

Review

Winds of Change: Urgent Challenges and Emerging Opportunities in Submerged Prehistory, a Perspective from the North Sea

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Abstract: Development of the continental shelf has accelerated significantly as nations around the world seek to harness offshore renewable energy. Many areas marked for development align with submerged palaeolandscapes. Poorly understood and difficult to protect, these vulnerable, prehistoric landscapes provide specific challenges for heritage management. Indeed, there now appears to be a schism between what underwater cultural heritage policy intends and what it is achieving in practice. Shortcomings in international and national legislature ensures that large parts of the continental shelf, including areas under development, may have little or no legal protection. Increasingly impacted by extensive development, these unique cultural landscapes are ever more at risk. However, heritage challenges posed by such development also create opportunities. An immense amount of data is being generated by development, and there is an opportunity to establish broader cooperative relationships involving industrial stakeholders, national curators, government bodies, and heritage professionals. As a matter of urgency, the archaeological community must better engage with the offshore sector and development process. If achieved, we may revolutionise our knowledge of submerged prehistoric settlement and land use. Otherwise, our capacity to reconstruct prehistoric settlement patterns, learn from past climate change, or simply manage what are among the best-preserved postglacial landscapes globally may be irreparably undermined.

Keywords: archaeology; cultural heritage; marine palaeolandscapes; heritage management; climate change; sea level rise



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1. Introduction

“How many kilowatts of green electricity offset one less submerged Mesolithic cultural landscape?” [1].

Although much climate debate concerns the challenges of sea level rise, contemporary sea levels around the globe are actually already higher than they have been for most of the last million years (Figure 1). This means that across the comparatively short time frame in which *Homo sapiens* have existed, large areas of previously habitable landscapes around the world are currently underwater (Figure 2). Many of these landscapes may hold vital information for answering important archaeological questions regarding how people lived on these lost plains, including how they coped with rising sea levels and climate change, and how they interacted with other groups inhabiting the emergent areas. For deeper prehistory, we need to appreciate how these lost landscapes supported our global diaspora as a species, and perhaps even how these landscapes related to our emergence as a contender among other, now extinct, hominins.

Many of the areas discussed here are almost entirely *terra incognita* and lie beyond the direct, exploratory reach of archaeologists and contemporary technology [2]. Given the strategic and informational value of such landscapes, our current inability to undertake direct investigation of surviving archaeological remains, or even to prospect for such sites across many of these areas, is a major challenge to our interpretative schema for the submerged prehistoric record.

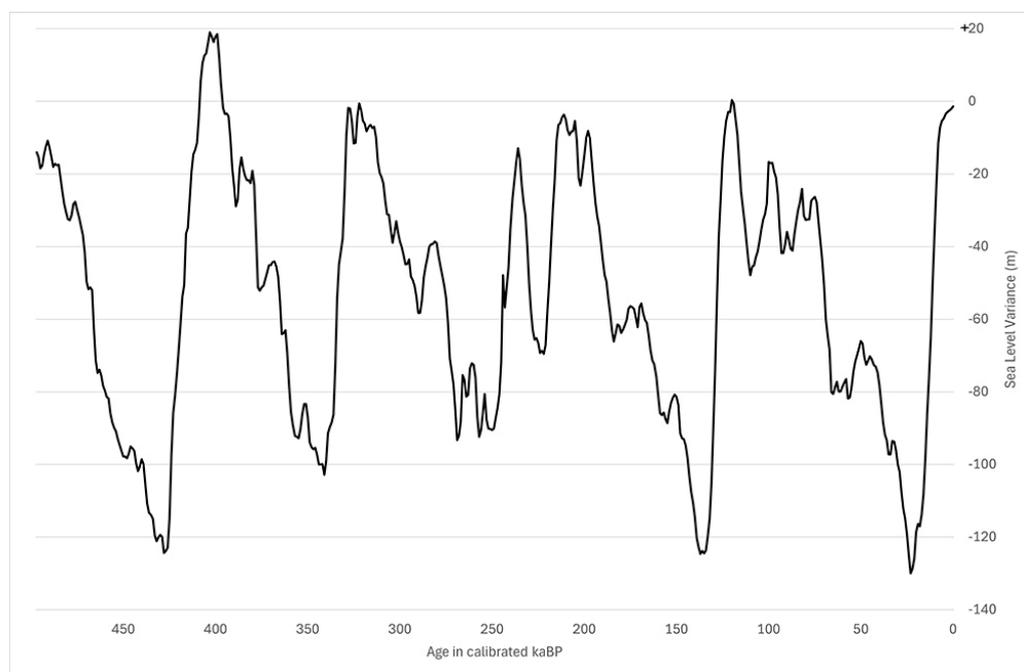


Figure 1. Simplified global sea levels over the last 500 thousand years. Data obtained from <https://sealevels.org/#sources> accessed on 26 February 2024 [3,4].

Given the significance and context of submerged prehistory and the reconstruction of submerged palaeolandscapes, it should not come as any surprise that research interest in these issues has grown rapidly, along with a concern regarding associated heritage risk at a regional level [5] (Figure 3) and [6–8]. However, any improvements to our archaeological knowledge that have emerged recently have not followed a trend of linear increase, nor do they reflect an even coverage of the areas of the continental shelf that are of interest. In those areas where submerged sites are accessible to investigation, there have been important discoveries [9–13]. Whilst these include a number of finds relating to earlier periods of time (e.g., [14–17]), the majority of discoveries and known sites postdate the Last Glacial Maximum. Most of these finds are linked to waters relatively close to the current shore. Where sites are known, as in the Storebælt waters in Denmark, the majority are later Mesolithic in age, i.e., close to the date of inundation [12]. Earlier postglacial sites are presumed to exist at greater depths and distances from the current shore [18–20]. In these deeper waters, relating to earlier phases of loss, our knowledge of existing archaeology is less substantive. Here, research has largely centred on palaeolandscape reconstruction through the analysis of 2D and 3D seismic surveys, frequently sourced from hydrocarbon and wind energy surveys, and using vibrocore data from a variety of sources.

Although a number of regions have undertaken such studies, the late Pleistocene and early Holocene landscapes of the southern North Sea are among the best understood submerged palaeolandscapes in the world [21,22]. Work here is gradually bringing us closer than ever to being able to conduct investigation of the prehistoric landscapes across a continental shelf, although the targeted prospection of archaeological sites within these landscapes remains a challenging proposition [23,24]. This situation is repeated elsewhere, and with respect to the Gulf of Mexico, Evans and Keith [25] have suggested that “after

four decades of regulatory compliant survey and assessment, no definitive prehistoric archaeological sites have been identified on the outer continental shelf". Indeed, such comments remain applicable to almost all previously habitable, deep-water palaeolandscapes around the world today. This situation remains, despite the increasing evidence for the archaeological potential of such areas, as these finds are overwhelmingly the result of chance discovery rather than directed prospection.

It is also true that the opportunities for implementing exploratory methods to remedy this situation may be diminishing across the world's submerged palaeolandscapes and, in some places, are at a critical juncture. As development of the seabed has increased and diversified, offshore wind farm infrastructure has emerged over the last decade as the largest driving force of change, with coastal nations around the world looking to establish cleaner, renewable, and politically reliable energy sources. In many areas, much of the continental shelf that is earmarked for development overlaps with submerged palaeolandscapes of strategic archaeological interest, and the rate and extent of ongoing and proposed developments, in the UK [26] and elsewhere around the world, are accelerating significantly, with 380GW of offshore wind capacity predicted to be in place across 32 markets by 2033 [27] (p. 2). As a consequence, urgent action is needed to establish an appropriate research strategy for the management and investigation of the submerged prehistoric heritage now at risk from development in the marine environment. This should include the combined issues of contemporary and future access as, even after decommissioning, foundations and supporting infrastructure installed into the seabed may not be removed.

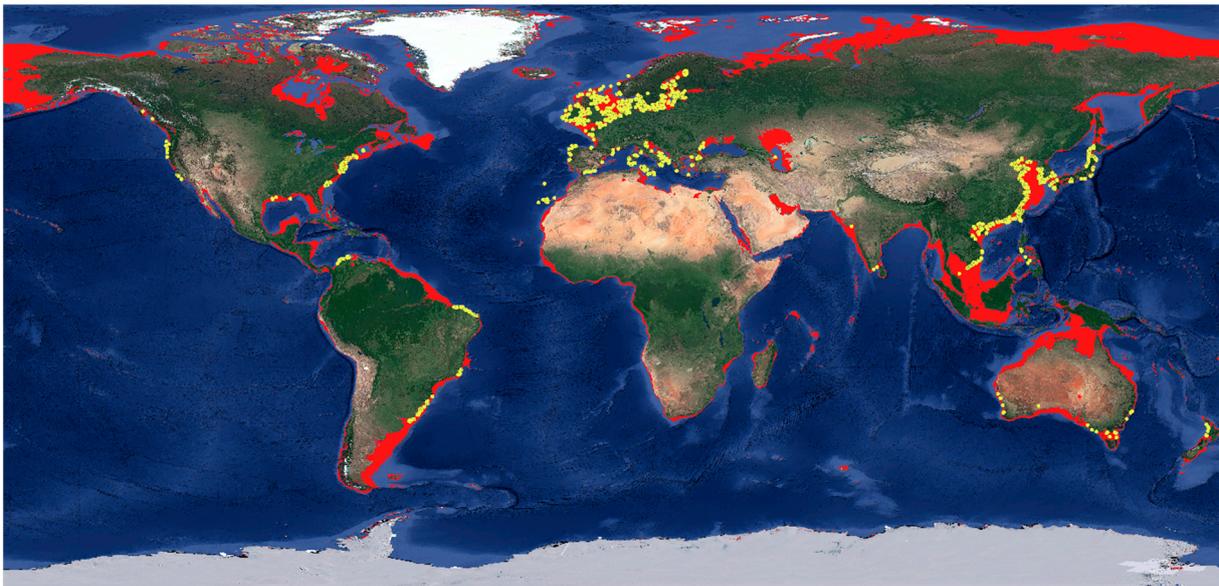


Figure 2. Distribution of offshore wind farm developments, including planned developments as of August 2023 (yellow circles) set against the approximate extent of marine palaeolandscapes (shown in red). Bathymetry source: GEBCO 2021. Wind farm development information from the 4C Offshore Global Offshore Map [28].

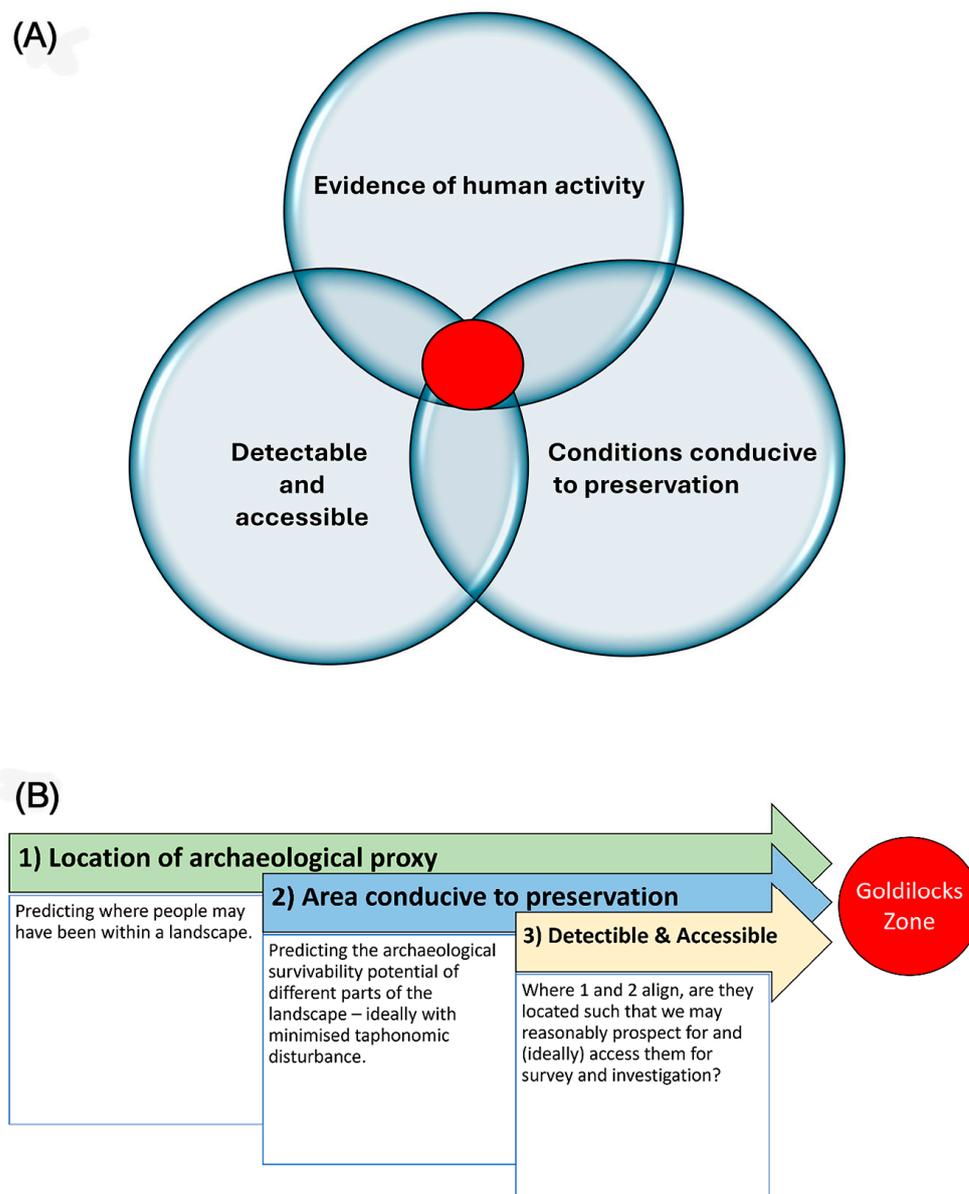


Figure 3. “The Goldilocks Zone” showing the three requirements that need to be met for a likelihood of finding prehistoric archaeological remains. (A) shows the Venn diagram of preconditions for locating prehistoric archaeology on the continental shelf, while (B) reveals the hierarchical relationship of the preconditions ranked as prerequisites of one another.

2. Offshore Wind Farm Developments and the Push for Self-Sufficient Greener Energy

Various motives exist for the rush to harness the latent capacity of the marine environment for energy generation. Whilst the quest for energy security may involve an increased reliance on hydrocarbons in the short term, as has been proposed recently in the UK sector [29], the latest Global Offshore Wind Report recognises that “the twin challenges of secure energy supplies and climate targets will propel wind power into a new phase of extraordinary growth” [30] (p. 9). In addition, reasons for investment in offshore wind energy infrastructure may include:

- Providing additional energy generation and/or production capacity.
- The provision of more cost-efficient and sustainable means with which to power economies [31], and in some cases, to provide a boost to local or nationally low employment rates (e.g., [32]).

- A means to capitalise on what has, up until now, remained a largely untapped part of Exclusive Economic Zone (EEZ) potential (e.g., [33,34]).

These motives, and particularly the primary drivers of climate targets and energy security, have achieved further significance in recent years following several developments, including:

- Increased recognition by various governments that global warming, and specifically anthropically induced global warming, presents a grand societal challenge that requires urgent address [35], particularly among post-industrial nations. The recent leap in global heating suggests that temperatures during 2023 surpassed any other period in the last 100,000 years. Together with the equivocal outcomes of COP 28, the world will probably exceed the 1.5 °C goal within the next decade, avoidance of which was previously viewed as a critical target [36]. Many parts of the developed world now face an existential need to lead on the provision of cleaner sources of energy provision in response to spiralling demands that are exemplified by widespread rises in energy bills across much of Europe since 2021 [37,38].
- The increased public acceptance of offshore wind results partly from discontent surrounding terrestrial wind infrastructure developments. The proximity of wind farms to homes and landscapes where space is increasingly contested, and where impacts upon local ecologies are more visible or keenly felt (e.g., [39]), has encouraged offshore wind investment. Although the continental shelf is itself an increasingly contested and politicised area [1], it may nevertheless be a preferable alternative to terrestrial development. It may also expand the energetic capacity of coastal nations whose potential for onshore energy infrastructure is limited. Recent studies in North America have also linked opposition to wind farm development with variable socio-economic and ethnic privileges [40], revealing that concern over development is a demographically variable phenomenon. Offshore wind farms, by contrast, offer greater opportunity for energy generation [41] from development areas that are largely out of sight and mind to many onshore communities [42], although the impact of offshore developments on natural marine resources as well as coastal heritage landscapes (as at St Abb's Head in Scotland, [43]) have also generated opposition to development.
- Heightened geopolitical tensions around the world have been acutely felt following the invasion of Ukraine by Russia in 2022. Some countries that are reliant upon Russian supplies of energy have sought to reduce their dependency in the wake of this event [44], but even in countries that are relatively less reliant upon Russian sources of energy, such as the UK, there has emerged a greater caution and a clearer desire to develop self-sufficient sources of energy provision [45]. Consequently, there is now an energy 'trilemma' between meeting the sometimes conflicting challenges of ensuring energy reliability, affordability, and sustainability [46].

Heritage professionals will have to navigate these challenges and potentially also reckon with the exploitation of archaeological narratives for diverse agendas. These may include disputes relating to rights of determination as justifications for the increased scrutiny of maritime borders [1,47,48]. This is reflected not only by the recent surge in offshore renewable investment, but also the desire to strategically expand jurisdiction over parts of the continental shelf and presumably maximise the potential utility of this resource. The legally recognised extent of the continental shelf can extend up to 200 nautical miles from land, but may be increased through application to UNCLOS (Article 76). The USA recently announced that it had expanded its extended continental shelf by a million square kilometres, one of 75 nations to undergo such expansion [49]. The intensifying focus on expansion of territory and assets in this regard further complicates the already politically sensitive nature of continental shelf development [47]. This is now an arena that is multifaceted, complex, increasingly contested, and rapidly evolving [1,48]. The interests of archaeologists and heritage professionals are a small voice among those of multiple larger stakeholders also vying for position [1], and in such a melee, continental

shelf prehistory has proven a difficult aspect of underwater cultural heritage (UCH) to satisfactorily detect, define, and manage [50].

3. Characterising Prehistoric Underwater Cultural Heritage

In most parts of the world, save for a few notable exceptions (e.g., [12]), submerged prehistoric archaeological sites remain a relatively rare phenomenon, restricted to areas relatively close to the current shore and at relatively shallow depths that are accessible to investigative divers [51]. Archaeological work further offshore on the continental shelf (i.e., at a distance and/or at depth) carries greater logistical difficulties and may incur considerable expense [52]. Nevertheless, these areas hold significant archaeological potential, as evidenced by the accumulation of chance discoveries of artefacts and faunal and human remains, as well as discoveries made following targeted investigations of shallower nearshore waters [7,15,53–58]. The southern North Sea is associated with probably the best studied and understood submerged palaeolandscape sequence in the world. This has been made possible by an archaeological community which has engaged with palaeolandscape research at the largest scales. In Britain, aside from commercial investigations, this has involved dedicated research programmes including *Europe's Lost Frontiers* and its predecessor the *North Sea Palaeolandscapes Project* [21,22]. The consequence of this and similar exploratory studies elsewhere within the southern North Sea and its adjacent waters is that the region can be used as an exemplar for submerged prehistoric archaeological research elsewhere [59–64].

The southern North Sea demonstrates that, unlike terrestrial palimpsests, submerged palaeolandscapes have largely escaped the impact of anthropically induced taphonomy, at least in the sense that they have not been industrialised, intensively farmed, or urbanised [51]. When submerged prehistoric sites have been found and investigated in or near these waters, some have been field-changing in terms of the insights they offer, as at Tybrind Vig in Denmark, Yangtze Harbour in the Netherlands, Bouldnor Cliff and Area 240 in the UK, and Hummervikholmen in Norway [9,10,65–67].

However, across much of the area presumed to be archaeologically significant, the potential for exploration and conservation of heritage resources is complicated by the question of what a site actually is, and how we might recognise such entities in these environments [51]. This question, apparently theoretical in nature, has significant, practical implications for prospection and legislation, particularly with respect to formal designation. The UK Offshore Energy Strategic Environmental Assessment 4, which considers the environmental impacts of energy development and associated infrastructure, highlights this problem. The cultural heritage appendix to this report notes that “designated sites are relatively few in number compared to those which are recorded, and with the exception of shipwrecks, all are terrestrial” [68] (p. xviii).

Consequently, one of the potential pitfalls of heritage management in marine environments is the accepted standard for what might be defined as cultural (rather than natural) remains, a requirement for a practical framework to support workable laws and pragmatic archaeological research strategies. Traces of prehistoric occupation, for example, may often be ephemeral in nature, difficult to detect, only fleetingly accessible, and poorly suited for identification. Recent mapping of uniquely preserved hunter-gatherer landscapes within the Great Lakes, and most recently in the Baltic Sea [69], demonstrates that significant cultural structures may appear as little more than an alignment of stones or wood [70]. A hearth may appear in the marine record as a smear of burnt sediment. Natural material with archaeological value, such as peats, sediments, and fossilised flora and fauna dating from prehistoric times will only be afforded protection under the UNESCO Convention of 2001 if they are directly associated with evidence of the presence of human communities [50] (p. 88). Although the dating of such sediments in a marine context may well suggest their archaeological significance, demonstrating clear and unambiguous association with human communities, prior to detailed archaeological investigation, is complex and fraught with difficulties.

Although, there have been a series of major policy initiatives in the North Sea [8,71]; as Joe Flatman has remarked, “new marine management policies in particular have failed to recognise the complexity of the marine historic resource, continuing to define materials in terms of spot ‘sites’ rather than blended layered cultural locales” [1] (p. 179). The recognition of landscapes as having an inherent cultural value is generally appreciated in terrestrial contexts, where historic landscape characterisation (HLC) is widely recognised as a significant heritage methodology for the assessment of landscapes at a local, regional, or indeed national level [72]. An attempt to apply these methodologies offshore has culminated in Historic England’s National Historic Seascape Characterisation dataset (HSC) [73,74]. An early attempt to implement HSC in deep waters was undertaken during interpretation of the first large-scale archaeological landscape dataset from the North Sea [22], but this remains a unique exercise as, in most situations, the lack or complexity of available data has made these landscapes less conducive to such analysis.

4. The “Goldilocks Zone”

In contrast, an alternative route to landscape assessment, initially proposed as part of the ERC-funded University of Bradford project *Europe’s Lost Frontiers* [21], is to use the concept of a “Goldilocks Zone”, a term initially used in astrobiology to describe a circumstellar habitable zone in which the complex requirements for life may be met. The conditions in such situations are “just right” for the presence of life, in deference to the eponymous fairy tale.

Here, we develop this concept to suggest that deposits with the potential to be of archaeological interest can be identified in a similar manner and provide a route for evaluating and ranking areas of interest and threat in deep waters (e.g., [22,75,76]). In the context of a targeted archaeological project that may be investigating submerged prehistoric remains, we may imagine a hierarchical Venn diagram as illustrated in Figure 3. Selection of an area of interest requires that the location will:

- (1) Exist at a position that is both detectable and accessible for recording or investigation.
- (2) Exist at a location that is (or was) conducive to archaeological preservation and is likely to have withstood significant taphonomic change.
- (3) Have been a location where human activity took place and at a sufficient intensity to leave archaeological traces.

Any project seeking to undertake archaeological prospection of palaeolandscapes across the continental shelf might seek to identify areas that fit this model. However, as in any model, there are several caveats. First, as noted with respect to the search for extraterrestrial life, the establishment of a Goldilocks Zone may meet the prerequisites for archaeological discovery but does not guarantee the presence of such evidence. Second, it is possible for archaeological discoveries to be made outside of these conditions, and these may result from the presence of archaeological features of a sort not previously known or anticipated by the model. Finally, as the model is devised specifically for locating finds within their primary depositional setting, it does not account for redeposited finds removed from their initial context, although these too may have considerable information value. It is also important to acknowledge that whilst apparently empty regions within marine landscapes may reflect a sparse resolution of relevant marine data, the cultural significance of empty spaces, or areas characterised by apparently low levels of activity, may also be a reflection or facet of a cultural landscape [77–79].

Such observations emphasise that heritage managers face a challenge when considering what constitutes an archaeological proxy worthy of investigation, mitigation, or protection. However, in contrast to the chance nature of previous finds in the southern North Sea, the Goldilocks Zone does provide a framework for finding previously elusive, primary archaeological deposits in a targeted manner. However, as on land, redeposited artefacts, “off-site” deposits (see Foley [80]), and non-material culture proxies of human activity are all still of archaeological interest and are frequently worthy of curatorial management in terms of the information they convey about past lifestyles and land use.

Given the complexity of understanding archaeological landscapes, on land but specifically at sea, the implementation of any methodology may be problematic. In some cases, such outputs may amount to little more than speculative assessments of cultural heritage threat potential; nevertheless, this emphasises that each development proposal must be evaluated on a case-by-case basis [81] (p. 228).

5. The Legal Context for the Management and Investigation of Continental Shelf Prehistory

Having considered the archaeological context of marine palaeolandscapes and, to some extent, the prerequisites required to provide an adequate heritage record for such areas, it is important to understand the legal framework in which marine heritage exists. Laws regarding the protection, curation, and investigation of submerged prehistoric heritage have only recently become an issue for international legislative concern. This may stem in part from an enduring pre-occupation with more tangible archaeological sites and more recent remains, namely discoveries relating to shipwrecks [82]. However, this also relates to persistent misconceptions regarding the survivability and accessibility of prehistoric archaeology from submerged contexts, and the perceived lack of value in searching for and engaging with such finds [20,83] (p. 35). While recognition of the significance and potential of submerged prehistoric heritage has historically varied from state to state [84–86], the shipwreck-dominated focus of marine archaeology only began to change in the late 1980s to include other subjects of interest ([50] (p. 71), [87] (p. 174)). This lag in attention is arguably reflected in the remit and scope of international legislation guidance.

6. The Jurisdictional Gap

To assess the threats facing the archaeology of the continental shelf, several sources of international law must be consulted. These include general principles of international law, the 1982 United Nations Convention on the Law of the Sea (LOS or UNCLOS [88]), and the 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage [89]. Various legal experts have discussed the different aspects and shortcomings of these pieces of legislation in both international [50,82,87,90,91] and national contexts (e.g., [92]). One area of concern is what Sarah Dromgoole describes as an effective ‘jurisdictional gap’ [82]. In essence, the situation is as follows. The 1982 UN Convention on the Law of the Sea divides oceans into three maritime zones, which are afforded different legal regimes under international law. These are ‘Territorial Seas’, ‘the Contiguous Zone’, and the ‘Area’.

Within territorial seas, which are delimited by a 12-nautical mile (22.2 km) perimeter around the shore of a coastal state, a nation has, by virtue of sovereignty over this zone, the right to regulate the removal of underwater cultural heritage. Beyond this zone is formally where the continental shelf begins. It is important to note that this definition of the continental shelf is a legal entity and is not equivalent to the way in which the term is used geologically. The shelf extends as far as 200 nautical miles (NM) from the coastal baseline or, in the case of ‘broad-margin’ states with continental margins that extend far beyond this 200 NM limit, this designation may stretch as far as the deep seabed [50] (p. 36). The first 12 nautical miles of the continental shelf from the margin of territorial seas, as legally defined, may be declared and then recognised as the ‘Contiguous Zone’. Within this zone, coastal states may extend their right to regulate the removal of underwater cultural heritage under Article 303 of UNCLOS. The ‘Area’ refers to the deep seabed beyond national jurisdiction or beyond the outer margins of the legally defined continental shelf. Here, underwater cultural heritage falls under protection from Article 149 of UNCLOS. These maritime zone divisions are represented in Figure 4 and explained in greater detail in Dromgoole [82].

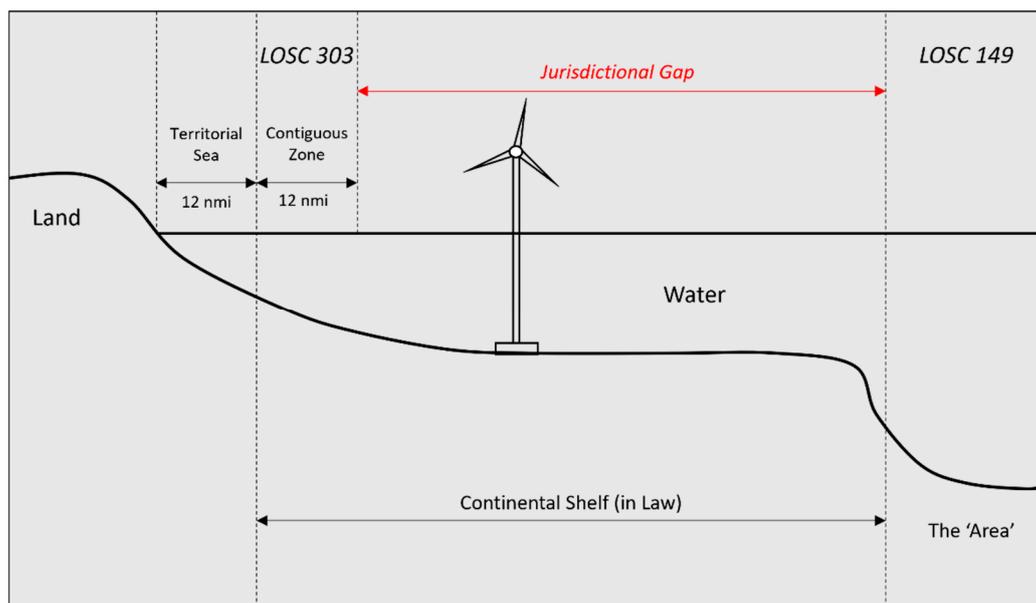


Figure 4. The ‘jurisdictional gap’ between areas protected by the United Nations Convention on the Law of the Sea (UNCLOS), redrawn from Dromgoole [82].

The key takeaway from this legislative framework is that a portion of the continental shelf falls between the protection afforded by UNCLOS Articles 303 and 149 and constitutes a ‘jurisdictional gap’ as termed by Sarah Dromgoole [82]. Although national and international law may offer some provision for territorial waters, the contiguous zone, and the ‘Area’, a significant extent of the continental shelf around the world has no heritage legislation to protect for prehistoric Underwater Cultural Heritage. It is in these areas where substantial evidence for submerged prehistoric sites and landscapes may exist, and it is here that existing, but generally unexplored, landscapes remain largely unprotected by the law.

The UNESCO Convention of 2001, which came into force in 2009, sought to address this issue, but as of July 2021, only 69 parties had ratified this treaty (Figure 5), with 71 having signed as of the time of writing (2024). The provisions and protocols specified by the LOSC and the UNESCO Convention of 2001 have been discussed in detail elsewhere [50,82], but for coastal states not participating in the latter, the area described by this ‘jurisdictional gap’ remains without legislated regulation [93] (p. 9). While there are ways around this (see Dromgoole [82]), currently “there is no legal protection afforded to submerged underwater cultural heritage sites expressly by the terms of UNCLOS III” [85] (p. 358). As González and colleagues note, among other considerations of a more geopolitically sensitive nature, the unsustainable expenditure presumed by a duty of care to archaeologically significant heritage (and not just prehistoric UCH) within this zone may be a factor dissuading some states from agreement [89] (p. 61).

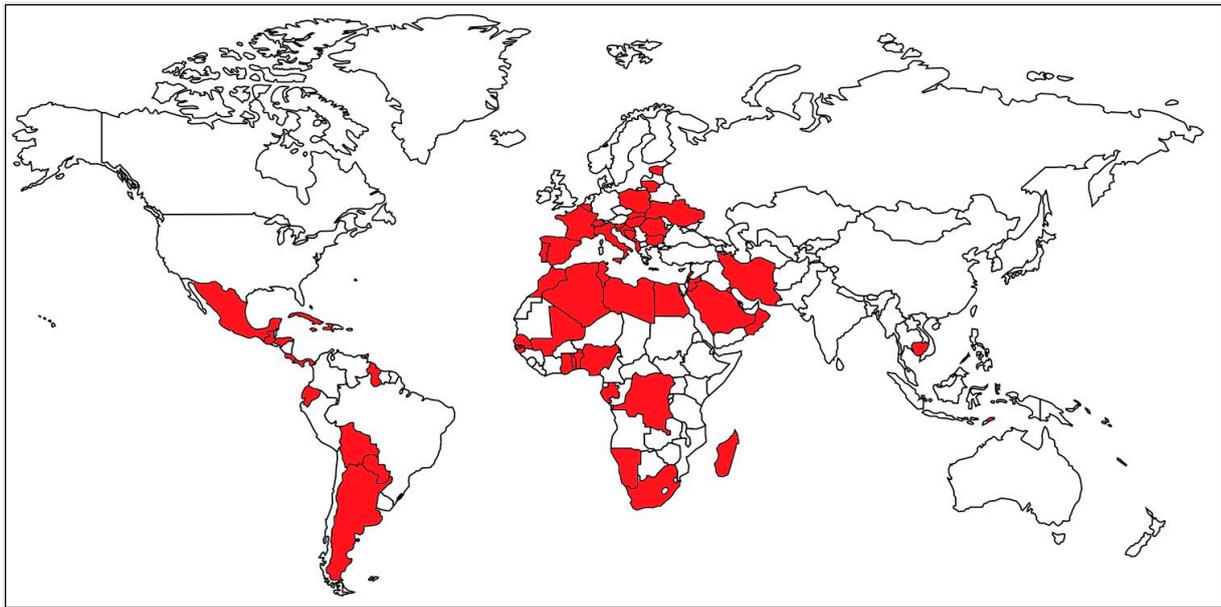


Figure 5. A Map visualisation of states around the world that have ratified the UNESCO Convention on the Protection of the Underwater Cultural Heritage, Paris, 2 November 2001, as of July 2021. Due to scale, not every signatory can be clearly shown. The full list of states include: Albania, Algeria, Antigua and Barbuda, Argentina, Bahrain, Barbados, Belgium, Benin, Bolivia, Bosnia and Herzegovina, Bulgaria, Cabo Verde, Cambodia, Costa Rica, Croatia, Cuba, Democratic Republic of Congo, Ecuador, Egypt, Estonia, France, Gabon, Ghana, Grenada, Guatemala, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iran, Italy, Jamaica, Jordan, Kuwait, Lebanon, Libya, Lithuania, Madagascar, Mali, Malta, Mexico, Micronesia, Montenegro, Morocco, Namibia, Nigeria, Niue, Oman, Palestine, Panama, Paraguay, Poland, Portugal, Romania, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Saudi Arabia, Senegal, Slovakia, Slovenia, South Africa, Spain, Switzerland, Togo, Trinidad and Tobago, Tunisia, and Ukraine [94].

7. The UK Sector of the Southern North Sea

Although the UK has not formally ratified the UNESCO convention, it is, in many areas, a leader in the management of marine heritage [95]. Recent research into submerged palaeolandscapes surrounding the UK (summarised in [21,71,96]), the history of the development of the UK offshore energy sector [26], and the largest offshore wind potential in Europe [97] makes the UK sector of the southern North Sea an excellent case study for the review of UCH in light of the practical and legislative challenges outlined above.

8. Doggerland: A Unique Submerged Landscape

The North Sea, and its UK portion in particular, has benefited from considerable investment into research targeted at the reconstruction of late glacial Pleistocene and early Holocene landscapes [21,22,98,99]. Other North Sea basin nations may lay claim to richer densities of findspots, but the UK continental shelf has been the subject of a series of research projects incorporating extensive 2D and 3D seismic and vibrocore surveys aimed at reconstructing palaeolandscape evolution from the late Pleistocene [21,22]. The southern North Sea palaeolandscape, often referred to as Doggerland, was a landscape of central importance in northern Europe, larger in area than many current European countries at its peak. It boasts a wealth of unexplored archaeological and environmental data imperative to a range of prehistoric research questions, including understanding how past populations met challenges of climate change and sea level rise [100–102]; see also [103]. It has been a habitable landscape connecting the British mainland to continental Europe at various points in the past and including critical cultural periods, starting with the earliest hominin occupation of Britain [15,104].

Our knowledge of the palaeogeography of this landscape stems from innovative research, using energy and extractive industry-generated seismic data, to support the mapping of more than 188,000km² of Doggerland's topography, coastlines, lakes, and rivers ([105] (p. 36), [22,98,99]). However, while large portions of Doggerland should be ideal for the preservation and location of prehistoric archaeology [106], few stratified sites are known from this area, and none are from waters more than 12 nautical miles from the current shore. The early Holocene (Mesolithic) site at Yangtze Harbour lies in Dutch waters [10], while the much older Middle Palaeolithic site at Area 240 and associated deposits lie within British waters [13,14,66]. However, as the UK Offshore Energy Strategic Environmental Assessment 4 notes, there are few cultural heritage site designations relative to the scale of the resource [68] (p. 50). Despite this, the quantity and nature of finds and sites from adjacent, shallow coastal waters indicate the potential of the area, and the palaeolandscape research conducted so far provides the best foundation for targeted prospection. Using these datasets, we may begin to think meaningfully about how we locate archaeological deposits, where they are accessible, and if they are at risk from development [81].

Various other areas of the continental shelf around the globe have been touted for their archaeological potential (e.g., [107,108]), but so far none have been afforded the extensive palaeolandscape mapping and reconstruction directed at the southern North Sea. The area has the potential to act as an exemplar for other nations looking to develop offshore wind capacity [109] and provide an international standard for preparatory work and management regarding these aspects of cultural heritage.

9. Offshore Wind and Energy Strategy

In 2020, as part of their goal to become “the world leader in clean wind energy”, the UK government pledged that all homes were to be powered by offshore wind by 2030 [110]. This was also a significant milestone on the route to achieving the national aspiration of net-zero gas emissions by 2050 [111]. Already a world leader in offshore energy provision [26] (Figures 6 and 7), this goal nevertheless requires significant expansion and acceleration of infrastructure installation over the coming years. However, the progression of green policies has recently become the centre of political and public debate within the UK, including objections to the extension of the Ultra-Low Emissions Zone in London [112] and a proposal to extend licencing for hydrocarbon extraction within UK waters [113]. Notwithstanding such dialogue, the scale of current plans and envisioned growth is demonstrated by the areas covered by the Dogger Bank A, B and C wind farms which are currently collectively set to become the world's largest offshore wind farm, capable of powering 6 million homes annually [114].

The UK is, of course, not alone in their aspirations to drastically increase offshore wind energy provision. The European market continues to grow and diversify. By 2030, it is projected that, across the EU, offshore wind installation capacity will outstrip onshore capacity [115] (p. 8). However, European growth itself has recently been outpaced by rapid growth in the Asia-Pacific market, driven primarily by China (Figure 6) [116] (p. 8). Rates of growth are, however, neither stable nor impervious to fluctuation, and 2022 was a notably slower year of growth in terms of megawatts installed, dropping from 21106 MW installed in 2021 to 8771 in 2022 [116] (p. 10), [27] (p. 53)). However, even with the current rates of installation, such expansion will still not be enough to achieve more than two-thirds of the wind energy capacity required by 2030 for a 1.5 °C (above pre-industrial levels) and net zero pathway in line with the goals of the IPCC [113] (p. 16).

When assessing the nature and scale of current development, it should be noted that wind farm infrastructure, like hydrocarbon infrastructure, can take a variety of forms (Figure 4, [117]), and the type of installation will govern seabed disturbance associated with it. However, the government requires that “physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access”

should be considered at all project phases [68] (p. xxviii). The text as it stands implies that these comments only cover construction and operation [68] (p. 17).

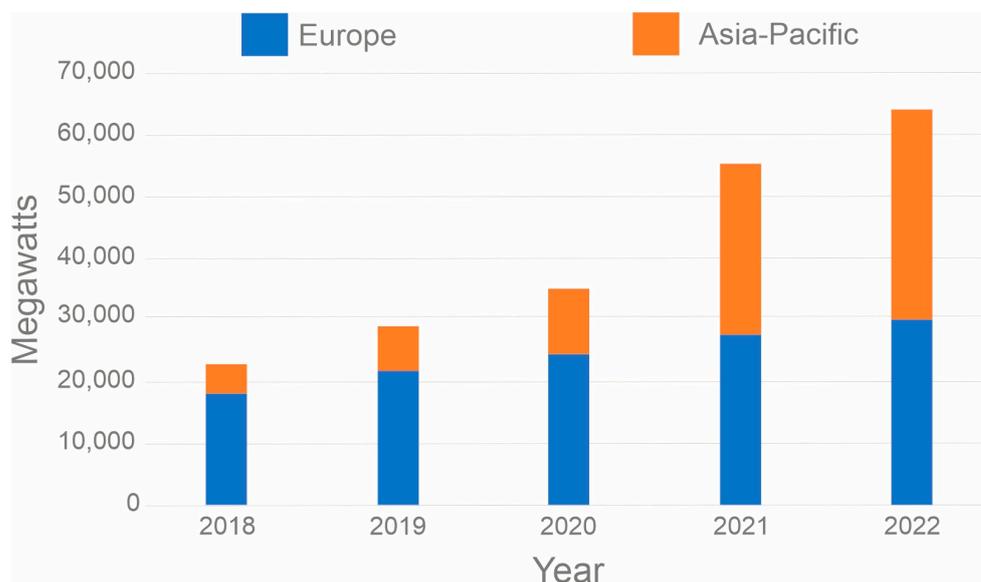


Figure 6. Comparison of Asia-Pacific and European growth rates for offshore installations (by megawatts) between 2018 and 2022. An explosion of growth led by China has recently surpassed Europe's position as the lead market for offshore wind installation. Redrawn with data sourced from GWEC [97,116,118–120].

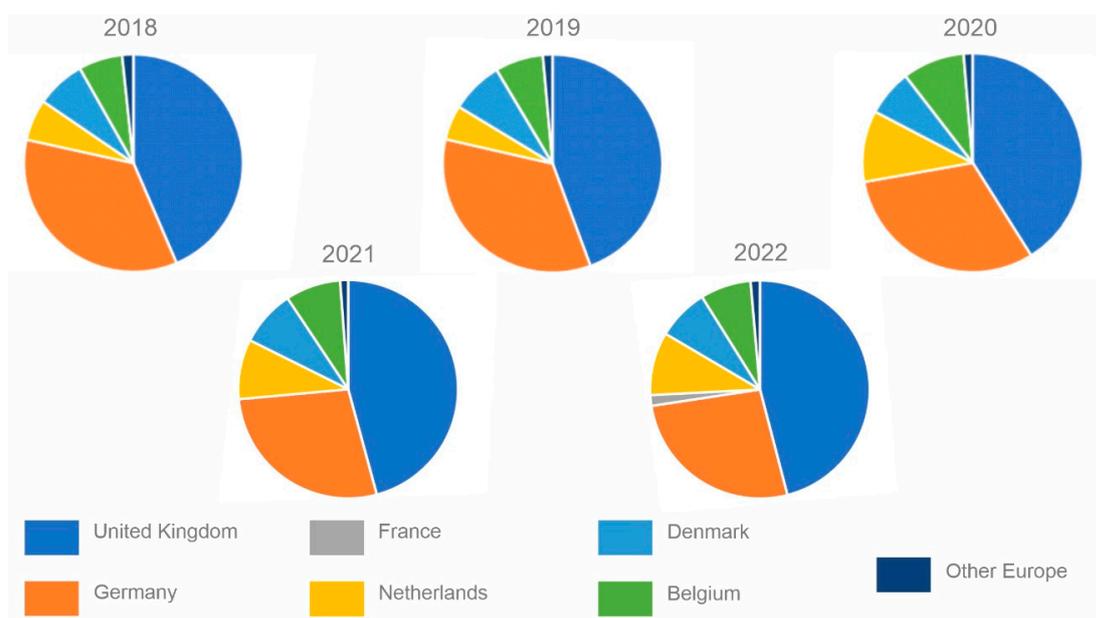


Figure 7. Showing the relative distribution of offshore new wind farm installations in Europe for each year from 2018 to 2022 (in Megawatts) by country. Redrawn with data sourced from GWEC [97,116,118–120].

However, wind farm construction, oil and gas extraction, carbon dioxide storage, and hydrogen production all require supporting infrastructure (cabling, hubs, pylons, pipelines, etc.) that may impact surface or shallow subsurface archaeological deposits directly or indirectly. The designation of exclusion zones for these also carry the potential to severely limit access to future heritage researchers. Also, throughout the wind farms' life cycle,

scouring of the seabed around the monopiles, influenced by local flow acceleration, is a critical factor affecting the preservation and accessibility of archaeological material within strata. The implications vary with sediment composition; for example, areas underlain by marine clay show limited scour, while those with sandy sediments may experience scour depths up to 1.38 times the monopile diameter [121]. Monopiles with diameters up to 10 m are now feasible as the industry advances into deeper waters [122].

10. Provisions and Guidance

Reviews of recent developments of underwater cultural heritage management in the UK do provide evidence of significant progress in some areas [84,123]. Initiatives include the establishment of the Marine Data Exchange portal; the MEDIN data portal; OASIS, the UK repository for development-led archaeological reporting and the archaeological work facilitated by the Marine Aggregate Sustainability Fund (MALSF) [124]. Together, these actions have provided access to data and raised awareness of issues associated with marine prehistory. Engagement with offshore stakeholders has also supported data gathering and academic output (e.g., [125,126]), which has helped to raise awareness of submerged prehistoric UCH and its associated issues [127], assisted in potential methodological development and disseminated best practice [127] (pp. 30–31). More recently, guidance has been developed from the experiences of the first four rounds of offshore wind development [128] and the revamping of the English North Sea Prehistory Research and Management Framework [71]. Guidance is, of course, always a work in progress, and archaeologists will certainly benefit further from advocating engagement with the expanding offshore sector as part of a broader collaborative endeavour, highlighting the various ways in which archaeological work may support development. Much like the case laid out for geoscience [129,130], the data gathered through surveys undertaken for archaeological work may also contribute information of value to developers.

Despite such opportunities, shortcomings with legislative frameworks have also been identified that render archaeology, and particularly prehistoric archaeology, vulnerable across large portions of the continental shelf [131]. A recent review of the UK's legislation for protecting underwater cultural heritage provides a thorough and incisive critique of the status quo, while raising concern over the unfolding impacts of Brexit alongside the UK's decision not to ratify the UNESCO convention [132]. In it, they note that there is no "effective legal mechanism for the protection of UCH within the additional contiguous zone permitted for UCH regulation or upon its Exclusive Economic Zone (EEZ) and continental shelf (up to 200 nautical miles)" [132] (p. 79).

Issues have also been acknowledged with regards to the structure, allocation, reporting, and synthesis of archaeological work in the marine domain ([133] (p. 5), [1] (pp. 177–179)). Ultimately, and despite considerable research and mitigation activity across the North Sea, it is not clear to what extent current practice is able to successfully identify archaeological areas of interest in advance of development, particularly if the application of such protocols becomes a matter of rote [134,135]. A primary reason for concern regarding current guidance is best illustrated by the general lack of prehistoric sites located within areas of development within the southern North Sea. Given the dearth of such evidence, strategies such as in situ preservation, the establishment of widespread exclusion zones, or the scheduling of 'microsites' are potentially ill-suited given the nature of much prehistoric archaeology, at least as we currently understand it [136]. In the UK, consent for development is accompanied by a specified protocol if archaeological remains are unexpectedly encountered [137,138], however this is the extent of jurisdiction for much of the continental shelf. Good curatorial practise may be evident in some areas, for example, in respect of the reporting frameworks established as part of a consent process prior to development. Yet, for many EEZs, archaeological work may be entirely dependent upon the goodwill and cooperation of developer stakeholders who, in any case, require input from the archaeological profession as necessary guidance [127]. This situation will likely remain until our capacity to locate areas of interest improves.

Again, with respect to the UK, the expansion of (then) English Heritage's remit to cater for the 12 nautical mile periphery in 2002 was a major landmark [139], and the drafting of the North Sea Prehistoric Research Management Framework (NSPRMF), initially in collaboration with Dutch authorities, was a significant achievement [96]. An update to the Dutch framework in 2019 [8] was followed by enhancement to the UK version in 2023 under the auspices of Historic England. This has now become a 'living' document, open to evaluative modification [71].

Currently, UK curators would stress that mitigation measures are primarily designed to support in situ avoidance of archaeology and that environmental impact assessments are required in support of development. As the UK has formally declared an Exclusive Economic Zone to 200 nautical miles offshore or the median line with adjacent states through the Marine and Coastal Access Act 2009 (Section 41 of the Marine and Coastal Access Act 2009), the UK government can set enforceable conditions within this area. In practice, any development consent may contain a written scheme of investigation, a protocol for reporting discoveries, and an agreement for the deposition of reports through the OASIS portal (<https://oasis.ac.uk/>, accessed on 26 February 2024). It should be acknowledged that within this framework, the UK offshore sector has a relatively good track record of compliance with regards to consideration of the historic environment [139], and examples of the prompt release of data for reuse can also be cited [140]. However, whilst evidence for compliance to existing heritage guidance is welcome, it remains true that any advice remains essentially based on prior archaeological knowledge which, in the case of most marine palaeolandscapes, is largely absent. Given the lack of a substantive archaeological context to guide action, it may not be surprising that many mitigation activities have failed to identify and locate prehistoric archaeology or substantively contribute to refining our knowledge of the seabed in light of their archaeological potential [11,13,141].

The extent to which we wish to remedy this situation and maximise the value of outputs derived from compliance activity requires that we must think carefully about the archaeological questions we need to address, how we engage with stakeholders, and the practical archaeological challenges that will be faced when attempting such work [133,142]. Without this, we may not have the capacity to undertake new types of prospective research, and we will run the risk of repeating processes that have not always contributed significantly to our knowledge of palaeolandscapes and their environment.

11. Emerging Opportunities in the North Sea and Globally

Despite previous comments, it should not be presumed that archaeologists and offshore developers have no shared interests. Materials fundamental to marine archaeological research, such as buried terrestrial horizons or peat deposits, are also of interest to marine developers during construction and site planning. The establishment of offshore wind infrastructure across much of the southern North Sea will, by necessity, provide information on sediment sequences associated with early Holocene and late Pleistocene deposits [81], i.e., the best understood stages of landscape evolution [21,98,99].

It has already been stressed that, in addition to the area of the southern North Sea, many other areas of the world's coastal shelves also contain submerged prehistoric archaeology. Although less well studied, they nevertheless face similar difficulties [6]. Our lack of knowledge in such areas clearly poses a significant challenge [1,131] but again presents a major opportunity [142] to work with industry and identify areas of mutual interest in advance of development. Building on the experience gained in areas including the North Sea, the appropriate integration of evaluative archaeological prospection with the planning or development process would help ensure that sustainable heritage management practices are devised to work in tandem with the development of sustainable energy infrastructure. The benefits of such an occurrence in terms of the efficient use of available resources, enhanced public relations, and the demonstration of corporate responsibility might also be significant. As interests dovetail, they present the possibility for a virtuous circle, providing benefits to all involved. It is significant that the UK National Policy Statement for Energy

now encourages development proposals that make a positive contribution to the historic environment [143].

12. Taken at the Flood: Finding Europe's Lost Frontier

Taken at the Flood is a new collaborative research project based at the University of Bradford Submerged Landscapes Research Centre (<https://submergedlandscapes.teamapp.com/> accessed on 26 February 2024). The project aims to foster dialogue and cooperative working relationships with other marine heritage professionals, curators, marine industry developers, and stakeholders, including offshore wind farms. The scale and resource available to offshore developers is significant, whilst that available to research archaeology is less substantial. However, an enhanced relationship between developers, contract archaeology, and the research community, may assist in identifying the elusive submerged prehistoric archaeology that we believe to be present across the coastal shelves. This could be achieved, for example, through the implementation of a methodology based upon the Goldilocks Zone as described above. As part of this, the project will enhance and update previous maps that sought to outline areas of the seabed according to risk, uncertainty, archaeological potential, accessibility, etc. [22,73]. Our understanding of marine palaeolandscapes has, of course, improved significantly since such analyses were initially attempted [75,98,99,144,145], but this remains an important ambition for submerged archaeological prospection [146] and one that is of importance if we are to utilise a Goldilocks Zone model.

The most recent addition to such extensive mapping was provided through the *Europe's Lost Frontiers* project [21]. Here, a multiproxy approach to landscape evolution reconstruction has provided a relatively detailed overview of the final Pleistocene and early Holocene history of the western portion of the southern North Sea. For parts of this area, the project was able to identify detailed topographic features, trends in landscape evolution over time, and the point at which transgression and eventual inundation occurred. These details, along with an understanding of the relict palaeolandscape relative to the overlying sediment deposits, allow for characterisation of survey areas, both in terms of a historic landscape used by the final hunter-gatherers of northwest Europe and a contemporary landscape used as a working environment for archaeologists and marine developers.

The opportunities provided through such data were evidenced during a 2019 Anglo-Belgian survey expedition, when a worked lithic was recovered from the banks of a submerged palaeochannel, off the Norfolk coast and known as the Southern River valley [24,147]. Prior coring campaigns had confirmed the presence of a channel and estuary at this position, but also that contemporary sediments, dated as active in the early Holocene, around 8827 ± 30 cal BP, were exposed at the seabed. Given the archaeologically and ethno-historically attested predilection of various hunter-fisher-gatherer societies for coastal and estuarine ecological settings and the presence of early deposits exposed at the seabed in this area, a speculative dredge was undertaken along a transect across the river mouth and the banks [24]. The recovery of a lithic flake, identified as a possible hammerstone fragment [23], presumably related to the exposed Holocene surface, was located either on, in, or very close to the dated horizon.

The lithic was recovered close to the iconic 'Colinda harpoon' findspot, recovered around 90 years ago from the Leman and Ower banks [148]. The significance of the Southern River find, in contrast to the Colinda point and other archaeological artefacts from the North Sea seabed, was that it was not recovered by chance or through prospection initiated following development work. Instead, it was recovered as a result of archaeological targeted prospection, based upon detailed palaeolandscape survey and prior archaeological expectation [24]. Currently unique, it is premature to speculate whether the find was recovered in situ, but the possibility is enticing. Although further testing is necessary to establish the context of the find, the recovery of the Southern River valley flint (Figure 8) indicates that marine exploration has progressed to the point where directed prospection may at last be feasible and attainable. This contrasts with those discoveries made in the

wake of industrial intervention (e.g., [10,11]), through chance [9], or alternatively located in shallower waters much closer to the shoreline (e.g., [12]).

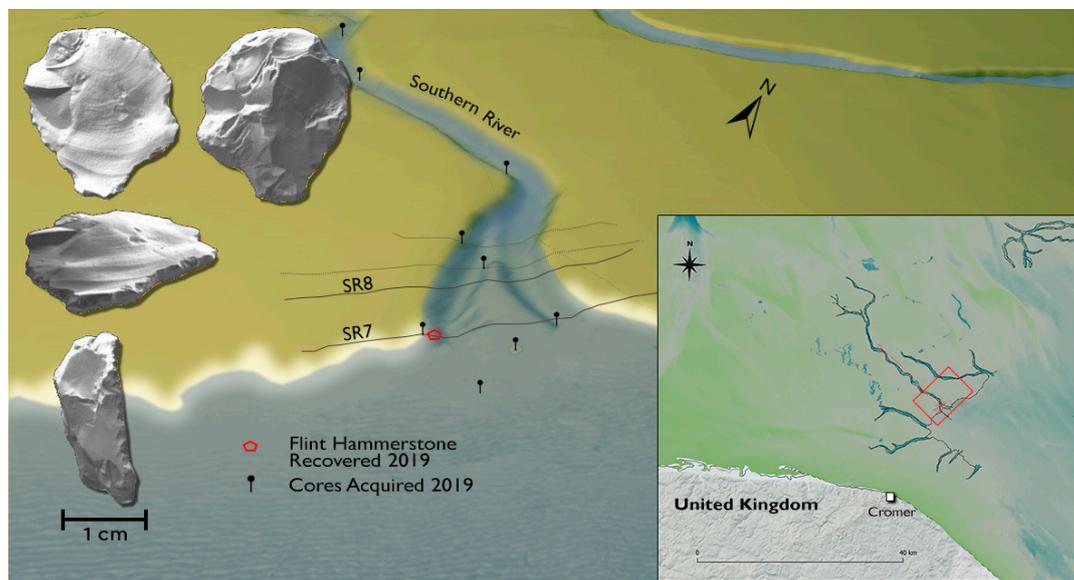


Figure 8. The Southern River estuary, lithic findspots, and potential hammerstone fragment. The 3D lithic scan was provided by Dr. Tom Sparrow (University of Bradford).

13. Conclusions

Europe currently leads in the study of archaeological, submerged palaeolandscapes [58], but this position could not have been achieved without the support and collaboration of marine developer stakeholders. It is also true that Europe occupies a significant position in the development of offshore wind farm infrastructure and that the scale and speed of proposed developments in both Europe and across the globe is likely to continue or gather pace. Such development will inevitably have an impact on areas of submerged palaeolandscape of strategic archaeological interest [28,149].

Despite this, Martin and Gane state that there is a schism between what UCH heritage policy intends and what it is achieving in practice [132]. The urgency of their appeal for reform applies to all aspects of underwater cultural heritage, but prehistory is arguably the most vulnerable category. Shortcomings in international and national legislature ensure that large parts of the continental shelf, including areas currently under development, have little or no legal protection for underwater cultural heritage. Signing the UNESCO 2001 Convention on the Protection of Underwater Cultural Heritage would at least oblige the implementation of legislation capable of protecting sites and relics in many parts of the globe. This could include prehistoric sites and finds, but at present, there is no legal requirement to even report discoveries of prehistoric artefacts [82]. The inevitable result of the current situation is that we are entirely reliant upon the goodwill and cooperation of marine developer stakeholders in many areas, including those substantial portions of the seabed that lack any legally enforceable protection for prehistoric UCH. The archaeological community has a duty to consider how future development will impact the marine historic environment. The need to improve how heritage managers and archaeologists engage with marine developers has been apparent for some time [138] (p. 52), and yet, the challenges facing submerged prehistoric archaeology have now reached a critical position. Future work is urgently required to engage researchers, contract groups, developers, and national curators to provide a methodology to remedy this situation. If this is achieved, we may revolutionise our knowledge of submerged prehistoric settlement and land use, but only if current mitigation practice is substantially updated. Otherwise, our capacity to reconstruct prehistoric settlement patterns, learn from past experiences of climate change, or

simply manage what are among the best-preserved postglacial landscapes globally, may be irreparably undermined.

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