iPACT

infrastructure for port cities and coastal towns

University of Brighton | University of East Anglia | Lancaster University | Queen's University Belfast | University of Southampton | University of Strathclyde Glasgow | UKRI Arts and Humanities Research Council | UKRI Engineering and Physical Sciences Research Council

Contents

Executive Summary

Prof William Powrie

Despite the potential benefits of a coastal location, port and coastal towns and cities can appear run-down and underperforming in both economic and social wellbeing terms. Common contributory factors include a low-quality built environment, derelict industrial and other legacy sites, the decline in traditional tourism and poor connectivity to the waterfront. Rising sea levels and coastal erosion may pose potentially existential threats. Combating all this needs innovation to rethink our port and coastal towns and cities and make them more resilient. The issues are common around the UK, transcending simplistic north/south or east/west divisions.

The *infrastructure for Port-cities And Coastal Towns network* (iPACT) was established to identify people-focused, infrastructure-based solutions to the complex problem of improving social well-being and prosperity in coastal communities through resilient and sustainable regeneration; with a key emphasis on taking advantage of the coastal location. Research questions have been based around themes of:

- ↗ Connectivity with the coast
- ↗ Inclusive infrastructure
- ↗ Maintaining and enhancing resilience
- ↗ Coastal region transport
- ↗ Nature-inspired, human scale engineering

Project partners include Southampton City Council, Lancaster City Council, Eden North and Coastal Partnership East (North Norfolk District Council, Great Yarmouth Borough Council, Waveney District Council and Suffolk Coastal District Council). Case study areas of Southampton, North Norfolk and Morecambe encapsulate the issues faced by the spectrum of port cities and coastal towns, including juxtaposition with major international ports, seaside resorts declining in popularity and historic communities with an ageing population facing coastal erosion and sea-level rise.

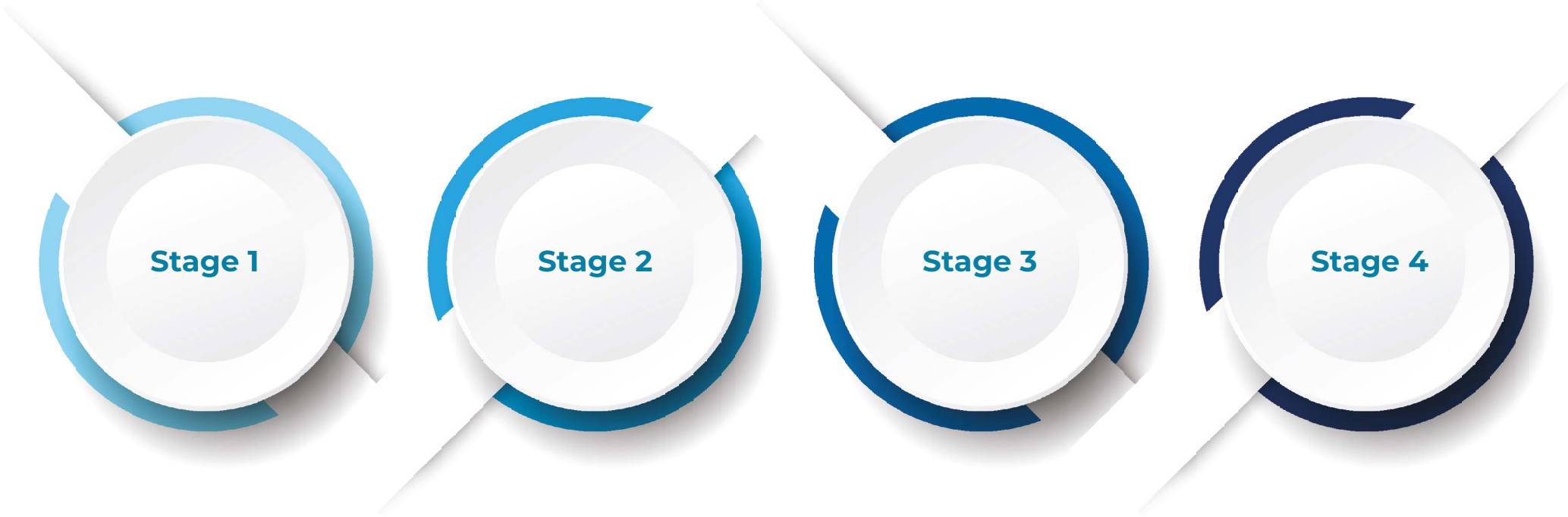
Reports from a series of *WeValue* community-based consultations informed three workshops with iPACT researchers, one in each case study location. From these we developed six pilot projects, to assess the feasibility of potential solutions. The outcomes of these projects are summarised in this brochure. Although the Pilot Projects and the initial grant funding are now at an end, the iPACT network continues as a collaborative research and user community to develop and help implement sustainable infrastructure solutions that improve the wellbeing, resilience and sustainability of the UK's coastal settlements for decades to come.

iPACT Research Strands

The activities of the iPACT Network are organised through five interdependent strands:

1. **Celebrating the major asset:** connecting the town/city with the waterfront, balancing the needs of a functional waterfront with ambience, public accessibility, leisure and heritage.
2. **Inclusive infrastructure:** engaging with communities, policymakers, the public sector and business to ensure effective infrastructure development and use.
3. **Maintaining and enhancing resilience:** making port and coastal city and town regeneration resilient to climate change, sea-level rise, coastal erosion and flooding.
4. **Coastal region transport:** addressing issues associated with the particular challenges of transport to/from and within port and coastal cities and towns arising from linear development along the coast or estuary, a current or former working waterfront, and the absence of up to half the hinterland.
5. **Nature inspired, human scale engineering:** including greening the grey infrastructure, to provide/enhance social value for the surrounding communities.

iPACT Stages



Community Consultations

A series of values-based community consultations using the WeValue In Situ approach have been carried out to elucidate key issues, particularly as felt by under-represented groups and less-heard voices from the public.

Research Sandpits

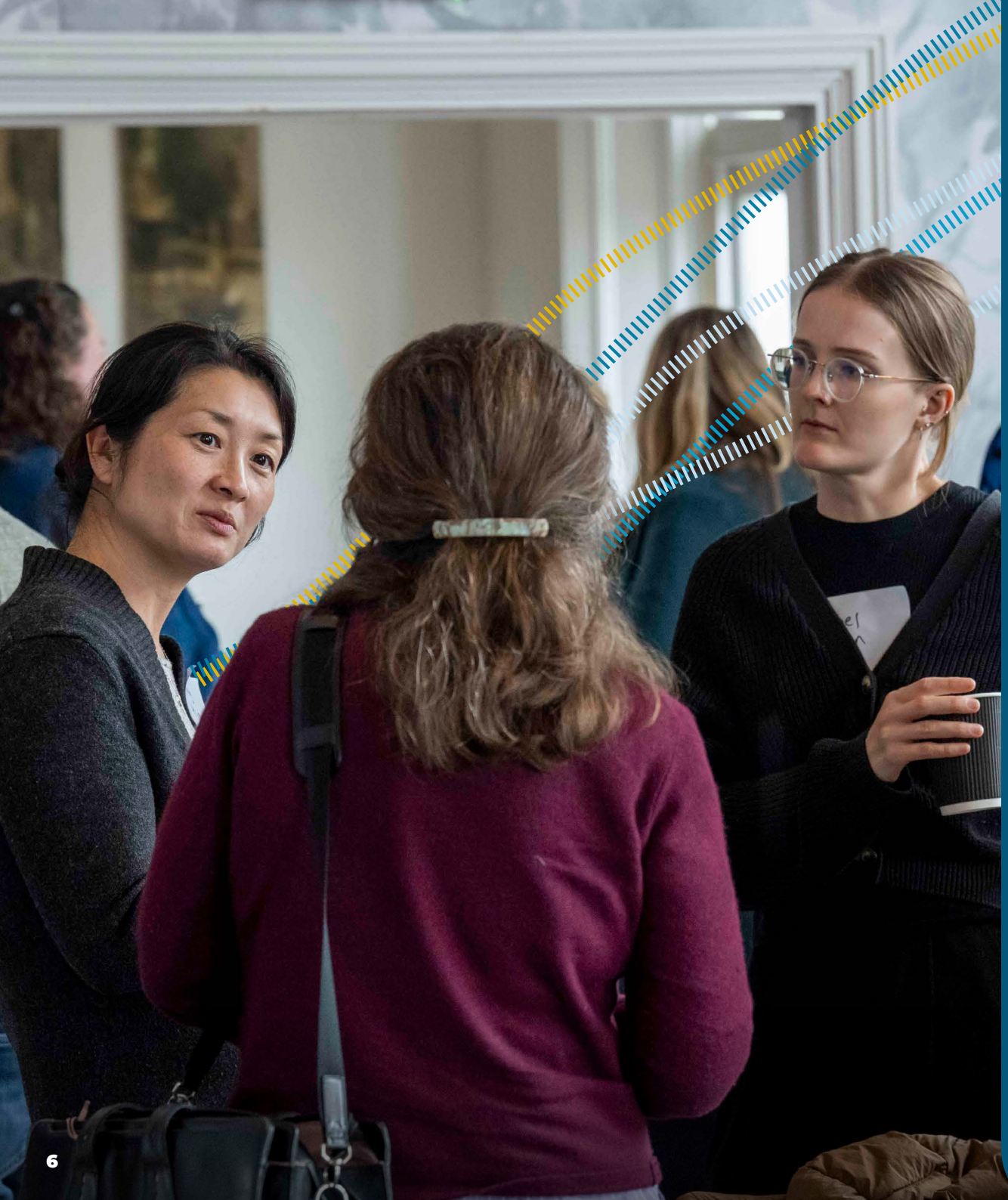
Three sandpits, one in each case study location, were attended by 75 of the iPACT network of researchers. The aim of these workshops was to develop collaborative, infrastructure-related projects to explore potential solutions aligned with community needs. We awarded funding for 5-10 such Pilot Study feasibility projects at £50-100k each.

Pilot Projects

Funding applications were submitted by groups of multi-disciplinary researchers and awards were made to six successful pilot projects. There was then a period of about 12 months, starting June 2023, during which the pilot studies were conducted and developed as bases for further research and funding applications. Reports from the researcher teams with details of these projects are presented later in this document.

Legacy

The iPACT Network is an established, thriving, collaborative research and user community, with the potential to develop and help implement sustainable infrastructure solutions that will improve the wellbeing, resilience and sustainability of the UK's coastal settlements for decades to come. The researchers are keen to engage with decision makers, offering their knowledge and expertise to a wide range of coastal concerns.



Community Understanding through ‘local crystallisation’

The iPACT project engaged with local communities in a novel manner, using the WeValue InSitu approach which ‘crystallises’ the in-situ shared values of local groups so that they become clearer to others.

By focusing on ‘what is important’ to local people first and assisting them in a workshop event to make sense and meaning of their shared values so they can be articulated in clear statements, it is possible to later find deeper answers to questions brought in by outsider researchers. These questions are posed in separate discussions, after the workshop, including, “What aspects of infrastructure do you think need to be improved?”

Infrastructure was presented as ‘any societal provision which is too complex or big to be organised locally’, and the discussions spanned infrastructures for engineering, governance, energy and resources, and socio-economic infrastructures.

The findings showed that although the participants were aware of the context of climate change and rising energy costs, they had more concerns about governance and socio-economic infrastructures than concerns about bridges or coast protection. Even transportation problems were seen primarily steeped in governance (regulation towards public interests) weaknesses. All three populations showed desire for stepwise changes for platforms capable of coordinating and support local people to organise themselves; more ownership in ward-level plans and decisions; and businesses and councils which were more society-focused.

Sandpits: Cross-disciplinary challenge finding events

iPACT brought together academics from a very wide range of disciplines crossing engineering, social science, the arts and humanities to collaborate together with communities and the public sector. We focused on three case studies sites, running 2-day workshops (or sandpits) at each of these. Working with 20 or so academic participants as well as community leaders, and contributions from district and county councils as well as local companies. These intense events we aimed at finding place specific research challenges that combined infrastructure, sustainability and community dimensions.

Each case study presented a context that was both distinctive, but also representative of wider issues in costal infrastructure. For example, Southampton is characterised by a shoreline dominated by port and industrial facilities that is almost completely devoid of public access. Morecambe has abundant access to the coast, but is notable for its very high levels of deprivation with the guest houses of old now often occupied by a transient population seeking jobs and a new life. The likely prospect of a £75M Eden centre with 1 million visitors a year adds to this unique context. North Norfolk has its own special context with very high levels of coastal erosion and a complex relationship between both onshore and offshore infrastructure.

Our collaborating academics used the 2-day deep dives of the sandpits to explore these locations and their challenges. This involved (often wet or very foggy) site visits, time with community leaders and very active contributions from our district and county council partners. The results of this intensive process and the following development work was, in the first instance, a series of fascinating short research proposals. The best of these were selected for full funding; you can read the results of these highly diverse research projects here.

Pipeline or Hub?

Harnessing critical energy infrastructure on the North Norfolk Coast

Primary Investigator

Prof Stuart Dawley
Newcastle University

Team members

Prof Will Eadson
Sheffield Hallam University

Dr Gareth Powells
Newcastle University

Dr Markus Steen
SINTEF, Norway

8 *Bacton community sign posts*

Research Challenge

Since opening in 1968, the Bacton Gas terminal on the North Norfolk coast has become a critical energy infrastructure asset for the UK. Bacton handles around 30% of the UK's national gas supplies, continues to serve a range of South North Sea (SNS) gas fields, provides two dual flow gas interconnectors with mainland Europe, and hosts operations for global energy giants ENI, Shell and Perenco.

However, in the face of the nation's Net Zero 2050 targets and the movement away from natural gas, a new future and vision for Bacton has emerged that could adapt Bacton's infrastructure into a new and potentially critical asset for industrial decarbonisation and low-carbon energy production. Forged around the deployment of Carbon Capture and Storage (CCS) within the South North Sea's depleted gas fields and saline aquifers, alongside the potential to produce Hydrogen (H_2). a new vision for Bacton has emerged that sees it "plays a major role in the UK's energy future" (North Sea Transition Authority 2021 p.1).

The point of departure for this pilot project was to first examine the opportunities and challenges for North Norfolk in harnessing and valorising Bacton as an infrastructural asset within the UK's broader energy transition. And then, secondly, to explore the extent to which the energy transition can make Bacton a development for rather than simply in North Norfolk. A third aim was to use the detailed case study to contribute to wider understandings of how geographically embedded assets enable and constrain just and sustainable energy systems and regional economies as they co-evolve.

Case study

A key aim of the pilot project has been to develop a better understanding of Bacton's 'place' as an infrastructural asset within the UK's approach to CCS and H_2. This work developed around three interrelated strands of activity involving 19 research interviews across national and local government, industry and local communities.

First, we began by exploring Bacton's 'place' within the evolution and development of the Carbon Capture and Storage (CCS) and Hydrogen (H_2) sectors nationally and internationally. Within the UK, after a series of false starts over the last 20 years, CCS has become a key element of the Government's strategy to support industrial decarbonisation. From 2019 onwards the focus has been on developing a policy framework through which the UK's most carbon intensive industrial clusters (e.g. Teesside, North West) could compete to become one of four locations granted regulatory approval, planning permissions and funding support for CCS investments to be up and running by 2030. In this national and state-orchestrated framework, priority in the UK has clearly focused on developing CCS mega projects within large coastal industrial clusters with pipeline connections to nearby to subsea storage sites.

Bacton's gas terminal stands in stark contrast to such developments. It is a key piece of national infrastructure but is set in a rural setting and

not connected to a high emitting industrial cluster. Instead, its assets are the decades-old gas terminal complex and its proximity to vast and globally significant CO_2 storage sites in the South North Sea (SNS). Realising the value of these assets will require transporting captured carbon from industrial emitters across an inter-regional and potentially inter-national network. That requires a model of CCS with a very different spatiality (distributed rather than clustered), which in turn will require new geographies of governing the relationships between emitters, networks and storage providers to precipitate the distributed model of CCS called for by Bacton.

To understand how this might be possible, our research looked beyond the UK to Norway's geographically distributed model of CCS development. While lacking large-scale industrial clusters, Norway aims to utilise its potentially mass CO_2 subsea storage by using both pipelines and shipping technologies to move CO_2 greater distances both domestically and internationally. Our international policy review, capturing 'beyond cluster' approaches, became particularly salient in 2023 as the UK Government released an updated CCS Vision which seeks to capture a more varied and geographical extensive transport and storage system in an attempt to valorise the vast subsea storage opportunities located beyond industrial heartlands (for example, new storage licences in the SNS). In this sense, Bacton's potential 'place' in the emerging CCS policy landscape was becoming clearer and more advanced.

Secondly, our research then sought to explore in more detail the 'place' of the Bacton gas terminal. In contrast to those industrial heartlands that have been encouraged to think and compete as locally integrated CCS clusters, with representative organisations, place-branding and more fully developed spatial and socio-technical imaginaries, visions of an integrated Bacton Energy Hub (NSTA) were still at an early stage. In what seems to be the first attempt of its kind, our project sought to unpack the anatomy of the Bacton site, specify the actors involved and their roles, and begin to better understand the complex and varied opportunities and challenges they face as they confront the transition away from natural gas extraction. This involves five different multinational terminal operators; a dense array of separately owned gas fields and CCS licences; a variety of emerging corporate visions for both national and international CCS networks.

Thirdly, our research sought to bring together our understanding of the policy landscape and the dynamics involved in the Bacton site to begin to sketch out two inter-related development paths for the site, one focusing on a CCS-led approach the other a more integrated CC and H_2 trajectory. In each case, developing CCS and H_2 are critical to maintaining high skilled offshore energy related employment within North Norfolk.

Bacton site with footpath sign

Insights

At the broadest level, our research has helped position Bacton within the next stage of 'beyond clusters' CCS and H_2 thinking. However, a more geographically extensive model of CCS and H_2 development has the potential to provide more continuity than change for Bacton in terms of its role as a node within broader inter-regional and national energy networks.

As a result, we offer five interrelated policy considerations:

1. **Visibility:** How to continue to improve the visibility of Bacton's role for 'UK plc'?
2. **Voice:** How to develop a more place-based and integrated 'voice' and territorial coalition of interests for Bacton and North Norfolk in the wider inter-regional and inter-national political-economies of CCS and H_2.
3. **Leverage:** How to leverage Bacton's strategic importance for the nation to help provide a more 'just transition' for North Norfolk. This is in the context of there being high rates of fuel poverty, low levels of domestic energy efficiency, alongside low rates of gas-grid connection adjacent to vast and important energy assets.
4. **Governance and planning:** How to coordinate, prepare and fairly manage Bacton's critical role within inter-regional CCS networks.
5. **Community and development:** How to help and guide Bacton's site operators (large, multi-national energy firms) deliver on their ambition to do more to engage local communities.

Coastal Connections:
Systems and Synergy

Primary Investigator

Dr Dawn-Marie Walker
University of Southampton

Team members

Dr Ranga Aeysooriya
University of Southampton

Dr Edilson Arruda
University of Southampton

Prof Jenny Brown
National Oceanography Centre

Dr Rebecca Collins
University of Southampton

Dr Kate Goldie
University of Southampton

Prof Paul Kemp
University of Southampton

Dr Bruno Salezze Viera
University of Southampton

Dr Clare Wood
Swansea University

Dr Xiaojun Yin
Swansea University

 Synergy workshop with community volunteers

Research Challenge

This pilot project explored the problem of unequal access to green and blue spaces by developing an innovative model that removes physical and societal barriers, enabling independence and equality in accessing these resources. Active travel, such as walking or cycling, provides a cost-effective means to increase daily physical activity which has significant benefits for both physical and mental health. In an urban context, the provision and enhancement of green infrastructure is a means to encourage active travel, to proactively reduce the burden of poor health through prevention. Furthermore, green space helps us meet targets for regenerating lost biodiversity. However, marginalised communities face significant challenges accessing urban green space as urban environments often fail to adequately integrate accessible pathways linking residential areas to these spaces, and do not consider their safety concerns, accessibility issues, culture, and stigma. This disproportionately impacts disadvantaged groups, reducing their engagement with active travel thereby further entrenching health and social inequalities.

Therefore, our research question was:

How can an inclusive, community-informed model enhance access to green and blue spaces through active travel infrastructure, addressing physical and societal barriers for marginalised populations in urban environments?

Case study

The project leveraged a comprehensive mapping approach and fieldwork to develop an inclusive map of Southampton's green grid, identifying barriers and facilitators to accessing green and blue spaces, including waterways and the coast. This involved merging various data sources to create an analytical map, which identified, classified, and prioritised active travel routes connecting residential areas with the city's green and blue spaces.

We developed multi-objective optimisation models for the design of an active travel network, considering distinct objectives: connectivity, safety (quietness), equity and cost, whilst promoting access to green and blue spaces. The rationale was to develop a user-friendly network to promote active travel by removing perceived barriers to access, such as poor connectivity, unsafe and inadequate design. The approach also allowed us to find the additional cost of prioritising safety and equity while maintaining similar connectivity. Therefore, beyond addressing cost and coverage, the model emphasised creating quieter, more user-friendly routes for active travel.

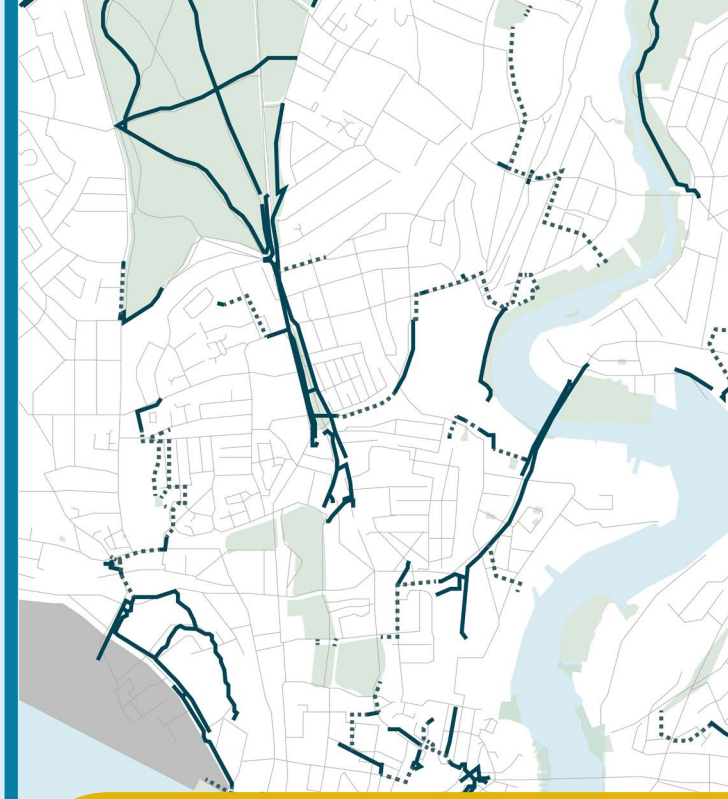
Workshops and interviews with marginalised communities ensured that their needs and perspectives shaped the project outcomes, fostering equitable access to health-promoting environments.

Following ethical approval, the project began with a community workshop held on February 1, 2024, at the John Hansard Art Gallery in Southampton. This workshop, led by post-doctoral researchers, co-produced a strategy with community leads to recruit participants for interviews and focus groups. Seven interviews and two focus groups (each with six participants) were conducted to ascertain barriers to using green and blue spaces and their thoughts regarding active travel such as walking and cycling. Transcripts were reviewed and analysis of data was completed. The qualitative data from marginalised community members revealed three main barriers to using green and blue space: Accessibility, Safety and Maintenance. They felt unsafe sharing space with busy traffic especially when routes stop at intersections and do not connect to desired destinations, or when routes go through perceived unsafe areas. Participants also commented on the routes being disjointed and poorly maintained, thereby supporting the mapping and literature review. Their perspectives informed the model which contemplates not only cost and coverage, but also quietness, and equity.

A multi-objective optimisation model, tailored to address barriers identified by the community, was developed to design an active travel network balancing four key objectives:

- **Connectivity:** Ensuring seamless travel between residential areas and green/blue spaces.
- **Safety (Quietness):** Promoting safer routes away from busy traffic.
- **Equity:** Prioritising access for marginalised populations.
- **Cost:** Balancing infrastructure investments with achievable outcomes.

The project identified significant barriers to using Southampton's current cycling infrastructure, including perceived safety concerns (especially for women and children), poor design (narrow or non-existent bike lanes), lack of connectivity, and limited integration with green and blue spaces which creates fragmented routes that discourage use. An inclusive framework was produced that links residential areas with urban green and blue spaces, whilst incorporating the perspectives of community members to address systemic barriers faced by marginalised populations to active travel. Therefore, the approach demonstrates how community engagement and data-driven optimisation can inform urban planning to reduce health and social inequalities.



Insights

The project revealed that current cycle routes were not perceived as user friendly. They often consist of isolated pieces with poor overall connectivity, sometimes forcing the user into high traffic and unsafe areas without proper cycle infrastructure, and often fail to link to blue or green spaces. This results from a combination of lack of expertise within council planners, staggered and poorly funded projects, and lack of input from current and prospective users.

Academic outputs include a submitted paper, and three in preparation; a Leverhulme Doctoral Scholarship and an application for a large grant.

Above image: Cycle System example routes

Connecting Coastal Concerns:

Engaging the local communities in long-term coastal challenges

Primary Investigator

Prof Paurav Shukla
University of Southampton

Team members

Dr Zhiying Ben
University of Southampton / University of Surrey

Dr Vanessa Marr
University of Brighton

Dr Dhritiraj Sengupta
University of Southampton / Plymouth University

Research Challenge

This project aimed to comprehend and align the concerns of the North Norfolk local communities with those of policymakers and in turn identify opportunities for building resilient coastal communities that will actively engage in long-term coastal concerns. Working closely with partners, including local councillors of North Norfolk, other impactful local partners, local community leaders, locals and seasonal workers, we employed both qualitative and quantitative research practices to simultaneously and uniquely capture lived experience of local communities.

We explored the challenges of coastal communities that are directly and indirectly affected and examine through their lived experiences:

a. what living in coastal community means?

b. how is it meaningful to them?

and most importantly,

c. what would make them take any action as an individual and as a community towards the long-term coastal challenges?

Case study

Our pilot project involved three phases of data collection and one phase of dissemination:

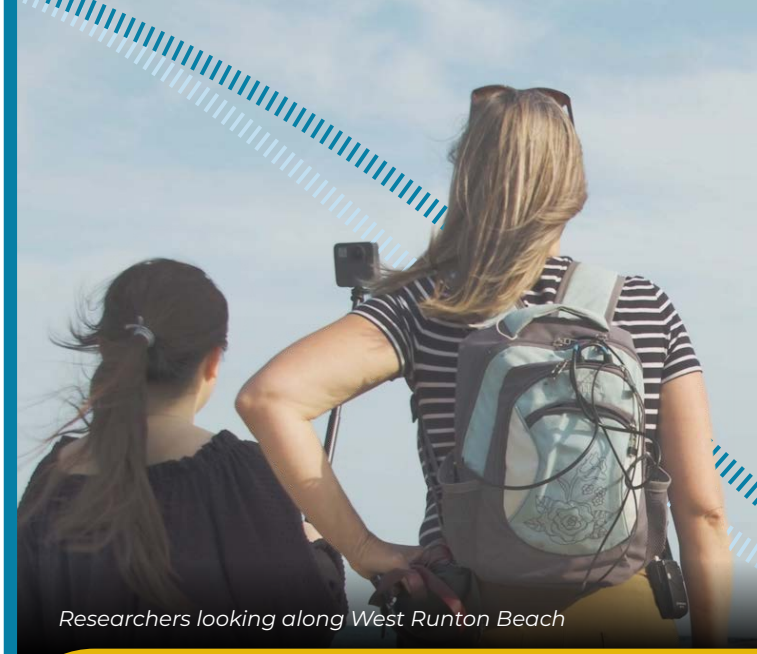
Phase 1 involved quantification of coastal land use and land cover with Earth Observation and machine learning approaches. This was done by using a high resolution (3.7m) Planet Scope Satellite to create an account of recent footprint of human expansion at the coast. We also compared historical aerial photographs between 1940s and 1988 derived from Historic England.[1] The findings from this phase showed that human encroachment close to sea, mainly in the form holiday homes was a dominant driver compared to coastline erosion. See image set 1 below.

Phase 2 involved unique ethnographic approach of narrative processing. The team contacted various caravan park managers, residents, and employees and carried out walking interviews in locations most pertinent to their lived coastal experience. This was captured using a 360-degree camera on a selfie stick and professional recording devices, as seen in the 2021 BBC series Walking With... Interviews were carried out at three different caravan sites. Each site represented a unique living experience due to their distance from the sea (i.e., almost at the sea to several hundred meters away from seafront). A number of transport, health and economic inequality concerns were laid bare in these interviews. Concerns around coastal erosion were clearly impacted by proximity to the beach, with those based near the shoreline recounting significant past issues and ongoing concern for the future. Those with strong flood defences and/or based further inland did not rate it highly as an immediate cause for concern.

Phase 3 focused on generalisability of the findings by using a quantitative study. Using various networks including local councils, other project partners, and a professional data panel, we collected data from 168 local residents regarding their lived experiences, meaningfulness of a coastal community and societal action. This data allowed us to triangulate some of coastal concerns. The findings showed that when specifically reminding residents of long-term challenges, coastal concerns were not at the front of their minds. A sense of helplessness and apathy was observed towards local and national governments in solving coastal community concerns. Lack of awareness and education, community engagement events, and funding support were also highlighted from an engagement perspective.

The dissemination phase included preliminary and final presentations to the iPACT team and other network partners in Glasgow and Norwich. Further to that, a dedicated website has been created by project partners[2] to share the findings with wider community. A video[3] capturing the snippets of the walking interviews is also shared publicly.

1 https://historicengland.org.uk/images-books/archive/collections/aerial-photos/
2 https://generic.wordpress.soton.ac.uk/ccc/
3 https://youtu.be/dt773vaYILE



Researchers looking along West Runton Beach

Insights

- ↗ Human encroachment of coastal land has worsened the challenge of coastal erosion more than natural progression.
- ↗ Unless experiencing immediate threat to their own land, coastal communities are more focused on transport, health, and economic inequalities than long-term environmental concerns and coastal erosion.
- ↗ Feeling of helplessness, lack of awareness and knowledge and indirect apathy observed towards the effectiveness of current policy.
- ↗ Citizens argue for increased public awareness and education, appropriate utilisation of social and local media for coastal community engagement.
- ↗ Disconnect between government and local community stems from a lack of awareness, education and specific financial support for coastal communities.

The role of biological-physical interactions in managing coastal dynamics

Primary Investigator

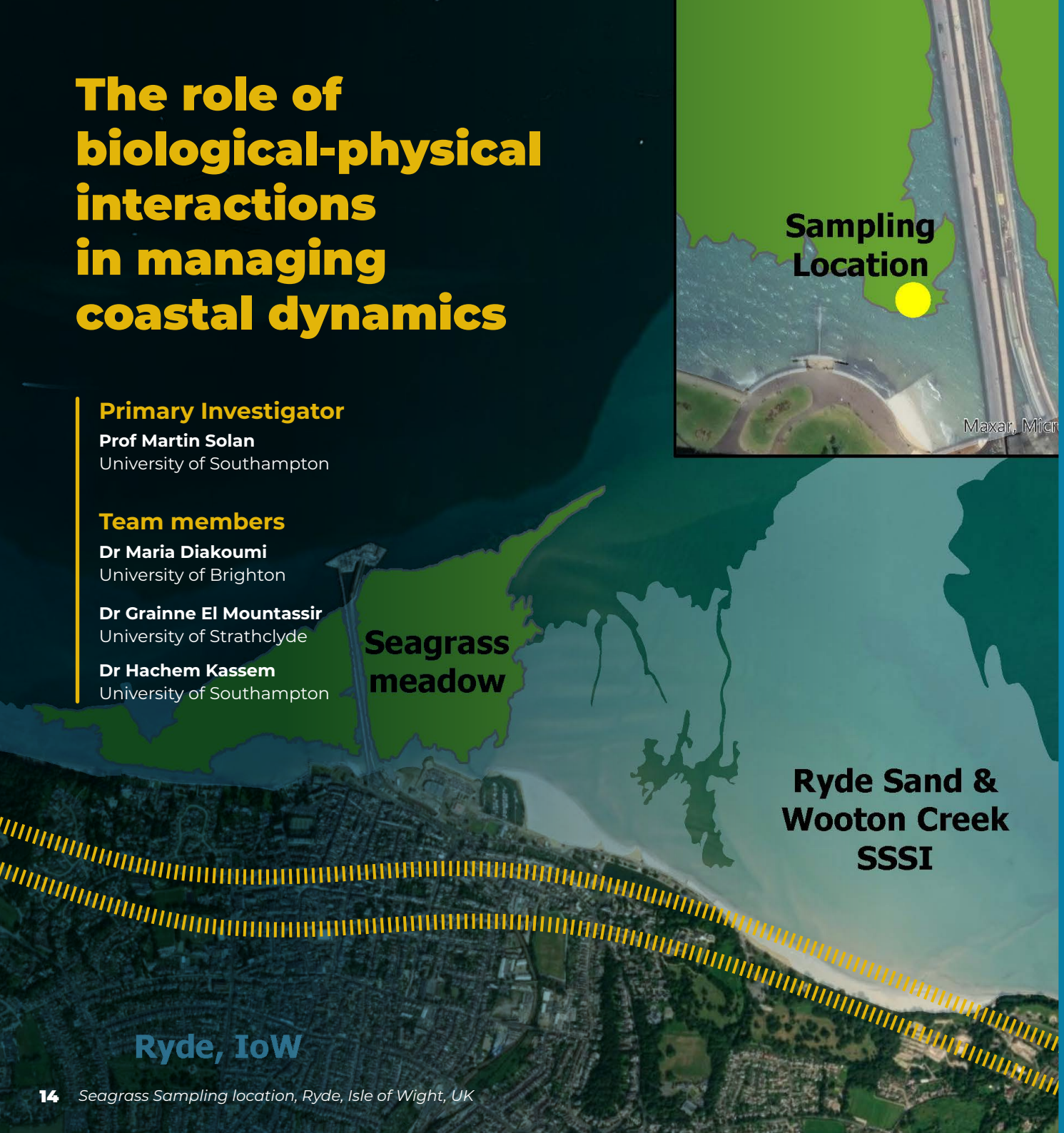
Prof Martin Solan
University of Southampton

Team members

Dr Maria Diakoumi
University of Brighton

Dr Grainne El Mountassir
University of Strathclyde

Dr Hachem Kassem
University of Southampton



Seagrass Sampling location, Ryde, Isle of Wight, UK

Research Challenge

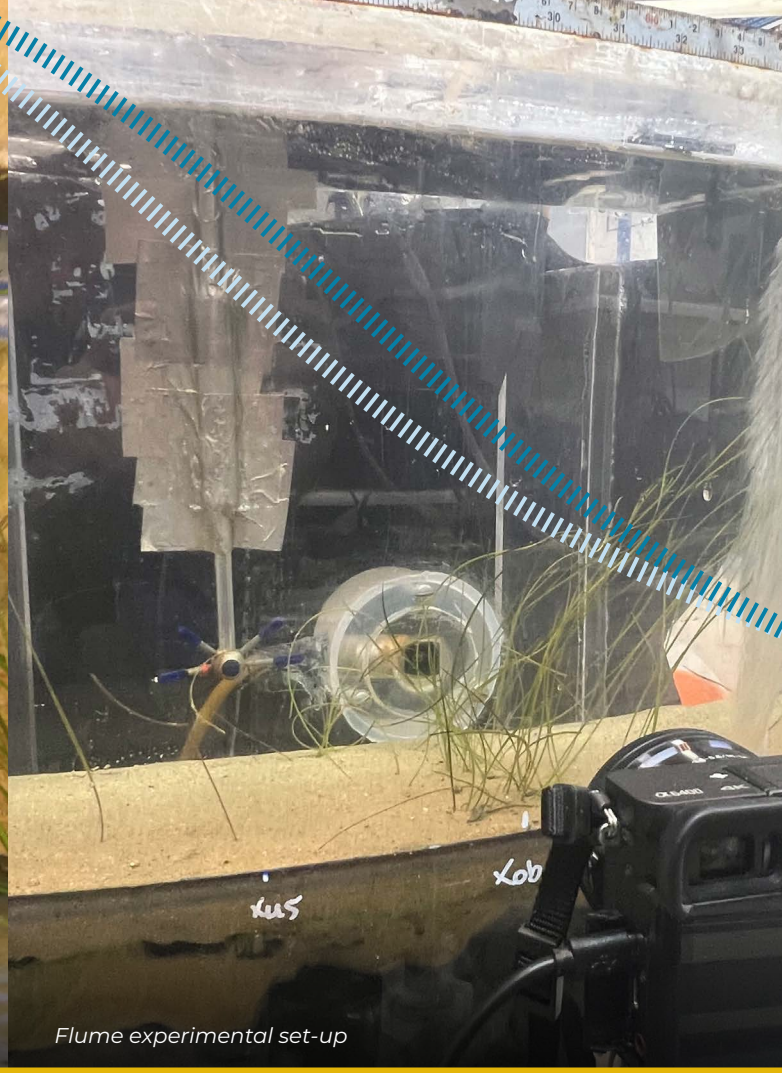
Previous assessments of coastal erosion have almost exclusively considered a set of physical control variables, largely in isolation. Yet it is known that the critical erosion threshold of natural sediment can be significantly altered by biological action and the presence of biodiversity. Here, in order to establish the role of physical, biological and coupled biological-physical dynamics in determining the response of coastal shorelines to erosive forcing, we perform highly controlled replicated laboratory experiments to explore which bio-physical processes hold greatest promise for potential nature-based interventions in coastal sediment systems. Of the few studies where these processes have been considered, investigations have only considered single species, leaving the influence of multitrophic interactions that are fundamental to the establishment and long-term functioning of nature-based solutions unexplored. Here, using different components if biodiversity (seagrass, fungi, invertebrates) we explicitly test the influence of individual and combined biological effects on erosion behaviour to support the design and selection of nature-based solutions for coastal erosion and resilience. Specifically, using highly controlled replicated laboratory experiments, we seek to establish the erosion threshold of sterile sediment (akin to standard modelling assumptions) versus sediments with natural microbial communities and increasing levels of community complexity (addition of fungal and invertebrate species, and/or seagrass). The generation of this new information may assist with practical solutions for coastal protection.

Case study

To support the design and selection of nature-based solutions for coastal erosion and resilience, we explicitly test the influence of individual and combined biological effects on erosion behaviour. Using intact curvilinear sediment cores containing living assemblages from Ryde, Isle of Wight, we tested the role of bare sediment versus communities of seagrass *(Zostera noltii)* and associated invertebrate communities of different densities and configurations in a ring-shaped flow tank (annular flume). These communities were subjected to incrementally increasing flows above and below the threshold for sediment motion. High frequency measurements of flow and water column turbidity are made, and bedform erosion and ripple migration rates are calculated from timelapse imagery. We used a cohesive strength meter to measure critical erosion shear stress, which progressively increases the force of a water jet to identify the point at which sediment erosion begins.

We ran a series of experiments investigating the inoculation of sands with a fungi, *Pleurotus ostreatus*, while subjecting the sands to water immersion every 12 hours to simulate tidal cycles. Although good fungal mycelium growth could be achieved by surface treatment (see photo), we were not able to integrate the mycelium into the sand, and it formed a blanket-like layer which was raised and lowered with the water level. Ultimately the high saturation level of the sands promoted growth at the surface and inhibited *P. ostreatus* from growing into the sand.

Critical erosion shear stress, the point at which sediment erosion begins, measured using a cohesive strength meter in a low-density seagrass (Zostera noltii) bed in a section of annular flume



Flume experimental set-up

Insights

- Biologically accommodated sediments show very different erosion thresholds relative to those of bare sands, raising the potential for intervention in areas where hydraulic activity is not above the threshold that allow species occupancy.
- The structure, density and composition of invertebrate, algae (seaweed) and plants (seagrass) has a significant effect on erosion vulnerability, but natural communities are dynamic and not evenly distributed.
- Fungal inoculation of sediments may be more suited for deployment in unsaturated zones (e.g. dunes) rather than the intertidal zone and (ii) identification of fungal species specifically adapted to the intertidal zone.

Repair and protection of coastal assets using native bacteria

Primary Investigator

Dr Gráinne El Mountassir
University of Strathclyde

Team members

Corina Avram
University of Nottingham

Dr Megan Barnett
British Geological Survey

Shayne Bessler
University of Nottingham

Dr Riccardo Briganti
University of Nottingham

Sam Cook
University of Nottingham

Matthew Kirkham
British Geological Survey

Jess Mackie
British Geological Survey

Dr Guijie Sang
University of Strathclyde

 Collecting samples at Happisburgh, North Norfolk

Research Challenge

With climate change predicted to contribute to rising sea levels and ultimately increased coastal flooding and erosion, it is imperative that in the UK we develop innovative approaches for protecting and managing our coastal assets, to ensure that coastal services can be maintained for communities in a changing climate. Conventional engineering materials (e.g. concrete) can exhibit accelerated degradation in coastal environments, resulting in degraded materials remaining on-site. Such materials also have a higher carbon footprint. In this pilot project, we propose that Microbially Induced Calcium carbonate Precipitation (MICP) could be used to repair and protect existing coastal assets by transforming locally available sand into sandstone. MICP has potential to be used in the repair and protection of assets and infrastructure at risk from scouring, including sea wall defences, access ramps and steps.

This pilot project explored two key research questions.

1. Traditionally MICP uses a specific bacterium *Sporosarcina pasteurii* which is introduced into the soil (bioaugmentation). Here we investigate 'Can native microbial communities already present in coastal sands be stimulated to trigger the precipitation of calcium carbonate?' (biostimulation) and if yes, 'How strong are sands treated using native bacteria?'

2. 'How erodible are MICP-treated sands under high-energy wave action?'

Case study

Can we use native bacteria already present in coastal sands for MICP?

We collected sediment samples from three different locations along a transect of the beach at Happisburgh along the North Norfolk coast in October 2023. We tested various methods of stimulating the already present bacteria in these sediments in a set of batch experiments to understand if we could promote urease activity in these samples. We took samples at different time points up to nine days and analysed the fluids, measuring optical density (a measure of bacterial concentration), pH and electrical conductivity. We also conducted DNA sequencing analyses on sediment samples to understand the natural microbial community present, and how it evolved over time in response to different stimulation media. Our results show that the existing natural community contained ureolytically active bacteria and that these were promoted using our stimulation media. Similar urease activity was achieved to that observed in bioaugmented sediments (i.e. where *S. pasteurii* cells were added), although the response was slightly delayed.

How strong are sands treated using native bacteria compared to sands treated using S. pasteurii?

Based on the promising results obtained in our batch experiments, we carried out column tests to compare the strength of sands treated using biostimulation (i.e. using native bacteria) and sands treated using bioaugmentation (i.e. using *S. pasteurii*). We packed columns with beach sand from Happisburgh and introduced stimulation media or *S. pasteurii*, and cementing solution. We repeated this up to nine times. Our biostimulation columns exhibited a maximum unconfined compressive strength of ~5 MPa, similar to that of the bioaugmentation columns although there was more variability in the results.

How erodible are MICP-treated sands under high-energy wave action?

To test MICP treated sands under high-energy wave action, we first developed a dam-break approach at the University of Nottingham, to generate waves with a velocity of up to 2 m/s simulating the types of wave action on beaches that is generated during storm surge events. Experiments were conducted in a hydraulic flume, with very gravelly sand emplaced to create a slope of ¼. Both untreated sand slopes and slopes with embedded MICP-treated sand cores were tested with up to 60 wave events generated for each slope tested. Laser scanning (LiDAR) was conducted to monitor changes in the slope profile as a result of the wave impacts. Our results show that the untreated sand was highly erodible and mobile under repeated wave action. By contrast MICP-treated cores demonstrated considerable resistance to erosion under the same wave events.

Testing wave impact in hydraulic flume at the University of Nottingham

Insights

- Results show that carbonate precipitation can be induced by stimulating existing microorganisms already present in the sand and that similar strengths can be achieved compared with the traditional bioaugmentation approach. Our approach using native bacteria could further lower the cost and carbon footprint of deploying MICP in coastal environments.
- Our results show that MICP treated sand samples exhibit strong resistance to erosion. This demonstrates that MICP has considerable potential to be used in harsh coastal environments to protect and repair coastal assets and infrastructure.

Coastal Nature Lab

Primary Investigator

Dr Serena Pollastri
Lancaster University

Team members

Dr Gloria Castro Quintero
University of Strathclyde

Dr Suzana Ilic
Lancaster University

Dr Keith Torrance
University of Strathclyde

Dr Enrico Tubaldi
University of Strathclyde

Research Challenge

The impacts of climate change on coasts, such as sea level rise and increased storminess, will exacerbate coastal hazards such as flooding, erosion and seawater intrusion, posing a significant threat to many coastal communities.

Coastal protection policies and interventions that rely on grey or hard infrastructure (such as sea walls or flood barriers) will become increasingly unsustainable in the long term. They cannot adapt to future coastal changes and uncertainties associated with climate change predictions without continuous and costly interventions.

There has been an increased interest in using nature-based solutions for coastal management (e.g. living shoreline barriers, beach nourishment/reprofiling, cliff stabilisation, dune regeneration). While this approach offers many benefits (coastal protection, enhanced biodiversity, benefits to the local economy, community well-being etc.), working with nature requires a more nuanced approach that focuses on the hyper-local interactions between social, economic, and natural resources. Moreover, there is a lack of general guidance on how to work with local materials and how to design nature-based solutions.

This research explored what natural materials, processes, and design strategies can be used to enable local communities to participate directly in the protection of their coastal environments.

Case study

The research process consisted of three interconnected work packages: Materials, Processes, and Design. The research teams at Lancaster University and the University of Strathclyde focussed mainly on the use of local materials and traditional techniques to produce structures for sediment trapping and techniques to improve the behaviour of materials available in coastal areas (e.g. sand) respectively.

Materials

Various local natural materials, traditionally used in crafts and for shoreline protection (e.g. willow, reeds, saltmarsh grasses, wool and timber) were identified and sourced for the design of local coastal structures.

Processes

The Lancaster team worked with a group of artists and craftspeople, who use traditional techniques such as willow weaving, felting, thatching, string making and netting to co-design structures that can be deployed on intertidal flats to reduce tidal and wave currents and to promote sediment accumulation. The techniques were adapted to be easily used by local communities for local interventions.

The Strathclyde team has developed two techniques to enhance the material properties. The first is a user-friendly and effective technique for engineered bio-mineralisation of knitted wool pieces by microbially-induced calcite precipitation. Alternative wools, treatment methodologies (spraying and soaking), and treatment cycles, were tested. The strength gains were measured by means of unconfined compressive testing of treated wool cylinders. Further work was carried out to assess the use of local bacteria for future studies.

The second technique is based on the bio-polymer impregnation of sand using alginate, a seaweed-derived polymer. Various types and contents of alginates were considered in treating sand. Unconfined compressive tests were carried out on treated cylindrical specimens subjected to increasing wetting-drying cycles with seawater.

Design

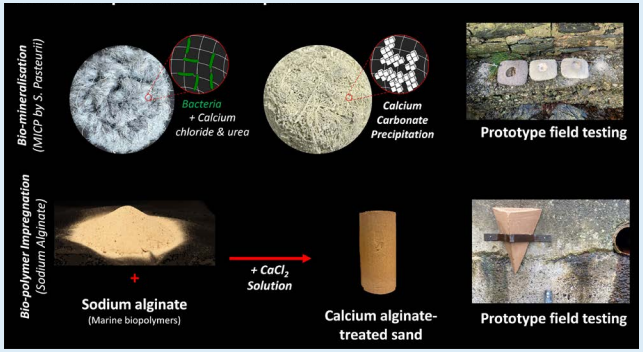
Small scale structures (willow “turtles”, nets and straw flow barriers) were co-created from local materials by members of the local Morecambe Bay community in workshops with artists and craftspeople.

These were deployed at Hest Bank (Morecambe Bay) from end of May to the end of July. Their effectiveness in trapping sediment as well as their durability and resistance to storms were monitored.

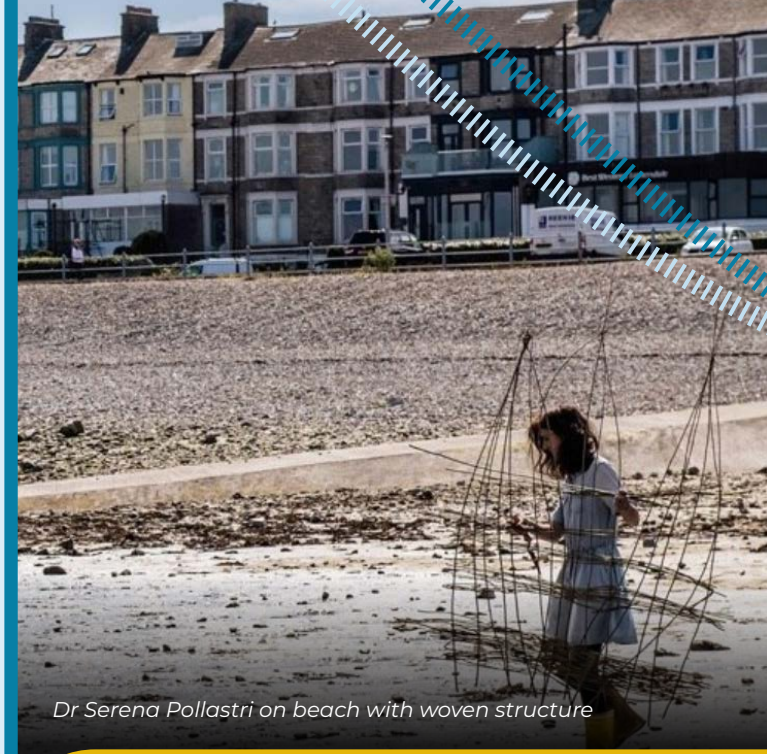
Small prototypes were made with bio-cemented wool and bio-cemented sand at the Strathclyde laboratory. These were placed on the Innellan beach in the Clyde estuary and monitored under the action of extreme weather conditions and flooding.

The website, which will include a Pattern book, summarising the materials and techniques used, and the findings from the project is currently being developed.

Lancaster City Council is in the process of extending the public involvement in the co-creation and deployment of the structures designed in this pilot project, as part of a “sister” project Our Future Coast.



Material Improvement Techniques



Dr Serena Pollastri on beach with woven structure

Insights

- The involvement of the local community in the co-creation of coastal structures facilitated the learning of traditional crafts, but also of future changes to the coast.
- The project enabled mutual learning between artists, craftspeople, researchers and local communities about materials, techniques and coastal processes.
- The tests carried out in the laboratory have shown that both bio-mineralisation and bio-cementation techniques effectively improve the mechanical properties of wool and sand (especially cohesion).
- The field tests have shown that further research is needed to develop effective prototypes and solutions (like anchoring) for coastal protection that can withstand the effects of powerful nearshore processes.

Southampton Port City Forum

Port cities are of critical importance to our way of life, providing considerable local, national and international benefits. However, they also create a range of negative impacts, such as environmental pollution, traffic congestion, visual blight and land-use pressure. Addressing these challenges is complicated by the differing objectives of port and city authorities, especially when the port is privatised. This can lead to a lack of cooperation towards what are often shared goals, such as increasing the adoption of renewable energy. To address this, the Southampton Port City forum was created, providing a space for port city stakeholders to share ideas, network and hopefully cooperate.

The first forum was hosted in July 2024 in Southampton and was attended by a diverse range of stakeholders, such as Southampton City Council, the University of Southampton, Solent Forum, Maritime UK, Solent Stevedores, ABP, DP World, Ramboll, Carnival UK, Southampton Voluntary Services and Old Town Community Forum. Following presentations from a panel of these stakeholders there was a co-creation workshop to draw out collaborative ideas and initiatives. Attendees were very supportive of the forum's goals and expressed high levels of interest in continuing the forum on an annual basis.

Outcomes

In addition to continuing the forum on an annual basis, some projects were identified during the forum which will be taken forward. These include:

- ↗ Student design projects to develop a gateway to the world trail highlighting Southampton's maritime heritage.
- ↗ A project reconnecting the city to the waterfront.
- ↗ A project developing the city's flood defence in a way to enhance the benefits for local people.
- ↗ Exploring an annual festival celebrating Southampton's maritime history and natural blue and green spaces.
- ↗ More discussion on the future of Southampton's waterfront when faced by climate and economic challenges.

Reflections on cross disciplinary working

Prof William Powrie, Principal Investigator, Civil Engineering, University of Southampton

Transport and civil engineering infrastructure pose multiple divergent challenges for port and coastal towns and cities. Transport both to/from and along the coast is essential to economic survival and human wellbeing but runs the risk of the transport infrastructure severing the connection with the coast and isolating neighbourhoods. The map of multiple deprivation indices for Southampton highlights the negatives of living along a major route to the port, except for The Avenue which is buffered by the extensive green public space of The Common. Civil engineering works for coastal defence can similarly cut off communities from the sea and damage the natural environment. Major infrastructure such as ports and gas terminals might bring wider societal benefit but blight the areas in which they are located. iPACT has brought cross-disciplinary perspective to all these issues, identifying potential solutions through re-thinking active travel route networks, nature-inspired coastal defence, and repurposing redundant large-scale infrastructure so that it has local as well as national benefit. There is much still to do including translating the findings for active travel to long-distance transport of goods and people, making better use of the water for port-to-port and along-the-coast transport, integrating land use and transport planning to encourage sustainable travel behaviour, reducing port transport-related air pollution, and developing multi-purpose infrastructure that enhances the natural environment and biodiversity while providing amenity and protecting communities from sea-level rise, flooding and coastal erosion.

Prof Leon Cruickshank, Imagination Lancaster, Lancaster University

Design is at its most effective at the intersection between other disciplines and so this has proved for the iPACT project. Here I worked closely with engineers of many types as well as academics from policy, management, architecture and many other disciplines. The result was a fascinating expansion of my knowledge (I now know more than is strictly necessary about the tidal flows around Southampton and the Isle of Wight) but also this has allowed me to contribute to the tremendous cross fertilisation of ideas and perspectives that characterise iPACT. This has included ethnographic explorations of the cultural microcosms found in caravan parks in Norfolk to a systems approach to cycle guidance in Southampton. There have been nature-based solutions ranging from the scientific cultivation of rock forming bacteria to community-led wicker structures intended to build coastal understanding in communities as much as reenforcing sand dunes. There has been a real joy in seeing these teams of mostly young academics grow and lay the groundwork for some exceptional research outcomes.

Prof Marie Harder, Values & Sustainability Research Group, University of Brighton

COMMUNICATION across divides

How can rich cultural ethnographic data be communicated to policy makers and engineers who don't want to read lengthy but fascinating narratives or descriptions? How can this kind of information be 'integrated' somehow with their own reductive, typically quantitative, data? This challenge of COMMUNICATING qualitative data was underestimated (certainly by me) in this project and ended up taking as much time as the public engagement events themselves.

GOVERNANCE is a type of infrastructure

Although most lay people think of infrastructure as 'grey' roads, railways, tunnels, in fact that is only one subsystem alongside socio-economic, energy & materials, and governance subsystems. Our interdisciplinary approach did not restrict participants to discuss 'grey' infrastructure, but their emphasis on weaknesses in governance infrastructure was difficult for the researchers (primarily engineers) to adjust to. This aspect of inter-disciplinarity – the need for everyone to accept other disciplines might be more important – can be tough.

Prof Rebecca Lunn, Nature Based Solutions, University of Strathclyde

Worldwide, the construction of coastal defences dates back thousands of years, with ancient structures being constructed primarily for defence against invaders. In the 16th and 17th centuries, embankments and sea walls in the UK were built using timber and stone for protection against flooding. By the start of the 20th century, traditional materials in coastal defences were being replaced by a new, cheaper material that revolutionised construction; reinforced concrete. Today, cement for making concrete is the most widely used material in the world, and accounts for 6%-8% of global carbon emissions. Now, in the face of a changing climate, we need to develop new nature-friendly construction materials, and coastal management strategies, that work in harmony with the environment to minimise the impacts of flooding and sea level rise on coastal communities.

Under iPACT, researchers are exploring alternative nature-based methods for construction and repair of coastal defences to support the regeneration of coastal communities. By mimicking natural processes and ecosystems, we aim to create bioengineered materials and environments that can help protect our coastline, whilst also promoting biodiversity in coastal habitats. For example, projects have been using indigenous bacteria to precipitate minerals to strengthen and stabilise loose sands, and have supported local craftspeople to create small willow-weaved structures on intertidal flats that can help reduce tidal currents and promote sediment accumulation . iPACT is breaking down the boundaries between disciplines to understand how natural processes can be harnessed to create resilient coastal environments, using locally produced materials.

Dr Jasna Mariotti, School of Natural and Built Environment, Queen's University Belfast

Connectivity between the town/city and their coast and waterfront areas has been a central focus in contemporary urban planning and design, particularly since the relocation of port activities from the traditional central areas of cities to their spatial peripheries. At present, the areas where port and urban spaces intersect are key strategic places for urban development in cities and serve as places for implementation of diverse climate change adaptation strategies.

iPACT proposes new and innovative research agendas, emphasising the complex interdependencies between port infrastructures and town/city. Research under iPACT highlights the necessity of interdisciplinary approaches that address the intersection of urban, ecological and social challenges. Coordinated proposals are required to facilitate community adaptation to climate change and mitigate future climate risks, as port cities continue to develop as critical nodes in global urban and logistical networks, reflecting on broader trends in urban development. These trends include explorations on how to preserve historical and cultural integrity of cities while meeting contemporary urban demands, creating inclusive waterfronts, integration of water management systems into urban design, and the promotion of ecological benefits alongside architectural innovations to foster sustainable urban growth.

Architecture and urban planning and design play an important role in mediating the complex interdisciplinary and governance structures between port authorities, maritime economies and city governments. Collaborative governance frameworks are essential for addressing these challenges at both local and global scales, facilitating solutions for socio-spatial intersections between the port and the town/city.

Prof Robert Nicholls, Tyndall Centre for Climate Change Research, University of East Anglia

Traditional expectations of coastal engineering remain the provision of hard fixed coastal defences even though in many locations these cannot be economically or environmentally justified. Equally it is imperative that we do not simply walk away from coastal communities if defence is not feasible and we continue to support their development. The iPACT project facilitated new ways of thinking about these issues in terms of what is the value of coastal areas and how we might manage erosion and hence buy time. Working with nature approaches to slow erosion attract great public interest, and these were explored in a participatory sense and in a more fundamental manner considering how coastal biological processes can promote more stability of the shore. Increasing the strength of coastal materials with cementation to delay erosion was also explored and provides an innovative technique for managing soft erodible coasts like Norfolk. As well as managing erosion, the value of coastal land use was also explored in the contrasting settings of caravan parks and major nationally-significant fixed infrastructure - a gas terminal. The overall message is one of needing to think more holistically about coastal areas and beyond managing a defence line. This was shown by the experience of our partners in the Coastwise project (North Norfolk District Council) who are addressing these issues in Norfolk. In a world of climate change and rising sea levels and changing economic conditions on the coast, the focus should be on sustaining communities and livelihoods. In many places traditional defences will continue to be provided but where this is not feasible our understanding of erosion and flooding still needs to be mobilised and applied in positive ways to support coastal communities. Research such as conducted in iPACT facilitates progress in this regard.

iPACT

infrastructure for port cities and coastal towns

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ipact.org.uk

CONTACT US
ipact@soton.ac.uk

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