Structures spread across our seas

Hawkins, Stephen J.; Firth, Louise B.; Evans, Ally J.

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Strapline: OCEAN SPRAWL

Title: Structures spread across our seas

Construction along coasts and offshore is accelerating. A new study estimates the extent of different developments and their wider influence and forecasts their expansion.

Stephen J. Hawkins, Louise B. Firth and Ally J. Evans

The built environment is spreading along the planet's coastlines and plunging into ever-deeper waters, a phenomenon aptly dubbed 'ocean sprawl'[1]. Most of the world's relentless current and projected population growth is in coastal areas, driving urbanization and land claim for homes, industry, commerce, tourism, transport and associated infrastructure. Coastlines will be simultaneously squeezed by rising and stormier seas, prompting proliferating sea defences[2]. Hydrocarbon exploitation went offshore 100 years ago and is penetrating ever-deeper waters. Renewable-energy generation has expanded rapidly in shallow seas and is now moving further offshore with floating wind turbines. Aquaculture has spread from enclosed to open waters, and deep-sea mining is next. But the accelerating expansion of construction across the ocean often passes unnoticed given deserved attention to anthropogenic climate change and overfishing. Deep-water expansion is out of sight and mind. Writing in *Nature* Sustainability, Bugnot et al.[3] provide a timely inventory of the current extent of such marine structures and forecast their likely spread.

Marine artificial structures modify habitats, changing the surrounding ecology. As on land, many habitats are literally built over. On soft muddy and sandy seabeds, structures generate islands of artificial hard habitat[2]; biological communities shift from sediment-dwellers to surface-attached filter-feeding animals and seaweeds. Structures like piers or oil rigs attract fish and crabs, which forage around them. Complex rocky reefs are replaced by simple, smooth surfaces such as quays or sea walls, often much less suitable as marine habitats[2]. Perhaps the most far-reaching impact is on connectivity: structures act as barriers on land, whereas at sea they can provide stepping stones, especially for invasive non-native species[4]. Local, piecemeal construction can scale up insidiously, epitomised by the increasingly crowded north Italian Adriatic and the recently recognized coastal 'Great Wall' of China[5]**.** As appreciated in cities, the attendant light and noise pollution and changes in electric fields (from under-sea cables) all influence sensory landscapes and hence animal behaviour kilometres away[3,6].

Bugnot et al. detail the extent and breakdown of this sprawl. They cast a wide net, considering hydrocarbon mining and associated pipelines, renewables, power and telecoms cables, ports, sea defences, land-reclamation areas, tunnels and bridges, artificial islands, recreationally oriented marinas, beach breakwaters and artificial reefs. Aquaculture accounts for >70% of the current global footprint, with 40% of the total within China's exclusive economic zone (EEZ). Almost half of offshore hydrocarbon production lies in the United States' EEZ; whilst most renewable-energy capacity is around the United Kingdom. The far reach of noise pollution from shipping suggests ports are indirectly responsible for virtually all (>99%) of the wider seascape modification associated with marine structures. The authors estimate that this impacts 1–3 million km^2 indirectly **–** 100 times greater than the footprint of the structures themselves – predicting that such broader seascape modification will increase by ≥50–70% over the next decade.

The overview of Bugnot et al. is both revealing and alarming, but as they acknowledge it has limitations. There are generalizations, assumptions and first-order estimates in compiling these statistics. The disparate data come from sources whose reliability and completeness varies, either in terms of geographic coverage and/or sector. Eighty-six percent of EEZs had missing data, with good coverage in the European Union and North America. Highly regulated energy and telecommunications sectors are well documented, whereas piecemeal coastal construction and unregulated artificial reefs often go unrecorded. The severity and reach of the various types of seascape impacts in different environments vary substantially, but remain incompletely understood. The minimal impact of a floating aquaculture cage in flowing, open water can be simply reversed by towing it away. Land claimed for a container port, by contrast, is a near-irrevocable switch from sea to land. The authors' global assessment of the extent and impact of ocean sprawl demonstrates the need for more coherent national and international mapping of marine structures, with both strategic and case-specific impact assessment to inform planning.

Although emptying rapidly, we consider the metaphorical glass still half full. Marine structures can have environmental benefits, often unintended. More filter feeders can improve water quality in bays and ports[7] (for example, restoring redundant dock basins in Liverpool; Fig 1a,b). Wind-turbine arrays (Fig. 1c) can prevent damage by obstructing bottom trawling. Should a structure be removed, many marine habitats, particularly shallow-water rocks and coarser sediments, would recover within 5–10 years; but those with long-lived, habitat-forming species will recover much more slowly, possibly taking decades (for example, seagrasses, saltmarshes and mangroves) to centuries (coral or oyster reefs), even with active restoration[8]. Marine spatial planning (MSP) provides a framework for managing expansion, siting, zoning and eventual decommissioning of offshore installations in the context of other users and marine life. In the European Union, MSP is a crucial element of the Marine Strategy Framework Directive, partly prompted by foreseen growth of marine renewables[9].

Marine life will settle rapidly on hard structures, even colonizing artist Antony Gormley's iconic shoreline statues[10] (Fig. 1c,d). Biodiversity can be enhanced by building in habitat complexity, a process termed eco-engineering. Coastal stakeholders actually favour multi-purpose structures that promote biodiversity and ecosystem services in addition to performing their primary functions[11]. Using a terrestrial analogy, wire fences are effective but ugly land boundaries while hedgerows are oases of biodiversity providing multiple goods and services. Eco-engineering of marine structures is best done to ameliorate already highly modified coastlines, but is unlikely to fully compensate for habitat loss when developing in unspoilt seascapes.

Bugnot et al. diagnose a fast-spreading, pervasive, pernicious problem. To ensure sustainable seas, a precautionary, evidence-based approach to coastal and offshore planning would minimize ocean sprawl. Eco-engineering to promote biodiversity and ecosystem services can be deployed for partial mitigation and compensation, but only when and where appropriate[12].

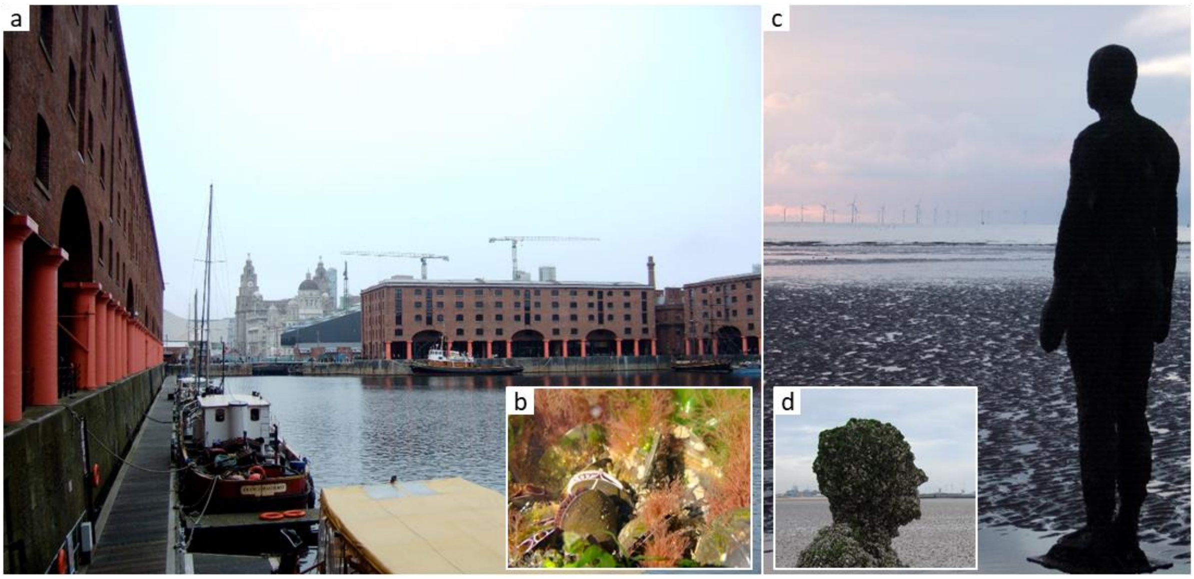

Fig 1. Examples of ocean sprawl considered by Bugnot et al. (a) The Royal Albert Dock and Royal Liver Building in Liverpool. Built on reclaimed mudflats from 1700 onwards, at their 1960s peak dock basins stretched >15 km along the Mersey estuary. The mid-nineteenth century Royal Albert Dock, redundant for shipping since the 1970s, became the centrepiece of an ambitious urban renewal scheme. (b) The dock basin is managed by mixing, with aeration allowing dense naturally settling mussels to bio-filter the dock basin's water volume every 1–2 days, creating a healthy and diverse but synthetic ecosystem[7]. (c,d) Nearby at Crosby Beach, one of Antony Gormley's 100 brass statues (*Another Place*) (c), itself covered with marine life[10] (d) looks out to a wind farm. Offshore wind farms can exclude seabed damage from towed fishing gear. Photo credits: Louise B. Firth.

Stephen J. Hawkins[1,2], Louise B. Firth[3] and Ally J. Evans[4]
[1] *School of Ocean and Earth Science, University of Southampton, Southampton, UK.*
[2] *The Marine Biological Association of the UK, Plymouth, UK.*
[3] *School of Biological and Marine Sciences, University of Plymouth, Plymouth, UK.*
[4] *Institute of Biological Environmental and Rural Sciences, Aberystwyth University, Aberystwyth, Wales, UK.*
e-mail: *S.J.Hawkins@soton.ac.uk; L.B.Firth@Plymouth.ac.uk; Ally.Evans@aber.ac.uk*

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