1. Introduction

For decades the perceptions of our past have been dominated by our rather fixed, and as a result flawed, concept of space. As can be seen from the impact of Norman Davies book 'The Isles – A History' (2000) even when we are dealing with a relatively static set of boundary conditions (the 'Isles' of the last 2000 years) we appear to have been incapable of getting to grips with the importance of geographical, social or political boundaries when looking at human history (Davies *ibid*: 1-19). It is consequently unsurprising that archaeologists and other researchers, when looking at the pre-historic period, have frequently failed to appreciate the magnitude of change in both the basic morphology of the globe and the environments it contained over relatively short archaeological timescales.

This lack of application of basic concepts of morphological change contrasts markedly with the acknowledged existence of submerged terrestrial landscapes on the world's continental shelves, which dates back to at least the 19th Century (e.g. Darwin, 1859; Lyell, 1832). Despite this long term knowledge, archaeological studies that address submerged archaeology directly have, over the past century, been somewhat sporadic. Since the mid-part of the 20th Century there has been an exponential increase in research into the location, identification and excavation of shipwreck material, but by contrast and bar one notable set of exceptions (see Masters & Flemming, 1983), the potential for, non-nautical or pre-historic, submerged archaeology has only really been explored over the last decade (e.g. Fischer, 1995a; Coles, 1998; Flemming, 1998). However, as explicitly cited by Coles (1998) the majority of this work is "speculative".

Concomitant, with the realisation of the archaeological potential of the continental shelves there has been a rapid increase in the development (in terms of both extraction and construction) of the worlds' continental shelves. This has inevitably resulted in increased stress on the submerged marine environment and both wreck and submerged prehistoric archaeology. Consequently, if a sensible and pragmatic legislative, and most importantly practical, response to this potential threat is required, our knowledge of such submerged environments, needs to extend beyond the "speculative" without just resorting to the purely site specific.

Recent publications (e.g. Flemming, 1998; 2002; Wenban-Smith, 2002) have started to tackle this question. Such works typically provide excellent syntheses of the current known archaeological record of certain periods and for certain regions. However, these publications fail to identify major problems in reconstructing these archaeological landscapes, for either predictive exploratory purposes or as an intrinsic part of their archaeological interpretation. Furthermore they fail to tackle the potential range of human responses to the attendant, dramatically changing, environmental conditions associated with transgressive and regressive cycles. Finally, such studies tend to simultaneously over-simplify the importance of the modification processes operating on the archaeological record, in terms of multi-episode, syn- and post-transgressive site formation processes.

This last point is key to our understanding of not only the archaeological record but also the Quaternary geological record. Although the impacts of marine transgressions have undergone detailed study with respect to earlier geological periods, the geological community's understanding of regional impacts is severely limited to

single-environment case studies which are then extrapolated to global scenarios. This extrapolative style is similarly employed in the small number of archaeological papers that tackle Flemming's (1998) concept of the "taphonomy of submarine occupation" (e.g. Kraft et al., 1983).

Therefore, if we are interested in interrogating the shelf environment for its archaeological resource we have to consider not just the practicalities of exploration, as is the focus of a number of other Aggregates Levy Sustainability Fund (ALSF) proposals (e.g. PD3322, PD3324, PD3362), but the realistic potential of the shelves for yielding useful (certainly in cost-benefit terms) archaeology.

1.1 Rationale

Our requirement to reconstruct submerged archaeological landscapes is multi-fold. Firstly, for the accurate interpretation of the terrestrial record it is essential we have a good understanding of the spatial context of this material. This requires identification of the land-sea boundaries at any point in time and so the extent, and variability, of the terrestrial environment (euphemistically and incorrectly described as the identification of "landbridges"). Secondly, we need to be able to comprehend the archaeological potential of these submerged landscapes, both in terms of primary context material (effectively preserved as a result of submergence) and secondary or even tertiary context material that has been re-worked through one or more cycles of marine inundation and exposure. Finally, recent work (e.g. Coles, 1998; Bailey & Milner, 2002) suggests that the coastal zone may represent a key environment of exploitation in pre-history and thus an essential component of human (as well as a myriad of other fauna and flora) evolution. Therefore, such coastal landscapes, many of which are now submerged, may provide exciting windows on pre-history and therefore need to be located and if possible interrogated.

The nature and scale of palaeo-geographic and palaeo-environmental change of our continental margins is of particular importance to the process of reconstruction, as it can alter radically over not only pre-historic but also historic timescales. For a full appreciation of this topic we need therefore to understand the nature of our continental margins and the short- and long-term processes that affect them. In this respect this approach parallels current thinking in palaeo-environmental research, specifically the use of a nested hierarchy of scales (e.g. Shennan et al, 2000b; Barron et al, 2003). In an ideal world research into the archaeology of submerged landscapes would proceed at a very small, "local", spatial scales (studies of the order of 10's metres through to a few kilometres), thus allowing very fine details to be observed. These smaller scale studies could then be mosaiced into larger "regional" overviews (10's to 100's Km's). In practice, the realities of underwater work render such a bottom-up approach impossible to undertake. Instead, we have to accept that the majority of research on continental shelf archaeology will be undertaken on the regional scale, with only occasional, more detailed analyses of local scale studies being possible. However, the positive adoption of a more top-down approach should be used to maximise the regional data and, through appropriate analysis, utilise it to target effectively the more labour intensive and inevitably cost limited local surveys.

The research presented in this report therefore represents a review of both the extant knowledge of the recent (c. last 2 million years) evolution of the continental shelves and the potential archaeological resource they may contain. Further, it aims to critique the process of submerged landscape reconstruction with particular emphasis on the

location of palaeo-shorelines, which as discussed above not only key to delimiting terrestrial regimes but of intrinsic archaeological importance in their own right. Due to the paucity of direct information on many topics of interest, we shall inevitably draw from a wide range of sources as well as presenting information from a variety of different temporal and spatial scales.

1.2 Basic Concepts: Continental Shelves and Sea Level Change

Continental shelves are the submerged portions of the continental margin, which slope gently down from the coastal zone (> 20-30 m depth) to the shelf break (c.100 – 250m depth). The width and area of individual continental shelves varies considerably, ranging from less than a kilometre to hundreds of kilometres (Figure 1), and is controlled by the tectonic history of continental break-up. In general, wide (tens to hundreds of kilometres) shelves tend to be associated with passive (tectonically benign) continental margins, and are relatively shallow; for example, the east coast of North America. Tectonically active continental margins, such as the west coast of South America, are characterised by shelves that are narrow (kilometres or less), steeper and deeper (Pickard & Emery, 1990; Leeder, 1999).

Continental shelves tend to be divided into two main categories. *Pericontinental* shelves are situated along continental margins and are typical of the marine boundaries of major continental landmasses (e.g. America, Asia, Africa, Europe). *Epicontinental* shelves tend be semi enclosed and are situated well inboard of the continental margins (e.g. the North, Adriatic and Baltic Seas (Leeder, 1999).

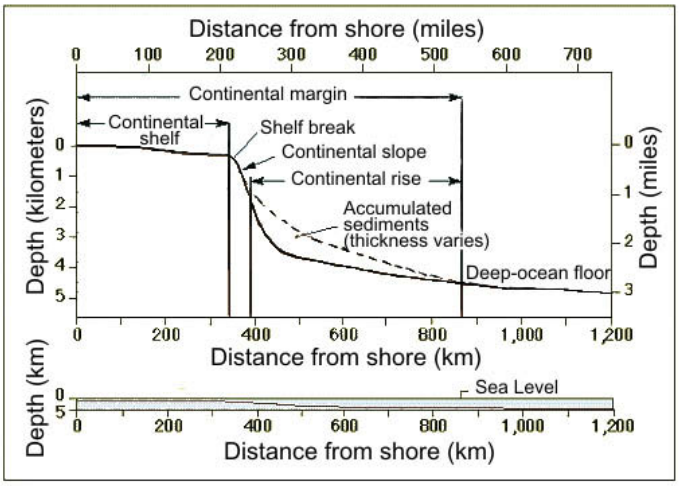

Figure 1. Generalized profile of a continental shelf

Both categories of shelf are susceptible to submergence and emergence induced by sea level change. Over the Quaternary, major (tens to hundreds of metres) changes in sea level have taken place (Rohling et al, 1998; Siddall et al, 2003) resulting in the exposure of and inundation of vast swathes of continental shelf. It has been estimated that the total area of shelf exposed globally during maximum sea level lowstands was potentially equivalent to the size of present day Africa (Figure 2 & Flemming, 1996).

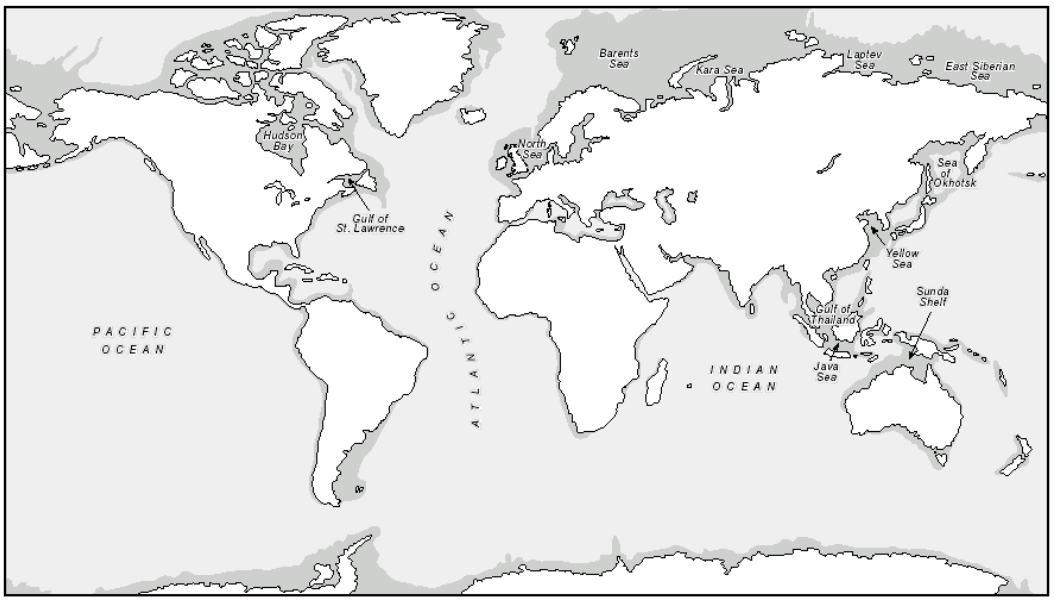

Figure 2. Extent of emergent continental shelves at the Last Glacial Maximum (c. 22 KaBP) (from Bridgland, 2002)

Given that global ocean volume is currently at its highest point since the highstand of Oxygen Isotope Stage (OIS) 5e (c.125 Ka BP: Siddall et al, 2003), it follows that the vast majority of evidence for the occupation of the exposed shelves would currently be submerged under tens of metres of water.

These large scale changes aside, the morphology and sedimentology of individual continental shelves is dictated by the complex interplay of both modern and geo-historical factors, including: global and regional fluctuations in sea-level; variability in sediment input rates and sources; and finally modes and rates of sediment transport. Inevitably, these processes not only affect the geological variability of shelves but also play a major role in determining their archaeological potential.

1.3 Basic Concepts: Continental Shelf Archaeology

Continental shelves are home to two broad categories of archaeology – shipwrecks and inundated terrestrial sites. This project will focus entirely on the latter. The vast majority of continental shelf archaeology is likely to be prehistoric; more specifically, Palaeolithic, Mesolithic and to some extent Early Neolithic. This arises from the fact that on a global scale, eustatic sea levels were at their lowest at various points during the Pleistocene and had broadly stabilized and reached near-present levels in the mid-Holocene (c. 7 ka BP) (Lambeck & Chappell, 2001; Bailey & Milner, 2002). Smaller scale, more localised relative sea level fluctuations resulting from influences such as sedimentation, tectonics or isostasy may have resulted in the submergence of later material in particular areas. Note for instance the underwater remains of a number of Bronze Age and Classical harbour structures in the Mediterranean (Flemming, 1998; Morhange et al, 2001). However, this project will focus primarily on Palaeolithic and Mesolithic material.

Aside from a few notable exceptions (e.g. Masters & Flemming, 1983; Fischer, 1995a; Coles, 1998; Flemming, 1998), the general archaeological attitude towards

submerged landscapes has been rather non-committal or speculative. Common assumptions are that sites have been eroded or destroyed by rising sea levels or are almost impossible to find beneath the ocean waters and seabed sediment. Thus, while it is rarely questioned whether these landscapes actually exist, there has been an overall tendency to simply gloss over their role in prehistory. This lack of research can be illustrated by the fact that globally, around 550 submerged archaeological sites are known from the Lower Palaeolithic through to the Bronze Age and beyond (Flemming, 1998). This contrasts somewhat with the quite literally thousands of archaeological sites that are known on land. As a point of comparison, around 1900 sites and findspots are known for the Lower and Middle Palaeolithic period of Britain alone (Wymer, 1999a & b).

An overview of both the archaeological and biogeographical literature also suggests that the actual role of submerged landscapes (rather the actual artefacts it contains) in prehistory is often stereotyped through the terminology that surrounds them. This is explicitly illustrated through the use of the term 'landbridge'. This seemingly innocuous concept has dominated discourse on continental shelves for at least the past 150 years. Note, for example, Charles Darwin's statement that:

"The northern parts of the Old and New World's will have been almost continuously united by land, serving as a bridge" (Darwin, 1859:300)

'Landbridge' implies a connection between two otherwise separated areas of land for the purposes of movement, be it of people or animals. With reference to prehistory, 'landbridges' are believed to have facilitated human entry into areas of land that are presently separated by the sea, the classic cases being Beringia; linking Asia and America, and the exposed North Sea Basin, joining Britain and continental Europe:

"*The hunters of the Late Glacial arrived in Britain dryshod by walking across the land bridge from the Continent"* (Smith, 1992:139).

"The journey of the ancestral Palaeo-Indians across the land bridge between Siberia and Alaska…was the final stage of a process of migration and colonization that had begun 1.5 million years earlier" (Fiedel, 1992:22).

This is even echoed in the recently postulated "out-of-Africa" migrations:

"There is increasing archaeological evidence that Australia was colonized (by boat, because no landbridges existed during the Pleistocene) before 50,000 years ago." (Stringer, 2000).

However, use of this term has handicapped our perception of submerged landscapes. The problem is that it implies that these areas were merely bridges, thus creating a false perception of submerged landscapes as nothing more than migration corridors or 'terrestrial avenues' (Case & Cody, 1987) that allowed access into and out of our present configuration of continents.

In reality, the inhabitants of these areas would probably have perceived them as 'land as place to be' (Coles, 1998:45). Given the long term nature of the colonization process, the size and extent of these areas, and the fact that these colonizers would have little or no conception that they were only "*en route*", these 'landbridges' would have been perceived as habitable areas of land in much the same way as the rest of the continent, rather than simple conduits for purposeful moves from point A to point B. Coles (1998) has rightly argued for a better understanding of the nature of these areas,

and the role they played in habitation as well as migration. This view contrasts somewhat with early work which based its research aims around the idea of these areas as primarily migration corridors. Note for instance, Marcus & Newman's (1983) work, which modelled palaeo-sea levels for the explicit purpose of investigating 'hominid migration routes' while Fladmark (1979) assessed the feasibility of a presently submerged coastal migration route into North America during the Late Pleistocene. Clearly, until quite recently, submerged landscapes have been relegated to a supporting role in the development of human society i.e. that of facilitating movements into the present continental configuration where the majority of the development of human society is assumed to have taken place.

Although, there are significant problems inherent with the concept of landbridges it is necessary to acknowledge that at least such work has some sense of palaeo-geographic space. Disappointingly there is still a significant volume of literature that present archaeological site distributions and palaeo-environmental data in general using modern day topographic maps (e.g. Bell & Walker, 1992; Bocquet-Appel & Demars, 2000: Figures 3 and 4).

Figure 3. Reconstructed vegetation patterns for the Late Glacial in North West Europe. Note the use of modern shorelines despite the Late Pleistocene dates. (from Bell & Walker, 1992:97).

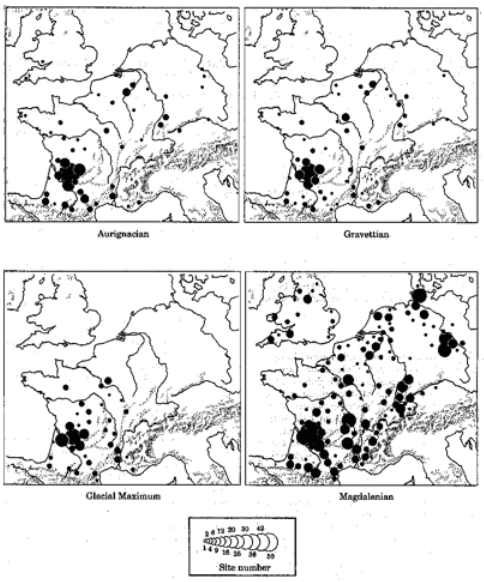

Figure 4. The broad pattern of archaeological site distributions in NW Europe before and after the Last Glacial Maximum. The Aurignacian ranges from 40 to 29 ka BP, the Gravettian from 29 to 22 ka BP, the Last Glacial Maximum from 22 to 16.5 ka BP and the Magdalenian from 16.5 to 11.5 ka BP (from Bocquet-Appel & Demars, 2000:553). Note the use of modern shorelines despite the known major shifts in sea level and hence shoreline positions during this period.

Although, as the authors would undoubtedly argue, such a presentation allows the reader to gain a sense of the patterning of the data in question, in relation to their own geographical knowledge, it suffers from the fact that the information is not placed within its appropriate palaeo-geographic context and serves to marginalize submerged landscapes in favour of the present coastline configuration. Where it does occur, the removal of modern geographical boundaries in reconstructions provides a strong visual reminder of the fact that currently submerged areas were not simply "bridges" connecting two landmasses but that they represented a seamless terrestrial landscape (e.g. Coles, 1998).

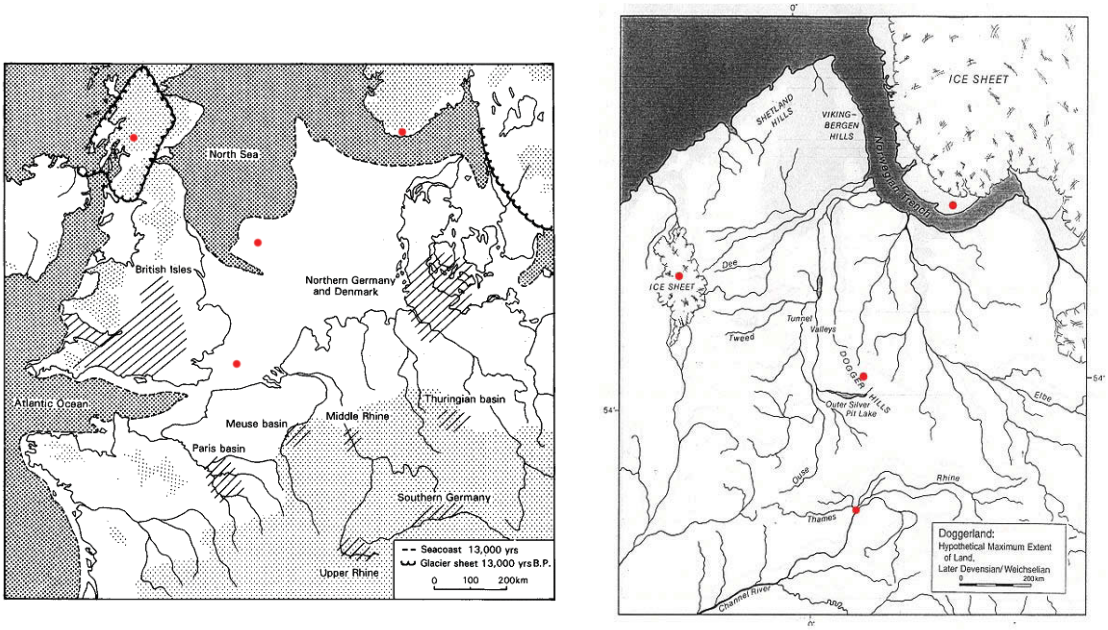

Figure 5. A comparison of two palaeo-geographic reconstructions of North West Europe showing different approaches to displaying palaeo-shorelines. The map on the left is from Housely et al (1997) and depicts the 13 ka (C^{14}) BP shoreline. The map on the right is from Coles (1998) and depicts the coastline between 16 and 13 ka (C^{14}) BP. The important aspect to note is how Coles emphasises the submerged area as an equal part of the landmass and highlights the probable palaeo-river courses. By contrast, Housely et al (1997) still present an overwhelmingly modern image and thus marginalize the submerged area. The red dots have been added to allow orientation.

1.4 Basic Concepts: Industrial Activity on Continental Shelves

Over the course of the twentieth century industrial activity on the continental shelves has increased steadily. Examples of the types of industrial activity taking place underwater include oil, gas and aggregates extraction, cable laying and trawling (Dykes et al, 2001; DTI, 2002). As an example Table 1 provides an indication of the total area in the North Sea affected by these activities.

% Area	Source	Area
54.	Fishing	309 204 km^{2*}
0.03	Aggregate extraction	180 km^{2*}
0.01	Dredging disposal	72 km^{2*}
0.001	Waste disposal	5.5 km^{2*}
0.001	Sludge disposal	5.5 km^{2*}
0.05	Platforms	313 km^2
0.05	Well heads	300 km^2
1.5	Pipelines	8374 km^2
1.27	Cables	7322 km^2
0.05	Wrecks	284 km^2
0.0001	Cuttings disposal	0.5 km^{2*}
56.95	Total	327 000 km^2

Table 1. Physical disturbance of the North Sea seabed by human activities in terms of both percentage area, and absolute values (modified from de Groot, 1996).

These activities are likely to affect archaeological assemblages on, or buried in the seabed through physical disturbance of the seabed, and/or sub-seabed sediment. For example, aggregate extraction can intensively disturb bottom sediment by substratum removal and alteration of bottom topography (de Groot, 1996). Studies have indicated that dredging may remove up to 5 metres of the sub-surface section (Desprez, 2000). Any archaeological material caught by a dredge will inevitably be removed from their depositional context and in the worst case scenarios destroyed. In either case the spatial, and hence temporal, relationships of an assemblage, and the information they contain, could be lost. Although the percentage area affected by aggregates is extraction is relatively small (see Table 1), the actual quantity of material removed from the seabed, which could include archaeological material, could be significant. This is because the key resource for the aggregate industry frequently coincides with zones of high archaeological potential, at least in terms of Palaeolithic material. Consequently, the greater integration of archaeological research with the industrial extraction (as supported by the ALSF scheme) could provide a significant increase in our knowledge of the shelf archaeology.

Similarly, the offshore oil and gas industries affect the seabed through construction of pipelines and platforms, and also by drilling for exploration and extraction purposes (Pickering, 1999; Flemming, 2002). This latter activity in particular could affect archaeological material buried at great depths within the seabed as well as on the seabed surface. Destruction of archaeological material or its removal from its context can also result from the burial of submarine telecommunications cables, and bottom trawling.

1.5 Report Structure

In order to re-assess the archaeological potential of the continental shelves we consider that there are 4 key themes that need to be considered:

- *Theme 1 – The regional reconstruction of submerged landscapes*

  A review of this topic should enable us to determine if current techniques of reconstruction are adequate enough to enable the wider investigation and management of the archaeological resource.

- *Theme 2 – The nature of the pre-submergence archaeological deposits*

  A review of current terrestrial archaeology and known submerged sites should provide an indication of the research potential that the submerged record has, both in terms of highlighting what material is likely to be present, as well as the research questions it is geared to addressing. Such a review should also provide some indication of the patterns that exist in terrestrial environments, and whether these are applicable to the continental shelf situation. Within the time constraints of this study it was necessary to narrow our spatial scope and so we have chosen the North-west European continental shelf as an illustrative case study.

- *Theme 3 – The modification of archaeological deposits by marine transgressions and regressions*

  A review of the impacts of marine transgressions and regression should provide an understanding of the nature and scale of landscape and coastal change in response to sea level fluctuations and how individual deposits of archaeological material may be affected by these forces.

- *Theme 4 - Predictive modelling of submerged archaeological sites*

  A review of current techniques of predictive modelling should provide an assessment of whether current modelling techniques are adequate or applicable to submerged continental shelf archaeology in the light of existing knowledge, and any insights drawn out of the previous three Themes.

1.6 Methodology

In order to tackle these 4 key issues for submerged archaeological studies this project has undertaken a wide-ranging literature review, in terms of both space and time. Literature from research disciplines spanning archaeology, anthropology, ethnography, oceanography, geology, biogeography and geophysics have been used. Although definitively resolving these issues was impossible for an 18 month study we aimed, at the very least, to identify the principle research questions to be set to the community over the next decade. Similarly, within the time constraints it was not possible to acquire new data to answer such broad questions. Therefore an essential component of the project include interaction with the large number of field based "terrestrial" and "marine" projects supported by the Aggregates Levy Sustainability Fund.