An Assessment of Opportunities for the Ecological Enhancement of Coastal Infrastructure in North and East Yorkshire

A Report for the Yorkshire Marine Nature Partnership and the 'Concrete Coast' Project

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Produced by Arc Consulting Isle of Wight Ltd

YORKSHIRE MARINE NATURE PARTNERSHIP

Environment Agency

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REPORT SUMMARY AND RECOMMENDATIONS

This report identifies twelve priority locations for active ecological intervention between Staithes and Spurn, utilising six different enhancement techniques broadly split into two types, retrofit and additional fixtures and fittings to existing and new infrastructures, and in-situ alterations to existing infrastructure fabric, including enhancement via routine repair and maintenance programmes.

Projects on the North Yorkshire coast are focussed on retrofit arrays of pools and panels, and reworking larger rock armour deployments (where some innovative ecological adaptation has already been done). On the East Yorkshire coast, projects are focussed on enhancements to timber and rock groynes.

Special project opportunities are proposed for the four harbours, Staithes, Whitby, Scarborough and Bridlington, where sheltered conditions allow for a wider range of standard and experimental interventions for biodiversity.

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 continues to grow. The Yorkshire Marine Nature Partnership (YMNP) project is an important part of this movement, its ambition and scale make it one of the largest planned ecological interventions in the UK and perhaps beyond. The existing collaborations between the borough councils, the University of Hull, NGOs and conservation charities that underpin the work of YMNP provide an ideal medium for the growth of new ideas, new techniques, products and innovations in the field of coastal and marine Integrated Green Grey Infrastructure (IGGI). This pioneering role sits well with other far-reaching changes in local policy and governance such as regional devolution and the new Scarborough Coastal Strategy; in national environmental legislation, mandatory Biodiversity Net Gain, Local Nature Recovery; and in public and private investment criteria, the rise of ESG, impact platforms, B Corps. The work of YMNP has the potential to focus all of these drivers of change onto the need for a new approach to sustainable coastal management, for better and more resilient ecological health, a concept that necessarily includes human communities.

REPORT SUMMARY AND RECOMMENDATIONS

There are a number of strategic recommendations given in the report intended to maximise the influence and impact of the Concrete Coast project:

The Concrete Coast project is **one of a very few landscape-scale initiatives in the field of ecological engineering** in the marine environment. There is an opportunity for YMNP to work with, for example, the EU-funded schemes Marineff and Ecostructure, and with centres of activity in West Wales and the Solent, to share knowledge and experience. There is the potential to create a UK-wide network of innovation that has significance for global practice on the urban coast.

It will be important to consider **gains for socio-economic and cultural conditions in the coastal communities** where eco-engineering schemes are proposed. There is great potential for these initiatives to leverage additional funding support, accelerate mandatory delivery of local nature recovery networks and Biodiversity Net Gain (BNG) contributions, and provide enhanced cost-benefit justification for projects and programmes arising from devolution, the new Scarborough Coastal Strategy, the Towns Deal, and future bids to the Department for Environment, Food and Rural Affairs (DEFRA); the Ministry of Housing, Community and Local Government (MHCLG), and the Department for Culture, Media and Sport (DCMS).

The Concrete Coast project will **push forward practice and innovation across the full range of constructed habitats** in the intertidal, but there are two areas where it can become an industry leader: options for the reworking of rock armour and timber groynes for enhanced marine bioreceptivity; and the techniques, tools and training required to equip repair and maintenance contractors (and the commissioning local authority teams) to ‘patch in’ enhanced texture and pattern for improved ecological performance across all types of coastal asset.

The stakeholder family that comprises YMNP will be essential to **a full exploration of ecological engineering**, its possibilities on the Yorkshire coast, and its adoption and funding as part of local plans and strategies. The partnership with the University of Hull is of particular importance as it generates evidence and creates opportunities for research and development.

A summary of locations and ecological enhancement projects is given in the accompanying table.

PRIORITY AREAS AND SUMMARY OF KEY ENHANCEMENT OPTIONS

STAITHES	Further develop the in-situ reworking of rock armour boulders already trialled at Runswick. Combine Statithes, Runswick and Robin Hood's Bay to create a zone of continuing experimental work, monitoring and evaluation.
WHITBY HARBOUR	Work with Groundwork NE to install a range of customised ecological enhancements within the harbour and estuary, including retrofit seawall features capable of catching and retaining sediment.
SCARBOROUGH NORTH BAY	Retrofit pools and panels on the stepped buttresses, in-situ works to rock armour, experimental 'self-cleaning' techniques for safer slipways and steps by encouraging grazers through the use of textured patches and repairs.
SCARBOROUGH HARBOUR	Retrofit features grouped to create larger arrays of pools and panels visible to visitors, assisting with project interpretation and public engagement.
SCARBOROUGH SOUTH BAY	Evaluate the habitat value of the existing Victorian sandstone sea walls (texture, complexity, links between cultural and natural heritage); add new retrofit features and patched repairs to the mix of rock armour, steps and slipways.
FILEY	The seawall at Coble Landing and the slipway at Cargate Hill both present opportunities for retrofit rockpool arrays. These may offer an opportunity to both relieve recreational impact from the SSSI rockpools at Filey Brigg and create a robust and accessible learning zone sympathetic to the designated habitats and the work of the country park.
BRIDLINGTON HARBOUR	Extend existing partnerships between stakeholders working in and around the harbour to create a programme of small-scale interventions through retrofit and repair; support the implementation of the Bridlington Harbour Forward Plan, adding ecological design into the harbour wall extension projects.
HOLDERNESS TIMBER GROYNE FIELDS	Develop a range of techniques and designs for timber groyne enhancement, using existing retrofit and in-situ techniques as well as new ideas and innovations, working with the local authority and with the University of Hull.
MAPPLETON ROCK GROYNES	In-situ reworking of selected rock armour boulders with drop-in units and 'seed' materials added; experimental designs for new, lightweight drop-in pools.
BARMSTON OUTFALL	Work with the Environment Agency to test patch repair techniques, adding texture and complexity to the concrete surfaces of the outfall. There is scope also for retrofit pools and panels and for enhancements to the surrounding rock armour boulders.
WITHERNSEA AND EASINGTON ROCK ARMOURS	Opportunities to 'future proof' rock armour at and above MHW, anticipating sea-level rise and texting the concept of pre-fabricating habitats in marine infrastructure that will eventually become intertidal and subtidal structures.
YORKSHIRE COAST TANK DEFENCES	Use existing survey data from the University of Hull to identify opportunities to add retrofit and in-situ habitats to elected defences. Look for opportunities to add 'bioblock' units to complement groups of tank traps.

THE PROJECT AREA AND OBJECTIVES

THE CONCRETE COAST

The YMNP project area includes large stretches of undeveloped, open coastline alongside busy industrial estuaries, ports important for the commercial landing of shellfish and finfish species, areas reliant upon tourism and recreational activities, with dramatic landscapes, long and exposed sandy beaches, soft glacial till cliffs and seafront towns. With the onshore terminals at Easington carrying a significant proportion of the UK's gas supply, and the growing importance of the Yorkshire coast's offshore wind energy capacity, set together along one of the fastest eroding shorelines in the country, the YMNP area is at the sharp end of policy and practice in the field of climate change adaptation and mitigation.

This unique combination of natural, economic and cultural infrastructures, of national and international significance, set out at a regional landscape scale, confers strategic importance to YMNP, the Yorkshire coast, their component local authorities and stakeholder networks. The critical task of designing and testing new and sustainable solutions for the built and urban coast is a global imperative and laboratories of innovative research, application and dissemination are essential. By adopting such an ambitious programme of positive and proactive intervention in coastal engineering, YMNP is establishing itself as a centre of IGGI excellence and a source of new evidence and expertise in a rapidly growing field.

The opportunities arising from the Concrete Coast project include:

- Working with the local authorities, DEFRA and the Environment Agency, pilot methods of cost-benefit evaluation that can validate and incorporate multipliers in social, cultural and natural capital secured through ecologically engineered marine and coastal infrastructure.
- Use the administrative and decision-making restructuring and adaptation required by regional devolution to embed new policy instruments favouring IGGI solutions in construction, development and infrastructure on the coast.
- Establish the Yorkshire Coast as a national leader in IGGI solutions for marine infrastructure, bringing together public and private landowners, regulators and academics to create a centre of excellence, piloting new techniques and disseminating evidence.

THE TWO COASTAL WATER BODIES

Waterbody Name: Yorkshire North

Unique Waterbody IDGB650401500004

River Basin District Name: Humber

Waterbody Category: Coastal

Waterbody Name: Yorkshire South

Unique Waterbody IDGB640402491000

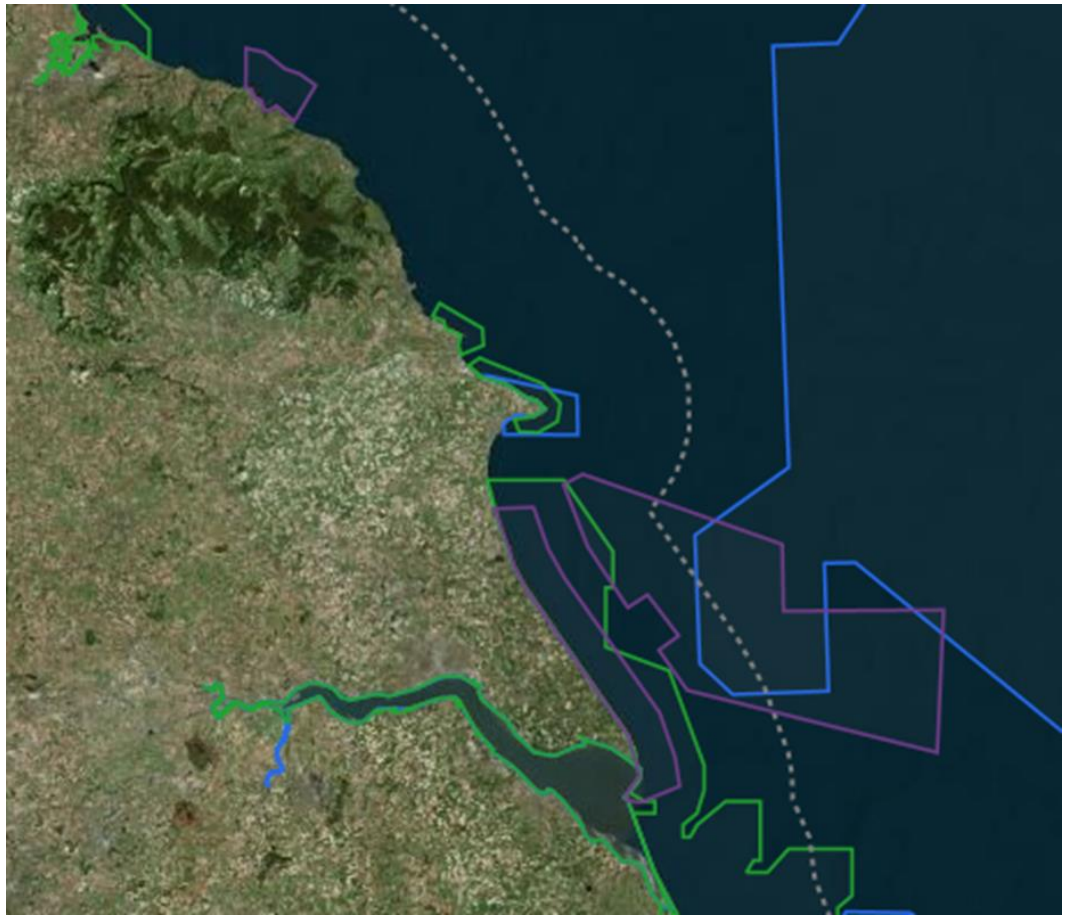
River Basin District Name: Humber

Waterbody Category: Coastal

NATURAL CAPITAL

The project coastline is heavily designated for its marine habitats, coastal ecology and palaeontology, at local, national and international levels. Within these protections, infrastructure projects and built installations of any kind will need to satisfy demanding regulatory obligations. However, many of the larger defended coastlines lie partly or wholly outside these protections, for example Bridlington, and Scarborough North Bay. Marine protections are more extensive and continuous at Holderness, incorporating some defended areas entirely, for example Withernsea. The pattern of coastal habitat protection along the YMNP coast reveals a number of these well-defined spaces, especially on the North coast, where restrictions on built interventions in the intertidal will be less complete and opportunities for experimental works more open.

These strategic gaps can be used as a provisional guide to larger ecological engineering projects, particularly where they are close to, or lie between adjacent designations, establishing areas of connecting ecological uplift. This approach may also be useful to the delivery of mandatory Local Nature Recovery along the Yorkshire coast, and in the establishment of receptor sites for offsite BNG and other environmental mitigation levies, helping to invest in and steadily expand zones of IGGI and increase their value to local coastal ecosystems.

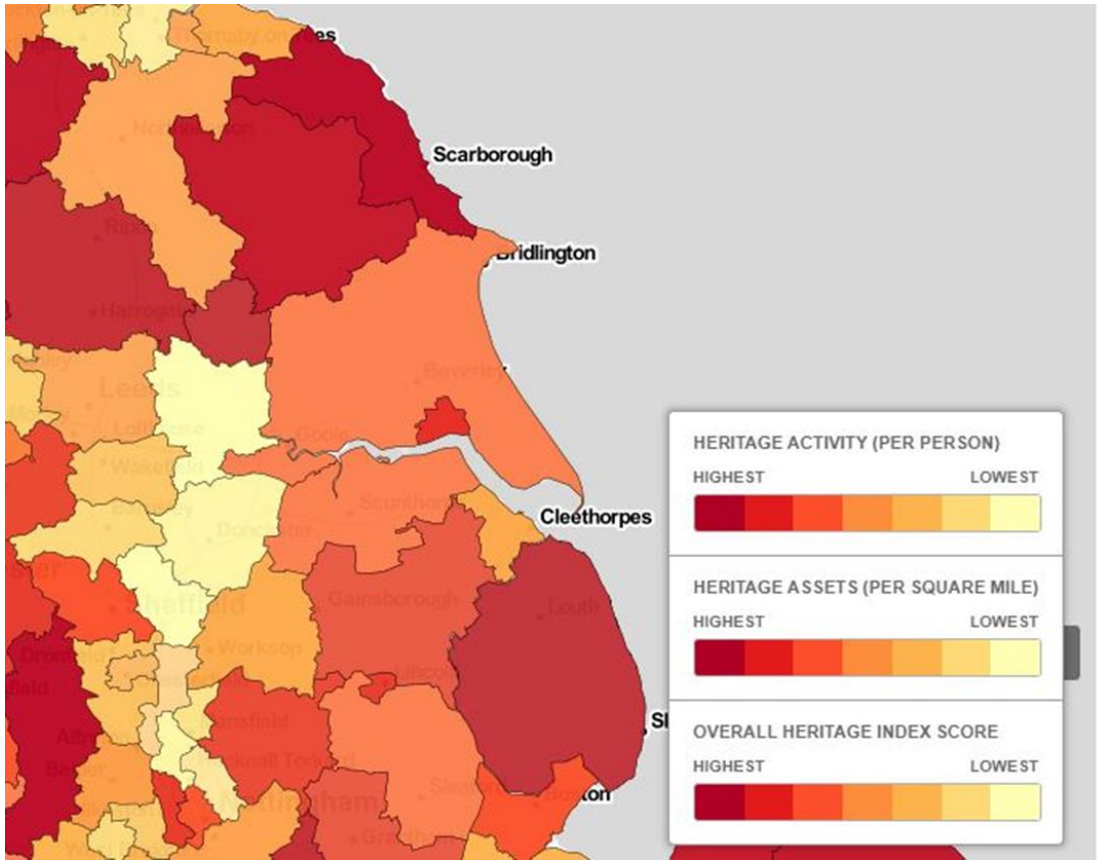


The Network of Marine Protected Areas on the Yorkshire Coast
https://jncc.gov.uk/our-work/marine-protected-area-mapper/

SOCIAL AND CULTURAL CAPITAL

The YMNP coastline is approximately 160 km in length with coastal towns evenly spread across its whole length: Staithes, Whitby, Scarborough, Filey, Bridlington, Hornsea, Mappleton, Withernsea and Easington, interspersed by smaller settlements such as Sandsend and Skipsea. The total resident population of the 36 constituent parishes that make up the coastal community of YMNP is approximately 160,000 (17 coastal parishes, 60,000 population in East Yorkshire; 19 coastal parishes, 100,000 population in North Yorkshire). Industry is characterised by higher than national averages in manufacturing, health and social care and tourism provision. The Yorkshire coast fishery, though depleted, remains an important regional and national industry, with working ports at Whitby, Scarborough and Bridlington.

The Yorkshire coast has remarkable time depth, still accessible in its pattern of settlement from the Iron Age, through its Roman and Norse invasions, medieval charters and spas, its Victorian resort expansion and maritime enterprise, and the rise of its creative industries and wildlife economy. This rich combination of local distinctiveness expressed in different ways across its coastal communities and parishes, provides a wide range of opportunities for YMNP to use the Concrete Coast concepts and interventions to create positive engagement and collaboration precisely because of the capacity of the designed built environment to respond to local character and content.



Heritage Index of the Yorkshire Coast
https://www.thersa.org/projects/heritage/index/2016-england

KEY REFERENCES

North East Inshore Marine Plan

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004484/FINAL_North_East_Marine_Plan__1_.pdf

East Inshore Marine Plan

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312496/east-plan.pdf

Natural Character Area Profiles 25, 26, 27, 40, covering Yorkshire North and East

https://www.gov.uk/government/publications/national-character-area-profiles-data-for-local-decision-making/national-character-area-profiles

East Yorkshire coastal erosion information

https://www.eastriding.gov.uk/coastalexplorer/homepage.html

North Yorkshire coastal erosion information

https://www.northeastcoastalobservatory.org.uk/

DRIVERS OF CHANGE

DRIVERS OF CHANGE – CLIMATE, PROTECTED AREAS, BIODIVERSITY NET GAIN

The need to mitigate the impacts of climate change upon both 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 increases land-take and adds requirement 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 around the world.

The YMNP and Concrete Coast project area (excluding the Humber Estuary) includes 3 Marine Conservation Areas (2 inshore), 1 Special Protection Area, 2 Special Areas of Conservation, 14 Sites of Special Scientific Interest, 3 Heritage Coasts, and 20 Designated Bathing Waters. The project area also comprises 2 distinct sediment transport cells coterminous both with the 2 Coastal Water Body designations under the Water Framework Directive, and 2 sea water circulatory systems (cold to the north, warm to the south), all dividing at or around Flamborough Head. This great complexity and diversity of biogeographical content also supports a resident coastal community of 160,000 that includes significant pockets of socio-economic deprivation (in Whitby, Scarborough, Bridlington and Withernsea) and an annual visiting population of approximately 10 million. The national focus on urban regeneration, via Coastal Community Fund, Levelling Up, Towns Fund and new government initiatives yet to come, creates opportunities to secure investment in places and services across the YMNP area.

As the Environment Act 2021 moves towards mandatory delivery of biodiversity net gain and local nature recovery networks in 2023, the need for effective compromise and combination between these socio-economic drivers and the statutory ecological priorities that co-exist along the coast, will become inevitably more urgent. YMNP, with its partners and stakeholders, is in the perfect position to design this compromise, finding ways to both meet multiple regulatory obligations and lever maximum social, cultural and ecological gains from the projects and programmes, new builds, extensions and repairs, that will take place between Staithes and Spurn over the next five to ten years. The innovations, experience and learning that will come from this approach will undoubtedly be of national and international importance.

DRIVERS OF CHANGE – REGULATION, SMP, BIORECEPTIVE ENGINEERING

The conservation, restoration and management of coastal and marine ecosystems also plays a key role in climate change adaptation and therefore the delivery of mandatory Net Zero by 2050 (Climate Act 2019), helping to buffer human societies from the impacts of climate change, such as rising sea levels, making space and time for more resilient designed solutions, and through the harnessing of carbon sequestration functions of algal and invertebrate species and their aggregations. Marine biodiversity, from the priority species and their habitats to the common communities that characterise different coastal environments, are all an essential component in this necessarily unified view of ecological health, biotic integrity and cultural wellbeing on the built and urban coast. The consenting and regulatory process required for marine infrastructure is already recognising the need for a more wide-angled and coherent approach to developed shorelines and this movement is only likely to continue, bringing together public realm, the historic environment, socio-economic factors and ecosystem services alongside water body status and wildlife law.

Shoreline Management Plans (SMPs) identify the best approach to managing risks from flooding and coastal erosion over the next 100 years for individual areas and the wider coast in the UK. SMPs are intended to deliver against two national objectives:

- To reduce the threat to people and their property.
- To deliver the greatest environmental, social and economic benefit, consistent with the Government's sustainable development principles.

The North East Shoreline Management Plan (2007) covers the North Yorkshire section of YMNP and the Flamborough Head to Gibraltar Point Shoreline Management Plan (2010) covers the East Yorkshire section. In both, the balance between the protection of people and property and the protection of the natural environment under the twin stressors of climate change and biodiversity loss, is challenging. Opportunities for positive ecosystem management on the YMNP coast have been traditionally assigned to those sections under 'No Active Intervention' but even there cliff-top land use and infrastructure may significantly limit the scope for natural process to establish or re-establish beach, dune and soft cliff habitats.

The rise of bioreceptive engineering and IGGI in the marine environment has created important opportunities to allocate at least some potential for ecological uplift to SMP categories 'Hold/Advance The Line'. Given the presumption of permanence (at least within the SMP cycle), these policies can now be used, as collateral, to support new impact investment in coastal infrastructure delivering against biodiversity, climate and sustainability objectives.

KEY POINTS AND REFERENCES

• Artificial structures on the coast can be readily adapted to enhance the richness and abundance of colonising marine biodiversity and extend ecological benefit within the intertidal environment. There is a growing body of evidence to support these measures and justify investment in their utilisation.

https://www.conservationevidence.com/synopsis/pdf/35

• Policy drivers at national and local levels are increasingly aligning with models of impact investment and ESG to create new cost-benefit models that recognise gains in natural, social and cultural capital as legitimate and necessary metrics.

https://www.netpositiveproject.org/

https://www.gov.uk/government/publications/greening-finance-a-roadmap-to-sustainable-investing

https://www.gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england-action-plan/flood-and-coastal-erosion-risk-management-strategy-action-plan-2021 (strategic objective 1.4)

https://www.gov.uk/government/publications/chief-medical-officers-annual-report-2021-health-in-coastal-communities

• A new approach to the design, management and repair of marine infrastructure and coastal defence is therefore required, effectively and imaginatively combining the twin priorities of shoreline management, to reduce the threat to people and their property, and to deliver the greatest environmental, social and economic benefit, consistent with local, national and international sustainable development obligations.

• The North and East Yorkshire coasts bring into sharp relief the interface between public and private investment priorities, conventional and emerging asset classes and developed and natural environments. In so doing they create a globally relevant case study for new thinking, better design and effective local and regional partnership across 400km² of coastal and intertidal landscape.

North East Coastal Authorities Group River Tyne to Flamborough Head Shoreline Management Plan 2

http://www.northeastsmp2.org.uk/docs/finalsmp2/SMP2-FinalV2.pdf

Humber Estuary Coastal Authorities Group Flamborough Head to Gibraltar Point Shoreline Management Plan 2

https://www.eastriding.gov.uk/environment/sustainable-environment/looking-after-our-coastline/defending-the-east-riding-coastline/

BUILT HABITATS FOR COASTAL INFRASTRUCTURE

OPTIONS FOR BUILT HABITATS ON DEFENDED COASTS

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 and the concept of 'Integrated Green-Grey Infrastructure' (IGGI) is now being incorporated into industry standards for construction, development and infrastructure through published best practice 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 acted to further encourage new thinking and practical innovation. This new movement is significantly better developed, and more ambitious, in the marine environment than in terrestrial and freshwater systems, benefitting from a longer time depth of experimental interventions in, for example, artificial reef creation and fishery enhancement, but also quickened by growing public awareness of the devastating impacts of marine pollution, over-fishing and seabed destruction.

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), to promoting commercial or subsistence fisheries, excluding non-native or nuisance species, enriching public realm and human experience of the coast, and opportunities for education and research. All of 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 six:

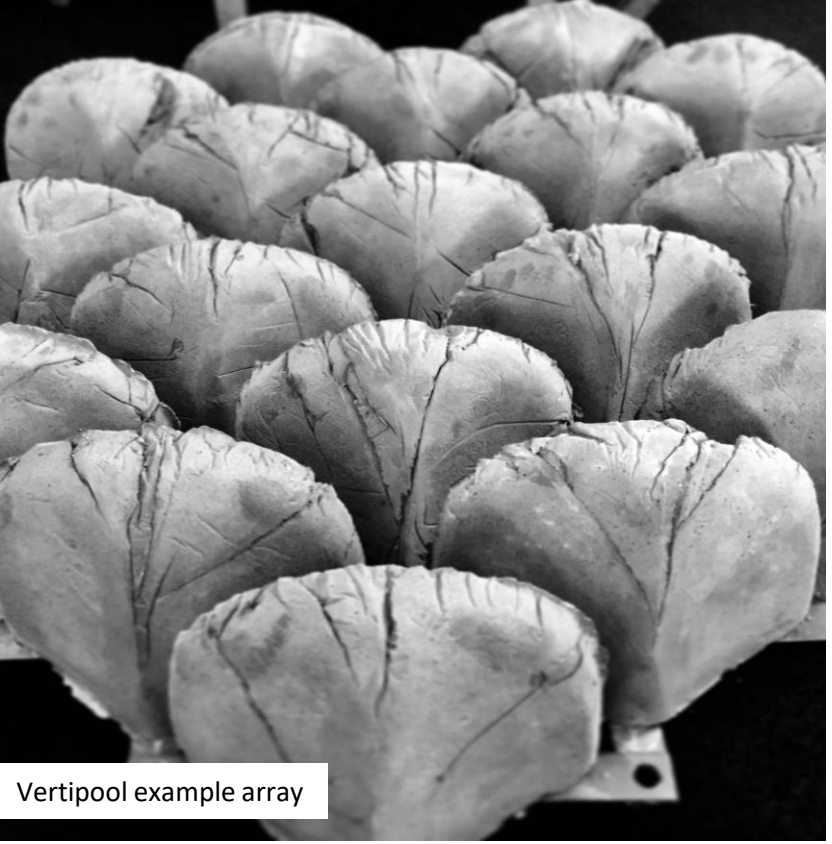
Small drilled holes

Small gouged pools

Gouged channels and pits

1. SMALL FEATURES WORKED INTO EXISTING STRUCTURES

The artificial rocky shore environments created by sea walls, rock armour, concrete and stone groynes, piers and jetties, steps and slipways, in general present a smooth finished surface or are patterned at a very coarse scale, both unfavourable to small colonising organisms requiring fine-grained refuge and settlement textures for successful establishment. By working into these existing surfaces, new habitat patches can be simply and advantageously created, and extended in an opportunistic way, when funding or circumstance allows. 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 steppingstones across the available infrastructure. The YMNP coast has already pioneered some of these techniques at Runswick Bay through the work of Dr. Alice Hall, Scarborough Borough Council and the University of Hull.



Vertipool example array

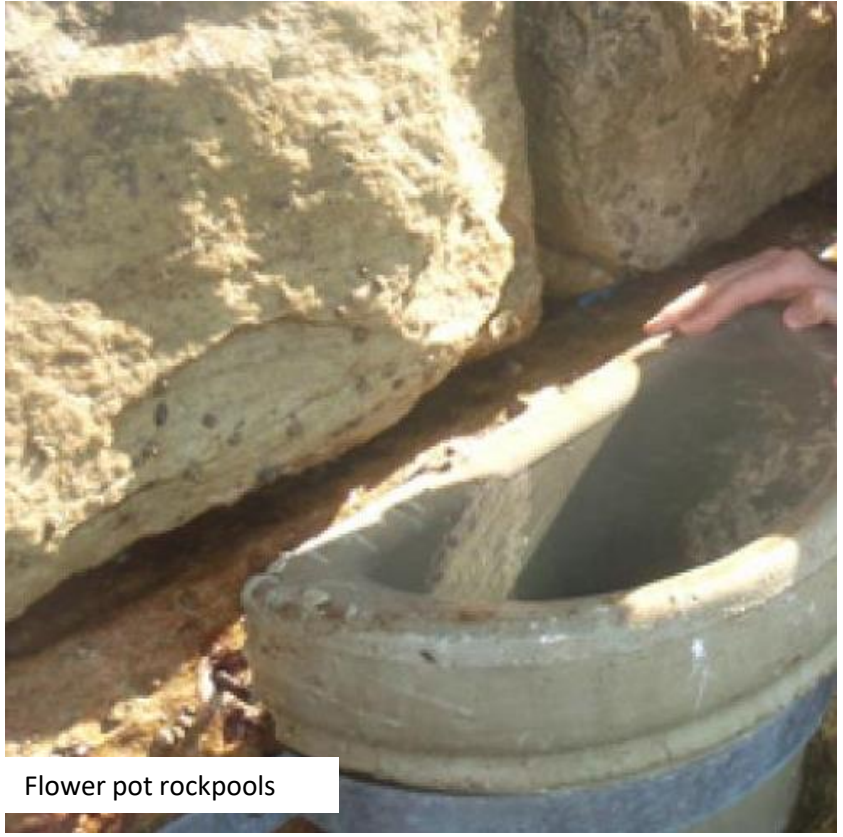
Small Vertipools in situ

Living Sea Wall panels

2. RETROFIT ROCKPOOLS AND PANELS

Vertical sea wall surfaces, timber and concrete groynes, sheet pile defences, all present large, uniform and suboptimal spaces for colonization from seabed to terrestrial interface. Retrofit fixtures such as Vertipools (Artecology), and the Living Seawalls project (Reef Design Lab), can be attached to almost any surface, in arrays and clusters that maximise differentiation of species assemblages within the tidal range. Both pools and tiles/panels have a striking visual impact, and this can be used to add interest and design aesthetic to the public realm in coastal locations, either as purely visual amenity, or as deliberately positioned attractors for wildlife encounter and beach exploration.

Pools fitted to gabions, intercepting freshwater outfall onto the shore to create small brackish habitats for soft cliff invertebrates, Isle of Wight



Flower pot rockpools

Sand-cast pools recolonising after beach feeding

2. RETROFIT ROCKPOOLS AND PANELS continued

The combination of densely textured surfaces and water-retention, together with 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 assists cost-benefit calculations when factored into schemes of punctuated intervention over larger areas of coastal infrastructure.

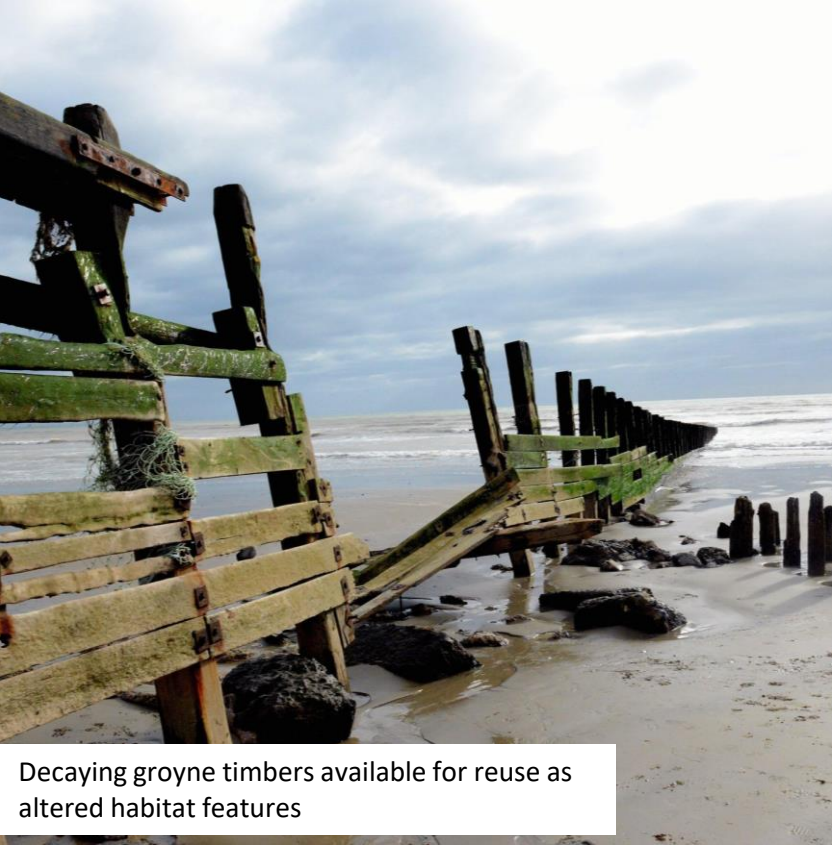
Precast pool unit within rock armour

Precast freestanding ‘bioblocks’

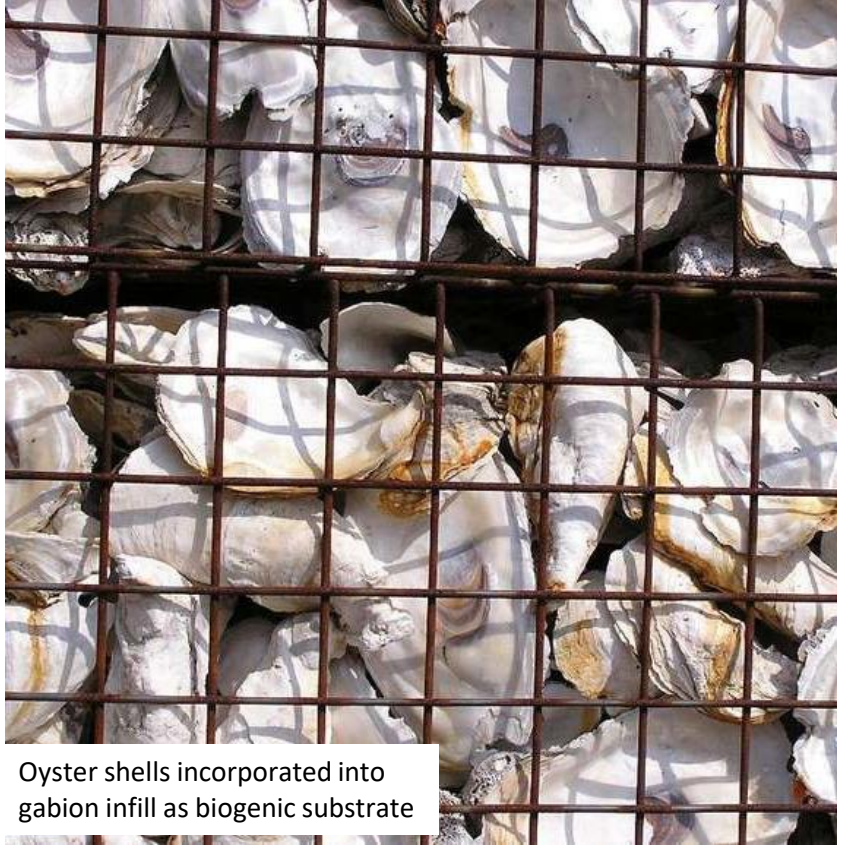
Precast tide pool set in rock armour

3. PRE-CAST ‘DROP-IN’ MODULES

Cast concrete blocks can be incorporated into rock armour during installation, dropped into gaps later, or added to the toe of the deployment, providing units of combined 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). Large self-contained features such as these can present novel habitat conditions not otherwise found in either 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.



Decaying groyne timbers available for reuse as altered habitat features

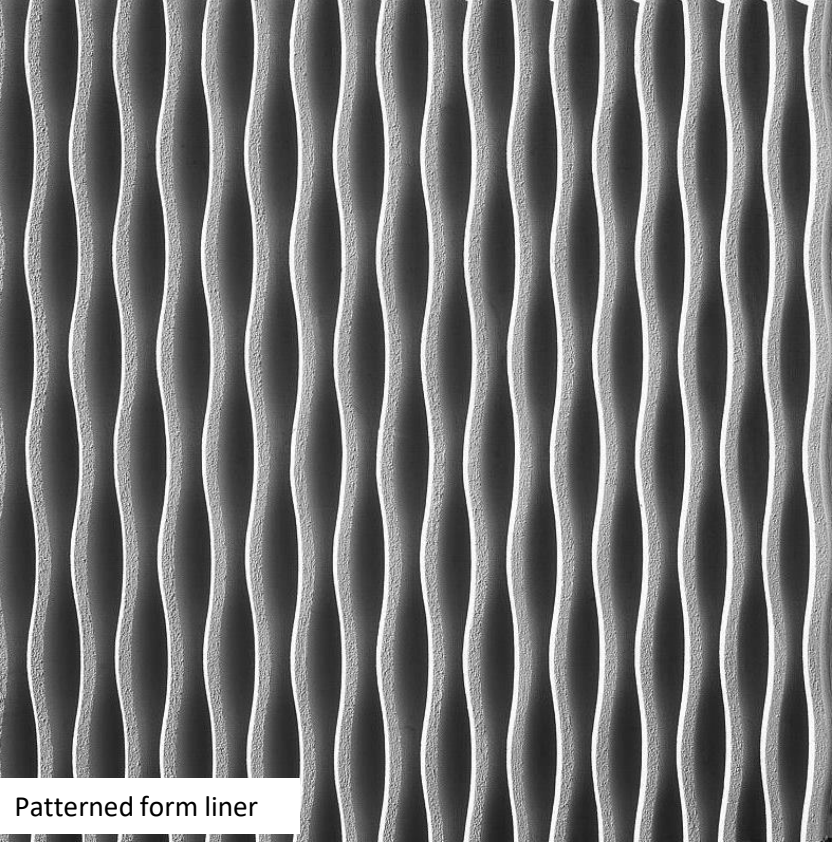


Oyster shells incorporated into gabion infill as biogenic substrate

Original quarry machine marks provide potential habitat if correctly aligned

4. UPCYCLED, RE-IMAGINED AND SACRIFICIAL MATERIALS

In the course of 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. In these cases, the 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, for example oyster shells added to aggregate fill for gabions. Gabions too provide ideal features for the combination of infill habitat enrichment and external retrofit attachments. Where conventional materials are used for coastal infrastructure, they may already carry incidental patterning or texture that is useful to colonizing marine life, for example the machine marks on quarry stone. Where this is the case, enhanced features for wildlife can be optimized by positioning the material in the most favourable way, for example with pits or grooves uppermost.



Patterned form liner

The Seattle sea wall project

North Portsea Island Coastal Defence Scheme

5. INTEGRATED FEATURES IN NEW CONSTRUCTION

New build 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 function, are now being promoted by companies such as Reckli and although recessed pools remain problematic to cast in situ, combinations of textured surface through pattern imprinting can be imaginatively combined to deliver niche diversity and heterogeneity. New techniques are being developed that may be able to safely and efficiently create inset pools 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.

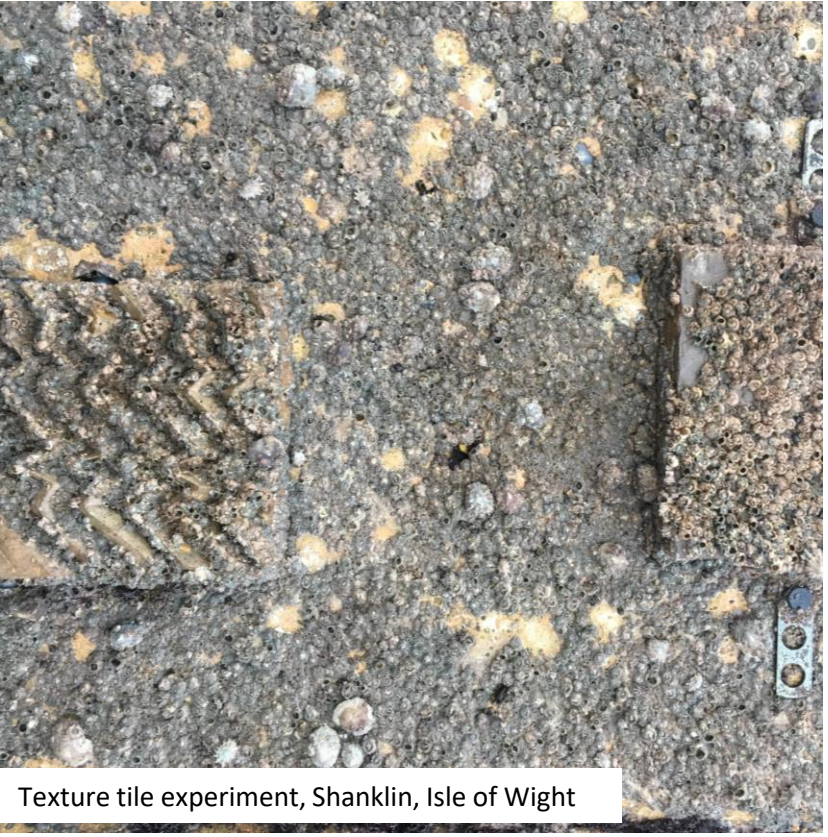
Sea wall repairs in Vancouver

Ecological niches created through texturizing wet cement

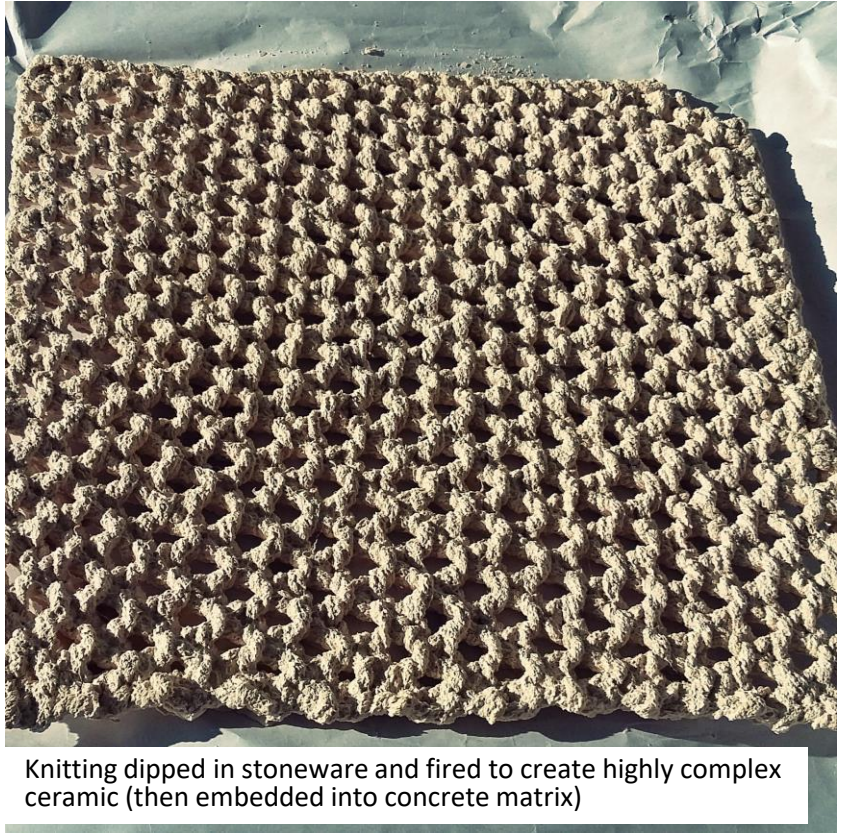
Small scale patching

6. REPAIR AND MAINTENANCE OF DAMAGED STRUCTURES

Aging and damaged assets present an important opportunity for the introduction of ecological enhancements as part of remedial, refurbishment and upgrade works, modifications or replacements. Larger repairs may in fact be versions of type 5 intervention whereby patterned form liners and integrated casting techniques are used, but most running repairs are likely to be smaller patched and temporary fixes pending asset replacement or simply as budgeted or emergency maintenance works. At this scale, repairs are essentially hand-made and so 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 to 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.



Texture tile experiment, Shanklin, Isle of Wight



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

Tiled pavement for fish passage on concrete spillway

6. REPAIR AND MAINTENANCE OF DAMAGED STRUCTURES continued

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. A similar advantage can be expected from cloaking effects of algal colonisation on biologically favourable patched surfaces. The same techniques used for enhanced repair can also be extended into bespoke wet concrete work to create features on site and directly in response to specific opportunities. This is especially effective when using fast-set cements such as Vicat Prompt. The potential to develop the concept of ‘self-cleaning’ slipways and steps by deliberately creating textured surfaces for grazer colonization is also an area of current research.

KEY POINTS AND REFERENCES

Conservation Evidence review of global interventions and techniques for constructed ecological enhancement in the marine environment.
https://www.conservationevidence.com/synopsis/pdf/35

A UK perspective on the progress towards uptake of eco-engineering approaches for enhancing biodiversity on artificial marine structures.
https://pure.aber.ac.uk/portal/files/28356134/Evans_et_al_From_Ocean_Sprawl_to_Blue_Green_Infrastructure_Accepted_MS.pdf

Frontiers in Marine Science review of Vertipools.
https://www.frontiersin.org/articles/10.3389/fmars.2019.00456/full

Frontiers in Marine Science sediment capture by artificial pools.
https://www.frontiersin.org/articles/10.3389/fmars.2021.780720/full?fbclid=IwAR2ffcwbdWGxCfHQDW1c0zguZ6-VHQW_cjuaMlmTU2m2IsgbLBtd8ot0Hfc

Runswick Bay surface heterogeneity pilot.
http://eprints.bournemouth.ac.uk/30904/

Passive enhancement techniques for rock armour defences.
https://www.sciencedirect.com/science/article/pii/S0048969720335014

Use of textured form liners to deliver ecological enhancement.
https://www.sciencedirect.com/science/article/pii/S259029031930001X

Commercial suppliers of marine ecological enhancement products and services:

Artecology https://www.artecology.space/

Arc Marine https://www.arcmarine.co.uk/

Reef Design Lab https://www.reefdesignlab.com/

ECOncrete https://econcretetech.com/

Reckli form liners https://www.reckli.com/en/products

Current UK partnership research programmes in constructed marine habitats:
http://marineff-project.eu/en/
https://www.ecostructureproject.eu/

Low-carbon cements and fast-set options for fine texture:
https://www.concretecentre.com/TCC/media/TCCMediaLibrary/Publications/Concrete%20Futures%202021/TCC_ConcreteFutures_Decarb_Feb22.pdf
https://www.vicat.com/faq/what-prompt-natural-cement

GENERAL COSTS AND SPECIFICATIONS

OUTLINE COSTS AND SPECIFICATIONS

This section of the report attempts to provide practical support on the deployment of built habitat solutions such that YMNP 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 around the world to allow for a systemic guide to installation, or at least to establish a convention or praxis that is robust enough to support immediate action and flexible enough to make space for new thinking.

Some of the ecological enhancements recommended have a standard unit cost for supply, though not for installation as this is most 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 harder to cost as they can be delivered in a variety of 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 arising from the EU Interreg-funded Marineff programme, a collaboration between France and the UK with the goal of developing 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 base 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, with benefits to the environment, to coastal communities, and to the blue and green sectors of the Irish and Welsh economies.

It is recommended that the YMNP team builds a working relationship with Marineff and Ecostructure, with the NRW team and with the Solent Forum, in order to share information and contacts. The prospect of a federation of marine eco-engineering hubs around the UK coast seems increasingly appealing and useful given the importance of coastal communities and coastal partnerships in local and national policy and planning.

POOLS AND PANELS

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

A basic functional array might then be specified as 3 pools and/or 3 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.

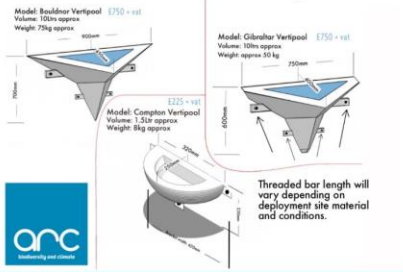
A guide price for a **3-pool array would be £1000**, supplied with fixings. An array with 3 pools and 3 panels is likely to double the cost. Installation costs will vary but given that these are simple items to affix, a rate of £500 per array is likely to be reasonable.

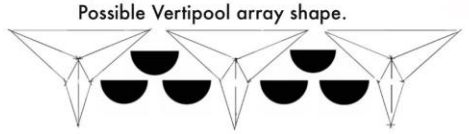
An ideal basic array would therefore be in the order of £2500 to create.

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

If the objective is to demonstrate coverage, for example along the linear length of a sea wall, then 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 through the halo effects spreading out from each vertical array. There is no definite optimum, but a working approximation would be 15m, meaning that 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 only were used as the basic array the cost would be £125 per linear metre.

Vertipool Fact Sheet 2022





Materials List

All fixings must be A4 (316) marine grade stainless steel.

M16 A4 threaded bar/rod (DIN 976-1)

M16 A4 washer (DIN 9021)

M16 A4 nylon insert Hex nut (DIN 985)

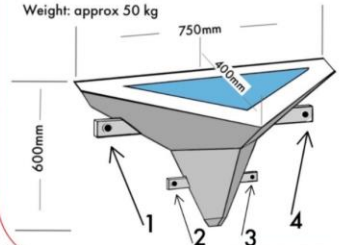
Fischer FIS VL 410c Vinylester Mortar Art.No. 539463

NOTE.
Lead times vary However they are usually no less than 8 weeks.

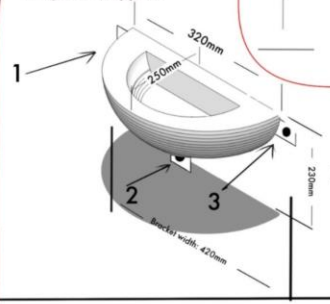
We strongly recommend you engage the services of our in-house scoping team for Vertipool position selection, unit number and array shape.
Our team will tailor a cost effective solution to your specific project that will provide the best possible ecological enhancement outcome.

Dimensions

Model: Gibraltar Vertipool
Volume: 10ltrs approx
Weight: approx 50 kg

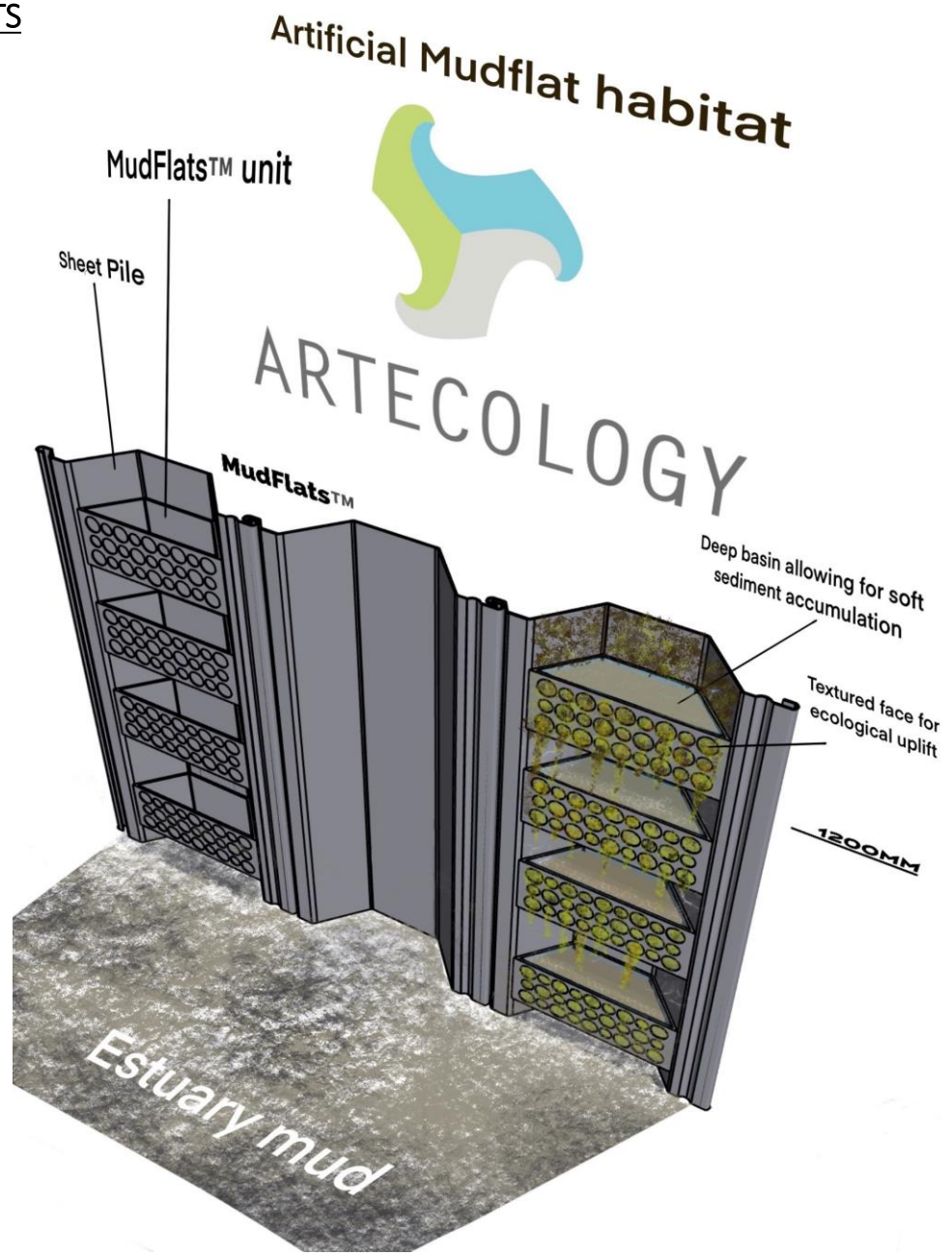


Model:Sandown Vertipool
Volume: 1.5Ltr approx
Weight:13kg approx



M16 threaded rod cut to specified lengths leaving 25mm exposed from the wall for washer and nut capture.

VERTIPOOLS AND MUDFLATS



CAST UNITS AND ‘BIOBLOCKS’

- These are stand-alone cast concrete modules that can be set in amongst rock armour or placed singly or together on the open shore.
- Units vary according to size and design but a cost of **approximately £2000 for a single drop-in** is a useful guide.
- Installation is likely to require heavy-lifting machinery.
- These installations are designed to provide multiple niche habitats within a self-contained unit and so can be used singly, in close array or spread out over larger distances. Because of their massive structure, these units can also be used as complementary defences within or alongside existing rock armouring.

IN SITU NICHE CREATION AND TEXTURED REPAIRS

Working into and onto existing sea defences and marine infrastructure provides a simple and expedient option whereby ecological gains in the built intertidal can be accumulated through maintenance and through opportunistic interventions when funding allows. The licencing route required will most often also be simpler than larger retrofit installations.

Patterns of perforation and added texture can be improvised, 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 as 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 pre-fabricated.

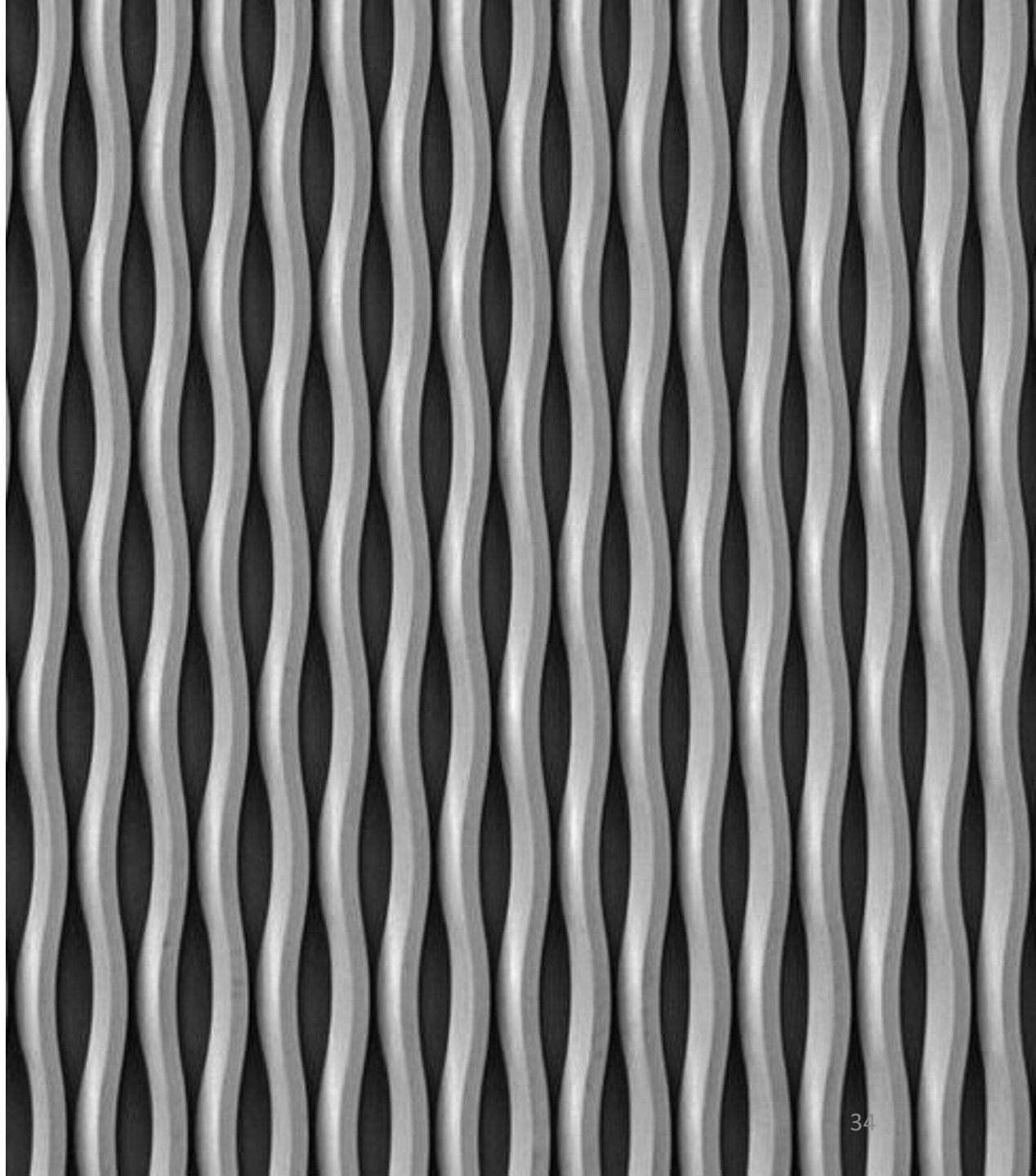
Costs are likely to vary widely according to accessibility, scale and substrate, but also departmental cost-centre and recharge rates when in-house. A rule of thumb based on existing experimental deployments of these techniques (including pioneering work at Runswick Bay) is a rate of **£50 per square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

PATTERNED FORM LINERS

The use of form liners to create textured concrete surfaces more receptive to biological conservation is becoming more frequently specified and manufacturers are producing some designs with a specific ecological function. These remain rare, but it is possible to adapt, combine and re-orientate existing decorative design 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.



KEY POINTS AND REFERENCES

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

- Ecostructure http://www.ecostructureproject.eu/
- Marineff http://marineff-project.eu/en/
- 3D PARE https://www.giteco.unican.es/proyectos/3dpare/news.html
- Natural Resources Wales Marine Area Statement https://naturalresources.wales/about-us/area-statements/marine-area-statement/?lang=en
- Solent Forum Building Biodiversity Hub http://www.solentforum.org/services/Member_Services/Building_Bioversity_hub/

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

There will also be alignments and utilisations of the existing habitat fixtures and features not yet trialled and 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 averages 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 more than deliver a 10% net gain for biodiversity.

Because all of the enhancement techniques provided in this report are modular, the final cost benefit analysis can be scaled until an acceptable balance is reached, both in terms of 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 but 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.

Additional benefits of natural capital / biodiversity net gain uplift, carbon sequestration and strengthening of FCRM assets can also be realised through this work and will need to be calculated for each delivery project.

YORKSHIRE COASTAL INFRASTRUCTURE

COASTAL INFRASTRUCTURE - ASSET REGISTER

The YMNP area covers the coasts of North and East Yorkshire. Coastal asset registers for both have been collated in order to quantify the scale and diversity of built structures potentially available for ecological enhancement.

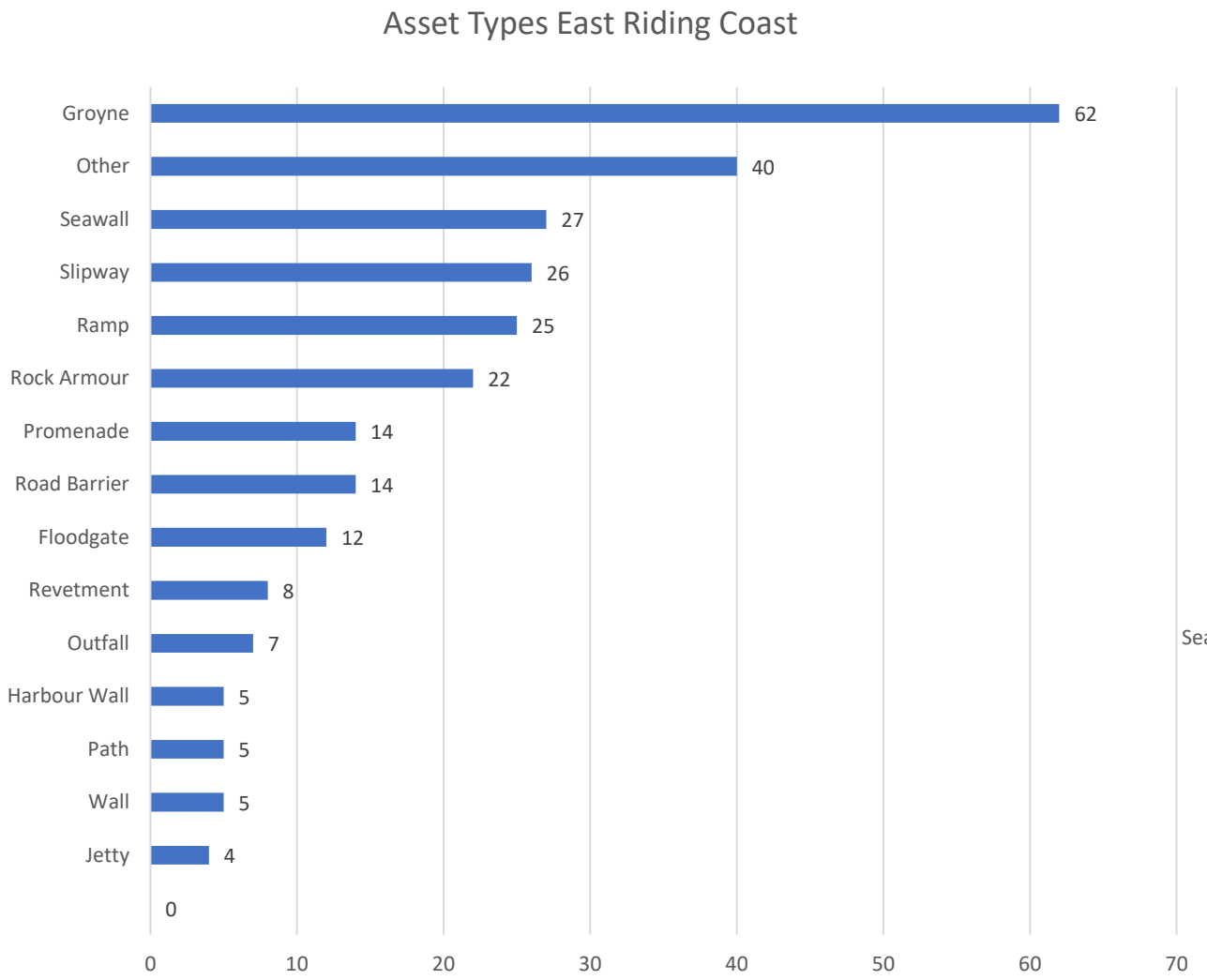
592 coastal assets have been recorded for the whole of the project area, 364 in East Yorkshire and 231 in North Yorkshire.

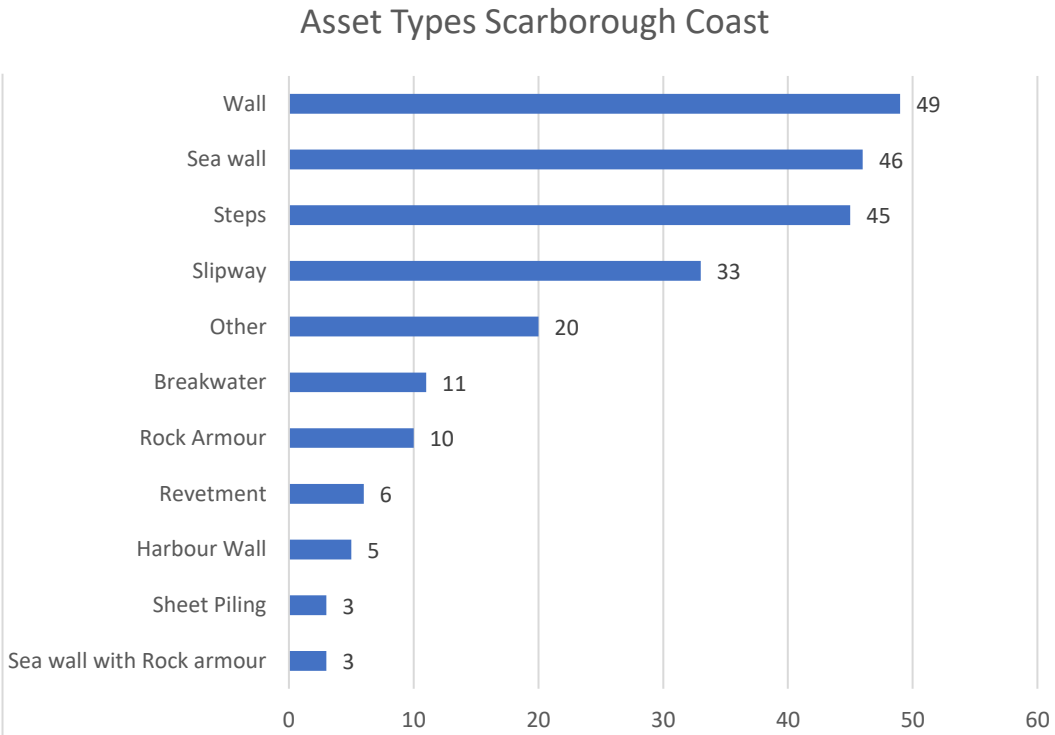
There are some built features that do not appear on the register, such as the anti-tank defences along the Holderness coast (some repositioned as sea defences in the 1970s), but the larger part of public and private infrastructure is described and located. The complete register has been translated into an interactive GIS map, which is available on the YMNP website.

For the purposes of this project, the register has been divided into a set of primary assets: seawalls, groynes and rock armour (considered to offer opportunities for larger planned ecological interventions that may require more significant planning, regulatory and funding efforts), and a set of secondary features (combining the numerous smaller built features, such as steps and slipways). There may be a more opportunistic and rapid-response approach taken to small scale enhancements, but safe public access, mooring, recreational use, and asset size, may constrain the scope for more substantial re-engineering.

Although this basic typology is necessary in order to be able to sensibly evaluate such an extensive project area, it should be stressed that all built features along the coast, no matter what their size or function, have the potential to add ecological value to intertidal habitats. Perhaps the most practical and sustainable approach to delivering the nationally significant gains for wildlife is to continue to accumulate small enhancements year on year wherever and whenever the opportunities arise, for example the new funding for sea wall repairs in Robin Hood's Bay, at the same time as bidding for, and implementing much larger installations as and when these become possible, for example the planned extension to Bridlington Harbour sea wall.

COASTAL ASSET TYPES ON THE YORKSHIRE COAST





The vast majority of the Scarborough (North Yorkshire) coastal assets are designated as Wall/Sea wall whereas Groynes dominate the defence infrastructure along the East Riding coast with only 2 recorded along the Scarborough coastline.

TOTAL ASSET COUNTS ACROSS THE YMNP PROJECT AREA (STAITHES TO SPURN)

Asset Type	Count
Steps	123
Seawall	**73**
Groyne	**63**
Slipway Apron	59
Wall	54
Rock armour	**32**
Ramp	26
Promenade	15
Revetment	14
Road Barrier	14
Floodgate	12
Breakwater	11
Harbour Wall	10
Outfall	8
Path	5
Jetty	4
Landing Stage	4
Pier	4
Bridge	3
Groyne constructed using rock armour	3
Pipe Line	3
Ramp/ Steps	3
Sea wall with Rock armour	3
Sheet Piling	3
Floodbank	2
Sloped Revetment	2
Access Road	1
Apron	1
Armouring	1

Asset Type	Count
Armouring to road end	1
Bastion and seawall	1
Beach Huts	1
Channel Side	1
Concrete Groyne and Slipway	1
Crane	1
East Pier	1
East Pier Extension	1
Fish Dock Area	1
Lifeboat Slipway	1
Obsolete Floodbank	1
Obsolete MOD Rubble	1
Obsolete MOD Structure	1
Observatory Building	1
Opening through splash wall	1
Pier Towers	1
Pumping Station	1
Redundant Toe Piling	1
Regraded Cliff Face	1
Splash Wall	1
Steel Sculpture	1
Steps and Ramp	1
Stream Dyke	1
Undefended frontage	1
Underpinning	1
Walkway	1
Wall/ Steps	1
West Pier	1
West Pier Extension	1

TOTAL ASSET COUNTS ACROSS THE EAST YORKSHIRE COAST

Asset Type	Count
Steps	78
Groyne	62
Seawall	27
Slipway	26
Ramp	25
Rock Armour	22
Promenade	14
Road Barrier	14
Floodgate	12
Revetment	8
Outfall	7
Harbour Wall	5
Path	5
Wall	5
Jetty	4
Pier	4
Groyne constructed using rock armour	3
Landing Stage	3
Pipe Line	3
Ramp/ Steps	3
Bridge	2
Floodbank	2
Sloped Revetment	2

Asset Type	Count
Access Road	1
Armouring	1
Armouring to road end	1
Beach Huts	1
Crane	1
Fish Dock Area	1
Obsolete Floodbank	1
Obsolete MOD Rubble	1
Obsolete MOD Structure	1
Observatory Building	1
Opening through splash wall	1
Pier Towers	1
Redundant Toe Piling	1
Regraded Cliff Face	1
Steel Sculpture	1
Stream Dyke	1
Underpinning	1
Walkway	1

TOTAL ASSET COUNTS ACROSS THE NORTH YORKSHIRE COAST

Asset Type	Count
Wall	49
Sea wall	46
Steps	45
Slipway	33
Breakwater	11
Rock Armour	10
Revetment	6
Harbour Wall	5
Sea wall with Rock armour	3
Sheet Piling	3
Apron	1
Bastion and seawall	1
Bridge	1
Channel Side	1
Concrete Groyne and Slipway	1
East Pier	1
East Pier Extension	1
Groyne	1
Landing Stage	1
Lifeboat Slipway	1
Outfall	1
Promenade Surface	1
Pumping Station	1
Ramp	1
Splash Wall	1
Steps and Ramp	1
Undefended frontage	1
Wall/ Steps	1
West Pier	1
West Pier Extension	1

TWO PROJECT AREAS

The two YMNP boroughs are quite different in their split between priority asset types; North Yorkshire is dominated by sea walls (almost 12km in total), with very few groynes, whereas the East Yorkshire coast is more evenly served by seawalls, rock armour and groynes in approximately equal lengths of deployment. The North coast is characterised by pockets of concentrated infrastructure in urbanised bays, separated by areas left to natural process, and inaccessible sea cliffs. The East coast has a sense of extensive low-key intervention throughout, with fewer and more isolated consolidated defences and a wider variety of smaller infrastructure types.

HIGH ENERGY SYSTEM

The YMNP coast and its coastal infrastructures have other features and characteristics of importance that are relevant when considering the most effective interventions and locations for built ecological enhancement. The whole coastline receives high energy wave systems with large scale accompanying sediment transport. Any deployment of ecological enhancements will need to consider these direct impacts as well as the effects of periodic burial under rapidly changing beach and foreshore profiles. Natural intertidal features, niches and habitats are of course subjected to the same sea conditions and patterns of seasonal impact and so it is not necessarily adverse to the sympathetic ecological function of constructed habitats, but it may be relevant to decisions on cost, maintenance, survey and evaluation, and replacement.

RESILIENCE OF INSTALLATIONS

Evidence from existing installations of retrofit ‘Vertipools’ in locations around the UK, as an example, suggest that, provided options for attachment are carefully evaluated and installation properly executed, they are resistant to storm conditions, for example in the Irish Sea and on the west coast of Scotland. Nevertheless, in very exposed sites it will be prudent to select spaces that include leeward shelter and other forms of localized protection (flank wall elevations for example) for at least some of the array. The ecological fixtures can themselves act as defence structures, breaking wave energy and providing shelter within and around arrays and this can help to design resilient layouts. Bioblocks and other precast drop-in features are massive in construction and designed to fit within rock armour, though placement and location may require additional fixing. Small patched repairs undertaken by hand are unlikely to be compromised through the addition of surface texture and complexity if sufficiently keyed into place; there is some evidence that additional protection is gained by ecologically enhanced surfaces through the shielding and surface energy displacement effects of algal, mollusc and crustacean screens.

KEY POINTS

The YMNP and Concrete Coast project area is very large, featuring **almost 600 separately listed built assets** that comprise its coastal infrastructure. These assets are now provided as a single comprehensive register accessible from the YMNP website. For the purposes of constructed ecological enhancement, the assets have been divided into two types. Primary assets are those affording opportunities for larger retrofit installations and integral designs for replacements and extensions. These comprise sea walls, rock armour and groyne fields. Secondary assets offer narrower scope for large intervention (due to size and public access constraints) but are potentially more suited to rapid delivery, adapted management and maintenance, and project collaborations with other stakeholders; these comprise steps, slipways and other ancillary features.

The North and East Yorkshire coastlines differ in the distribution and composition of their infrastructures. The North coast is dominated by seawalls concentrated within sheltered and defended bays. The East coast has a more even split between walls, rock armour and groynes but is, in comparison with the North section, proportionally more populated by groyne fields. The natural areas of the north comprise sandy bays, rocky platforms and rocky headlands whereas the east is entirely sandy bays and beaches. The only hard substrate in the east is built infrastructure and the ecological response here will be different, driven by different natural systems and larval flows.

The rich cultural and biological diversity encompassed by the built and natural heritage of the Yorkshire coast provides multiple hooks for local engagement and collaboration any of which can be reflected through the medium of retrofit or integrally designed constructed habitat features. Interventions and actions for biodiversity delivered in this way can also act as information objects, interpretive features, orientation and waymarking points, sculptural public art, citizen science and environmental education resources, and locations for graduate and post-graduate research work in the growing field of marine ecological engineering.

The distribution of environmental policy protections create different conditions for ecological enhancement. The North coast designations create a series of small strategic gaps excluding the main concentrations of urban impact; by contrast the East coast has far more extensive and continuous protective coverage which largely envelopes its main developed localities.

OPPORTUNITIES FOR ECOLOGICAL ENHANCEMENT ON THE YORKSHIRE COAST

GENERAL PRESCRIPTIONS

It is important to reiterate that the ecological techniques and fixtures set out in this report 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 considered approach will generate greater gains for wildlife, and help to avoid some of the risks (impact on other uses, storm damage, nuisance species etc.). Opportunistic deployment should always be capitalised upon. To help with a general prescription for built ecological interventions, the YMNP coast can be divided into its two distinct zones, north and south of Flamborough Head.

The northern section, between Staithes and Filey, is characterised by its sequence of large shallow bays with intervening headlands, inshore and subtidal rocky reefs with extensive kelp. From Filey to Spurn, interrupted by the massive chalk promontory of Flamborough Head, habitats are dominated by mobile sediment, inshore sand and offshore shingle.

Interventions for built ecological gain in the northern area should focus on ancillary support to rocky shores with large scale deployments of retrofit pools and plates, preferably in mixed arrays, at practicable locations along the seawalls in the major defended bays, together with special project locations for rock armour enhancements where these provide sufficient surface for colonisation within the normal tidal range.

These locations, such as Scarborough, are significant visitor attractions and also popular recreational destinations for local communities. Here there is much scope for large arrays (which may be built up a little at a time as funding and opportunity permits) to provide striking public ornament, contribute to environmental education and interpretation, and create new spaces for wildlife encounter.

In the southern zone, ecological interventions should seek to deliver shelter, and other lifecycle support, to sandy shore habitats (replacing those lost to coastal squeeze, agricultural improvement and recreational development). This can best be done via the extensive groyne fields, allowing for a transect of habitat enhancements down through the tidal range where installation below mean high water is possible, retrofits and adaptations to the scattered tank defences and other wartime debris, and upper shore interventions within the sections of rock armour where these fall low enough in the tide (many do not). These works would comprise customisation of groyne timbers, in situ and as replacements, arrangements of retrofit pools and panels at the low tide end of groynes, and drop-in built habitats and in situ alterations to rock armour.

IN-SITU ENHANCEMENTS VERSUS RETROFIT/ADDITIONAL

Taken at the level of general prescription for marine and coastal ecological engineering, there are two approaches available. The first is to add new biologically receptive fixtures and fittings to existing or new infrastructure, for example retrofit rockpools, dropped-in cast pools and bioblocks, or designed-in features integral to new construction work. All of these projects are likely to require fundraising to support special budgetary allowance, and some level of regulatory oversight, through the local planning authority, Natural England, Environment Agency and the Marine Management Organization. The second is to make smaller alterations to the existing fabric of coastal infrastructure by working into or onto surfaces as part of repair, maintenance and replacement programmes. These projects are less likely to require significant additional funding and may reduce or avoid the need for regulatory compliance.

Techniques may overlap, and there will be intermediate examples, but as a coarse filter for decision-making it can help project managers to consider sites as being best suited to one or another at a particular time. Timelines can be an important part of these considerations as in-situ reworking and small-scale hand-made modifications are helpful in testing ideas and designs at an early stage pending larger interventions, essentially a ‘meanwhile’ use.

Similarly, where environmental designations and policy protections create significant constraints (notably along the Holderness coast), in-situ approaches, especially through repair and maintenance where ecological enhancements can be steadily accumulated within existing operations, may offer a rapid or opportunistic response to the urgency of work for marine biodiversity particularly as there is robust data to support the efficacy of patterned and imprinted complexity as repairs delivering significant ecological enhancement compared to the surrounding surfaces (for example Victorian sea walls). The diversity of built assets and infrastructures present within the YMNP area, together with the range of designated and undesignated locations, make it a nationally significant test bed for landscape-scale ecological engineering and for the development of new and better techniques, designs and products to deliver enhanced conditions for marine life on the defended coast. Work on enhancements to timber groynes for example is an area where the project has the potential to make globally significant progress.

It is important to add that although smaller interventions may not require planning permission, plans and projects for ecological enhancement should be shared with the local planning authorities (including the North York Moors National Park Authority) in order that principles and methods can be more readily incorporated into best practice and regulatory process.

Examples of Ecological Enhancement delivered by repair and maintenance to marine timber infrastructure (Artecology)

Repair & Renewal

Training may be required

Tools and Techniques For Ecological Enhancement

Timber

Drilling

Using portable battery drills and various drill bits can be very useful for creating 'bioreceptive' pattern, shape and form in new & old timbers or retro-fit timber add-ons.

Shaping timbers with pattern and form using the skills a wood sculptor is also an excellent way to create bioreceptive surfaces combined with interpretation.

Shaping with tools.

Forstner drill bits are great for creating shallow or deep holes and tubes in timber.

HARBOURS AND CORPORATE INFRASTRUCTURE

The general prescriptions for ecological enhancement on the developed coast can help to frame a strategic approach to nature recovery within the YMNP project area and establish criteria for funding, including 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. There are two special cases creating locally distinctive project opportunities within the project area. These are included in the detail of the next section but can be summarised:

Harbours

Staithes, Whitby and Scarborough in the north, and Bridlington in the south, all have working harbours and these present conditions for wildlife, and for ecological intervention, very different to the exposed defences of the open coast. Whitby and Scarborough are both municipal ports owned and managed by Scarborough Borough Council; Staithes and Bridlington are trust ports managed by Harbour Commissioners. These sites provide extensive built defences protecting sheltered marine and estuarine conditions within, presenting a wide range of options for ecological engineering, including arrays and arrangements that would not survive the high energy regime on the open coast. Harbours also offer useful opportunities for collaboration with the mix of environmental, educational, commercial and civic stakeholders that are naturally clustered in such locations.

Corporate Infrastructure

This report deals mainly with coastal structures owned and managed by public and civic organizations, primarily local councils; these stakeholders are by far the most important in terms of their ability to initiate and deliver ecological enhancements, but there are locations along the YMNP 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). Three such sites are prominent along the Holderness coast: the Bridlington-Skipsea gap between marine protected areas, serving the offshore windfarms; the Barmston outfall, owned and maintained by the Environment Agency and a significant and established hard anthropic habitat within the soft coast; and the Easington Gas Terminal, presenting a distinctive set of defensive infrastructure with potential for longer term enhancement linked to future intertidal habitats created under conditions of sea level rise.

SOCIO-ECONOMIC IMPACTS

Ecological engineering, as a special feature of the North and East Yorkshire coasts, as proposed by YMNP, has the potential to usefully contribute to current and future economic regeneration in the region, both as a tool for efficient regulatory compliance and as evidence of a progressive political environment for public and private investment. The premise for designed retrofit and integral marine habitat enhancements incorporates 'net gain' obligations, adaptation and mitigation solutions for sea level rise and coastal squeeze, local nature recovery on the developed coast, 'green finance' leverage on public funding in critical infrastructure, and architectural innovation.

There are a number of local opportunities available to YMNP to apply these advantages to current plans and programmes:

Scarborough Town Deal - In November 2019, the Ministry of Homes, Communities and Local Government (MHCLG) announced that Scarborough and Whitby had been identified as two of 101 towns in England that they wish to work with to develop Town Investment Plans and bid for a share of the Government's £3.6bn Towns Fund. Both town plans include objectives that would be strengthened and supported by the work of the Concrete Coast project. For example, Section 5 of the Scarborough Town Improvement Plan (TIP) sets out measures to *'encourage deeper connections with our natural assets',* while the Whitby TIP looks to '*build back greener'* in its maritime sector. Ecological engineering, as a specialism of the Yorkshire coast, could also add value to the Maritime Academy proposed in the Whitby Blueprint.

Coastal Management Strategies - The two Shoreline Management Plans (see Drivers of Change section) set out how both Scarborough Borough Council and East Riding of Yorkshire Council intend to manage the coastlines, in the long-term. In addition, Scarborough Borough Council has commissioned Royal Haskoning DHV to renew its coastal defence strategy. The incorporation of ecological enhancement objectives and strategic value to biodiversity net gain requirements and coastal nature recovery within this review, has the potential to strengthen the cost-benefit case being made for local investment.

Yorkshire Harbour and Marina Project - East Riding of Yorkshire Council and Bridlington Harbour Commissioners have agreed to continue working together to explore a revised proposal for an extended sea wall and associated infrastructure improvements, after feasibility work (undertaken by engineering consultancy Arup) concluded that the scheme may not be commercially viable in the current economic climate. By adding a new theme around enhanced marine ecosystem services, within and around the harbour, it may be that new funding opportunities, and new operational value, will improve the scheme's prospects.

KEY POINTS AND REFERENCES

Opportunities to deliver built ecological enhancements for intertidal marine wildlife on the Yorkshire coast can be divided into seven project areas:

- Retrofit arrays and integrated features in new construction primarily in the North Yorkshire bays.
- In situ and passive adaptation of rock armour units, primarily in the northern bays.
- Bioblock and similar cast additions to armoured defences, primarily on the Holderness coast.
- Retrofit arrays and pre-fabricated replacements boards in groyne fields, primarily on the Holderness coast.
- Routine maintenance and running repairs to public and private coastal infrastructure used to deliver hand made ecological enhancements to infrastructure through the YMNP area.
- The three harbours (Whitby, Scarborough and Bridlington) as special projects combining multiple built interventions.

The harbours provide the conditions for more concentrated work packages, combining existing and new habitat solutions for both the interior sheltered/estuarine conditions and the exposed exterior breakwater walls. The harbours also represent important and useful clusters of stakeholder interest, public, private, civic, commercial and recreational. Partnerships developed here can be used to support wider initiatives along the YMNP coast. An important example is the collaboration with Groundwork in Whitby.

The Scarborough Town Deal and associated regeneration and investment documents

https://www.scarborough.gov.uk/home/community-and-living/town-deal

Groundwork NE and Yorkshire, 'Revitalising Our Estuaries' programme (includes Whitby harbour)

https://www.groundwork.org.uk/hubs/north-east-and-yorkshire/revitalising-our-estuaries/

INITIAL SITE SELECTIONS

ASSET LOCATIONS

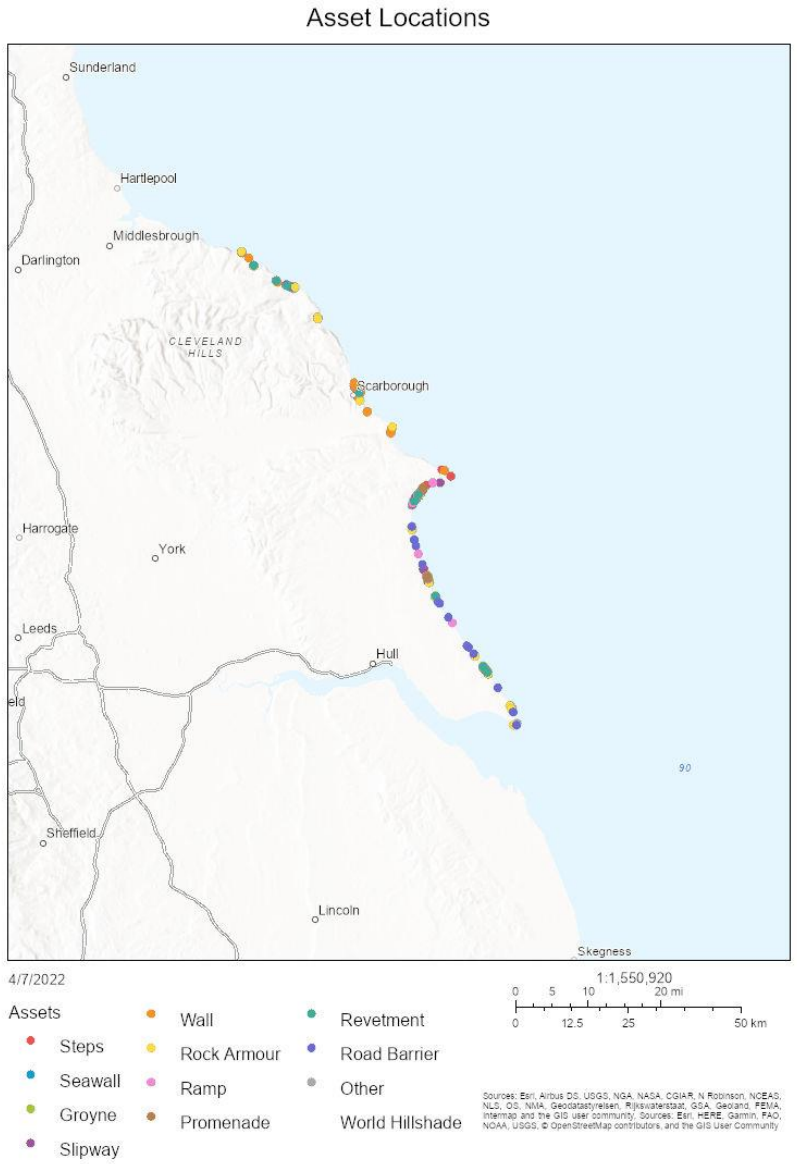
Twelve locations for ecological enhancement work along the Yorkshire coast have been identified and are set out in this section of the report.

These locations have been selected based on advice and preference from the stakeholders consulted alongside an assessment of the type and context of the infrastructure present.

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

Most coastal assets below mean high water can be enhanced for colonizing 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 repeated over distance by ‘punctuated intervention’, acting as steppingstones across the built environment.

Interactive GIS map of asset locations and possible enhancements available on the YMNP website.



STAITHES

- Implement existing feasibility study (April 2020, Universities of Bournemouth and Hull) recommending excavation into the surfaces of selected granite boulders within the rock armour.

- Bring together projects in Staithes, Runswick and Robin Hood's Bay to create a focus of research into enhancement techniques in rock armour defences building on the pioneering work already implemented.

- Extend existing methods (in situ surface working and passive enhancement) to include new experimental techniques such as dosing rock armour with woody debris, using river restoration techniques to secure timbers and brash (including recycled groynes) within interstitial spaces, combining with pre-colonized material to help 'seed' structures.

- Look to extend ecological enhancements upstream along the tidal reach of the Staithes Beck from the harbour as opportunities permit.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

WHITBY HARBOUR

- Work with Groundwork NE and Scarborough Borough Council to combine the efforts of the *Revitalising Our Estuaries* project with those of YMNP and the Concrete Coast, together with the Esk and Coastal Streams Catchment Partnership and the North York Moors National Park Authority to create a major hub of innovation in constructed intertidal and estuarine (and potentially freshwater) habitats.

- Look to combine standard Vertipool and Living Wall arrays with new designs for sediment capture (Mudflats™) and experimental hanging systems for colonization such as those being proposed by Biomatrix.

- Develop the *kintsugi** approach to repairs and modifications to harbour and estuary infrastructure, inlaying texture, complexity and niche provision in designed patchworks.

*(*kintsugi* is the Japanese art of putting broken pottery pieces back together with gold — built on the idea that in embracing flaws and imperfections, you can create an even stronger, more beautiful piece of art.)*

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

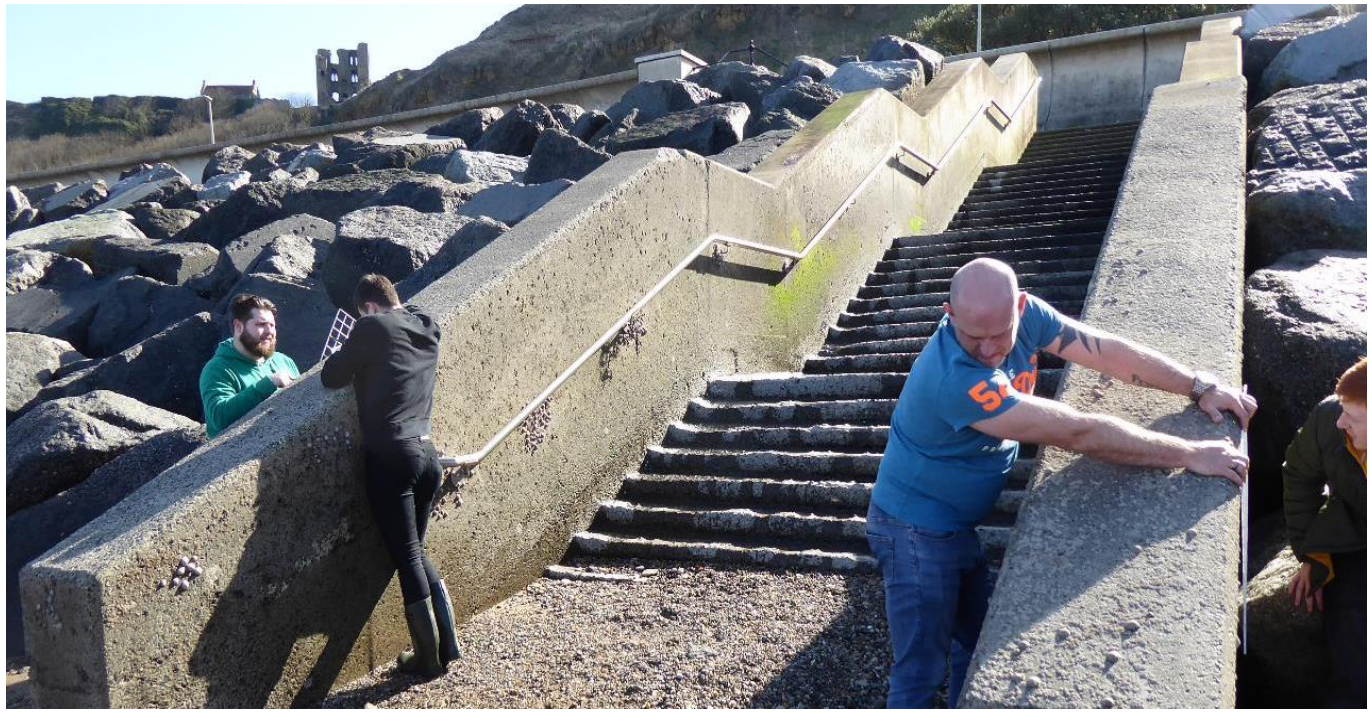
SCARBOROUGH NORTH BAY

- Priority areas for biological enhancement are the stepped structures south of the Oasis Café, presenting multiple surfaces and aspects for retrofit pools and panels. These areas are easily accessible and so provide platforms for interpretation and public information to support the work of YMNP and the Concrete Coast project.

- There are opportunities to retrofit holes and grooves into the rock armour around the headland.

- Additional opportunities are provided by the 20 sets of steps that provide access from the esplanade to the beach in North Bay. The combination of concrete wall and rock armour together running down into the tide presents unusual opportunities for building zones of enhancement around each using combinations of drop-in and surface retrofit options in close proximity. This would be an excellent trial area to test designs for 'self-cleaning' by encouraging the settlement and colonization by grazing molluscs.

- Working with commercial stakeholders may create additional opportunities for the project, for example a collaboration with the Sealife Centre around the conservation of local marine habitats and species.



Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

SCARBOROUGH HARBOUR

- Use wall surfaces away from moorings where retrofit pools and panels can be installed without compromising harbour operations. Look to create a few larger installations visible from the pedestrian walkways around the harbour.

- Combine these installations with high-quality interpretation and public information, about YMNP, the Concrete Coast project and the vision for a new relationship between Yorkshire's built coastlines and its natural world.

- There are likely to be additional, and potentially more accessible opportunities for retrofit pool and plate arrays, and patched texture repairs, on the concrete wall of the RNLI lifeboat station alongside the harbour.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

SCARBOROUGH SOUTH BAY

- The massive sandstone block walls of the Spa site provide a range of unique niches and intertidal communities because of its curved design and irregular block construction. These habitats should be documented and disseminated by YMNP as part of the Concrete Coast project. There is growing research interest in the interface between historic and cultural assets and species colonization on the coast, with lessons for maintenance contracts, risk assessment and the future management of built and natural heritage. Scarborough's sea walls, as they are, can therefore be considered important and relevant to the constructed habitat work of YMNP.

- The concrete structures, slipways and rock armouring of the South Bay, for example at Holbeck, all provide areas potentially suitable for ecological enhancement, retrofit pools and panels, drop-ins and inserts amongst the granite boulders and patched repairs. The coastal slope of the adjacent parkland offers additional opportunities to combine intertidal and terrestrial interventions for wildlife within the same locality.

- One of the most interesting features is the site of the South Bay sea pool, opened in 1915 and finally closed in 1989, now completely infilled. There is increasing interest in resurrecting tide-filled swimming pools around the UK coast, and these now present very significant opportunities to integrate features for wildlife with recreation and sport. Even if there is no prospect recreating a tide pool, the connection between local cultural history and the new approaches to coastal management may be a relevant narrative for YMNP to exploit.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

FILEY

- Potential for a small demonstration and research project linking the built environment of the seafront with the natural habitats of Filey Brigg SSSI and providing an additional orientation point for interpretation and information provided from the local authority country park.

- The sea wall at the Coble Landing beach access has room to support an array of retrofit rockpools. These could be designed and arranged specifically as features of public interest, encouraging wildlife exploration and active engagement. By creating an accessible and robust artificial rockpool environment such an array may help to reduce recreational pressure on the natural pools at Filey Brigg.

- A second potential location is The Beach slipway at the bottom of Cargate Hill; the lower end is regularly flushed by the tide and there may be space for rockpool creation within an accessible public location here. There is an interpretative and educational connection to be made with the sculpture trail that runs along the seafront here.

- There is potential research material in comparing the colonization of the artificial pools with those on Filey Brigg, also in evaluating the impacts of human disturbance on the development of communities of algae and invertebrate present in and on the constructed habitat.

- The creation of artificial 'surrogate' rockpools that are close to the main centres of visitor activity, and which are easily and safely accessible, might develop a local project that can both interpret and help to conserve the SSSI intertidal environment.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

BRIDLINGTON HARBOUR

- Work with Harbour Master and Commissioners, the Holderness Fishing Industry Group and the Yorkshire Marine Research Centre to explore experimental techniques for marine ecological enhancement in and around the harbour (there is already co-working with the 3DPARE project that might be extended).

- There is considerable scope to use patched '*kintsugi*' techniques to test small-scale interventions, for example on the southern outer wall, and at the same time to deploy arrays of artificial panels and pools (including sediment capturing designs) inside the harbour.

- Work with the harbour and with East Riding of Yorkshire Council to secure a joint approach to the extended sea wall proposals and to the wider Bridlington Harbour Forward Plan.

- Look to add ecological features to the proposed 255m Harbour Road quay wall replacement scheme. A new steel sheet piled wall with concrete capping beam will be built in front of the similar failing existing wall. There is an important opportunity to use ecological gain potential of the project to support its funding proposals.

- There are the remains of old timber groynes on the beach adjacent to the harbour. These offer much scope for imaginative 'totem' work for marine wildlife, combining sculpturally interesting designs, textures and worked surfaces that can both interpret and attract an enhanced colonising marine community.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

HOLDERNESS TIMBER GROYNE FIELDS

- Focus on accessible locations, for example the prominent Hornsea and Withernsea groyne fields.

- Combine in situ treatment of timbers (drilling), with pre-treatment of replacement timbers, and retrofit of pools and panels where structures will allow.

- Use the full length of the groynes within the tidal range but also cluster retrofits at the groyne end to create features away from high levels of beach accretion. Outer groynes, for example at the north and south ends of Hornsea and Withernsea, will be less prone to these smothering effects.

- Consider nominating one groyne as a 'shop window' for the wider project, displaying several kinds of ecological enhancement, providing interpretation, habitat and species descriptions, and links for further information.

- Work with the University of Hull to develop techniques for timber groyne enhancement for wildlife, an area with much scope for innovation and dissemination.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

MAPPLETON ROCK GROYNES

- The 1991 sea defence works at Mappleton created an unusual alignment of large rock groynes, with one arm running parallel to the shore and one perpendicular.

- This arrangement offers significant opportunities for ecological enhancement, as a transect down through the tidal range, and as a concentration of installations laterally within similar tidal zones.

- This site is potentially suitable for large scale use of drop-in pre-cast pool units positioned within the boulder arrays. There is much scope to develop this concept further, creating cheaper, lighter and more maneuverable pools that can be moved by hand or small plant.

- The rock groynes are also suitable for in-situ reworking with holes, pools and grooves.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

BARMSTON OUTFALL

- Environment Agency-owned infrastructure, an unusual and substantial concrete structure combined with mid and upper shore rock armour. The outfall has the potential to feature clustered examples of all or most of the enhancement techniques described.

- Opportunities for partnership working focussed on coastal (and other) assets including initiatives such as the proposed ‘Living Lines’ project could integrate this with community engagement, at suitable sites.

- The outfall structure presents surfaces suitable for retrofit pools and panels (including some in the brackish zone), there is also scope to add free-standing bioblock objects to the existing scatter of boulders at the low tide end. Rock armour around the outfall structure in the upper and upper-mid shore can be enhanced with cut-in holes and grooves. Repairs to the outfall offer opportunities to test and develop patched texture and complexity improvements.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

WITHERNSEA & EASINGTON LARGE ROCK ARMOUR GROYNES

- Both sites have large rock armour deployments which are in the main above Mean High Water, limiting the impact of any ecological enhancement techniques.

- The two sites do however present potentially useful and important examples of defensive infrastructures, which will become new intertidal habitats within the next 20 years under conditions of climate change and sea level rise.

- There is therefore an opportunity to work with local authority and corporate stakeholders to adapt and enhance these defences in preparation for their becoming permanent marine habitats. There is an urgent global need for case studies and practical examples of ecological design in coastal development that anticipates inundation and, ultimately, abandonment to nature.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

TANK DEFENCES

- These objects are spread out in clusters along the whole of the Yorkshire coast. They are no longer maintained and have no formal coastal defence role. As with the Scarborough sandstone sea walls, these are cultural and heritage assets that have acquired ecological value, and the combination of built and natural significance is of value, in interpreting the work of YMNP and potentially also in securing future project funding.

- There are over 600 individual units of military defence and a variety of designs and structures, some will already be providing refuge habitats for intertidal species. There is an opportunity to use biological survey data already collected for these features by the University of Hull, to evaluate the potential for new projects, for example the addition of prefabricated bioblocks of a similar mass and scale, to enhance both the informal defence and active habitat functions of the tank traps in locations such as Kilnsea, Fraisthorpe and Speeton.

Potential enhancements

Texture | Retrofit | Drop-in | Sacrificial | Integrated | Repair

CONCLUSIONS

CONCLUSIONS

The Concrete Coast project and the work of the Yorkshire Marine Nature Partnership represent a nationally, and internationally, important opportunity to demonstrate constructed ecological enhancements for marine infrastructure on the defended coast. The broad stakeholder family that supports YMNP, the regional devolution process that is underway, and the strong focus on ecological enhancement clearly articulated by local authority engineers and planners, has created a space for radical change in the way coastal infrastructure is built and managed in North and East Yorkshire.

The Yorkshire coast joins the Irish Sea and the Solent region as one of the leading centres of research and development in the globally accelerating field of constructed intertidal habitat and climate change mitigation.

To fulfil its potential, the Concrete Coast project, and the work of YMNP, will need support and active collaboration from statutory and regulatory partners, helping to embed ecological enhancement into public and private decision-making.

Similarly, the role of the University of Hull is critical to the success of the project, providing data and evidence from graduate and post-graduate study and establishing the Yorkshire coast as a major centre of applied research in sustainable blue infrastructure.

The combination of regulatory, public, private and academic partnership, brought together by a shared focus on nature recovery on the coast, its relationship to the management of marine protected areas and to the health and wellbeing of coastal communities, is likely to create new opportunities for enterprise in the YMNP region. The rise of ESG impact investment, environmental levies and offsets, and 'greentech' innovation will become only more significant as drivers of economic regeneration and business funding support. YMNP will play an important part in securing these benefits by spearheading new conservation techniques and leading best practice in sustainable coastal management.

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An Assessment of Opportunities for the Ecological Enhancement of Coastal Infrastructure in North and East Yorkshire

A Report for the Yorkshire Marine Nature Partnership and the ‘Concrete Coast’ Project

April 2022

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