Chapter 1
Archaeology and Palaeolandscapes of the Continental Shelf: An Introduction

Geoffrey N. Bailey, Jan Harff, and Dimitris Sakellariou

Abstract The past decade has seen a rapidly widening interest in archaeological and scientific exploration of the submerged landscapes that were flooded by sea-level rise at the end of the Last Glacial period. That interest is shared by many different disciplines and constituencies, including archaeologists who recognise the potential significance of these underwater archives to improved understandings of world prehistory, palaeoclimatologists interested in modelling sea-level change, and government agencies charged by national and international legislation with managing the underwater cultural heritage in the light of expanding industrial exploitation of the seabed. This introductory chapter sets out the background to these developments and the role of the European network – SPLASHCOS – in promoting awareness of this new agenda to the many scientific disciplines involved in underwater research, government agencies, commercial and industrial interests, and a wider public. Here we set out the major themes that we have used to structure the chapters in this volume, ranging across techniques and strategies of underwater investigation, examples of underwater archaeological excavations, reconstructions of underwater landscapes, the role of the continental shelf in shaping patterns of early human dispersal and geographical expansion, and issues of training, outreach and management. Examples are drawn widely from Europe and other parts of the world. We summarise the individual chapters, identify their inter-relationships with each other and with the themes of which they form a part, and highlight their wider significance.

1.1 Background

It is by now a well-established fact that for most of human history on this planet over at least the past 1 million years, sea-levels have been substantially lower than the present, oscillating between short periods of extreme high sea level as today and low stands of −100 m or more at glacial maxima, with many lesser perturbations in between, and a long-term average some 40–50 m below the present level. When sea levels were low, extensive tracts of new territory, amounting to some 4 million km^2 around the coastlines of Europe and the Mediterranean, and at least 20 million km^2 at the global scale, became available for terrestrial plants and animals and, of course, for human populations. Much of that territory most likely represented some of the most fertile, well-watered and ecologically diverse land

G.N. Bailey (✉)
Department of Archaeology, University of York, the King's Manor, York YO1 7EP, UK
e-mail: geoff.bailey@york.ac.uk

J. Harff
Institute of Marine and Coastal Sciences, University of Szczecin, Mickiewicza 18, PL 70-383 Szczecin, Poland

D. Sakellariou
Institute of Oceanography, Hellenic Centre for Marine Research,
46.7 km Athinon-Souniou Av, Anavyssos, P.O. Box 712, 19013 Athens, Greece

G.N. Bailey et al. (eds.), *Under the Sea: Archaeology and Palaeolandscapes of the Continental Shelf*, Coastal Research Library 20, DOI 10.1007/978-3-319-53160-1_1

available, especially given the relatively arid climates that persisted during glacial periods. These coastal lowlands and their immediate environs presumably supported denser concentrations of human settlement than the more remote continental hinterlands where most of the currently-known surviving evidence of the Stone Age era has been recovered.

The last period of high sea level was about 130,000 years ago during the Last Interglacial period, commonly referred to Marine Isotope Stage (MIS) 5. As the continental ice caps grew again in the succeeding millennia, sea level dropped, reaching a maximum depth of −130 m at the Last Glacial Maximum 20,000 years ago. When the ice started melting, sea level rose again, progressively drowning these ancient landscapes, their coastlines and the material traces of their previous inhabitants until the present level was reached about 6000 years ago. This long period of lowered sea level spans some of the most important developments in human prehistory: the emergence and world-wide dispersal of anatomically modern humans with new technologies, skills and cognitive abilities; early experiments in sea travel including the earliest colonisation of New Guinea and Australia; exploitation of shorelines, marine resources and offshore islands; and the early development of agriculture and its dispersal around the coastlines and islands of the Mediterranean and NW Europe. It must follow from the history of sea-level change that a very significant part of the evidence for these developments lies hidden on the continental shelf.

In the past decade, the expanding industrial and commercial exploitation of the seabed, our growing knowledge of the inexorable and continuous effect of changes in sea level and climate on human affairs, and the development of national legislation and international conventions to protect the underwater cultural heritage, have all combined to focus attention on the potentially valuable archives of cultural and natural data locked up on the seabed of the continental shelf.

These underwater archives are of great interest and relevance to many different disciplines and constituencies—to archaeologists interested in the long-term record of human development and dispersal, to climatologists interested in obtaining well-dated index points for low sea-level stands to develop better predictive models of sea-level change, to geomorphologists interested in processes of coastal change and large-scale patterns of erosion and sedimentation, to geophysicists and geologists interested in the dynamics of plate motions and changes in the Earth's crust, to governmental agencies and heritage organisations charged with managing and protecting the underwater heritage, and to a wider public perennially fascinated by the idea of lost civilizations slipping beneath the waves.

Alongside this growing interest, industrial exploitation of the seabed has intensified. Beam-trawl fishing, drilling for oil and gas, sand and gravel extraction, laying of pipelines, building of wind farms, and engineering works associated with new harbours, bridges, tunnels and other infrastructure all pose a threat to the cultural and natural features of the pre-inundation landscape, to say nothing of natural changes in the underwater environment that lead to erosion or burial of ancient land surfaces. At the same time, as on land so underwater, these destructive processes can also have a potentially positive effect in exposing to discovery material that would otherwise remain deeply buried and hidden from view.

It was with all these factors in mind that the European SPLASHCOS research network came into being in November 2009 (COST Action TD0902 SPLASHCOS—Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf), originating from an earlier series of meetings in 2008 and early 2009 to discuss ways of raising large-scale research funding for a pan-European research project entitled Project Deukalion (see Flemming et al. 2017). From the beginning, the SPLASHCOS network was organised around the need to address simultaneously not only the scientific evidence, both archaeological and palaeoenvironmental, but also issues of training, public outreach, management and industrial collaboration.

The chapters in this volume cover all of the above topics, and are organised around five principal themes that move progressively from method to interpretation, and from the study of individual sites to the wider landscape setting, beginning with a discussion of techniques and research strategies (Part I), progressing to examples of underwater archaeological investigation (Part II) and palaeolandscape reconstruction (Part III), moving on to issues of interpretation in relation to broader themes in prehistory (Part IV), and concluding with examples of wider public outreach and management (Part V). The organisation is thus primarily thematic, but with a subsidiary axis of organisation whereby chapters dealing with geographically neighbouring regions are put together, wherever possible and appropriate. The divisions between these major Parts or sections are not, of course, watertight, and some issues recur in different sections. In this introductory chapter, we highlight important issues that arise from the chapters in each section, cross-referencing wherever possible those topics that occur in more than one section.

1.2 Techniques and Strategies

The chapters in Part I address the three key questions that are usually the first to be raised by the interested outsider or the novice investigator. (1) How do we set about finding underwater traces of the submerged landscape and its archaeology, given the specialised skills and the costly technology required and the rarity of upstanding features that can be easily spotted on the seabed? (2) What are we likely to find preserved under water, given the likelihood of damage and destruction, or burial under marine sediments, during and after inundation by sea-level rise? (3) Having found a target, whether a landscape feature such as a palaeo-river channel or traces of an archaeological settlement, how do we extract the evidence for dating and other analytical investigations, and in the case of an archaeological site how do we conduct excavation to the same standards as on dry land?

Chapter 2 provides the first step in seeking answers to these questions, presenting a comprehensive review of the varied technologies available for underwater investigation. As Missiaen et al. emphasise, the challenge is considerable, with needs that range from survey and detection of submerged landscapes extending over thousands of square kilometres at one end of the scale, to discovery of tiny artefacts such as microlithic stone arrow heads at the other. Diving surveys, acoustic techniques and drilling or coring of sediments play a major role, augmented by underwater photography, airborne and satellite remote-sensing, and the development of underwater vehicles and robotics. New technologies and equipment are under continuous development, much of it driven by the needs of commercial exploitation of the seabed and the need to investigate deeply buried geological structures. Moreover, discovery of landscape features and especially archaeological remains often requires more sensitive instrumentation capable of producing high resolution images of shallow deposits and materials. Increasingly, the particular requirements of archaeological and geoarchaeological investigation are stimulating the development of new technological solutions. For example, during the course of the SPLASHCOS meetings, discussions between specialists in acoustics and archaeology led to pioneering experiments in the development of sensitive remote-sensing techniques for detecting buried flint artefacts (Hermand et al. 2011). These experiments are ongoing with underwater excavations currently in progress to test the validity of the acoustic signatures (Ole Grøn, pers. comm., 2016).

Turning from methods of detection and discovery to the question of what might survive inundation, the issue of sea-level change becomes paramount. There is now an extensive and growing body of knowledge about the rate and pattern of sea-level rise and fall during the Last Glacial (and earlier)—both absolute changes resulting from changes in the volume of sea water in the world's oceans, and relative changes resulting from vertical movements of the Earth's crust (e.g., Lambeck et al. 2002, 2014; Harff et al. 2017a, b). From the geoarchaeological point of view, it is not so much the rate of vertical movement that is important during sea-level rise as the rate of shoreline retreat in the spatial dimension. This in its turn is a complex function of the interaction between relative sea-level rise, the slope of the continental shelf and locally and regionally variable topography. Chiocci et al. address this issue in detail in Chap. 3 and develop an algorithm for measuring 'transgression velocity', the rate of shoreline retreat (or advance when sea level is dropping). This measure can be applied at different geographical scales depending on the detail and accuracy of the available information. The examples presented highlight significant variation at every geographical scale with important implications for evaluating the human impact of sea-level change and some predictive power in identifying areas most likely to have preserved material in the face of inundation.

The next challenge that has to be faced is the sheer complexity and cost of the technology needed, especially if it requires large research vessels and ship time. One solution is to enlist the cooperation of industrial companies engaged in exploitation of the seabed. Provided that archaeologists and government agencies engage with industry at an early stage in the planning process, the incorporation of underwater research can be achieved with minimal interruption to the timetable of the commercial operation. The scientific work gains enormously from free access to equipment and resources, and sometimes from direct financial contributions to research personnel and analytical work, the costs of which would otherwise far exceed even the most generous scientific grants, but which represent a relatively minor amount in relation to the total budget of the industrial operation. Commercial companies in their turn gain good publicity and can point to the wider educational and social benefits of the collaboration. Some excellent examples have taken place in NW Europe in recent years, for example with North Sea oil companies and with the Port of Rotterdam authority, producing quite spectacular and unexpected results generating wide interest and publicity (see also Glorstad et al. Chap. 19, Gaffney et al. Chap. 20, Momber and Peeters, Chap. 21, Satchell, Chap. 25, Sturt et al. Chap. 28).

Homlund et al. describe another type of commercial collaboration in Chap. 4, between an archaeological research institute and a company that provides commercial technological services in underwater investigation. The examples they present offer an illuminating illustration of the benefits of long-term collaboration, the technologies that can be deployed in underwater research, the results that can be achieved, and how such collaboration can be developed to mutual advantage at little extra cost, not only generating wider publicity for the commercial company involved, but stimulating new technological solutions in response to the demands of archaeological investigation that can have subsequent commercial application.

Not all underwater research requires big ships and big budgets. The last two chapters in this section (Chaps. 5 and 6) give good examples of what can be achieved in shallow water with divers and relatively simply equipment. Both projects were carried out as part of the SPLASHCOS training programme and provide good examples of the various constraints that limit the discovery and investigation of underwater archaeological sites, detailed guides as to how to go about conducting underwater excavation, the techniques and technologies required, and something of the detail and quality of material that can be preserved in underwater anaerobic sediments. They also demonstrate the importance of training and capacity building (see also Satchell, Chap. 25).

Denmark and Sweden are the pioneering countries for developing underwater research on submerged remains of prehistoric archaeology, as Uldum et al. emphasise in Chap. 5, with a long history of systematic investigation going back to the 1970s (Fischer 1996; Skaarup and Grøn 2004; Andersen 2013, see also Skriver et al. Chap. 8, Larsson, Chap. 11). In Denmark, professional archaeologists, with the support of the government agency responsible for the cultural heritage, currently known as the Danish Agency for Culture and Palaces, have over a long period developed protocols of investigation that include regular inspection of shorelines aided by reports from members of the public, methods of site monitoring and excavation, and predictive modelling of site discovery that takes account both of coastal locations attractive to prehistoric people and also of preservation conditions. The outcome is the discovery of many hundreds of underwater Stone Age finds, the largest concentration in the world, including well-known underwater settlements with unusual preservation of organic artefacts such as Tybring Vig and Møllegabet II.

The discovery and investigation of the Falden site described in Chap. 5 was the result of active exploration and test excavation made possible by the funding of a SPLASHCOS training exercise. The authors draw attention to the importance of public engagement and note that the majority of Denmark's underwater finds have been discovered by members of the public. Monitoring and reporting of chance finds, however, have their limitations. Lack of research funds except for rescue excavations of important finds under threat of destruction by new engineering developments, reporting only of those finds that are visible because of erosion near the modern shore, and lack of time and money for intrusive excavation or more extensive underwater survey, all mean that the many underwater sites in the Danish government records may represent a quite biased picture of the original site distribution.

Exploratory work at Falden included hand-fanning of sediments and test-pitting in an area deemed potentially productive of preserved prehistoric material. A 10-day test excavation revealed a site with undisturbed deposits rich in flint artefacts in an area that had not previously given any such indications. The training programme also made possible experimentation in methods of photogrammetry and computerised imagery, with great potential for future development and use elsewhere. Uldum et al. emphasise the importance of funding systematic investigation of sites such as Falden in correcting and advancing existing knowledge—and in protecting undisturbed sites from further loss and destruction—even if the resulting material is not as spectacular as the more famous sites. Above all, they emphasise the need to provide a sustained international training facility that can promote understanding and expertise. This is important not only for those intent on a research career but for those destined for employment in cultural-heritage organisations and government agencies responsible for informed evaluation and management of the underwater cultural heritage.

Underwater investigations have as long a history in Israel as in southern Scandinavia (Raban 1983), and have produced evidence of comparable importance. The 9000-year-old Pre-Pottery Neolithic site of Atlit-Yam, described by Galili et al. in Chap. 6 was first discovered in 1984 and has been subject to regular inspection and periodic excavation over a long period. It is arguably one of the best-known and best preserved underwater prehistoric sites in the world, with its remarkable evidence of a fishing-farming village with stone-structures and stone-lined wells. The details set out in Chap. 6 are an object lesson in the preparatory work, procedures and methods required for systematic excavation of an underwater settlement.

One of the interesting aspects of the Atlit-Yam site is the circumstances of its discovery. Originally buried under a protective layer of marine sand, the site is intermittently exposed by storms that temporarily remove the overlying cover. The time-window of opportunity for discovering the archaeological remains is clearly quite limited before they are either covered again by sand, or are destroyed and damaged by prolonged exposure to underwater currents. Discovery therefore depends to a very large degree on chance. But the chances can be improved by regular monitoring, whether by professional underwater archaeologists, sports divers, fishermen or other members of the public.

1.3 Underwater Archaeological Sites

Part II provides a range of examples of projects that amplify the results of the Falden and Atlit-Yam case studies, illustrating the various ways in which underwater archaeological sites are discovered and excavated, and the scientific impact of the resulting discoveries.

Examples of the ways in which material is exposed to discovery include: removal of sand cover by seasonal storms (Chap. 7, see also Chap. 6); commercial sand extraction (Chaps. 7 and 9); reporting of chance finds of artefacts or submerged tree trunks by sports divers (Chaps. 7, 9 and 10); expansion of harbour facilities, bridge building and other offshore constructions (Chaps. 7 and 11); dredging of marine channels (Chap. 11); natural erosion of overlying sediments by marine currents (Chap. 8); and scientific sampling of the sea bottom for zoological or other scientific investigations (Chap. 11). Additional examples of excavation and recovery methods include coring and auguring, the use of divers to excavate gridded trenches, and the application of induction dredges for removal and sieving of deposits.

These chapters also provide a range of examples of the types of evidence that can be recovered from submerged settlements, evidence of importance both to archaeological interpretation and to the development of more precise chronologies of sea-level change—and evidence that would rarely if ever be preserved on terrestrial sites.

In Chap. 7, Galili et al. present detailed findings from a group of eight Pottery Neolithic settlements discovered in the shallow offshore and intertidal zone of the Israeli coastline. As with the earlier Pre-Pottery Neolithic site of Atlit-Yam discussed in Chap. 6, the results present an extraordinarily diverse and well-preserved assemblage of artefacts, food remains and structures, including wooden implements and containers, basketry, stone- and timber-lined wells, house foundations, the earliest currently known evidence for olive-oil production, and a large group of human burials. The excellent conditions of preservation and the spatial mapping of site features over a considerable area also highlight one of the factors that may have led to the creation of separately demarcated burial grounds or cemeteries. In the relative confines of a narrow coastal strip, excavation in order to construct wells, house foundations and other structures, perhaps added to by the need for regular removal and renewal by a shifting shoreline, would have regularly disturbed the remains of earlier burials interred in domestic surroundings, leading to competition for sub-surface space and hence eventually to the need for separately defined sacred and domestic areas.

In Chap. 8, Skriver et al. present the results of recent investigations at Hjarnø Sund, another good example of a site first identified because of artefacts observed eroding out of intact sediment near the present shoreline. A small-scale excavation revealed a rich collection of flint, bone, antler and wooden artefacts, typical of other underwater Danish sites, and two other features more rarely recovered. The first is two wooden paddles with paintwork still preserved. Similar paddles have been recovered from two other Danish underwater sites, and the addition of the Hjarnø examples highlights regional differences in design. The authors suggest that these differences might indicate markers of different social or individual identities, especially since paddles would be highly visible artefacts and ones widely travelled during canoe journeys. The other feature is the presence of shell-midden deposits. These are common on shorelines above present sea level, often accumulating numerous thick mounds, most famously in the late Mesolithic Ertebølle examples of Denmark itself. However, underwater examples are rare, with only a few known—from the Danish site of Møllegabet II (Grøn 2004, pp. 41–45) and isolated examples in other parts of the world Faught 2014, pp. 43–44, Hayashida et al. 2014, pp. 283–284)—perhaps because unconsolidated shell deposits are especially vulnerable to erosion and destruction by wave action, or simply through lack of underwater survey. The Hjarnø Sund evidence demonstrates that shell deposits can survive if covered with a layer of protective sediment, but equally that they are vulnerable to rapid erosion by water currents once exposed.

Similar underwater conditions to Denmark are found in the German territorial waters of the western Baltic and in recent years these have begun to produce a comparable range and richness of underwater material (Harff and Lüth 2011). New discoveries from the Strande site LA 163 near Stohl Cliff in the Kiel Bay are presented by Goldhammer and Hartz in Chap. 9 and add to that growing body of information. The site has yielded a typically varied collection of artefacts made of stone, bone and wood, remains of a log boat, plant remains, shells of edible marine molluscs, animal bones including freshwater and marine fish, sea birds and land mammals, and fragments of human bone. Rapid survey over a larger area including the removal of the sand cover shows that more extensive terrestrial sediments with archaeological potential lie beneath the marine sand. Here, as at Hjarnø Sund, preliminary investigations have revealed the potential for the survival of more extensive and substantial archaeological deposits and the need to fund more detailed excavations if valuable material is not to be lost.

In addition, radiocarbon dating and high precision dendrochonological dating of the abundant wooden remains at Stohl Cliff have given a precise measure and date of sea level position. Similar evidence is present at the nearby location of Friedrichsort in the Kiel Fjord, and is discussed by Feulner in Chap. 10. This site is of interest in demonstrating the value of regular monitoring by an archaeological diver, and the preservation of intact sediments in a location subject to disturbance by regular ship movements. As at Stohl Cliff, the first indication of a submerged land surface was the discovery of remains of a submerged forest. Radiocarbon dating of a sample from a tree stump adds to the growing evidence of sea-level change in the area, and points to the possibility of discovering intact and well-preserved archaeological remains, given the frequent association of submerged forests and artefacts (e.g., Homlund et al., Chap. 4, Hansson et al. Chap. 13).

Finally, in Chap. 11, Larsson, who was involved in some of the earliest underwater work in southern Scandinavia in the 1970s and 1980s, brings together the results from a number of underwater discoveries in the Öresund Strait that separates Denmark and southern Sweden. None of these are individually spectacular or especially well-preserved, but in their collective totality they demonstrate how the cumulative growth of information from different underwater locations, combined with regional reconstructions of changing shorelines and palaeogeography, can lead to new interpretations at a regional scale of spatial and temporal patterns in the distribution of settlements, anticipating a theme that is developed in greater detail in Parts III and IV. Coastal settlements are notoriously absent from the earlier Holocene record, as in so many other regions, not least because the shorelines are mostly submerged and under-investigated, but perhaps also because earlier peoples showed less interest in coastal and marine resources. Hints of an earlier coastal interest are present from the terrestrial record in Sweden—coastal sites on uplifted shorelines further north, and hints of early contacts with the coast in the form of occasional marine shells and other marine indicators in inland sites. However, it is the underwater record that has provided fuller archaeological evidence of early coastal settlements, even if the evidence is not yet sufficient to show whether marine and coastal resources were exploited with the same intensity as demonstrated in the later coastal sites on shorelines above present sea level. In any case, interpreting the changing intensity of exploitation of coastal and hinterland resources, and their relative palaeoeconomic importance, is greatly complicated by the fact that the available environments and resources on the coast and in the hinterland in southern Scandinavia were continuously changing because of postglacial changes in climate, environment and forest cover (see also Hansson et al. Chap. 13, Glorstad et al. Chap. 19). Large samples of environmental and archaeological data from many points in time and space will be necessary to unravel these changing relationships, and further underwater research has a vital role to play.

One final point of interest in this Chapter is that one of the best known Mesolithic coastal settlements in southern Scandinavia on the present shoreline, including evidence of numerous human burials, the Swedish site of Skateholm II, was flooded by sea level rise and then exposed again because of land uplift, giving some insight into how well different sorts of materials survive inundation. In this case, interestingly, the human graves, perhaps because they were buried and covered over when first created, seem to have survived better than the remains from domestic activities.

Two final comments arise from a consideration of these chapters as a whole. The first is that they are dominated by evidence from just two major geographical centres: the coastlines of the western Baltic, especially Denmark; and the Mediterranean coastline of Israel. It could be argued that this results from uniquely favourable conditions for underwater archaeological preservation and discovery in these two regions. However, that is far from demonstrated. Rather, what the present concentration demonstrates is the importance of long-term engagement. Both regions have a long history, extending over many decades, of interest in and development of protocols for regular monitoring and recording of finds as they become exposed, in the refinement of methods of underwater survey and excavation, and in the continuity of expertise and interest sustained by the dedication of key individuals.

Conditions of survival and discovery are unlikely to be uniformly similar around all the coastlines of Europe—or indeed further afield. Nevertheless, increasing numbers of underwater finds are beginning to appear elsewhere (some are referred to in later chapters of this volume). There is no reason to doubt that similar settlements as substantial as the best-known from Israel and Denmark will eventually be forthcoming from other regions, and every reason for optimism given the number of new finds that are now appearing elsewhere—off almost every coastline in Europe (see the online data base at http://splashcos-viewer.eu/). Long-term scientific engagement and funding support, encouragement of public interest, regular offshore monitoring to check for the appearance of new finds, and training programmes for the next generation stand out as key ingredients for future success.

The second comment is that all the examples so far considered are from the early Holocene, and that is for the simple and obvious reason that the submerged shorelines of this period belong to the final stage of postglacial sea-level rise and are therefore relatively shallow and easily accessible to inspection on or close to the modern shoreline and by diving in shallow water. What about earlier and more deeply submerged shorelines? What if sites like Atlit-Yam and Tybrind Vig existed 25,000 or even 60,000 years ago, and now lie hidden on these earlier shorelines? Galili et al. (Chap. 6) address this question and suggest that the likelihood of encountering preserved prehistoric settlements decreases with depth: because of the technical challenges of working beyond the limit of SCUBA; because shorelines would have been exposed for shorter periods before inundation by sea-level rise; and because the remains left by hunter-gatherer activity might have been more ephemeral. The technical challenges of working at much greater depths are formidable and should not be played down. But there is no reason to suppose that periods of low sea-level at much earlier periods would not have stabilised long enough to create suitable conditions for the development of substantial and permanently occupied coastal settlements, assuming that environments and resources were available to support such a possibility, and that people were sufficiently numerous and sufficiently motivated to take advantage of it.

The belief that settlements with an elaborate material culture, permanent and substantial structures, and a sedentary way of life could not have existed 20,000 years ago (or earlier) is based on a circular argument, which assumes that the final rungs of ascent in a ladder-of-progress interpretation of human history—intensification of resources, especially marine resources, permanent village settlements, social stratification, population growth and ultimately agriculture—could not have happened before about 10,000 years ago at earliest. Why not, we might ask? Because there is no earlier evidence is the standard answer. And why is that? Because—as any informed reader must now be aware—the coastlines where such evidence would be mostly located are now deeply submerged and have scarcely begun to be investigated. We know from isolated artefacts and faunal remains recovered from the seabed that prehistoric material is preserved at great depth in the 60–>100 m depth range (e.g., Long et al. 1986; Fedje and Josenhans 2000; Stanford et al. 2014) . The discovery of settlements like Atlit-Yam or Tybrind Vig on much earlier and now deeply submerged shorelines would radically overturn current preconceptions about world prehistory, and for that reason alone should become a target for future investigation—even if we are still far from having the skills and resources to reach that target (but see chapters in Part IV for projects with that target in view).

1.4 Underwater Landscapes

The chapters in Part III move the focus of attention away from individual sites to the reconstruction of submerged palaeolandscapes at a larger geographical scale. The emphasis is mostly on geophysical and palaeoenvironmental techniques of reconstruction rather than underwater archaeological finds. Nevertheless, all the studies are motivated by archaeological questions and many involve multiple collaborations between archaeologists and geoscientists, underscoring the need to integrate many different types of expertise. They also illustrate a number of different archaeological uses of palaeogeographical and palaeoenvironmental reconstruction: as a means of identifying the distribution of significant concentrations of food resources and water supplies on the pre-inundation landscape (all Chapters); as a first step in assessing where underwater prehistoric sites and settlements are likely to be located and archaeological material is likely to be preserved (Chaps. 12, 13, 15, and 16); as a guide to the interpretation of underwater finds where they are already known (Chaps. 13 and 15); and as a means of refining the explanation and interpretation of archaeological sites and archaeological sequences on the present-day coastline (Chaps. 12 and 16).

Approaches presented in these chapters divide broadly into two categories: those that use bathymetry and other geophysical techniques to locate or infer the position of submerged shorelines and other physical features of the submerged landscape such as palaeo-river channels and physical topography (Chaps. 12 and 16); and those that use intrusive methods such as coring of sediments or sampling of speleothems, sometimes in combination with geophysical techniques, to recover dateable sequences of palaeobotanical and geochemical indicators of past environmental and climatic conditions (Chaps. 13, 14, 15, and 17). In an ideal world, the full range of geophysical and palaeoenvironmental techniques would be combined. However, the extent to which that is possible or necessary will depend on the nature of the offshore topography, the balance between sedimentation and erosion on the submerged shelf, the budget available to the research team, the availability of relevant equipment and expertise, and the nature of the archaeological problems to be addressed.

One important point about underwater mapping emphasised by Bicket et al. in Chap. 12, and one that recalls the approach developed by Chiocci et al. in Chap. 3, is that datasets of bathymetry or other underwater features are often already in existence and publically available and can be exploited to good effect (a point also made by Goldhammer and Karle in Chap. 15). In this Chapter, the authors show how far one can go in using existing data to map the changing configuration of coastlines and sea channels of relevance to routes of travel and communication by sea, to identify broad-scale changes in shoreline geomorphology and resource potential such as the varying width of the intertidal zone or the balance between rocky and sandy shores, to make sense of the location of existing settlements on the present shoreline, and to assess underwater areas promising for future exploration. Such publically available datasets, because they have usually been collected for other purposes, may not be ideal in their detail or resolution for archaeological purposes. Local shoreline positions taking account of glacio-isostatic movements may have to be estimated by reference to more generalised models of relative sea-level change (see also Harff et al. 2017a), so too the depth and character of the seabed in the absence of sub-bottom profiles. Nevertheless, such data provide usable information for many purposes, and a guide to where more detailed and localised investigation would be worth pursuing.

In Chap. 13, Hansson et al. provide a good example of how geophysical measurements and coring of sediments can be integrated to provide a detailed, high resolution reconstruction of environmental conditions on the submerged palaeolandscape. Detailed examination in this case was made possible through the collaboration of geoscientists, marine geologists and archaeologists with access to commercial ships and equipment and was focussed by the existence of already-known underwater archaeological remains (see also Holmlund et al. Chap. 4). One point that emerges very clearly from this presentation is the extraordinarily complex, dynamic and often subtle changes of shoreline configuration, environments and hydrogeological regime associated with the final stages of deglaciation and global sea level rise in the study area. The complexity arises from the interaction between sea-level rise, melting of ice barriers, regionally variable isostatic adjustments, and periodic damming back or release of Baltic waters. Such complexity places a high premium on the location, accuracy and detail of geophysical reconstructions and dateable palaeoenvironmental sequences.

Another point of interest, given the claims that have been made in other regions, notably the Black Sea, for catastrophic flood events and their human impact (Ryan et al. 1997; Lericolais et al. 2009; Yanko-Hombach et al. 2011), is the evidence in the western Baltic region for periodic, rapid and dramatic changes of water level through an amplitude of up to 25 m. As the waters of the Baltic were periodically dammed back to create a vast freshwater lake and then released again to connect with the world oceans, so they created large areas of newly exposed coastal lowland territory, only to flood them again, a sequence that occurred on at least two occasions over a period of less than 2000 years. Such a rapid complex of changes must have occasioned almost continuous disruption, re-adjustment and adaptation of settlement patterns and subsistence strategies for the human populations of the region, no doubt with more far-reaching social and demographic consequences.

This theme of dynamic and rapid change carries through to the work described in the following two chapters, both of which integrate a variety of geophysical and palaeoenvironmental techniques and reconstructions. Hepp et al. in Chap. 14, in another example of combined geophysical and palaeoenvironmental analysis, demonstrate what can be achieved by way of reconstruction over quite extensive areas, focussing on the submerged rivers systems of the ‘Duck’s Beak’, which connected with the Palaeo-Elbe Valley, and the slightly later Palaeo-Ems. These are both part of a major system of river channels which drained northwards from the NW German land mass into the vast territory of ‘Doggerland’ exposed at lowered sea levels in the southern part of the North Sea Basin (see Glorstad et al. Chap. 19, Gaffney et al. Chap. 20, Momber and Peeters, Chap. 21). These valley systems would almost certainly have been a major focus of attraction for late Upper Palaeolithic populations already established in NW Europe during the closing stages of the Last Glacial, and most probably major arteries of communication, movement and animal migration (see Fischer 2004).

Karle and Goldhammer in Chap. 15 examine the southern rim of the North Sea, the Wadden Sea, one of the largest coastal and intertidal wetlands in the world. Here, because of long-term subsidence of the North Sea Basin, the sea has continued to encroach on dry land up to the present day, accompanied by rapid accumulation of marine, fluvial, estuarine and terrestrial sediments in a complex and ever-changing mosaic of drainage patterns and environmental conditions. The authors focus on the German sector of the Wadden Sea, between the estuaries of the Ems and Elbe Rivers, and thus complement the deeper offshore research of Hepp et al. discussed in Chap. 14. The approach adopted here is to exploit existing datasets including seismic profiles, borehole data representing some 3000 cores, geological and historical maps, nautical charts, and databases of archaeological finds. The primary output is environmental reconstruction with archaeological objectives: to audit the status of the information currently available with a view to ensuring effective management of the cultural heritage; to aid the interpretation of existing archaeological material; and to assess the potential for future discoveries and the most likely target locations.

Most of the known archaeological material, which is recorded from over 100 locations ranging from settlement data to individual finds, belongs to the past 2000 years, and that reflects the rapid rate of sedimentation and the fact that only the most recent millennia of the archaeological sequence have left a visible mark in the present-day offshore and intertidal mudflats. Much of that archaeological record is of intrinsic interest in demonstrating the various ways in which people attempted to protect themselves against encroaching flood waters, for example by building artificial mounds and constructing dykes. The corollary, of course, is that earlier material, particularly from the Stone Age, must be more deeply submerged beneath a thick overburden of later sediments, posing a considerable challenge to future discovery. Nevertheless, the authors point out that their mapping work has already led to the discovery of a previously unknown site, a 300-year-old farmstead destroyed by flooding, and to other locations with high archaeological potential where investigation should be carried out in advance of any offshore engineering or construction work.

Chapter 16 switches attention back to the Mediterranean and to the very different offshore conditions of the south Italian coastline, where steeper topography, predominance of erosion over sedimentation and tectonic activity pose very different challenges in assessing the effects of sea-level change on coastal topography. In this Chapter, Scicchitano et al. bring together a wide variety of geophysical and archaeological data to examine the relationship between coastline change and evidence of changing belief systems and social identities associated with a rich sequence of archaeological sites on the present-day coastline extending from the Neolithic through to the historical period. A combination of publically available mapping data, specially commissioned LiDAR and bathymetric survey, the use of underwater vehicles, isostatic modelling, and dating of uplifted sea-level indicators shows how a commanding promontory with a major settlement became progressively isolated and ultimately cut off from the mainland with corresponding changes from residential to ritual activity.

Finally, in Chap. 17, Radić Rossi and Cukrov highlight the significance of freshwater supplies located deep in coastal caves formed in karstic limestone country. The caves usually have a connection with the sea even if their entrances are above modern sea level. Accumulated freshwater floats on the surface of seawater and many of these freshwater sources are well below present sea level. Over 100 such caves are present in Croatia alone and they are well known to seafarers and the local inhabitants as a source of freshwater and in some cases for their medicinal benefits because of the presence of trace quantities of chemicals such as sulphur. They play an important role in supporting settlements in arid regions, and archaeological data within some caves show that they have been exploited since at least the Bronze Age. Many have been submerged since the time of formation and dating of speleothems provides evidence for the history of their formation and index points for refining sea-level curves. Little research has been devoted to their archaeological significance despite their potential importance. One intriguing question is how widespread they were during periods of low sea level. There is considerable interest in the significance of coastal springs in reinforcing the attractions of coastal regions during periods of low sea level when climate conditions were generally more arid (Faure et al. 2002, see also Bailey et al. Chap. 23). Anchialine caves in karst regions close to palaeo-shorelines could have further enhanced these attractions.

1.5 Landscapes of the Continental Shelf and Human Dispersals

In Part IV, discussion moves out onto a much broader geographical canvas, looking at whole sections of the continental shelf and deploying a range of archaeological, geophysical and palaeoenvironmental data and techniques, including more ambitious explorations of more deeply submerged landscapes. The central problem that motivates all these chapters is the grand theme of early human dispersals. This refers for the most part to human range-expansion into wholly new territory by our immediate ancestors, anatomically modern members of *Homo sapiens*, believed according to the current consensus to have originated in Africa and to have spread out from there at some time after about 200,000 years ago. This theme can also extend to include much earlier expansions from an African centre of origin by earlier members of the genus *Homo*. Range expansion may refer to territory never previously occupied, such as the Americas and Australia, territory made available again for human occupation after periods of abandonment, for example the recolonization of NW Europe following deglaciation, or territory already occupied by earlier human populations. The term may also refer, secondarily, to later colonising movements, for example the expansion of Neolithic farmers into European landscapes with already established hunter-gatherer populations. Since these processes of dispersal, for the most part, were in train when sea level was lower than present, they cannot be properly understood without systematic investigation of the submerged landscape, a point made by Flemming in Chap. 18 which provides a world-wide review of the issues relating to *Homo sapiens* dispersal.

As Flemming emphasises, an important source of new information lies in the rapidly expanding field of palaeogenetics, which has opened up many new ideas about the timing and pathways of population dispersal. However, new and sometimes contradictory interpretations are constantly emerging from this new research field along with conclusions that have not yet been tested against independent field data. Claims that genetic similarities between modern populations living in, for example, East Africa and the Indian subcontinent, can be used to derive not only a reliable date for the timing of the earliest dispersal between the two continents, but also the specific geographical pathway of movement—usually expressed as the shortest distance that can be drawn between them on a small-scale map—look over-optimistic and open to challenge. Uncertainties about the uniformity of mutation rates, methods of inferring dates that are subject to margins of error much greater than those typically associated with radiometric dates, the possibilities of multiple dispersals, overprinting of earlier genetic signatures by later dispersals, two-way movements and alternative geographical pathways, all need to be factored into the assessment. Ancient DNA, where preserved in human bone, offers an additional refinement and a check on palaeogenetic inferences.

At any rate, there is a need here for greater communication and collaborative research between the various disciplines involved, and especially more intensive research on the changing configuration of palaeoshorelines and palaeoenvironments on the submerged landscapes of the continental shelf, and a wider understanding of their significance. In his review, Flemming assesses what is currently known about all the relevant shelf areas in relation to these issues and the likelihood of further discoveries, drawing on the experience of submerged landscape reconstructions in Europe, and focussing on the key regions of particular significance for early human dispersal: the Mediterranean, the Red Sea, SE Asia, Australia-New Guinea, and Beringia.

Chapters 19, 20, and 21 form a group that deals with different aspects of 'Doggerland', the large area of the southern North Sea that united Britain, southern Scandinavia and the NW margins of continental Europe into a single territory during glacial periods, and which was progressively flooded by sea-level rise during the late Pleistocene and early Holocene. Since Coles (1998) first coined the term Doggerland and reviewed the existing evidence, new investigations have taken place, most notably the work of the Birmingham North Sea Palaeolandscapes Project (Gaffney et al. 2007, 2009). Palaeoenvironmental reconstructions and the recovery of artefacts and terrestrial fauna dredged up from the seabed by commercial operations all point to this region as a major focus of human settlement, and of movement and communication between the adjacent land masses.

Chapter 19 examines the timing and pathways of population expansion along the Norwegian coast following deglaciation. This issue is of particular significance because an ice-free corridor seemingly suitable for human occupation and accessible either from Doggerland or from southern Sweden and Denmark became available as early as 16,000 years ago, but there is no reliable archaeological evidence of settlement until about some 5000 years later (Bjerck 2008). One explanation for the time lag is that populations already established to the west and the south were primarily reindeer hunters, and that it would have taken time for them to adapt to the new conditions and develop the skills and motivation necessary to develop a way of life dependent on sea-mammal hunting and seafaring, both necessary for successful colonisation of the northern Norwegian coastline.

Glorstad et al. suggest a simpler explanation. Taking advantage of an evaluation project financed by the Norwegian Government in advance of offshore wind-farm construction, and exploiting already existing seismic profiles and bore-hole sediment data made available by oil companies working in this sector, they were able to reconstruct the sequence of landscape changes associated with the most likely pathway between Doggerland and Norway, using techniques for seismic profiles pioneered by the North Sea Palaeolandscapes Project referred to above. Their results demonstrate that this route would always have been blocked, initially by an ice-dammed lake and then by a marine channel in the vicinity of the present day Norwegian Trench, both too wide to be easily crossed by boat. To the south, the principal access route was blocked by an ice barrier, and it was only when that melted that easy passage northwards became available at about the time when archaeological evidence of settlement further north first appears.

In Chap. 20, Gaffney et al. outline the objectives of the newly funded Lost Frontiers Project to carry out more extensive reconstruction of the early Holocene Doggerland landscape, following on from their original work in the North Sea Palaeolandscapes Project. In the new project, they aim to bring together all the available seismic data to provide a comprehensive topographic mapping of the region, and to conduct a programme of coring in two target areas with evidence for well-established early Holocene river networks. The plan is to recover 100 cores and to conduct a range of dating and palaeoenvironmental analyses of their contained sediments.

One important innovation is the analysis of traces of ancient DNA incorporated in the sediments (sedaDNA) for clues to the plants and animals present on the now submerged palaeolandscape. Pilot research on sedaDNA has already been conducted at the submerged Mesolithic site of Bouldnor Cliff on the English south coast (Momber et al. 2011). The Bouldnor site, excavated over a period of many years by Garry Momber and his team, and referred to in the following chapter, is equivalent in importance to the Danish sites referred to earlier and elsewhere in this volume. Recent sedaDNA analysis there has established the presence of cultivated wheat in deposits sealed by later marine sediments, demonstrating the introduction of domestic cultigens from Europe at a much earlier date than previously suspected. This and the presence of Neolithic pottery recovered from the floor of the North Sea suggest that early farmers were already moving into this region before it was fully inundated by sea-level rise. Hence, another focus of this project will be to explore the significance of the Doggerland submerged landscape and the impact of its changing configuration on the socio-economic transitions associated with the spread of farming and the Mesolithic-Neolithic transition.

The theme of changing social and economic interactions and patterns of population movement and cultural diffusion is taken up by Momber and Peeters in Chap. 21. They examine the role of Doggerland in relation to the surrounding countries at a broad regional scale, looking at late Upper Palaeolithic and Mesolithic culture groupings and the mosaic of their changing distributions against the changing pattern of climate and sea-level change from 16,000 years ago onwards. They draw on recent archaeological discoveries both on existing coastlines and below modern sea level, particularly the underwater sites of Bouldnor Cliff on the English south coast and the Yangtze Harbour finds on the Dutch side of the English Channel (see Satchell, Chap. 25), to identify links and patterns of dispersal and communication as sea level rose. These include connections across the south of Doggerland from the earliest period after glacial retreat, early connections between Scotland and northern Europe perhaps involving seafaring around the northern coastlines and estuaries of Doggerland from as early as early as 12,000 years ago, and growing evidence in the Mesolithic of maritime connections around the coasts and archipelagos of northern and western Britain after about 10,000 years ago.

Also at about 10,000 years ago, semi-sedentary Mesolithic settlements with hut structures and a mixed terrestrial-marine palaeoeconomy appear on the modern coastline in northern Britain (where earlier shorelines are visible because of land uplift compared to southern Britain). The authors raise the interesting question of whether this phenomenon represents a new phase of intensification and adaptation to the loss of lowland territory with progressive sea-level rise, or is simply the first visible evidence of an adaptation that was already present at an earlier period on the now submerged coastlines of Doggerland—a question that cannot be resolved without further underwater investigations.

Dating from a little later, the Bouldnor Cliff site on the English south coast, with its well-preserved underwater finds, has evidence of precocious skills in axe manufacture, wood-working technology, including wooden structures and possible boat-construction, and DNA evidence for the presence of cultivated wheat (also discussed by Gaffney et al. Chap. 20) substantially earlier than elsewhere in Britain. These indicate close connections with France at a time when easy travel by boat between southern England and France was still possible around sheltered coastlines and estuaries before sea-level rise finally breached the land connection between the two regions.

The remaining chapters in this section move the geographical focus away from NW Europe, to the Aegean, the Red Sea, and Western Australia, all key regions in relation to early human dispersal patterns, and all with potential for new underwater research. These chapters have a common thread, which is the emphatic assertion in all three cases that the offshore environment, including the submerged landscape at lower sea levels and the marine environment created when sea level rose with its offshore islands, archipelagos and 'seascapes'—or 'aquapelagos', the term used by Ward and Veth in Chap. 24— should be treated as a coherent entity, forming a seamless whole with the adjacent mainlands, a focal centre of interest for the people who lived there as much as for the archaeological investigator.

The Aegean is of particular interest because it is on the major pathway for connections between Europe, the Near East and Africa, both for successive hominin expansions out of Africa during the Pleistocene and also for the later dispersal of farming communities, who left some of their earliest traces on Aegean islands as on islands elsewhere in the Mediterranean. The Aegean, along with Cyprus, has also provided some of the earliest evidence for seafaring—or at any rate sea crossings—in the northern hemisphere, with unequivocal evidence for a human presence on islands from at least

13,000 years ago, long before the spread of agriculture, and claims for even earlier dates on the island of Crete (Ammerman and Davis 2013–2014).

As Sakellariou and Galanidou emphasise in Chap. 22, the relative placement of land and sea, and the status of islands and their connections with—or separation from—their adjacent mainlands, have undergone dramatic changes on the Pleistocene time scale. This is not only because of sea-level change as elsewhere, but because of very active tectonics associated with the collision of the African Plate with Europe and subduction and volcanic activity along the Hellenic Trench, promoting long-term subsidence throughout the Aegean punctuated by more localised episodes of uplift. The authors tackle this puzzle by breaking the Aegean region down into nine sub-regions, and draw on available seismic, geological and archaeological data within each sub-region to reconstruct changing patterns of palaeogeography and the nature of connections and pathways of movement. As with similar mapping projects in other chapters, this exercise plays a double role, illuminating the interpretation of existing archaeological sites on land, and focussing attention on submerged areas worth closer investigation.

The southern Red Sea, discussed by Bailey et al. in Chap. 23, has acquired prominence in recent debates about the dispersal of *Homo sapiens* out of Africa as a key pathway for range expansion, following the so-called southern corridor from The East African Rift to SW Arabia and onward around the coastlines of the Indian Ocean into SE Asia and Australia. The project described here is part of a larger project designed to test these ideas, combining archaeological and landscape investigations on the mainland of SW Saudi Arabia, the Farasan Islands and the submerged shelf. Exploitation of existing core data and bathymetry combined with sea-level modelling shows that, at low sea levels, the Red Sea between Africa and Arabia would have been reduced to a narrow and easily crossable marine channel with the exposure of extensive coastal lowlands some 100 km wide on both sides. Targetted surveys with a research vessel and a full suite of acoustic, seismic and coring equipment and an ROV has demonstrated the presence of a complex topography on this submerged landscape with numerous fault-bounded basins, some of which are likely to have formed freshwater lakes, making this an important refugium during periods of climatic aridity. The results also demonstrate the very different character of the shoreline at lowest sea level. Offshore archipelagos were present that could have facilitated early experiments with seafaring and exploitation of marine resources, with further implications for possible patterns of dispersal via maritime corridors, a theme also discussed in the following chapter.

The Australian continent is the paradigm case of early sea travel as the primary means of colonising a new continent, since it would always have required sea crossings to travel from SE Asia even at lowest sea level stands. As Ward and Veth emphasise in Chap. 24, a maritime aspect to human activity was present from the very outset, with cave sites on steeply shelving or uplifted shorelines on the islands of Wallacea and the Bismarck Archipelago showing evidence of sea travel and intensive exploitation of marine resources from at least 40,000 years ago. Investigation of the offshore landscape and its submerged shorelines is therefore of more than usual importance in understanding the history of dispersal and settlement (see also Flemming, Chap. 18). In this chapter, the authors discuss the coastline of Western Australia. They are reliant mainly on bathymetry and models of sea-level change to chart the changing character of the submerged landscape. But they also have access to well-preserved archaeological sequences on a series of offshore islands that were progressively isolated as sea-level rose, as well as evidence from the adjacent mainland, giving a window into the changing character of the submerged landscape. The changing composition of food remains in these sites through time, together with evidence for the movement of raw materials for making stone artefacts, provide a measure of changing patterns of adaptation and movement in response to rising sea level, with evidence that coastlines and marine resources were important throughout the sequence. More detailed underwater work is planned to further test these conclusions.

1.6 Outreach and Management

The importance of engagement with a wider public, of training, and of collaboration with industrial companies and government agencies is a recurring theme in many of the earlier chapters. In this final section, four chapters address more fully these issues.

Satchell (Chap. 25) draws on the experience of the Maritime Archaeology Trust (MAT) in training, education and public outreach, and the initiatives developed within the SPLASHCOS Action, to identify examples of good practice. She identifies four different audiences that need to be addressed: scientists involved in coastal and underwater investigations of various sorts, who have often accumulated data archives that can be turned to advantage for archaeological purposes; commercial companies, who also often acquire data of archaeological and palaeoenvironmental value and who, in addition, need advice on how to implement national and international directives on the mitigation of damage to the underwater heritage; government agencies and planning authorities responsible for management of the onshore and offshore heritage, who can also benefit from archaeological and geological studies of coastline change; and members of the public, who ultimately pay for underwater research and help to make the wider case with local authorities and government agencies.

A key difficulty is the remoteness of underwater finds and difficulties of access especially for non-divers. However, MAT, which is also involved in the work on the submerged site of Bouldnor Cliff (see Momber and Peeters, Chap. 21) has developed a number of innovative practices for many different audiences ranging from 10-year-old school children to professional archaeologists. These include teaching packs for school teachers, writing of illustrated story books, hands-on experience with post-excavation work, and a travelling ‘Maritime Bus’ with videos, leaflets and examples of underwater artefacts, experience that has been extended more widely through collaboration with neighbouring European countries and through the SPLASHCOS network. She also gives detail on the training programmes developed during the SPLASHCOS Action (see also Uldum et al. Chap. 5, Galili et al. Chap. 6), and on a variety of initiatives in the UK setting for defining protocols to encourage commercial operators, fishermen and members of the public to record and report underwater artefacts and other features.

Tidbury et al. (Chap. 26) describe case studies that bring together evidence from underwater archaeology, palaeoenvironmental data, historical maps and archives, and old photographs and paintings to chart long-term changes in coastal geomorphology. Their approach has much in common with that described by Karle and Goldhammer (Chap. 15) with the difference that in this chapter the research is aimed primarily at providing evidence of coastal change to inform local authorities and policy makers responsible for coastal management and planning. This approach contributes to a wider research agenda in which the reconstruction of the geological past can be used for future projection of coastline change (see Harff et al. 2017b). For another example of the value of ancient maps for palaeogeographical reconstruction and the refinement of geomorphological models, see also Deng et al. (2016). The examples presented in this chapter give detail on the mapping of small-scale changes, for example in rates of erosion leading to the retreat of the coastline on a time scale of decades and centuries, as well longer-term changes in sea level, and evidence for their human impact and response.

Missiaen et al. (Chap. 27) take up the issue of the threats to the coastal and underwater heritage by intensifying commercial and industrial activity in the Belgian context, particularly in the shallow waters immediately offshore, which are especially vulnerable to damage by engineering and construction work. The authors provide interesting detail on the development of new and efficient methods of underwater survey in shallow water—a good example of how archaeological imperatives are leading to new technological solutions with practical and commercial benefits as well as archaeological ones. They also provide a useful review of the international conventions for protecting the underwater heritage and the issues involved in translating these into a workable legislative framework and in providing advice to commercial operators who have to implement it. The discussion highlights the benefits of three-way collaboration between government agencies, commercial companies and underwater archaeologists.

Finally, in Chap. 28, Sturt et al. reflect on the long-term history of developments in the study of submerged landscapes and archaeology in the English context over the past century, and what we can learn from this history in looking into the future. They bring out the very interesting history of thinking and practice extending back to the discussion of submerged forests at the beginning of the twentieth century, emphasising the changing but closely inter-twined and complex relationships between scientific and academic research, industrial exploitation of the seabed, government legislation, public interest and outreach, and the different historical trajectories of on-land and underwater archaeological research and cultural heritage management. They point to the great mutual benefits that have come about as a result of a co-evolution between these very different interests, particularly in recent decades, but also to the risk of complacency in persisting with a particular way of doing things, simply because it has worked in the past, or because of the particular technologies and datasets made available by current funding budgets or industrial activity. Deciding what scientific and archaeological questions are worth asking, and what techniques and data are needed to answer them, communication across the many boundaries between the different worlds of academic and scientific research, commercial activity and public policy, and above all the engagement of wider public interest, are all essential ingredients, as they see it, in shaping future research agendas. This final chapter usefully draws together the different strands of investigation discussed in the other chapters in this section, and indeed represents a fitting finale to the themes of the volume as a whole.

References

Ammerman AJ, Davis TW (eds) (2013–2014) Island archaeology and the origins of seafaring in the eastern Mediterranean. Eurasian Prehistory 10–11

Andersen SH (2013) Tybrind Vig. Submerged Mesolithic settlements in Denmark. Jutland Archaeological Society Publications 77. Jutland Archaeological Society, Højbjerg

Bjerck HB (2008) Norwegian mesolithic trends: a review. In: Bailey G, Spikins P (eds) Mesolithic Europe. Cambridge University Press, Cambridge, pp 60–106

Coles B (1998) Doggerland, a speculative survey. Proc Prehist Soc 64:45–81

Deng J, Harff J, Giza A, Hartleib J, Dudzinska-Nowak J, Bobertz B, Furmanczyk K, Zölitz R (2017) Reconstructions of coastline changes by the comparisons of historical maps at the Pomeranian Bay, southern Baltic Sea. In: Harff J, Furmanczyk K, VonStorch H (eds) Coastline changes of the Baltic Sea from South to East – past and future projection. Coastal Research Library. Springer, Heidelberg

Faught MK (2014) Remote sensing, target identification and testing for submerged prehistoric sites in Florida: process and protocol in underwater CRM projects. In: Evans AM, Flatman JC, Flemming NC (eds) Prehistoric archaeology on the continental shelf: a global review. Springer, New York, pp 37–52

Faure H, Walter RC, Grant DR (2002) The coastal oasis: ice age springs on emerged continental shelves. Glob Planet Chang 33:47–56

Fedje DW, Josenhans H (2000) Drowned forests and archaeology on the continental shelf of British Columbia, Canada. Geology 28:99–102

Fischer A (1996) An entrance to the Mesolithic world below the ocean. Status of ten years' work on the Danish sea floor. In: Fischer A (ed) Man and sea in the Mesolithic. Coastal settlement above and below present sea level. Oxbow, Oxford, pp 371–384

Fischer A (2004) Submerged stone age – Danish examples and North Sea potential. In: Flemming NC (ed) Submarine prehistoric archaeology of the North Sea. Research priorities and collaboration with industry, CBA research report, vol 141. Council for British Archaeology, York, pp 23–36

Flemming N, Harff J, Moura D, Burgess A, Bailey G (eds) (2017) Submerged landscapes of the European continental shelf, Quaternary palaeoenvironments. Wiley-Blackwell, Chichester

Gaffney V, Thompson K, Fitch S (eds) (2007) Mapping Doggerland: the Mesolithic landscapes of the southern North Sea. Archaeopress, Oxford

Gaffney V, Fitch S, Smith D (2009) Europe's lost world, the rediscovery of Doggerland CBA research reports 160. Council for British Archaeology, York

Grøn O (2004) Description of the dwelling pit. In: Skaarup J, Grøn O (eds) Møllegabet II. A submerged Mesolithic settlement in southern Denmark, BAR international series, vol 1328. Archaeopress, Oxford, pp 41–74

Harff J, Lüth F (eds). (2011) Sinking coasts. Geosphere, ecosphere and anthroposphere of the Holocene southern Baltic Sea II. Bericht der Römisch-Germanischen Kommission 92. Römisch-Germanische Kommission des Deutschen Archäologischen Instituts, Frankfurt a.M. Philipp von Zabern, Mainz am Rhein

Harff J, Flemming N, Groh A, Hünicke B, Lericolais G, Meschede M, Rosentau A, Sakellariou S, Uscinowoicz S, Zorita E (2017a) Sea level and climate. In: Flemming N, Harff J, Moura D, Burgess A, Bailey GN (eds) Submerged landscapes of the European continental shelf, Quaternary palaeoenvironments. Wiley-Blackwell, Chichester

Harff J, Furmanczyk K, Von Storch H (eds) (2017b) Coastline changes of the Baltic Sea from South to East – past and future projection. Coastal Research Library, vol 19. Springer, Dordrecht

Hayashida K, Kimura J, Saski R (2014) State and perspectives of submerged sites in Japan. In: Evans AM, Flatman JC, Flemming NC (eds) Prehistoric archaeology on the continental shelf: a global review. Springer, New York, pp 275–290

Hermand, JP, Grøn O, Asch, M, Ren QY (2011) Modelling flint acoustics for detection of submerged Stone Age sites. Proceedings of OCEANS 2011 IEEE Conference, Santander, Spain. http://www.lamfa.u-picardie.fr/asch/f/p/ac/7816Ed01_final_opt.pdf. Accessed 20 June 2016

Lambeck K, Esat TM, Potter E-K (2002) Links between climate and sea levels for the past three million years. Nature 419:199–206. doi:10.1038/nature01089

Lambeck K, Rouby H, Purcell A, Sun Y, Sambridge M (2014) Sea level and global ice volumes from the last glacial maximum to the Holocene. Proc Natl Acad Sci U S A 111(43):15296–15303. doi:10.1073/pnas.1411762111

Lericolais G, Bulois C, Gillet H, Guichard F (2009) High frequency sea level fluctuations in the Black Sea since the LGM. Glob Planet Chang 66:65–75

Long D, Wickham-Jones CR, Ruckley NA (1986). A flint artefact from the northern North Sea. In: Roe DA (ed) Studies in the upper palaeolithic of Britain and Northwest Europe. British Archaeological Reports International Series 296, Oxford, pp 55–62

Momber G, Tomalin D, Scaife R, Satchell J, Gillespie J (eds) (2011) Bouldnor cliff and the submerged Mesolithic landscape of the Solent, CBA research report, vol 164. Council for British Archaeology, York

Raban A (1983) Submerged prehistoric sites off the Mediterranean coast of Israel. In: Masters PM, Flemming NC (eds) Quaternary coastlines and marine archaeology. Academic, London, pp 215–232

Ryan WBF, Pitman WC III, Major CO, Shimkus K, Moskalenko V, Jones GA, Dimitrov P, Gorür N, Sakinç M, Yüce H (1997) An abrupt drowning of the Black Sea shelf. Mar Geol 138:119–126

Skaarup J, Grøn O (2004) Møllegabet II. A submerged Mesolithic settlement in southern Denmark. BAR International Series 1328. Archaeopress, Oxford

Stanford D, Lowery D, Jodry M, Bradley BA, Kay M, Stafford TW, Speakman RJ (2014) New evidence for a possible Paleolithic occupation of the eastern north American continental shelf at the last glacial maximum. In: Evans AM, Flatman JC, Flemming NC (eds) Prehistoric archaeology on the continental shelf: a global review. Springer, New York, pp 73–93

Yanko-Hombach V, Mudie P, Gilbert AS (2011) Was the Black Sea catastrophically flooded during the Holocene? In: Benjamin J, Bonsall C, Pickard C, Fischer A (eds) Submerged prehistory. Oxbow, Oxford, pp 245–262