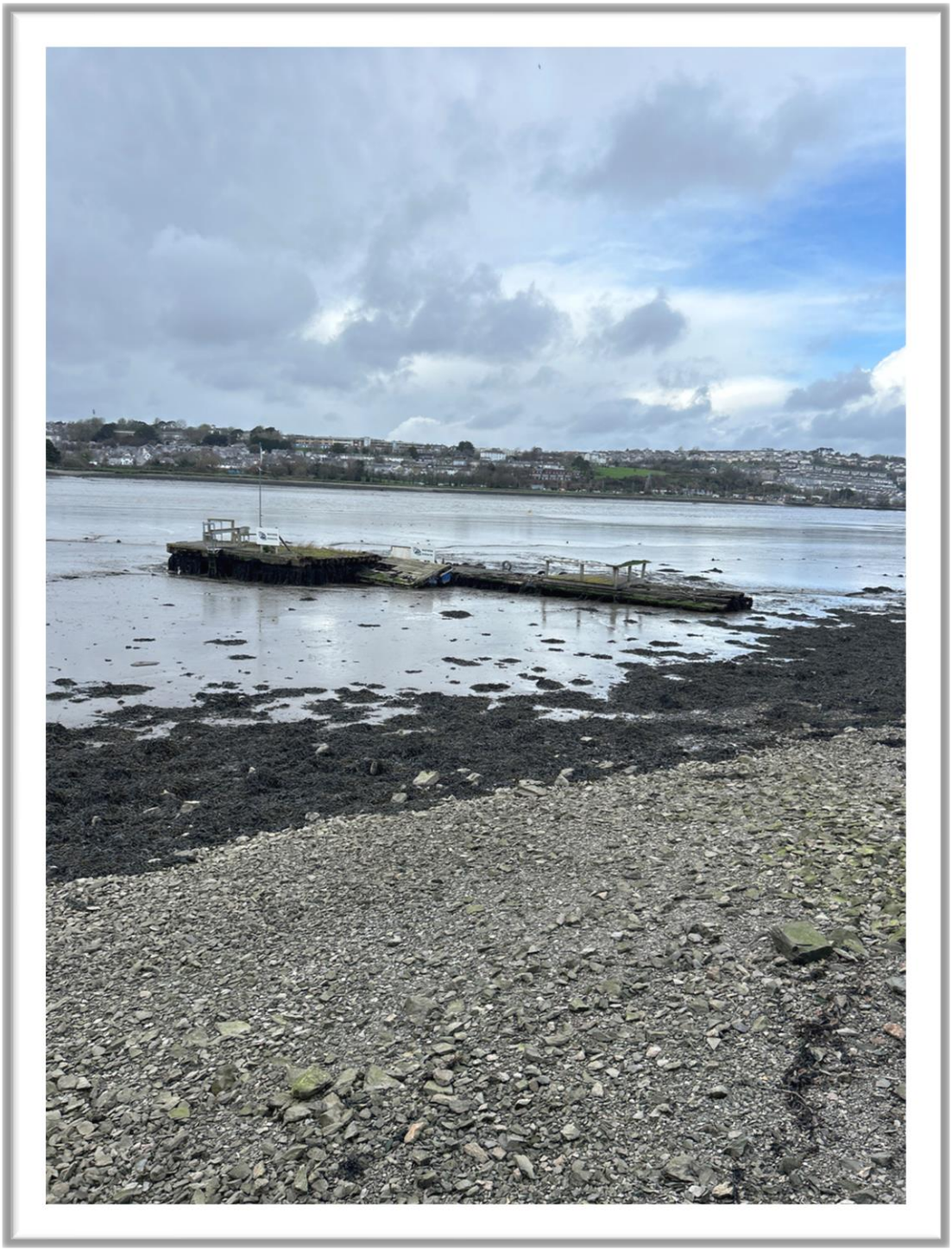
An Assessment of Opportunities for the Ecological Enhancement of the Plymouth City Council Foreshore



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Contents

Summary

This report explores the opportunity and potential to provide habitat enhancements to the intertidal foreshore environments across Plymouth.

The network of environmental designations that cover Plymouth, along with the role of the Plymouth Sound National Marine Park, is assessed in the context of the landscape character and the opportunity for habitat enhancement and creation around the existing habitat assets of the city.

Assessment of current and future pressures that will affect the communities, infrastructure and wildlife across the intertidal areas are also considered to gain a clear understanding of the appropriate and effective interventions needed.

To inform the strategic sites that present opportunities for enhancement, a site-scoping visit was undertaken to priority sites identified by Plymouth City Council and partners. Field-scoping and desk-based assessments of the pressures and habitat character of the locations then informed the most effective interventions for wildlife and the local communities surrounding the sites.

As active innovators in the marine and terrestrial eco-engineering sector for over 20 years, the authors of this report have been able to apply experience from undertaken interventions across the UK and internationally, as well as from the learnings of other organisations with similar ambitions. As such, the proposals given are evidence-based and built from a history of experience and innovation.

This report outlines several appropriate actions that would be most applicable to the sites chosen, outlining the benefits that could be achieved and the pressures that could be mitigated. Indicative cost analysis and recommendations are provided to benefit developers and others involved in infrastructure maintenance, repair, and replacement along the intertidal zone of Plymouth.

This report is intended to provide the principles and potential options as tools that could bring functional and intentional habitats for wildlife, enhance existing intertidal infrastructure, and engage communities with their local environment.

Acknowledgements

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Thanks are also extended to all those stakeholders and experts who shared their knowledge and provided input, advice, and ideas for potential ecological enhancements in the intertidal areas around Plymouth.

1. Introduction

Plymouth City Council and partners have commissioned Arc Biodiversity and Climate to produce a feasibility study to identify the opportunities to improve the Plymouth Sound National Marine Park (PSNMP) foreshore biodiversity opportunities. The focus of this report is the foreshore within the Plymouth City Council Boundary, shown in Figure 1 below.

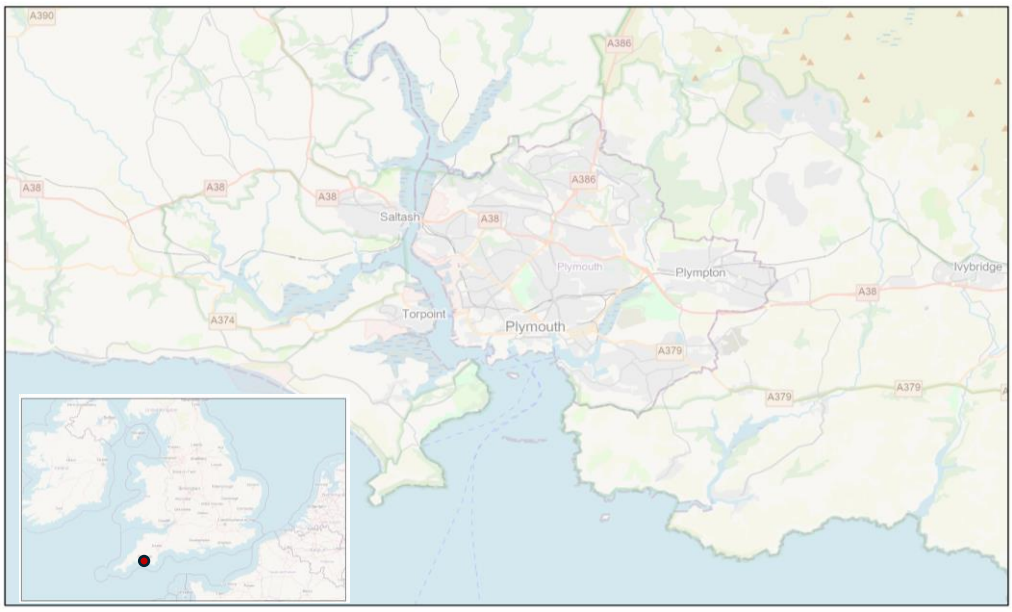


Figure 1 Location

The PSNMP, a first of its kind in the UK, is anticipated to cover an area stretching from southwest of Salcombe to Portlooe. The area encompasses several estuaries, fed from the River Tavy, River Lynher, River Tiddy, River Tamar, and River Plym. The PSNMP covers a landscape of diverse habitats, as well as the Plymouth urban environment and the rich naval history of the region. The scope of this study was limited to the Plymouth City Council boundary, focusing on deliverability to best support the city's population, with a focus on recreational access points.

Local Stakeholders were invited to comment on the opportunities and constraints regarding improving the PCC foreshore for biodiversity. Constraints included costs and concerns about adding more hard infrastructure to an already highly engineered coastline and recognising the value of intertidal heritage structures to support more wildlife than modern constructions. Potential harm to existing infrastructure was discussed alongside the opportunities for eco-engineering to extend the life and usefulness of structures. Other benefits identified, beyond those to biodiversity, included making projects more attractive to funders and opportunities to create points of contact with the public.

This report identifies eight locations for active ecological intervention, utilising various enhancement techniques broadly split into two types: 1) retrofit and additional fixtures and fittings to existing and new infrastructures, and 2) in-situ alterations to existing infrastructure fabric, including enhancement via routine repair and maintenance programmes. Ensuring access to and engagement with potential ecological enhancements was a key priority that has been considered for all the identified opportunities. This ranges from citizen science for site enhancement monitoring to engaging creative pieces that help increase public awareness of surrounding wildlife and the role the enhancements have in habitat provision.

There are no common standards on the optimum design and extent of ecological engineering in the marine environment. The field is still rapidly evolving, and with an increasing number of new research projects, publications and partnership installations, learning, experience, and evidence continue to grow.

2. Habitats and Conservation Designations

Plymouth Sound National Marine Park covers an area that consists of a mosaic of existing European and English designations, attributed to the important habitats and species within and around the estuaries.

Plymouth Sound & Estuaries Special Area of Conservation (SAC)

See Figure 2, below.

Legislation: EC Habitats Directive 1992 (European), The Conservation of Habitats and Species Regulations 2010 (UK).

Qualifying features: Allis shad (*Alosa alosa*); Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*); Estuaries; Large shallow inlets and bays; Mudflats and sandflats not covered by seawater at low tide; Reefs; Sandbanks which are slightly covered by sea water all the time; Shore dock (*Rumex rupestris*).

Tamar Estuaries Complex Special Protection Area (SPA)

See Figure 2, below.

Legislation: EC Birds Directive 1979 (European), The Conservation of Habitats and Species Regulations 2010 (UK).

Qualifying features: Avocet (*Recurvirostra avosetta*), non-breeding; Little egret (*Egretta garzetta*), non-breeding.

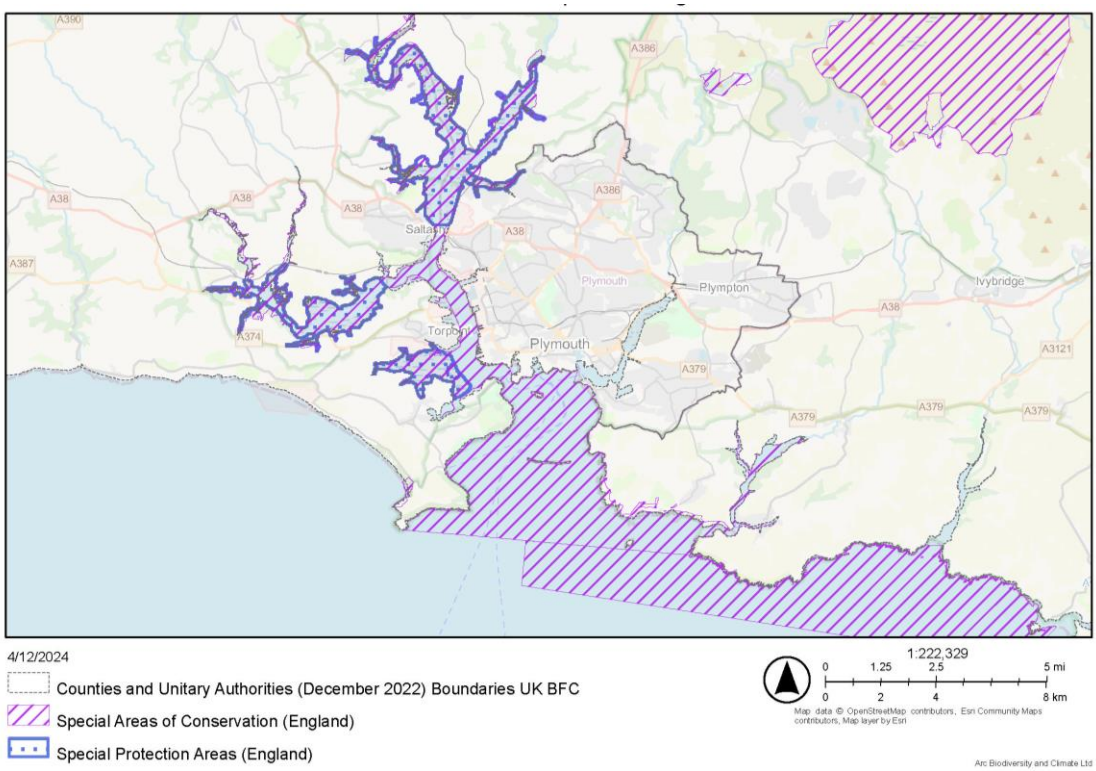


Figure 2 International and European Designations

Plymouth Sound & Estuaries Marine Conservation Zone (MCZ)

See Figure 3, below.

Legislation: Marine and Coastal Access Act 2009 (UK).

Designated features: Blue mussel (*Mytilus edulis*) beds; Intertidal biogenic reefs; Intertidal coarse sediment; Native Oyster (*Ostrea edulis*); Smelt (*Osmerus eperlanus*).

National and local designations (Sites of Special Scientific Interest (SSSI), National Nature Reserve (NNR), Local Nature Reserve (LNR))

See Figure 3, below.

Legislation: Wildlife and Countryside Act 1981 (SSSI), National Parks and Access to the Countryside Act 1949 (NNR and LNR).

Designated features: Plymouth has 9 SSSI's, 3 selected for ecological importance, 6 for geological importance.

National and local designations are small sites across Plymouth's intertidal and terrestrial landscapes. Many of these sites, particularly NNRs and LNRs, also provide dedicated sites for public access to nature. These designations are established to protect the most important areas for wildlife, hold consideration in planning, and provide scientific research opportunities.

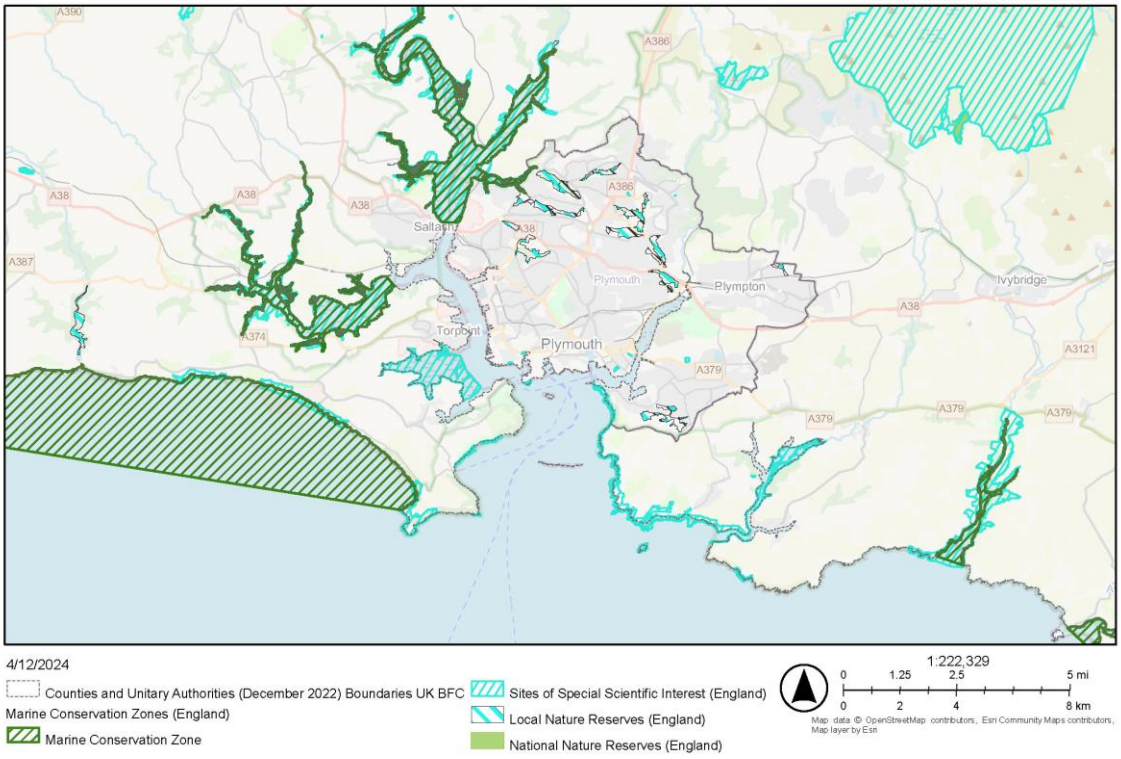


Figure 3 National and Local Designations

Plymouth Sound National Marine Park

The Plymouth Sound National Marine Park (PSNMP) was declared in 2019; the vision of the PSNMP is:

Our National Marine Park will value the environment, heritage and tradition of Plymouth Sound and its estuaries. It is where people and the planet will come together to realise a new, sustainable relationship with the sea.

The purpose of the PSNMP is:

1. Take us back to the sea
2. Inspire each and every generation
3. Restore a sense of pride and identity for the city
4. Enhance our marine environment
5. Improve the health and wellbeing of people through better access
6. Support the development of a truly sustainable economy

The proposed delivery workstreams for the PSNMP are:

1. Blue-green economy
2. Marine nature recovery
3. Marine science, education and skills
4. Placemaking

The coastline of the marine park covers a wide range of habitats (see Figure 4) - rocky shore, sand, saltmarsh, and mudflats. However, it also has a vast amount of concrete with very little wildlife- much of it a legacy of previous decisions and abandoned infrastructure.

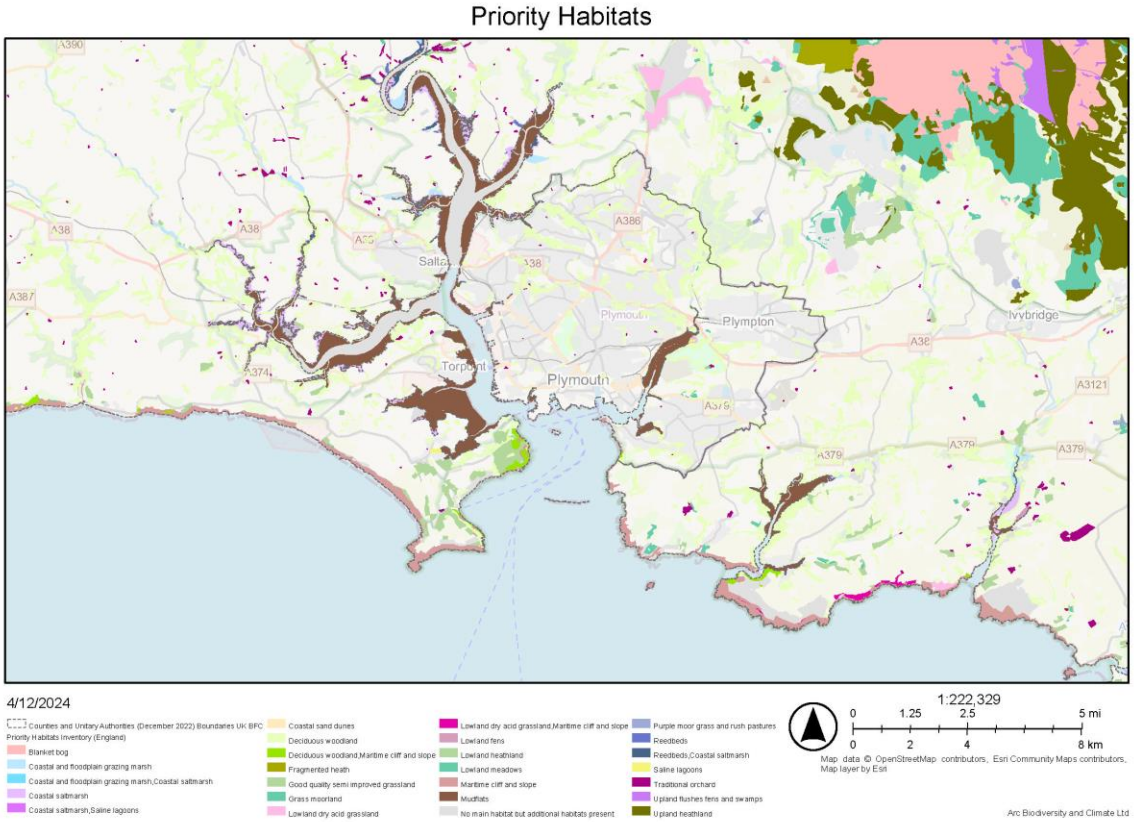


Figure 4 Priority Habitats

The Plymouth Sound and Estuaries is a designated Marine Protected Area (Special Area of Conservation (SAC), Special Protection Area (SPA), Marine Conservation Zone (MCZ) and Sites of Special Scientific Interest (SSSI) shown in Figure 3.

3. Pressures on the Foreshore

Foreshores, including coastal and estuarine transition habitats, face particular stresses driven by climate change, the consequences of sea level rise, and the increased severity and frequency of storm events.

There are two critical effects:

- The first is the retreat of intertidal and splash zone habitats, squeezed against marine and coastal infrastructures and constrained into stream channels within a tidal range that is migrating upstream. This is referred to as coastal squeeze.
- The second is the increase in storm discharge within coastal streams, elevating freshwater volumes. These storm flows may mobilise larger amounts of sediment and associated contaminants from catchment land uses (agriculture, industry, combined sewer outfall), bringing these down into estuaries.

These effects are likely to concentrate and amplify the extremes of the existing sporadic change between freshwater and saltwater conditions, between states of turbidity, and between peaks and troughs of nutrient input.

Increasing climate change pressures on the foreshore from sea level rise and more frequent storms will necessitate more hard-engineered protection, especially where there is already significant public and private infrastructure, as is the case in many of the project locations considered in this report. Changes to coastal and riparian defences, channel alterations, and bank and shoreside reconstruction can further obstruct the safe passage of migratory fish.

A meaningful connection exists between the growing field of ecological design and the need for ecological engineering in the coastal environment. Under conditions of climate change, the effects of coastal squeeze may accelerate coastal development or, at least, place additional pressure on existing structures.

The access infrastructure and natural appeal of their locations make foreshores important areas for public attention. This also makes them places where communication and interpretation can be concentrated and delivered to large audiences of residents, businesses and visitors. With the area already densely designated for environmental protection, the Plymouth Sound National Marine Park has a vital role in recognising and mitigating other pressures, e.g., recreational pressure, socioeconomic inequality of coastal towns, and improved access and education of the local landscape.

Drivers of Change

The need to mitigate the impacts of climate change upon human communities and wildlife is nowhere more apparent and urgent than on the urban coast. The loss of intertidal, strandline, and upper shore habitats to the combination of built infrastructure and ‘coastal squeeze’ continues to accelerate as tourism and residential development increase land-take and add requirements to the case for sea defence repair and extension.

The significant expansion in UK marine protected areas over the past two decades and the consolidation of policy and legal instruments for their protection have concentrated a regulatory environment in which the integration of, and compromise between, societal and ecological priorities is driving innovation on developed coasts worldwide.

As the Environment Act 2021 moves towards mandatory delivery of biodiversity net gain, local nature recovery networks, and national environment objectives 2023, the need for effective compromise and

combination between these socio-economic drivers and the statutory ecological priorities that coexist along the coast will become more urgent.

Actions to Mitigate Pressures on the Plymouth Foreshore

Pressures affecting the Plymouth foreshore are similar to those affecting other coastlines across the UK. As such, a range of interventions are needed to mitigate the complex cluster of pressures. Below are suggested actions undertaken in similar environments as mitigation approaches.

- **Creating or restoring adjacent wetlands:** sparing adjacent marginal land, for example, to open backwater habitats and side channels where vegetation can establish and natural debris can accumulate, providing a range of refuge niches.
- **Incorporating vegetation:** adding new planting, particularly in engineered channels' upper fresh and brackish zones. Reduced maintenance may, in places, release the natural regeneration of bankside, emergent, and splash zone cover. Techniques for stabilising new in-channel planting are well-established in standard river restoration specifications. Bankside cover, for example, tree and shrub canopy, can add roost and cover habitat for emerging riverflies.
- **Creating fish passages:** the impact of increased spatial, temporal and salinity barriers to the safe transit of aquatic fauna (fish, crustaceans, insects) between marine and freshwater systems via transition zones can be alleviated by providing stepping-stone refuge niches and facilitated crossing points where required. For example, a mix of built artificial habitat features (pools, tiles, blocks) fitted to channel walls within and above the tidal range and small ladder and pavement installations, modular or single unit, can create arrays supporting built habitat for wildlife transit.
- **Implementing sustainable stormwater management:** practices within and adjacent to the foreshore help reduce additional surface water inputs and associated contaminants. The work of catchment and coastal partnerships in advising on local development projects and ensuring the incorporation of rain gardens and similar storage solutions is directly relevant to water quality management.
- **Encouraging positive behaviours:** foreshores and transition zones are often characterised by significant public pressures because of their access routes to the shore and the recreational spaces they provide. The concentrated presence of visitors creates an opportunity for engagement in these spaces and a chance to talk about fresh and saltwater environments simultaneously and in the same place. By grouping and clustering built and designed interventions for wildlife that combine fresh and saltwater systems, riparian and coastal habitats, aquatic and terrestrial ecology, there is an opportunity to concentrate visible action for habitat enhancement, maximise encounters with wildlife (through these installations), and focus public messaging, interpretation, and orientation into the wider environment (upstream and down).
- **Creating pools and retrofitting panels:** adding texture, surface, and interstitial complexity to existing coastal infrastructure is proven to increase intertidal habitat availability for colonising species. These can be comparatively low-cost and non-technical options for enhanced ecological performance. Pre-cast pools and panels fixed to smooth vertical built surfaces can also boost intertidal habitat and niche provision without impacting the structure's integrity. Constructed habitats in the intertidal can deliver compound gains for wildlife when grouped to generate ‘halo’ effects that extend enhancements beyond and between arrays. Similarly, reworking existing features such as rock armour, timber groynes and sea walls by cutting directly into surfaces to create additional texture and complexity and by adapting maintenance programmes to include ‘patching’ techniques that add textured finishes to repairs and fills, which will build surface complexity and support greater biological interest.

- **Fish and mussel refuges:** Coastal transitional zones are essential for migratory fish species and as nurseries for juveniles. Opportunities exist to embed fish refuges and fish passes into coastal enhancement projects, including additional shelters, 'swim-through' habitats, ladders, and stepped retrofits. Mussel enhancements add niche features for colonisation in the built environment and can be used to build up new populations in previously sub-optimal environments.
- **Self-cleaning slipways and steps:** most commonly constructed with a relatively smooth concrete texture. Algal growth on these surfaces can heighten the risk of slipping. As a result, many of these structures are routinely chemically cleaned or pressure-washed, potentially contaminating the water environment. The need for a safe working and recreational environment for people is paramount, but there are potentially nature-based solutions that can achieve a better balance. Creating textured surfaces to encourage intertidal grazer (limpets, periwinkles, etc.) colonisation can reduce the levels of algae cover naturally and maintain clear access. The research supporting such enhancements is still in its infancy. However, it is known that adding small holes, grooves, and channels allows grazers to colonise more easily. Applying this theory to slipways and steps could add intertidal habitat whilst reducing the need for regular cleaning. A study by Natural Resources Wales is currently exploring this method. However, the extensive literature on mollusc and limpet grazing suggests a design solution for slipways whereby adjunct pools and texturising treatments on the slipway walls provide refuge/homing bays for grazers. Therefore, hotspots for grazing through these interventions can be on or near slipways, ideally in low-footfall areas, maximising the potential for helpful algae grazing.

4. Intentional Habitat Options

The design and testing of conservation interventions and applied research in the field of ecological engineering in the built marine environment began in the early 2000s, though experimental work on structures as habitats was being undertaken twenty years earlier. Academic and industry collaboration has accelerated considerably in the last decade. The concept of 'Integrated Green-Grey Infrastructure' (IGGI) is now being incorporated into industry standards for construction, development and infrastructure through published best practices and training, for example, Natural Environment Research Council (NERC) and DEFRA guides, Construction Industry Research and Information Association (CIRIA) and Chartered Institute of Ecology and Environmental Management (CIEEM) courses and seminars.

The requirements of the Environment Act 2021, and especially the mandatory provision of biodiversity net gain (BNG) as part of environmental regulatory compliance, have encouraged new thinking and practical innovation. BNG and other environmental financial obligations are gaining traction and present opportunities to collaborate with the private sector to generate more resources for ecological enhancement through intentional habitat creation. Ecological design and the construction of intentionally built habitats as integral to, and as retrofitted to, buildings and infrastructures (as fixtures, fittings, attachments, renders and repairs) is at present better developed and more ambitious in the marine environment than in terrestrial and freshwater systems. It can benefit from a more extended time depth of experimental interventions, such as artificial reef creation and fishery enhancement. Still, it can also be quickened by growing public awareness of the devastating impacts of marine pollution, over-fishing, and seabed destruction. The number of active and published research papers, academic course content, international university collaborations, and product innovations available for construction projects provides evidence.

Protecting, enhancing and rebuilding habitats for marine and coastal wildlife remains the primary driver in the field, but there are other important goals of eco-engineering and IGGI practice:

- Supporting ecosystem functions and services (e.g., attracting filter-feeders to improve water quality)
- Promoting commercial and recreational fisheries
- Excluding non-native or nuisance species
- Provide nature-based solutions (NbS) to mitigate pressures from coastal erosion induced by climate change impacts (sea level rise, increased storms, coastal flooding)
- Enriching the public realm and human experience of the coast
- Opportunities for education and research

All these objectives nevertheless remain, to a greater or lesser extent, underpinned by certain species (or groups of species) that make up the biodiversity colonising structures, and by the effects of interventions on marine macroalgae, microalgae, invertebrates, and fishes on and around structures and within the wider receiving environment.

The Conservation Evidence publication in 2021, Enhancing the Biodiversity of Marine Artificial Structures, Global Evidence for the Effects of Interventions, appended to this report, identifies 43 separate conservation interventions that could be carried out to enhance the biodiversity of marine artificial structures in subtidal and intertidal environments. The set relating to the intertidal can be conveniently grouped into a typology of seven: Small features worked into existing structures, Retrofit rockpools, Pre-cast 'drop-in' modules, Upcycled, re-imagined and sacrificial materials, Integrated features in new construction, Repair and maintenance of damaged structures, Retrofit textured panels. In addition to these seven, we propose an additional Community element that can be applied to all examples. Details and example case studies for these approaches are outlined below.

Small features worked into existing structures

Suitable Sites

These interventions are suited to rocky shore environments created by sea walls, rock armour, concrete and stone groynes, piers and jetties, steps, and slipways. Generally, they present a smooth finished surface or are patterned at a very coarse scale, unfavourable to small colonising organisms requiring fine-grained refuge and settlement textures for successful establishment.

Potential Ecological Benefits and Example Methods

By working on these existing surfaces, new habitat patches can be simply and advantageously created and extended opportunistically when funding or circumstances allow. Similarly, repairs to existing features can be modified to add patches of complexity otherwise absent from structures. Holes, pits, scrapes and pattern-imprinting are all effective interventions capable of increasing species richness and abundance repeated over distance by 'punctuated intervention', acting as stepping stones across the available infrastructure.

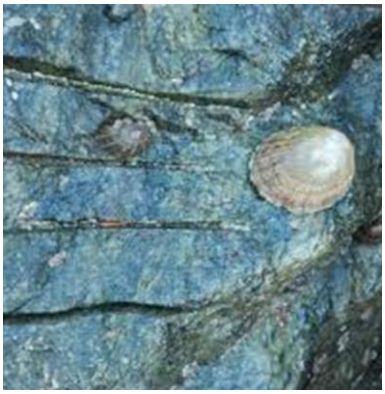


Figure 5 Gouged channels and pits

Figure 6 Small drilled holes

Figure 7 Small gouged pools

Retrofit rockpools

Suitable Sites

Vertical sea wall surfaces, timber and concrete groynes, and sheet pile defences present large, uniform, suboptimal spaces for colonisation from the seabed to the terrestrial interface.

Potential Ecological Benefits and Example Methods

Retrofit fixtures, such as Vertipools (Artecology), can be attached to almost any surface in arrays and clusters that maximise the differences in groups of species living in different parts of the tidal zone. The combination of densely textured surfaces, water retention, and the establishment of new patterns of fine-grained interstitial space, humid low-tide 'envelope' surrounding an array, and drainage across and between individual units creates a strong halo effect extending beyond the installation. This further supports cost-benefit calculations when factored into schemes of punctuated intervention over larger areas of coastal infrastructure.

Both pools and tiles/panels have a striking visual impact, which can add interest and a design aesthetic to the public realm in coastal locations, either as a purely visual amenity or as deliberately positioned attractors for wildlife encounters and beach exploration.

Figure 8 Vertipools on Gabions

Figure 9 Vertipools in situ

Figure 10 Vertipool Array

Pre-cast ‘drop-in’ modules

Suitable Sites

Cast concrete blocks can be incorporated into rock armour during installation, dropped into gaps later, or added to the toe of the deployment.

Potential Ecological Benefits and Example Methods

Drop-in modules can provide a habitable design to the otherwise hostile environment of quarry stone or tetrapod defences. These features have been developed and diversified as commercial options by companies such as ECOncrete (Israel) and Arc Marine (Plymouth, UK). Where blocks are free-standing or partly exposed, they can also host retrofit fixtures such as pools and panels (where wave energy and sediment impact allow). Extensive self-contained features such as these can present novel habitat conditions not otherwise found in natural or defended shorelines, especially on exposed coastlines. Existing colonised boulders from the shore can also be re-positioned as drop-ins and used to ‘seed’ rock armour.

Figure 11 Precast pool unit within rock armour

Figure 12 Precast freestanding ‘bioblocks’

Figure 13 Precast tide pool set into rock armour

Upcycled, re-imagined and sacrificial materials

Suitable Sites / Situations

During coastal defence and other infrastructure works, it is sometimes possible to retain older features as sacrificial habitat provision, for example, building rock armour around a degraded timber groyne, allowing the older structure to take on deadwood habitat functions.

Potential Ecological Benefits and Example Methods

Redundant structures can be further enhanced for biodiversity by attaching retrofits or perforating. Waste materials can similarly be incorporated into some structural works on the coast, such as oyster shells added to aggregate fill for gabions. Gabions also provide ideal features for infill habitat enrichment and external retrofit attachments. Where conventional materials are used for coastal infrastructure, they may already carry incidental patterning or texture beneficial to colonising marine life, such as the machine marks on quarry stone. Where this is the case, enhanced features for wildlife can be optimised by positioning the material most favourably, for example, with pits or grooves uppermost.

Figure 14 Decaying groyne timbers available for reuse as altered habitat features

Figure 15 Oyster shells incorporated into gabion infill as biogenic substrate.

Figure 16 Original quarry machine marks provide potential habitat if correctly aligned.

Integrated features in new construction

Suitable Sites / Situations

All new installations, such as sheet piling (steel and plastic), rock armour, sea walls, and groynes, can include integral features that promote better habitats for wildlife.

Potential Ecological Benefits and Example Methods

New builds in the coastal environment can offer essential opportunities for the integration of niche habitats for marine wildlife if these are identified at an early stage in the design and planning process. Highly textured form liners, some with explicitly defined ecological functions, are now being promoted by companies such as Reckli. Although recessed pools remain problematic to cast in situ, combinations of textured surfaces through pattern imprinting can be imaginatively combined to deliver niche diversity and heterogeneity. New techniques are being developed that may be able to create inset pools safely and efficiently in cast concrete walls, for example, using inflated inserts or sacrificial softwood shapes that are then left to decay under the action of wave impact and deadwood invertebrates (Artecology). Where new timber groynes are being installed or where new/replacement planks are required, these can be pre-modified, most easily, by drilling and recessing groups of small holes along the sides and into the top of the timber.

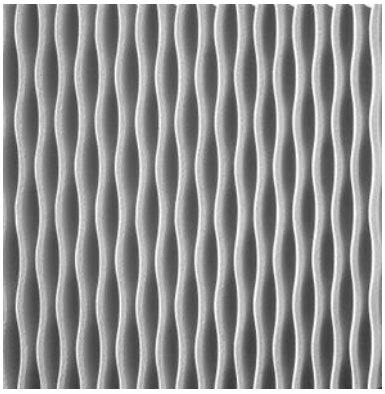


Figure 17 Patterned form liner

Figure 18 The Seattle Sea wall project

Figure 19 North Portsea Island Coastal Defence Scheme

Repair and maintenance of damaged structures

Suitable Sites

Ageing and damaged assets present an important opportunity to introduce ecological enhancements as part of remedial, refurbishment, and upgrade works, modifications, or replacements.

Potential Ecological Benefits and Example Methods

Most running repairs will likely be small patches and/or temporary fixes pending asset replacement or as budgeted or emergency maintenance works. At this scale, repairs are hand-made and offer an unusual opportunity for patterning and texture creation within the scope of standard works using simple tools and techniques to add ecological value and accumulate enhanced conditions for wildlife over time. These interventions can be used to connect and add value to more substantial retrofits on nearby assets and to newly constructed features where infrastructure is extended or replaced, helping to improve habitat connectivity within the intertidal environment.

Figure 20 Sea wall repairs in Vancouver

Figure 21 Texturizing wet cement

Figure 22 Small-scale patching

Figure 23 Texture tile experiment, Shanklin, Isle of Wight

Figure 24 Knitting dipped in stoneware and fired to create highly complex ceramic (then embedded into concrete matrix)

Figure 25 Tiled pavement for fish passage on concrete spillway

Retrofit textured panels

Suitable Sites

Like artificial rockpools, panels can be used in the intertidal wherever they can be fixed, for example, sea walls, timber and concrete groynes and sheet pile defences.

Potential Ecological Benefits and Example Methods

In retrofitting textured panels along the foreshore, opportunities arise to enhance marine habitats and ecological diversity within the existing coastal environment. Innovative textured form liners, including those with specific ecological functions, are now championed by companies like Reckli. While traditional methods for casting recessed pools in situ pose challenges, creative combinations of textured surfaces through pattern imprinting offer a promising avenue for delivering habitat diversity and heterogeneity. Emerging techniques, such as inflated inserts or sacrificial softwood shapes, are being developed to create inset pools safely and efficiently within cast concrete walls. Through these initiatives, the integration of textured panels not only contributes to the ecological richness of the foreshore but also exemplifies the importance of innovation and collaboration in coastal conservation.

There is some evidence that biogenic protection from encrusting organisms such as barnacles, which favour textured surfaces, can add protection to the built surfaces of marine infrastructure, reducing thermal stress and chemical erosion. The potential to develop the concept of ‘self-cleaning’ slipways and steps by deliberately creating textured surfaces for grazer colonisation is also an area of current research.

Figure 26 Habitat Panels (mussel style)

Figure 27 Blue Cube Hex Tiles

Figure 28 Living Seawall Tiles

Terrestrial ecological transition habitat

Suitable Sites

All sites where there is space for interventions.

Potential Ecological Benefits and Example Methods

The provision of terrestrial habitat gives numerous ecological and socio-economic benefits. Ecologically, it serves as a refuge and breeding ground for diverse flora and fauna, fostering biodiversity and supporting intricate ecological networks. These habitats play crucial roles in carbon sequestration, soil stabilisation, and nutrient cycling, contributing to climate regulation and ecosystem resilience. Terrestrial habitats can add recreational opportunities and experiences and help to promote environmental awareness. Examples could incorporate features that support species' lifecycles, including planting schemes, nest and roost boxes, plus refuge & resting spots. Terrestrial habitats can be introduced to complement the context of the site. For example, planting can be provided using species appropriate to the geology and climate and native to the local area. This diverse mix can then provide a multi-species functional habitat. At the more manufactured end of the spectrum, built habitats can provide the conditions for a specific species, e.g., structures with punctuated holes for bees. This provides critical habitat and has the scope to provide nature-education engagement creatively.

Figure 29 Biototems – Solitary bee habitat

Figure 30 Nature Bricks – River Lugg Embankment

Figure 31 Location-appropriate planting

Citizen Science and Engagement

While not a type of habitat, community engagement and citizen science play pivotal roles in safeguarding the foreshore's ecological integrity and cultural heritage. Involving local communities in monitoring and conservation efforts can foster a sense of ownership and responsibility while harnessing collective knowledge and passion for the area. Through citizen science initiatives, local people can actively contribute to data collection, research, and decision-making processes, thus promoting transparency and inclusivity in environmental management. Moreover, public engagement fosters a deeper understanding of the foreshore's significance, fostering a connection that inspires stewardship and sustainable practices.

Figure 32 Texture tile experiment, Shanklin, Isle of Wight

Figure 33 Beach Bugs Bones community event

Figure 34 Sculptural Interpretation – beyond signage with little or no explanatory text

Transferable Techniques

It is important to reiterate that this report's ecological techniques and fixtures can potentially be used at any urbanised coastal location and, in any combination, justified simply by their contribution to habitat niche provision within altered and degraded marine environments. A more locally designed approach will generate significant gains for wildlife, engineering, and environmental performance.

The general prescriptions for ecological enhancement on the developed coast can help frame a strategic approach to nature recovery within the Plymouth project area and establish funding criteria. These include a costed menu of modular items and actions that can be ‘bought’ through environmental mitigation tariffs and invested in as measures of ESG and other sustainability performance metrics.

This report deals mainly with coastal structures owned and managed by public and civic organisations, which are essential in initiating and delivering ecological enhancements consistent with the enhanced biodiversity duty and local nature recovery objectives. Still, there are locations along the Plymouth coastline where private industrial and corporate infrastructure is particularly concentrated. In these localities, there are opportunities for the project to develop new or extended partnerships with commercial interests around Biodiversity Net Gain, Environmental Social Governance (ESG), impact investment performance, and the delivery of the UN Sustainable Development Goals (SDGs).

5. Plymouth Case Studies

Eight locations for ecological enhancement work along the Plymouth City Council coast have been identified and set out in this section.

Figure 35 Case Study Locations

These locations have been selected based on the consultees' advice and preferences and by assessing the type and context of the infrastructure present.

It is important to stress that these recommendations represent the potential of the whole built coast to deliver constructed habitats for ecological enhancement in the intertidal zone.

All coastal assets below mean high water can be enhanced for colonising organisms by increasing surface complexity. Holes, pits, scrapes, pattern-imprinting and retrofit fixtures and fittings are all effective interventions capable of increasing species richness and abundance scaled cost-effectively by ‘punctuated intervention’, acting as steppingstones at ecologically meaningful distances across the built environment.

The listed sites offer opportunities to enhance existing structures with new ecological interventions in the built environment of the coast but in the context of intertidal sediment, saltmarsh, and rocky shore.

The project sites, comprising eight foreshore and estuarine locations from Batten Bay to Ernesettle Creek, were visited in February 2024. The objective of the visit was to identify a suite of options to enhance the foreshore for wildlife.

The following table summarises the case study locations' habitat types and National or International designations:

Site Name	Priority Habitat present or proximate	European Marine Sites (EMS) Habitat	International / National Designations	Ecological Coastal Unit[1][2]
Tamerton Lake and Ernesettle Creek	Mudflats, Coastal Saltmarsh, reedbeds	Intertidal mixed muddy sediments	Plymouth Sound & Estuaries SAC Tamar Estuaries Complex SPA Tamar Estuary Sites MCZ Tamar - Tavy Estuary SSSI (favourable condition) Tamar Valley National Landscape (previously AONB)	6
Hooe Lake	Mudflats	Intertidal mixed muddy sediments	None	3
River Plym – Laira Bridge and Arnold's Point	Mudflats	Intertidal mixed muddy sediments	County Wildlife Site	6
Mount Batten	Maritime cliff and slope	Subtidal mixed sediments, Intertidal rock and boulder communities	Plymouth Sound & Estuaries SAC - Batten Bay and South side of Pier Plymouth Sound Shores and Cliffs SSSI - Favourable Condition (Batten Bay Only)	3
Sutton Harbour	None	Intertidal rock and boulder communities (nearby), Intertidal mixed muddy sediments (nearby)	None	6
Devils Point Tidal Pool	None	None	Plymouth Sound & Estuaries SAC (does not cover the lido) Western King SSSI Condition: unfavourable, no change (does not cover the lido)	3
Stonehouse	Mudflats	None	Plymouth Sound & Estuaries SAC	3/6
Mutton Cove	None	None	Plymouth Sound & Estuaries SAC	6

[1] https://www.esri.com/arcgis-blog/products/arcgis-living-atlas/mapping/ecus-available/
[2] ECU: 6: sloping, sinuous, medium erodibility, warm temperate moist, moderate river discharge, low wave energy, macrotidal, euhaline-hypoxic-moderate to cool, moderately turbid, low chlorophyll
ECU: 3: sloping, sinuous, low erodibility, warm temperate moist, moderate river discharge, low wave energy, macrotidal, euhaline-hypoxic-moderate to cool, moderately turbid, low chlorophyll

Tamerton Lake and Ernesettle Creek

Habitat Context

A creek running off Tamerton Creek leads out to the River Tamar with areas of mudflat and saltmarsh at low tide. The creek is bordered by woodlands with grassland areas and community orchards further inland from creeks. There is rock armour around Tamerton Creek. The causeway is all that remains of the old budshead farm tidal mill. The causeway's current role is to support a public right of way and protect the mudflat habitat and wading birds of Ernesettle Creek from higher energy waters.

The following National and International conservation designations protect Ernesettle Creek:
See Figure 36 below.

- Plymouth Sound & Estuaries SAC
- Tamar Estuaries Complex SPA
- Tamar Estuary Sites MCZ
- Tamar - Tavy Estuary SSSI (favourable condition)
- Tamar Valley National Landscape

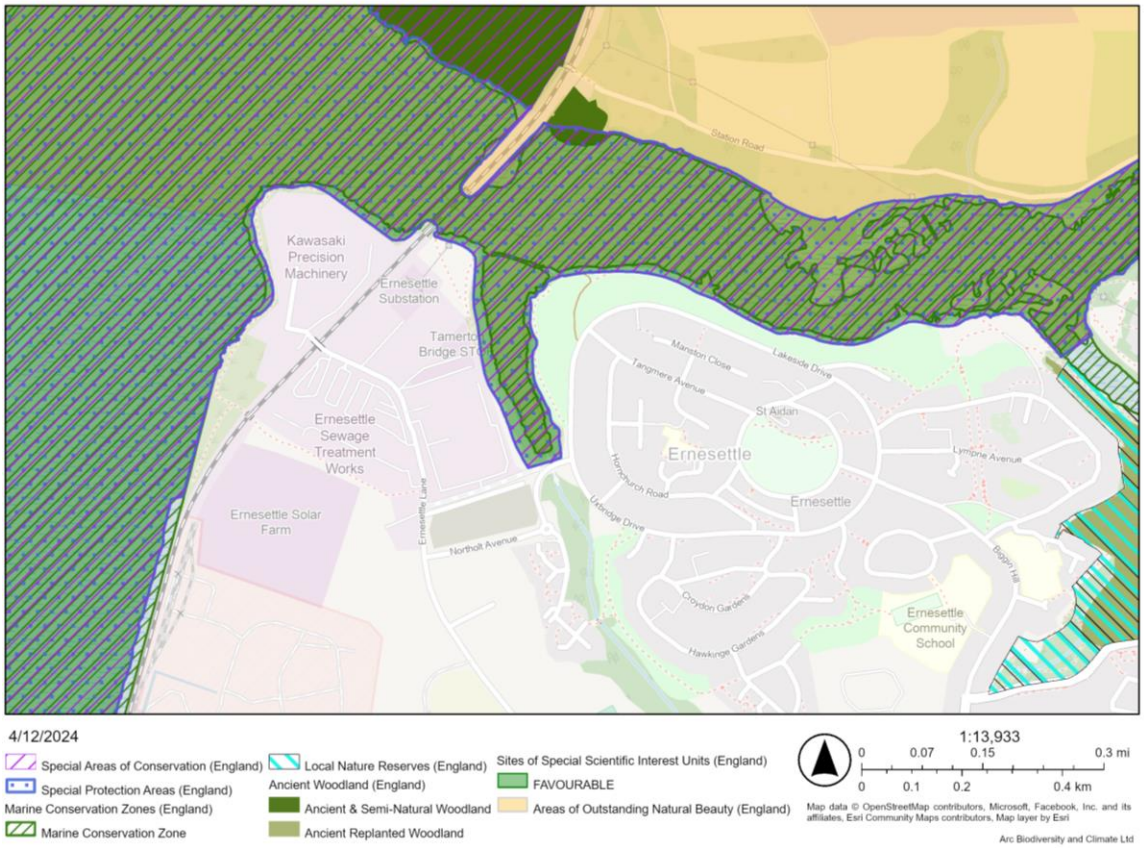


Figure 36 Ernesettle Creek - Designation Context

Opportunities

While the creek is privately owned, it is well-used by the local community and bordered by a residential area and several schools. This mudflat and saltmarsh habitat has footpaths along the creek's edge with bird habitat, bordered by a woodland corridor. The hill just above the creek has a sizeable community orchard, with another not far away, pointing to an active community willing to engage with future projects. The causeway across the mudflat has three concrete brick bridges. The step structure at the start of the bridge has a running feature (at the time of the survey), which could be used in conjunction with water retaining structures. There is space for optimising natural successional habitats forming under the bridges where water is already pooling due to a concrete ridge (visible from the footpath).

Limitations

- Multiple conservation designations protect the Creek.

Ecological Enhancement Potential

Figure 37 Tamerton Lake / Ernesettle Creek Aerial

Magnetically deployable intertidal MicroPools on Tamerton Railway Bridge stanchions and handcrafted Intentional Habitats called PodPools will create dynamic rocky shore intertidal reef habitats, fostering biodiversity and providing ecological and nature recovery value. Community involvement could be encouraged through workshops, ensuring a sense of ownership and stewardship over Ernesettle Creek's natural resources.

Project Objectives:

- Enhance intertidal biodiversity: Deploy MicroPools on the bridge stanchions and PodPools in Ernesettle Creek's intertidal zones to create habitat structures supporting diverse marine species, enriching the local ecosystem.
- Foster community engagement: Engage residents in hands-on workshops to construct and install MicroPools and Pod Pools, promoting pride and stewardship over the creek's ecological restoration.
- Promote ecological education: Develop interpretive materials and educational programs to raise awareness about the importance of intertidal habitats and the species they support, educating both residents and visitors.
- Monitor and evaluate habitat effectiveness: Implement monitoring protocols to assess the ecological impact of MicroPools and PodPools on local biodiversity and ecosystem health over time.

Implementation:

1. MicroPool Deployment on Bridge Stanchions:
    a. Utilise magnetically deployable intertidal MicroPools on the bridge stanchions to create additional habitat structures within Ernesettle Creek's intertidal zones around the causeway.

   b. Design MicroPools to provide shelter and foraging opportunities for small intertidal and shoreline organisms, enhancing biodiversity and promoting ecological connectivity along the bridge infrastructure.
2. PodPool Construction Workshops:
   a. Organise community workshops to construct and install Pod Pools in targeted areas of Ernesettle Creek's intertidal zones.
   b. Facilitate hands-on learning experiences for participants of all ages and skill levels, encouraging a sense of ownership and connection to the creek's ecological restoration efforts.
3. Monitoring and Evaluation:
   a. Implement monitoring programs to assess the colonisation and utilisation of MicroPools and PodPools by marine organisms, documenting changes in species diversity and abundance over time.
   b. Engage community volunteers in data collection and analysis, providing training and resources to support ongoing monitoring efforts and adaptive management strategies.

Community Engagement and Knowledge Sharing:

- Develop interpretive signage and educational materials to be installed at key locations along Ernesettle Creek,
- Providing information on intertidal ecology and the role of habitat enhancement in supporting marine biodiversity.
- Organise guided tours, outreach events, and educational programs to engage residents, schools, and community groups in hands-on learning experiences focused on intertidal habitats and conservation.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

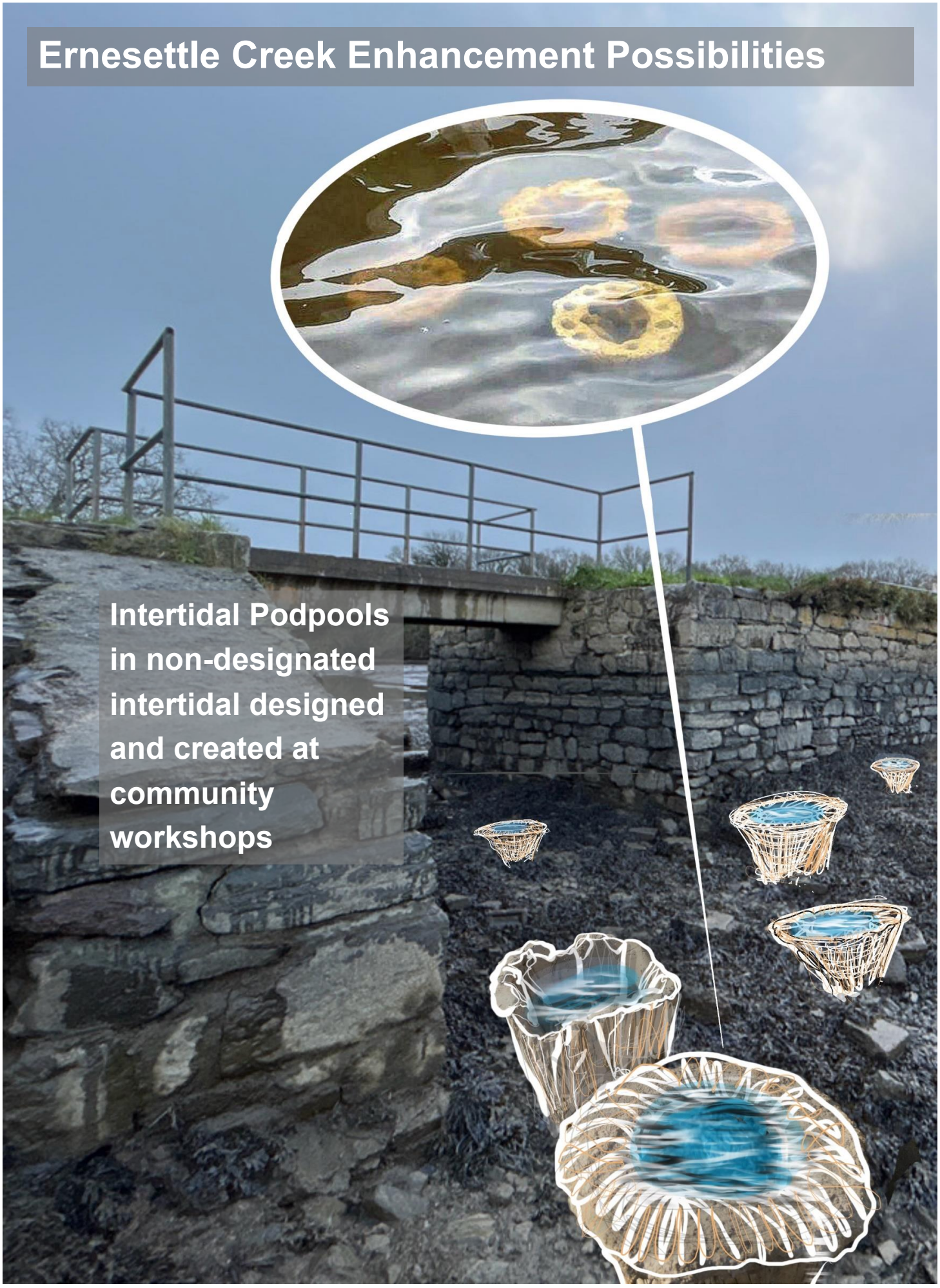


Figure 38 Ernesettle Creek Enhancement Possibilities

Figure 39 Tamerton Railway Bridge Enhancement Possibilities

Hooe Lake

Habitat Context

At low tide, the Lake is an expansive mudflat habitat leading to the River Plym. Hooe Lake is bordered by rock armour, concrete walls, woodland, and sewage treatment works with residential areas behind. The South West Coastal Path (SWCP) follows the periphery of Hooe Lake. There is a small sandy beach area by the northern car park. On the other side of the bridge/car park, a footpath leads through Radford Woods Local Nature Reserve and Radford Park. Radford Lake is a freshwater lake on the other side of the bridge, surrounded by woodland and footpaths.

Hooe Lake is not protected by any National/International conservation designations:
See Figure 40 below.

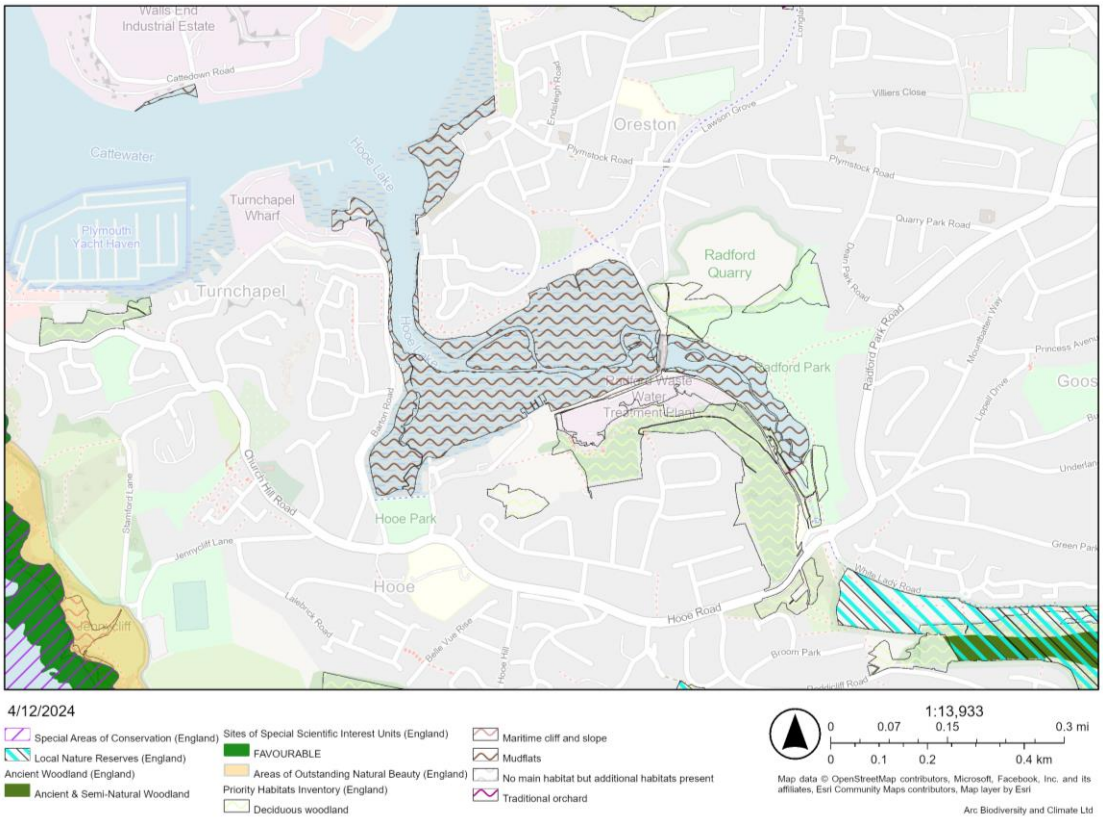


Figure 40 Hooe Lake - Designation Context

Opportunities

Hooe Lake: Radford Castle

This site offers an excellent opportunity for enhancement as there are already building works around the concrete structures and the tower. The site is a large, expansive mudflat habitat backed by a lake and an area of woodland with paths on either side of the lake. Across the mudflat, there are various wooden shipwrecks, as well as smaller boats, docked up around the edges. At the bridge/tower end, there is a small car park that joins the SWCP. A path runs around the edge of Hooe Lake, backed mainly by a residential area. The concrete defence structures are mostly concrete blocks and some areas of encased rock armour.

Hooe Lake: Beach

At low tide, a sandy/silty beach area borders the rock armour edge of Hooe Lake, which has limited accessibility. A weaker/older stone wall borders the lake below from the car park.

Limitations

- Hooe Lake is privately owned, so the nature of the owner may determine actions.
- Radford Bridge and Castle is a listed building.

Ecological Enhancement Potential

Figure 41 Hooe Lake - Aerial

Project Objectives: Wreck Repurposing

- Enhance intertidal biodiversity: Repurpose the deteriorating boat wreck within the intertidal zone of Hooe Lake to create micro-habitats and niches for marine wildlife.
- Preserve existing ecological value: To maximise ecological benefits, use the decaying structure of the boat wreck, which already supports considerable biodiversity.
- Explore additional opportunities: Investigate the feasibility of incorporating high-water bird roosts into the wreck structure to enhance habitat diversity further.

Implementation: Wreck Repurposing

1. Drill varying sizes and depths of holes into the timber sections of the boat wreck to create microhabitats and niches for a diverse array of marine wildlife, including fish, crustaceans, and molluscs.
2. Assess the wreck's structural integrity to determine the feasibility of incorporating high-water bird roosts, providing additional bird habitat opportunities.

Project Objectives: Steel Bridge Stanchion Habitat Installation

- Establish diverse habitats: Install magnetically deployable Intentional Habitats on the old steel bridge stanchions to create a multi-layered ecosystem supporting intertidal and terrestrial species.

- Promote biodiversity: Enhance habitat diversity and connectivity within the intertidal zone of Hooe Lake, providing nesting and foraging opportunities for wildlife.
- Explore innovative habitat designs: Investigate the potential for constructing planted habitat platforms at the top of the stanchions to support ground-nesting birds, invertebrates, and other species.

Implementation: Steel Bridge Stanchion Habitat Installation

1. Deploy magnetic MicroPools for intertidal rockpool habitats and bird nesting pods on the high sections of the steel bridge stanchions, maximising vertical habitat space and ecological functionality.
2. Construct planted habitat platforms at the top of the stanchions to support ground-nesting birds, invertebrates, including solitary bees, and other pollinators, enhance habitat diversity, and promote ecosystem resilience.

Community engagement and knowledge sharing:

Engage the community through excellent signage and interpretation to raise awareness about the projects' ecological importance and encourage community involvement in habitat monitoring and conservation efforts.

The ecological uplift projects at Hooe Lake present innovative opportunities to repurpose existing structures for biodiversity enhancement. By optimising the boat wreck and steel bridge stanchions, we can create a mosaic of habitats supporting diverse marine and terrestrial species.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

Figure 42 Hooe Lake - Wreck Enhancement Possibilities

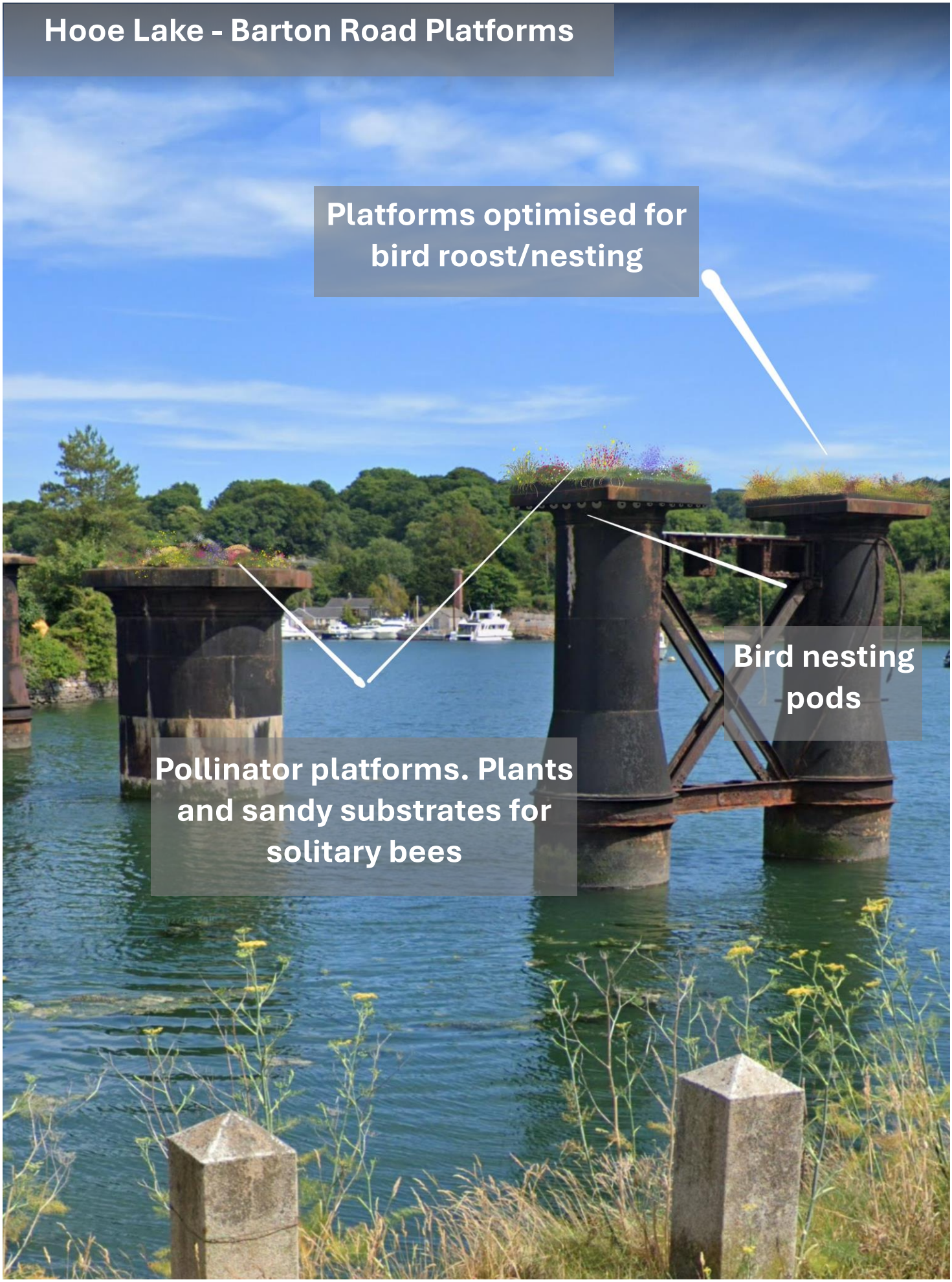


Figure 43 Hooe Lake - Barton Road Platforms Enhancement Possibilities

River Plym – Laira Bridge & Arnold's Point

Habitat Context

Expansive area of mudflats at low tide. The main widths of the river do not appear accessible and are built up on either side with some soft vegetation buffer verges. Concrete wall and rock armour along much of the length of the river. The river flows into Plymouth Sound and begins from/passes through the National Trust Saltram Estate, where there are areas of saltmarsh, woodlands, meadows and saline lagoon.

The River Plym near Laira Bridge is not protected by any National/International conservation designations, see Figure 44 below.

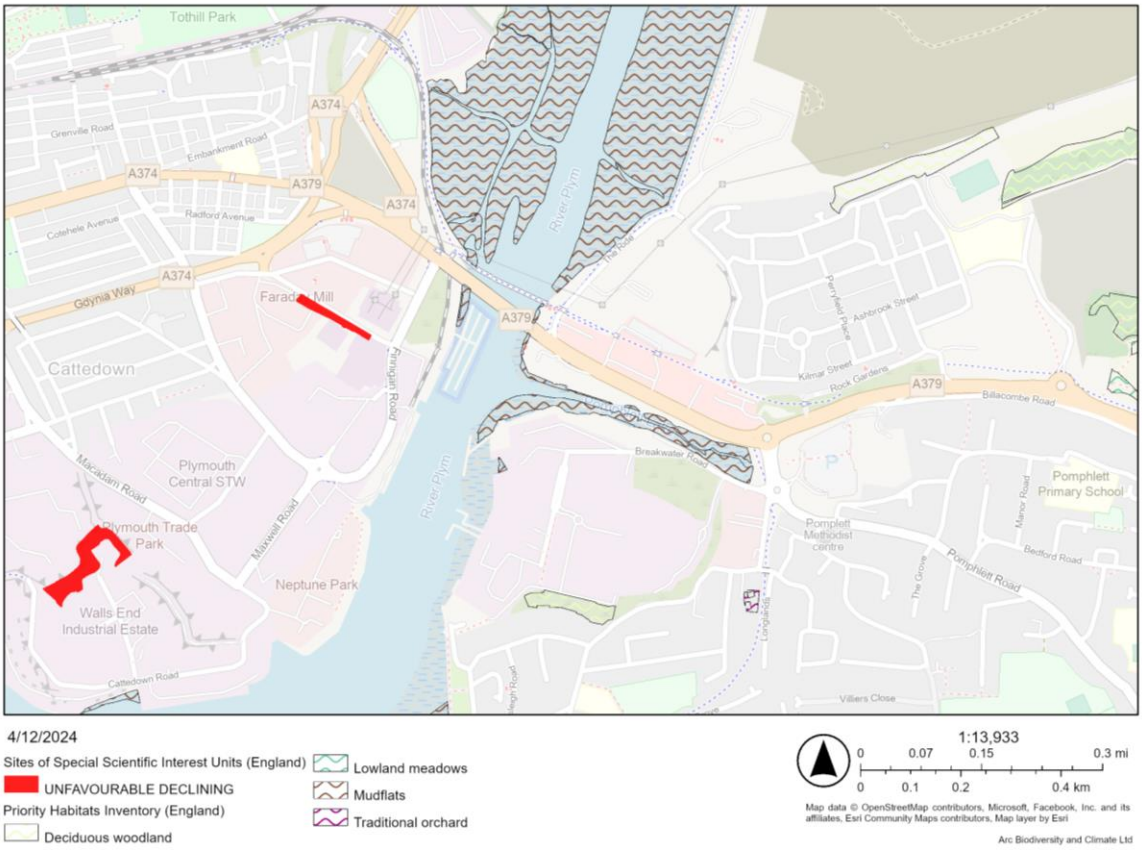


Figure 44 River Plym - Designation Context

Opportunities

The main wide section of the river is mostly inaccessible along busy roads and the train line. Further up the river, it is within the Saltram estate, Leigham Wood and Plymbridge Wood - where there are more footpaths. Around the section by the Old Laira Bridge on the eastern side, a footpath and cycle path runs along the river's edge along 'The Ride' and contains some concrete infrastructure. Rock armour is along this edge of the riverbank, with a large sewage outflow. The location is also opposite a recycling centre. The concrete infrastructure is old and needs repair, so it is an excellent opportunity for enhancement with a mix of concrete blocks and smoother concrete walls. The other riverbank has a softer edge but is inaccessible, backed by a main road and a railway.

Old Laira Bridge

Another opportunity would be at the feet of the pedestrian and road bridge that crosses the river. There could then be complementary engagement opportunities on the pedestrian bridge, explaining the enhancements below. This popular walking route connects the East and West sides of Plymouth and appears to be a school/college commute route. The verges cover the river edges with grass or trees—the strips are limited but could benefit from soft enhancement.

Pontoon

An old pontoon is sitting within the river, exposed on mudflats at low tide. This structure looks to be unused and likely in disrepair. This is a potential site for bird nesting and provides a public engagement opportunity via the opposite footpath and cycle path.

Ecological Enhancement Potential – Laira Bridge

Figure 45 River Plym, Laira Bridge - Aerial

Plymouth City Council could initiate a visionary project to transform Laira Bridge into a vibrant ecological corridor, bridging communities and promoting biodiversity. Leveraging Artecology's principles outlined in our "Shaping Better Places" manifesto, this project aims to revitalise urban environments and create interconnected habitats for wildlife and people.

Project Objectives: Laira Bridge

- Enhance biodiversity: Retrofit Laira Bridge with intentional habitats to support a diverse range of intertidal, terrestrial, and avian species, contributing to the conservation of local wildlife populations.
- Foster community engagement: Designate Laira Bridge as a shared space for people and wildlife, encouraging meaningful interactions and enhancing a sense of stewardship among residents.
- Promote ecological connectivity: Establish Laira Bridge as a vital link within a network of urban biological corridors, facilitating wildlife movement between urban green spaces and coastal/estuarine habitats.
- Celebrate local heritage: Showcase Laira Bridge's unique character and historical significance, enriching the sense of place and reinforcing community pride.

Implementation:

1. Intentional Habitat Retrofit:
    a. Implement punctuated ecological interventions on Laira Bridge to create a series of engineered habitats tailored to provide the lifecycle resources of local wildlife.
    b. Incorporate features such as intentional habitats for - intertidal zones, vegetated surfaces, and nesting sites to provide breeding, feeding, and roosting opportunities for various species.
    c. Utilise innovative materials and designs to minimise environmental impact and enhance structural resilience.
2. Community Engagement Initiatives:
    a. Organise outreach programs, workshops, and guided tours to raise awareness about the ecological importance of Laira Bridge and its surrounding habitats.
    b. Collaborate with local schools, community groups, and volunteers to participate in habitat monitoring and stewardship activities.
    c. Install interpretive signage and interactive exhibits to share knowledge with visitors about the bridge's ecological significance and the species it supports.
3. Ecological Monitoring and Research
    a. Establish long-term monitoring protocols to assess the effectiveness of habitat interventions and track changes in biodiversity over time.
    b. Partner with academic institutions and research organisations to conduct studies on wildlife utilisation of the bridge habitats and their contribution to local ecosystems.
    c. Use data collected from monitoring efforts to inform adaptive management strategies and optimise habitat designs for maximum ecological benefit.

Heritage Interpretation and Art Integration:

- Commission local artists to create site-specific installations and artworks inspired by Laira Bridge's natural and cultural heritage.
- Develop interpretive materials highlighting the bridge's history, architecture, and ecological significance, integrating storytelling and multimedia elements to engage visitors.
- Host public events and performances celebrating the bridge as a symbol of community identity and ecological resilience.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

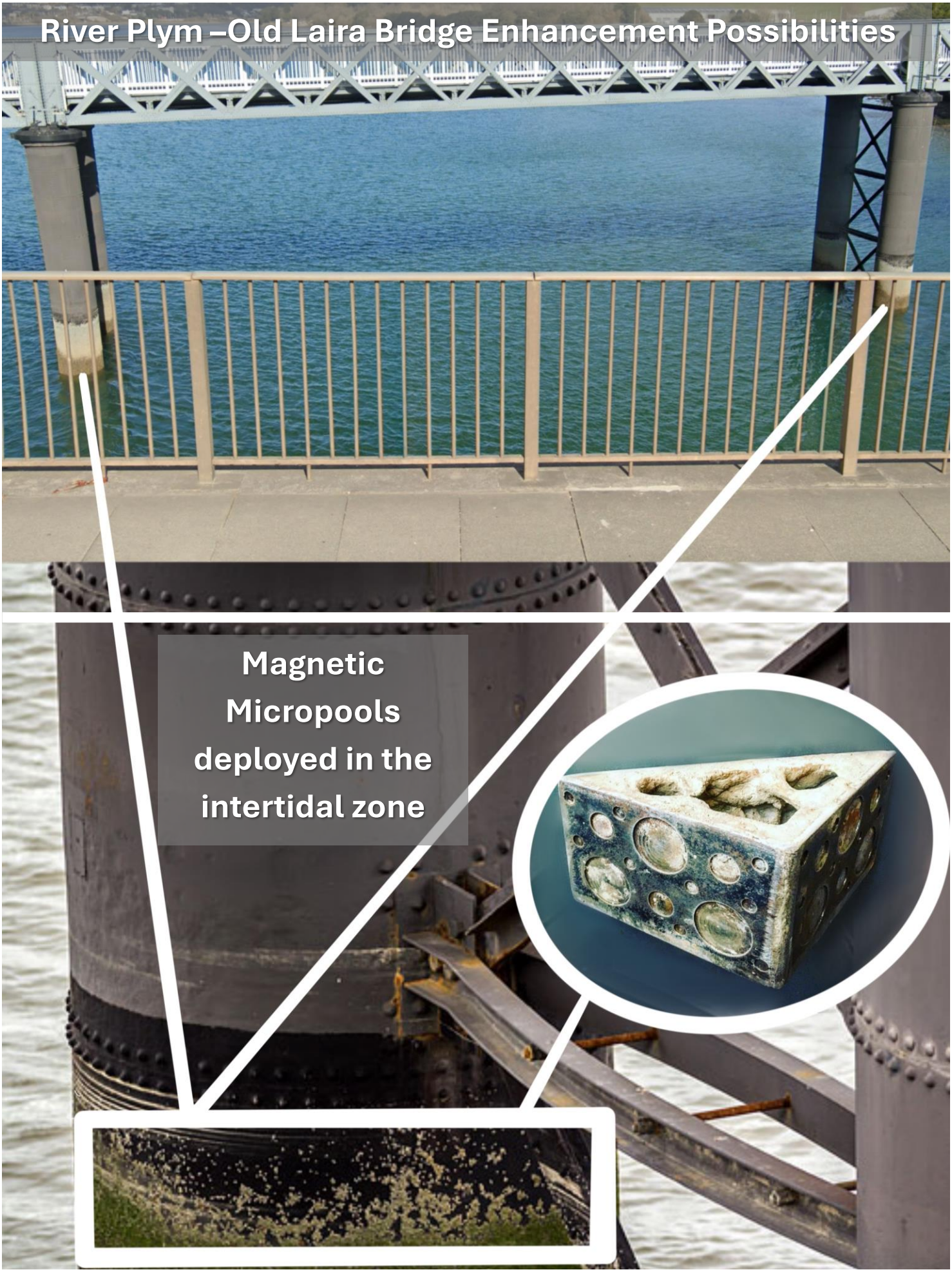


Figure 46 River Plym –Old Laira Bridge Enhancement Possibilities

Figure 47 River Plym –Old Laira Bridge Enhancement Possibilities

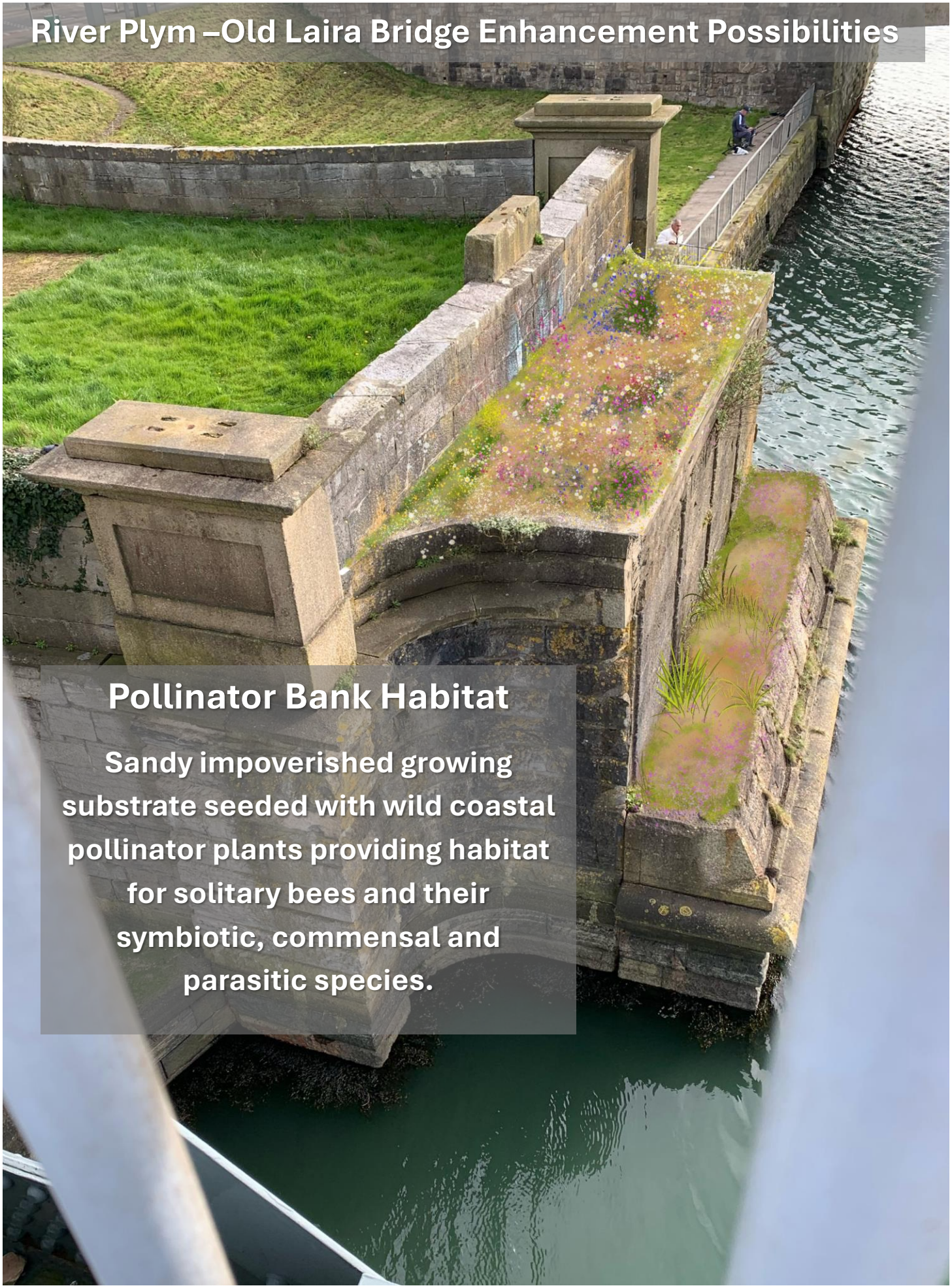


Figure 48 River Plym –Old Laira Bridge Enhancement Possibilities

Ecological Enhancement Potential – Arnold Point

Figure 49 Arnold's Point – Aerial

Enhancing Biodiversity and Flood Resilience at Arnolds Point

Arnolds Point, located along Embankment Road in Plymouth, is a critical area facing increased flood risk due to rising sea levels. This proposal aims to integrate flood defence infrastructure with innovative ecological enhancements to promote biodiversity and resilience against future flooding events. The scale of this project necessitates a comprehensive stand-alone scoping document to explore ecological enhancement possibilities and flood mitigation strategies. We suggest collaborating with local experts in habitat restoration, flood engineering, and urban planning to develop concept designs that integrate ecological enhancements with flood defence infrastructure.

Note: We understand that it may be too late to implement any new design ideas for Arnold's Point simply because planning may have progressed too far, making additions or changes to the existing scheme design and delivery impossible.

Project Objectives

- Enhance ecological resilience: Implement innovative habitat enhancements and flood defence measures to promote biodiversity and ecosystem health at Arnolds Point.
- Improve flood resilience: Integrate flood defence infrastructure with nature-based solutions to protect critical road and railway infrastructure from the impacts of rising sea levels and increased flooding frequency.

- Foster community engagement: Engage stakeholders and residents in the planning and implementation, promoting awareness and participation in flood resilience and ecological restoration efforts.

Scope of the Project

Arnolds Point requires a detailed scoping document to explore various ecological enhancement possibilities and flood resilience strategies. The project will address the following key components:

Ecological Enhancement Interventions

- Explore habitat enhancement opportunities similar to those we've proposed for other sites in Plymouth, tailored to Arnolds Point's unique ecological and flood timeline context.
- Consider how deploying habitat structures such as Vertipools, Invertipools, MicroPools, Flat bottomed pools, and Habitat Panels, plus soft landscaping interventions, might support biodiversity and bio-abundance as existing habitats transition from terrestrial to intertidal over time.
- Potential for CoCreate interventions made possible through hands-on community workshops.

Flood Defence Infrastructure

- As above, design and implement flood defence measures that integrate nature-based solutions, such as green infrastructure and coastal habitats, to allow flood risks to develop into enhanced ecological resilience.
- Evaluate the feasibility of combining flood defence infrastructure with habitat enhancements to create multifunctional and sustainable solutions, particularly using the 'InVertipool' currently in development at Artecology.

Community Engagement and Stakeholder Involvement

- Engage local stakeholders, including residents, businesses, and transportation authorities, in the project planning and decision-making process.
- Conduct outreach activities, workshops, and public consultations to solicit feedback and foster community support for flood resilience and ecological restoration efforts.

Implementation

1. Conduct Site Assessment:

- Understand the current ecological conditions and future possibilities relating to transitioning habitats, identify critical areas for intervention, and focus on ecological enhancement now and future transitional habitats.

2. Develop Concept Designs:

- Collaborate with local experts in habitat restoration, flood engineering, and urban planning to develop a concept flood defence infrastructure that integrates hard and soft ecological enhancements over a given timeline of environmental change (e.g., 50 years).

3. Detailed Scoping Document:

- Prepare a comprehensive stand-alone scoping document outlining proposed ecological enhancement interventions, flood vs emerging habitat resilience strategies, implementation timelines, and monitoring.

Figure 50 Arnold's Point Enhancement Possibilities

Mount Batten

Habitat Context

24m outcrop rock on a 600m peninsula. Vegetated with exposed rock faces, one section is used as an outdoor climbing wall. Mount Batten Breakwater is a primarily concrete structure with rock outcrops, rock pools, and a small sand and stone beach at low tide. Batten Bay is a sandy/rocky beach within a bay of exposed rocky coastline and concrete sea walls, extending to small cliffs covered by grasses. There are areas of rock armour and older concrete seawall infrastructure at the cliff foot. Exposed rocks extend down the beach and across the seabed.

Mount Batten is protected by the following National and International conservation designations, see Figure 51 below.

- Plymouth Sound & Estuaries SAC - Batten Bay and South side of Pier
- Plymouth Sound Shores and Cliffs SSSI - Favourable Condition (Batten Bay Only)

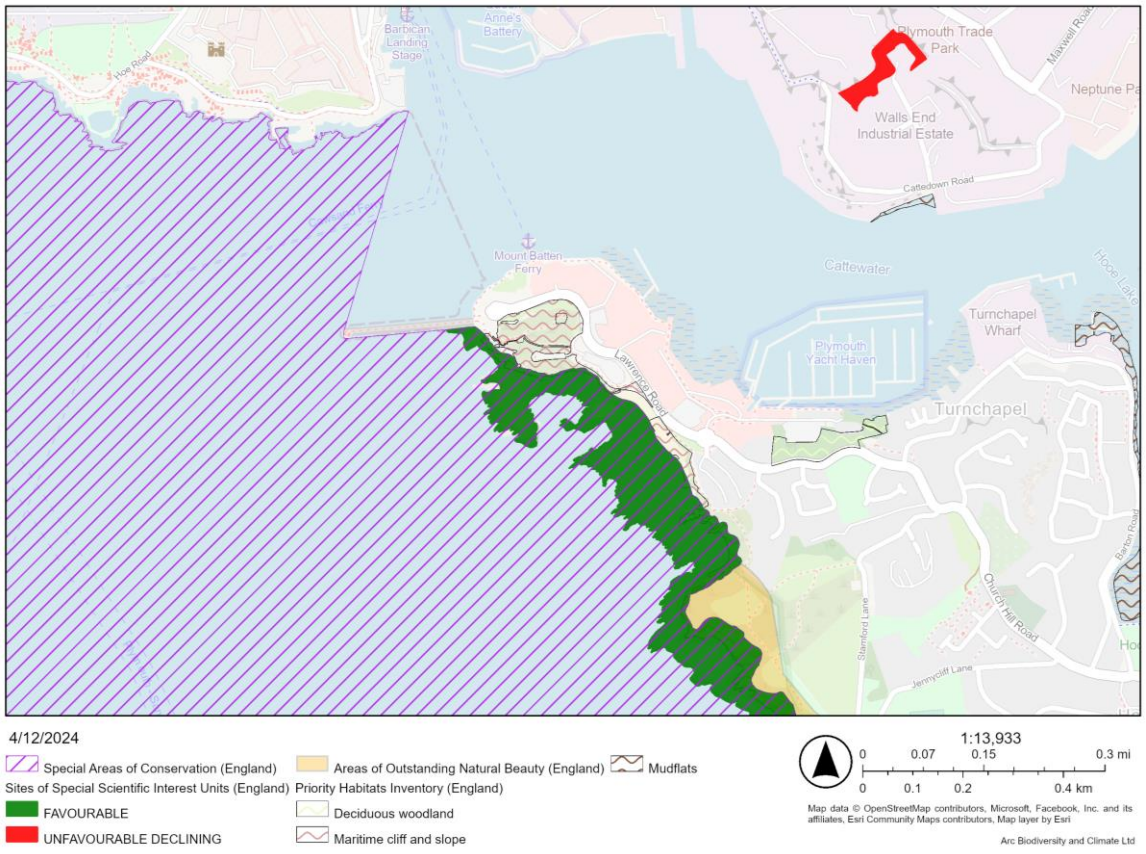


Figure 51 Mount Batten - Designation Context

Opportunities

Overall, it is a good location with easy access and is a popular place for families and recreational fishing. The pier is long and wide, with a concrete wall on the left and a metal railing along the right. At the entrance of the Pier on the right side is an area of flat wall that sits above a small beach and varied pools in the exposed rock. Along the pier's length, extensive rock armour presents opportunities for added texture and niche habitat provision. The wall along the left of the pier is ideal for public engagement and fostering visitor awareness of rock pool habitats and marine wildlife. There are several 'Bait boxes' where fishing tackle is encouraged to be recycled, with some boards explaining why; these would provide a valuable connection to local recreational fishing clubs and bait shops. Given the historical relevance of the site, there is an opportunity for a storyline along the wall, weaving together the built and natural heritage of the pier.

Around the Pier is a car park, public toilets, a restaurant/café, a hotel, and a water sports area further up the road. There is an area of amenity grassland next to the car park with some tree cover. A

footpath (SW Coast Path) crosses the central outcrop rock feature, with more vegetation diversity and an additional car park on the other side. Further up the road are arts/creative organisations and a yacht haven, which may present a collaboration opportunity. There is a large hill to get to the area. At the top is a school, a bungalow estate, a community centre, and a hospice, again providing an opportunity for close community engagement.

Mount Batten: Batten Bay

A small beach area, backed by a slanted concrete sea wall, on the other side of the rock outcrop. A ledge at the bottom of the slanting wall and concrete grooves within the wall. The wall runs parallel to the road and car park. There could be opportunities for plant colonisation on the wall along with engagement infrastructure. Depending on how high the tide comes up, having pools or textured tiles along the face of the ledge would provide beneficial texture and habitat to the existing structure. Further along the beach is older concrete block infrastructure in disrepair. The structure runs between two rock exposures, offering an excellent opportunity to transition the rocky/textured habitat to the currently texture-less blocks. A path down to the beach starts from an outdated engagement board. Again, there is an opportunity to update with the addition of intentional habitat to the existing infrastructure and refreshed information on the current natural habitats and species. A block of creative organisations, the water sports facility, and the yacht club backs the bay, which offers opportunities for collaboration with a creative community while encouraging stewardship of enhancements via their use of the area.

Limitations

- Various conservation designations protect Batten Bay and the south side of Mount Batten Pier.

Figure 52 Mount Batten - Aerial

Project Objectives - Project 1: Vertipool Deployment on Pipe Outfall Infrastructure

The pipe outfall infrastructure at Batten Bay is mounted on a series of concrete footings that bridge into the intertidal zone. This structure presents an excellent opportunity for deploying Vertipools, similar to those on the concrete footings at Kinterbury Creek. By providing habitat niches on the concrete elements of the pipe outfall structure, we can enhance biodiversity and ecological resilience within the intertidal zone of Batten Bay.

Suitability & Implementation - Project 1: Vertipool Deployment on Pipe Outfall Infrastructure

1. Site Assessment: Conduct a detailed assessment of the pipe outfall infrastructure and surrounding intertidal area to identify optimal locations for Vertipool deployment.
2. Design and Fabrication: Customise Vertipools to suit the specific characteristics of Batten Bay's intertidal habitat and ensure compatibility with the pipe outfall structure.
3. Installation: Secure Vertipools to the concrete footings of the pipe outfall infrastructure using marine grade 316 stainless steel fixtures and fittings, taking into account tidal fluctuations and environmental conditions to ensure stability and functionality.
4. Monitoring and Maintenance: Implement a monitoring program to assess the colonisation and utilisation of Vertipools by marine organisms.

Public Engagement- Project 1: Vertipool Deployment on Pipe Outfall Infrastructure

There is an opportunity to link with the existing citizen science project, “The Rock Pool Project”, which is already collecting data on the existing rockpools, which could be compared with the installed versions. There may also be an option to create access to the installed pools for people who cannot usually access natural pools.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

Figure 53 Mount Batten Outfall Enhancements

Project Objectives - Project 2: Addition of Cored Basins and Holes in Existing Rock Armour

In addition to the pipe outfall infrastructure, opportunities for ecological uplift can be created by adding cored basins and holes of various sizes in the existing rock armour. These features will provide additional habitat complexity and refuge for intertidal species, enhancing biodiversity and promoting ecosystem resilience.

Implementation - Project 2: Addition of Cored Basins and Holes in Existing Rock Armour

1. Site Assessment: Identify suitable locations along the existing rock armour line where cored basins and holes can be added to maximise ecological benefits.
2. Construction: Cored basins and holes will be drilled into the rock armour using appropriate equipment and techniques, ensuring minimal disruption to existing habitats and coastal processes.

Monitoring and Evaluation: Monitor the colonisation and utilisation of the cored basins and holes by intertidal species and assess the effectiveness of the intervention in enhancing biodiversity and habitat complexity.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

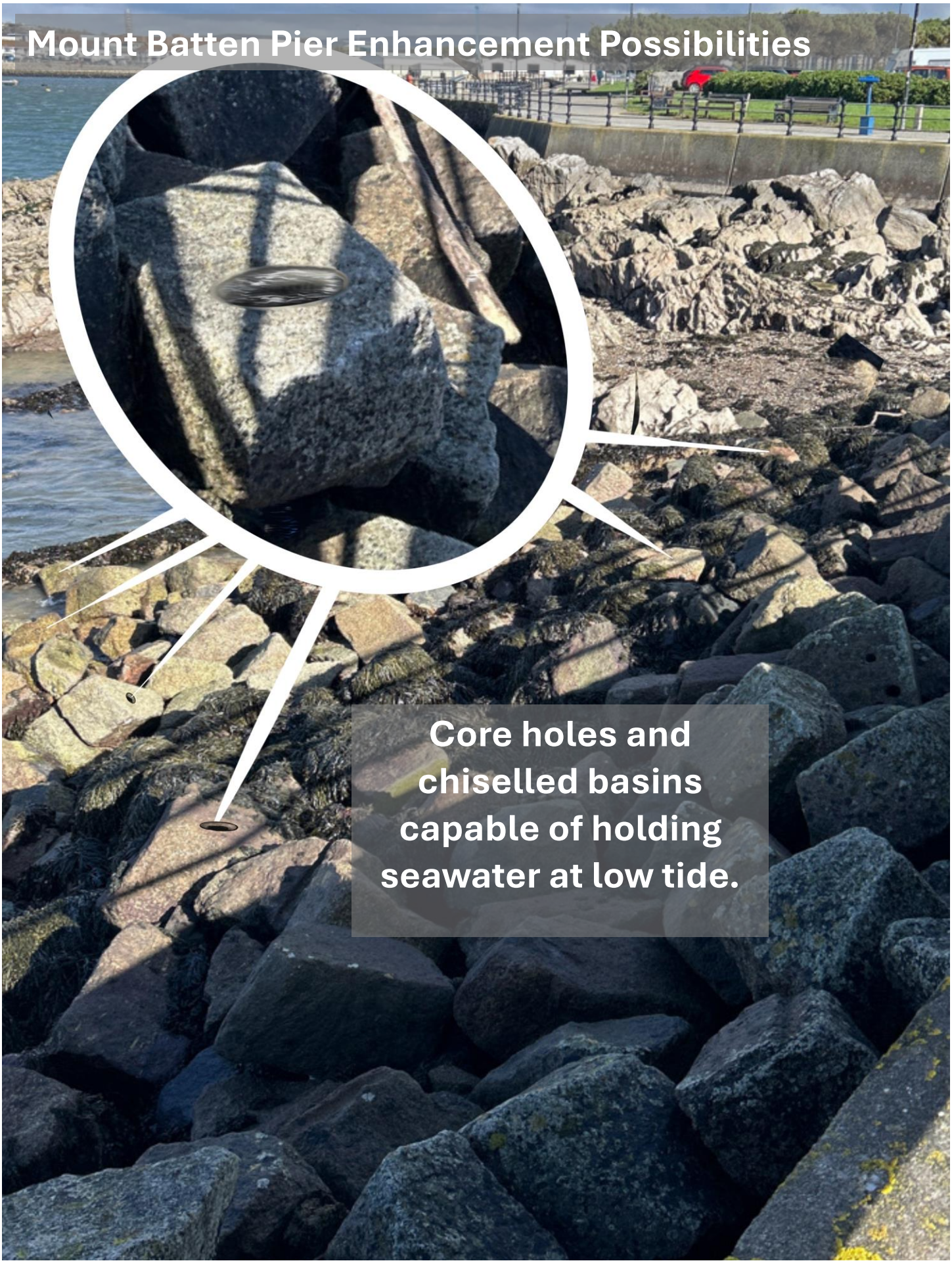


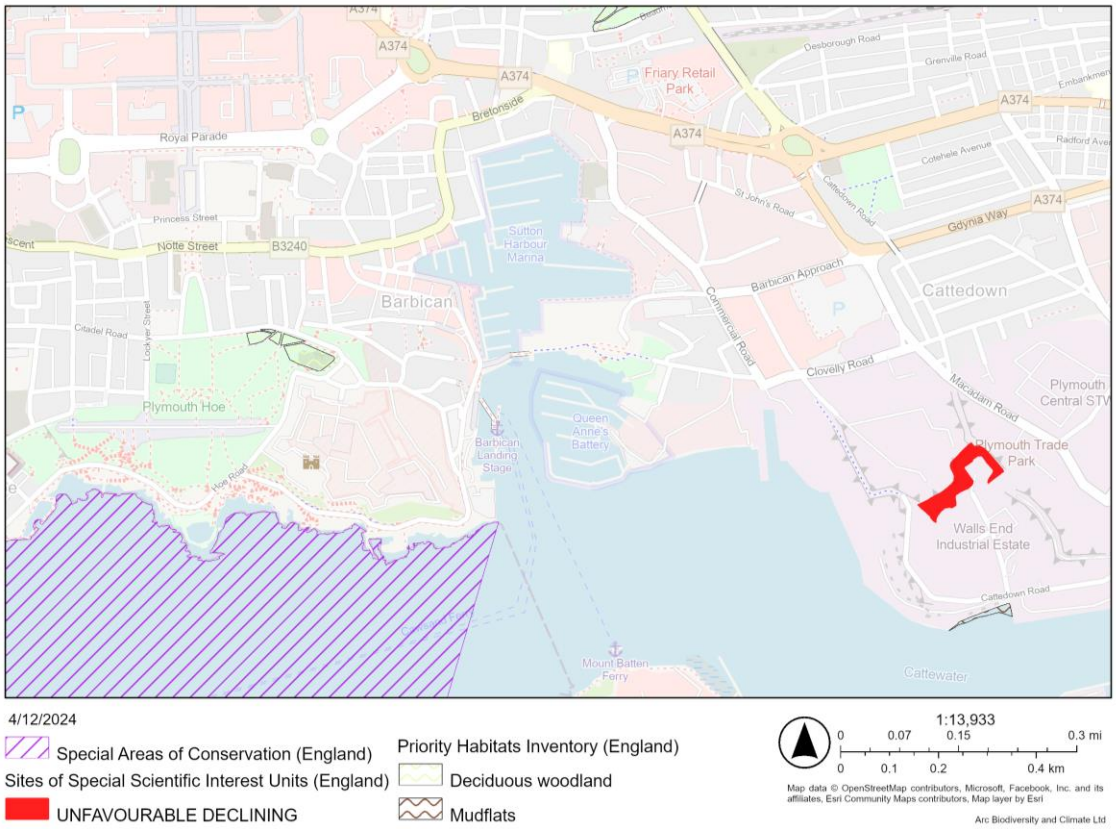
Figure 54 Mount Batten Pier Ecological Enhancements

Sutton Harbour

Habitat Context

Highly built-up concrete wharf of docked boats and yachts, an industrial area with a cluster of restaurants and entertainment venues.

Sutton Harbour is not protected by any National/International conservation designations, see Figure 55 below.



A374
Friary Retail Park
Royal Parade
Bretonside
Desborough Road
Grenville Road
Cotehele Avenue
Radford Ave
St John's Road
Gdynia Way
Princess Street
Notte Street
B3240
Sutton Harbour Marina
Barbican
Barbican Approach
Commercial Road
Cattedown
Clovelly Road
Macadam Road
Plymouth Central STW
Plymouth Trade Park
Walls End Industrial Estate
Cattedown Road
Citadel Road
Lockyer Street
Plymouth Hoe
Hoe Road
Barbican Landing Stage
Queen Anne's Battery
Mount Batten Ferry
Cattewater
4/12/2024
Special Areas of Conservation (England)
Sites of Special Scientific Interest Units (England)
UNFAVOURABLE DECLINING
Priority Habitats Inventory (England)
Deciduous woodland
Mudflats
1:13,933
0 0.07 0.15 0.3 mi
0 0.1 0.2 0.4 km
Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri
Arc Biodiversity and Climate Ltd

Figure 55 Sutton Harbour - Designation Context

Opportunities

There are opportunities to enhance the concrete walls that cover the perimeter; however, the water is kept at a high level for the boats and boardwalks, which will need to be considered.

Ecological Enhancement Potential

Figure 56 Sutton Harbour – Aerial

This proposal focuses on implementing intertidal intentional habitat interventions on the pier infrastructure and introducing a floating wildlife pontoon system. These interventions aim to create thriving ecosystems within urban water features, providing essential habitat for native wildlife where there are currently few opportunities.

Project Objectives:

- Enhance intertidal biodiversity: Implement habitat interventions on the Pier infrastructure to support a diverse range of marine and intertidal species.
- Promote wildlife habitat on urban water features: Introduce a floating wildlife pontoon system to provide shelter, nesting sites, and feeding grounds for birds, fish, and pollinators.
- Improve public engagement: Raise awareness about the importance of urban biodiversity and eco-engineering through informative signage and interactive educational programs.

Proposed Interventions at Sutton Harbour Marina Office (below) off Vauxhall Quay

- Sandown Model Vertipools
    - Description: Vertical artificial rock pools designed to provide habitat complexity for marine organisms.
    - Implementation: Install Vertipools on the Pier infrastructure using appropriate fixing methods for timber and concrete surfaces, featuring Artecology's complex bioreceptive 3D detail.
- Metal-cased MicroPools

    - Description: Metal-cased rock pools designed to enhance intertidal habitat complexity.
    - Implementation: Integrate Metal-cased MicroPools into the Pier infrastructure, providing additional habitat niches for marine organisms.
    -

- Habitat Panels
    - Description: Custom-designed panels with bioreceptive 3D detail to attract and support intertidal wildlife.
    - Implementation: Fix Habitat Panels to the Pier infrastructure, offering diverse habitat structures suitable for various species.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

Figure 57 Sutton Harbour Marina Office (below) off Vauxhall Quay Enhancement Possibilities

Proposed Intervention at Sutton Harbour - Floating Wildlife Pontoon System by BioMatrix:

- Description: A floating wildlife pontoon system designed to create a habitat for birds and fish and planted for pollinators.
- Implementation: Deploy a floating pontoon system at Sutton Harbour, which will provide shelter, nesting sites, and feeding opportunities for aquatic and terrestrial wildlife.
- Site Assessment: Conduct a detailed assessment of the Pier infrastructure at Sutton Harbour to identify optimal locations for habitat interventions.
- Design and Fabrication: Design and fabricate the floating wildlife pontoon system.
- Installation: Secure habitat pontoon system to designated locations using appropriate methods and materials, ensuring compatibility with existing infrastructure.
- Monitoring and Maintenance: Establish a monitoring program to assess the colonisation and utilisation of habitat structures by marine organisms and wildlife and implement a maintenance schedule to ensure the longevity and functionality of the interventions.

Public Engagement and Interpretation

Develop interpretive signage and educational materials explaining the purpose and benefits of eco-engineering interventions at Sutton Harbour—options to engage the community with citizen science monitoring of installations where safe.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

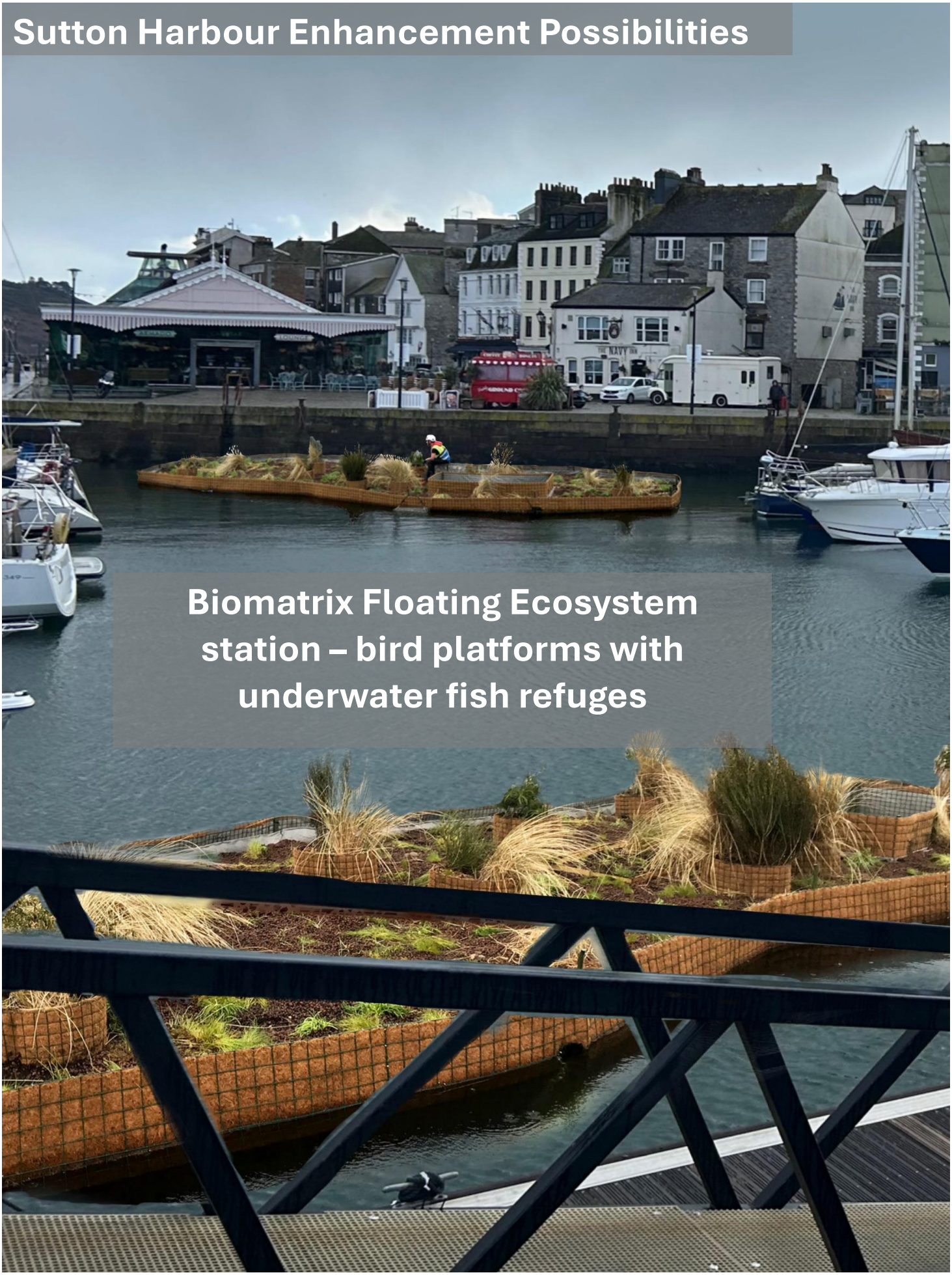


Figure 58 Sutton Harbour Enhancement Possibilities

Devils Point

Habitat Context

It is set on a rocky coastline with a sandy/stoney beach. Exposed rocks are along the beach and seabed. Rocky reefs are already an excellent habitat.

Devil's Point is protected by the following National and International conservation designations: see Figure 59 below.

- Plymouth Sound & Estuaries SAC (not covering the lido)
- Western King SSSI Condition: unfavourable, no change (not covering the lido)

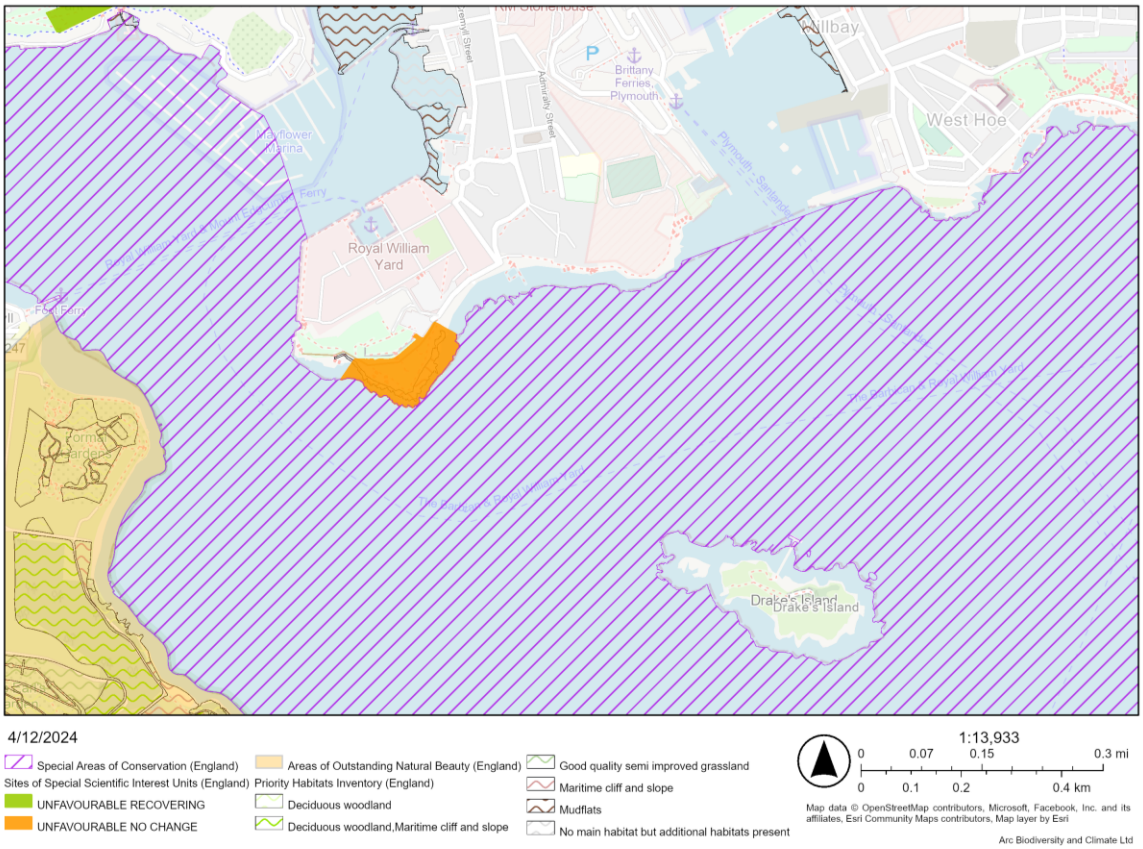


Figure 59 Firestone Bay - Designation Context

Opportunities

The 200-meter-long lido is built into the beach with a concrete wall. An area of beach is on either side of the lido within the Bay, creating a popular spot for swimming, snorkelling, and walking. A car park and footpath network are available from Devils Point Park. The walls of the lido offer an opportunity for ecological enhancement. They are currently smooth with limited textured habitat and in need of repair.

Figure 60 Devil's Point - Aerial

Inspired by the Japanese art of Kintsugi, a bioreceptive repair system can be employed, utilising fast-setting, reduced carbon concrete to fill cracks in the retaining walls, creating complex colonisable textures for intertidal species. This innovative approach transforms maintenance into eco-engineering, promoting the concept of Integrated Grey Green Infrastructure.

Project Objectives

- Repair and enhance infrastructure: Utilise Artecology's bioreceptive repair system to address structural issues in the Devil's Point Tidal Public Swimming Pool, simultaneously improving the site's ecological value by creating habitat features for intertidal species.
- Promote sustainable infrastructure: Demonstrate the feasibility and effectiveness of integrating ecological principles into infrastructure repair and maintenance practices, promoting the concept of Integrated Grey Green Infrastructure.

Share knowledge with the community.

Use the public's close proximity to engage them with the process via interpretation and citizen science to follow the biological progress of the repairs.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

Alternatively, if replacement of the pools is favoured over repair, there is a similar opportunity for creating bioreceptive structures while maintaining the recreational function of the pool. Following the same approach outlined in this report, punctuated texture on the structure at varying heights could provide habitats for diverse species across the tidal range. This could be achieved using textured tile designs and Sandown model Vertipools across different heights around the pool exterior edges. A new pool could also use corners and edges, sharing the tidal pool with wildlife by creating smaller pools in the corners, similar in structure to Bouldnor model Vertipools. This would bring engagement closer to the public and carry the Shaping Better Places principle of creating integrated habitats and functional spaces for wildlife and people. Scoping the details of a complete replacement scheme of the pool would require a separate detailed analysis beyond the scope of this report.

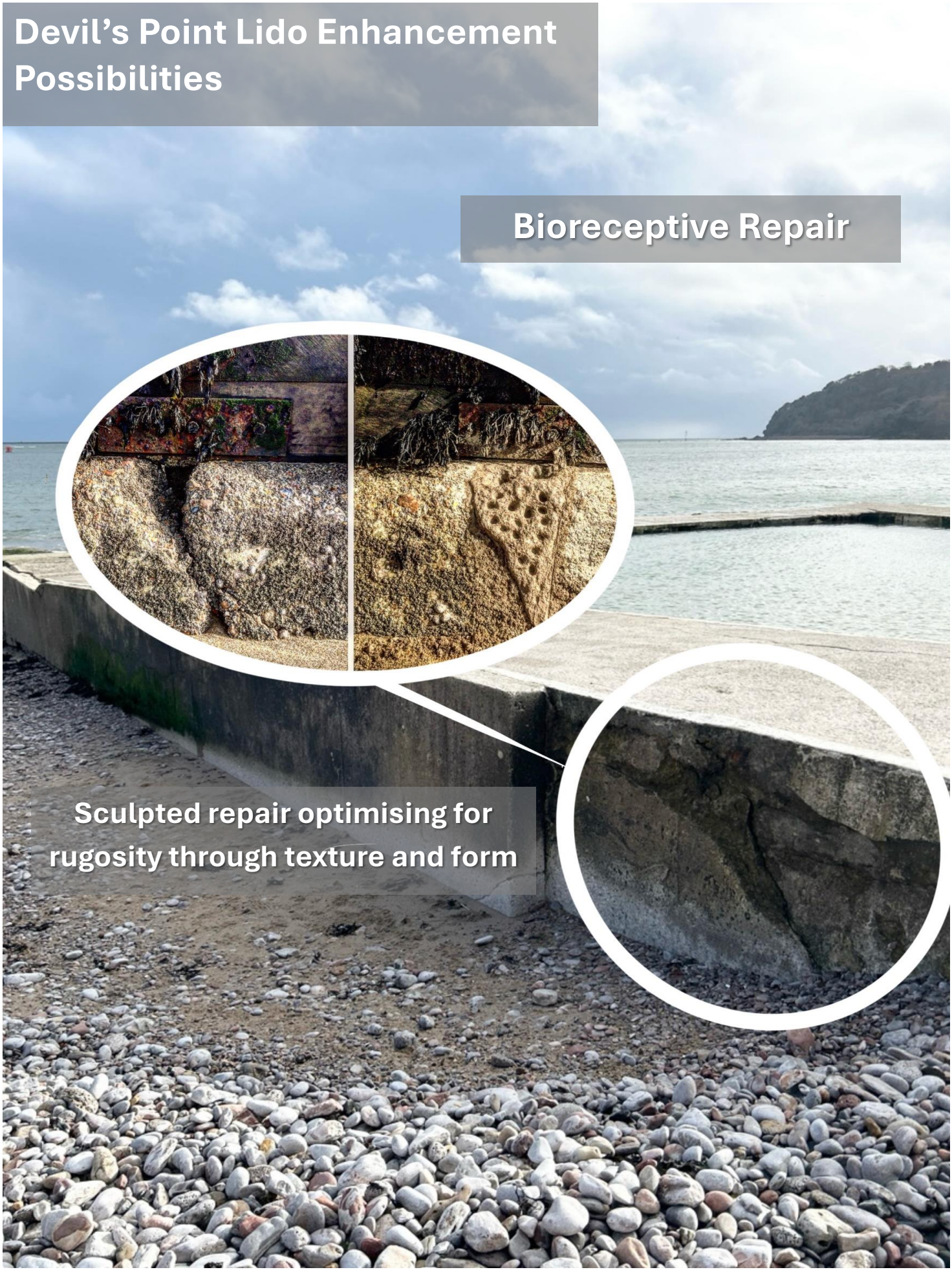


Figure 61 Devil's Point Lido Enhancement Possibilities

Stonehouse

Habitat Context

The coastline around Stonehouse is characterised by hard-engineered sides with boat access, bordered by industrial areas, residential areas, larger historic buildings, and boat docking. Areas of mudflat are exposed at low tide. The Royal William Yard has a large area of smooth concrete brick seawalls that perimeter the buildings.

Stonehouse area is protected by the following National/International conservation designations: see Figure 62 below.

- Plymouth Sound & Estuaries SAC (outer Tamar area)

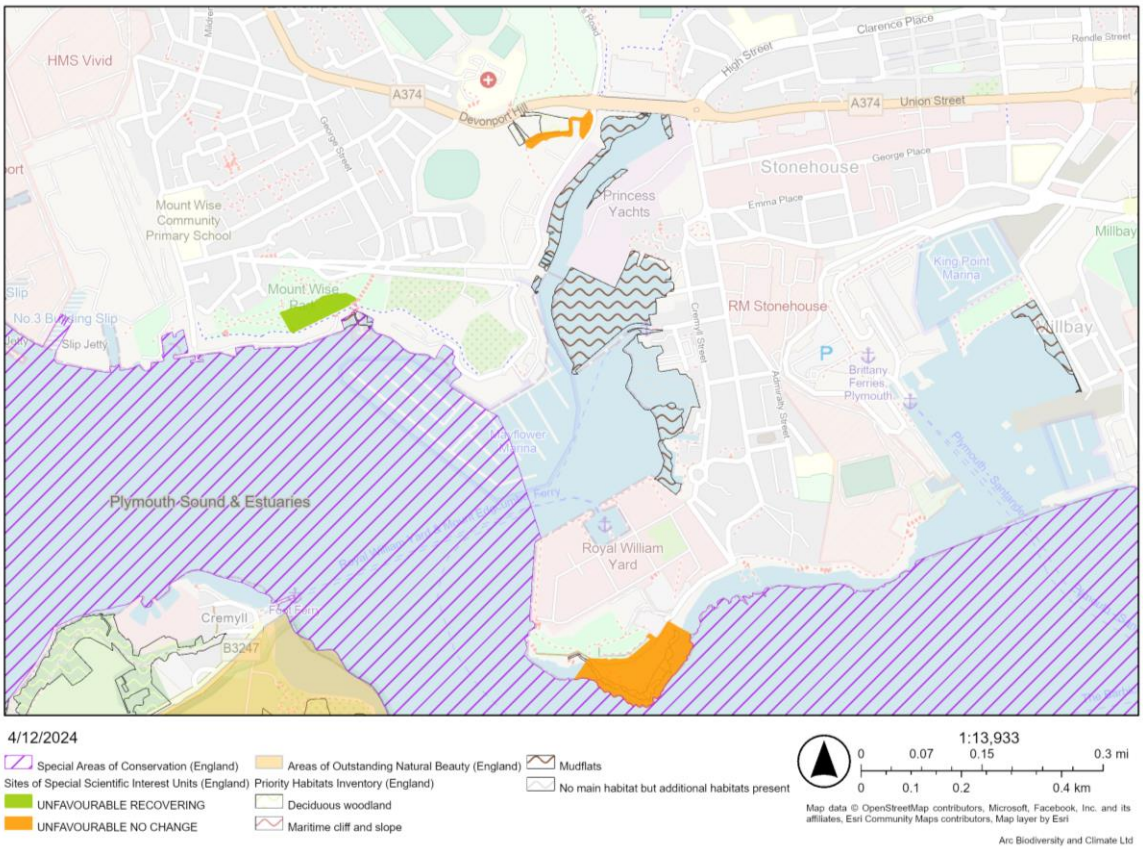


Figure 62 Stonehouse - Designation Context

Opportunities

Telegraph Wharf is lined with wooden pillars around the concrete wall's edges. Below Royal William's Yard are large areas of smooth brick seawalls which would benefit from additional texture to support wildlife.

Limitations

- Some listed buildings in the area.

Ecological Enhancement Potential

Figure 63 Stonehouse – Aerial

Telegraph Wharf, Stonehouse

Telegraph Wharf, located in the historic waterfront district of Stonehouse in Plymouth, presents an opportunity for eco-engineering interventions. Several timber piles serving as harbour wall infrastructure were identified as ideal locations for habitat deployment. This proposal uses these timber piles to create habitat structures, including Sandown model Vertipools, Mussel Panels, and high-tide fish refugia.

Project Objectives - Telegraph Wharf, Stonehouse

- Enhance intertidal biodiversity: Implement interventions to create habitat structures that support a diverse range of marine and intertidal species within the area.
- Improve ecological resilience: Enhance habitat complexity and provide refuge for marine organisms, promoting resilience against environmental stressors such as coastal erosion and habitat degradation.
- Promote public engagement: Through interpretive signage and educational programs, raise awareness about the importance of habitat conservation and restoration efforts, fostering a sense of stewardship among Stonehouse residents and visitors.

Proposed Interventions:

- Sandown Model Vertipools:
  - Vertical artificial rock pools are designed to provide habitat complexity for marine organisms. Fix Vertipools to the timber piles at intertidal heights, creating tide pools, microhabitats and niches for a diverse array of intertidal species.
- Mussel Panels:
  - Structures designed to promote the settlement and growth of mussel populations serve as a valuable food source and habitat for other marine organisms.
  - Install Mussel Panels on select timber piles to enhance habitat diversity and filter-feeding capacity within Stonehouse Harbour.
- High-Tide Fish Refugia:
  - Refuge areas are designed to provide shelter and protection for fish species during high tide events.
  - Create alcoves or recesses within the timber piles to serve as high-tide fish refugia, enhancing habitat complexity and promoting the recruitment of fish populations within Stonehouse Harbour.

Implementation - Telegraph Wharf, Stonehouse

1. Site Assessment: Conduct a detailed assessment of the timber piles and surrounding intertidal areas to identify optimal locations for habitat interventions.
2. Design and Fabrication: Customise habitat structures to suit Stonehouse Harbour's specific characteristics and ensure compatibility with existing infrastructure.
3. Installation: Secure habitat structures to the timber piles using appropriate methods and materials (usually 316 stainless steel fixtures and fittings, taking into account tidal fluctuations and environmental conditions.
4. Monitoring and Maintenance: Implement a monitoring program to assess the colonisation and utilisation of habitat structures by marine organisms and establish a timber maintenance schedule to ensure the ongoing effectiveness of the interventions.

Public Engagement:

Engage the local community and stakeholders, highlighting the interventions' ecological significance and promoting opportunities for community involvement in habitat monitoring and conservation efforts.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

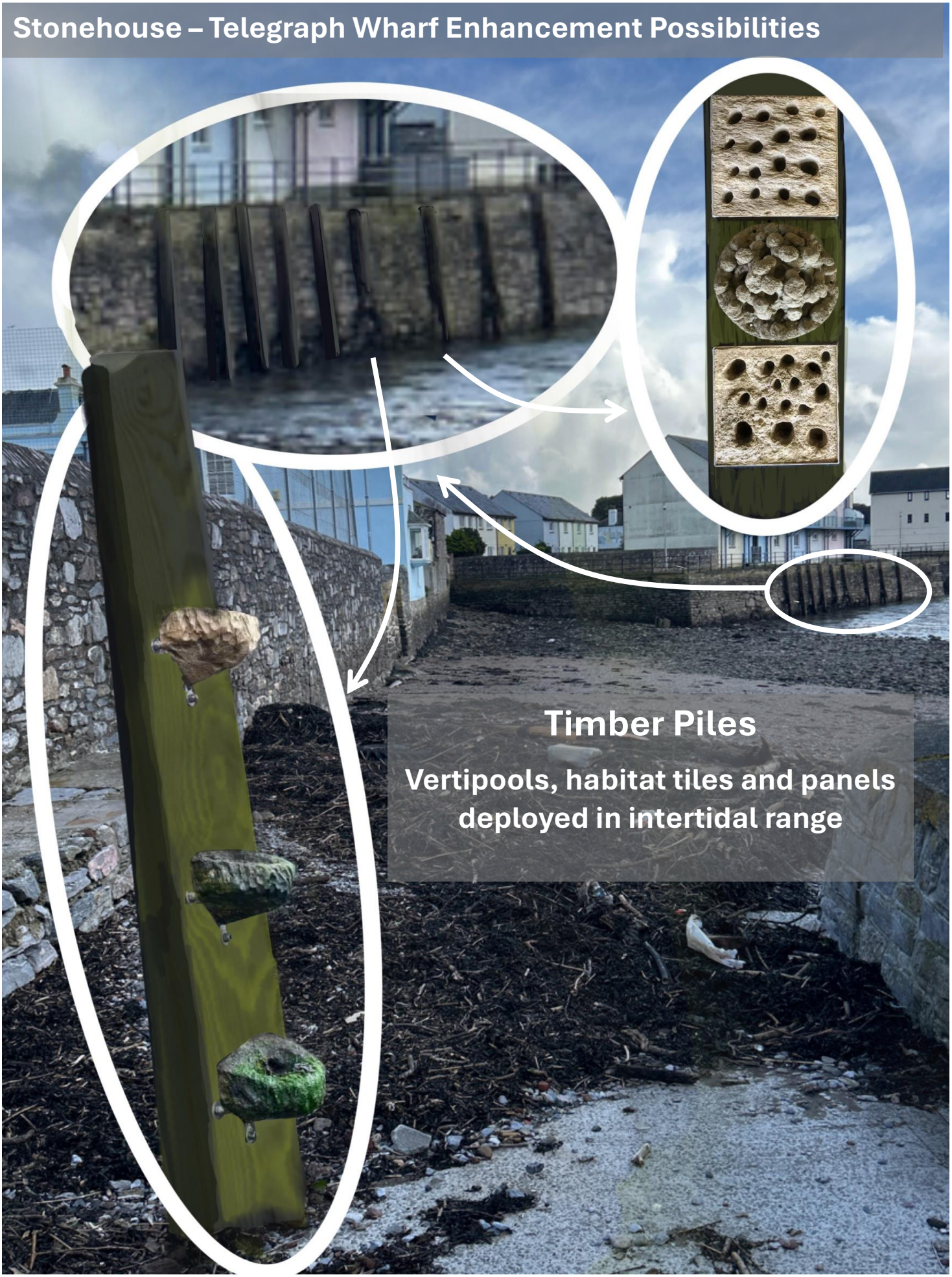


Figure 64 Stonehouse – Telegraph Wharf Enhancement Possibilities

Royal Williams Yard, Stonehouse

A collaboration is proposed between Artecology, Living Seawall Tiles and Blue Cube Marine in a pioneering project. This project involves the side-by-side deployment of differing bioreceptive tiling systems. While each organisation takes a unique approach to designing and manufacturing their engineered tiled habitat systems, the shared goal is to boost biodiversity and bio-abundance on urban infrastructure in the intertidal zone.

Bioreceptive Tiling Deployment at Royal William Yard

Project Objectives - Royal Williams Yard, Stonehouse

- Enhance intertidal biodiversity: Deploy bioreceptive tiling systems to create new habitat structures and promote ecological gains within Firestone Bay, enriching the local marine ecosystem.
- Evaluate tiling effectiveness: Assess marine organisms' colonisation and utilisation of tiling systems, documenting changes in species diversity and abundance over time to inform future habitat restoration efforts.
- Foster collaboration: Facilitate knowledge exchange and collaboration between organisations, researchers, and stakeholders to advance eco-engineering practices and promote sustainable urban coastal development.

The combined projects represent a holistic approach to coastal infrastructure enhancement and biodiversity conservation. By deploying differing bioreceptive tiling systems close to innovative repair techniques, we can create resilient and biodiverse marine ecosystems while promoting sustainable urban development practices.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

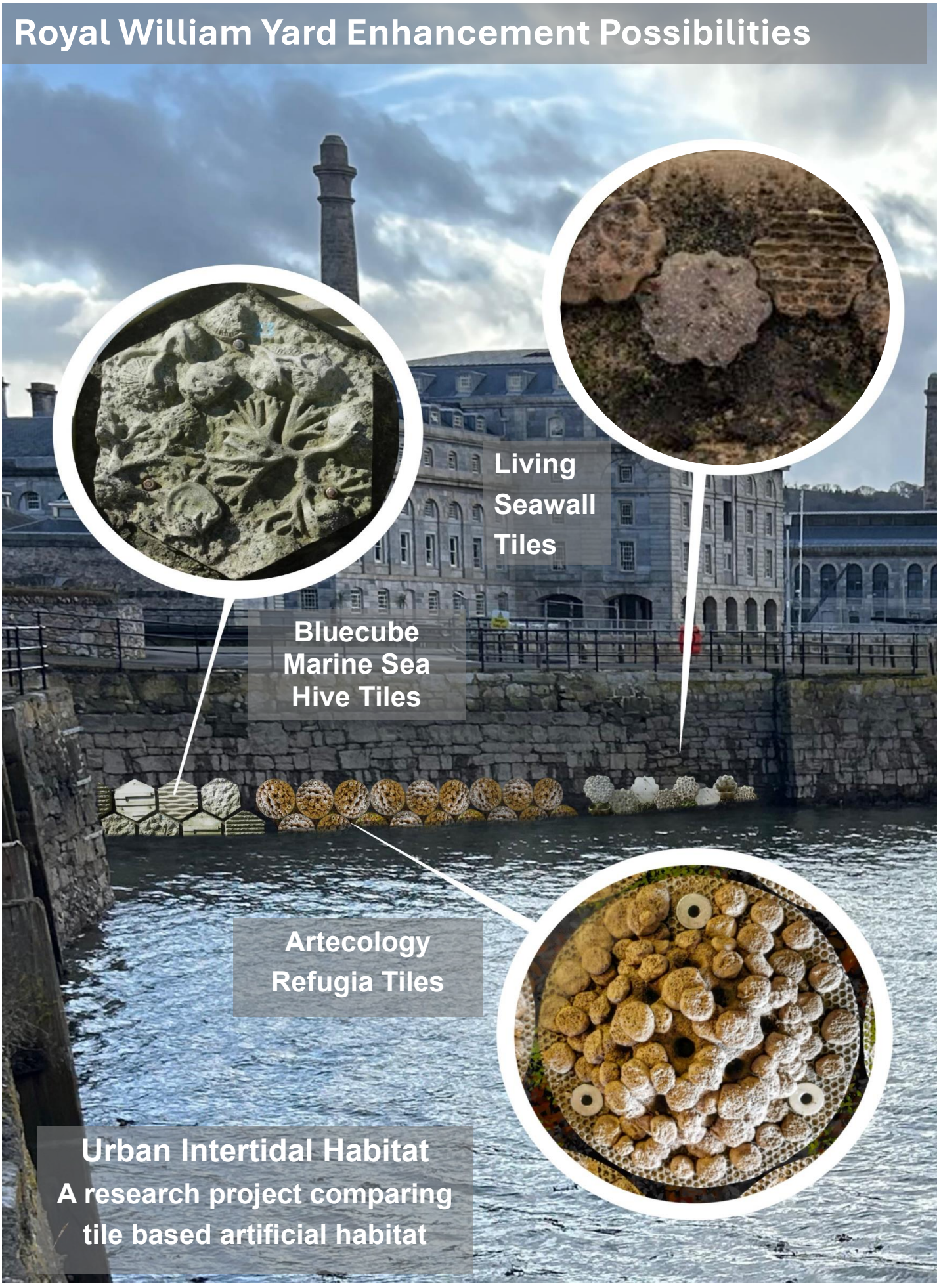


Figure 65 Royal William Yard Enhancement Possibilities

Mutton Cove

Habitat Context

Concrete walls border the inlet. There are Mudflats at low tide.

Mutton Cove is protected by the following National/International conservation designations, see Figure 66 below.

- Plymouth Sound & Estuaries SAC

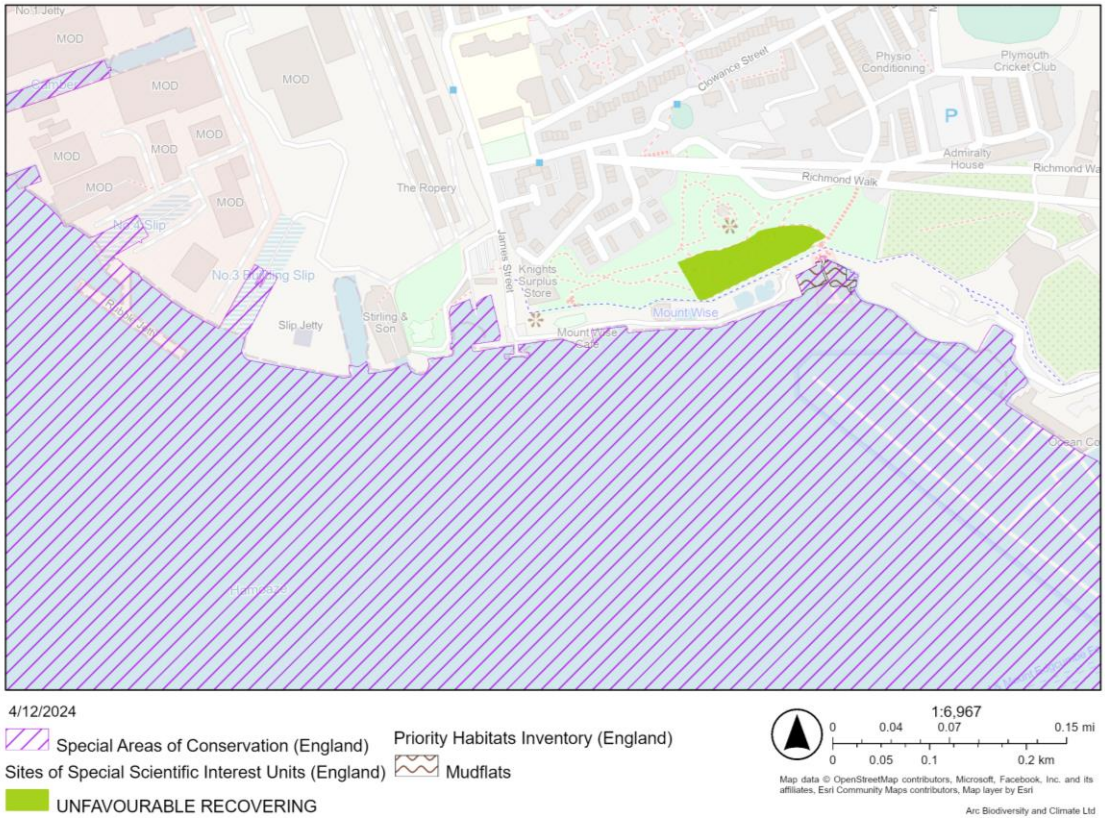


Figure 66 Mutton Cove - Designation Context

Opportunities

Small inlet area by an Olympic Park, café and other commercial buildings. Several docked boats and a slipway. Large car park just above the cove and public toilets. Wooded area with footpaths also neighbouring the cove that leads to Mount Wise Park. There are concrete steps down to the cove on either side, built into the concrete brick walls enclosing the cove. There is an engagement board that would benefit from an update.

Limitations

- Mutton Cove Harbour and Pier is a listed building.
- The SAC conservation designation protects the area around the cove and pier.

Ecological Enhancement Potential

Figure 67 Mutton Cove – Aerial

There is good scope for hinterland work here, utilising the symmetry/reflection between the inland wall and green in front. With the popular playground and car park, the location may work as a unit of contiguous ecological gains across the site. It is a manageable size which could gradually become a hotspot for demonstration techniques. The amenity grassland has some wide edges which would benefit from coastal planting with thrift, plus rock samphire, sea spurrey, wild carrot, sea campion and vipers bugloss. Employing species that can be planted in patches around the site and then allowed to spread. The wall could host novel bird and bat installations, especially amongst the trees, plus swift boxes where the aspect is more open.

Project Objectives:

- Enhance biodiversity: Implement interventions to create habitat structures that support a diverse range of species within Mutton Cove from terrestrial, through intertidal to marine.
- Respect heritage listing: Ensure that all interventions are sympathetic to Mutton Cove's heritage status, preserving its historic character while promoting ecological enhancement.
- Promote public understanding: Develop accessible, sensory, and informative public interpretation features highlighting the interventions and their ecological significance.

Proposed Interventions:

- Intertidal Wildlife Refugia:
  - Custom-designed structures featuring textured surfaces and microhabitats to attract and support marine organisms.
  - Install wildlife refugia at strategic locations around Mutton Cove, such as along the harbourside, providing accessible public interaction and observation opportunities.
- Terrestrial Habitat Features:
  - Coastal planting around edges of grassland
  - Roosting and nesting boxes
  - Biototems and Bee benches provide a habitat for invertebrates and sculptural interpretation.
- Public Interpretation Components:
  - Develop interpretive signage and tactile displays explaining the purpose and benefits of habitat interventions, such as concrete wildlife refugia.
  - Provide opportunities for visitors to access and interact freely with the habitat structures, encouraging hands-on learning and exploration.

Implementation

1. Heritage Assessment: Conduct a heritage assessment to ensure that proposed interventions align with Mutton Cove's heritage listing.
2. Design and Fabrication: Collaborate with experts to design and fabricate custom wildlife refugia and interpretation elements.
3. Installation: Secure habitat structures and interpretation components at designated locations around Mutton Cove to ensure accessibility and safety for visitors.
4. Monitoring and Maintenance: Establish a monitoring program to assess the effectiveness of habitat structures in enhancing biodiversity and implement a maintenance schedule to ensure longevity and functionality.

Public Engagement and Interpretation:

- Engage the local community and visitors through interactive workshops, guided tours, and educational programs focused on eco-engineering and habitat conservation.
- Develop engaging public interpretation features that invite visitors to learn about marine ecology and the importance of habitat restoration in urban waterfront areas.

Below are examples of how these enhancements may be deployed. Please note that the indicated position, while optimal for biodiversity, may need to be adjusted depending on other constraints particular to the location and not covered within the scope of this report.

Figure 68 Mutton Cove Enhancement Possibilities

Figure 69 Mutton Cove Enhancement Possibilities

6. Indicative Costs and Supplier List

This section of the report attempts to provide practical support on deploying built habitat solutions so that PCC and others can plan and budget for the early adoption of techniques and fixtures. There is sufficient evidence and experience from research and commercial projects worldwide to allow for a systemic guide to installation or establish a convention or praxis robust enough to support immediate action and flexible enough to make space for new thinking.

Some of the recommended ecological enhancements have a standard unit cost for supply, though not for installation, as this is often picked up within civil engineering contracts or public works maintenance programmes already in place. Other techniques, especially the small-scale alteration of existing infrastructure, are more complex to cost as they can be delivered in various ways, using in-house or specialist teams and through strategic programming or chance and opportunity.

Costing details are taken from personal communication with suppliers and buyers, particularly those arising from the EU Interreg-funded Marineff programme. This programme, a collaboration between France and the UK, aims to develop coastal infrastructure to enhance and protect the ecological status of cross-channel coastal waters. The project aims to produce new ecological enhancement units to improve the ecological status of coastal and transitional watercourses.

Costings are also taken from the evidence-based note ‘Coastal Enhancements Guide’ produced by Arup for Natural Resources Wales (NRW) in 2021. NRW has created test areas for ecological engineering in the intertidal at Milford Haven, also an area of research for the EU ERDF-funded Ecostructure project, working with five universities in Wales and Ireland to research and raise awareness of eco-engineering solutions to the challenge of coastal adaptation to climate change. Ecostructure aims to promote the incorporation of secondary ecological and societal benefits into coastal defence and renewable energy structures, benefiting the environment, coastal communities, and the blue and green sectors of the Irish and Welsh economies.

It is recommended that the PCC team build working relationships with Marineff and Ecostructure, the NRW team, and the Solent Forum to share information and contacts. Given the importance of coastal communities and coastal partnerships in local and national policy and planning, the prospect of a federation of marine eco-engineering hubs around the UK coast seems increasingly appealing and helpful.

Pools and Panels

These modular units work best when positioned to cover the whole tidal range. This can be as simple as placing one unit at mid-tide, one between this and Mean High Water Springs (MHWS), and one between the mid-line and Mean Low Water Springs (MLWS).

A primary functional array might be specified as three pools and/or three panels. An ideal minimum would be 3 of each, but given the very few suppliers of these products at present, this may not be possible.

A guide price for a 3-pool array, supplied with fixings, would be £1000. An array with 3 pools and 3 panels will likely double the cost. Installation costs will vary, but given that these are simple items to affix, a rate of £500 per array is likely reasonable.

Therefore, an ideal primary array would be in the order of £2500 to create.

If the objective is to build up a large array for ecological impact and public spectacle, units can be added to the original installation as required.

Suppose the objective is to demonstrate coverage along the linear length of a sea wall. In that case, the basic deployment must be repeated at a spacing that keeps the project cost-effective while

maximising the likelihood of arrays aggregating overall ecological impact through the movement of marine life between them and the halo effects spreading out from each vertical array. There is no definite optimum, but a working approximation would be 15m, meaning there would be 3 sets, totalling 18 units (9 pools, 9 panels), in a 30m stretch of sea wall, assuming it is 'bookended'. This would cost £7500 pro rata (though there would be savings on installation) and a unit cost of enhancement of £250 per linear metre. If pools were only used as the primary array, the cost would be £125 per linear metre.

In Situ Niche Creation and Textured Repairs

Working into and onto existing sea defences and marine infrastructure provides a simple and practical option for accumulating ecological gains in the built intertidal through maintenance and opportunistic interventions when funding allows. The required licensing route will often be more straightforward than those needed for larger retrofit installations.

Patterns of perforation and added texture can be improvised and used to complement existing surface features or replace holes, gaps, and crevices as they are infilled. As with pool and panel arrays, clustered groups of constructed niches will provide greater ecological value than separate single features. The interstices within groups benefit from improved functionality, as does a region around/beyond the array (the halo effect).

Similar techniques and patterns can be used on groyne timbers as on quarried rock and concrete surfaces. Where whole planks are to be replaced, patterning and perforation can be prefabricated.

Costs will likely vary widely according to accessibility, scale, substrate, and departmental cost-centre and recharge rates when in-house. A rule of thumb based on existing experimental deployments of these techniques (including pioneering work at Runswick Bay) is a rate of **£50 per square metre**.

Patterned Form Liners

Using form liners to create textured concrete surfaces more receptive to biological conservation is becoming more frequently specified, and manufacturers are producing some designs with specific ecological functions. These remain rare, but it is possible to adapt, combine, and reorientate existing decorative designs to improve ecological value.

An example is Reckli's 'Gascogne' liner, which can be used with a vertical pattern alignment or turned to the horizontal; by mixing both orientations, a more varied and complex delivery of niche habitats, including some water holding capacity, can be achieved.

Assuming a 3m sea wall height (from beach level), a vertical strip 3m x 2m will require 3 liner panels at a unit cost of £297 per square metre (for the 50 times re-use option), a total of £1782 per vertical strip. If these are repeated every 15m, as for pool and panel retrofits, and taking the bookended section as a precaution, a 30m linear length of seawall would cost £5346 for textured ecological uplift, £178 per metre length.

Supplier and Research Links

Useful information on suppliers, techniques, implementation and licencing is available from recent ecological engineering research collaborations between UK and European universities and institutes:

3D PARE www.giteco.unican.es/proyectos/3dpare/news.html

Artecology www.artecology.space/products

Products – Vertipools, BioTotems, NatureBricks, MudFlats, CoCreate Training, Refugia Tiles, Habitat Panels

Biomatrix http://www.biomatrixwater.com/

Products – Floating Ecosystems

Blue Cube Marine https://bluecubemarine.co.uk/

Products – Sea Hive Tiles

Emorsgate Wildflower seed www.wildflower.co.uk

Ecostructure https://ecostructureproject.aber.ac.uk/

Living Seawalls https://www.livingseawalls.com.au/

Products - Habitat Panels

Marineff https://builders-ingenieurs.fr/en/marineff

Solent Forum Building Biodiversity Hub
https://www.solentforum.org/services/Information_Hubs/Building_Biodiversity_Infrastructure/

The products and interventions described can be combined and varied to maximise the use of space allowed within an array and to deliver higher surface and structural complexity levels for colonisation, even where installation is constrained.

There will also be alignments and utilisations of the existing habitat fixtures and features that have not yet been trialled, so there is much room for new thinking and innovation even within the current product menu. Most R&D has, for example, concentrated on retrofit features for ecological enhancement of marine infrastructure rather than in-situ and re-working techniques for rock armour and groynes. These areas offer much scope for innovation and positive ecological impact.

Cost Benefit Calculations

Given that conventional construction costs for seawalls average at £5000 per linear metre (plm), rock armour is £4000 plm, and timber groynes £1000 plm, the costs of ecological enhancement, averaging between £50 and £200 plm, are good value for money, representing a maximum likely uplift in costs of 5%.

Evidence of ecological uplift from constructed habitat enhancement in the intertidal is available from recent publications. In the case of both the Runswick Bay ‘holes and grooves’ experiment in North Yorkshire and the Bouldnor Vertipool array on the Solent coast of the Isle of Wight, the new features demonstrated a significant increase in species richness compared with a control site on the same asset, the number of species recorded from the constructed habitat being double that of the control.

These data can only provide a heuristic approach to cost-benefit calculation, but given the general nature of anthropic rocky shore construction and the communities of marine life they attract, it seems reasonable to at least propose that a 5% increase in construction costs for new coastal defences will likely more than deliver a 10% net gain for biodiversity.

Because all the enhancement techniques provided in this report are modular, the final cost-benefit analysis can be scaled until an acceptable balance is reached regarding the number of units in an array and the number of arrays deployed onto an asset.

Similar broad metrics are likely to apply to maintenance budgets and repair-based enhancements. Still, these are harder to quantify as there will be numerous ways to deliver small-scale texture and complexity enhancements through in-house work programmes and external contracting.

This work can also realise the benefits of natural capital/biodiversity net gain uplift, carbon sequestration, and strengthening of FCRM assets, which must be calculated for each delivery project.

Below is a summary of all indicative costs described. Costs are subject to change due to market fluctuations.

Summary Table of Indicative Costs

Item	Indicative Cost	Other Information
Conventional construction costs for seawalls average	£5000 per linear metre	
Conventional construction costs for rock armour average	£4000 per linear metre	
Conventional construction costs for timber groynes	£1000 per linear metre	
Habitat Enhancements		
Sandown Model Pool	£350 (excl. VAT) per unit	
Tile models: Circular "Mussel" model refugia with multi-functional structure complexity	£350 per tile	
Tile models: Smaller Mussel Habitat Panels	£200 per unit	
Pools and Panels: Functional 3-pool array	£1000	Includes fittings.
Pools and Panels: Functional 3-pool array and 3 panels	£2000	Includes fittings.
Pools and Panels: Pool and panel installation	£1000 per array	Will be variable by site.
Pools and Panels: Ideal primary array and installation	£2500	
Pools and Panels: High-coverage array across linear length of seawall	£7500 pro rata and unit cost of enhancement of £250 per linear metre If only pools were used for the primary array - £125 per linear metre	3 array sets at 15m spacing. Total 18 units (9 pools and 9 panels). Across 30m stretch of seawall.
In-situ Niche Creation and Textured Repairs: Adding	£50 per square metre	Based on experimental deployments and pioneering work at Runswick Bay.

patterns of perforation and added texture		Costs vary depending on site accessibility, scale and substrate.
Patterned Form Liners: Vertical strip 3m x 2m requiring 3 liner panels	£297 per square metre	Assumed for 3m seawall height (from beach level).
Patterned Form Liners: Vertical strip 3m x 2m requiring 3 liner panels (50 times re-use option)	£1762	Total per vertical strip.
Patterned Form Liners: Vertical strip 3m x 2m requiring 3 liner panels (50 times re-use option), repeated every 15m	£5346 total, £178 per metre length	For a 30m linear length of seawall.

7. General Recommendations

Passive restoration

The report has explored the benefits of adding engineered habitats for wildlife to existing intertidal and coastal infrastructure. While the creation and installation of these features are a form of active intervention for wildlife enhancement, their function can operate as a passive intervention for wildlife. Monitoring existing Artecology ecologically enhanced structures across the UK and internationally has shown that natural colonisation occurs without post-installation management or intervention. Further, species have been shown to transition naturally into new assemblages as the structure matures. Notably, observations of an array of pools installed on a groyne on the Isle of Wight have shown that the structures provide essential nursery habitats for Limpets. In addition to wildlife benefits, if done in the correct location, arrays can reduce wave overtopping and, therefore, extend the time needed to plan for seawall-raising works. Arrays can also serve as tools to manage recreational pressure. Creating more accessible rock pools closer to public access can reduce pressure on sensitive areas further down the beach. Combined with supporting artistic engagement pieces, this can aid behavioural management as part of the same investment in ecological enhancement, creating additional passive restoration tools for vulnerable coastlines.

The extensive suggested interventions provided in this report range from in-built structures to external fixable additions to existing infrastructure. This enables choice that would continue habitat enhancement when future infrastructure updates/removal need to take place. Interventions could make up part of the repair of the structure itself or could be re-deployed when infrastructure is required to be removed and replaced. Combining the interventions would provide a sustainable and longevity approach to habitat enhancements within the intertidal.

Interactions with Designations

As outlined throughout, the extensive coverage of conservation designations within the Plymouth Sound NMP provides an exciting opportunity for biodiversity and potential limitations in the scope of what can be installed per the management agreements of these sites. However, it should be noted that much of the designations will still contribute to key targets laid out in the Environment Act (2021) and the Environmental Improvement Plan (2023), and as such, have been given various biodiversity enhancement targets and duties from the central government. Therefore, by working collaboratively with landowners and statutory bodies, there is an opportunity to create meaningful and targeted intentional habitats that can support designated sites to improve in condition and meet their environmental policy targets. Hence, all proposals should be presented to statutory bodies in the first instance for compliance with management and a starting tone of collaboration for action.

Outside of existing designations, the proposals in this report provide an opportunity to create replicated habitats that can enhance the connectivity of the existing protected site network. Target features of existing designations could be carried through as core functions of engineered enhancements, contributing to a bigger, better, and more joined-up landscape of functional habitat. Given the coverage of the Plymouth Sound National Marine Park, filling gaps in the designated network could be a focus for future work to both complement existing important sites and create new sites of importance, which could potentially develop a pipeline of new designated sites, contributing to the UK target of 30% more land designated by 2030 (Kunming-Montreal Global Biodiversity Framework, 2022).

Developer considerations

Intentional habitat and engineered ecological enhancements provide a well-rounded solution to uplifting biodiversity, creating long-lasting functional habitats, and providing accessible and creative nature engagement. Applying to existing hard infrastructure ensures spaces are maximised for their biodiversity potential and showcases Greening the Grey principles.

The example interventions in this report can also be crafted to alleviate some of the site-specific pressures. This is an essential consideration in the context of climate change, whereby future pressures will also have to be mitigated. Although creating natural habitats, particularly to mitigate loss of priority habitat, is the favourable approach. Engineered and intentional habitats can provide an effective solution where site context does not provide the necessary space or conditions to make those natural mitigations, e.g., loss through coastal squeeze. Instead, engineered and intentional habitats can readily use limited space and have built-in flexibility to move and respond to growing pressures. Colonisation of habitats can be relatively quick, and maintenance is not resource-intensive.

In accordance with the current BNG guidance, the hierarchy of BNG provision prioritises onsite. This can be difficult to provide meaningfully, particularly along built-up coastal and estuarine environments. Examples provided in this report enable innovative use of existing immovable structures to transform a singular functionality into a multi-functional structure of biodiversity gain and creative engagement. The creation and installation of many options encourage community engagement, strengthening the likelihood of greater appreciation and awareness of the actions made to create these additional habitats and, thus, long-term stewardship of them.

Artificial rock pools such as Vertipools are a potential mitigation for rocky shore habitat loss. They have been shown to significantly enhance species colonisation and diversity compared to similar natural rock pools.[3] However, in the absence of Marine Biodiversity Net Gain guidance and further clarity on existing intertidal guidance, the full scope and detail of what is permissible should be sought from future guidance and the Local Authority. From current guidance, it is not yet clear the role engineered habitats could have within the Marine Biodiversity Net Gain Metric.

Nonetheless, such interventions would provide valuable habitats to monitor biodiversity gains. Ecologists or even Citizen Science can do this if the site is safe and accessible. This would enhance the community's value in addition to the biodiversity provision.

Considerations of these enhancements should be made early in the design process. The designs can be site-relevant and suitable for the site's appropriate species and habitat fabric. Biodiversity enhancement conversations early on can also present cost-saving benefits, creating potential for built-in biodiversity beneficial repairs over replacement or built-in features to a replacement design. When biodiversity enhancements are considered post-development, reduction in ecological function or barriers to installation may be encountered, which could have been avoided. Considering these options also allows for time to bring communities along with the design, installation, and monitoring process. As discussed, this can improve public engagement and appreciation for the enhancements made.

Overall, the recommendations presented in this report can provide a suite of benefits for the Plymouth foreshore, from gains in biodiversity and ecological function to climate change resilience to community engagement and structural repair and integrity.

[3] Hall, A.E. et al. (2019) 'Shelving the coast with Vertipools: Retrofitting artificial rock pools on coastal structures as mitigation for coastal squeeze', Frontiers in Marine Science, 6. doi:10.3389/fmars.2019.00456.