Copyright Statement

The Environmental, Social and Economic Impacts of an Artificial Surf Reef - The UK Experience

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The Environmental, Social and Economic Impacts of an Artificial Surf Reef - The UK Experience, by Emma Jane Rendle.

The study presented in this thesis discusses the topic of ASRs through the use of a specific case study constructed at Boscombe, UK. With the main aim to provide an impartial and independent study into the environmental, social and economic impacts of an ASR. The research presented is therefore multidisciplinary in nature, the separate components utilise key techniques from the geophysical, numerical modelling and socio-economic disciplines are combined to present a significant contribution to the knowledge and understanding of ASRs. Whilst previous studies have focused on one of these disciplines, there are no independent detailed studies of a constructed ASR utilising an multidisciplinary approach.

The ASR concept and structures are still in their development infancy, the subject has received cursory independent review in the literature. There have been few successful projects, those that have survived structurally in the ocean are not being used primarily for surfing. The Boscombe ASR is an example of high overspend, poor management and construction, loss of geotextile SFC and users deem the project a failure. The consequences of not correctly planning, managing and overseeing the construction has resulted in a poorly viewed project of limited success. All stages of this project could have benefited from thoughtful planning, thereby avoiding this outcome. If lessons are to be learnt from this project then the planning and management are key areas of the process that need addressing.

Ensuring that any future ASR projects are securely integrated with the coastal zone management plan will provide sustainability and success. The DPSIR framework approach can be used to highlight and address the causes of problems in the project. This framework enables the various disciplines to be discussed in relation to each other; links can be identified between the environmental, social and economic impacts of the ASR construction. Strict protocols will increase the success of any ASR project. The final crest height of the Boscombe ASR was 0.5 m higher than the final design height, this is a fundamental design flaw that should not be occurring in modern coastal engineering practice. It is suggested that guidelines are written based on this research for the design and construction process of an ASR. The recommendations and guidelines for ASR monitoring are provided by this research. The emphasis for future projects should lie in the final design and in monitoring, baseline field data should be collected to understand the environmental state change and socio-economic impacts. Planning and government proposals should be accompanied by extensive stakeholder engagement ensuring transparency for the project and ownership within the coastal community.

The exclusion of stakeholders at key decision points created distrust and misunderstanding towards the Boscombe ASR project. Avoiding unrealistic expectations within the surfing community and wider coastal community was discussed throughout this research, and by others in the literature. This research agrees with these statements, the issue of poor surfability would be improved by a greater area to manipulate the bathymetry. However this would come at a greatly increased cost in geotextile SFCs, which the current construction method is certainly not capable of delivering successfully. It would be recommended in this case that an alternative construction material was used that is resilient to the marine environment and readily adaptable given poor performance. Further testing of materials, both geotextile SFCs and alternatives, are required for the successful advancement of ASR technology.

Contents

List of Figures

List of Tables

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Author's Declaration

At no time during the degistration for the Doctor of Philosophy has the author been registered for any other University award without the prior agreement of the Graduate Committee.

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Relevant scientific seminars and conferences were regularly attended at which work was often presentated; several papers were prepared for publication (Appendix C).

Articles and proceedings published

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Chapter 1

Introduction

An Artificial Surf Reef (ASR) is a man-made submerged structure, which is designed to provide coastal protection and to provide breaking waves suitable for recreational surfing (Gardiner, 1999). Also referred to as multi-purpose reefs (or m-ASR) they have been claimed to provide watersports tourism, offer coastal defence whilst the structure can enhance fisheries given increased habitat complexity. ASR designed specifically with surfing in mind to enhance the oceanographic conditions for surfing and provide a surfing amenity to boost the local economy. Re-designing the bathymetry in a nearshore area so the breaking wave is controlled and contained, the wave is more "surfable" as it peels along the coast.

> "A relatively new form of low impact coastal structure designed to be placed in shallow water in areas with large wave climates to break the waves into a manner suitable for board surfing. In addition to providing recreational amenity, ASRs can be designed to provide coastal protection by dissipating wave energy through wave breaking and by rotating incoming waves to drive currents which combat longshore sediment transfer" (ASR Ltd., 2007).

This thesis focuses on ASRs constructed using geotextile sand bags primarily as there has been a focus on this method in the past 20 years. Interest in geotextile technology is growing rapidly internationally as more practitioners turn to alternative solutions to traditional hard engineering and want to incorporate multipurpose uses to coastal defence. More recently, there is a greater emphasis in best practice guidelines for coastal management to consider a multitude of coastal users, as well as enhancing or protecting surfing and the right to surf, or protecting the surf breaks from shoreline change, sand banks or construction in unwanted areas. As set out in the principles of integrated coastal zone management it is important to understand environmental, social and economic benefits and burdens of ASR construction to a coastal community, including the potential to ameliorating coastal erosion and the impact to surfing conditions.

More specifically this thesis draws on the experiences of Boscombe, UK. The ASR was constructed to enhance the local economy through the focused development of the local surf tourism industry. The Boscombe ASR was specifically designed to be a surf facility, first and foremost. However, claims regarding the capability of ASR structures are wide ranging and mostly made by the companies that design and install them, as well as the council who purchases the structure. In addition to the primary purpose of construction i.e. surfing and recreational benefits, 'the construction, design and environmental effects report for Boscombe Artificial Surf Reef, UK' (ASR Ltd., 2006) makes secondary claims regarding the impacts to the physical coastal environment, socio-economic and ecological benefits. Any negative consequences, expected impacts and benefits are ignored or avoided in the report, it is not a typical objective environmental impact assessment required for construction in the marine environment.

This chapter introduces the motivation for this research, the claims that were made prior to the construction of Boscombe ASR and lays out the structure of the thesis.

1.1 Claims and Motivation of research

To illustrate the potential benefits from an ASR project a number of different claims have been made to justify the construction. Often, when surfing is the primary design objective (as in the case of Boscombe) the project is supported by description of the potential benefits for coastal or shoreline protection and fisheries enhancement. Mead (2009) describes the use of offshore, submerged reef to unify amenity, coastal protection and marine ecology; "coastal protection measures can be moved offshore and underwater, opportunities arise for the incorporation of amenity (e.g. high-quality surfing breaks) and ecological enhancement (e.g. the provision for species specific habitat), while the natural character of the beach is maintained and the amenity value is enhanced (e.g. wider beach)". This is an idea that has captured the minds of coastal managers and developers, enthusiastic to keep a wide range of coastal users satisfied and provide an additional marketing tool for a town.

Mead and Black (2002), amongst others (Jackson and McGrath, 2005; Rafanelli, 2004; Challinor and Weight, 2009) have noted that these surf reefs could provide ecological benefits and can be used for coastal defence. ASRs are said to offer protection from coastal erosion and in many cases can encourage the build-up of sand and therefore widen beaches (Mead and Black, 2000; Jackson and McGrath, 2005). Salient formation and sand build up will occur leeward of a structure 'because the reef reduces wave height in its lee and thereby reduces the capacity of the waves to transport sand' (Mead and Black, 2000). The sand is thought to build up because of two reasons; firstly as a result of the reef causing sheltering from wave energy thereby encouraging deposition of sand, and secondly longshore gradients in wave height and radiation stress drive convergent currents and sediment fluxes into the lee of the structure. These claims were tested during this research.

The main interest and drive for the thesis came from ASR Ltd. literature and advertising documents which were not backed up by independent, objective research. An ASR Ltd. (2009) document entitled "Multi-purpose reefs for coastal protection and prosperity" was released as advertising to an Indian market, specifically looking to enhance coastal protection from monsoon conditions. It is written as a marketing document summarising the benefits of ASR construction. Other documents include the media releases from the Bournemouth Borough Council's Tourism Department and the original design specifications for the UK ASR. Quotes are represented here in four main categories (recreational, coastal protection, social economic and physical structure):

1.1.1 Recreational

- With the reef in place to make the waves break suitably for surfing, many thousands of surfers will benefit (ASR Ltd., 2009).
- After the reef is constructed, there will be safe sheltered swimming for families and tourists (ASR Ltd., 2009).
- There are no adverse rip currents or changes to the currents with the reef present that could strongly affect public swimming or surfers using the reef and beach (ASR Ltd., 2009)
- The reef can be used for a variety of water sports which will take place under different conditions. Surfers, body boarders and stand up paddle boarders will use it on days with good ground swell from the south west. Kite-surfers and windsurfers benefit when there are strong winds, while calmer conditions will be ideal

for diving and snorkelling (Bournemouth Borough Council Tourism Department, accessed 2009).

- The reef is designed to work on days with good ground-swell, coming from the South West, as opposed to wind swell, which creates messier, choppier waves (Bournemouth Borough Council Tourism Department, accessed 2009).

- The reef is designed to greatly improve surfing conditions and the number of quality surfing days at Boscombe in swells from 0.5 m and larger. To greatly increase the number of surfing days, the crest of the reef is shallow (just below water level at the lowest tides) so that even the very common small waves (0.5 m) will break around low tide (ASR Ltd., 2006).

- The reef provides a right-hand surfing wave with a surfing ride length of 65 m plus a steep left-hand breaker which initially has a ride length of 20 m. The left is expected to increase in length after the reef has been installed as sand is forecast to intermittently build up against the west side of the reef during common swell conditions creating a natural sand bank to extend the left hand rides (ASR Ltd., 2006).

- The reef provides some shelter from waves at the shore and greatly improves the natural sand banks for surfing (ASR Ltd., 2006).

1.1.2 Coastal Protection

- Reefs save beaches by eliminating the wave power offshore, the beach is protected from storms. The unwanted erosion of beaches during high waves will be eliminated (ASR Ltd., 2009).

- In the sheltered lee of the reef, the beach will become wider by up to 40 m (ASR Ltd., 2009).

- Modelling of sand banks and currents demonstrated that the reef beneficially protects the coast from erosion. In the long-term, no negative impacts are anticipated, as the reef protects the coast in its lee and has no measurable effect away from the reef along the coast. No adverse effect on the existing nourishment and groyne programme is anticipated. There are no adverse rip currents or changes to the currents with the reef present that could strongly affect public swimming or surfers using the reef and beach. The reef provides some shelter from waves at the shore and greatly improves the natural sand banks for surfing (ASR Ltd., 2006).

1.1.3 Social Economic and Perception

- Multi-purpose soft reefs and surfing greatly increase tourism and property values (ASR Ltd., 2009).

- International high-powered studies by reputable agencies all over the world show that multi-purpose soft reefs bring 10-80 times their full construction cost back to the community through better, safer beaches, coastal protection and visitor spending (ASR Ltd., 2009).

- Reefs provide an excellent foundation for an eco-system. The reef will produce more fish for fishermen and options for recreational divers or snorkelers (ASR Ltd., 2009).

- There is no visual impact (ASR Ltd., 2009).

1.1.4 Physical Structure

- Modern geotextiles are durable materials with a postulated life of up to 100 years when submerged, even in a challenging marine environment. Testing has shown that geotextiles installed in the UK suffer little or no danger from UV degradation, especially when submerged and covered with marine life" (ASR Ltd., 2006).

- The guaranteed life of the geotextile material will depend on the fabric used. By way of example, the material specified for the Noosa Artificial Surfing Reef in Australia carried a 25-year manufacturer's guarantee.

- In the event that the material is damaged, experience on previous projects has shown that torn tubes only lose sediment within a small area either side of the tear and so caused no serious damage to the structure (ASR Ltd., 2006).

- When correctly installed, failures are rare (ASR Ltd., 2006).

1.2 Thesis Aims

The aim of this thesis is to provide an impartial and independent study into the environmental, social and economic impacts of the Boscombe Artificial Surf Reef, UK. The design and implementation process for Boscombe ASR will be investigated taking into consideration the principles of integrated coastal zone management (ICZM). The impacts of the construction of Boscombe ASR will be investigated using the Drivers Pressures State Impact Response (DPSIR) framework, allowing recommendations for future projects. Outcomes will aid understanding and generate further interest into a topic of limited independent research. The outputs will include protocols to regulate implementation and define standards for monitoring studies.

1.3 Thesis Objectives

The thesis objectives can be broken down into the physical, social perception and economic analysis, and ecological disciplines of research that will be addressed within this thesis.

1.3.1 Physical analysis

- To make a provisional evaluation of the longevity and resilience of the Boscombe ASR in terms of predicted life span of an ASR.
- To evaluate the physical impact of the Boscombe ASR on the coastline in terms of shoreline response, and erosion and accretion effects.
- To evaluate the physical impact of the Boscombe ASR on the local hydrodynamics; the ability for wave shadowing and amelioration, rip current generation and the surf conditions and frequency.

1.3.2 Social economic and perception analysis

- To assess the impact of Boscombe ASR on quality and volume of recreational surfing activity.
- To evaluate public perception and opinion of the Boscombe ASR in terms of benefits to local stakeholders and visual impacts.

- To quantify the social value of the Boscombe ASR to the tourism industry, local economy and fisheries benefits.

1.3.3 Ecological

An assessment will be conducted on the literature, forming only a minor aspect of the thesis, identifying the current understanding of the ecological impacts of artificial reefs. The ecological research into Boscombe ASR is being considered by Bournemouth University, as commissioned by Bournemouth Council. Therefore it was deemed poignant to summaries the study to date in the literature review, as the subject was an original motivation for the conception of artificial reefs and a claim for this study to address. The decision was made to remove this element of study since it was no longer deemed novel to further investigate the ecological impacts of the Boscombe ASR. An initial investigation into the contribution of the Boscombe ASR to sustainable fisheries has been presented to the Marine Maritime Organisation in summary of this ongoing work (Herbert et al., 2013).

1.3.4 Linking themes

- To bridge the knowledge gap between the behaviour of submerged structures such as an ASR and their interaction with the environment, specifically how the geotextile sand filled containers (SFCs) act in a marine environment.

- Integrating the different disciplines, drawing on the conclusions from each chapter and providing a concise discussion.

- To provide improved guidelines, inform policy and decision makers on the suitability and performance of ASRs and equivalent structures.

- To establish a set criteria and protocol of good practice for the monitoring and performance assessment of ASRs.

1.4 Thesis Content

A literature review follows including the development of artificial reefs and the later emergence of artificial surf reefs. A conceptual framework is presented through which the thesis will be described. A separate case study chapter is provided of Boscombe, UK and the Boscombe ASR. The main analytical content of the thesis is divided between the two main themes physical and socio-economic in four chapters.

Two physical environmental chapters; the first provides the direct observation of the structural resilience and the impact it has had on the shoreline, and the second comprises of an investigation using a numerical model to simulate the implication on local hydrodynamics and the sedimentary environment.

Additionally, there are two socio-economic chapters; one addresses the direct users of the ASR for whom the structure was designed, the surfers and other board sports representatives, and the other the indirect users, those that are deemed by the various claims above to benefit from the ASR construction such as residents, hoteliers, business people, fishermen and anglers. A discussion chapter allows the synthesis of the conclusions of these four analytical chapters, the output of which provides recommendations for consideration in the future construction of ASRs. The research conclusions are summarised after the synthesis and discussion chapter.

Chapter 2

Literature Review

This chapter aims to introduce key literature used throughout the thesis and to discuss the use of artificial reefs throughout history. Presented here are the key themes and interests surrounding artificial reef structures so as to introduce the topic fully. The more general background on the historical use of reefs for fisheries, leads into more detailed sections providing an overview of the current state of environmental knowledge on artificial reefs and surfing reefs. After which, the appropriate socio-economic literature is introduced followed by an overview of the current policy on artificial reef creation.

2.1 Introduction to Artificial Reefs

Artificial reefs (AR) can be defined as purposely built structures, or objects, deliberately left on the seabed, to mimic some characteristics of a natural reef (Jensen, 2002). ARs are not a new concept; they have been used in coastal management for decades. The Japanese are currently the world leaders in AR technology and have used artificial structures for centuries. Historically, natural reefs have been replicated by man to exploit fish aggregation. Fish will use whatever is lying on the seabed or in the water column to shelter from prey, or in the case of predators, to hunt around. Reefs have been used by fishers in this manner, making them from simple plant based natural materials. In more recent years, other materials have been employed as interest grows in protecting our natural fisheries. ARs are typically created using many different objects depending on their use, for example sinking oil rigs or shipwrecks, or built from stone or concrete blocks placed on the seabed (Magagna et al., 2012).

Conservationists and fishers have been developing reefs for numerous years in an attempt to rehabilitate loss of habitat, typically due to anthropological interference such as trawling, weapons testing and coastal construction. A combination of observing fish in natural habitat and trialling new designs has led to the idea of complexity in reef design being key to success, simply the more complex the reef, the more inviting a habitat for local flora and fauna. Introducing new man-made structures and materials into the oceans creates new surfaces and more structural complexity (Magagna et al., 2012). This is commonly found to be positive for marine organisms as new surfaces can be colonised by sessile species and the added structural complexity attracts different mobile species that utilise the structure for protection and feeding. There are still questions as to whether ARs increase species number and, or biomass on a larger scale, or as some argue a local attraction that concentrates biomass around the AR to the detriment of surrounding habitats (Magagna et al., 2012). As mentioned previously fish aggregating devices (FADs) are designed deliberately for this manner and have been used as a fishing method for centuries. The aim of constructing FADs is similar to that of ARs and their importance has long been recognised (Ibrahim et al., 1996).

Another benefit from reef creation is the resulting closed off areas from pleasure boats, anglers and fishers. Unless the aim is for specific fishing tourism, marine reserves where fishing is reduced or banned have been shown to have beneficial impacts on fish and the marine ecosystem they encompass, and thus benefits fisheries (Sanchirico et al., 2006). The concept of closing an area of the ocean off from fishing has been discussed in relation to stabilising fish stocks, as breeding grounds and nurseries are protected from dredging and artisanal fishing practices. ARs, for either conservation or tourism, have also the potential of acting as "no take zones", this is a contentious subject with commercial fishers. Where conservationists argue that positive effects are observed to the local or regional fish stocks, other stakeholders raise concerns regarding access to local fishing grounds and causing increased costs.

Whilst there is research published in the field of ARs for fisheries, the study for reefs for recreational activities such as surfing and diving is comparatively limited. Therefore, much of the environmental and socio-economic impacts of ASRs specifically are poorly understood. Little quantitative information exists by which to assess the impacts of ASRs. Most of the monitoring studies related to the performance of ASRs are authored by professionals with a commercial interest in ASR development (Simioni and Esteves, 2010). A summary of the existing knowledge on the impacts of ASR on the quality of waves for surfing, coastal protection, ecology and socio-economic aspects are presented through this literature review.

2.2 Existing knowledge on Artificial Surf Reefs; Impacts and Performance

The majority of physical and structural ASR research has been undertaken in the last decade (Mendonca et al., 2012). The concept of ASRs has become a reality born from academics (Borrero and Nelson, 2003; Pattiaratchi, 1999; Mendonca et al., 2012; Scarfe et al., 2009b; Black and Mead, 2001) passionate about surfing studying the physics of breaking waves. ASR Ltd is one commercial company set up for the purpose of advancing research, testing and constructing ASRs (Ranasinghe et al., 2001a). Researchers have traced the evolution of ARs from empirical and theoretical perspectives (Pitt, 1996; ASR Ltd., 2010b; Ranasinghe and Turner, 2004), whilst other studies have provided reviews and perspectives of ASRs (Borrero and Nelson, 2003; Scarfe et al., 2009b; Pilarczyk, 1998; Jackson and Corbett, 2007; Bohnsack and Sutherland, 1985; Jackson and Corbett, 2007) or focused upon specifics such as the use of ASRs to promote surf tourism or coastal protection (Mendonca et al., 2012; Bortone, 2006; Baine, 2001; Pattiaratchi, 2003). Some monitoring studies (Bortone, 2006; Pattiaratchi, 2003; Davidson, 2010; Jackson et al., 2010) have quantified the performance of ASRs objectively, however many are published by professionals with a commercial interest in ASR development (Mead, 2009; Mead et al., 2010). Compared to similar structures such as groynes and breakwaters, reporting on the progress and success of ARs from a marine and coastal policy perspective is still in the early stages.

The aforementioned studies contributed significantly to current knowledge, however they have tended to be narrow in focus, assessing ASRs in terms of economic theory or physical processes without extending their analysis beyond the bounds of the surf industry. Surfing is a popular and continuously growing trend in the UK, with participants estimated to be over 600,000 in 2005 (Simioni and Esteves, 2010). Today it is estimated that surfers and wave-riders combined make up over 1% of the UK population (Mead and Black, 2002). As a comparative guide, in 2007 there were reported to be approximately 2.5 million surfers in the USA and 2 million in Australia (RYA, 2007). Visit Britain (Visit Britain, 2011) figures show growing popularity of British seaside resorts with a record 2.9m inbound visitors to Britain in June 2011. Increased interest in activity breaks with tourists learning or trying new sports such as surfing and kayaking have been reported throughout the country. In the UK alone the learn-to-surf industry has grown by over 400% in the past decade and is a significant contributor to Cornish economy (Lazarow and Nelsen, 2007).

An ASR is designed primarily with surfing in mind in order to enhance the oceanographic conditions for surfing and provide a surfing infrastructure to the local economy. Through re-sculpting the bathymetry in a nearshore area so that breaking waves are controlled and contained by the ASR, the wave is more "surfable" as it peels along the coast. The peel angle of the wave (between the breaking crest and the shoreline) is optimised and the form of the wave is steeper and plunging in form, as opposed to a spilling breaker type (which is not as thrilling for the rider). Some of the best surf breaks in the world have been created inadvertently by the construction of coastal defences for example Sandspit, (Santa Barbra, California), and Kirra and Duranbahm (Gold Coast, Australia). Although these structures have been recognised as creating good surfing their primary construction was not to enhance surfing conditions. The ASR are designed to replicate observations from breaking waves in nature and near these previous construction projects. Observations of waves breaking over reefs have been conducted by surfers and engineers interested in the use of submerged structures to dissipate wave energy before it reached the coastline (Button, 1991; Mead and Black, 2000; Ranasinghe et al., 2001a; Black and Mead, 2001; Black et al., 2003).

It has been claimed (ASR Ltd., 2007, 2009; Black and Mead, 2001; Black et al., 2000; Mead, 2009; Mead and Black, 2002) that ASRs provide coastal defence, improvement of biodiversity, enhancement of surfing and improving the local economy due to better watersports facilities and tourism amenity. Although such functionality may have resonance in integrated coastal zone management (ICZM), the main public appeal is related to its effects on the aesthetics and surfing. Coastal management projects, the like of which are required to effectively organise the human impacts on the coastline, need to include transparent scientific evidence (Scarfe et al., 2009a). It is imperative that the solution to a coastal management issue comes with solid scientific and environmental support and other management options are seriously considered. The solution must be fully comprehended by all stakeholders and interested parties. Integration of coastal protection and surf improvement is practical but a design brief simply to "improve surfing" needs to be better defined, or the results can be seen as a failure (Jackson et al., 2001).

2.2.1 Ecology

Fishing communities around the world learned hundreds of years ago to fish around natural reefs and other large objects underwater, creating the first ARs, often out of nothing more than a pile of rocks (De Alessi, 1997). The development of AR technology has seen numerous stages and material used. One of the most popular reef-building materials to date has been old car bodies due to easy of deployment and low costs. Car bodies unfortunately only last for about five years and as they break apart or moved by storms they can interfere with commercial fishing. Other methods have included sand dredging, concrete structures, old cargo ships and even decommissioned tanks but none of which have been successful in the long term (Gardiner, 1999). The variety of materials used reflects material readily available, cost and ease of transport. Experimenting with large concrete mould that will last much longer than a car and which will be moveable. However, concrete structures are difficult to manage, while a car can simply be rolled on and off a boat (De Alessi, 1997). Attempts have also been made by dredging sands to form a bank, old car tyres are seen as a viable option by some and a means of recycling unwanted materials. Degradation of tyres in the marine environment is cause for concern as they are adversely affected by UV light and salt water.

In Japan, the rights to sub-tidal lands are clearly defined and the level of investment is huge. Custom reefs are designed for specific habitats and species production. Vigilant reef protection and great research efforts demonstrate the potential for positive benefits of private ownership (De Alessi, 1997). There are also many uncounted small scale projects in South and Central America, and Asia. The largest AR construction began in 2014 in the Mexican Caribbean, parallel to the coast of Punta Brava, Yucatan. Made out of 1,000 concrete pyramids, it will cover 1.9 km stretch of the coast, it is hoped it will make an artificial barrier protecting the shoreline in addition to providing habitat.

ARs are assumed to cause aggregation of scattered specimens and secondary biomass production through increased survival and growth of juveniles (Edelist and Spanier, 2009). The construction of the ASR modifies natural habitat (e.g. substituting a soft unconsolidated bottom by a semi-solid, firm geotextile surface), which in principle can increase the local biodiversity and species abundance. Altering a natural ecosystem, no matter how apparently barren is not considered appropriate by conservationists. It should also be noted that the implementation of new structures in the marine environment may have detrimental effects. In the light of the spread of unwanted, invasive species, new structures may act as “stepping stones” (Petersen and Malm, 2006) for such species, improving the chances of further spread. New colonisers put pressure on commodities, causing competition for food and space, encouraging the migration of foreign species and increasing predation of native species. ARs affect the substrate characteristics and the food resources available to an assemblage (Davis et al., 1982). Similarly, changes in hydrodynamics provide sessile species shelter; however the predator has an easier environment in which to hunt prey. Colonisation of an ASR will more likely reflect ‘hard’ coastal protection structures. Although, different substrate surface texture, encrusting or ‘fouling’ species and mobile species will diverge from those species with the ability to colonise an ASR.

It is unlikely that an ASR designed for surfing will have the specific AR design components of reefs designed for ecological purposes. The concept of multipurpose ASR benefiting needs of commercial fishermen, anglers, divers and nature conservation is an attractive one from economic and social view and a considerable design challenge for AR scientists and engineers (Jensen et al., 2000a). Monitoring surveys indicate that biodiversity at the Narrowneck reef is lower than adjacent natural reefs but there are (qualitative) accounts that the ASR is popular with local recreational fishermen and divers (Jackson and McGrath, 2005). The Boscombe ASR ecological monitoring was awarded to Bournemouth University who have much experience in the development of ARs for fisheries. The following is a section from Herbert’s (2013) report summary:

> “Although the original ecological assessment suggested the reef may actually lead to local enhancement of biodiversity through the increased hard substratum available for colonisation, the construction of the surf reef has raised concern among some stakeholders over its potential ecological impact. To complement simultaneous studies on both the benthic colonisation of the ASR and its impact on the commercial fishery of Poole Bay, we compared fish, pelagic invertebrates and zooplankton abundances within the close confines of the structure (110 m) and in control sites 1 km to the east and west. Sampling was undertaken using a beach seine net between July 2011 and November 2012 and light traps between July 2011 and July 2012. Between control and ASR sites, there were no significant differences recorded in fish community composition and catch per unit effort. No significant differences were recorded in zooplankton and invertebrate community structures between control and ASR sites. These data suggest there has yet to be any significant,

measureable effect of the construction and presence of the Boscombe ASR on these aspects of the fish and pelagic invertebrate population. However, literature suggests that biomass and production may yet increase with continued successional development on the reef. It is recommended that this be monitored in the long-term to detect any future impacts."

2.2.2 Improving the Surf

ASRs made from geotextiles sand bag containers (SFCs) are an innovative coastal engineering concept aiming to foster local economy by promoting multi-functionality through improving wave quality for surfing. Incorporating the sport of surfing into coastal management is a relatively new phenomenon that is gradually gaining attention because of the importance of surfing breaks to coastal communities (Pratt, 1994; Lazarow and Nelsen, 2007; Scarfe et al., 2009b; Wagner et al., 2011). Often the initial drive for such structures comes from the surf community who may have suffered a loss of a natural surf break due to human interference and development on a coastline. Historically there have been many surfing breaks altered or destroyed by coastal development (Scarfe, 2009b).

ASR Limited was a company based in New Zealand and later the US, that was evolving the concept of ARs for multi-purpose uses. The idea is based on replicating the effects of natural reefs in enhancing surfing and providing coastal protection observed worldwide (Mead and Black, 1999a). ASRs are claimed to enhance local biodiversity, provide coastal protection and improve wave quality for surfing. This provides a surfing infrastructure to the local economy (Gardiner, 1999). More than a decade has now passed since the construction of the world's first ASR at Cable Station near Perth in Western Australia (Shand, 2011). Since then seven further reefs have been constructed with varying degrees of success: USA (later removed), Australia, two in New Zealand, India and most recently the UK received Europe's first ASR (Table 2.1). Each reef was constructed based on a detailed design (ASR Ltd., 2006; Borrero and Nelson, 2003; Jackson and Smith, 1997; Mead and Black, 1999a; Pattiaratchi, 1999; Skelly, 2002) supported by numerical and/or physical model results, indicating a likely (or theoretically likely) improvement in surfing conditions (Shand, 2011). This new and rapidly developing research area has mostly occured in the last 20 years. The majority of physical and structural ASR research has been undertaken in the last decade (Scarfe et al., 2009b). There are more projects of this kind being considered by practitioners internationally, including proposed ASRs in the USA, Spain, Portugal (Ten Voorde et al., 2009), Brazil and United Arab Emirates to name but a few.

An ASR is designed with the intention of altering the local wave field to enhance environmental conditions for surfing. ASRs essentially replicate the form of natural reefs, i.e. sand bars (bar and channel lower beach topography), rocky reefs (remains of cliffs, sheet or rubble) or coral reefs (can be atolls, barrier or fringing reefs). ASRs are often claimed to be multifunctional (Mead and Black, 2002) as this enhancement of the environmental conditions is often claimed to not only provide increased tourist amenity through surfing (ASR Ltd., 2009; Black et al., 2003; Pitt, 2010), but also to provide habitat for the marine ecosystem (Bortone, 2006; Jackson and McGrath, 2005; Mead, 2009; Moschella et al., 2005; Pratt, 1994) and protect the coast from erosion (Martinelli et al., 2011; Oh and Shin, 2006). Submerged breakwaters are becoming a popular option for coastal protection, mainly due to their low aesthetic impact on the natural environment (Ranasinghe et al., 2010). The ASR is designed to mitigate the wave energy to a certain level, allowing water to overtop and circulation at the nearshore to still occur.

ASR Projects	Date	Location	Volume [m^3]	Material	Total [AUS$]	BPS US$	£/m^3
Bargara	1997	Harvey Bay, QLD, Australia	300	Rock	10,000	6,509	22
Cables	1999	Perth, WA Australia	5,000	Rock	1,400,000	911,257	182
Narrowneck	2000	Gold Coast, Australia	70,000	SFC	2,800,000	1,822,513	26
El Segundo	2001	El Segundo, CA, USA	1,350	SFC	385,000	250,596	186
Mt Maunganui	2008	North Island, NZ	6,000	SFC	1,450,000	943,802	157
Opunake	2006*	North Island, NZ	4,800	SFC	760,000	494,682	103
Boscombe	2009	Bournemouth, UK	13,000	SFC	4,762,654	3,100,000	238
Kovalum	2010	Kerala, India	4,300	SFC	1,640,321	1,067,681	248

Table (2.1). The current ASRs projects to date, with details of size by volume of sand filled containers (SFCs) or rock. Adapted from Jackson and Corbett (2007) and updated. *not officially completed, therefore construction start date given. Exchange rate www.xe.com, accessed 05/05/11

The first ASR was built close to Perth in Australia and named Cable Station or Cables (Henriquez, 2004). The design was tested by (Button, 1991) in a series of flume tests to determine the optimal bottom slope for the reef. Loyns (1992) took on further physical testing and determined the shape for the reef. Hurst (1996) applied a numerical model to determine the increase in the surfability by placing an ASR (Henriquez, 2004) at the site. It was predicted that the placement of a surf reef would increase the number of surfable days by a factor of five. Constructed aboard the pre-existing limestone reef, a granite V-shape layer was added to increase the height of the reef from the seabed thereby creating a shallower point at which wave energy will focus during swell events and increase annual surfable days. Constructed out of granite stone the cost of construction was US$1.2 million. Pattiaratchi (Pattiaratchi, 2003) discusses how 142/365 surfable days is achievable at cables i.e. 38% per year. Conversely, Pitt (2010) states that Cable Reef, in its current form, has failed to meet the design brief essentially the reef is too deep for the available wave height climate maintenance is required. Although not the primary objective Hegge (Hegge, 1994) discusses an increased resistance to erosion and reduced coastal instability.

Designed solely to enhance recreational surfing the ASR at El Segundo, USA was constructed in response to degrading natural breaks (Borrero and Nelson, 2003; Nelson, 1996). The construction of a 275 m jetty to protect a marine terminal and underwater pipelines at a Chevron oil refinery facility had a negative impact to the regions beaches and agreed to pay out US$300,000 in order to build an ASR as a restoration project (Cohen, accessed 2009). The El Segundo Reef (also known as Prattes Reef after the campaigner against the coastal works being carried out by Chevron) was designed by Skelly Engineering and constructed began in 1999. Some monitoring was undertaken by (Borrero and Nelson, 2003); Prattes Reef did not perform to expectations, there few reports of wave breaking at the reef only 1-5 times per year. Although the surfing was not considered consistent, there was a success in constructing an ASR from geotextiles. Closer inspection of the ASR showed damage to the bags, likely responsible for significant lowering through scouring effects, affecting the wave breaking. The ASR began to sink into the sediment, lessons were learnt and since the El Segundo ASR a geomat has been placed on the seabed.

Constructed on the Gold Coast, Australia between 1999 and 2000, the primary function of Narrowneck Reef was to decrease sediment transport and enhance coastal protection, and secondly to enhance surf tourism through increasing surfable days (Black and Mead, 2001; Jackson and Corbett, 2007; Jackson and McGrath, 2005). Designed by ASR Ltd. Physical and numerical modelling were used to estimate the shoreline response and surfability of breaking waves over the structure. The project resulted in a widening of the beach and reduced alongshore transport of recharge material from nourishment scheme. Claims have been made regarding the additional recreational amenity has been provided by this wider, more stable beach alongside the attraction of surfing. Filled onshore and loaded onto a barge, 110 geotextile SFCs were positioned by a barge mounted crane in 2000. The ASR was designed to enhance surfability by increasing peel angle and breaking wave energy offshore. Seabed fluctuations and damaged containers lowered the ASR and claimed to cause the poor surfing conditions. A second installment of an extra 90 bags was undertaken in April 2001 to raise the crest elevation and increase volume by 80% after seabed fluctuations caused bags to be lost during the winter and, scour and accretion at the toe of the reef. According to (Jackson et al., 2001) Narrowneck cannot be classed as a world class reef break, but more as a classic reef break for intermediate to expert surfers using a range of surfcraft. Narrowneck does not break as steeply as other natural world class reef breaks in the nearby area under the same or similar oceanographic conditions, therefore it is not an improvement on the surfing conditions offered naturally in the area.

Considerable monitoring of the Narrowneck ASR has been carried out and a number of monitoring reports have been published (Tomlinson, 2004). The Narrowneck reef project has been successful in coastal protection; despite a number of significant storm wave events, the reef has proven been effective in stabilising the beach and a salient is generally present (Turner, 2006). Jackson et al (Jackson et al., 2001, 2002, 2005, 2007, 2010) report on the Narrowneck ASR project, these studies highlight little erosion shoreward of the reef and state that they plan for further coastal protection reefs along the Gold Coast, although at the time of writing this has not occured. The reports state that waves break approximately 50% of the year under good swell conditions of >1m. That is, when there is a clean swell without wind, the modelling is replicated in the real world. Sand bars naturally migrate in the cross and alongshore direction and are not impacted by the presence of the Narrowneck ASR. In addition to enhanced surfability, Jackson et al report that the ASR has provided a suitable substrate for biological attachment and has become a popular location for sport fishing and diving. These amenity enhancements have been linked to attracting additional tourism and therefore improved the economy. Stabilising the sediment leeward of the Narrowneck ASR is also beneficial to the local coastal defence and therefore considered an economic benefit.

The main criterion for the New Zealand's first geotextile ASR was to enhance surf tourism at Mt. Maunganui in the Bay of Plenty, north-eastern coast of New Zealand's north island (Mead and Black, 1999a; Taranaki Regional Council, 2009). The relatively wide range of wave directions in the bay allows both the left and right to break during different conditions, providing more consistent surfability. Another aim was to reduce competition for waves and crowding in the bay. The reef was designed and constructed by ASR Ltd., officially completed in June 2008. Construction was very slow due to site conditions and costs (NZ$1.6M) had been considerably over budget (NZ$0.8M) (Jackson and Corbett, 2007). The reef was designed to produce left and right peeling waves with ride lengths of approximately 50 m break from a single focusing point. The ASR slope is such to produce the desired hollow, challenging wave. Neilson (2010) rates Mt Managui reef as 6-7 on the Hutt scale, therefore the ASR is not suitable for inexperienced surfers. The ASR was not fully completed and the part public and part privately funded project was criticized for not providing the intended surf facility and for creating dangerous rip currents. The Bay of Plenty Regional Council decided to partially remove the ASR to reduce risk to swimmers (Bay of Plenty Times, 2014). An independent report found that the ASR structure was not as it was originally designed. This is because of errors made during construction (including under-filling of the containers which make up the structure), removal of one of the major containers when it was damaged, and other damage and sand leakage over time. The review recommended the ASR structure be removed in a staged process. Removing the largest geotextile containers at a cost of about NZ$60,000 would likely eliminate health and safety and environmental issues (Bay of Plenty Times, 2014).

Harbour Engineering Department contracted ASR Ltd to design and construct a multipurpose Artificial Surfing Reef (m-ASR) within the bay of Kovalum, India in order to provide coastal and shoreline protection, provide additional tourist amenity and additional habitat for marine wildlife (ASR Ltd., 2010a; Tourism Concern, 2012). The "m" was added to ensure that stakeholders understood it was designed for coastal protection and therefore their benefit, as much as it was for surfing and providing tourism. The local economy is highly dependent on tourism and is currently being threatened by loss of beach via coastal erosion. The ASR claimed to offer an alternative option to the typical hard coastal structures, such as rock walls and concrete revetments in the region. Funding for this project has come from an international aid source, the Tsunami Rehabilitation Project after the 2004 Indian Ocean disaster, and is a cause for much dispute within the local and state government. The project itself was granted to ASR using a single tender process, no Environment Impact Assessment (EIA), Social Impact Assessment (SIA) or Fisheries Impact Assessment were insisted on for such a major geo-physical intervention (Kerala Tourism Watch, 2010). After its construction the reports in the media became negative and concern was raised to the effectiveness of the ASR, and the supporting documentation; "The [Harbour Engineering Department by the Kerala Tourism Department or ASR Ltd.] reports seems to be done in haste and clearly seem to represent only one side of the story, the side of the company and, amongst others, seems to have irked the local fishing communities. The reports have not even taken enough efforts to cross-verify most of the statements professed by the company" (Kunhu, 2010).

Little has been published on the Kovala ASR, the Keralan Tourism Department is quoted in the media. As parts of the reef washed ashore and loose bags are caught in fishers nets questions were raised to ASR Ltd. regarding the structures ability to perform as a surf reef, and other concerns regarding the bags that have been washed ashore were answered by a "rather lengthy response from the company, while not denying the use of tsunami money, skirted most of the issues and read more like a sales pitch" (Kunhu, 2010). An image of the clear up after the first monsoon highlighted the fragility of the Kovalam ASR in the monsoon conditions (Figure 2.1). There is little quantitative discussion in the original reporting surrounding the ASR construction as a means of rehabilitating the shoreline post Tsunami or monsoon (ASR Ltd., 2010a).

Figure (2.1). Kovalam ASR, Kerala, India. September, 2010. Photograph showing the clear up of the beach after the first monsoon post-construction of the Kovalam ASR; one of the geotextile sand bags is washed ashore.

2.2.3 Shoreline protection: Physical processes and submerged structures

Submerged breakwaters are commonly used for coastal protection on many eroding coasts, Japan and Italy have notable number of references utilising this technology (Okuzono, 1998; Cho et al., 2001; Mutagami et al., 2001; Giarrusso et al., 2003; Pilarczyk, 2003; Baldwin and Casarin, 2004; Ranasinghe and Turner, 2004; Cokgor and Kapdasli, 2005; Johnson, 2006; Alvarez et al., 2007; do Carmo et al., 2011; Martinelli et al., 2011). A desirable feature of submerged breakwaters (and low crested structures, in general) is that they do not interrupt the clear view of the sea from the beach. This aesthetic feature is important for maintaining the tourist value of many beaches and it is usually one of the considerations in using such structures for shoreline protection. The submerged structure is used to reduce the wave energy reaching the beach by triggering wave energy dissipation over the structure, and thus reduce sediment transport and the potential for coastal erosion. A proper understanding of the effect of submerged breakwaters on nearshore waves and currents is necessary for the calculation of sediment transport and morphological evolution in the vicinity of such structures. This is important in order to achieve a good functional design of the submerged structure for coastal protection.

Developers of ASRs are using more complex numerical modelling techniques to refine their designs. AR research is becoming more sophisticated from a technical perspective, but needs to address the inherent problems in working in a boundless environment that often is impacted by human interference (Bortone, 2006). However, numerical modelling is not an exact science and often proved to be floored if all parameters are not taken into consideration and simulated precisely. The ability to represent a coarsely resolved model is possible (Bortone, 2006), however small-scale coastal processes are a long way from being resolved numerically even by the most complex of models. This is simply because the processes responsible for sediment transport and morphological change in the intertidal zone of natural beaches are not very well known (Aagard and Hughes, 2006). As Ranasinghe et al. (2006) describe, shoreline erosion occurs when the resultant current field contains divergent alongshore currents and sediment fluxes at the shoreline in the lee of the structure. Conversely, shoreline accretion occurs when convergent alongshore currents and sediment fluxes are generated at the shoreline in the lee of the structure. With reference to a submerged breakwater (similar to an ASR in structure), the development of the salient in the lee of the structure when it is placed far from shore is due to the sediment deposited in the lee of the structure by the convergent longshore currents induced by the two secondary inshore circulation cells adjacent to the shoreline.

When the structure is close to shore, the erosion leeward of the structure for both shore normal and oblique waves is due to the strong onshore flow over the structure and the diverging longshore currents in the lee of the structure. Ranasinghe et al. (2006) showed that when a 2D hydrodynamic numerical model and 3D scaled physical model tests were undertaken to investigate shoreline response to broad-crested, submerged structures the processes governing shoreline response to submerged structures are entirely different to those associated with emergent offshore breakwaters. They describe how the shoreline response to submerged structures is governed by a nearshore circulation pattern consisting of onshore flow over the structure and longshore gradients in water surface level in the lee of the structure (and currents along the sides of the structure, in the particular case of artificial surfing reefs). This is in direct contrast to emergent offshore breakwaters, where the shoreline response is governed principally by wave diffraction at the structure. The numerical and physical model results presented indicate that the mode of shoreline response to submerged structures can vary between erosive or accretive responses dependent on the proximity of the structure to the coastline.

The desire to preserve assets in the coastal zone has resulted in the widespread installation of coastal defences, i.e. structures designed to resist the erosion or flooding of land by the sea (Brampton, 2002). The primary purpose of defence structures are to prevent or reduce erosion and flooding of high value coastlines, to stabilise and retain beaches and reclaimed land, and to increase the amenity value of the coast (Airoldi et al., 2005). There a numerous examples of well-intended coastal defence schemes that have resulted in detrimental effects on adjacent stretches of shoreline, often requiring subsequent maintenance and repair (Brampton, 2002). Research into alternative structures is being developed to mitigate these negative impacts. In the strategic realignment of coastal management there is scope for the coastal zones to return to a more natural pattern and the removal of hard traditional solutions to coastal change. It is thought that, in some coastal regions, allowing for more simplistic solutions will prove more cost effective and sustainable than continuing to defend the coastline (Brampton, 2002).

Although coastal protection is normally one of the claimed functions of ASRs, only the Narrowneck and Kovalam ASRs have been built with the primary objective of coastal protection. Turner et al. (2004) suggest that some beach accretion was observed adjacent to the Narrowneck ASR. However, this might be due solely a consequence of the beach nourishment conducted in conjunction with the construction of the reef (Simioni and Esteves, 2010). No other studies have investigated the effect of ASRs on the coastline as their primary objection was in surfing and surf tourism. It is apparent that the environmental and structural conditions under which shoreline erosion and accretion will occur leeward of submerged structures are not yet fully understood (Ranasinghe et al., 2006). The response to erosion and deposition at the coastline is often to out-engineer nature using a variety of structures. These structures have a tendency to set up energy discontinuities along the coast and in some places exasperating the problem (Gardiner, 1999). In modelling and laboratory studies of shoreline response to submerged structures (Ranasinghe et al., 2006) showed how (a) shoreline accretion is likely to occur in the lee of submerged structures located on coastlines with significant ambient longshore sediment transport, and (b) shoreline erosion is likely to occur in the lee of submerged structures located on coastlines with predominantly shore normal wave incidence. This has significant implications for the reaction of the coastline to an ASR.

Not only is there insufficient published information available on shoreline response to multi-functional ASRs, relatively little is known about shoreline response to submerged structures in general (Ranasinghe et al., 2006). Reduction of wave energy reaching the coastline will undoubtedly slow erosion however there is potential for scouring to occur as a response to the reef construction, either at the foot of the structure or surrounding coastal region. Beach nourishment is often not successful alone on medium to high energy beaches where re-suspension of sediment occurs easily. Reliance on beach nourishment without control structures would be an extremely high-risk (Hamer et al., 2000) coastal management option. Movement of nourishment material alongshore and offshore needs restricting although not completely hindered in order for a coastal protection project to be successful. The use of groynes, reefs, barriers and breakwaters can be used to retain sediment with a varying degree of success. Consideration to alongshore movement is vital in ensuring adverse effects to adjacent coastlines are avoided. Shore-normal structures are likely to require a shore-management plan to accompany them (Hamer et al., 2000) where as a shore-parallel system, such as one or more reefs, can be developed to reduce impact to longshore transport whilst prevent beach losses offshore. ASR Ltd. hope for the use of their technology to be used in this manner and have designs for ASRs to be used in arrays as well as individually.

2.2.4 Design and Construction of Geotextile ASRs

Conventional breakwaters and beach protection structures with rock and concrete units have a long history and much experience has been gained on their design and construction. Groins and emergent breakwaters are becoming increasingly unpopular, mostly due to their adverse impact on beach amenity and aesthetic considerations (Ranasinghe et al., 2006). In a move to make shoreline stabilisation more attractive than the traditional rock and concrete hard structure, decision makers for coastal management are considering alternative materials for construction. With an increasing need for more economical and environmental designs and shortage of natural rock (for hard structures) and sand (for beach nourishment) in certain areas have stimulated in recent years the alternative designs utilising geosystems and other local materials (Pilarczyk, 1998). Several types of material and container systems have been developed specifically for the design of coastal erosion protection systems (Pilarczyk, 1996). Due to the improvements in geosynthetic materials sand and water-filled geosynthetic container systems for coastal erosion control, storm protection and ARs have been developed (Harris and Sample, 2009).

The concept of employing sand filled containers (SFCs) of various sizes and shapes for erosion control has been in existence for centuries (Koerner, 1998). Sand bags less than a metre in length are often used in rapid flood defence response and coastal protection internationally. The container is often a woven polymer or a natural material, such as canvas or hessian, and considered to be a temporary solution. However, small sand bags are often relied upon in the longer term in prolonged disaster situations or where funding does not allow more permanent structures to be present, simply being replaced as the materials degrade. The smaller sizes and weights of these sandbags limit their use and effectiveness often being rolled or swept away in storms and rough weather conditions. Earliest fabrics employed suffered severe limitations due to degradable natural materials, the deployment of synthetic fibres has provided stronger and more durable material (Harris and Sample, 2009). Even more recent example in the past decade, the material is not as resistant to mechanical damage, so care must be taken when designing and handling geotextile systems (Black et al., 2006) as well as post-construction protection.

Advances in SFC system engineering, and developments in composite geosynthetic materials technology will continue to increase the strengths, extend the longevity and expand the applications and capabilities of these unique materials (Harris and Sample, 2009). Temporarily used until recently, geotextiles were deemed to have relatively low resistance to the marine elements (hydraulic loading of wave and currents), vandalism and UV-radiation damage were thought to also effect the integrity of the structure; aesthetics are also of interest (Pilarczyk, 1998). Lifespan claims range from the sand-filled container systems design having a 25 years (ASR Ltd., 2006) to a postulated life of up to 100 years when submerged, even in a challenging marine environment (Naue Fasertechnik, 2001). With developments in the materials it is hoped that the lifespan can be vastly improved. A number of exposed groynes along the Australian coast have been built using 5-10 tonne sand-filled containers, the oldest of these at Russell Heads has performed very well since its installation in 1993 despite constant exposure to ultra-violet and wave attack (Black et al., 2006).

Geotextiles have been used in coastal engineering for over 25 years many construction methods have been improved or have been made more economical (Heerten, 1984). Specifically for ASR construction, the geotextile utilised is a synthetic needle punched composite material manufactured from either polypropylene (woven) and polyester (non-woven). The main characteristics of geotextile SFCs fibre non-woven, mechanically bonded and needle-punched (Heerten et al., 2000). The raw material is 5.5+ mm thick UV stabilised composite polyester and polypropylene with a mass of 1200 g/m^2. Durability and high tensile strength aid the larger sand filled containers (SFC) to be resistant to marine exposure; low gravity waves, storm-surges, erosion and UV-light. Lengths over 70 m, with diameters of 3 m have been used in the creation of artificial surfing reefs. The shape, container core material, geotextile material colour can be altered with respect to the project area making this material malleable to coastal management and design needs. Depending on the specific design, other factors such as permeability, colour, and thickness also can be factors in the performance and aesthetic appearance (ADB, 2008).

Initially, the main emphasis was on hydraulically filled geotextile tubes (typically 1.2 m) used mainly as groynes to protect beaches, this focus has changed to individual containers used in coastline protection and marine structures (i.e. ASRs) (Restall et al., 2002). Individual bags or compartmentalised designs have evolved due to failures and large scale sediment losses. Theoretically, a decreased effort is needed in the repair and refill process of SFCs and, in the event of removal, compared to traditional hard coastal construction. The core material is sand derived from dredging of the local seabed material or can be sourced from quarries. Due to the vast proportion of sand to geotextiles the volume of surface material is relatively small. Generally, the effort is reduced when compared to other construction materials such as concrete, brick and steel. Transport of materials mainly via road, ship or rail, association with fossil fuel consumption, of large quantities of construction materials, which increases rapidly with weight and distance travelled (Challinor and Weight, 2009). If the core materials are sourced locally this will dramatically reduce the cost to the constructor and to the environment.

Sediment supply is an important issue in ASR construction. The origin of the ASR core sediment will dictate the cost and environmental impact of an ASR project. Ideally, locally sourced quarried sediment or dredge spoil is placed on a barge or on land and pumped as slurry to the construction site. The utilisation of sediment from the littoral zone is common place in the construction of ASRs to top up bags or to fill them entirely. For example, at the Kovalam ASR (India) the sediment supply was already in short demand and the construction company resorted to sediment dredged from the nearshore lower beach area to fill the SFCs. Dredging large borrow pits during the construction process can destabilise the natural system. Depending on local dynamics and coastal processes the bathymetry will take time to return to equilibrium; it is not fully understood whether this is in timescales of years or decades to recover. Nearshore dredging for construction aggregate or beach nourishment can result in a perturbation of natural littoral processes, changes in wave transformation patterns, and a net loss of sand from the littoral system (Demir et al., 2004). Sediment taken from the seabed is essentially fixed when pumped into the sandbags and therefore is considered to be removed from the system, it requires the surrounding beach material to fill these borrow pits. A geomat is also laid under the sand filled containers to help prevent abrasion and the scouring effects from locally driven currents and eddies. Scour is not the only issue surrounding SFCs, geotextile manufacturers warn designers that the material is potentially at risk from chemical and biological influences and must be effectively protected from ultra violet degradation. Although no recorded degradation from UV light or chemical influence has been reported on ASRs to date. The range of application for geotextile products is extensive and reliable uses do exist in marine construction and engineering, covering areas such as scour protection, groynes, berms, and containment of hazardous materials (Restall et al., 2002) in both fluid and marine systems.

2.3 Socio-economic aspects

With high claims of cost to benefit ratio, ASRs are desirable to coastal managers interested in integrating coastal protection with tourist amenity. However, there is no clear definition on the ways this value was estimated and the time frame in which such return should be expected. It is necessary to establish specific criteria to objectively quantify the environmental and socio-economic impacts of the ASRs and measure their performance.

There are few references to socio-economic impacts of ASRs in the literature. Raybould and Mules (1999) completed a cost-benefit analysis for the Northern Gold Coast Beach Protection Strategy (NGCBPS) amounting to AUS$8 million in 1996 of mainly beach nourishment and included the construction of an ASR. A high economic return value of 1:60 was placed on this scheme due to the protection of the beach face from cyclones and storms therefore avoiding loss of tourism revenue. This high cost:benefit is often misquoted in ASR Ltd. sales literature (Borrero and Nelson, 2003; ASR Ltd., 2006) as the achieved cost-benefit ratio at Narrowneck ASR. The ASR was part of the overall NGCBPS, and in terms of monetary outlay, comprised a small percent of project expenditures. There are no economic studies that evaluate the ASR directly so substantiation that the benefits have indeed justified the costs is lacking (Slotkin et al., 2008). The reef will never prove to meet this prediction of 1:60 through enhancing the economy through surf tourism, as it was never intended for the structure alone. In 1998, a report by the same authors acknowledges that the transfer of surf tourism activity from other locations on the Gold Coast to Narrowneck would mean that "there would be no net benefit to the region" (Raybould and Mules, 1998).

Slotkin et al highlight that the assessment of sustainability of surfing is hampered by the paucity of economic data and the subjective interpretation of success (Slotkin et al., 2009). These same issues arise whilst addressing the economics of ASRs. The benefits of ASR construction to the local community are therefore debatable and heavily reliant on economic monitoring pre- and post-construction. In a further study Slotkin et al independently assess the proposal for an ASR in Brevard County, Florida (Slotkin et al., 2008). They significantly undermine the claim made by ASR Ltd of a 1:4 cost to benefit ratio. They stated that the project recreational benefits were unlikely to justify costs since uncertainty surrounded the economic benefits of holding surf competitions at the site; the original economic analysis presumed to take these competitions as a matter of fact. Rafanelli (2004) claimed that an ASR proposed for Geraldton in Western Australia would generate US$1.5 million per annum through tourism, with 97% of this income being respent within the city. However, the study provides no cost-benefit ratio or discussion of income from the ASR after the first year. This reef has not been constructed and so no figures exist to support this optimistic claim.

The results of a 2004 survey conducted by the Cornwall County Council and the South West Regional Development Agency in the UK showed visiting surfers spend approximately 8.5% more in Cornwall than the average visitor (Butt and Russell, 2009). The study showed the surfing industry turnover was £64 million in Cornwall, about 20% more than the sailing industry and twice as much as the golf industry. Generally, surfing has been shown to enhance coastal economies (Butt and Russell, 2009). Similarly, a Spanish study in 2008 investigated the impacts of surfing on the small coastal community of Mundaka (population size 2000), where they showed surfing attracts 30,000 visitors to the town per annum, supports 95 jobs and contributes up to US$3.4 million (£1.9 million) per annum (Murphy and Bernal, 2008). A study of the confluence of surf tourism, ASRs and environmental sustainability in Florida found that the overall average daily spend per surf visit is about US$60 (Slotkin et al., 2009). This is consistent with other similar studies in the US (Nelson, 2007) and on the Gold Coast, Australia (Lazarow, 2011). Lazarow (2011) also gives a global estimation for the value of surfing at US$15.5 billion calculated from the three largest international surf companies based solely on surf equipment and clothing alone.

Progress in AR research has been and will continue to be slow (Bortone, 2006). The interest in the use of ASRs to support tourism and benefit the local economy is not supported necessarily with peer reviewed independent research. Fundamentally, this is a reflection in the lack of funding internationally into this area of coastal research. That said there is a strong interest in the topic at the undergraduate and post-graduate research levels. This research is often left unpublished and does not reach the scientific community, let alone the public. Research in Europe has reached a stage where scientific priorities for the future need to be developed in the light of previous research and experience (Jensen, 2002). The European Artificial Reef Research Network (EARRN) funded by the European Commission "AIR" programme (Jensen, 2002) in 1995 initiated a combined research approach and attempts to compile data collected. EARRN (Jensen, 1998) and the OSPAR convention (OSPAR, 1999) define an AR as "a submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef" (Jensen, 1998).

In 2002, it was estimated that there were 10 million surfers globally (Buckley, 2002; Corne, 2009). Events and surfing competitions are highly publicised, their popularity rising rapidly internationally. On the Gold Coast, Australia, it is estimated that a single high profile surfing event is worth AU$2.2m (£5.5m) (Mead, 2009; Raybould and Mules, 1998). Demand for economic development in coastal communities, lead to the desire of replicating the success of internationally acclaimed surfing locations. Few studies on surfing impact invariably show the high value of natural assets (Mead, 2009) however, these studies are often carried out by companies with a vested interest in the enhancement of surfing amenity. The cost:benefit prediction indicated for the construction of Narrowneck ASR was 1:60 (Raybould and Mules, 1998) whilst a lower ratio of 1:20 was estimated for Bournemouth, UK (Black et al., 2000), it still represents a healthy return. Despite favourable estimates there is clearly no guarantee that economic effects of ASRs will be positive, and there is a danger that ARs will be constructed in circumstances which do not justify them (Whitmarsh and Pickering, 2000). There are no studies of the actual economic return from the construction of ASRs.

Funding for the majority of ASR projects to date have been generated through the public sector, which expects to see financial investment returned to the local economy, mainly through tourism, at least at the cost:benefit rates estimated by ASRs developers.

The lack of baseline and monitoring information to date has meant that it is suitably difficult to ascertain exactly how much money the ASR was intended to provide, be it through enhancing tourist amenity, increasing the consistency of waves for the surf community, or by how much the construction would aid coastal protection efforts in the area.

2.4 Current Law and Policy

Currently, no regulations or protocols of good practice exist specifically for the construction of ASRs. Due to the lack of independent studies and established monitoring protocols, relatively little is known about the impacts of ASRs on the coastal environment. Other AR research provides a review with relation to the law and economics in the UK (Jensen, 1998; Jensen et al., 2000a; Whitmarsh and Pickering, 2000; Pickering, 2000; Lazarow and Nelsen, 2007; Christie, 2009; Lazarow, 2011) for ecological enhancement or coastal protection. The notable research project by Jensen (1998) named the EARRN produced much of the knowledge and resources our policy makers have today on ARs. Most of this research was carried out almost 20 years ago and still remains the most up to date resource available from which to reference on the subject of ARs in Europe. Since the EARRN project the subject of ARs did experience a lag in interest and publications on the subject dropped off. Interest in the subject has risen again over the past few years as ecodesigns and ecotechonology and ecoengineering become more popular throughout the marine industry sectors (Lok, 2015). There has been momentum in the coastal defense, maritime and harbours sectors as research into concretes and surfaces that increase biological grown, from the initial biofilms to the beginnings of a more complex ecosystem. However, there is the ongoing debate surrounding ARs, the "production verses attraction" argument continues and until this is quantified many in the marine ecology and biology and fisheries sectors remain sceptical to the true benefits of ARs.

In light of the surfing reef concept being adopted in Europe, investigation into ARs and ASR policy do need updating and a system of principles should be developed for there implementation. There have been few papers on specific policy for these structures. With reference to ARs, Whitmarsh (1997) points out that arguably law and economics have received cursory treatment in the literature to date. This was addressed in The Convention for the Protection of the marine Environment of the North-East Atlantic (OSPAR) in 1997, with the resulting provision of guidelines on ARs in relation to Living Marine Resources shortly after (OSPAR, 1997, 1999). The OSPAR convention (1999) define an

AR as “a submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef” (Jensen et al., 2000a). In more recent years, there has been some improvement after the EARRN project on European ARs and work that has been carried out by ASR Ltd. in New Zealand. The International Multi-Purpose Reef Symposium (IMPRS) and International Conference on Artificial Reefs and Artificial Habitats (CARAH) are meetings repeated annually. The new Reef Journal had its first edition in 2009 and includes a wide-ranging spectrum of authors from around the globe, both from academic institutions and the private sector.

Within Europe, the rapid growth of interest in ARs [and ASRs] has outpaced the development of law applicable to such structures (Pickering, 2000). Quite often a country’s stance on AR deployment is based on opinion rather than reliable research. The legal requirements for permits and permissions vary widely across Europe; no two countries have the same approach to licensing reef deployment (Jensen et al., 2000a). In England and Wales, DEFRA (Department of Environment, Fisheries and Rural Affairs) have adopted an approach somewhere in-between. Any reefs deployed for other than experimental purposes will have to be multipurpose (Jensen et al., 2000a), meaning that submerged structures for coastal protection are more likely to be consented than ARs or ASRs for fisheries or tourism alone. The MMO (Marine Management Organisation) on behalf of DEFRA consult with the Environment Agency, CEFAS and the Crown Estate in order to produce a consent license to dump at sea under the Food and Environmental Protection Act 1985 (FEPA). This consent is in line with the Marine and Coastal Access Act (2009) and the EU’s Integrated Maritime Strategy Blue Book (2009).

In the following chapter a theoretical framework is presented through which the thesis is described and the multidisciplinary nature of the thesis is explained and contextualised.

Chapter 3

Theoretical and Conceptual Framework

This short chapter introduces the theory of Integrated Coastal Zone Management (ICZM) and the concept of the Drivers-Pressure-State-Impact-Response (DPSIR) framework (Figure 3.1). ICZM is utilised by managers aiming to be inclusive of all activities at the coastal zone, the integrated approach is sensitive to geographical and political boundaries and aims to achieve sustainability. The DPSIR framework is used to summarise and present this thesis coherently as this conceptual model provides an appropriate mechanism for dealing with the multidisciplinary nature of the thesis, and to provide strength to the discussion (Chapter 9). This thesis uses the structure of the framework initially to unite different science disciplines in a more concise fashion so that the layout of the thesis is clear and logical from the outset. These frameworks will be introduced fully in this chapter and referred to again after the main analytical chapters in Chapter 9 where conclusions are linked together and discussed using this framework.

3.1 Introduction to ICZM

The concept of ICZM was borne at the 1992 Earth Summit of Rio de Janeiro. This is a widely respected iterative process to manage coastal zones sustainably and has adopted into modern coastal management methods. The European Commission defines ICZM as "a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning, decision making, management and monitoring of implementation. ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics. 'Integrated' in ICZM refers to the integration of objectives and also to the integration of the many instruments needed to meet these objectives. It means integration of all relevant policy areas, sectors, and levels of administration. It means integration of the terrestrial and marine components of the target territory, in both time and space" (of the European Communities, 2000).

This thesis reflects on the theory of ICZM and discusses it again in the synthesis of the analytical work (Chapter 9). The vision of a fully integrated ASR project is considered achieveable given consideration and inclusion to the multiple layers of management and key stakeholdes, and with equal weight to the natural dynamic environment. This research alters the future implementation of ASRs, providing details on what should provide a balanced and coherent strategy for meeting the drivers and pressures of the project.

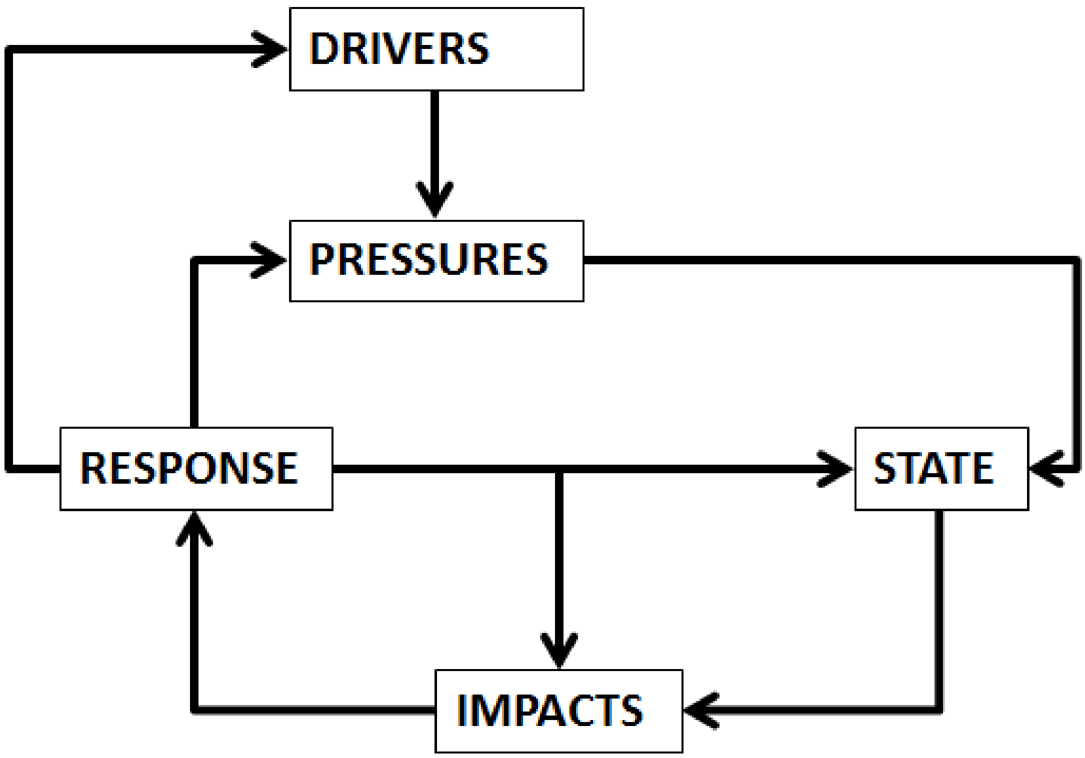

Figure (3.1). The DPSIR framework.

3.2 Introduction to the DPSIR framework

The DPSIR framework is a conceptual model that embraces the process and indicator linkages of environmental functions (Figure 3.1). The DPSIR framework demonstrates well any issues within the ICZM model, highlighting pressures on land and changing states in coastal waters, for example. Originally developed by the Organisation for Economic Cooperation and Development (1993) (Vandermeulen, 1998; Mangi et al., 2007), the objective of this framework is to clarify multi-sectorial relationships and to highlight the dynamic characteristics of environmental and socio-economic changes (Elliott, 2002; Belfiore, 2003; Mangi et al., 2007). Such links are best made by identifying and addressing indicators, which act as information tools to characterise the status of the specific environment and social situation (Jennings, 2005). The DPSIR is a conceptual framework because it shows the concept of a causal network.

The DPSIR framework is used here in order to clarify the key themes and impacts on the coastal system. It helps demonstrate the causal links between drives through the steps to responses in coastal waters. By utilising the DPSIR framework (Figure 3.2) in this thesis and the linkage of the key socio and economic drivers (tourism) to pressures (ASR construction) and to the state change (physical changes) and socio-economic impacts (for surf community), so that potential policy or management responses can be made effectively. Mangi (2007) describes how this framework has become increasingly popular in studies involving the management the marine environment, particularly in anthropogenic alterations to a natural or to a relatively balanced state (Turner et al., 1999; Smith et al., 1999), ICZM (Casazza et al., 2002; Bowen and Riley, 2003), development in catchment areas (Cave et al., 2003) and offshore wind-power generation (Elliott, 2002).

3.3 DPSIR framework in context

The DPSIR conceptual framework is used to analyse the socio economic issues, environmental changes and suggest policy responses to the emergence of the Boscombe ASR, in order to select appropriate indicators to evaluate any associated problems. This thesis focuses on the physical and socio-perception indicators to inform about the existing pressures. Better understanding of these help increase transparency and highlight possible trade-offs involved in policy and management.

The DPSIR framework (Figure 3.2) highlights the cause or reason for the decision to construct the ASR at Boscombe, the present state of the ASR to be described clearly and impacts will be highlighted. The links between a) the current socio-economic drivers, b) the associated pressures caused, and c) the created opportunity for the ASR to be constructed are vital to understand in order to better manage future ASR construction and similar projects. Once the link between drivers, pressures and impacts is clear, policy response can be discussed that might lessen the pressures created by the ASR construction, so that future projects might be perceived as more successful. In the following sections this is further broken down and explained in context with the Boscombe ASR and this thesis structure.

3.3.1 Drivers and pressures

The introductory chapter and the literature review describe some of the key DRIVERS and the environmental PRESSURES that are involved with the ASR projects more generally (Figure 3.2). The case study chapter further extends our understanding of the system and the drivers and pressures surrounding the Boscombe ASR project, specifically.

Drivers describe large-scale social, demographic and economic conditions and sectorial developments which exert pressure on the environment, forcing change. External influences such as climate change can augment this pressure. State indicators describe observable changes in environmental dynamics, which in turn can impact social benefit values. Environmental pressures are directly related these drivers and are linked to socio-economic as well as natural forces such as; tourism, additional surfers or other recreational users competing for space, more cars and pressure on the transport system, pollution and adding to the global issue of coastal squeeze associated with any new developments as the area is regenerated. There could be other pressures on the sediment budget or ecology as a result of the ASR construction.

In Chapter 4, the drivers and pressures are described that are directly responsible for the Boscombe ASR being considered, designed and constructed, and then the progression of the structure through the first few years post-construction. Drivers that have been identified early on in this research are as follow: the desire to regenerate a town, enhance tourism, provide new surfing or other recreational experiences and better the commercial fishing activities. The added benefit of coastal protection is discussed and also was a valuable opportunity to trial an alternative to replacement of groynes and nourishment retention. There is a distinction between physical and social-economic drivers; for example, Boscombe ASR the main focus is surfing and tourism, however coastal defense would be considered the main driver for the Narrowneck and Kovalam ASRs.

3.3.2 Environmental state changes

The environmental STATE change, that is the physical processes changes are further discussed in Chapters 5 and 6 (Figure 3.2). The state of the environment relates to the monitoring during which any indicators of change will be observed and recorded. The state indicators might be changes to the local wave climate and currents, the sediment budget, and also fish stocks (e.g. reduction or increase in biomass or complexity). The latter is beyond the scope of this study. These indicators should not be deemed negative, rather the observation and recording of the changes to the environment.

For the purpose of this study, the physical environment was observed and measured over a period of three years (Chapter 5). The geomorphological changes leeward of the Boscombe ASR are observed and recorded over time using regular profiling of the beach surface and assessing the beach volume changes enabling comments to be made regarding the impact of the reef to the beach and littoral zone. Similarly, the structure is monitored from regular bathymetric surveys and aerial photographs which highlights the changes to the structure to be captured over time. Addressing the impact to the physical environment as well as the structures resilience to the marine environment are key objective for this research project.

Additionally, the numerical model MIKE21 is used to investigate waves and hydrodynamics in the nearshore area and at the Boscombe ASR (Chapter 6). Particular areas of interest are the leeward areas where interactions between with the ASR, the surfers and the swimmers is being actively encouraged. The implication of constructing an ASR in the nearshore environment will have an impact on waves and hydrodynamics and therefore coastal processes. The model allows a detailed view of the complexities of the currents and waves without the expense of deploying equipment. With the model fully validated understanding of the coastal state changes is possible; when the model is run with the ASR in the bathymetry and compared against model runs without the ASR in the bathymetry.

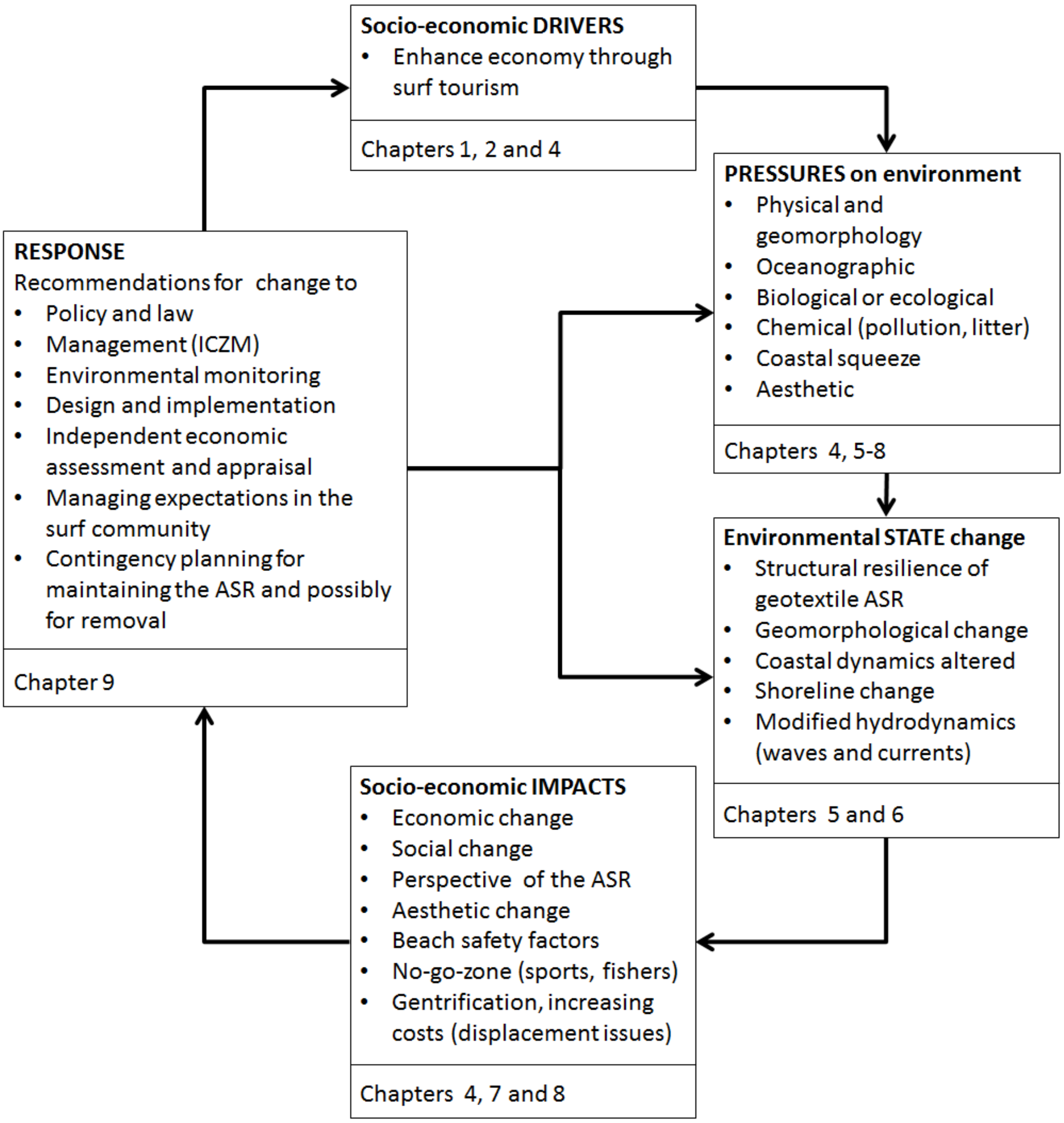

Figure (3.2). The DPSIR conceptual framework applied to this thesis, taken and adapted from Mangi (2007) and Svensson (2010). The themes in each section of the framework are highlighted and the chapters referenced where these points are discussed in more detail. The framework describes the links between key environmental and socio-economic issues of the thesis and in which chapters they are predominantly addressed.

3.3.3 Social economic and perception impacts

The social economic and perception IMPACTS describe the affect on the surfing community (direct users) and local coastal community (indirect users) after the construction of the Boscombe ASR, these are discussed in Chapters 7 and 8 (Figure 3.2). Interviews and questionnaires are used in stakeholder engagement as a survey tool to collect information about the communities and economy in a cost effective manner. Surveys of the surfer community, tourists and local seaside visitors, and residents and business owners are conducted in order to generate a full picture of the coastal community at Boscombe. The questions enable the impacts experienced and any changes linked to the construction of the reef to be highlighted. The economic benefits and burdens are quantified through the use of NVIVO; software that allows a review of the qualitative responses. This enables a quantitative analysis of the writtern opinions and perceptions of the respondents. These responses are related to a wide array of subjects such as changes to the coastline and the environment directly, they relate to safety, aesthetics, financial loss for some whilst others have gained, increased revenue for the council, and captures the alteration in peoples habits, and their opinions and perceptions of the ASR idea and future use of this technology.

3.3.4 Responses

Response indicators constitute institutional responses to changes in the system, mainly influenced by state and impact indicators (Holman et al. 2005; Mangi et al. 2007). The synthesis and discussion in Chapter 9 focus back to the DPSIR framework and presents the RESPONSES to any issues and impacts underlined throughout this research (Figure 3.2). The synthesis chapter brings together the multidisciplinary thesis and draws links between the contributions made in each of the analytical chapters. Responses in the case of this thesis relate to the recommendations in the synthesis chapter to coastal managers, decision and policy makers in councils and governments. This is related to the environmental state changes and local opinion and perception to the recorded and reported impacts and implications of the ASR construction. If the reef is deemed a success then there would be little need to change policy, although there might be valuable lessons to be learnt from this novel and innovative project. Chapter 9 addresses the impacts felt by the ASR construction that arise throughout this research, and are further emphasized by stakeholders for the management, monitoring and general handling of future AR and ASR projects.

3.4 Summary

The ICZM and DPSIR frameworks are an excellent guide to discussing and presenting the thesis. These frameworks provide opportunity to explore and describe links between the different disciplines tackled during this research. At the outset of the thesis the drivers and pressures are introduced and further discussed in relation to the research results found in the analytical chapters (5-8) where the environment state and socio-economic impacts are presented in detail. The thesis is drawn together in Chapter 9, where the components of the research are discussed and responses are proposed in the form of recommendations to policy and management of ASRs.

In the next chapter, the Boscombe ASR case study is presented. Providing an introduction to the ASR structure that was built at Boscombe, additionally it will introduce the site and surrounding environment. The case study chapter covers the history of Boscombe, the physical processes and hydrodynamics in the local area, the need for coastal defence and history of beach widening at Boscombe. The Boscombe ASR is introduced as a structure for tourism enhancement and some preliminary data sources collected by the council and lifeguards are discussed.

Chapter 4

Case Study: Boscombe Artificial Surfing Reef

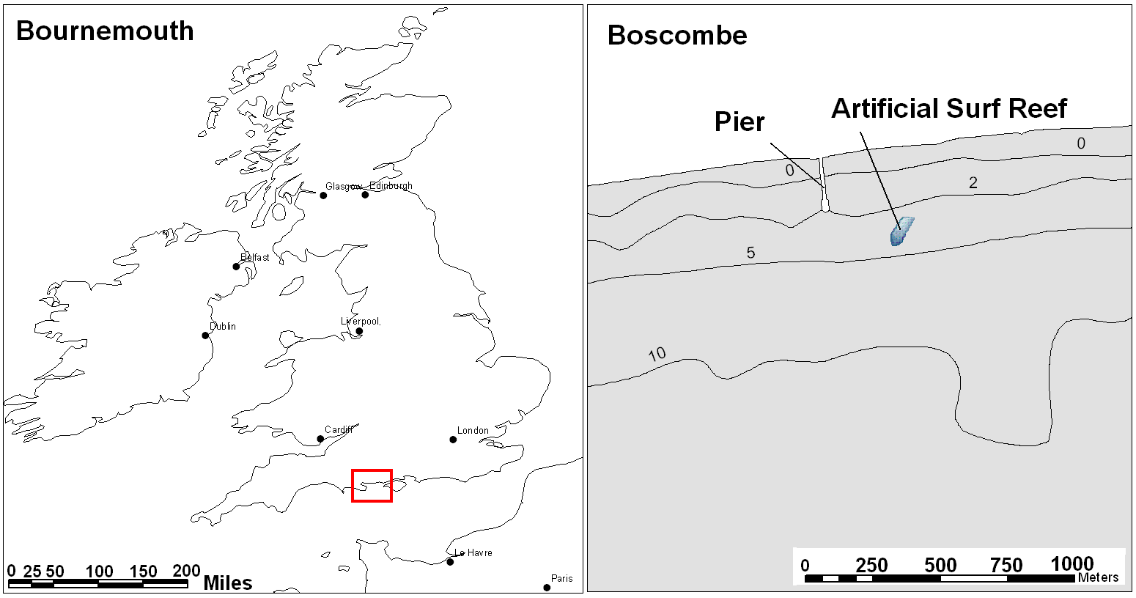

Figure (4.1). Position of Bournemouth, UK and the Artificial Surf Reef in relation to the Pier at Boscombe

4.1 Regeneration of an old seaside town

Boscombe is situated on the south coast of the UK in Poole Bay, west of the Isle of Wight (Figure 4.1). In the late 1800s and early 1900s, urban sprawl linked Boscombe with Bournemouth. The area thrived as one of many seaside resorts linked by rail on the south coast of England. It was an attractive holiday destination with its pier, promenade hotels and attractive gardens. Boscombe became dilapidated after interest in the seaside town declined associated with the decreasing cost of foreign travel, and the town lost income from tourism. Originally one of the wealthiest areas of Bournemouth, Boscombe is more recently perceived as a deprived area with a reputation for crime and drug use (Holland, 2011). The Bournemouth Borough Council recognised the increasing demand in the watersports industry and were receptive to the valued tourism industry that surrounds the area. The Boscombe ASR was agreed, designed and constructed as there was economic sense in investing in the growing surf market and associated tourism.

Since the 2008 recession, there has been increased interest in the British seaside holiday and councils are more confident about reinvesting in their shorelines. In a global context, the popularity of watersports and related industries have grown dramatically and have been seen as an increasingly important aspect of the marine and tourism market in recent years (Lazarow and Nelsen, 2007; MMO, 2013). For example, the surf industry grew by an estimated 10% globally from 2004 to 2008, but the recent economic recession has subsequently reduced growth (SIMA, 2009, 2011). The recreation sector in the UK experienced high growth in the 2000s, particularly in surfing, wakeboarding, kitesurfing, SUP, kayaking and coasteering (UKMMAS, 2010; Environment Agency, 2009; The University of Brighton, 2011; MMO, 2013). The strategy for water based recreation in the south-west (2009-14) stated that the number of people taking up water based sports (rowing, surfing and paddlesports) is likely to grow. This is due to a general shift towards the experience economy (where people prefer experiences to material possessions), and an aging population interested in activities associated with health and wellbeing (MMO, 2013). The investment into watersports development and seaside leisure activities is encouraged the watersports sector will grow in the long term.

The south-east and south-west coasts of England are the most significant regions for the marine leisure industry in the UK, contributing approximately £1.7b in total revenue during 2011/12 (MMO, 2013). Tourism is an important economic resource to the wider Bournemouth area and estimates show £600m was generated by the industry in 2011 (John, 2011). With a mild climate and good transport system to inland cities, the south coast offers a variety of different coastal and marine features such as bays, lagoons, rocky coast and beaches with generally good access and facilities to attract participants (MMO, 2013). A wide and diverse range of marine recreation activities are undertaken along the south coast including boating, recreational angling, surfing, wind surfing, sea kayaking, SCUBA diving (BMF et al., 2011). Surfing and body boarding are undertaken over natural beaches and reefs. Some of the UK's most popular surfing breaks are situated on the south coast of England, they include Bournemouth, the Isle of Wight, The Witterings, Eastborne, Birling Gap and Brighton. Higher quality surfing breaks are found in Dorset, to the west of the study site, such as the reefs at Kimmerage Bay (MMO, 2013). The south coast generally receives infrequent, short duration swell waves and wind generated waves, with the accompanying onshore winds which reduce the number of quality days with clean waves (Surfers Against Sewage, 2009; MMO, 2013). Approximately, 501-1000 boardsport users frequent Bournemouth and Boscombe annually (MMO, 2013).

4.2 Planning the Boscombe ASR and regeneration

Beach nourishment within Poole bay provides a supply of sediment to the east keeping the area relatively stable. Beach replenishment along the stretch of Poole Bay was initiated by the Bournemouth Borough Council in the 1970's (Table 4.1) when sand was placed on the Bournemouth to Southbourne region. There have been four Beach Improvement Schemes (BIS) since, the most recent being a phase of nourishment of over 2 million m^3 from 2005 to 2010. The BIS program allows for replenishment every 15 years. As well as the groyne field and sediment nourishment, the piers in Poole Bay have had a major influence on sediment dynamics at the coast. Boscombe Pier was originally built in 1889 as a 183 m long wooden and iron structure. The head was re-built in concrete in 1927 and the neck in 1960. The period 1991-1993 saw the extension and replacement of timber groynes. It was after this period that the David Weight, chairman of Wessex Surf Club and local Bournemouth resident lobbied the council to install an ASR in Bournemouth.

Weight's brother, Anthony Weight, is civil engineer and the ex-Director of Newquay Artificial Reef Company. Antony Weight was the lead enthusiast for an ASR to be built on the Atlantic coast of Cornwall, UK. The two brothers were eager to employ the geotextile technology on their local beaches and promoted the ASR Ltd. concept. The race to build the first UK and European ASR was carried out between these two brothers. David Weight was influential in Bournemouth Borough Council and named the Boscombe ASR "Weights Reef", although this name has not been widely accepted by the public.

Armed with multiple designs for the south coast region, the Boscombe ASR proposal was agreed in 1999 to be included with the next BIS. In order to fund the wider project Bournemouth Bourough Council invested in the frontage and pier, generating the funds for the ASR within this regeneration scheme.The ASR was agreed upon in principle in November 2003 (Table 4.1). Work began on Boscombe ASR in 2008 and was

Date	Event
11 Oct 1999	Bournemouth Council approve Feasibility Study.
15 Nov 1999	Approval of Feasibility study specification and costs.
2000	David Weight's cost:benefit estimate through Curry and Brown.
16 Jun 2000	Bournemouth Council Tourism committee recommend proceeding, in principle.
19 Nov 2003	Bournemouth Council Cabinet approve leisure content of Boscombe Spa Village proposals including the ASR, and the potential full use of the capital receipt from the housing development for the leisure proposals.
06 Nov 2004	Authority given to procure the field studies data and initial design study for the ASR through ASR Ltd. No evidence of a tender process.
23 Feb 2005	Revised Boscombe Spa Village leisure proposals, following listing of Pier Entrance building, submitted to Cabinet. Council approved the land-based proposals but requested a presentation from ASR Ltd. on the initial design report for the ASR for the Cabinet to consider.
2006-2010	Shoreline management is "hold the line" at Boscombe. Council being a 5 year contract for nourishment, ensuring beach stability (BIS 4: 2,010,244 m^3)
10 Jan 2007	Regeneration begins, Phase 1: Restoration of the pier and seafront.
Feb 2007	Planning permission for Boscombe ASR submitted to DEFRA.
Jun 2007	Fishermen raise objections with DEFRA.
Oct 2007	Approval for ASR granted by DEFRA.
30 Aug 2008	Phase 2: Works starts on construction of ASR.
13 Nov 2008	Work suspended for Winter.
18 Apr 2009	Work continues over Spring and Summer.
02 Oct 2009	ASR official opening the final cost is reported at £3.2m.
2010	BIS 4 officially finished.
April 2010	Hydraulic reworking of sand noted, misshaped SFCs.
Mar 2011	SFC failure recorded by annual bathymetry survey.
31 Mar 2011	ASR closed for safety reasons.
Aug 2011	Repair work discussed with ASR Ltd. but company went into liquidation in September 2012.
April 2012	Further SFC failure recorded by annual bathymetry survey.
2012	"Advance the line" as the beach width and grain size are increased deliberately through BIS 4 across the entire beach face (Harlow, personal communication)
2013	The council received £306,531 from its insurers after a two-year wait to fix the damage.
2013-14	The total cost for a marine park including ASR repairs and safety checks, is reported to be a further £700,000. Funding was assisted by the insurance money and a £254,000 grant from the government's Coastal Communities Fund plus the insurance money. It is unclear where the remaining money came from. HR Wallingford have completed a safety check and declared it safe to use.
April 2014	Boscombe Seafront has now been re-branded as Coastal Activity Park with a focus as a marine park or dive trail for divers, snorkellers, wind and kite surfing, and onshore sports such as beach volleyball. There is no longer a sole emphasis on surfing and the website does not mention the ASR.

Table (4.1). Case study timeline from ASR project conception, to the construction phase through to the present day situation. Department for Environment, Food and Rural Affairs (DEFRA), Beach Improvement Scheme (BIS), and Sand Filled Container (SFC).

completed in November 2009; taking 18 months to construct. It should be noted here that the Boscombe artificial surf reef was designed to enhance surfing opportunities in the area, not as a means of coastal protection within BIS. An independent report from HR Wallingford, UK concluded that in principle the concept of the reef would have "a broadly neutral" effect upon coastal protection and therefore unlikely to widen the beach (West, 2010).

Bournemouth Tourism PR Department (2009) states that "main purpose [of the ASR] is a leisure amenity, research suggests than a potential added benefit is that the reef may decrease the rate of coastal erosion by dissipating wave energy before it has a chance to hit the beach", also that "other artificial reefs built have provided good protection on the beaches".

4.3 The economics of Boscombe ASR

There is a history of escalating cost surrounding construction of ASRs to date. The same pattern occured at Boscombe ASR, with an original costing of £600,000 (Black et al., 2000), which increased to £1.1m (ASR Ltd., 2006) but the final construction cost in the region of £3.2m. The cost were based on unrealistic approach to visa requirements, shipping and procurement of equipment in the UK and weather downtime. The quote (£1.1m) did include a 20% contingency for weather downtime and unforseen equipment expense, however that did not prove to be sufficient and was poorly estimated. Further costs to the council came as storms in 2008 moved anchoring and navigational markers. Eventually the geotextile SFCs began to fail and the repair work has amounted to an additional £700,000. This will be further discussed later in the structural resilience section of Chapter 5. This does not support studies evaluating construction costs produced by ASR Ltd "that a single reef could replace two groynes, and that the construction cost would be similar" (Mead, 2009). A council Economic Impact Assessment has suggested that the reef could provide direct income of up to £3m per annum (UKMMAS, 2010). It is difficult to convince local population that such an investment that favours only a small group of people (i.e. the surfers) directly can bring revenue that will benefit the wider community indirectly. This is further investigated in Chapter 8.

The original cost:benefit estimate (Table 4.2) was carried out in 2000 by David Weight, then a cost modeller at Curry & Brown (Weight, 2000). The Weight (2000) cost:benefit analysis was based on personal research, a visit to the Narrowneck Reef (Australia), the designers (ASR Ltd.) provided the data and figures for the analysis, and Weights knowledge of surfing in the region (Table 4.3). The accompanying letter to Weight's estimation addressed to the Head of Leisure Services at Bournemouth Borough Council, Mr. Rodger Brown, states that "the number of surfers per day at Boscombe would be increased" due to two distinct reasons:

1. The reef will work through a much larger tidal range than the sandbars used now."

2. Carry capacity will be increased by:

a) Increased length of ride (people take longer to paddle back after a ride),

b) A higher proportion of waves will offer reasonable rides,

c) Increased height of wave, and

d) Improved quality will attract more surfers, and surfers will tolerate longer waits if the quality of the waves they get merit it.

Assumption	Cost:benefit ratio	Payback period in years
Pessimistic	5.63	2.27
Moderate	9.42	1.66
Optimistic	15.61	1.12

Table (4.2). Summary table of the original cost:benefit ratios and years to return costs, as estimated by David Weight of Curry & Brown (Weight, 2000)

Detail of project	Cost	Who made estimate
Boscombe (2 reefs)	£480,000	Jackson, A (ICM, Auz)
Design fees	£135,000	ASR Limited, NZ
MAFF flood protection license	£3,000	Approximated by Weight, D (Curry & Brown)
Total cost	£618,000	

Table (4.3). Details of the Boscombe ASR costs as composed by David Weight of Curry & Brown (Weight, 2000)

Weight's (2000) estimate assumes that turnover on surf equipment would rise in proportion to the increase in number of surfable days (i.e. if surfing at Boscombe currently accounts for 10% of surfing by local surfers and the surfing here increases by 300%, then turnover on surf equipment should increase by 30%). Another assumption of the estimate relates to sales of surf merchandise that is expected to rise, but this increase is assumed to be 50% the increase in surf equipment. A "value added" percentage (10%) for fashion clothes etc. is accounted for in estimating the extra income to the region. A brief breakdown of the "moderate assumptions" scenario:

- Surfing days at Boscombe should double to 150.

- Surfing sessions per surf day should also double, so that overall surf sessions per year will increase from about 3,750 to 15,000, being a 300% increase.
- The number of surfing tourists should increase from about 84 to 2,025 per year, which, if spending an average of £20 per visit, totals £40,500 per annum.
- The fully reported turnover from surf equipment shops is £4,430,000, being about £932,500 on surf equipment and £3,497,500 on non-surf equipment.
- Turnover on surf equipment shops should increase by 30%, being about 280,000.
- Turnover on non- surf equipment shops should increase by 15%, being worth around £52,500 in increased revenue to the area.
- The combination of tourism, surf equipment and spin-off non-surf equipment equals £40,500 + £280,000 + £52,500 = £373,000 per annum.
- When evaluated over 25 years but discounted at 4% per annum, this equates to a present value of about £5.8m, giving a cost:benefit figure of 9.42 (the "moderate" assumption in Table 4.2).

Weight (2000) notes figures are not attached for the following benefits that could further enhance the economic benefits (such as "wave-windsurfers, snorkellers and divers, spectators, fishery enhancement, advertising and image benefits, publicity, coastal / pier protection") and dis-benefits to deduct (such as "the use of fishing rods on Boscombe pier, but could use lines and there would be more fish to catch"). Weight (2000) refers to this as a "partial cost:benefit" analysis as it excludes the wider benefits and costs. This does seem appropriate as the ASR was not designed with the coastal protection or additional amenity benefits (such as fishing) in mind, later reports do however make claims which will be investigated in the thesis. The quoted 1:20 cost:benefit ratio widely reported in the media is thought to have been calculated from the "optimistic assumption" with the additional benefits added. However, the breakdown has not been mafe available during this research. This estimate ends with a request to the council to consider the social benefits alongside the economic benefits:

> "Finally, as if the economic case were not enough, I urge that Bournemouth Council consider the social and health benefits. This would be a very good and beneficial facility even if it did not have great economic benefits."

This estimate does not appear to be objective, rather an argument for swaying decision makers that the project will be successful; the figures are provided by the contractor (which proved to increase rapidly) and it is calculated by an enthusiastic surfer eager to install the technology. It would have been more appropriate for this work to be carried out by an independent expert, a non-surfer ideally to provide a non-bias cost:benefit estimate. It would have been an ideal opportunity to create an economic baseline at this point from which the value of the project can be calculated.

It is inherently difficult to establish the economic baseline for this regeneration project as little information was collected or exists before the project was initiated. The economics of the project is inherently entwined with the gentrification of the wider area, it is claimed that the Boscombe ASR proposal was used as the decider for where Bournemouth Borough council would focus their attentions in redevelopment of the local seaside towns. The economics are hard to separate with the three aspects of the wider beach improvemement scheme (BIS) running in parallel; the BIS for renourishing the beach, the regeneration of the buildings and pier on the seafront and construction of the ASR.There were other contenders along the neighbouring coastline. The ASR and regeneration scheme were used to gentrify the severly delapidated seaside frontage, the intention was for the combined project to bring tourism and increase the economy. Other councillors have claimed that the Boscombe ASR was not in the original designs and that it was added onto the regeneration plans at a later date. It has proved difficult to accertain the baseline (pre-construction of the ASR) economic situation and seperate it from the regeneration scheme. The calculation of the value added to the area is reliant on these baseline and separation from the wider seafront enhancements. Presented in this chapter is a qualitative description of the seafront and the wider area, where available timelines and costs have been provided.

4.4 Boscombe ASR

4.4.1 Design and Construction

Construction used 32 geotextile sand filled containers of various sizes set in opposing directions were positioned by SCUBA divers in two layers and filled with sediment *in situ*. In the design specifications (Table 4.4) the ASR is located 225 m offshore and covers an area of seabed approximately 45,000 m^2 in extent between 2.7 m and 5.0 m depth (chart datum). The ASR has the design plan of length 120 m and height of between 2.8 m to 4.1 m. Geotextile SFC are up to 67 m in length and between 100-800 m^3 in volume, with a total reef volume of approximately 13,000 m^3. An aerial photo of the Boscombe ASR is given in Figure 4.2. Boscombe ASR was designed to provide a high-quality right-hand surfing break up to 80 m long during clean swell conditions and a shorter left hand break (ASR Ltd., 2007).

Figure (4.2). An aerial photo of the completed Boscombe ASR

The Boscombe ASR is constructed with the inshore end on the 3 m chart datum (CD) isobath, located approximately 220 m from the base of the seawall, and at a position 240 m east of the Boscombe pier (ASR Ltd., 2006). Reef designers claim sediment throughput can be regulated by the position of reefs in the cross-shore direction (Mead and Black, 1999b). With the reef structure built nearer the shoreline increased prevention of littoral transport may occur. If the reef is required to not block alongshore drift it must be adequately offshore.

The reef design aimed to provide a right-hand surfing wave with a surfing ride length of 65 m plus a steep left-hand breaker which initially has a ride length of 20 m (ASR Ltd., 2006). The left ride was expected to increase in length after the reef has been installed as sand was forecast to intermittently build up against the west side of the reef during common swell conditions creating a natural sand bank to extend the left hand rides (ASR Ltd., 2006).

The design crest height is 0 m relative to chart datum (1.66 mODN = MSL). This height is designed to produce surfable conditions at mid-tide through to lowtide. Important for forming the surfing wave, the crest height also influences sediment transport leeward of the structure and therefore nearshore coastal processes. The design crest should therefore not be visible except on extreme tidal and wave conditions, under which it was expected that waves would break on the lower section. It is worth commenting here that the Boscombe ASR was not built to this specification and that the constructed crest height is approximately 0.5 mCD (2.16 mODN).

Parameter	Value
Volume	11,900 m^3
Reef Footprint	5,450 m^2
Reef Length	120 m
Crest Level	0 mCD
Reef Height	2.8 to 4.1 m
Ride Length (Right)	65 m
Ride Length (Left)	20 m
Peel Angle (Right)	$60° \pm 5°$
Peel Angle (Left)	$70° \pm 10°$

Table (4.4). The design specifications for Boscombe ASR (ASR Ltd.,2006)

4.4.2 Surf characteristics at the beach and ASR

A 6-month assessment of the performance of the Boscombe surfing reef was carried out, quantitatively assessed against specified design criterion and compared to conditions on the neighbouring beach alongside the existing pier at Boscombe (Davidson, 2010). The report found that the ASR was meeting four of the eleven performance criteria (in surfability, wave form, peel angle and wave height amplification) and partly meeting a further two (ride length and physical shape). These criteria were not evenly weighted in terms of importance but considered a guide to assess the success of the ASR in terms of various surf parameters. Bournemouth County Council and ASR Ltd were preparing refinement works for 2011-12 alongside maintenance works to improve Boscombe ASRs performance; however it is now unlikely that the reef will be refined for surfing after the damage it has received (as discussed in Chapter 5).

Davidson's (2010) findings discuss a success in producing an additional surfing resource at Boscombe, however the wave is more challenging than designed, and restricted to more advanced level surfers. The constructed reef performs loosely to the initial design; the wave is steep and frequently plunging, a ride length is possible of 20 m and 40 m to the left and right respectively; the latter is short of the original design plan. His findings indicate that the wave is too challenging in comparison to the design criteria, meaning novice surfers and intermediates would not be able to surf the Boscombe Reef. The ASR is designed to increase quality surfing days at Boscombe in swells from 0.5 m and larger (ASR Ltd., 2006). The crest of the reef is shallow (just below water level at the lowest tides) so that even the very common small waves (0.5 m) will break around low tide (ASR Ltd., 2006). In reality this is not the case and the ASR produces surfable waves at mid-tide for a brief period (1 to 2 hours) around mid-tide. The horizontal extent of the reef, orientation and the orthogonal reef gradient conform well to the original design, but the reef crest is higher than planned. Since the reef crest is fully exposed at low tide, no surfing is possible at this state of the tide. At high tide, given the wave climate, surfing is not possible due to the depth of water above the ASR preventing waves breaking. The ASR is certainly capable of producing surfable waves however not as consistently as designed or intended. This will be further explained with data in the following section.

Figure (4.3). Surfing at the Boscombe ASR, and (top-right) to the west of Boscombe Pier with waves breaking over the reef in the background.

4.5 The regeneration scheme

Boscombe needed regeneration of the now dilapidated 1950s seafront to bring it inline with neighbouring modern tourist hotspots. Bournemouth Borough Council looked for an innovative focal piece for the Boscombe Spa Resort and choose ASR technology and surfing to be flagship elements of the regeneration scheme at Boscombe seafront. The ASR was poised to provide Boscombe Seafront with a new surf-cool image. The regeneration project also included shortening and replacing the pier at Boscombe, making the seafront more appealing to tourists, developing 'The Overstrand' (a large 1950's low-rise building that spans from the east of the pier) into new facilities including shops, restaurants and to house the lifeguards (RNLI) and tourist information. The entire Boscombe seafront regeneration scheme totalling £13.5m was funded through both private and public investment (Marsh, 2010). Council funding for both these projects was mainly through the sale of an apparently underused car park to housing developer Barratt Homes (£10.4m) as well as grants (£1.3 m) and sale of new beach huts (£1.8m) (Marsh, 2010).

Figure (4.4). (a) The new build Barrett's Homes apartment complex (Honeycombe Beach flats) built on the old car park, and (b) The shortened and renovated Boscombe pier, lit up in the evening.

Some initial benefits that the seafront has received are noticeable and have greatly improved the general safety and welfare of those visiting the seafront. Regular patrols are made of the beaches and the abuse of alcohol and drugs are not tolerated on the beach. Increased street lighting and the removal of public benches on the seafront and in parks have provided a strong message. The buildings and pier have been modernised and improvements are listed below:

- The new build Barrett's Homes luxury apartment complex with sea-views (Figure 4.4a).

Figure (4.5). Before and after the shortening and regeneration of Boscombe Pier, here the view of the entrance to the pier and shops that flank the gates.

Figure (4.6). (a) The Overstrand building has a cafe and bar (Urban Beach, a new addition to the seafront), tourist information, the RNLI lifeguard office and storage, and (b) Sorted Surf (shop and hire); the latter was a pre-existing business that visibly expanded into further premises with the regeneration of the seafront and addition of the surf reef. The 'surf pods' are on the first floor of The Overstrand.

- The shortened and renovated Boscombe pier is in keeping with the traditional look but has a fresh modern appeal (Figure 4.4b).
- Before and after images of the grade-II listed Boscombe Pier entrance highlights the restoration of the dilapidated and derelict frontage (Figure 4.5a and b).
- The 1950s Overstrand building has new cafes, bars and surf hire and shops selling equipment and clothing. The seafront has traditional wooden beach huts and modern 'surf pods' on the first floor of The Overstrand (4.6a and b).
- Luxury living developments such as 'Honeycombe beach', 'The Reef' and 'Waves'.

Economic estimates show the value of the regeneration to be £41.5 m Gross Value Added (GVA) (Bournemouth Tourism PR Department, 2009). According to the Bournemouth Council PR Department (2009) the regeneration had created 80 jobs on Boscombe seafront alone:

- 3 jobs have been created at the RNLIs Boscombe station.
- 90 subcontractors have been employed in the 3-year build of the Honeycombe Beach flats (Figure 4.4a); 12 long-term construction and sales staff (i.e. project managers, site managers).
- Both Urban Reef and Urban Beach restaurants (Figure 4.6a) have contributed 40-50 extra jobs so far this year (2009).
- Sorted Surf Shop has invested over £300,000 in new premises, store fit-out and warehousing. Sorted Surf has been running in Boscombe since 2000 and comprises of a seafront surf shop and school, complete with water sports and surf equipment hire and year-round lessons. Sorted Surf have recruited up to 15 extra staff this year and expanded into further inland premises (Figure 4.6b).

4.6 Physical processes

4.6.1 Geology

Poole bay is a shallow embayment extending from Durlston Head to the west to Hengistbury Head in the east. Much of the coastline features formerly rapidly eroding soft cliffs that are now fronted by a substantial traditional seawall and promenade (SCOPAC, 2004). The coastline was previously subject to continuous erosion throughout the late Holocene period resulting in the development of steep retreating cliffs 20-35 m in height and supply of much gravel and sand to the beach (Halcrow, 1999). The solid geology of the cliffs, and the seabed beneath Poole Bay, is composed of rocks of the Tertiary Bracklesham Group, consisting of a sequence of fine, medium and coarse sands (Bristow et al., 1991). At Hengistbury Head there are younger rocks of the Bartonian group, forming an outlier, made up of a series of sands and interbedded clays, with four distinct bands of ironstone nodules (SCOPAC, 2004). The ironstone strata are exposed at Hengistbury head.

Since 1914, the initiation of the coastal defences and nourishment of the shoreline, there is very little natural input of sediments supplied by local cliff falls. Sub-aerial processes of weathering and mass movement continue to operate but is considered minimal; estimates circa 0.01 m per annum of cliff top retreat for Boscombe, giving a yield of 15m^3 per annum (Harlow, 2001). The cliffs are geomorphologically dead as they are protected by the wide artificial beaches and vegetation makes them more stable (West, 2014).

Figure (4.7). Satellite images available through Google Earth; (a) Original pre-regeneration frontage in December 2002, (b) April 2007 construction works begin at Boscombe seafront, shortening of the Pier and work begins at the car park site, (c) The Boscombe ASR is completed and the sand pile smoothed across the beach face by December 2009, and (d) The building works can be seen to be completed in this image from January 2012.

Various studies have described and reviewed the current knowledge and understanding of sediment transport in Poole Bay (Lacey, 1985; Hodder, 1986; Lelliot, 1989; Bray, 1993; Halcrow, 1999; Harlow, 2000). These studies conclude that there is no permanent onshore sediment migration likely from the Bournemouth and Sandbanks beaches since there is no corresponding supply from further offshore to maintain such a large sediment demand. Two categories of marine input are recognised, comprising: (i) input of fresh sediment to the Poole Bay system; and (ii) sediment supply to beaches and Poole Harbour entrance from existing nearshore/offshore stores within the Poole Bay system (SCOPAC, 2004). Sediment migration from Bournemouth to Southbourne is predominantly eastward; the littoral drift is dominantly driven by a wave induced energy gradient (SCOPAC, 2004) and predominant angle of wave approach being from south-southwest. The net movement of sand along this coast is believed to be from west to east (Harlow, 2000), in response to the dominant westerly wave climate. Reflection and diffraction of wave energy occur around a large offshore sandbank (Hook Sand), alongside diffraction of energy entering from the English Channel around Durlston Head make prediction complex (SCOPAC, 2004).

4.6.2 Beach morphology

The beach is predominantly medium coarse sand with pebbles interspersed at the shoreline. According to Wright and Short's (1983) beach classification Boscombe beach behaves in a dissipative manner (Voulgaris and Collins, 2000), characterised by gentler slope calculated by (Davidson, 2010) to be between 0.019 and 0.025. As Poole Bay is subject to strong erosion, groynes have been installed within the shoreline, with beach replenishment schemes being implemented (Voulgaris and Collins, 2000).

During the last 30 years periodic recharge using imported sand and gravel, though groynes remain critical as means of controlling drift rates and beach levels (Harlow, 2001; May, 1990; Cooper, 1997; Cooper et al., 2001). In calmer, summer conditions the beach appears well sorted. Coarsening towards Mean High Water is evident. A value of 1.8 phi is a critical size, with finer material likely to move offshore; some of this is deposited on shore-parallel bars (SCOPAC, 2004). During high energy events the beach material becomes coarser and moderately sorted. A general decrease in energy in the longshore current towards the east of the bay can begin to explain the larger grain size found to the west, coarser grains are deposited as the current weakens with finer grains being carried further eastwards. Beach gradients are gentle, increasing eastwards in the lower energy conditions (SCOPAC, 2004). A combination of limited natural sediment supply and the presence of a steep, backing seawall results in "squeezing" of the intertidal beach and a consequent steepening of gradient.

Dissipative beaches wave climates can be characterised by a broad surf zones with spilling breakers (Davidson, 2010), it has been identified that the spectrum of water motions frequently exhibit high levels of infragravity energy (Aagard and Hughes, 2006). Dissipative beaches are attributed to the high-energy end of the beach spectrum, displaying stable and persistent behaviour (Short, 2006). In the case of Boscombe the spilling waves break on an offshore bar 150m from the mean shoreline of Boscombe, it has been identified that in dissipative beaches waves have the propensity to reform after the initial break and break a second time closer to the shoreline (Davidson, 2010). The characteristics of dissipative beaches have relatively fine sediment sizes with a greater sand volume (Voulgaris and Collins, 2000).

Seasonal variation in beach height, area and profile form are apparent (SCOPAC, 2004). Maximum beach area and summer profile is normally characteristic of late summer and early autumn (August to October). High-energy storms can result in up to 1 m decrease in beach profile height in a few hours as sand is transported offshore to form nearshore bars (Henderson and Webber, 1977) . Typically, this material would be returned to the beach during calmer intervals with an associated decay of nearshore bars.

4.6.3 Hydrodynamic conditions

Boscombe is a complex microtidal, semi-diurnal tidal regime (Figure 4.8) with a spring tidal range of 2 m (Davidson, 2010). The tides are semidiurnal, which exhibits double high tides due to the influence by the tidal flow in and out of the Solent around Portsmouth and the Isle of Wight. It is the shallow water effects that are the formation of tidal harmonics that give rise to the double high water. The average spring tide range is 1.7 m and the average neap range is 0.6 m (Royal Haskoning, 2004). The tide ranges from -1.78 m to 1.95 m when analysing 9 years of data from the Bournemouth pier, 3km from Boscombe. Storm surges have been known of up to 1 m, this is considered significant given the relatively small tidal range (Gardiner, 1999). Tide generated currents are generally considered to be strong at Bournemouth, there are strong tidal currents from west to east which influence the tidal stream regime of the entire Poole Bay. As a guidance for the tide the UK Hydrography Office publishes flows in the English Channel as currents four hours before the time of high water on a neap tide are in the region of 0.77 m/s and on a spring tide are in the region of 1.34 m/s.

The dominantly semi-diurnal tide at Boscombe has a double high and a double low (although the double low is less clear in the tide curve) due to the interaction of the tide

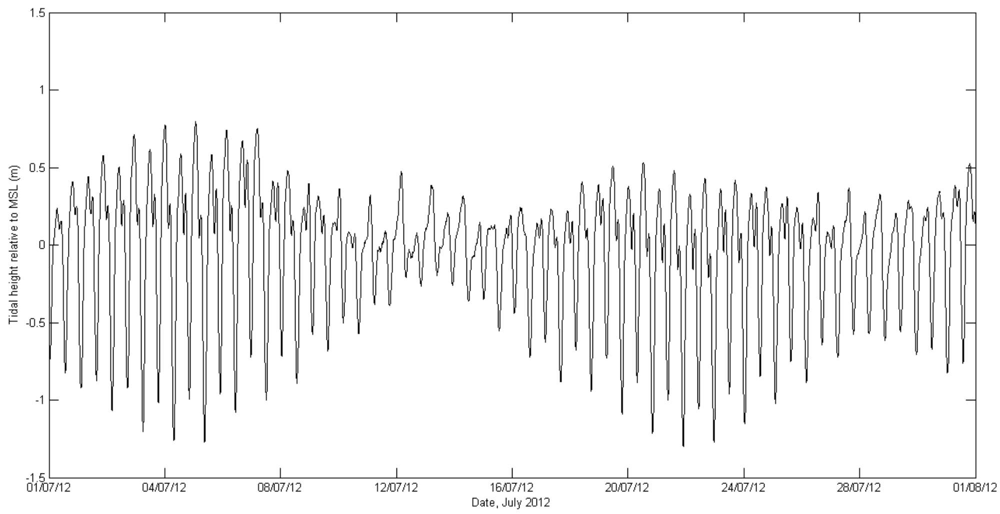

Figure (4.8). One month of tide data from the BODC, recorded at Bournemouth pier from 1 July 2012 to 01 August 2012

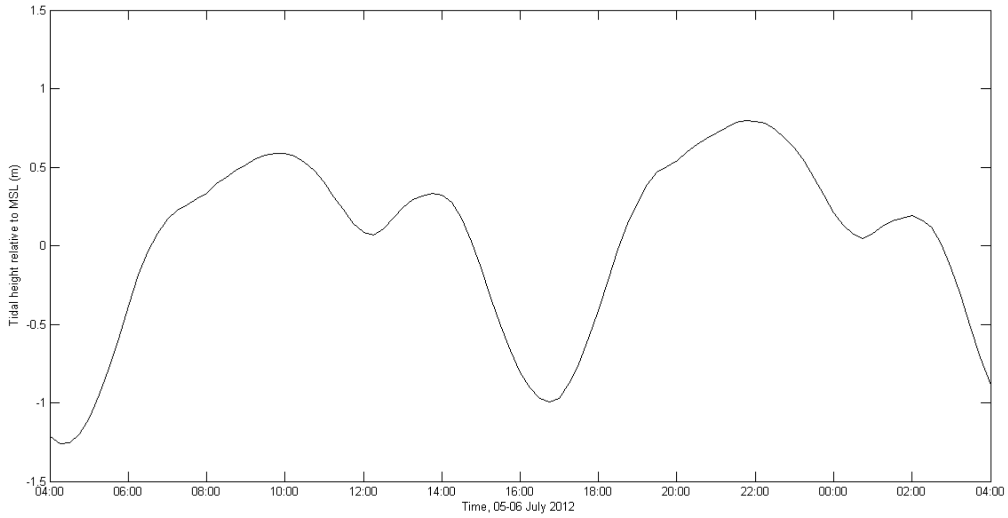

Figure (4.9). Twenty four hours of tide data from the BODC, recorded at Bournemouth pier from 0:400 5 July 2012 highlighting the a mixed predominantly semi diurnal tidal cycle

from the North Sea and the NW Atlantic Ocean, the Isle of White and the Solent region at Portsmouth. The uniqueness of the tidal curve does mean that high tide fluctuates around the high tide point therefore lasting longer than a normal diurnal tide would at high (Figure 4.9). A similar observation can be made for low tide conditions however the fluctuation is less. The result of this phenomenon is the appearance of longer high and low tidal state and a shorter mid-tide situation.

Due to Boscombe's locality along the English Channel, much of the long period swell from the Atlantic Ocean is dissipated as it propagates over the continental shelf before it reaches this coastline. Landforms such as Hensbury Head at the southwest extent of the bay also refract and dissipate energy, providing a natural shelter to the coastline (Harlow, 2000). The fetch limited wave climate can be described as medium to low energy, especially in summer months (May to August). The coastline receives frequent localised storm conditions during the winter months (September to April), although storms can occur in any season of the year. Hydrodynamic behaviour of the English Channel is influenced by a mix of tidal and wave activity (Anthony et al., 2004). Conditions are predominantly driven by storm waves, with short wave period predominantly from 130° to 210° (south-east to through to the south-south-west), the modal angle of approach (θ) is 191° (Figure 4.11). High energy wind waves with peaks between 4 to 9 seconds occur between longer intervening periods ranging from order of days in winter, to several weeks in summer where lower energy wind waves are consistent (Anthony et al., 2004). The largest waves in the area are from the south-west and the most frequently occurring from the south (Royal Haskoning, 2004). Wave data collated from the channel coastal observatory identified that the percentage of waves 0.5 m, 0.75 m and 1 m being 40%, 27% and 15%, respectively (Davidson, 2010). The modal wave height and period measuring 20 cm and 6 s, respectively (Davidson, 2010). Studies in the offshore wave climate have established the predominant wave height being less than 0.6 m (Voulgaris and Collins, 2000). Figure 4.10 highlights the more frequent occurrence of short period, low energy waves.

The winds are predominant south-westerly that coincide with large fetches from the south west. Switching occasionally to south-easterly winds during periods of storms over Europe and the English Channel. The wind climate can be severe with winds frequently exceeding 10 m/s (19.4 knots) (ASR Ltd., 2006). Occasional swells with an easterly component occur, and these are associated with local storms in the English Channel (ASR Ltd., 2006).

4.7 Secondary data: surfer numbers

4.7.1 Sea Front Ranger Data

This section makes use of data collected by the Bournemouth Borough Council's Seafront Rangers; the observations of surfer numbers hourly are recorded on a) the Boscombe ASR, and b) the pier beaches of Bournemouth, Boscombe and Southbourne (the pier has been long removed but the piles remain and waves break on the fixed surrounding sand bar). The data range is inclusive of 2004 to 2009. After 2009 the data was deemed too sensitive by the Bournemouth Borough Council, therefore the further years data were not

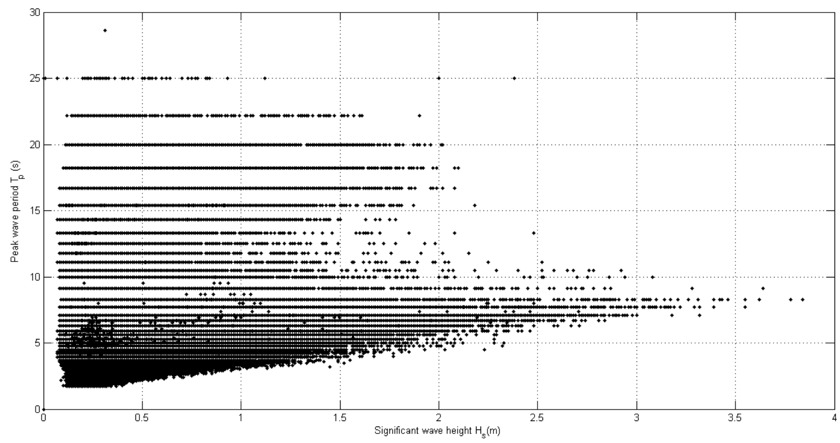

Figure (4.10). Scatter diagram of peak wave period Tp (s) vs significant wave height Hs (m); Boscombe wave rider buoy data from the Channel Coast Observatory 2003-2009

made available to this study. The sensitivity of the data relates to the negative press and media coverage that followed the ASR project. Observational evidence from the Seafront Rangers suggests that the reef was being surfed (before closure due to safety reasons); although evidence suggests that the reef is less consistent for surfing than the neighbouring beach. The council considered the statistics that highlight any count of the Boscombe ASR being less surfable than the Boscombe beach surf break could prove damaging to the overall success of the regeneration project of Boscombe seafront. Although there are no statistics for the period after the construction period, the concern for the release or publishing of this data indicate the ASR was not particularly successful.

Bournemouth and Boscombe beaches are the two most popular sites for surfing in the area with peaks of 14,883 and 24,920 surfers, respectively. There is a general trend of decreasing surfing activity at Southbourne beach as popularity doubles at Boscombe beach from 2004 to 2006, the surfers shift from Southborne as the sand banks become less consistent for surfing after the recent beach nourishment scheme was implemented. The data indicates that in 2008 when the first layer of the ASR was constructed surfers began to surf on the reef (Table 4.5 and Figure 4.12). The number is not expected to be high since no official marketing or opening of the ASR had occurred at this point. Interest in the project grew and over the summer of 2009 surfers were eager to commence surfing during the autumn and winter seasons. The number of surfer on the reef has increased by an order of magnitude (from 83 to 808 surfers), however was not as popular as the beach break for surfing (16,619 surfers). The total surfers has increased by over 3,000 from 2008 to 2009. However higher counts of surfers were recorded by rangers in 2004 and 2006. This increase is within the previously observed fluctuations of surfing activity

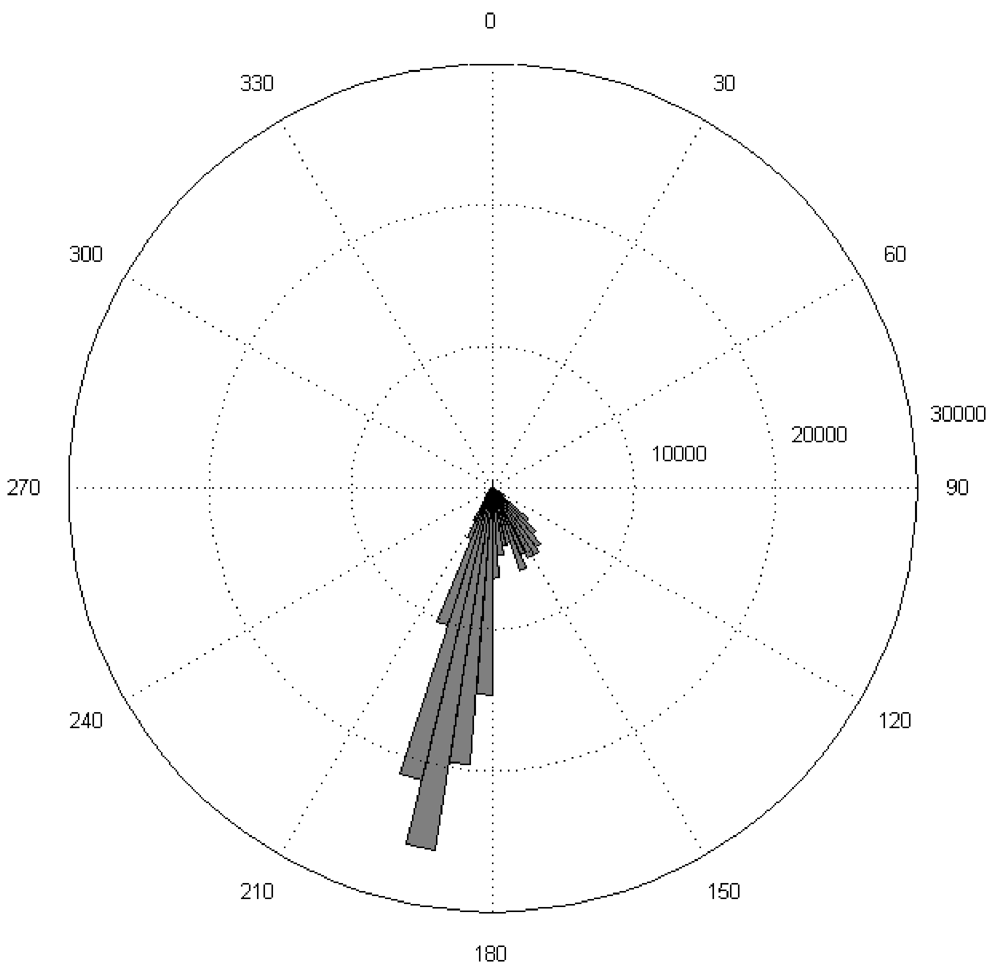

Figure (4.11). Directional histogram showing wave direction data recorded at Bournmouth pier between 2003 and 2012, data from the British Oceanographic Data Centre

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at these three beaches.

These data were also used by Davidson (2010) to ascertain whether the reef is being surfed and the environmental conditions under which surfing on the reef is taking place. The temporal variability of surfing intensity highlights that the majority of surfing activity occurs in the Autumn months (September, October and November) and accounts for over 40% of surfing activity (Figure 4.13a). There is a peak also in June corresponding with the beginning of the summer holiday season. The ASR was open during the Autumn of 2009 and the days that were surfable were utilised by the surf community. The surfing intensity data hourly shows that peak surfing times at Boscombe occur between 11:00 and 16:00 hours (Figure 4.13b). The distribution is normal but skewed towards the earlier hours reflecting a minority group of the surf community, probably surfing before work. The reduced daylight during the autumn and winter months is the reason surfers are rarely seen in the water after 16:00 hours. Boscombe's surf scene is a mobile or travelling surf

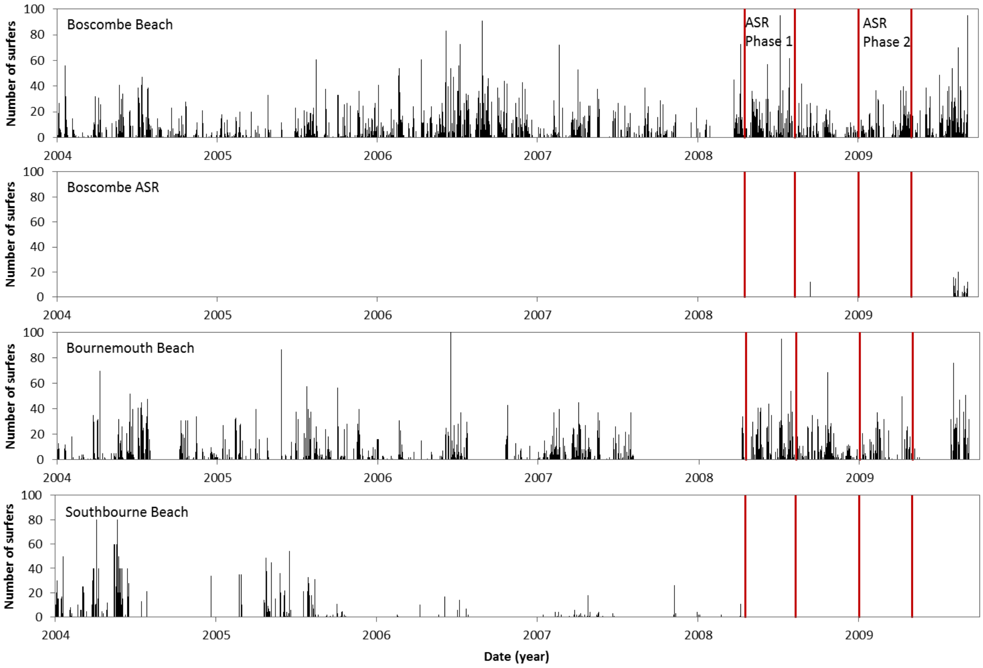

Figure (4.12). The number of surfers (as counted by Bournemouth Borough Council's Seafront Rangers) at each of the three local beaches for comparison. The ASR construction phases are marked in red to highlight the beginning and end of the construction during the summer months of 2008 and 2009.

community from nearby cities and towns in the winter, and predominantly a novice surfer destination in the summer months due to the wave climate.

	Bournemouth	Southbourne	Boscombe	Boscombe ASR	Total	Rank
2004	11,863	12,698	11,480	na	36,041	1
2005	13,399	5,413	8,169	na	26,981	5
2006	10,583	417	24,920	na	35,920	2
2007	10,781	157	13,285	na	24,223	6
2008	13,978	336	14,767	83	29,164	4
2009	14,883	0	16,619	808	32,310	3

Table (4.5). Six years of Seafront Ranger's surfer count data from 2004 to 2009, supplied by the Bournemouth Borough Council.

4.7.2 RNLI lifeguard data

The RNLI (Royal National Lifeboat Institute) beach user data is a similar data set to the seafront rangers data. The RNLI patrol the popular bathing and surfing beaches in the UK. Lifeguards record daily users at the beach and the activities such as water users or surf/craft users, data from 2007 to 2011 was made available for this project (Figure 4.14). The total beach users has increased over the first three years as the seafront was improved. There is a marked difference in the total beach users between the Boscombe East of the

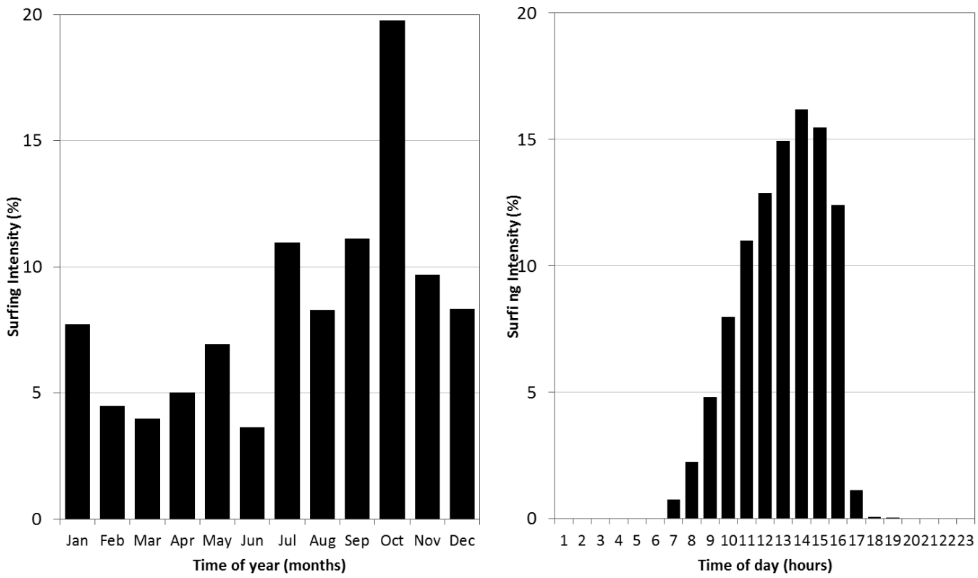

Figure (4.13). Temporal variability in surf intensity from Bournemouth Council Ranger data.

pier (main focus of development and overlooking the ASR) and the Boscombe West of the pier (limited new facilities). The total beach users in the East and West reflect a similar pattern to the total users data, there is a general increase over the first three years which reaches a plateau on Boscombe West but peaks in 2011 on Boscombe East.

The water users data includes anyone paddling ankle deep, through to emerged swimming and those using a board or craft (Figure 4.14d). The trends at both beaches reflect the same increase interest. This highlights that there a general trend towards watersports becoming more popular at the seaside resort, initially Boscombe West rapid increase in popularity for water activities up to 2009 and the comparatively slow increase on Boscombe East (this is due to the construction works for the ASR and large sand piles on the beach, and other seafront building works). After the ASR completion by 2011 both sides of the pier are receiving similar numbers of water users. Surf and craft users a drawn in increasing numbers from 2007 to 2009 at both sides of the pier (Figure 4.14c). After 2009 the surf / craft user counts plateau on Boscombe East and decrease on Boscombe West in 2010 and 2011.

Incident data is recorded amongst many other parameters. Table 4.6 gives the incident data from 2007 to 2011 for Boscombe Beach either side of the pier. The East lifeguard unit is generally more popular due to the avaliable facilities, it is this unit which overlooks the ASR. The popularity is reflected in the incident numbers. Whilst the West unit reports

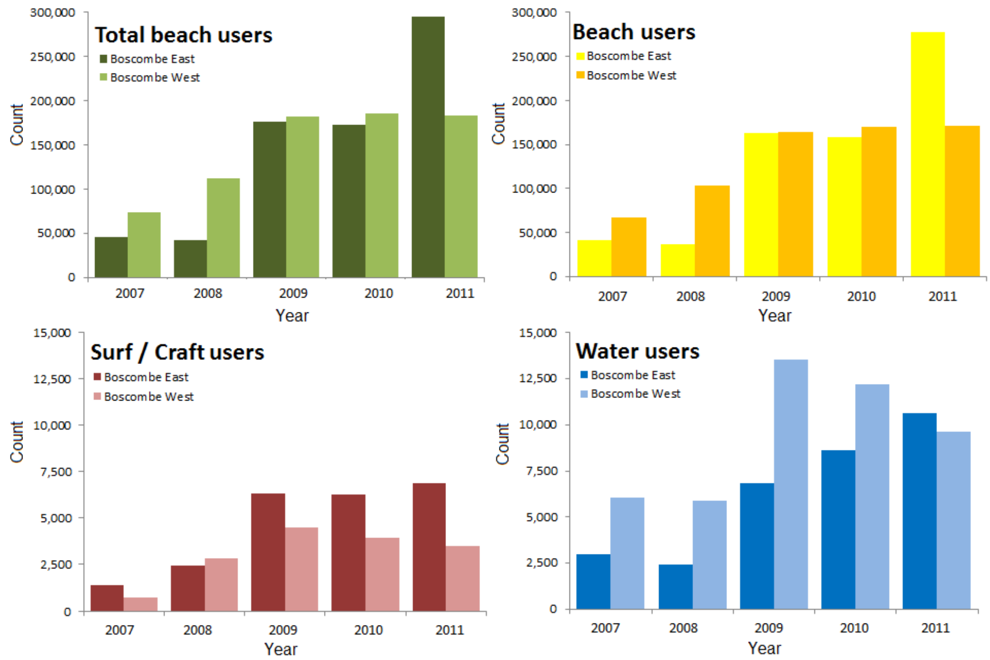

Figure (4.14). RNLI data watersports and board sports counts at Boscombe East and West between 2007 and 2011.

relatively steady incident rates, the East unit rates have increased over time. There is a peak in both data sets in 2010; the East unit reports more than double the incidents at the West unit reflecting an increasingly busy beach.

Year	RNLI Unit West	Total Incidents	Boscombe East	Total Incidents
2007		62		68
2008		92		76
2009		66		134
2010		116		288
2011		85		187

Table (4.6). RNLI incident data 2007-2011 for Boscombe West and Boscombe East (leeward of the ASR).

4.8 Summary

Boscombe, Dorset is home to the first European Artificial Surfing Reef. Located on the south coast of England on an open beach in the wider Poole Bay. The bay is protected from open Atlantic swell by more southerly and westerly regions of the UK, however does receive swell from a southwesterly direction. The area is also fetch limited due to the continent, wind waves dominate the coastline (from southeast through to southwest) and the accompanying onshore wind.

The ASR was built with controversy surrounding surrounding the design and cost of the project. With an original plan to increase consistency for surfing at Boscombe Beach, the reef has appeared to fail to meet this design criterion. It is yet to be tested to whether the reef will provide other benefits to the surf community and wider stakeholders. It is particularly relevant to this project to understand the reasons that increased numbers of visitors and surfers were drawn to Boscombe beach and why the observations of tourist numbers has not continued to rise steadily over time.

The following two chapters will investigate the impacts of the ASR on the physical environment, particularly morphology and hydrodynamics. After which two chapters explore the social and economic implications of the Boscombe ASR from the perspective of direct users and indirect users.

Chapter 5

Observations of structural and geomorphological change

5.1 Introduction

As stated in the introduction chapter, the aim and objectives of this thesis have been derived from key claims that have been made by ASR Ltd. and the Bournemouth Borough Council in the original design documentation for Boscombe ASR. It was stated that "modern geotextiles are durable materials with a postulated life of up to 100 years when submerged, even in a challenging marine environment" and "the guaranteed life of the geotextile material will depend on the fabric used. By way of example, the material specified for the Noosa ASR in Australia carried a 25-year manufacturer's guarantee" (ASR Ltd., 2006). This understandably led Bournemouth Council to believe that they were investing in a product that would last for a minimum lifespan of 25 years and that the structure would remain intact during that time.

Although the Boscombe ASR was not designed to have any coastal protection element, it was heavily suggested in the original design specification presented to the council that the reef would widen the beach and possibly prove to negotiate any need for groyne replacement in the immediate area. Further to these pre-installation claims regarding the structural response, post-construction claims regarding a salient formation widening the beach at Boscombe came from ASR Ltd. in 2010. "Monitoring of the beach response has recorded the development of a large salient in the lee of the reef. This salient is asymmetrical, with the location being more west of the reef position offshore, which is a consequence of the predominant west to east sediment transport direction. This beach response to the Boscombe Reef provides support that detached and submerged reefs or breakwaters would be a useful option for retention of nourishment material in Poole Bay in the future" (Mead et al., 2010). However, an independent report from Hydraulics Research, Wallingford UK concluded post-construction that in principle of the concept of the reef would have "a broadly neutral" effect upon coastal protection and therefore unlikely to widen the beach (West, 2010).

The aims of this chapter are to address whether these claims of beach widening and the potential for coastal protection are being realised. Specific aims are: (a) to provide an evaluation of the physical impact of the Boscombe ASR on the coastline in terms of coastal response and their interaction with the marine environment further offshore, and (b) to investigate the longevity of the reef in terms of predicted life span of an ASR and ask whether the structure is withstanding the environmental conditions.

The primary objective is to analyse topographic and bathymetric data made available by the Bournemouth Borough Council and the Channel Coast Observatory (CCO) in order to meet these aims. The surveys of the Boscombe ASR are presented and discussed in order to understand the pattern and behaviour of morphological change at the beach pre-construction, during the ASR construction phase and for 3 years after the completion of the project. It is important to determine the extent to which the ASR has effected morphological development, created new beach features or eroded those that were there previously in order to address the research objectives. This chapter quantifies the changes observed and, with the help of the literature and previous studies, explains the observed responses in order to meet the third aim of the chapter.

The structure of this chapter includes; an introduction to the methods used to observe changes in the shoreline and morphology, a results section which includes a description of the hydrodynamic conditions of the study period, followed by analysis of the bathymetry of the structure to assess the structural resilience of the ASR, and a discussion of the morphological reaction of the intertidal beach and its ability to recover. Specific interest of this section of study is in the interaction between the ASR and shoreline in the leeward region, so this region will be investigated in detail for beach widening and salient formation. The analysis of secondary field data, as opposed to gathering data under laboratory conditions or through modelling, provides a realistic view of the ASRs physical impacts, both temporally and spatially. This chapter seeks to address the claims regarding the ASR structure and observations of impacts on physical processes at the coastline and nearshore from photographic evidence, regular beach profiling and bathymetric surveying. The observational investigation in this chapter will determine the actual impacts to the shoreline and ASR structure, and compare with the predicted or conceived impacts by ASR Ltd and the local council. This chapter will contribute to knowledge regarding the impact of offshore structures and suggest where their implementation might be improved.

5.2 Methods

Presented in this chapter is a morphology dataset collected using a differential global positioning system (DGPS) technique by the Channel Coast Observatory (CCO) based in the National Oceanographic Centre in Southampton, UK. Information is gathered to be used to inform government and councils and in shoreline management planning, general coastal management schemes and research such as beach processes and cliff movements. GPS survey techniques are often used as a method to collect high resolution data with less than a centimeter accuracy through the use of navigation satellites to pinpoint three dimensional positions anywhere on the earth. DGPS systems allow for unparalleled accuracy through the use of base stations located over known benchmarks to calculate the difference between the two GPS units. The use of the second reference receiver cancels out the man-made and natural errors that occur, such as the earth's atmosphere. Repeatability of the data is ensured without the need to mark out sections of the beach for subsequent surveys. Bathymetric surveys are taken using small vessels with a shallow draft that are able to enter shallow waters, these surveys are taken at high tide using a boat mounted echo-sounder and real time kinematic (RTK) GPS. Topography surveys are taken at low tide when the beach is at its widest using RTK GPS attached to either a quad bike or simply walked manually along the beach at pre-defined transects. The combination of these two data sets allows a seamless data set of the entire beach face to be analysed.

Topographic and bathymetric surveys are taken by CCO at regular intervals throughout the year forming spring and autumn data sets of the beach and nearshore regions. These data are of a resolution to resolve major beach features, enabling the construction of the beach digitally to 12 m below mean sea level. Data was processed to remove erroneous data points and checks run to ensure observations were realistic. All bathymetry and topography data were interpolated using Matlab R2012b, from which the shoreline and contour plots were extracted. Detailed bathymetry data for 2009 to 2011 were made available by the Bournemouth Borough Council for the region of interest, i.e. those which included the ASR. The intertidal data were intergrated with the bathymetry data.

Structural resilience was investigated using the bathymetry data surveys, all were were plotted and analysed using Matlab R2012b. A digital terrain model of the intertidal topography and offshore bathymetry (<10 mODN) was generated. The contours of elevation were extracted from this regular grid. The same cross-section of the ASR can be plotted for sequential surveys and profiles of elevation through the structure compared to observe temporal changes. Regular bi-annual surveys of the ASR have been commissioned by the Bournemouth Borough Council since its construction. The surveys made available to this project for analysis are; October 2009, May 2010, October 2010 and April 2011. The more recent surveys have been deemed too politically sensitive to be released by the council for analysis. The negative press surrounding the closure of the ASR was partly the reason for this reduced data access. Additionally, the volumetric change of the ASR structure was calculated using the AutoCAD images combined with the volumes of the geotextile containers, as provided in the design and construction report ASR Ltd. (2006).

Shoreline response was addressed using the bathymetry and topography CCO dataset. A specific cross-shore transect in the lee-section of the ASR was used to ascertain the extent to which the beach profile was impacted by the ASR. This profile is taken from the top of the beach (at the seawall) to the depth of closure (the point at which the profiles converge at the limit of wave-driven sediment transport) and includes the entire beach profile. The profiles are discussed with reference to the mean beach profile, which is calculated by averaging 10 profiles used in the plot. Profiles were measured between between June 2005 to March 2011 (Table 5.1). These data are also used to calculate volumetric changes at the beach over time; before, during and after construction of the ASR. The mean volume of the profiles post construction is added to provide a reference point. The trapezium rule is used to calculate the area under the profiles and to determine volume change over time for the section of interest leeward of the ASR.

5.3 Results: Hydrodynamics of study period

As discussed in Chapter 3, the wave climate at Boscombe is characterised by depth limited, wind generated waves. The Channel Coast Observatory (CCO) maintain a Waverider buoy at approximately 12 m (ODN) water depth offshore at Boscombe. The data from this buoy (Table 5.2 and Figures 5.1 and 5.2) spans when the bathymetry surveys were taken and are presented in this chapter (i.e. from 2003-2012). The mean significant wave height (Hs) is 0.53 m, with a maximum height of 3.84 m over this 10 year period. The

Bathymetry survey date	Topography survey date	Year
31 May	multiple in June	2005
18 September	19 September	2005
12 May	multiple in June	2006
24 April	17 April	2007
3 October	13 September	2007
9 April	11 April	2008
18 October	3 October	2008
21 September	22 September	2009
23 November	07 and 23 September	2010
Multiple in March	23 March	2011

Table (5.1). Survey dates with complete profiles (both bathymetry and topography data were collected in as close succession as possible) that are comparable for the profiling of the leeward area of the ASR.

mean and modal zero upcrossing wave periods (Tz) are 7.2 s and 3.5 s, respectively. The modal wave direction is approximately south-southwest at 191^o, however there is significant wave influence from the south and the southeast. The maximum tidal elevation recorded during this period was 1.95 m and the minimum -1.78 m (the tidal data is shown in more detail Chapter 3).

	Significant wave height (m)	Peak wave period (s)	Direction (deg)
max	3.84	6.3	
average	0.53	7.2	179
rms	0.66	4.0	181
std	0.38	0.9	24.1
mode	0.22	3.5	191
median	0.42	3.8	187

Table (5.2). Wave statistics for the period of interest for this chapter, calculated from significant wave height, period and directional data collected at the Waverider buoy at Boscombe between 2003-2012.

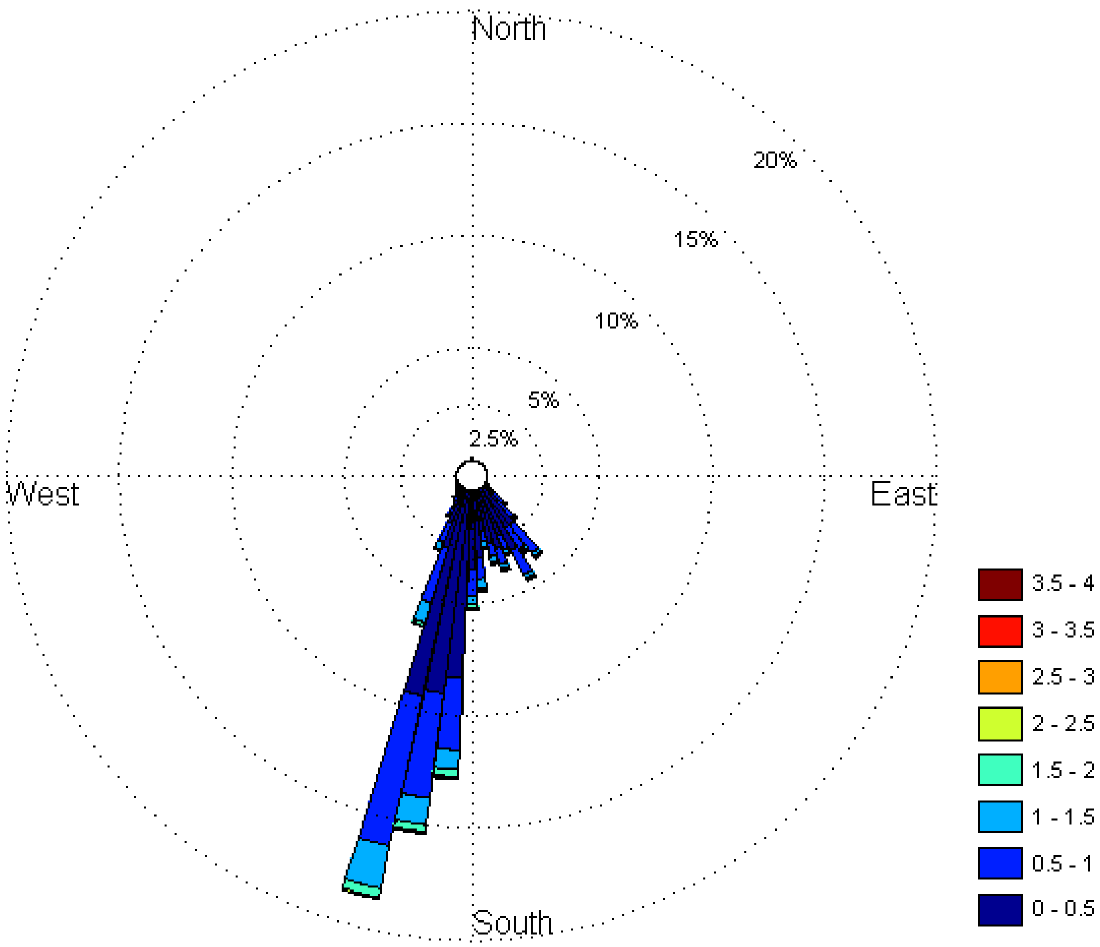

Figure (5.1). A directional wave rose using significant wave height (m) data collected at the wave rider buoy at Boscombe between 2003-2012.

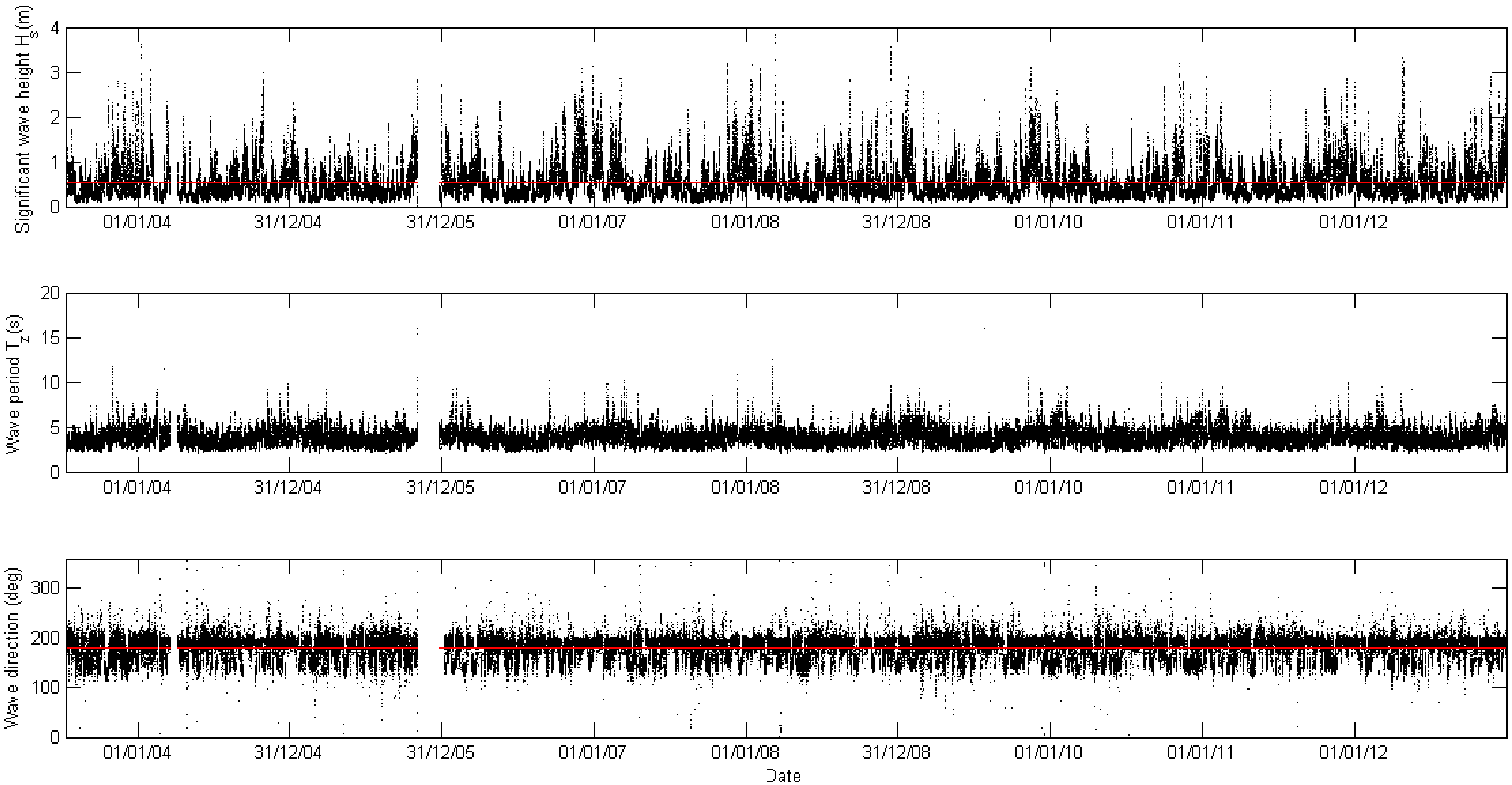

Figure (5.2). Time series of significant wave height (Hs), zero-upcrossing wave period (Tz) and mean wave direction (Dir); data recorded at the CCO Waverider buoy at Boscombe between 2003-2012. The red horizontal lines represent the average significant wave height (0.53 m), modal wave period (3.5 s) and modal wave direction (191^o).

5.4 Results: Structural Resilience

This section investigates the Boscombe ASR in terms of structural resilience to hydraulic loading and to potential damages caused. As introduced in Chapter 4, the Boscombe ASR visibly changed shape after the winter of 2009-2010 and sediment moved in the containers through the hydraulic action of the waves. The compression and settling of sediment within the bags caused a misshaped appearance and was became referred to as a "pillowing" effect. The redistribution of the sediment within the container does not appear random. Sediment has been displaced from seaward extent of the geotextile containers towards the landward extent, reducing the elevation of the outer edge of the ASR and further elevating the landward section of the ASR above the design criteria. Major damage of a geotextile container occurred after the second winter, in 2011. It is contested as to whether this was caused by geotextile container weakness, accidental damage from a boat propeller, or through deliberate vandalism. This container was one of the largest size containers known as a T4 in this construction, a significant volume of sediment was lost (Green in Figure 5.3 and 5.4). A further T4 container was damaged due to the lack of support from the lost neighboring container, and therefore removed in 2012. These changes are best observed in the photographs in Figure 5.5; two major geotextile containers have degraded in the upper section of the dissipating element of the ASR in the two years post-construction. This has become a concern to the council and local surf community for two reasons; the modified form of the reef causes deviation from the original design that potentially impacts on the quality of the waves for recreational surfing, and the person-sized voids in the structure produce a potential trapping hazard for recreational surfers.

Plotting the surface of the reef in three dimensions provides a view of the damage caused to the structure overtime and an understanding of exactly where the structure failed and containers were lost. The images in Figure 5.6 provide a visual comparison of the subtle changes observed at the reef in the first three surveys, from 0.2 m to 1.5 m in crest height and up to 10 m width voids in top of the ASR. The survey taken in October 2009, shortly before the completion of the ASR was announced shows the smooth undulations of the completed structure. The darker red in these images highlights the peaks along the crest of the structure, at the highest points. The darker patches shift from year to year indicating the morphing of the structure from survey to survey. The May 2010 and September 2010 surveys remain relatively similar, the most obvious change to the structure is seen in the April 2011 survey after the geotextile container is damaged and sequentially removed.

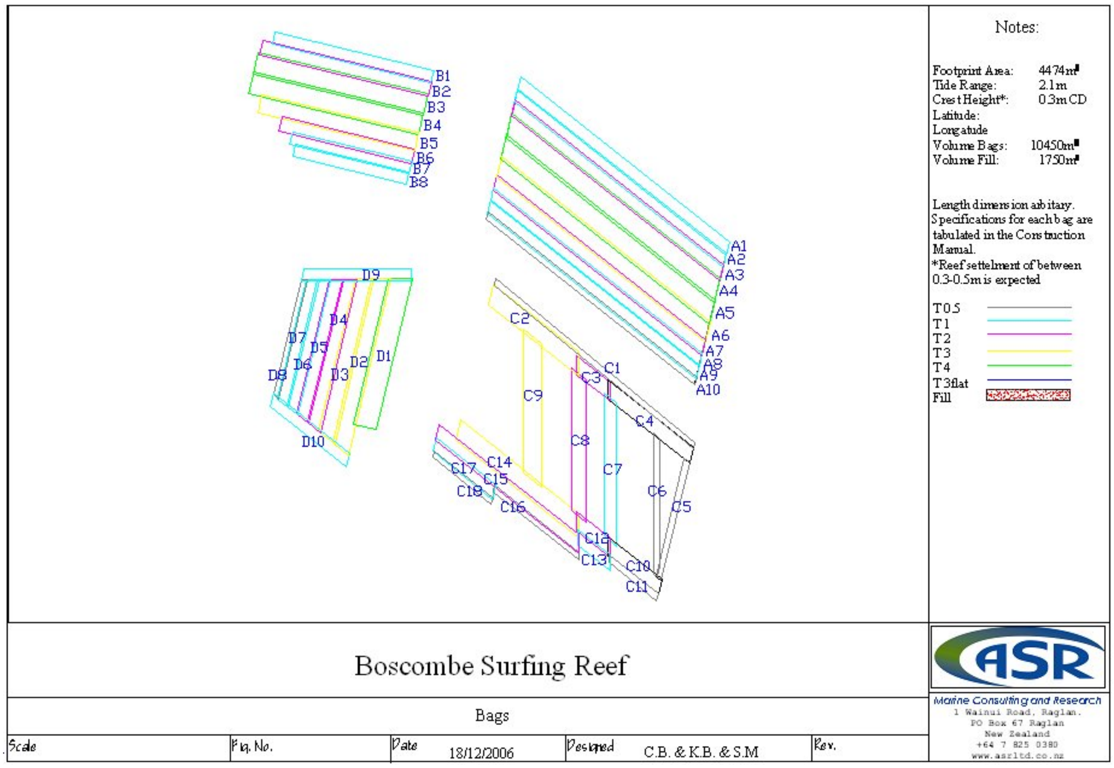

Figure (5.3). Bag Layout of the SFCs needed to build the Boscombe Reef

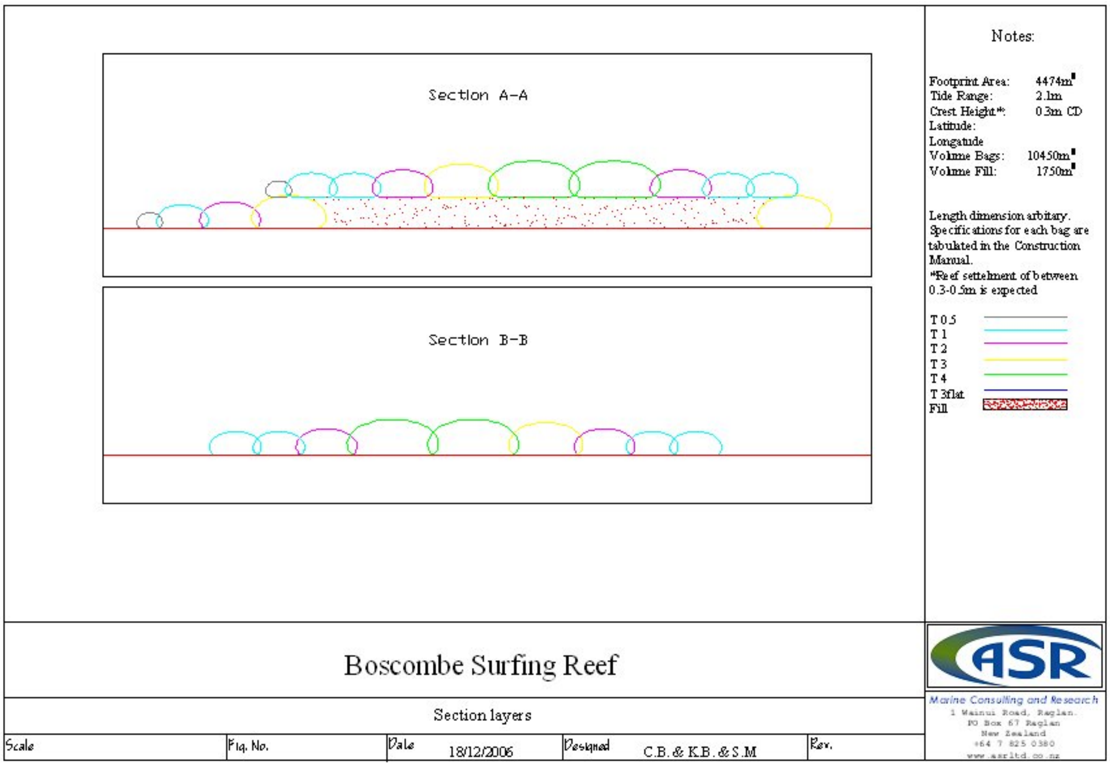

Figure (5.4). Example cross sections.

To provide an accurate quantification of the magnitude of the changes to the reef, transects of the reef are extracted and plotted for comparison. Figure 5.7 illustrates where transects of the ASR were taken from all four surveys made available by the Bournemouth Borough Council across and along the reef structure. This does not include a 2012 survey; as afore mentioned after the second container was lost as the data has been deemed sensitive and has not been made available to this study.

The profile plots (Figure 5.5) taken across the container shape clearly illustrate the morphing of the ASR as sediment moves within the bags over the years. In the profiles taken across the ASR (Figure 5.8a), there are subtle changes in the profiles as sediment is reworked in the containers. This has lead to some areas of containers experiencing increased crest height of 0.25 m, whilst other areas of the containers have a reduced crest height up to 0.5 m. The surface of the containers becomes increasingly undulated over time. There are notable changes to the surrounding seabed level from the first to the second survey; approximately 0.5 m erosion towards the west and northwest, and between 0.25 m to 0.5 m accretion to the east and southeast areas. Few changes are seen over the 2010 summer months as wave energy is considerably reduced and the October survey is similar to the May survey. Following the 2010-2011 winter, further hydraulic reworking of sediment in the geotextile containers is evident as the ASR shape is changed from the original construction and design. The lost container is evident as the large 2 m deviation from the other three profiles, and a 4 m gap between geotextile containers.

In the profiles taken along the ASR structure the same is observed (Figure 5.8b); the geotextile containers morph and change shape. There is indication of erosion at the toe of the structure towards the northern (landward) extent. The October 2009 survey shows the original profile of the upper section focusing and dissipating elements of the ASR; the containers are smooth with few undulations. After the 2009-2010 winter, changes in the shape of the reef are evident in the May 2010 survey; as previously described sediment has migrated within the containers. The depression in crest height of 2 m is evident in the April 2011 profile. This container is considered significant as the change to this geotextile container resulted in an undulating crest. The ASR was deemed dangerous by the council after the removal of this container as the gap enhanced turbulence over the reef crest, endangering surfers and swimmers. The ASR was subsequently closed to the general public in April 2011. Further damage was discovered by a Spring 2012 bathymetry survey; the geotextile container to the right of the gap (in Figure 5.8b) is now also missing from the structure making the gap between containers between 8 to 10 m (as can be seen in the last aerial photograph in Figure 5.5).

In order to quantify the volumetric change the approximate container volumes are used from the design and construction manuals (ASR Ltd., 2006). Accordingly, the larger geotextile containers (4 m in diameter and 70 m in length) used in this project contain

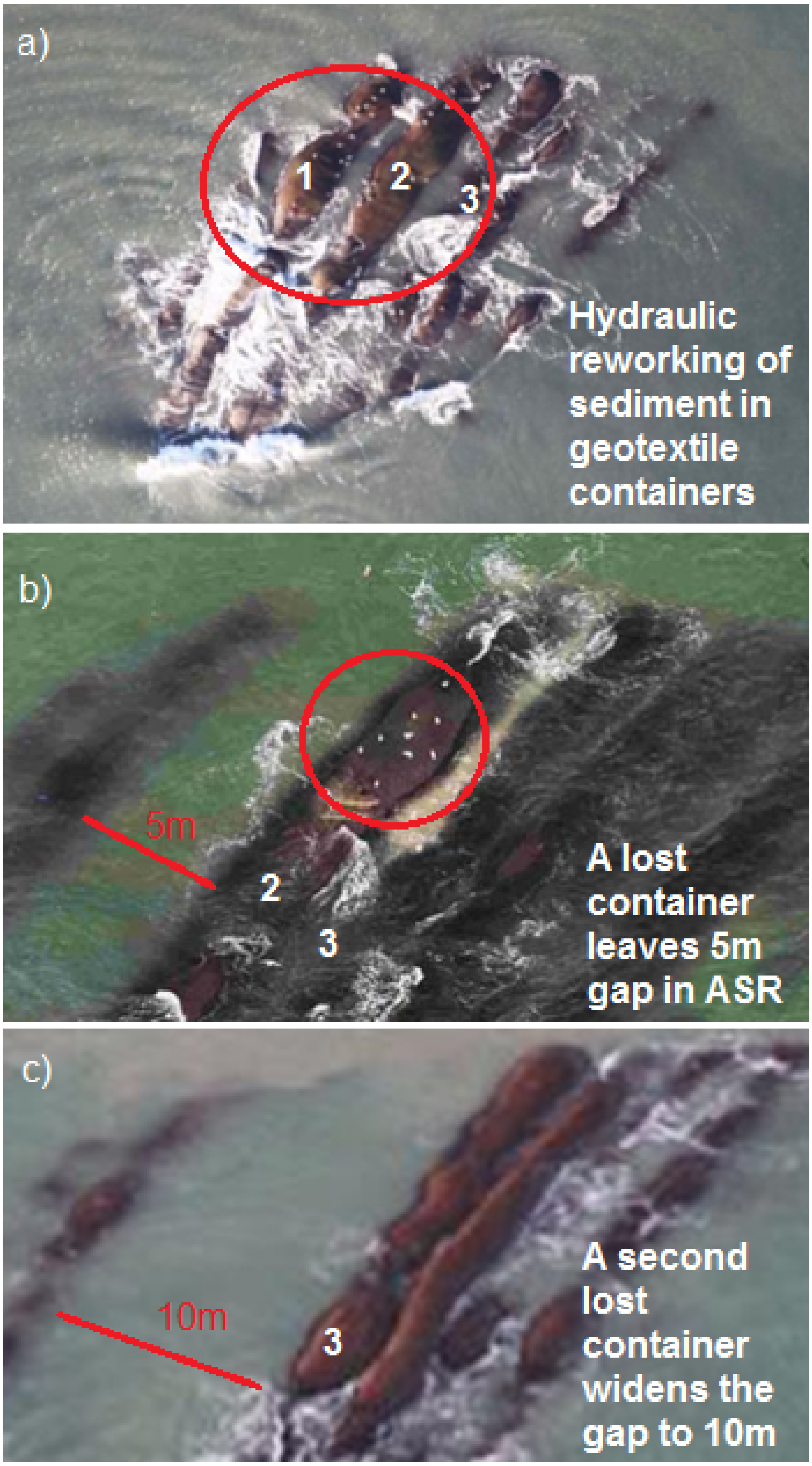

Figure (5.5). The upper, dissipating section of the Boscombe ASR where the geotextile containers failure is seen over a two year period; (a) concern raised after the first winter in spring 2010 regarding the containers becoming misshaped or experiences ‘pillowing’, (b) a container was lost in 2011 once the sediment had been removed and loose material a 5 m gap in the structure can be observed, and (c) another container lost in 2012 leaving a gap approximately 10 m wide.

746.7m^3 of sand, this is also the approximate loss after the second winter. A further container was lost in the following year, equating to a total volumetric loss of 1492.4m^3 from the ASR structure after the third winter. Alternatively, this can be viewed as a percentage of the total volume (11,900m^3), 12.5% of the structural volume was lost in the first three years (Table 5.3). It must be noted that the containers were “not all filled to the capacity specified in the original design documents and it is thought one or more of the containers are missing from the original designs” personal communication; Carpenter 2013.

There were a variety of reasons given by ASR Ltd. for the containers not being fully filled during the construction process. These included the incorrect grain size provided by the council for the construction, the distribution of grain size (mixed rather than consistent and therefore all material had to be sieved) and unpredictable poor weather (however typical of UK summers). All these resulted in the ASR construction being interrupted and delayed, initiating a final rush to complete the ASR and shortcuts were made to meet the end of summer deadline. Given that all containers were unlikely to be filled to full capacity this percentage is still relative to the overall volume of the ASR.

Geotextile container	Width (m)	Height (m)	Length (m)	Area (m^2)	Volume (m^3)
A4	5.9	2.3	65.5	11.4	746.7
A5	5.9	2.3	65.5	11.4	746.7
				Total volume lost	1,493.4 m^3
				Total ASR volume	11,900 m^3
				Percentage lost	12.5 %

Table (5.3). Dimensions of the two largest geotextile sand filled containers (called T4 in the construction manuals; ASR Ltd. 2006) that were damaged, and the resulting volumetric change overall to the ASR structure

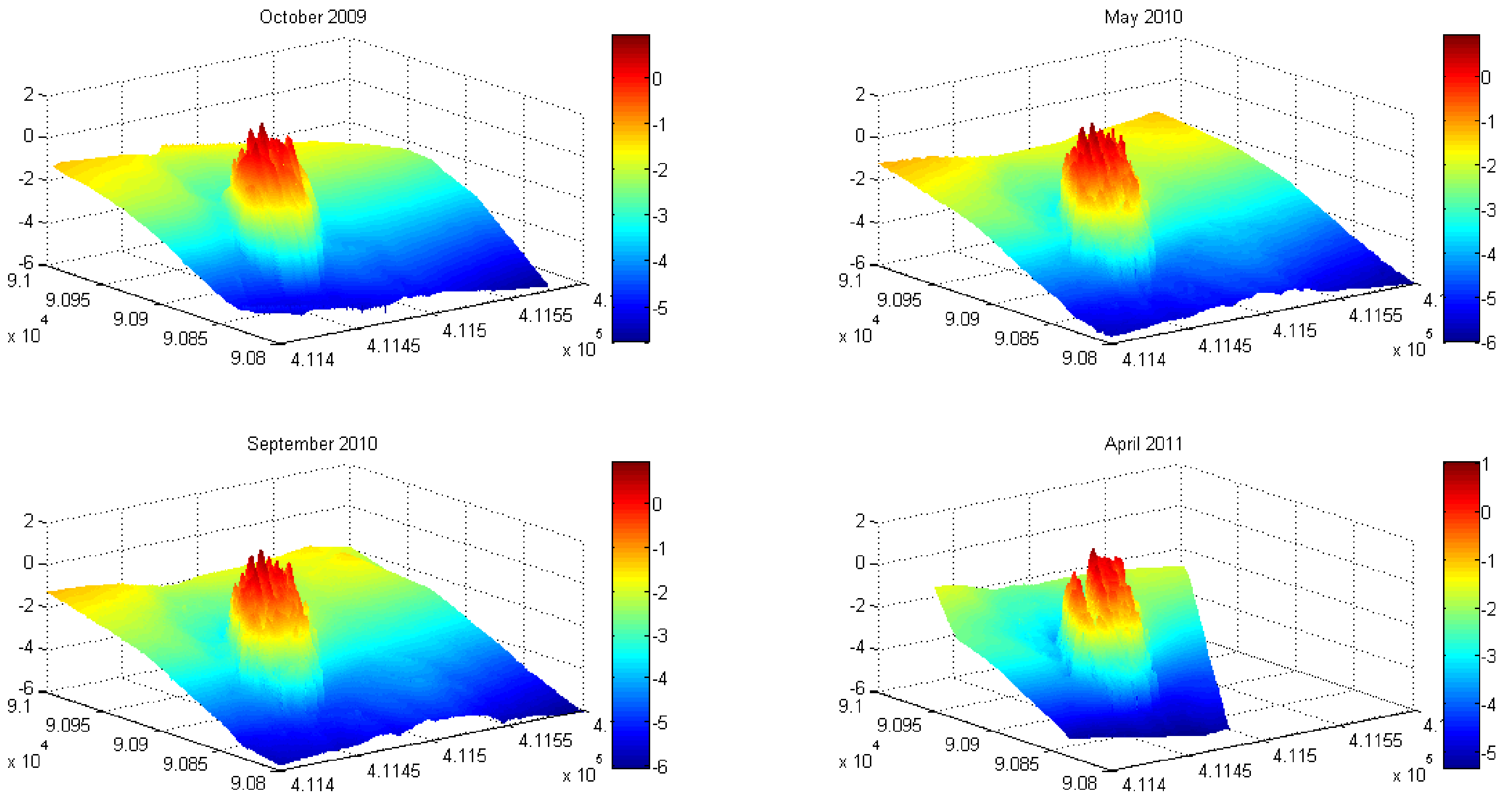

Figure (5.6). Three dimensional surface plots (all measurements in metres relative to MSL) of the Boscombe ASR created from the four surveys collected on behalf of the Bournemouth Borough Council. These surveys were made available to this project by the council for use in this thesis.

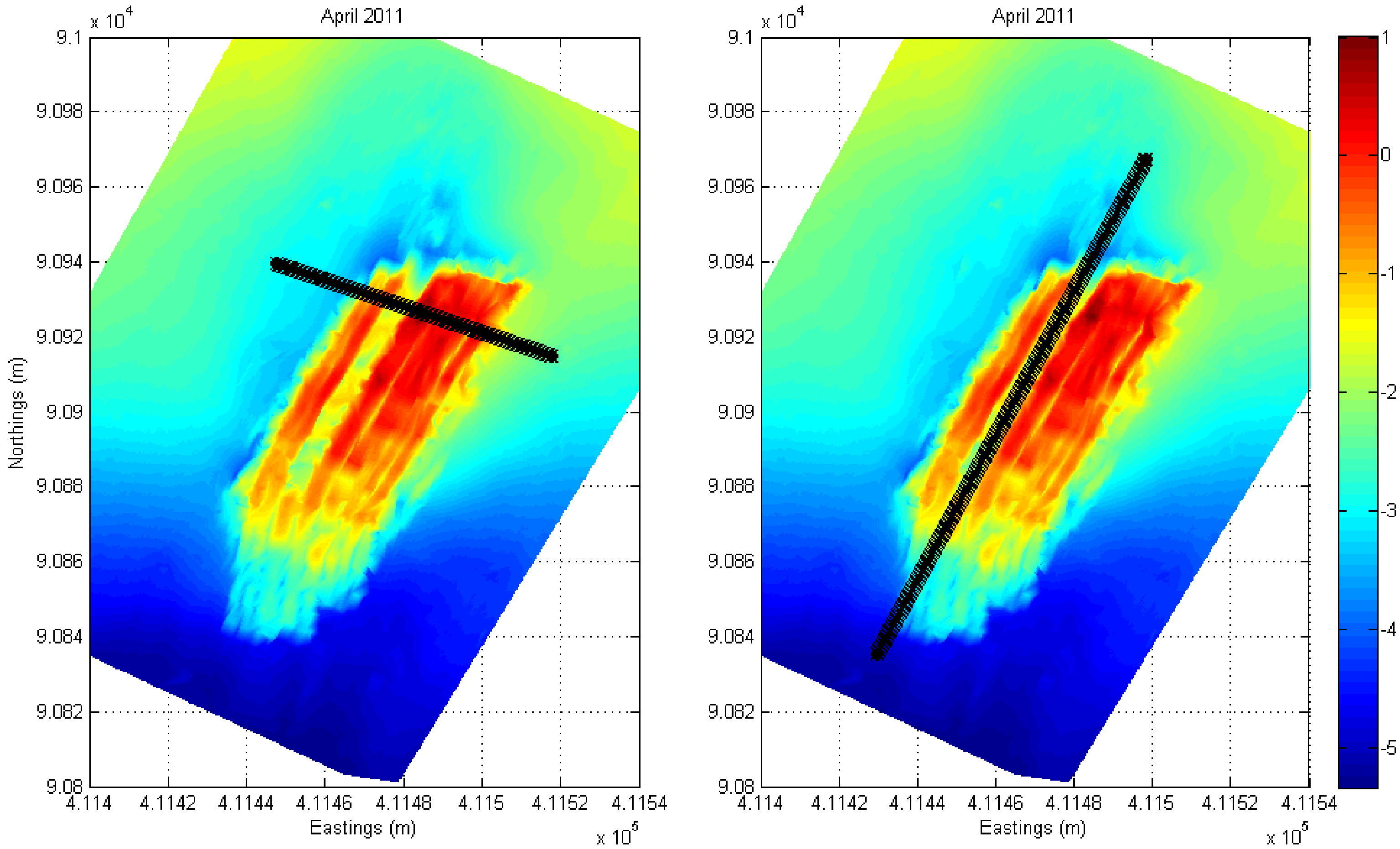

Figure (5.7). Surface plots of the ASR with overlaid transects taken for comparison of any structural changes to the Boscombe ASR (a) across the structure, and (b) along the structure. Specifically chosen are areas which suffered the most damage after the Winter 2010/2011.

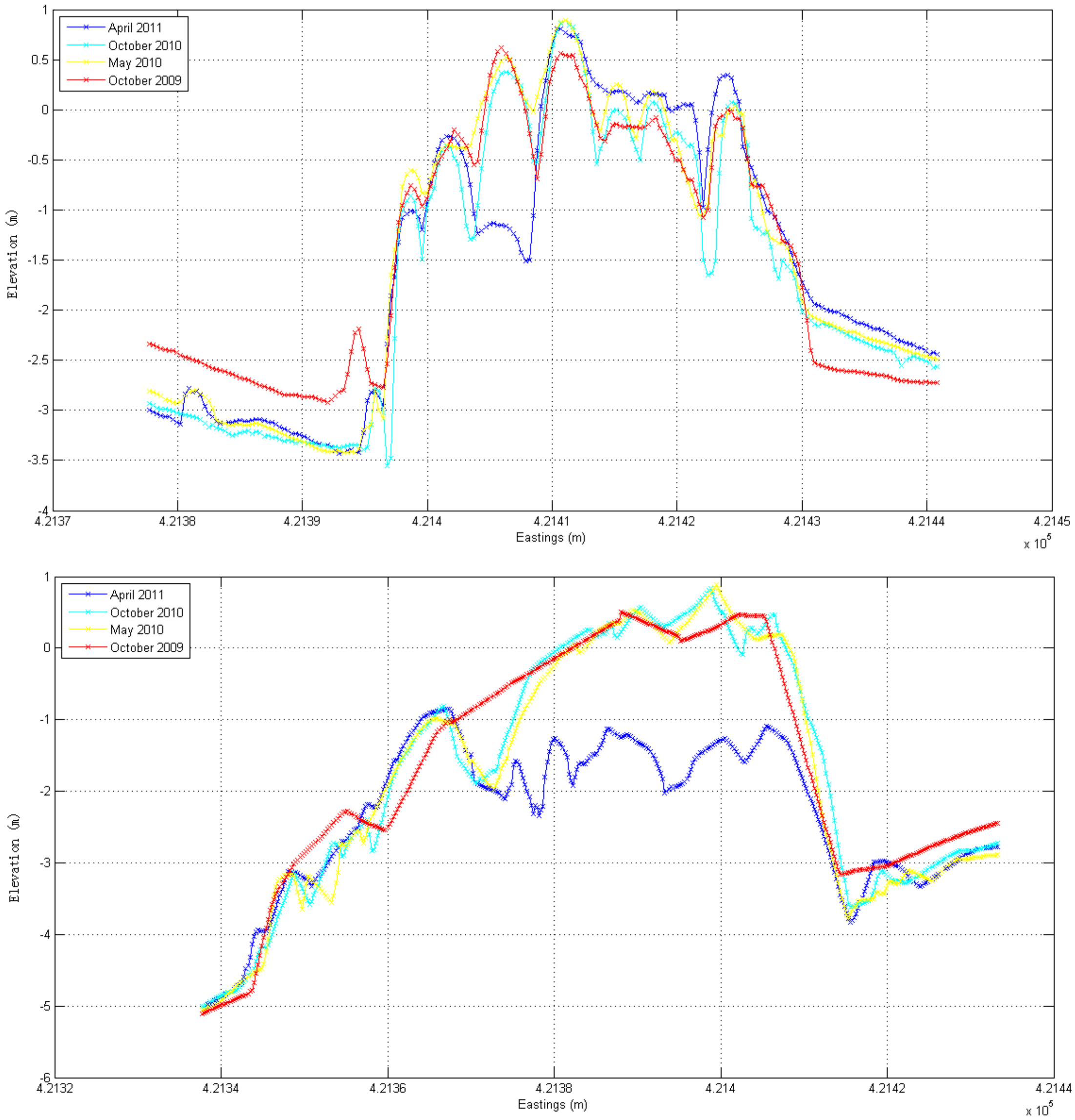

Figure (5.8). Profiles plotted from the transects taken over the Boscombe ASR in two directions; a) across the width of the main dissipating section, and b) along the length of the structure to illustrate structural changes particularly where containers have been damaged and removed.

5.5 Results: Geomorphological response

5.5.1 Shoreline Response

The response at the shoreline and other contours of the beach morphology are highlighted in the next series of figures where we track the contours of the bathymetry incrementally every metre. Figure 5.9 shows the topography and bathymetry of Boscombe beach previous to the ASR being completed. These contours will later form the bathymetric boundary conditions for baseline modelling tests in Chapter 5 which include pre- and post- reef comparisons of the hydrodynamics and sediment dynamics. The pier and area where the ASR is to be constructed are included for reference. The shoreline (0 m ODN, in red) and -3.5 m ODN contour (in blue) are highlighted for reference between the individual images. A regular fluctuation in the natural state of the beach morphology is observed between rhythmic bar features (i.e. Winter 2006 and Spring 2007) and a smooth seabed state (i.e. Autumn 2005 and Autumn 2007), this can be attributed to the environmental conditions previous to the surveys being conducted. Most of the fluctuation observed occurs in the intertidal area and surf zone. The last image in this figure is impacted by the initial lower layer of the geotextile containers in the first summer of the ASR construction (in the white box).

The beach and ASR surveys post-construction are compared with the shoreline and -3.5 m contour highlighted as before (Figure 5.10). As previously mentioned the 2012 bathymetry survey is not available for comparison. Overall, there is little impact to the shoreline (in red) and the beach morphology fluctuates in a similar manner to that seen previous to the ASR construction. Over the three years investigated there has been no significant shoreline response to the Boscombe ASR; the small fluctuations (<0.2 cm) that are observed are not different from elsewhere along the coastline, or out of line with normal seasonal fluctuations (Figure 5.11). The mode of shoreline response is neither in a state of accretion nor erosion. No salient (or tombolo) formation can be observed from these contour plots, this will be further investigated later on in this section. Offshore, at the -3.5 m contour is where the ASR has made more significant changes to the bathymetry in a 50 m radius of the structure. There is some localised scouring at the base of the structure creating a steepening of the bathymetry towards the beach in the leeward area of the ASR. This contour has migrated 50 m from the ASR towards the shoreline in the leeward area.

To closer examine the shoreline contours before and after the ASR construction the

0 m, -2 m and -3.5 m ODN beach contours are plotted in the same figure for all surveys taken where there is topography and bathymetry available (Figure 5.11). As previously mentioned, there is little variation in the shoreline contour but more evidence of disturbance caused by the ASR can be seen in the -3.5 m contour. The intertidal area and surf zone are highly dynamic and during construction were possibly even more so, the -1 m contour in the left panel of Figure 5.11 demonstrates this point. There is a disparity between the resolution of the survey data hence the difference in the smoothness of the contours. The -1 m contour for the post-ASR figure highlights a large shift in bed level in November 2010, this is the position of a groyne and the bed level change associated with seasonal storm fluctuations. It is interesting to observe that this region becomes more stable after the construction of the ASR, less fluctuations are observed in the contours from year to year. The sand banks that were prevalent in the nearshore and surf zone area are less apparent due to a decreased wave energy. There is some evidence that the ASR has ameliorated the wave field and therefore the contours are less susceptible to change. This is the case for the entire beach face; the -3.5 m contour is altered previous to the ASR construction by the nourishment of the beach between 2006 and 2008. After 2008, this increased beach width is eroded near the ASR and a steady steepening of the beach occurs leeward of the ASR structure.

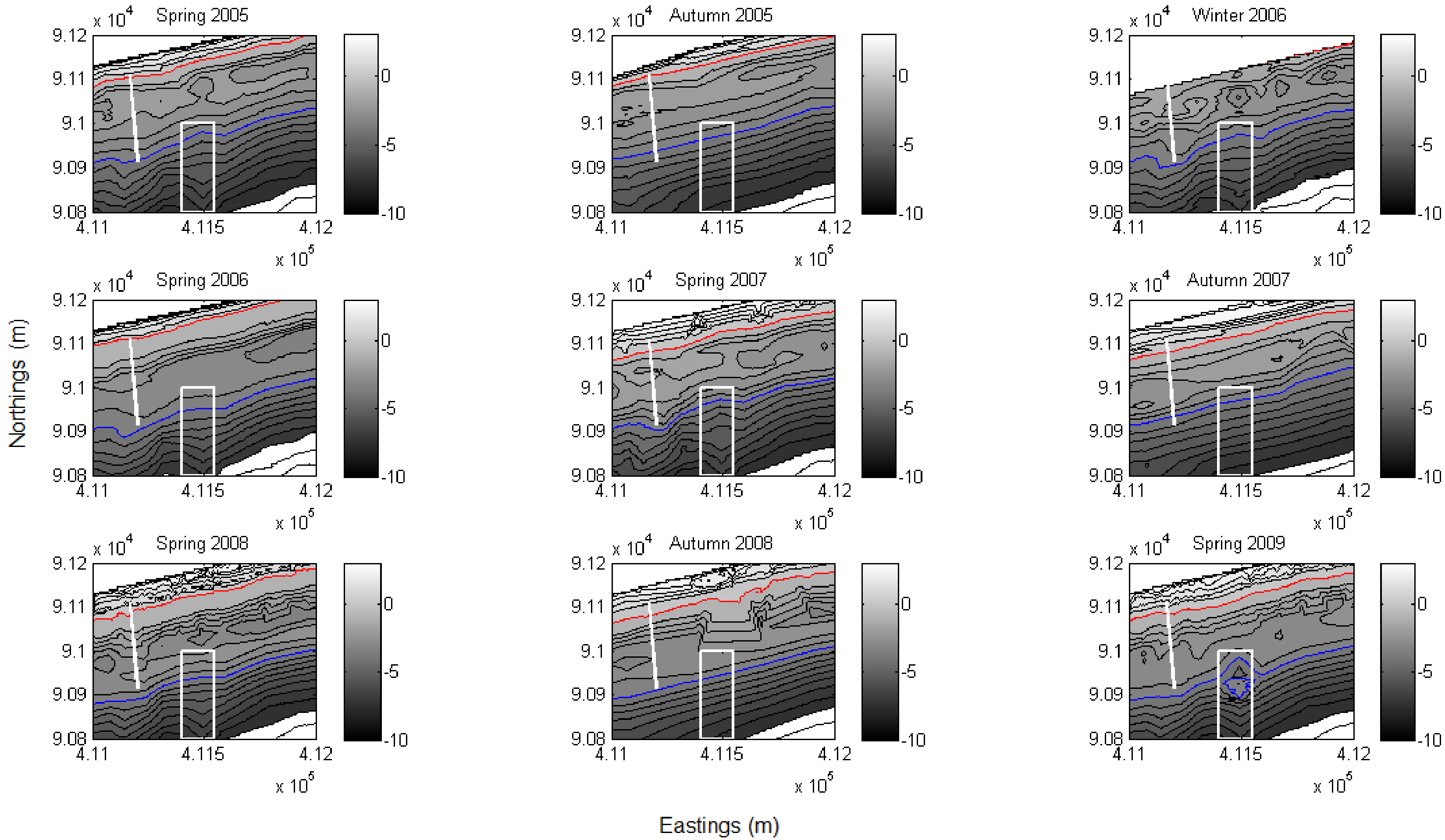

Figure (5.9). Contour plots of Boscombe beach leading up to the construction of the ASR. The first layer of geotextile containers were installed in Summer 2008, they are visible in the Spring 2009 survey. The bathymetry and topography are chosen from respective surveys similar in date from CCO. The white box and line illustrate the area of the ASR and pier for reference between images. The red and blue line represent the 0 m and -3.5 m contours. All surveys are relative to Ordnance Datum Newlyn (ODN).

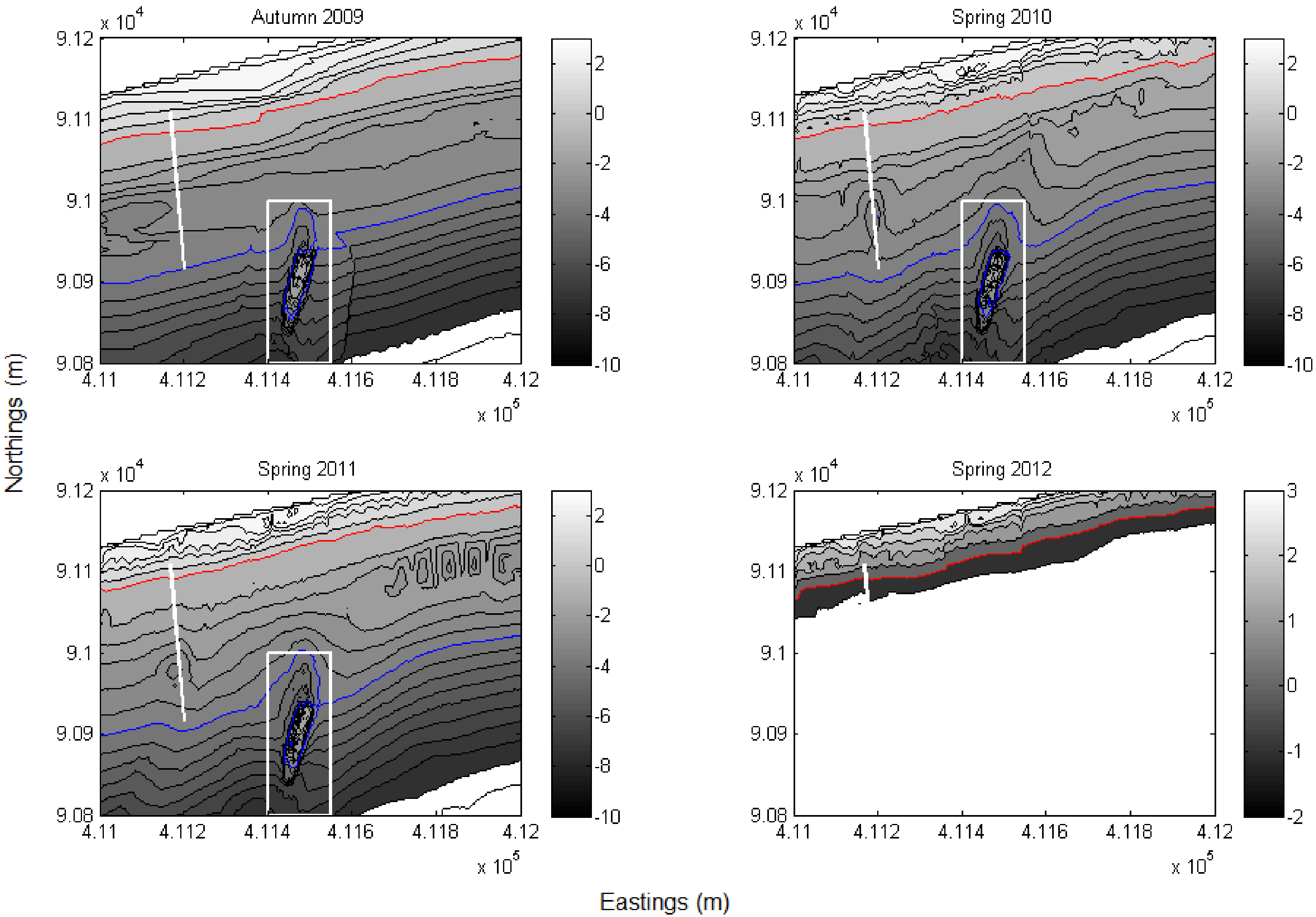

Figure (5.10). Contour plots of Boscombe beach after the construction of the ASR. The bathymetry and topography are chosen from respective surveys similar in date from the CCO database. The Spring 2012 bathymetry survey was not made available. The white box and line illustrate the area of the ASR and pier for reference between images. The red and blue line represent the 0 m and -3.5 m contours. All surveys are relative to Ordnance Datum Newlyn (ODN).

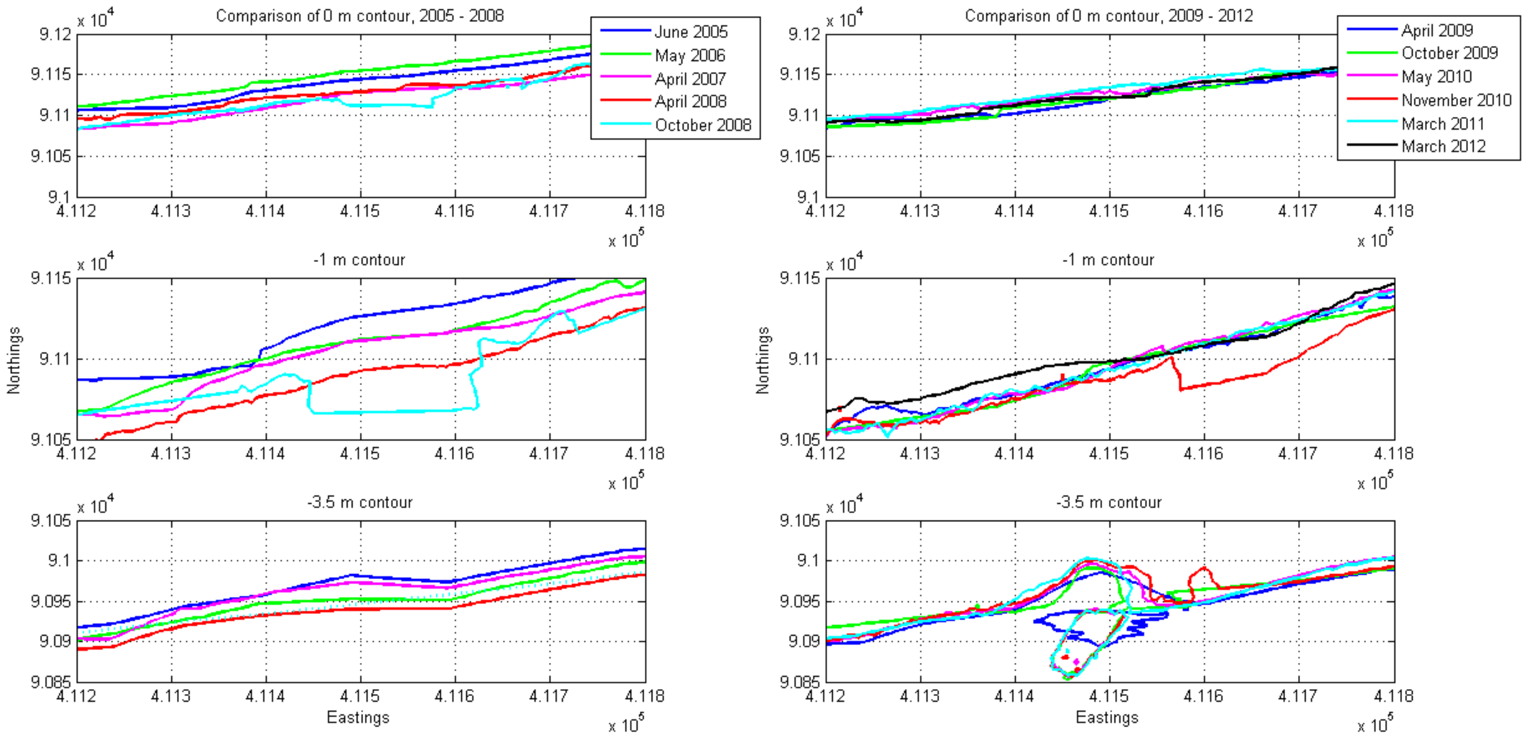

Figure (5.11). A comparison of 0 m, -1 m and -3.5 m beach contours pre-ASR construction in the left panel, the same contours post-ASR construction are compared in the right panel. In the UK, mean sea level (MSL) is equivalent to Chart Datum, Newlyn, UK.

5.5.2 Morphological response

The standard deviation (SD) highlights the variability in the measurements of the beach elevation obtain from the CCO surveys, this indicates the stability of the bathymetry. The SD is calculated from a total of seven surveys over a 400 m stretch of Boscombe beach. Four surveys are used to create the pre-ASR (2005-2007) plot and three are used to create the post-ASR 2007-2011 plot. Although the number of surveys is low, and it is acknowledged that this limits the stability of the estimate, this provides an indication of the magnitude and spatial distribution of the changes in bed level within the number of surveys available. The SD is plotted to demonstrate changes in beach morphology over the period of interest (Figure 5.12a). The dark red highlights features that have an SD $>$1m. The ASR is an obvious area of increased SD as the 2005-7 surveys do not include the ASR. As discussed in Chapter 3, the first layer was constructed in 2008 and finished in 2009. The offshore area is susceptible to the least SD, with the upper beach and nearshore experiencing the most change. There is an area to the right of the image (east) which highlights an area that coincides with additional sediment placed on the beach during various stages of the beach nourishment scheme (mostly during 2006-7). The SD in the three years before the construction of the ASR, 2005-7 (Figure 5.12b) shows this nourishment impacted the area east of Boscombe beach, as opposed to causing and specific accretion. The majority of the intertidal and nearshore zone has low SD, the more static green regions are nearshore bar features and the areas between groynes. Areas near the groynes are often susceptible to scour and accretion depending on wave interaction at the base of the structure during higher tidal levels. Fluctuation in the embayments between the groynes can also be observed.

The third image (Figure 5.12c) shows the SD of the morphology in the years during and after the ASR completion, 2007-2011. The ASR is again highlighted by this analysis as the first 2007 bathymetry data does not include the reef. The area in the lee of the ASR is the region that has been scoured by the construction of the ASR, and as previously discussed SD shows as between 0.5 m to 0.6 m. The surf zone in this image is variable where as the beach is more stable, a similar pattern at the offshore bars can be observed.

In order to examine the SD in beach morphology leewards of the ASR, a 120 m stretch of Boscombe beach is plotted (Figure 5.13). Close to the reef there is some variation, this has been shown in previous analysis both to the leeward side and to the east and west of the structure. The beach and shoreline leeward of the structure show areas of variance and areas of stability. Therefore it cannot be categorically stated that the beach or bathymetry is more stable due to the construction of the ASR.

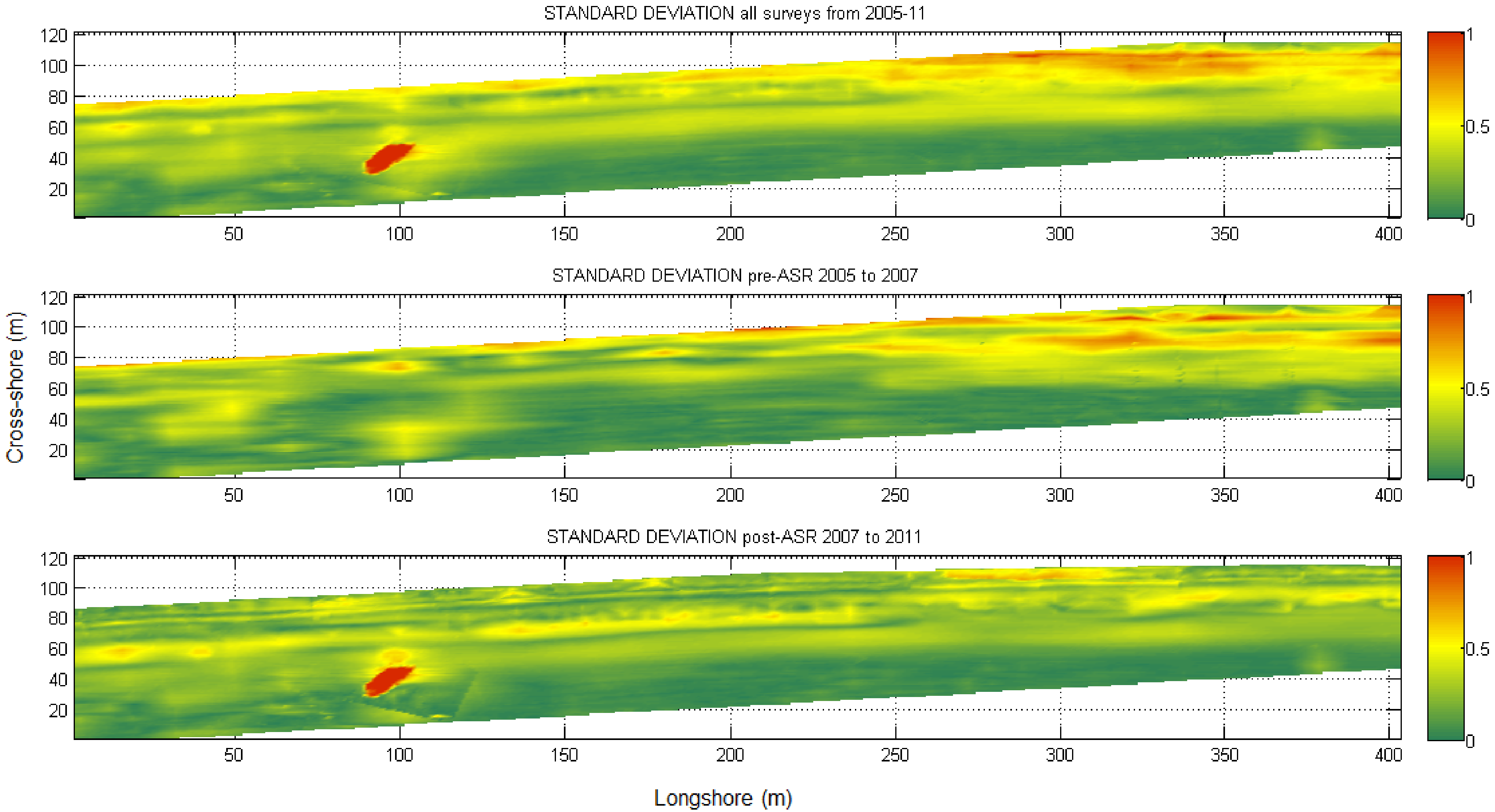

Figure (5.12). Standard deviation (SD) in the morphology at Boscombe beach, from top to bottom; a) The SD calculated between all surveys taken from 2005-2011, b) The SD pre-ASR construction from 2005-2007, and c) the SD post-ASR construction from 2007-2011.

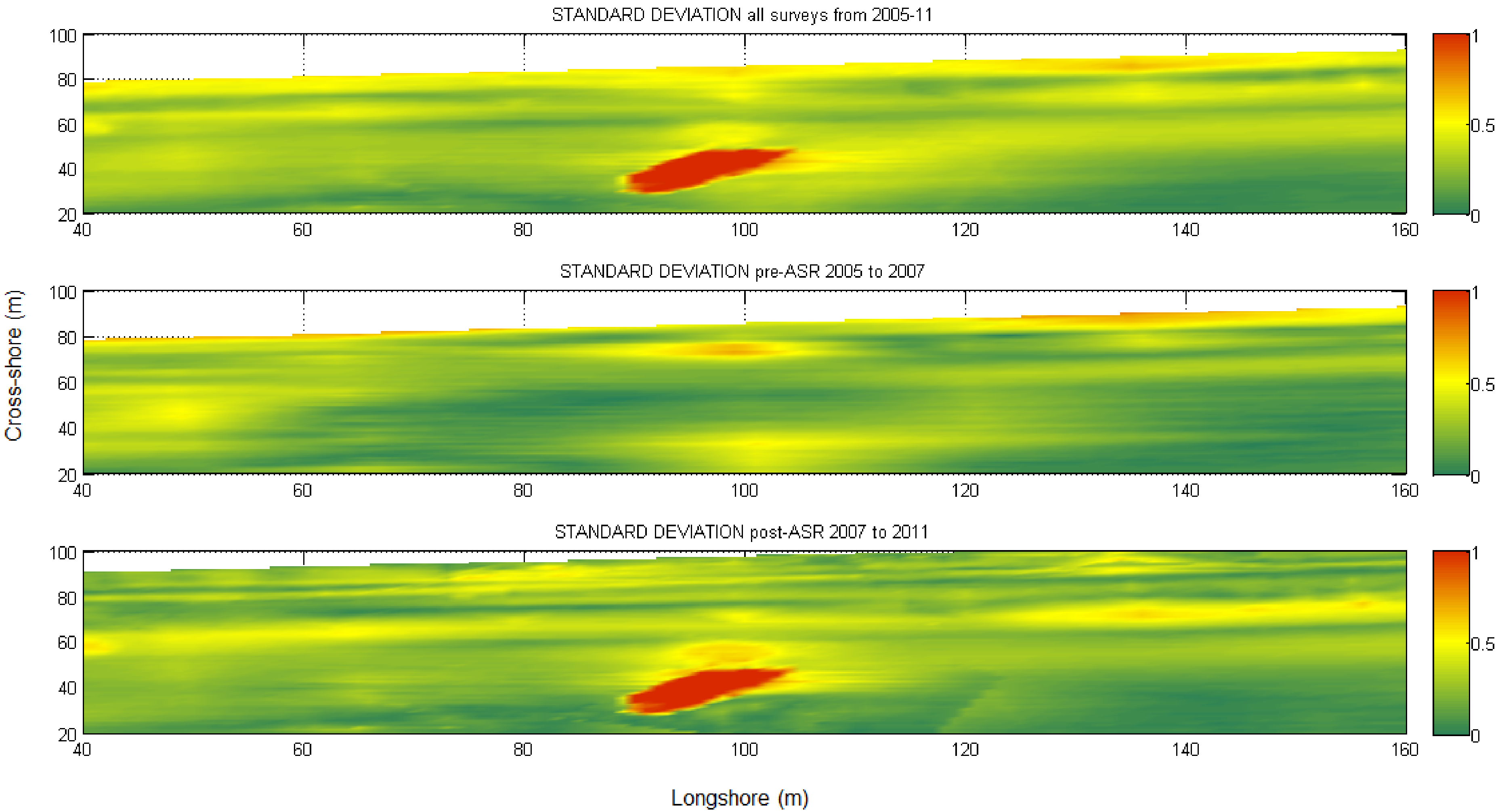

Figure (5.13). A closer view of the area of interest at Boscombe ASR, from top to bottom; a) The SD calculated between all surveys taken from 2005-2011, b) The SD pre-ASR construction from 2005-2007, and c) the SD post-ASR construction from 2007-2011.

To investigate whether the leeward beach face is prone to accretion in further detail, two transects have been extracted from several years of CCO topography and bathymetry data (Figure 5.14 profile 1 and 2). These transects from the DGPS data are common to all the surveys used to produce the profiles, the raw data is therefore comparable between profiles of consecutive years (Figures 5.15 and 5.16). The influence of the ASR is apparent in these profiles even though the profiles are not directly leeward of the ASR, they are the closest available to this structure. Profile 3 is illustrated and is taken from the same transect through the consecutive years, however this profile is taken through gridded data which has been interpolated on to a line as opposed to raw observations. Due to this shorter profile (as not all years cover the same extent) and the extraction from interpolated or gridded data, profile 3 is not directly comparable with the other two profiles (Figures 5.17 and 5.18).

The progression of the profiles are informative and indicate seasonality and variance from the mean profile. The entire profile of the beach is captured by these profiles, to the point of convergence; the depth of closure is therefore 300 m offshore.

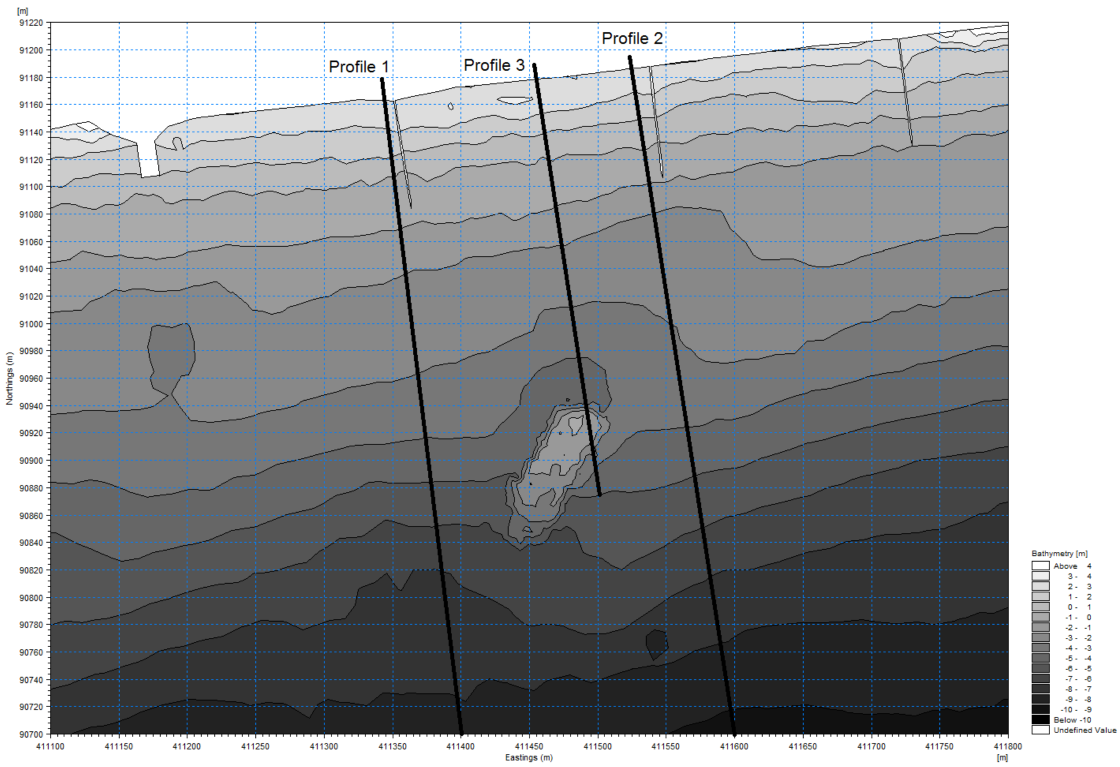

Figure (5.14). Three transects are analysed for volumetric chance over time taken from the DGPS dataset that is regularly surveyed by the CCO. Profiles 1 and 2 are raw data, the availability of raw data in this transect is preferable to compare. Profile 3 is extracted from data integrated onto a mesh grid.

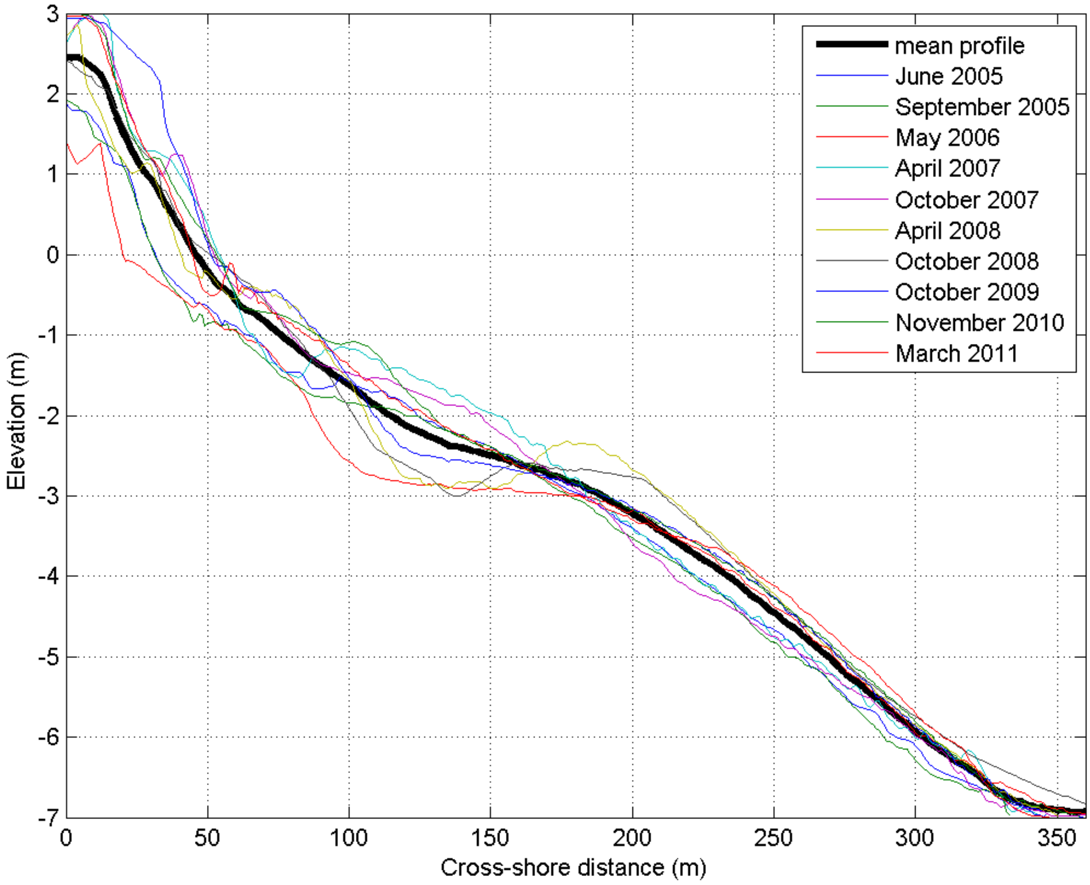

Figure (5.15). Profile 1 is the nearest westerly profile to the ASR extracted from the CCO dataset. Profiles of Boscombe beach and bathymetry leeward of the artificial surf reef using raw data from the DGPS transect as surveyed by CCO. Elevation is relative to MSL.

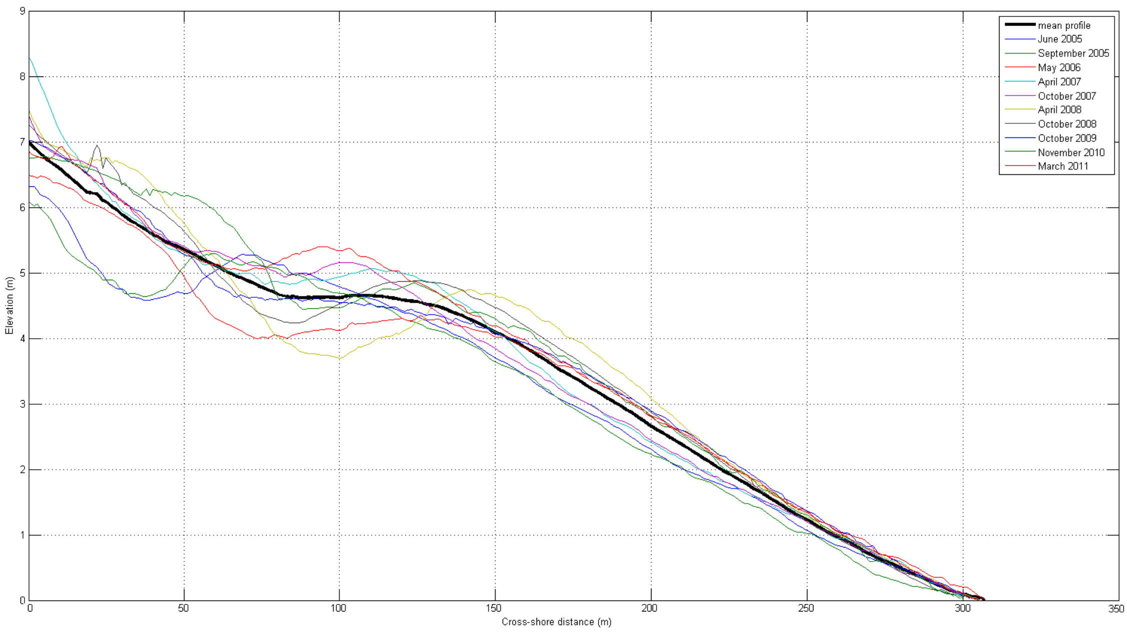

Figure (5.16). Profile 2 is the nearest easterly profile to the ASR extracted from the CCO dataset. Profiles of Boscombe beach and bathymetry leeward of the artificial surf reef using raw data from the DGPS transect as surveyed by CCO. Elevation is relative to ODN.

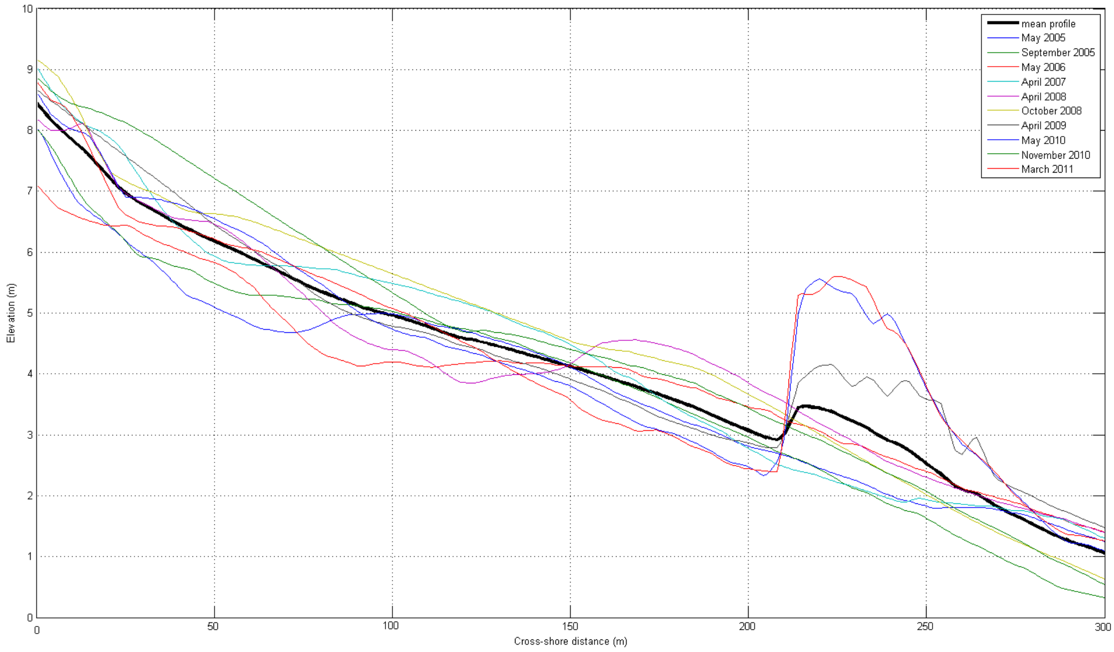

Figure (5.17). Profile 3 is the central profile, taken through the leeward section of the ASR, extracted from the gridded CCO data. The first layer of the ASR is visible in the April 2009 survey and the 2010 and 2011 surveys indicate the full structure. Elevation is relative to ODN.

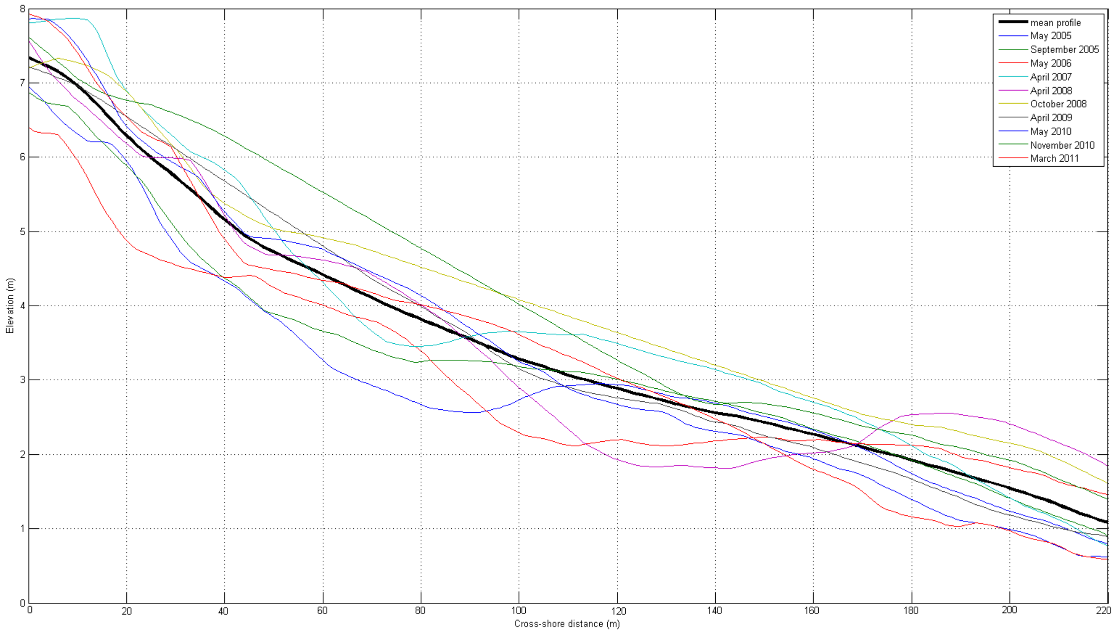

Figure (5.18). Profile 3 is extracted and reduced by 100m (zoomed-in) to only include the leeward section, not the ASR structure so that pre- and post-ASR profiles are comparable. Elevation is relative to ODN.

A key objective for this chapter is to answer questions regarding shoreline change, and it is important to understand the change to the volume of the beach leeward of the ASR. It has been shown that the beach is not demonstrating any dramatic erosion or accretion as seen by the contour and profile plots. The volume of beach increases and decreases about the mean, as one would expect during a period of nourishment and large scale construction (Figure 5.19). The change in volume over time suggests that the variation is decreasing after the ASR installation highlighting that the beach has become more stable. The initial disruption from by construction and the additional nourishment in the area leeward of the ASR caused some instability. The shoreline leeward of the ASR is not showing signs of impact on a longer temporal scale. That is, the fluctuation in the profile volume post-construction is not consistent with permanent salient formation. Since the main concept of the ASR was to increase surfing and not to interfere with the beach, this lack of change to the shoreline should be seen as a positive outcome for the project.

The dates when the survey data was collected by Mead (2010) is highlighted by the yellow arrows on the x-axis of Figure 5.19. This illustrates how the images and profiles shown in this article were taken during a period where the beach is full post-renourisment, and there is an elevated beach level. Unfortunately, the raw data was not shared with this research project and therefore the data points can not be included on this plot. It is clear that the period during which the beach was surveyed was indeed in a state of increased volume, compared to the mean of the post-nourishment profiles. Profiles 2 and 3 (Figures 5.20 and 5.21) are shown for comparison and highlight how the beach is in a state of decreased volume in other areas of Boscombe Beach, whilst the increased volume described in Mead (2010) can only be seen in the easterly profile, between Boscombe Pier and the ASR.

The root mean square (RMS) variability was calculated for each point along the profiles and plotted (Figures 5.22, 5.23 and 5.24). It is provided to illustrate the change about the mean profile in the morphology. There is a general decreasing trend in RMS, which has a direct relationship to stability of the shoreface leeward of the reef. There is one increased point of variability directly related to the increased nourishment at the beach, and during the construction process there is understandable variability in this transect. Otherwise, the beach is shown to be more stable after the settling of the beach has occurred; the RMS variability has decreased from approximately 4 m to 3.5 m. Since the most recent point on this plot is an increased RMS, it it cannot be stated that the stability will continue to increase due to the ASR or that it is simply a reflection of the stabilising beach. Further data would allow the fluctuation of the beach to be understood after the construction of ASRs into the more recent years.

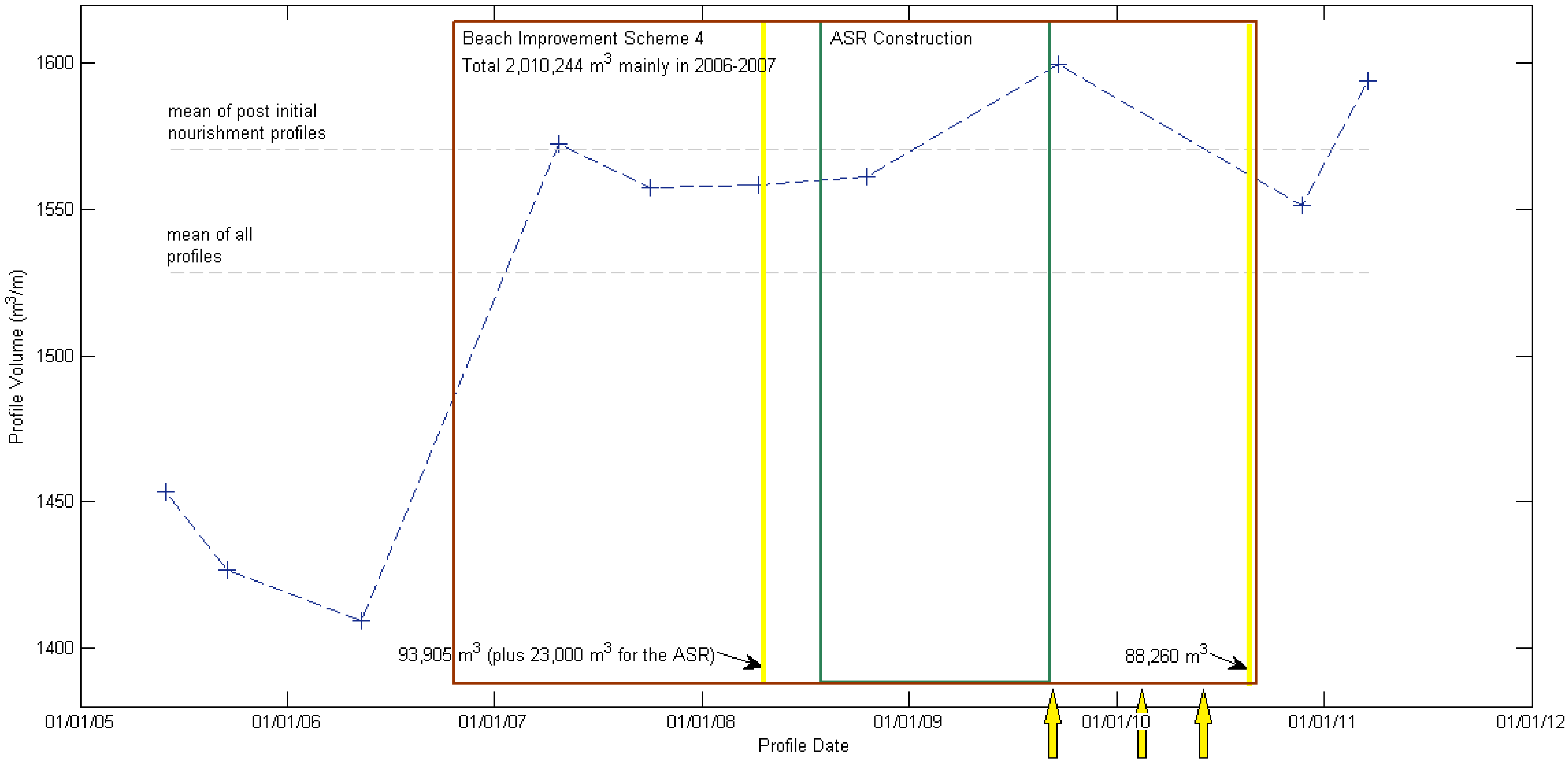

Figure (5.19). Profile 1 volume as comparable change in total beach volume leeward of the ASR over time. The red box highlights the time span of the most recent beach improvement scheme (BIS4), the yellow lines indicate when specific nourishment occurred at the beach leeward of the ASR and for its construction, and the green box indicates the period during which the ASR was being constructed. The yellow arrow point at surveys by Mead et al (2010) in October 2009, March 2010 and January 2010.

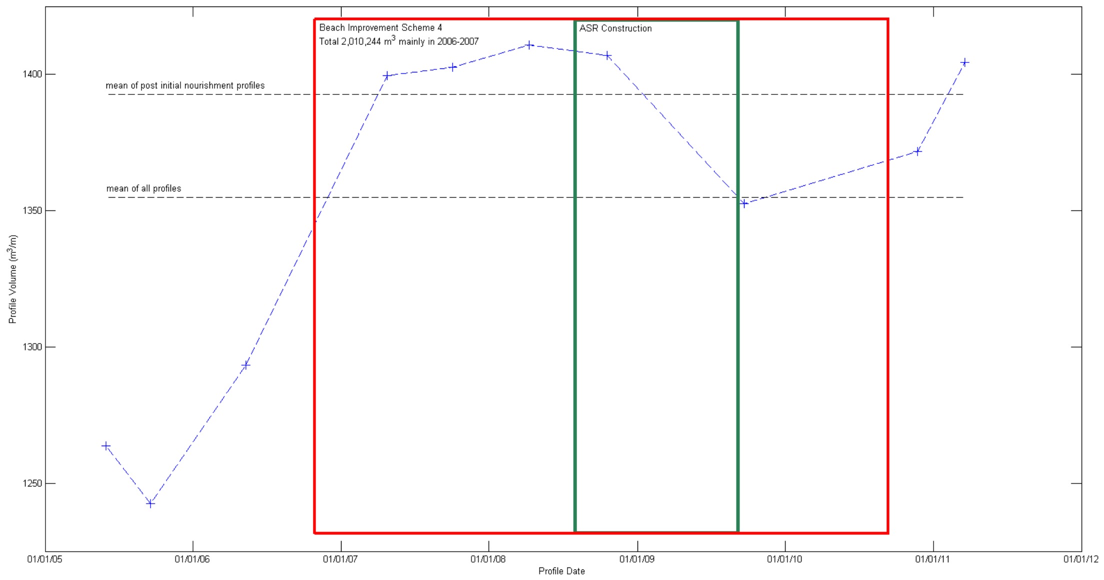

Figure (5.20). Profile 2; the change in total beach volume (m^3/m) over time in the nearest easterly profile to the ASR. The beach improvement scheme and ASR construction periods are highlighted by the red and green boxes, respectively.

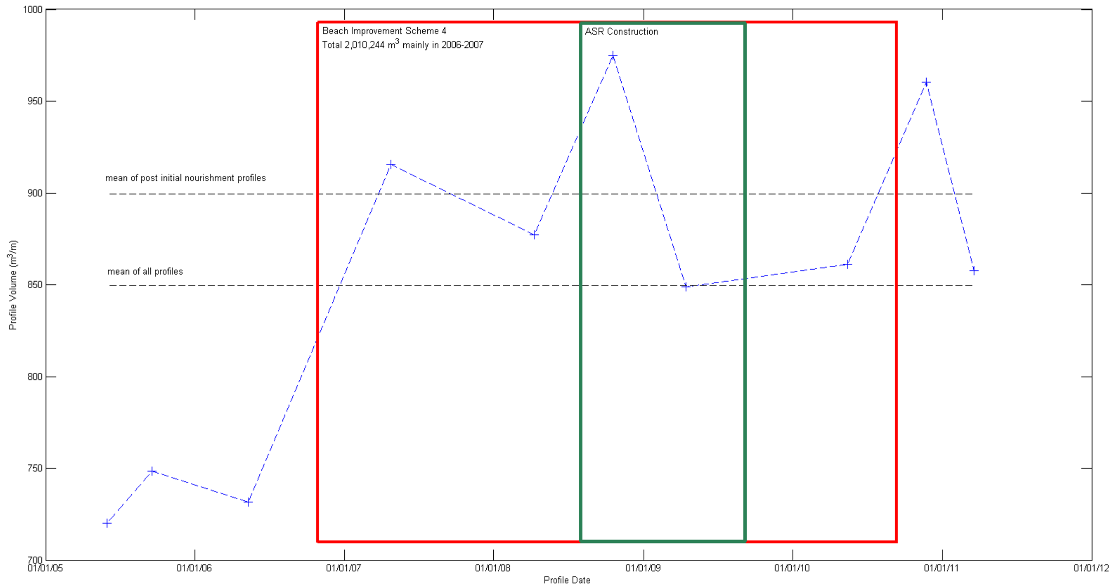

Figure (5.21). Profile 3; the comparable change in total beach volume (m^3/m) over time in the leeward profile generated from interpolated CCO data. The beach improvement scheme and ASR construction periods are highlighted by the red and green boxes, respectively.

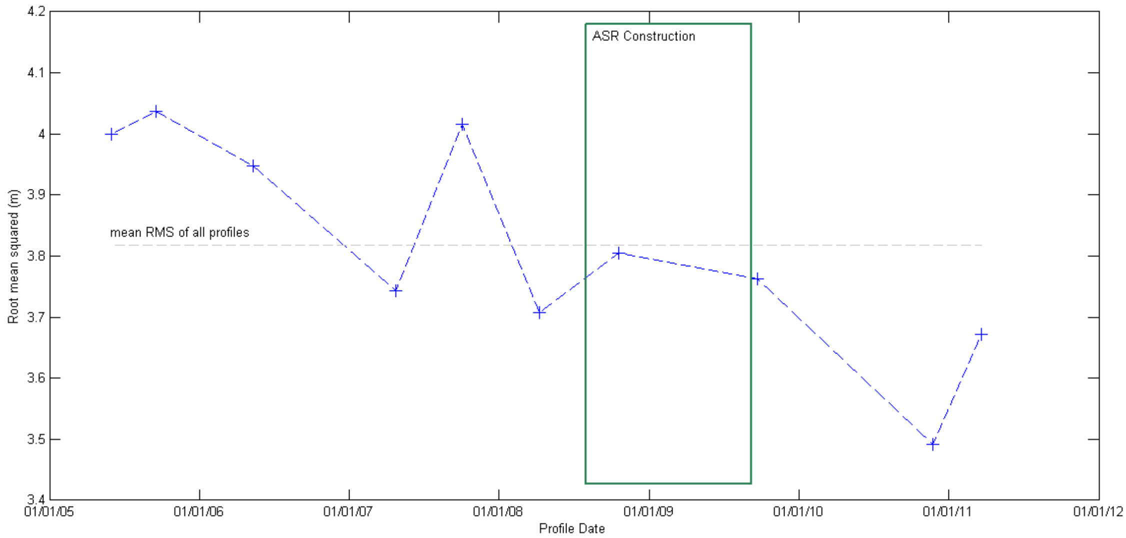

Figure (5.22). Priofile 1; the root mean square of the profile volumes taken from the CCO data DGPS transect leeward of the Boscombe ASR. The ASR construction period is highlighted by the green box.

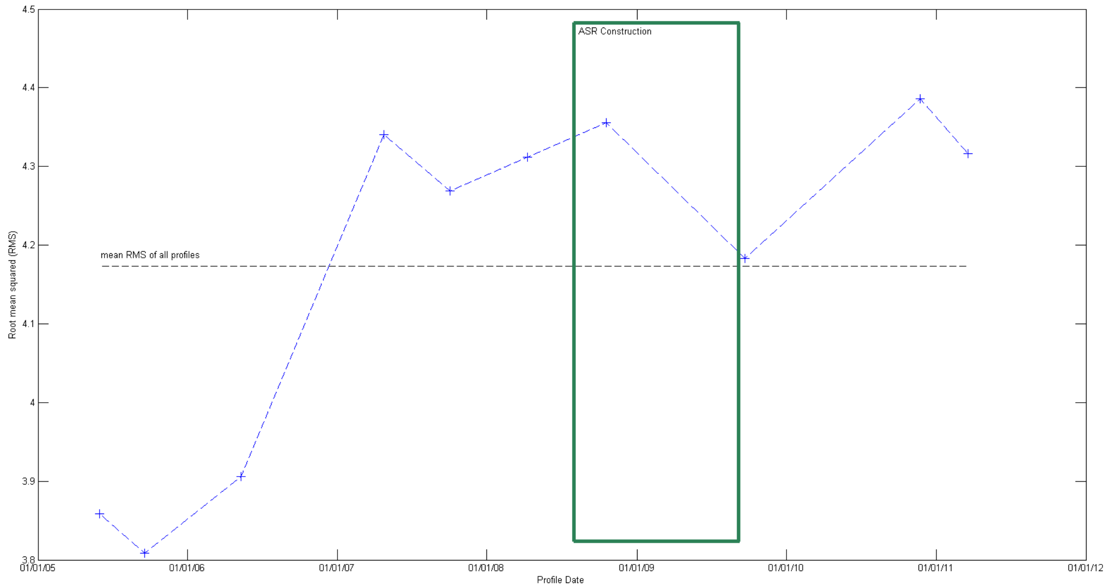

Figure (5.23). Profile 2; the root mean square (m) of the profile volumes over time taken from the CCO data, the nearest easterly DGPS transect to the ASR. The ASR construction period is highlighted by the green box.

5.5.3 Mode of change at the shoreline

In order to understand the impact of the ASR on the shoreline the mode of change graphical plots proposed by Ranasinghe and Turner's (2004) article are used to make predictions regarding the amount of shoreline change given some simple structural dimensions. According to this empirical theory the magnitude of shoreline change (Y) relates to structure length (B), distance offshore (S_a) and surf zone width (SZW). When the magnitude of maximum shoreline change is negative there the shoreline is described as being in a state

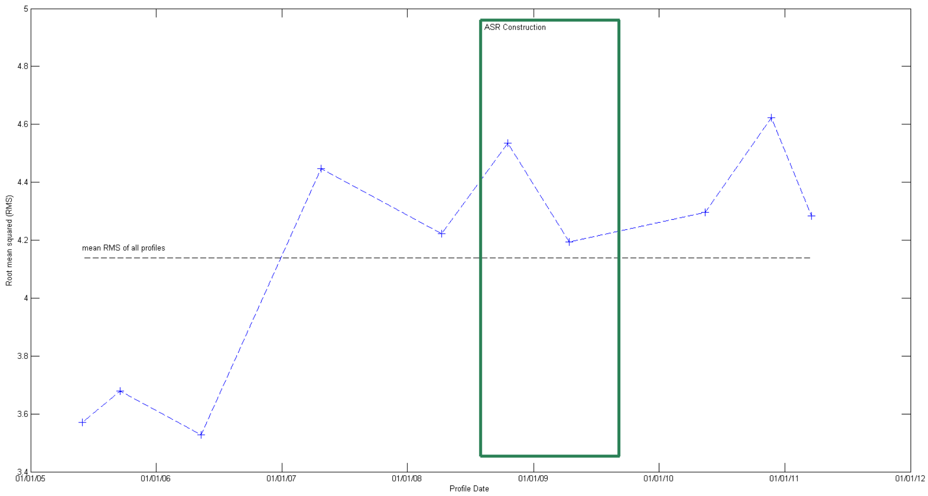

Figure (5.24). Profile 3; the change in the root mean square (m) over time in the leeward profile. The ASR construction period are highlighted by the red and green boxes, respectively.

of erosion, and in accretion when the shoreline change is positive. Given the Boscombe ASRs dimensions; surf zone widths of 75m (H_s = 1m < 15 % of the time) and 200m (H_s = 2m < 2 % of the time) should produce accretion in the shoreline of 35m and 12m, respectively. Table 5.4 provides further estimations of the reaction of the shoreline given different environmental conditions, the relationships proposed by Rangahsinge (2006) as seen in Figure 5.25, are to be used as a preliminary engineering tool to evaluate the potential shoreline response to submerged structures. The Boscombe ASR values have been plotted onto this chart to illustrate where the structure lies according to the proposed relationship. The ASR fits this empirical relationship in that given the distance of the structure offshore; there has been little observed accretion at the shoreline and no salient (or tombolo) formation that can be attributed to the ASR in the short to medium term.

	Wave height (m)		
	1.0	1.5	2
SZW	75	150	200
S_a / SZW	3.33	1.66	1.25
Y/B	0.35	0.55	-0.1
Resulting Y (m)	+17.5	+27.5	-5

Table (5.4). Predicted change in shoreline (m) using Ranasinghe et al. (2006) model based on varying natural shorezone width (SZW) given the structural dimensions of the breakwater, in this case the Boscombe ASR.

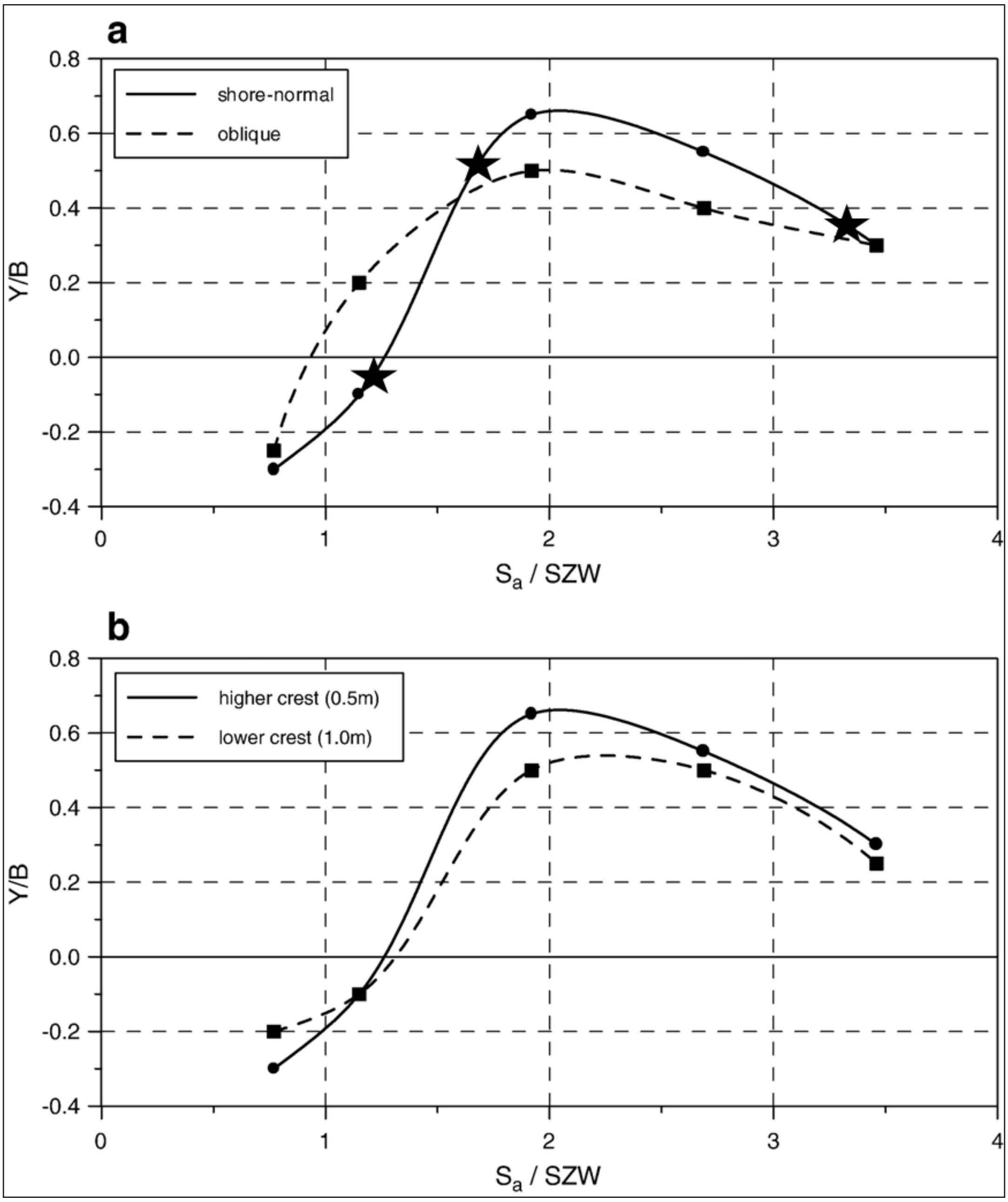

Figure (5.25). Taken from Ranasinghe (2006), plots of Y/B vs. S_a/SZW for (a) shore normal and oblique wave incidence (structure crest level constant at 0.5m below MWL) and (b) for higher and lower structure crest levels (shore normal wave incidence). The black stars represent the Boscombe ASR, data in Table 4.4.

5.6 Discussion

5.6.1 The longevity of the ASR and geotextile SFCs

As introduced in the literature review (Section 2.2.4), sand-filled containers (SFC) can be used in engineering designs for coastal erosion control. Geotextile SFCs are being developed as a soft solution to sediment management, typically used alongside beach nourishment schemes. The SFCs are placed shore parallel to enhance the back beach and dunes, or shore normal in the formation of groins. SFCs can form an individual structure or can be used complementary to artificial beach nourishment schemes as a low cost solution for submerged beach retention schemes (Pilarczyk, 1998). Improvements in the geosynthetic materials, fabrication methods, and designs of these systems have increased the applications and longevity of these structures. These improvements include better material properties, the use of a protective armour layer, multi-celled containers, improved seam design and fabrication, and gentle seaward sloping container system surfaces.

Development of technology to manufacture and place large SFCs (Jackson, 1998) in the past two decades have brought SFC into the forefront of marine engineering. Combining high strengths and resistance to abrasion, puncture, tear and ultraviolet deterioration (Harris and Sample, 2009) the geotextiles SFCs are an alternative artificial reef material. A hairy outer layer of the exposed surface is designed to resist puncture with an additional claimed ability to aid the capture and attachment of marine life in early stages of development. Heerten et al (2000) discuss how success with geotextile "Soft Rock Structures" various disciplines are needed to cooperate and special attention had to be paid to the seams and the prefabrication of the inlets and outlets for the filling process. The selected heavy needle-punched non-wovens prevent stress peaks in the geotextile due to their high elongation performance and provide very high installation robustness. Originally designed for use on roads and land construction the material has shown success to date in resisting the pressures of the marine environment. The use of geotextile materials in a shallow and exposed area such as this should be carefully considered given the major SFC failure seen at Boscombe, as highlighted by this research.

The stability of the Boscombe ASR has been questioned since construction began. Failures in construction were apparent in the first inspection report; tears that were poorly repaired and patches that came loose after a few storms. Two apparent tears in the SFCs with temporary tie-wrap stitching were located and several anomalies were highlighted which are defects where the reef has been patched in places (Richards, 2009). The bags were repaired however these weaknesses remain a serious concern for the continued integrity of the structure. The original shape of the ASR was lost relatively quickly as sediments were reworked, having not been fully packed into the containers as designed. Failures in the ASR structure have highlighted weakness in the design and construction method and the geotextile material used for the containers. ASR Ltd. (2006) claim that "when correctly installed, failures are rare" it is presumed then that there were indeed errors made during installation.

Another claim that "in the event that the material is damaged, experience on previous projects has shown that torn tubes only lose sediment within a small area either side of the tear and so caused no serious damage to the structure" (ASR Ltd, 2006). Unfortunately, this has not proved to be accurate. Damage to one container equated to a large volume loss of 12.5% of the entire volume of the structure. The largest geotextile containers (T4) are approximately 4 meters in diameter, there are only 8 containers of this size and they make up the vast bulk of the structure. The knock-on impact of losing this first container was further container damage; in April 2011 and in the following winter in 2012.

The debate remains open regarding why the first container failed. The SFCs were incorrectly installed and suffered from strain as a consequence. The strain caused by hydraulic forces have been discussed, the geotextiles are not resilient to the impact of storm waves in the surf zone. It has also been suggested that the reef was intentionally damaged by fishermen, those that had been displaced by the structure and the no-go-zone (this is a verbal account will be readdressed in Chapter 8). Regardless of the reasons why the containers failed, it is important to consider that it is unlikely the ASR at Boscombe will survive for the proposed lifespan (25 years) without multiple repairs, given the changes to the structure to date. Technically, it has not survived as it is closed and no longer 'fit for purpose'. There is concern for the reliability of these structures if they are serious contenders for future marine engineering, particularly in high energy environments. The concern here lies mostly with the construction process and with the geotextile material in this exposed situation. The material does appear to be vulnerable to damage, although it has been proven to be more resilient in a covered or submerged environment. Sand dune stabilisation, groynes in low energy marine systems, and river bank management are all examples of successful geotextile SFC construction. There is currently more emphasis on their use submerged in sand or low energy environments, for example; the Mediterranean Italy, Yucatan Peninsula Mexico, and Persian Gulf coast, UAE.

The geotextile material is not as resistant to mechanical damage as hard coastal construction materials (rock or concrete), so care must be taken when designing and handling geotextile systems (Black et al., 2006). This research at Boscombe ASR highlights how delicate these materials can fail if incorrectly installed. Some case studies show the necessity of careful geotextile selection, considering the special requirements of the application, the harsh coastal engineering environment and the rough building practice found in all fields of hydraulic engineering (Heerten et al., 2000). The structure must be correctly configured and constructed; no bags should be missing from the modelled final design and the crest should be the correct design height. The structure should be designed so that the accurate freeboard (the crest relative to surface water) is achieved. If there is a significant difference in the seabed level then this needs to be readdressed in the design; the construction should not continue and be redesigned accordingly. There were bags missing in the final construction that were in the original plan designs, it is speculated that these smaller side bags would have supported the larger bags and prevented movement in the structure and loss. The fill ports should be correctly sealed carefully with attention to how the covers are attached. Additional hydraulic stress was caused in the larger upper bags by the exposure to extended surface interaction due to the ASR's increased crest elevation (+0.5 m). The results of this study highlight that the filling of the geotextile containers and selection of materials is essential, and that the shortcuts taken in this construction likely caused some, if not all, of the SFC failures at Boscombe ASR.

Easy construction is one of the unique features, geotextile SFC installation requires simple equipment; a pump or dredge, hydraulic fill in situ sand into the geotextile tubes (Chien et al., 2013). Some of the advantages of using plastic based geotextiles in ASR and other coastal engineering construction are reduced transportation costs, owing to the low density of plastic, and the varied shapes that can be produced from it (Bortone et al., 1994). Geotextile containers are therefore an attractive construction option because of ease of placement and low cost (Ranasinghe et al., 2001b). Costs to the environment as well as the construction project can be reduced using lighter materials and mobilising construction materials via sea rather than land. Additionally, sand is estimated to have saved 50% of the costs of rock construction for the Narrowneck ASR (see Section 2.2.2) and allow the reef to be easily maintained (Challinor and Weight, 2009; Heerten et al., 2000). The experiences at Boscombe ASR highlight the need for careful design and construction with thought given to the dynamic environment in which the construction is being installed.

The beneficial features of easy installation, eco-friendliness and cost-effectiveness (Chien et al., 2013) outweigh those of hard engineering structure; this is highly dependent on the projects success. The structure must remain inert in the environment, as opposed to Boscombe ASR which arguably introduced plastic and microplastics waste into the marine environment. Minimal maintenance or SFC replacement is needed as costs for remobilising dive teams and dredging is high. Additionally, the project management and time keeping should be good in order to prevent project drift and escalating costs. Boscombe ASR suffered from a series of poor management and structural failures causing the project to become substantially more expensive than the original budget.

The council attempted to recuperate the damaged costs from their insurer in August 2011, whilst other remedial works were taking place. Repairs were not carried out due to a break down in relations between the construction company (ASR Ltd.) and the council. Therefore the ASR was left exposed to further damage the following winter. At time of writing (August 2013) the ASR is still closed to the public due to concerns regarding the safety of the reef. ASR Ltd. has since gone into liquidation and the ASR remains uncertain, with insurance claims pending and discussions of a marine park for snorkelling replacing the focus on surfing amenity.

5.6.2 Evaluation of physical impact of the coastline and coastal responses

As well as predicting the life span of a structure, there is a need to be confident in the ability of ASR designers to predict beach response. It is well known that the construction of structures can have serious erosional consequences. Structures also remove the wave action and eliminate the energy required to transport the littoral sediments, resulting in accumulation of sediment (Komar, 1998). Comparing the predicted morphological response to the reef using numerical models by designers (ASR Ltd.) with the presented observed response indicates the level of confidence in future ASR designs. Figure 5.26 was provided by Kerry Black (of ASR Ltd.), it is interesting to note that the shoreline (0 m contour) was not predicted to be impacted by the ASR, as is supported by the observed results presented here. As stated in the introduction to this chapter, HR Wallingford also produced an independent report predicting little or no shoreline change (**?**). According to the empirical theory given by Ranasinghe and Turner (2004) the magnitude of shoreline change relates to structure length, crest height and cross-shore distance offshore. The theory is that circulation induced by gradients in wave height at the ASR cause increased erosion or accretion. At Boscombe ASR this effect is occurring a significant distance offshore (>200 m) and any impact on the shoreline will be minor. Therefore observations of the shoreline are unlikely to highlight any change.

Additionally, the steepening of the bathymetry at the -3 m contour leeward of the ASR was predicted in the model (Figure 5.26), and has been observed in the surveys presented. The bathymetry has certainly steepened towards the beach in the leeward side of the ASR. This steepening in the leeward area in close proximity to the ASR, approximately 50 m

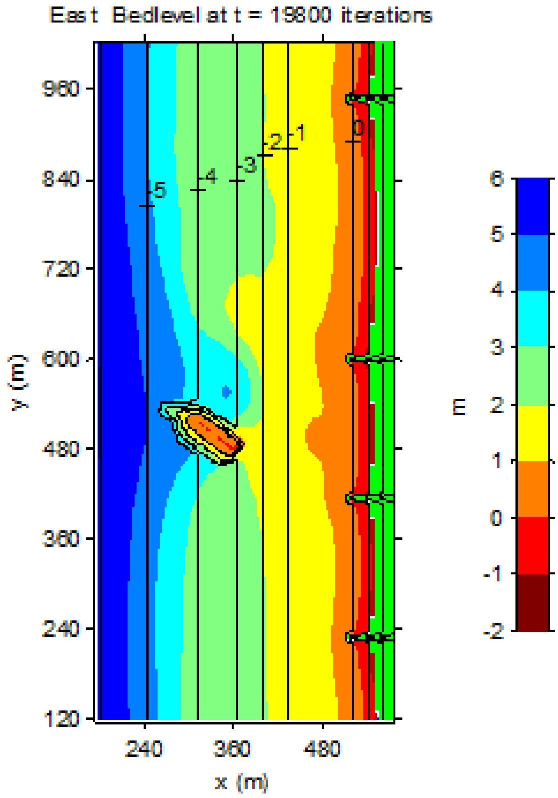

Figure (5.26). Prediction of shoreline changes and bathymetry contours, increase can be observed in the 1m contour. Numerical model image obtained from personnal communication with Kerry Black (2010) extracted from the inhouse modelling by ASR Ltd.

shoreward of the foot of the ASR, after which the effect is dissipated. Salients are relatively inconspicuous perturbations leeward of submerged reefs or islands, much of the feature is submerged and most obvious at low tide (Masselink and Hughes, 2003). The prediction of a salient formation of approximate 40 m at the -1 m contour can be seen in the model output by ASR Ltd. (Figure 5.26). From the measured data presented in this thesis no obvious shoreline response has been observed. Given the structures distance offshore, no salient (or tombolo) formation or widening of the beach has occurred directly from the construction of the ASR. The nourishment of Boscombe Beach previous to the construction of the ASR, combined with the additional sand not used in the construction process that was added to the area landward of the ASR is the cause of the temporary widening of the beach (as shown in Profile 1). This was not observed directly leeward of the ASR where sediment was depleated and in the area closest to the ASR it is considerably eroded.

Instead the observed shoreline displacement appears to agree with the theoretical predictions in the literature (Ranasinghe and Turner, 2004; Ranasinghe et al., 2006), as it would seem that the ASR has a minimal interaction with the shoreline. This can be observed in the bathymetry surveys since the shoreline has not migrated since construction began in 2008; there has been no observed accretion at the shoreline up until the latest detailed bathymetry dataset made available to this project (2011). Enough energy must be removed from the system to enable sediment to accumulate towards the structure and induce a salient formation (Komar, 1998). This is not the case with the Boscombe ASR since no obvious widening of the beach has occurred. There is significant diffraction leewards of the reef which smooths out longshore differences in wave height (wave modelling will be used in Chapter 5 to further investigate).

Regardless of the fact that the ASR was not built for coastal defence, there were claims that modelling of sand banks and currents demonstrated that the reef beneficially protects the coast from erosion (ASR Ltd, 2006). The claims have confused the original aims of the project. Claims were made that might have provoked an expectation of beach widening from stakeholders; "in the sheltered lee of the reef, the beach will become wider by up to 40 m" (ASR Ltd, 2009). Alongside which, no negative impacts were anticipated, as the reef was claimed to protect the coast in its lee and have no measurable effect away from the reef along the coast (ASR Ltd, 2006). Since construction, ASR Ltd. has claimed that it would result in salient formation as a by-product (Mead et al., 2010). It is therefore important to ascertain whether this has indeed eventuated and, if so, to what degree.

The importance of looking at longterm beach profiles and changes in volume over longer periods, rather than just the initial few months post-construction is that the results will then account for the settling and adjustment of disturbed sediments from the construction process. The bathymetry data presented by Mead (2010) is collected particularly close to the initial reef build, just 6 months post-construction (October 2009 to January 2010) shown in Figure 5.27. The morphology and beach processes are often impacted for longer periods before an equilibrium beach profile is reacged, especially when a large scale nourishment program is implemented. If the profiles are consistently above the mean since the ASR construction then it could suggest a salient formation. To better understand this a volumetric analysis of the profiles was performed. Since the volume fluctuates around the mean (post-nourishment volume) then there is no conclusive evidence for an increased volume and therefore salient in the leeward area. The presented observations of the beach in the leeward area indicate that the structure has acted to temporarily retain the additional sediment placed at the site for construction.

As with most of the ASR projects to date, beach nourishment has been combined with ASR construction. The beach is fuller behind the ASR after construction due to 23,000 m^3

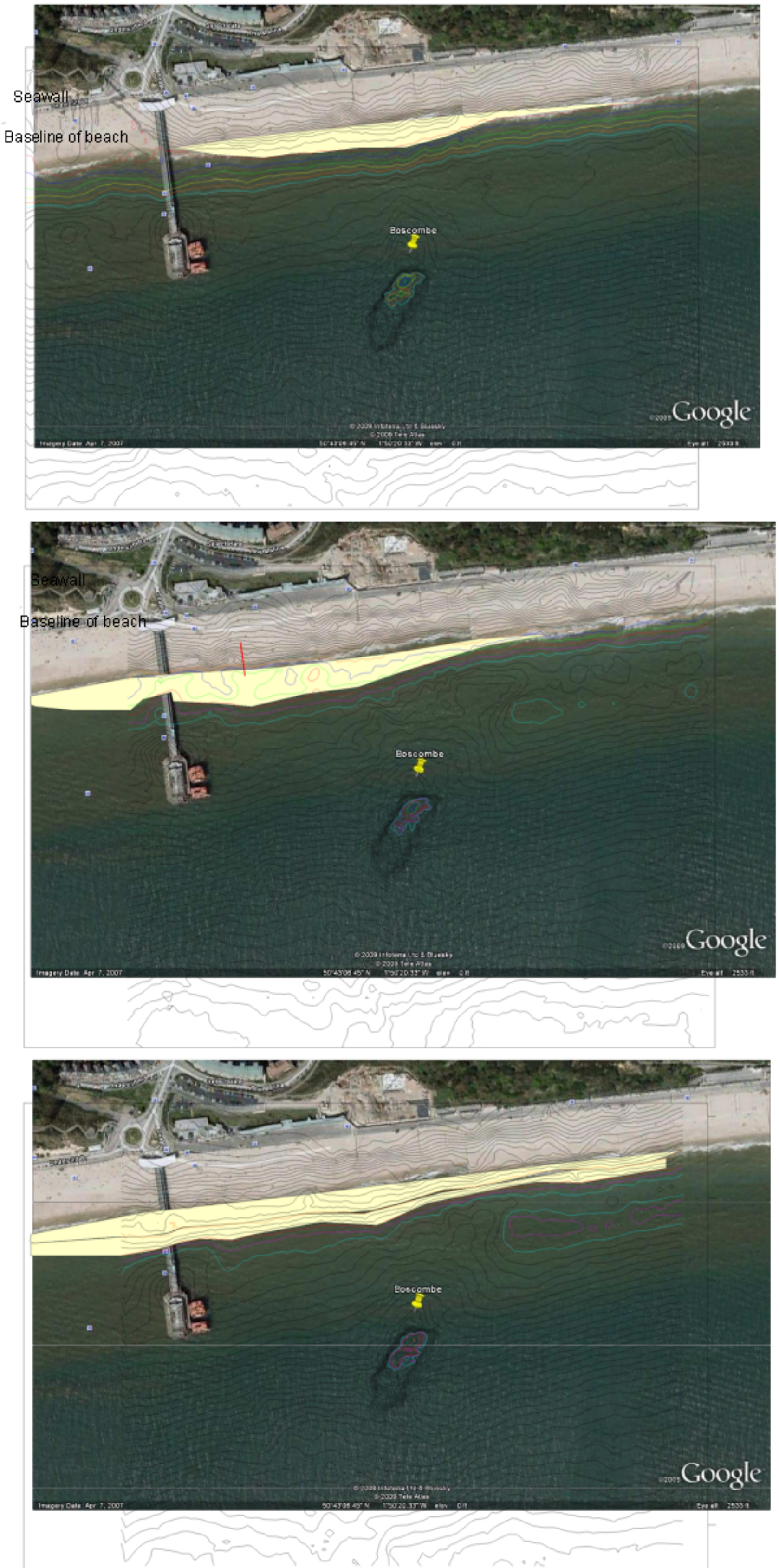

Figure (5.27). Satellite images of Boscombe beach and ASR overlaid with beach survey data on (a) 09/10/09, (b) 31/01/10, and (c) 22/03/10, taken from Mead (2010) original caption; "Time-series bathymetry and beach profile surveys indicating the development of the salient in response to Boscombe Reef".

Figure (5.28). Photograph showing the sand pile during the construction phase, this sand is used to fill Boscombe ASR geotextile containers.

of sand piled on the upper beach face in order to be pumped offshore to fill the geotextile bags (Figure 5.28). The ASR construction required 11,900 m^3, if built to design. It was noted by the council that not all SFCs from the design are in the final construction and the SFC are not all filled to capacity. The remainder 11,100 m^3 remained on the beach, spread in the area between Boscombe Pier and the first groyne. This remaining sediment is an increased average grain size to the rest of Boscombe Beach. The sifting and pre-processing of the sediment before it could be pumped offshore as slurry has lead to the courser pebbles remaining on the foreshore. Once construction was complete the larger sediment grain and the additional nourishment became part of the beach profile, taking 6-12 months to dissipate.

Sediment transport depends on the properties of the sediment (size, mass and density) and the hydraulic forces (shear, turbulence and velocity) acting on the particles. The removal of wave induced shear and turbulence by the ASR, combined with the increased sediment size, would account for a reduced sediment suspension, therefore reducing transport away from the leeward area. If the critical bed shear stress is not achieved then sediment transport will not be initiated (Masselink and Hughes, 2003). High energy conditions would be needed to resuspended sediment for transport, this sediment contributed to the appearence of a salient formation in the first 6 months.

In Narrowneck, Australia 10 years of monitoring highlighted an approximately 30 m salient (100 m wide) which is often visible in the leeward section (Jackson et al., 2010). Video and observational analysis show that the feature is not always present and is exposed to the same variability as the rest of the coastline (circa 20 m of the shoreline). Any indication of a salient signal need to be carefully interpreted over longer timescales before conclusions can be made.

The results of this study do not support the observations of Mead (2010). This temporary salient formation disperses after the first winter period, since this period no evidence of the salient has been observed, although the most recent surveys (2012 and 2013) are not included in this study. The initial retention of this sediment maybe partly due to the ASR structure and the reduced nearshore circulation, however it is not possible to categorically claim the ASR is responsible for the temporary salient. This beach also has hard wood groynes and a predominant longshore littoral drift (from west to east). The coastal defence system in place at Boscombe could equally have been responsible for the increased retention of sediment between the groynes leeward of the ASR. Due to the locality of the Boscombe Pier and groynes on Boscombe Beach, it is difficult to differentiate between the effect of the ASR and that of the pier and groynes to any increase in beach width or seaward migration of the shoreline, albeit temporary.

5.7 Conclusions

The research presented shows that predictions for sediment migration are quite accurate. In terms of the claims of the designers in respect to coastal defense, the reef can be considered successful as it has had no significant effect on the natural shoreline position. There is some mild scour highlighted in the bathymetry surveys in the leeward section of the ASR, however it is considered relatively minor. The ASR project has not been successful in terms of structural resilience in the marine environment and in terms of its longetivety. Geotextiles SFCs used proved to be weakened through hydraulic reworking of sediments and multiple containers have been lost at a major cost to the project. Due to the closure of the ASR for safety reasons, the project has failed to produce increased consistency and increased surfability at Boscombe for the local and travelling surfing community.

Construction materials and the installation process should be considered at design phase through numerical and physical modelling to predict temporary salient formation corresponding with the nourishment near the time of construction. The reef designers were not requested to create a sediment retaining structure for coastal management and therefore it is not appropriate to compare the abilities of this structure with one designed for coastal protection. However, given the marketing for the ASR (or multipurpose-ASR) design it is important that lessons are learnt from this project. The composition of sediment, wave climate and littoral drift will all play a role in the ability of an ASR to provide shelter and coastal protection. If the aim of the project was to provide beach widening and stability, the structure should be design accordingly. The distance to the shoreline, ASR construction on a much larger scale, or as an array of ASR structures. The aims of the design and feasibility studies should reflect this and be agreed on in the early stages. Altering aims later on and making unsubstantiated claims for coastal protection outside of the project remit incites confusion and scepticism towards the designers. This will be an important discussion point in further chapters with stakeholder engagement.

The following chapter will investigate wave and hydrodynamic response at the Boscombe ASR using a calibrated and validated numerical model built with DHI's MIKE21 software. The investigation allows for a greater understanding of the physical processes surrounding the structure that are responsible for the issues highlighted in this chapter.

Chapter 6

Numerical model investigation: waves and currents at the Boscombe ASR

6.1 Introduction

In the previous chapter, the observations of shoreline change were made and some small variations were noticed. It has been suggested that the ASR acts to ameliorate wave energy in the leeward section encouraging sediment deposition leeward of the reef. There is a delay as the nourishment material is dispersed across the foreshore suggesting there is some protection provided to the beach, but it is unclear to how and to what extent it impacts the foreshore. As set out in the literature review, there are a number of claims that the designers of surfing reefs have made in the past regarding the amelioration of wave energy in the leeward area:

> "Modelling of sand banks and currents demonstrated that the reef beneficially protects the coast from erosion. In the long-term, no negative impacts are anticipated, as the reef protects the coast in its lee and has no measurable effect away from the reef along the coast. No adverse effect on the existing nourishment and groyne programme is anticipated. There are no adverse rip currents or changes to the currents with the reef present that could strongly affect public swimming or surfers using the reef and beach. The reef provides some shelter from waves at the shore and greatly improves the natural sand banks for surfing" (ASR Ltd., 2006).

This chapter will address the amelioration of wave energy further with the main aim to address whether the claims are being realised; (a) to evaluate the physical impact of the Boscombe ASR on local hydrodynamics, (b) to further explain the coastal response observed in the previous chapter through the investigation of waves and currents, and the linking theme (c) to bridge the knowledge gap in the understanding of the physical processes surrounding semi-submerged geotextile structures and their interaction with the marine environment. More precisely, the primary aim of the modelling study is to develop an understanding of the hydrodynamic current circulation patterns at Boscombe ASR and test the original claims of the contractors. To further understand the force behind the observed modes of morphological change observed, as shown through surveying previously (Chapter 4). The secondary aim for this modelling work is to better understand the potential safety implications of the ASR to the public (both for surfers and bathers) under a variety of environmental conditions. This is also addressed in Chapters 8 and 9.

The objectives of this chapter are to provide a scenario based examination of the ASR and the surrounding hydrodynamics using numerical modelling. The setting up of a numerical test facility enables scenario based replication of the coastal environment. The modelling work is split into three sections. Firstly, wave only conditions are investigated to understand the effect of varying water level, wave height, period and direction on the current speeds and circulation patterns produced. Secondly, tidal conditions were investigated for neap, mean and spring tidal cycles. Thirdly, combined wave and tidal cycle conditions were modelled. Tidal currents are important to differentiate from wave induced stresses hence testing them separately to derive their relative contribution to morphological change. Both types of forcing are considered important in assessing the safety for sea users.

The chapter describes the construction, calibration and validation of a hydrodynamic and spectral wave model. The reasons for approaching the hydrodynamic investigation with a numerical model, as opposed to insitu observations or a physical model, was related to cost efficiency and having control over the wave and hydrodynamic response to the ASR under a range environmental conditions. The alternative approach would have been physical modelling, which would be an interesting and valuable investigation, however this method is beyond the scope of this research.

6.2 Method: MIKE21 FM coupled model

A commercially available ‘state-of-the-art’ numerical modelling tool was used for prediction and analysis of the wave climate at Boscombe. The Danish Hydraulic Institute’s

MIKE21 mode was used to replicate the environmental conditions at Boscombe and the ASR. The coupled flexible mesh (FM) model was used with the spectral waves (SW) and hydrodynamics (HD) modules. This includes a spectral wind-wave model based on unstructured meshes. The model is capable of simulating the growth, decay and transformation of wind-generated waves and open ocean swell in offshore and coastal areas. This model was deemed appropriate to use for this investigation due to its wide coastal application in the commercial world and proven success in managing complex coastal situations (Siegle, 2003; Fairley, 2009; Aird, 2009; Ranasinghe et al., 2010; Baldock et al., 2014).

MIKE21 Coupled Model FM is a truly dynamic modelling system for applications within coastal, estuarine and river environments (DHI, 2012b). For the purpose of this study the HD and SW modules will be used. The HD and SW modules are the basic computational components of the Mike 21 Coupled Model FM, using a dynamic coupling between the modules (DHI, 2012b). Area models or 2-dimensional models simulate the conditions in a horizontal domain, which may include the coastline and coastal structures (Mangor, 2004). The flexible mesh is triangular in MIKE21; unstructured models typically utilise finite elements (triangular) as opposed to finite difference (rectangular meshes) of varying dimensions. The smaller elements (or higher resolution) are used in this case in areas of particular interest, such as structures in the surf zone or tidal inlets (Mangor, 2004).

Since reliable data sources could provide the boundary conditions for both tide and waves the model is more reliably accurate than using a generated wave spectrum. The tidal data is recorded by British Oceanographic Data Centre (BODC) at Bournemouth Pier, 2 km from the area of interest. The Channel Coastal Observatory (CCO) operate an inshore Waverider buoy at 10m water depth seaward of the ASR at Boscombe.

6.2.1 Hydrodynamic module

The HD module simulates water level variations and flows in response to a variety of forcing functions in lakes, rivers, estuaries and coastal regions (DHI, 2012b). The module is capable of representing the following:

- Flooding and drying,
- Momentum dispersion,

- Bottom shear stress,
- Coriolis force,
- Barometric pressure gradients,
- Tidal potential, and
- Wave radiation.

In the case of this study the module is being used to solve two-dimensional problems. In 2D the model is based on the shallow water equations; the depth-integrated incompressible Reynolds averaged Navier-Stokes equations (DHI, 2012b). MIKE21 HD 2D is a depth-averaged model for simulating water levels and depth-integrated fluxes driven by wave breaking (radiation stress), wind, atmospheric pressure conditions and tide (Johnson, 2006).

6.2.2 Spectral wave model

The SW module is a numerical tool for prediction and analysis of wave climates (wind generated and swell waves) in offshore and coastal areas (DHI, 2012a). It includes a new generation spectral wind-wave model based on unstructured meshes. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas.

MIKE21 SW includes two different formulations:

- Directional decoupled parametric formulation, and
- Fully spectral formulation.

The directional decoupled parametric formulation is based on a parameterisation of the wave action conservation equation. The parameterisation is made in the frequency domain by introducing the zeroth and first moment of the wave action spectrum as dependent variables following (Holthuijsen et al., 1989). The fully spectral formulation is based on the wave action conservation equation, as described in Komen et al. (1994) and Young (1999) for example, where the directional-frequency wave action spectrum is the dependent variable (DHI, 2012a). For the purpose of this study, the fully spectral formulation is used. The basic conservation equations are formulated in Cartesian co-ordinates. The governing equations are computed across the geographical and spectral space using cell-centered finite volume method. For the model bathymetry (the geographical domain) an unstructured mesh technique is used, the flexible mesh described previously. Time integration is performed using a fractional step approach or a timestep, this is where a stepwise approach is applied for the propagation of the wave equations through the model domain. This ultimately allows the wave action to be represented.

Mike 21 SW includes the following physical phenomena:

- Wave growth by action of wind
- Non-linear wave-wave action
- Dissipation due to white capping, bottom friction and depth induced wave-breaking
- Refraction and shoaling due to depth variations
- Wave-current interaction
- Effect of time-varying water depth and flooding and drying.

6.3 Model set-up

All dates and times are specified in Greenwich Mean Time (GMT). Latitudes and longitudes are expressed in the Ordnance Survey of Great Britain (OSGB) coordinate system. Eastings and Northings are given in metres as national grid references based on the OSGB datum. The vertical datum for the model used to generate the database that this tool uses is Mean Sea Level (MSL) or ODN = 0, therefore water level and surface elevation are given in MSL. Current direction refers to the direction which the current is flowing, in degrees clockwise from true north (^{o}T). Current vectors point in the direction of current flow.

The water level boundary conditions for the regional model were generated by DHIs Global Tide Model (GTM) tool. The resolution is 0.125 degrees (just over 13km) of the version of the GMT tool which generated this data. This data was supplied by DHI as it is a finer resolution than that supplied with the software as the tidal regime is complex in the area (as described in Chapter 3). The local model domain is significantly smaller than this, to avoid associated boundary issues a regional model was constructed of the wider Poole Bay. The data from the GTM is used to drive this larger area, coarser resolution model from which more suitable boundary conditions were extracted for the smaller area and finer resolution local model. The regional model was validated against tidal gauge data at Bournemouth Pier from British Oceanographic Data Centre (BODC); this is discussed in more detail in further on in the chapter.

6.3.1 Regional model

As mentioned two layers of model resolution are used in this method (Figure 6.2). The larger area regional model is courser in resolution and was constructed to provide more precise boundary conditions for the local model (Figure 6.1). The regional model domain covers the entire Poole Bay but does not resolve Poole Harbour, the area covered is approximately 14 km by 10 km. Due to the intricacies of flooding and drying in this area the large harbour has been omitted for this relatively simple modelling investigation. Although the harbour has a large capacity and will have implications on the tide the difficulties for model construction and impact on run time were considered to outweigh any benefits to the accuracy of the model. The depth averaged 2 dimensional flexible mesh model is comprised of 1994 nodes and 3811 elements. The minimum depth cut off is 3.16 m and the datum is MSL.

A combination of data was used to create the topography and bathymetry. Bathymetry was generated from the CCOs DGPS biannual surveying of the Boscombe ASR using the spring 2010 dataset, as described in Chapter 4 . The Ordnance Survey maps (chart datum) were digitised and corrected to MSL for deeper waters and areas beyond the CCO data coverage.

6.3.2 Local model

The local model domain covers a 2 km by 1 km stretch of coastline, Boscombe Beach in Poole Bay (Figure 6.2). The domain was made wide enough to ensure that boundary effects dissipated prior to the region of interest, the groynes were removed from nearer the shore-parallel boundaries as they had a deleterious effect to model stability. The depth averaged 2 dimensional flexible mesh model is comprised of 4688 nodes and 8985 elements. The minimum depth cut off is 4 m and the datum is MSL.

The finite element mesh generated was refined so that shallower areas of interest had finer resolution (Figure 6.4). The maximum and minimum element area is 300 to 10 m^2, respectively. The ASR is incorporated as bathymetry and internal boundaries used to preserve the ASR's shape in the flexible mesh. The CCOs 2010 spring data set was

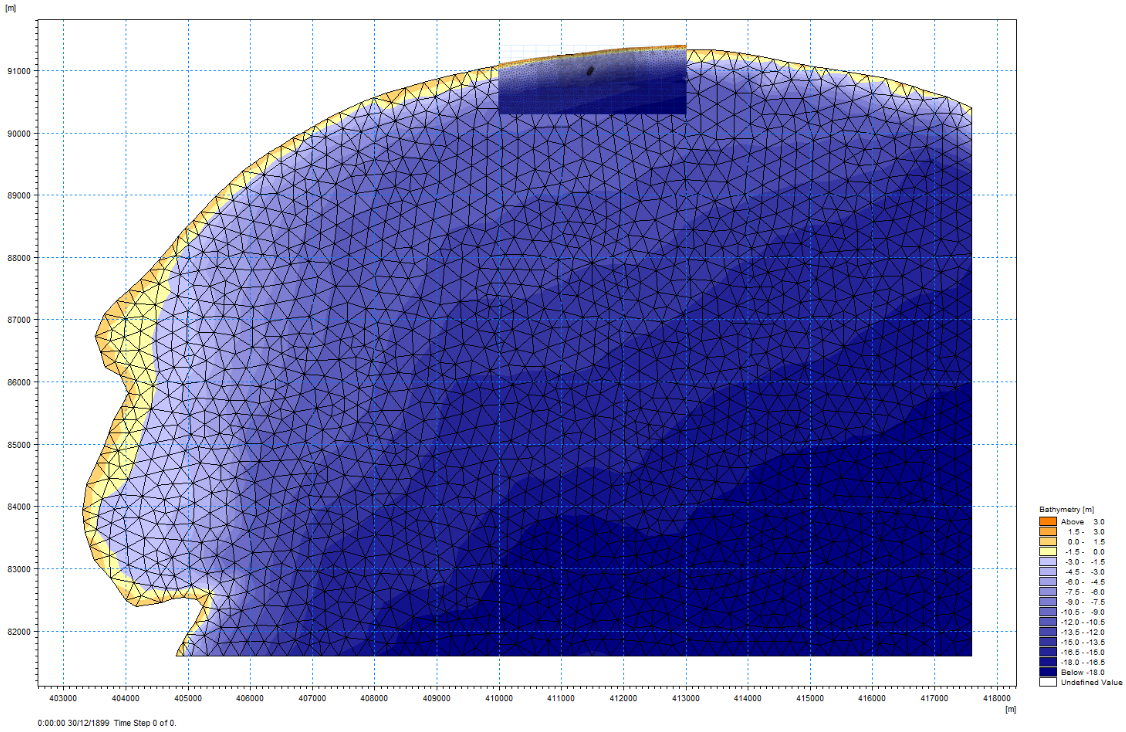

Figure (6.1). Regional model domain of Poole Bay with triangular mesh with insert of finer mesh local model domain.

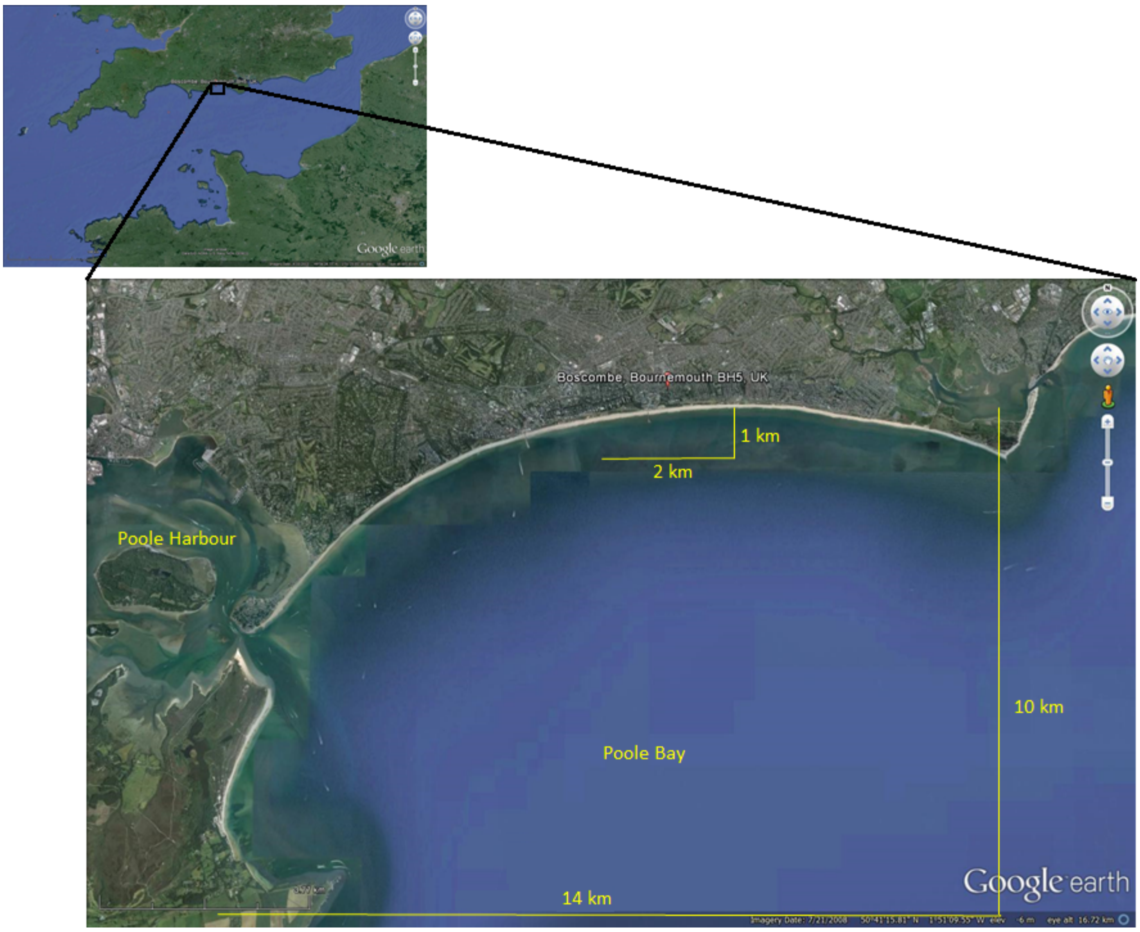

Figure (6.2). Overview of the model domains built for investigating the impact of wave climate and induced currents surrounding the Boscombe ASR.

chosen as it is the most detailed and shows the ASR before any damage to the structure was observed. The structure is therefore in its most finished and complete state. This also ensures that the environmental impacts of the entire structure are being replicated and not the effects of any damaged sections that might confound the results. The mesh for the same model domain was also generated for a pre-ASR scenario using CCO data from spring 2008 (Figure 6.3). This ensured that the beach refill was present (as discussed in Chapter 4) however the ASR is not present.

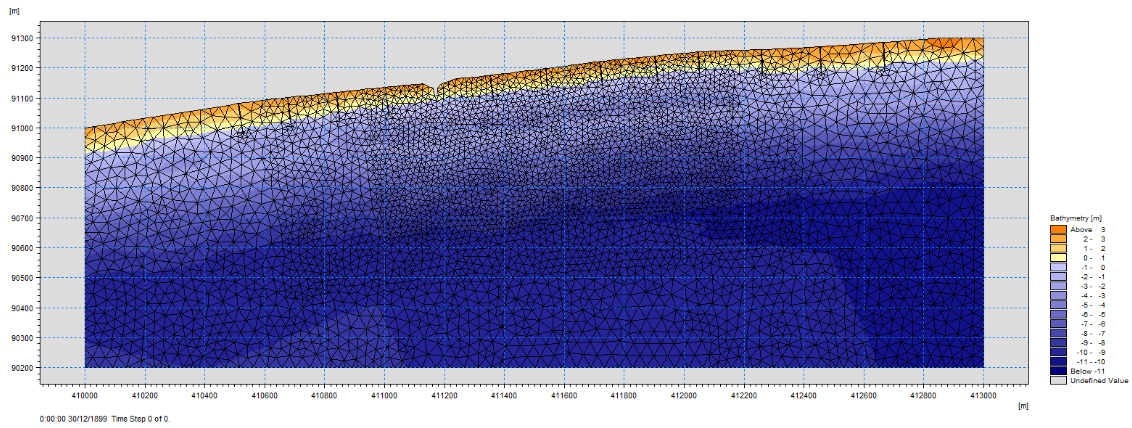

Figure (6.3). Local model without ASR in the bathymetry

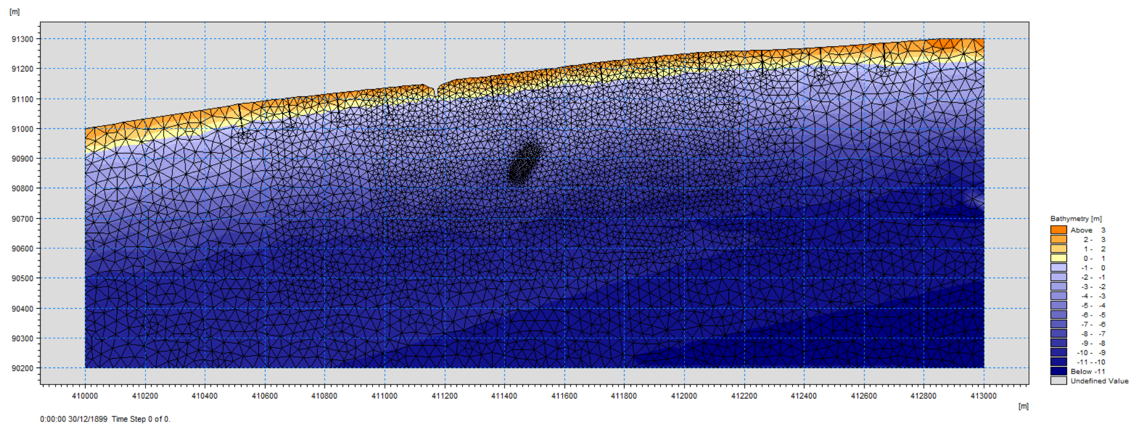

Figure (6.4). Local model with ASR included in the bathymetry

The presence of the pier and groynes are included in the model; piles of the pier are incorporated in the model set up and groynes are built into the back wall of the beach. The model does not truly replicate the nature of the groynes, more energy dispersion is likely as some wave energy would normally pass through, or overtop the groynes. Therefore the groynes were shortened by one metre to sufficiently replicate the effect to the hydrodynamic and wave models. In reality, the groynes are not fully submerged and do not extend far out to sea to interfere with the lee area of the ASR construction, that is the main area of interest. The Boscombe Pier is represented in the model using the MIKE21 inbuilt facility to enter each pile. 10 circular piles were entered with a 3 m diameter and 10 m height. In preliminary testing of the model set-up, the model was tested with and without the piles and showed to have an impact on the hydrodynamic model. The presence of Boscobme Pier was deemed important in dampening the local circulation and hydrodynamic flow in the area of interest.

Boundaries are set accordingly; the inshore is closed and impermeable, the east and west are set as lateral boundaries, and the offshore boundary is forced with obliquely incident waves. A directional WaveRider MKIII buoy positioned at 10m water depth has been collecting data for five years prior to the ASR project. The south boundary of the model has been positioned so that data from the buoy could be used to drive boundary conditions, calibration and validation. Characteristic wave conditions for this area have also been calculated using this data set (as introduced in Chapter 3).

As the beach at Boscombe is highly popular with water sports users all year round a nearshore rig to position data recorders was not appropriate. Data on wave attenuation in the leeward area of the ASR was collected by pressure transducers (PTs) attached to the ends of four groynes during spring tide low for one calendar month January 2011. Two PTs were placed leeward of the ASR on groynes 23 and 24 and for comparison two were placed on groynes 27 and 28 (Figure 6.5). The latter were chosen as they represented a similar stretch of beach without the influence of the ASR. This data was collected in order to validate wave height in the spectral wave model.

6.3.3 Run period and timesteps

The regional model was run for period of two months during the winter 2011 to provide a selection of tidal conditions from which to extract the boundary conditions for the local model. The model was run with a timestep of 60 seconds. The model boundary timestep was 900 s (15 minutes) for the regional model. These intervals provide sufficient resolution of the changes in elevation/flux throughout the run. The run period was as follows: regional mode run from 01/01/2011 00:00:00 to 01/03/2011 00:40:00.

The local model was run under typical neap and spring tidal conditions (i.e. neap and spring periods that display average tidal ranges). The model was run with a timestep of 10 seconds. The model boundary timestep was also 900 s (15 minutes) for the local model. The run periods for the local model were; a) neap from 14/02/2011 05:45:00 to 15/02/2011 08:45:00, and b) spring from 19/02/2011 21:00:00 to 21/02/2011 00:00:00.

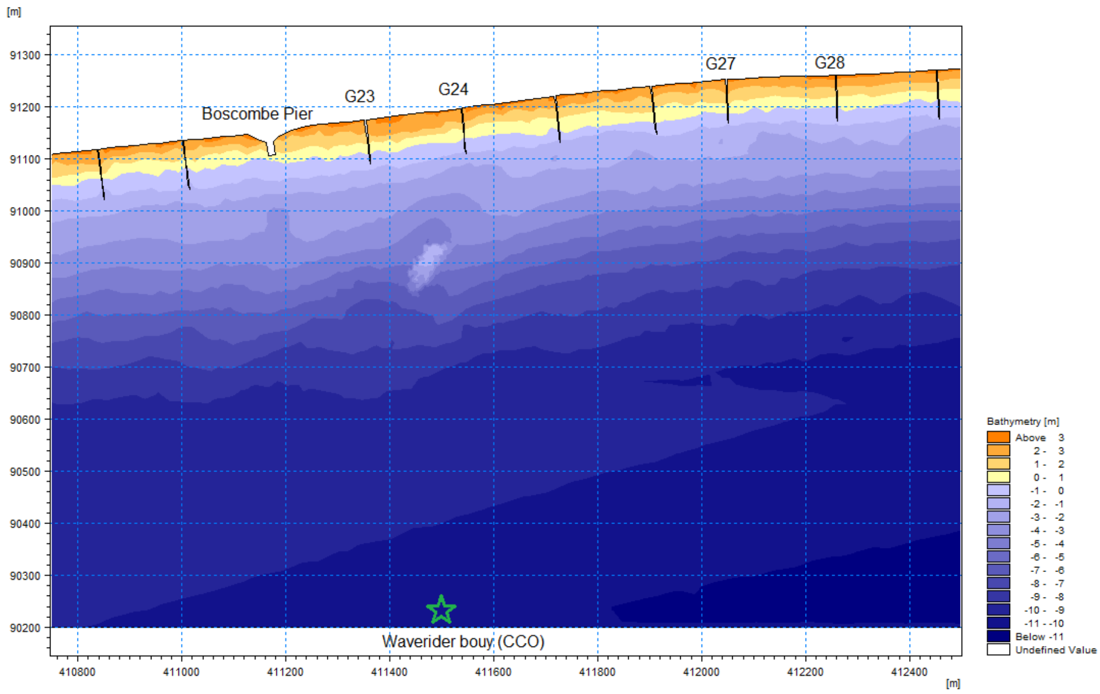

Figure (6.5). Wave buoy and pressure transducer locations used for calibration of the local model

6.4 Model calibration and validation

Validation of the hydrodynamic model was undertaken using observational data and modelling the same conditions, in order to demonstrate the capability of the model and ensure the model was performing correctly. Tidal elevation data was obtained from the BODCs National Oceanographic data base for the tidal gauge on Bournemouth Pier. The time series of tidal height for the same period as the regional model run (2 months) was collated to allow comparison with the regional model output at the same point. Bournemouth Pier tide gauge is located at 408930.74E, 90531.22N (OSGB). This is the only point of reference in the bay however it is in close proximity to the local area model domain. For this project the model is considered a good fit for approximating the tidal regime, although consideration must be given to the limitations of the models capability to accurately represent the tidal pattern in this complex area.

Validation of the Mike 21 SW model was carried out using wave buoy data for the same time period as the measured data by the pressure transducers that was collected (Figure 6.7). Comparison of the measured (red) and modelled (blue) wave data is good. The 10 m wave buoy data (black) have been included to provide evidence that the pressure transducers and model are accurately representing the nearshore environmental conditions. The model is considered to be resolving dissipation of wave energy appropriately due to the accuracy of the model prediction. The wave height is the most fundamental parameter under investigation and the model is able to determine the inshore wave heights given the offshore wave forcing with a high degree of confidence (errors were $< +/-$ 0.15m). Regression analysis provides further confidence in the data allowing us to predict 78% to 85% of the variance in the measured data with the model. Sensitivity analysis on a sensible range in gamma was conducted, however the best fit was the default of 0.78. The Courant number, manning number (Bed resistance) and eddy viscosity were also tested to understand their impact in this shallow water area, these parameters were kept at their default values as they were found to have little impact on the wave height.

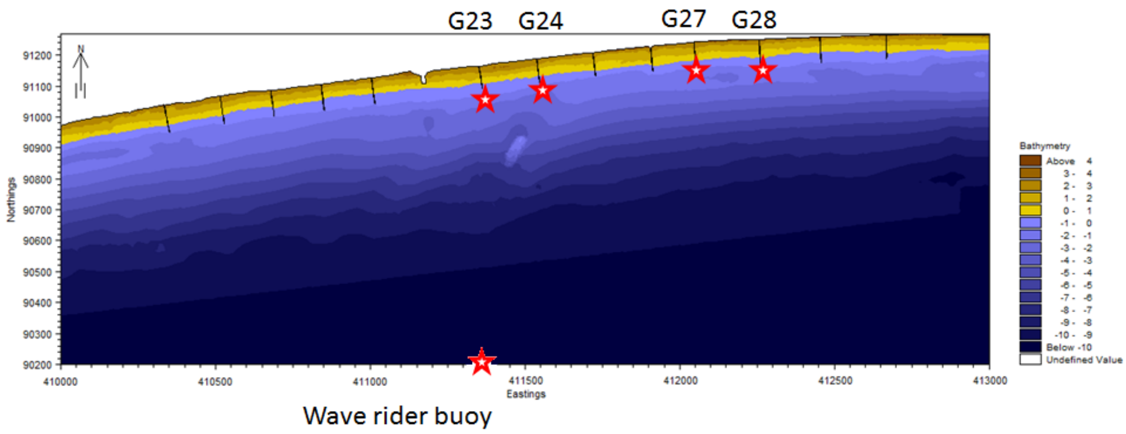

Figure (6.6). Model domain and bathymetry illustrating where the groynes which had pressure transduces attached leeward of Boscombe ASR and further along Boscombe Beach, also highlighting the position of the CCO waverider buoy.

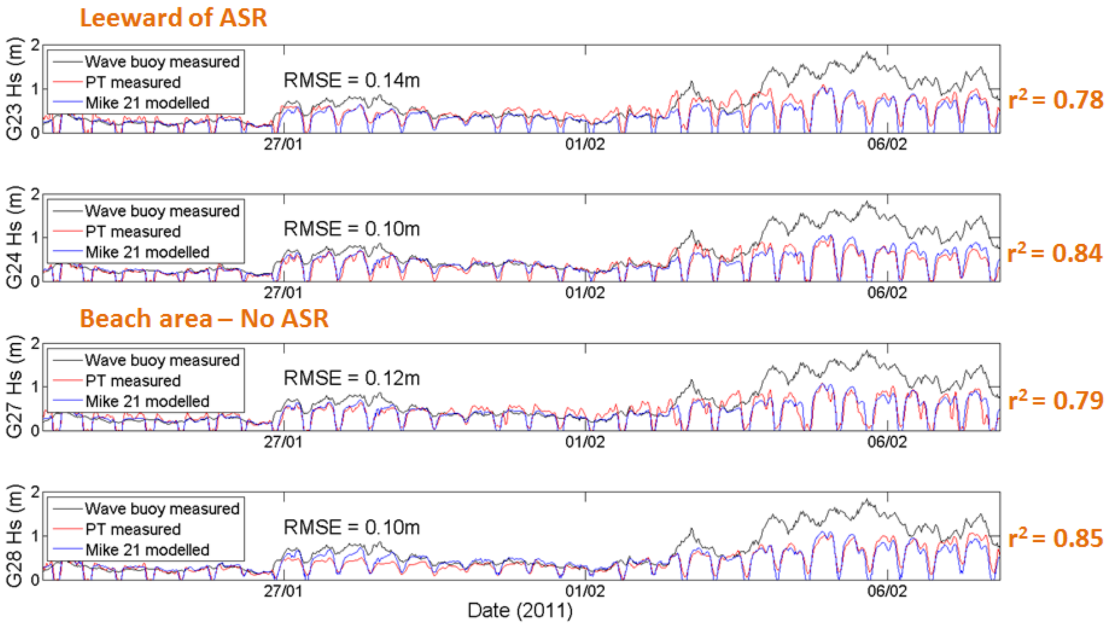

Figure (6.7). Measured data from the pressure transducers (PT) plotted against the modelled results with the wave buoy data included for reference. With groynes 23 and 24 leeward of the ASR and groynes 27 and 28 in an area of beach considered to be unaffected by the ASR.

6.5 Results

6.5.1 Wave attenuation over the ASR

To investigate the claim that the ASR would provide a safe, sheltered area for bathing the SW model was used to simulate the local conditions and understand whether the ASR was impacting the wave climate at Boscombe. The model was used as a tool to understand if there were conditions under which the reef may focus or dissipate wave energy thereby increasing or decreasing breaker height leeward of the ASR.

An assessment of the wave climate in the area shoreward of the ASR and at an area of Boscombe Beach 500 m alongshore from the reef position. The wave height at breaking for a given scenario was calculated for the ASR (H_a) and this was compared to the breaking height at the beach (H_b) under the equivalent conditions. Environmental conditions were tested through a variety of test cases with different wave heights, periods and water levels. Wave attenuation coefficient (A) is considered to be a function of wave height (H), tide, wave period (T) and direction (θ) as given by:

$$H_a/H_b = A = f(H, tide, T, \theta) \quad (6.1)$$

Theoretically, it is logical that small amplitude waves propagating in deep water (around high-tide) will focus wave amplitude leeward of the ASR (A>1) due to the absence of dissipation and refraction. Conversely, higher amplitude waves propagating in shallower water will be dissipated by the reef leading to reduced wave height at the leeward beach (A<1).

A matrix of model tests was planned spanning the parameter space of the dependent variables in equation 1; in all 180 simulated scenarios were generated. All tests were run at an angle of oblique wave approach (173^o) as the effect of angle of approach simply shifts the effect to the east or west of the ASR and wave direction has limited bearing on the mode of shoreline response (Ranasinghe et al., 2006). Due to the typically low energy environment at Boscombe, H ranged from 1 m to 0.125 m in five increments, tide represented the spring tidal range 1 m to -1 m in nine increments, and period of 5 s, 6 s, 7 s and 12 s were investigated. An assessment of the wave climate was carried out using the model in the area shoreward of the structure and a beach area that is considered unaffected by the structure. The model was run using typical wave height conditions for Boscombe, the period was set at the average for Boscombe, 6 s and the tidal range was 2 m. The results were gathered and then averaged for a typical tidal cycle.

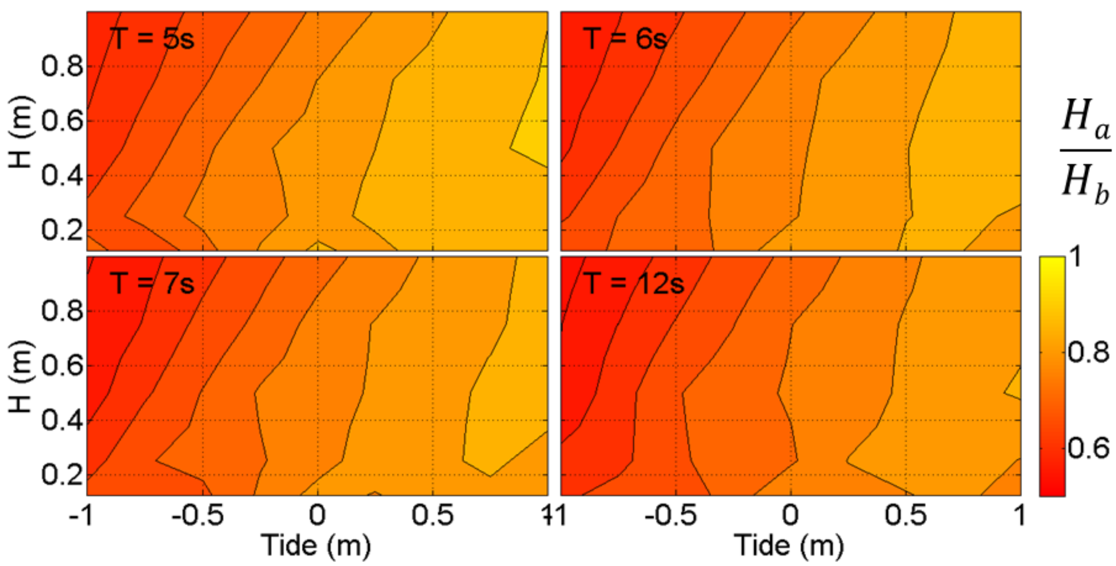

Figure (6.8). A filled contour plot of the height at breaking leeward of the ASR (Ha) over the height at breaking at the beach (Hb) for 1 m wave heights, tidal height is 2 mODN and for period of 5, 6, 7 and 12 s.

Figure 6.8 provides a summary of the wave attenuation leeward of the ASR as a comparison with an are of Boscombe Beach over 500m away from the structure. All values of A<1, meaning that the waves are significantly attenuated by the structure relative to the neighboring beach. Consistent with theoretical predictions, the reef attenuation coefficient (A) increases proportionately with water depth but inversely with wave height. The filled contour plots show that attenuation (A) does not approach, nor exceeded 1 (bright yellow). When plotting the breaker height in the leeward area of the ASR (Ha) over the breaker height at an area of beach unaffected by the ASR (Hb) we see that under all conditions tested there is attenuation of wave energy. Wave heights in the lee of the reef are generally higher for the longer period waves, this is attributed to higher diffraction of the longer period waves. For all the scenarios tested the Boscombe ASR proves to dissipate wave energy and provide an ameliorated wave field shoreward of the structure. In terms of wave height, the ASR therefore fulfils the claim that the area leeward of the reef is safe for bathers; certainly it is no more dangerous at the nearshore than the rest of the beach area. Under no conditions are wave breaker heights leeward of the reef greater than the offshore wave height at the boundary.

6.5.2 Mode of shoreline change

To investigate the mode of shoreline change at the Boscombe ASR site and to extend understanding of the observation in Chapter 5, work by Ranasinghe et al. 2006; 2006 was compared with results from the Boscombe ASR. In this work, physical and numerical model simulation of a theoretical reef were examined to establish under what conditions the mode of shoreline response to a submerged structure might be accretive or erosive. They concluded that when a 2-celled circulation pattern was present divergent currents were created leading to erosion at the shoreline. When a 4-celled circulation pattern was present convergent currents were created leading to accretion at the shoreline (Figure 6.9).

To further explain the wave driven currents at the ASR, typical conditions for Boscombe (1 m wave height, 6 s period, angle of approach is shore normal, 173^o) are simulated at three different water levels (1 m, 0 m and -1 m) to reflect spring tidal conditions (Table 6.1). Additional manually placed directional arrows have been included to highlight the circulation pattern at the ASR. In lower water level (-1 m) conditions a 4-celled circulation pattern is apparent (Figure 6.12). With increased water level (0 m) the concentric secondary cells are lost and a 2-celled circulation pattern of divergent currents can be observed (Figure 6.10). When the water level is at -1 m and 0 m the crest of the ASR is emergent and the circulation pattern is enhanced compared to when the crest is submerged. Simulation of the water level at 1 m generates a weaker 2-celled circulation pattern of convergent currents and associated with accretion (Figure 6.11).

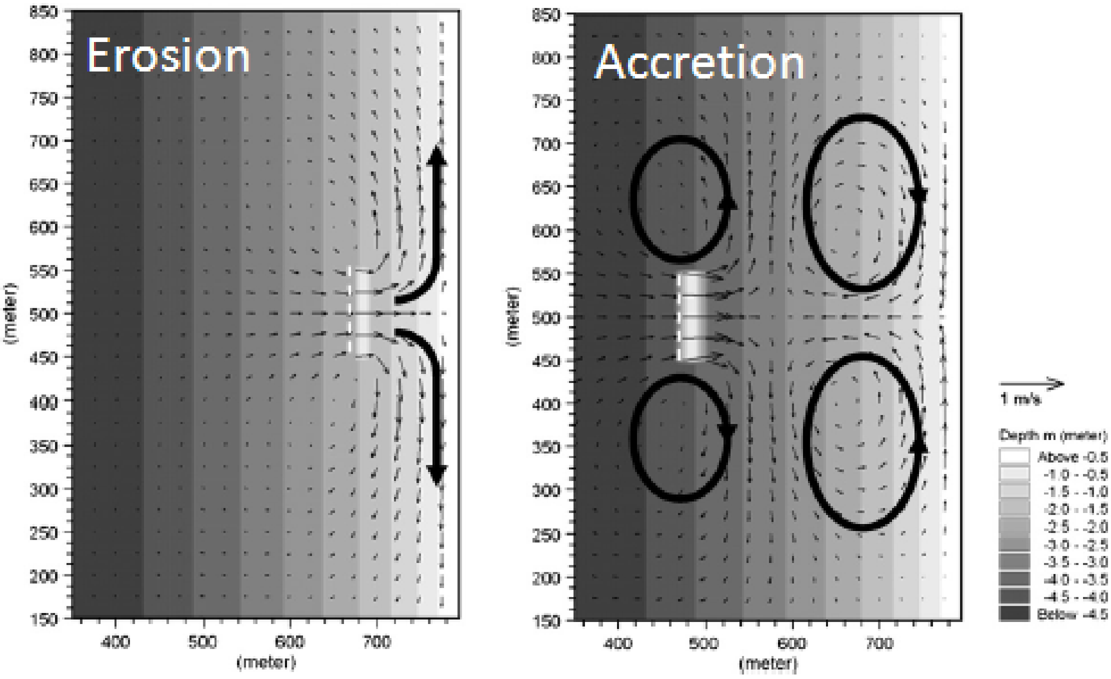

Figure (6.9). Example of submerged breakwater induced circulation patterns leading to: (a) shoreline erosion and (b) shoreline accretion, taken from Ranasinghe et al. (2010). The arrows indicate the general circulation patterns found through physical and modelling tests. The cross-shore distance from the shoreline to structure (Xb) and breaker height (Hb) effect the pattern of circulation; Ranasinghe et al. (2010) found that increasing Xb (from 100 m to 300 m) and Hb (from 2 m to 4 m) produced the 4-celled circulation pattern.

Simulation	Condition	Environmental description	Wave height	Wave period	Direction
2.	SW	Surf conditions, shore normal	0.25 m	6 s	173^o
3.	SW	Surf conditions, shore normal	0.5 m	6 s	173^o
4.	SW	Surf conditions, shore normal	0.5 m	10 s	173^o
5.	SW	Surf conditions, shore normal	1.0 m	6 s	173^o
6.	SW	Surf conditions, oblique	1.0 m	6 s	150^o
7.	SW	Surf conditions, oblique	1.0 m	6 s	200^o
8.	SW	Surf conditions, oblique	1.0 m	6 s	220^o

Table (6.1). These were run for the SW model: the current magnitude in the without ASR and with ASR scenarios illustrated in these figures

The model was also used to investigate the current patterns surrounding the ASR; of particular interest is the return of water mass around the reef and the potential for generation of rip currents. The resulting current speeds from averaging the model output over 12 hours of the tidal cycle (i.e. from low to high to low tide) are given for five wave heights typically experienced at the Boscombe ASR (Figure 6.13). This shows the effect of wave induced currents only and does not include the effect of tides. Little response at the shoreline is simulated however there are areas of divergence highlighted during the larger wave simulations near the structure. There is divergence in current direction when

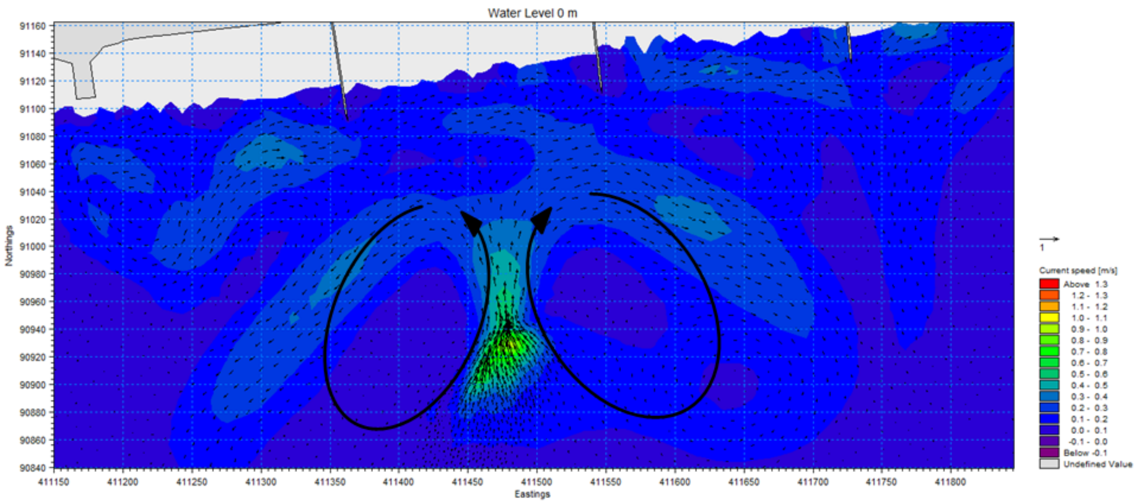

Figure (6.10). Mike 21 model output for 1 m wave height at 6 second period at various water levels with the change in circulation and velocity being dependent on crest height. Water level at 0 m. Heavy black arrows added to highlight circulation patterns.

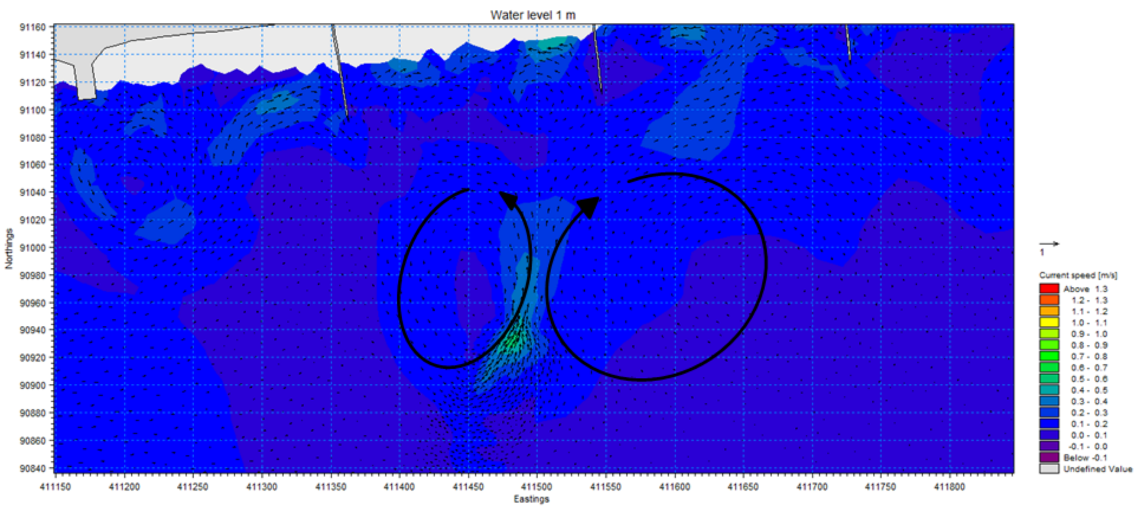

Figure (6.11). Mike 21 model output for 1 m wave height at 6 second period at various water levels with the change in circulation and velocity being dependent on crest height. Water level at 1 m. Heavy black arrows added to highlight circulation patterns.

Hs = 1 m and Hs = 0.75 m, indicated by the larger black arrows (Figure 6.13), highlighting areas of potential erosion. There is minimal divergence or convergence of currents and therefore no likely shoreline response when wave heights are simulated for 0.5 m, 0.25 m and 0.125 m. This is reflected in the observations in Chapter 5, that there is very little positive or negative migration of the shoreline in the leeward area of Boscombe ASR. Water velocity near the coast is typically >0.2 ms^{-1} during calm conditions. The set-up of gradients in wave height near the ASR cause increased water velocity over the reef, ranging from 0.2 ms^{-1} to 0.7 ms^{-1}. The results show no response to the wave currents under the smaller wave conditions of 0.125 m, 0.25 m and 0.5 m wave height. Although weak, divergent currents are highlighted in the 0.75 m and 1 m wave heights scenarios.

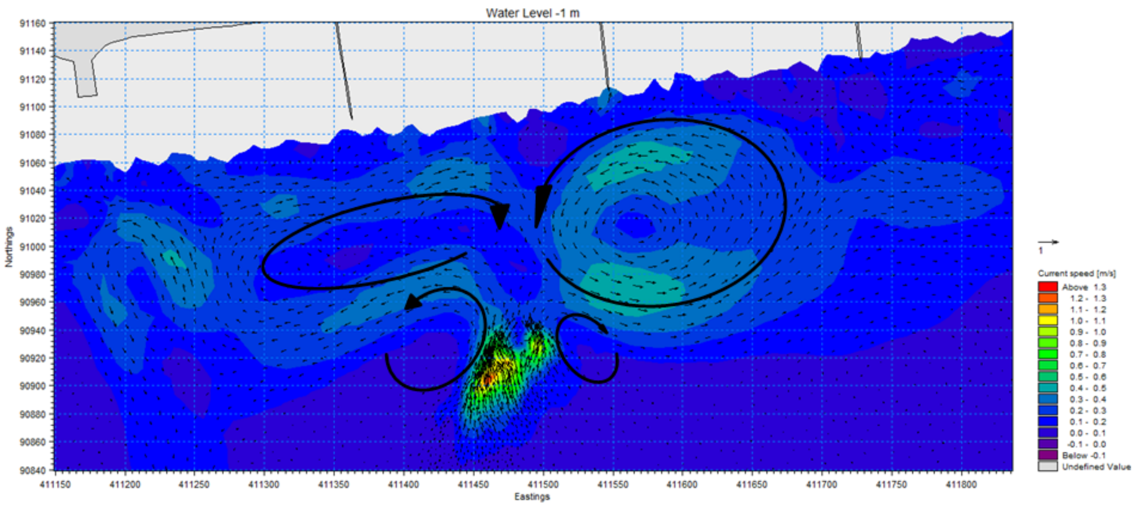

Figure (6.12). Mike 21 model output for 1 m wave height at 6 second period at various water levels with the change in circulation and velocity being dependent on crest height. Water level at -1 m (lower). Heavy black arrows added to highlight circulation patterns.

Given the small size of the reef and its distance offshore is far enough that any erosional effects are not observed at the shoreline or in the beach topography.

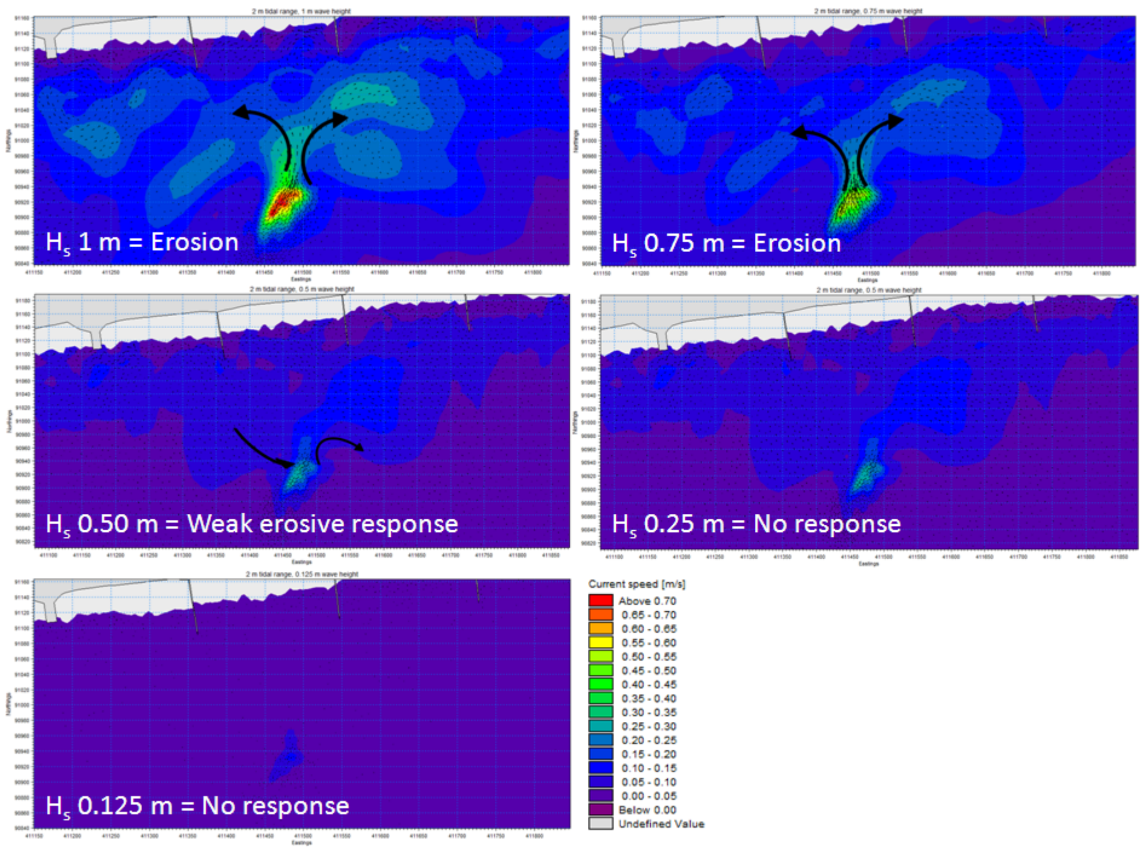

Figure (6.13). Wave induced model simulation averaged over 12 hour tidal cycle, for varying wave heights, from 1 m to 0.125 m.

6.5.3 Currents at the ASR

A key research question in this thesis relates directly to the safety of ASR construction at popular surfing and bathing beaches. The currents in the leeward area of any ASR should be considered carefully since the general public are being encouraged into the water. The Boscombe ASR is aimed at intermediate surfers and the leeward area is said to be sheltered and therefore safe. With a public beach any member of the public can engage with this structure. General tourism and surf tourism at all levels of sea experience and standard are being encouraged to visit the ASR and actively encouraged to enter the sea and try water sports. As with any coastal engineering structure, there is an inevitable risk to the public. The potential for the generation of rip currents, and the magnitude of the circulation were key objectives to investigate using the model. Therefore tidally driven currents are combined into the hydrodynamic model in order to understand potentially strong tidal currents or wave return flow (rip currents) at the ASR.

Similarly to the previous sections, coupled SW and HD simulations were run to investigate the impact of the constructed ASR on current and circulation at the reef due to the local tide and wave environment. There were two model bathymetry used, one with the ASR present and one without the ASR to highlight the impact of the ASR to the current field. There is a need to understand the local hydrodynamics at the reef from an engineering, design and construction perspective. Additionally, there is a social interest in the impact of the ASR on the current pattern and strength particularly for surfer and bather safety in the leeward and surrounding areas of the reef. A discussion on the wider social implications of the Boscombe ASR is provided in Chapters 7 and 8 where stakeholder opinion and perception of safety discussed in more detail. In this section, the magnitude and velocity of the currents at the ASR are investigated using the model set up in Table 6.2. The model was used to explore the effect on the current pattern surrounding the ASR as key environmental parameters are altered.

The results from the numerical model highlight that the presence of the ASR increases current velocity in the near-field area around structure, and the surrounding region (Figure 6.14). Increasing the wave height (0.25 m, 0.5 m and 1.0 m) also increased the current velocity and a circular pattern in the return flow can be observed (simulation 1-4). This figure illustrates current magnitude (ms^{-1}) and vectors due to wave driven current patterns, the same timestep at slack tide (when the tidal influence is minimal) is extracted for each scenario.

Simulation	Condition	Environmental description	Wave height	Wave period	Direction
1.	Tide only (HD)	Calm conditions	n/a	n/a	n/a
2.	HD and SW	Calm conditions	0.25 m	6 s	173^o
3.	HD and SW	Rough conditions	0.5 m	6 s	173^o
4.	HD and SW	Surf conditions	0.5 m	10 s	173^o
5.	HD and SW	Rough conditions	1.0 m	6 s	173^o
6.	HD and SW	Rough conditions, oblique	1.0 m	6 s	150^o
7.	HD and SW	Rough conditions, oblique	1.0 m	6 s	220^o
8.	HD and SW	Rough conditions, oblique	1.0 m	6 s	200^o

Table (6.2). The combinations of simulations to cover various scenarios of hydrodynamic and spectral wave conditions in order to investigate current magnitude at the ASR.

Similarly, the model is run (simulations 5-8) and compared to test the impact of wave direction (Figure 6.15), from wave angles of south-south-east (150^o), shore normal (173^o), south-southwest (200^o) and southwest (220^o). There are obvious changes to the current field, as the angle of wave approach moves east there is an increase in the circulation and a increase in the wave-driven longshore currents. The increase of wave angle in the westerly direction removes the occurrence of the circulation pattern in the locally generated wave-driven currents near the ASR and all current vectors become easterly in direction. This is important to note as the predominany tidally driven current at Boscombe is renown for being strong (west to east), with the addition of the ASR it does not appear to alter the current field on a regional level. There is an area of decreased current velocity between 100 m and 150 m offshore. This effect does not reach the shore however as the predominantly easterly natural currents are strong in the surfzone.

With the wave height fixed at 0.5 m but altering the boundary conditions to illustrate the relative short (6 s) and long (10 s) wave period conditions common to Boscombe. The output images are compared (Figure 6.16) but there is a lesser impact on the wave-driven current velocities due to wave period than was seen with the change in height and direction. Although this section of coast is exposed to longer period swell wave conditions it is infrequent, the nearshore shorter period tide-driven component of the spectra is more important to study at this site.

A combination of conditions were tested to understand the current pattern over a typical spring tidal cycle for simulations 1 to 8 as before, with and without the ASR in the bathymetry (Table 6.2). The resultant currents are a combination of the wave-driven longshore currents and tidal currents. Appendix A (Figures A1-A8) contain figures of the model outputs of current speed vectors (ms^{-1}) at a timestep that represents the peak

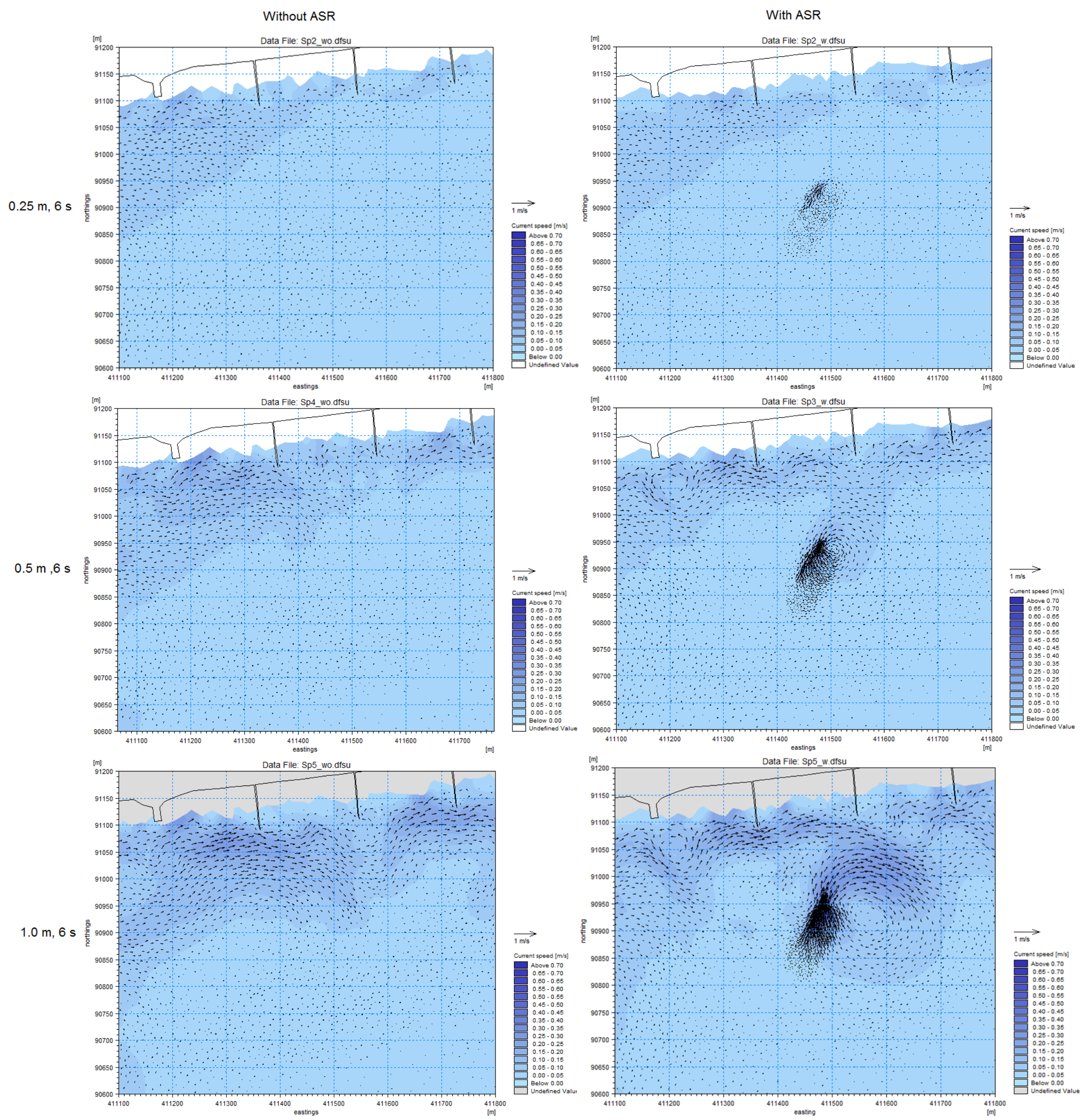

Figure (6.14). The current magnitude (ms^{-1}) and vectors on the slack tide to illustrate wave driven current patterns, the same timestep is extracted for each scenario image. Simulation results are shown for modelled scenarios without ASR (left column) and with ASR (right column) in the bathymetry, the three rows illustrate the impact on current with increasing modelled wave height and period of 6s (Top = 0.25 m, Middle = 0.5 m and Lower = 1.0 m).

ebb and flood conditions for each of the conditions simulated (in Table 6.2). With the absence of the ASR the current is generally higher, apart from the near-field region at the ASR. There is a reduction of current velocity in the leeward area of the ASR and down current, creating sheltered areas. It can be seen that during the simulations the current magnitude varies depending on the wave height (increased radiation stress) and the angle of incidence. The peak current speed (ms^{-1}) are seen in the flood and ebb of the tides, this is accurately represented by the model, with the ebb tide often producing the greater magnitudes.

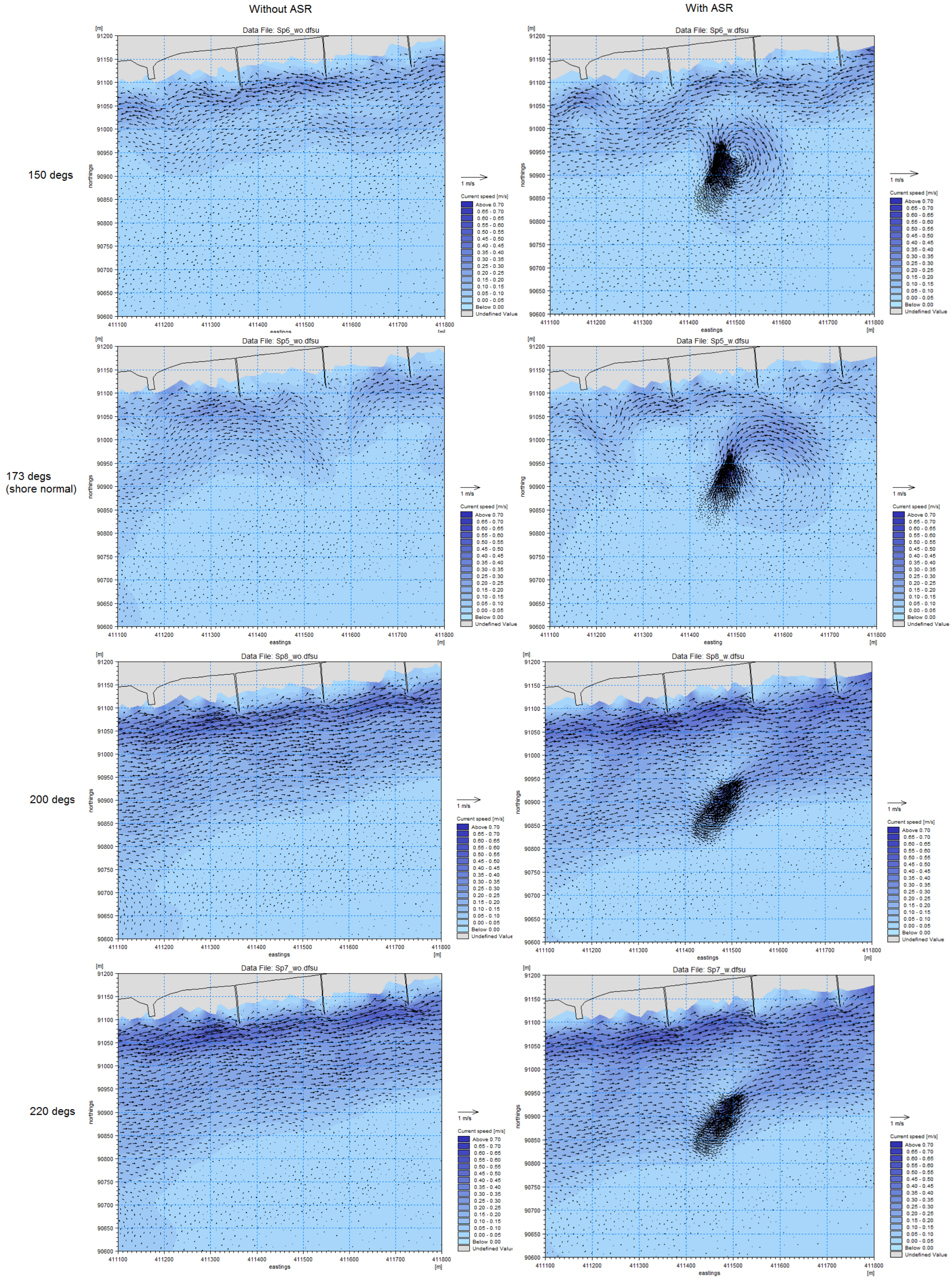

Figure (6.15). The current magnitude (ms^{-1}) and vectors on the slack tide to illustrate wave driven current patterns, the same timestep is extracted for each scenario image. Simulation results are shown for without ASR (left column) and with ASR (right column) in the bathymetry, the four rows illustrate the impact on currents with increasing modelled wave direction (Top = 150^o, Middle = 173^o (shore normal), Middle = 200^o and Lower = 220^o).

6.5.4 Change in current magnitude due to Boscombe ASR

In order to better highlight the change in current magnitude in the lee area of the ASR, a transect line was extracted from the current speed data spanning from the 0 m contour

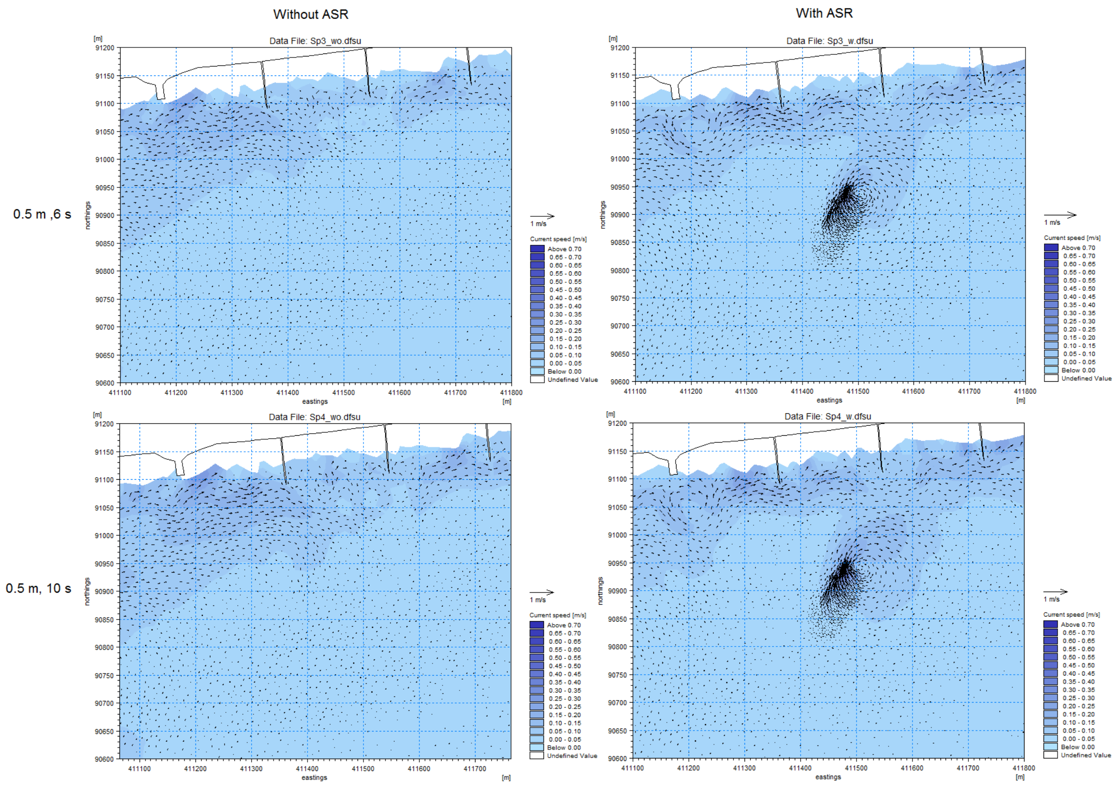

Figure (6.16). The current magnitude (ms^{-1}) and vectors on the slack tide to illustrate wave driven current patterns, the same timestep is extracted for each scenario image. Simulation results are shown for without ASR (left column) and with ASR (right column) in the bathymetry, the two rows illustrate the impact on currents with increasing modelled wave period (Top = 6 s and Lower = 10 s).

to 300 m offshore. The current values were extracted from the scenario 1 model results (for both the with ASR and without ASR results) every 25 m along this profile. Scenario 1 is the hydrodynamic model run with no wave input from the SW module in MIKE21, therefore simulating tidally driven currents only. The maximum values are used in the calculation of a current magnitude ratio; the ‘with ASR’ value divided by the maximum ‘without ASR’ value. These data are plotted on two axis in Figure 6.17.

With increasing distance offshore there is an observed increase in current magnitude in both the results as expected. In the lee area of the ASR there are very small deviations from the without ASR simulation that are in the region of 0.02 ms^{-1} and considered negligible. At the reef structure, around 150-250 m, there is a significant increase in current magnitude over the ASR as expected, the rise in bathymetry causes the an increase in current speed as the water circulates in this shallow area. Additionally, plotted is the current magnitude ratio across the transect, the maxium current in the with ASR results divided by the maxium current in the without ASR results. The ratio is greater than 1 when the with ASR simulated current speeds are greater than the without ASR simulated

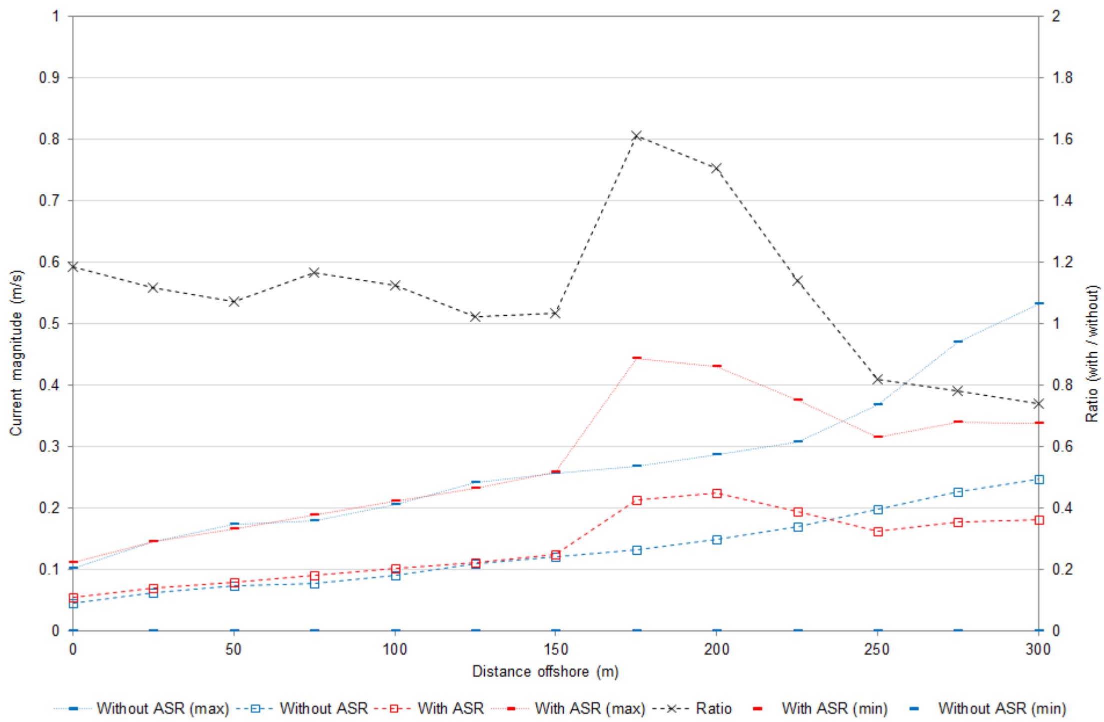

Figure (6.17). Simulation 1; HD run tidally driven currents only, no wave driven currents. The modelled current magnitude (ms^{-1}) without ASR and with ASR in the bathymetry with offshore distance, marked points at 25 m intervals. On the second axis, is the ratio of the modelled current magnitude with ASR, and the current without ASR as a function of offshore distance (black).

current speeds (ratio between 1.0 and 1.6), this is the case for the entire profile accept the last 50 m offshore of the ASR (drops to between 0.75 and 0.8). The reverse situation occurs at the seaward side of the ASR, where the influence of the ASR appears to reduce the current speed over the ramp in comparison with the without ASR situation. This illustrates that the ASR generally increased the tidally driven currents in the leeward area and over the ASR.

This ratio method was repeated for simulations 2, 5, 6 and 7 (Figure 6.18a-d). The effect of introducing wave driven currents in simulation 1 to the model does not significantly increase the currents experienced at the site (Figure 6.18a) due to the small wave condition (Hs 0.25 m, Tp 6 s). However, the same pattern is held across the simulated scenarios, the currents peak over the ASR and this is evident in all simulation profiles. The ratio in current magnitude between the with ASR and without ASR is significantly increased over the ASR in Figure 6.18b, there is greater disparity between the simulations and therefore the ratio ranges from 1 to 2. However, the ratio in the leeward section is consistently below 1 (ratio range from 0.5 to 0.95) highlighting the ameliorating effect of the reef in the larger wave conditions. This illustrates that the influence of the ASR gen-

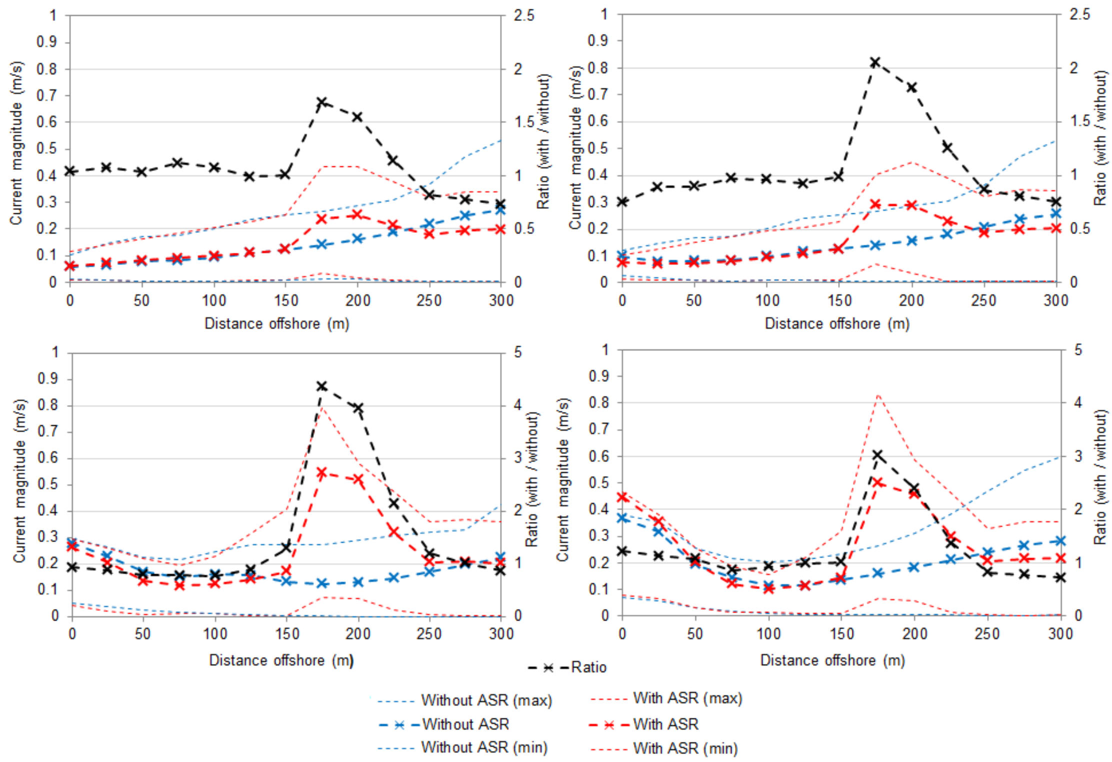

Figure (6.18). HD and SW tide and wave driven currents for: a) sim 2; 0.25 m, 6 s, 173^o, b) sim 5; 1 m, 6 s, 173^o, c) sim 6; 1 m, 6 s, 150^o, and d) sim 7; 1 m, 6 s, 220^o. Axis X offshore distance, at 25 m intervals. Axis Y1, the modelled current magnitude (ms^{-1}) without ASR (blue) and with ASR (red). Axis Y2, is the ratio of the modelled current magnitude (ms^{-1}) with ASR over without ASR, as a function of offshore distance (black).

erally decreases the wave driven currents in the leeward area but significantly increases currents over the ASR and in the very localised area.

Altering the angle of wave approach into the model domain caused there to be little effect in the leeward section of the ASR, in both easterly and westerly simulations the ratio of the wave approach fluctuates around 1 (Figure 6.18c and d). The greatest disparity in simulated current speed over the ASR occurs in the southwest simulation where they reached 0.5 ms^{-1} and the ratio peaks at 4.2 at 175 m offshore. There influence of the ASR does not offer shelter or amelioration in the leeward section of the ASR. There is an increase in the current speed ratio at the shoreline to 1.2 in the east driven waves (Figure 6.18d) where the nearshore region experiences increased currents to 0.45ms^{-1}.

When the ration of current speed are plotted as a function of wave height or direction it enables the various sections of the transect to be visualised and compared (Figure 6.19). In the bathing water area, as the wave height is increased from 0 m to 0.25 m there is a marked decrease in the ratio to around 1. Some shelter is provided by the ASR in calm conditions but with increasing wave height similar current speeds are observed in both the with and without ASR simulations. The wave direction change from east to west

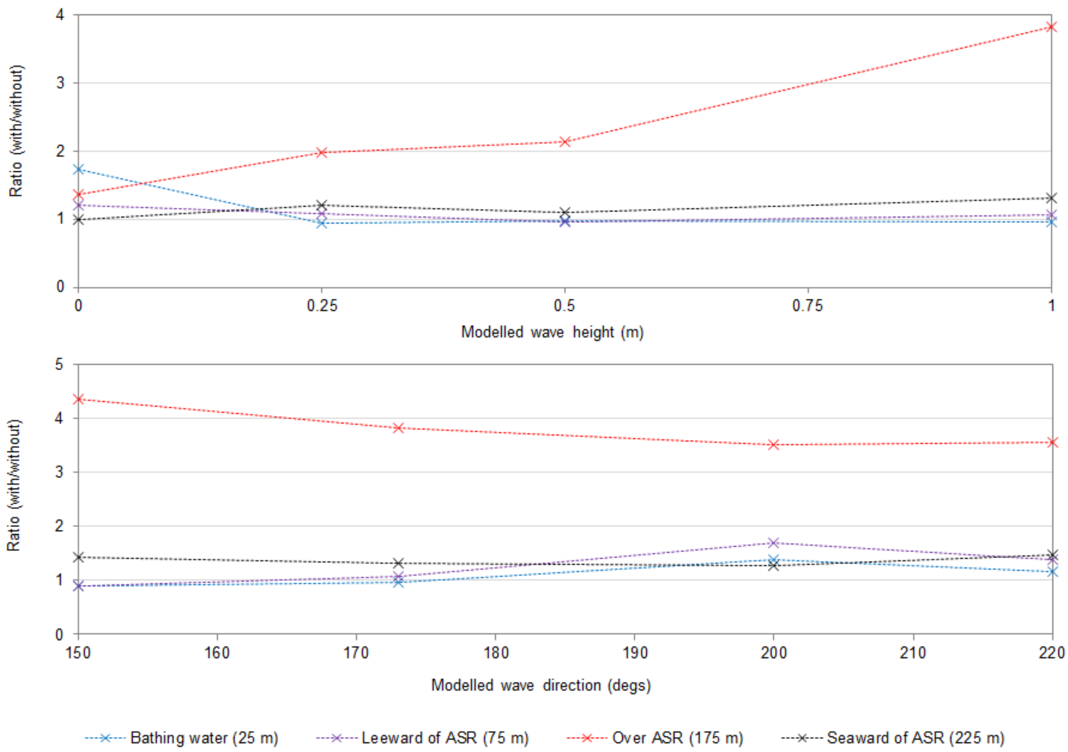

Figure (6.19). The ratio of current magnitude (ms^{-1}) with and without ASR is show here as a function of a) modelled wave height (m), and b) modelled wave direction (degrees) in four locations; in the shallow bathing water (25 m), leeward of the ASR where swimming is expected (75 m), over the ASR where surfing is expected (175 m), and seaward of the ASR where surfers are expected to line-up before surfing the waves (225 m).

increases the ratio from an ameliorating current speed situation for the east and shore parallel simulations through to enhancing the current speeds by the addition of the ASR in the 200^o and 220^o simulations.

The leeward area at 75 m, offshore of the typical bathing water but in an area novice surfers and paddler might be encouraged to swim out to with reduced current speeds. The ratio is generally higher than 1 showing that the ASR increases the currents in the area closer to the structure. This is a small but significant amount and is the probable cause of the localised scour at the foot of the structure, as described in Chapter 5. In the leeward area at 75 m, a similar pattern for the wave direction is observed as with the bathing water area but with a higher ratio; the current speed ratio is less than 1 in the east, but for the shore parallel and westerly wave directions there is an increase in the ratio.

The ratio of current speed with increasing wave height are further investigated as a function of tidal elevation at one point at 25 m offshore, in the bathing water area. To explain this three of the model scenarios are presented; scenario 2 (0.25 m waves, 6 s, 173^o), scenario 3 (0.5 m waves, 6 s, 173^o) and scenario 5 (1 m waves, 6 s, 173^o) in Figure 6.20. The three scenarios have second order polynomial relationships fitted to highlight

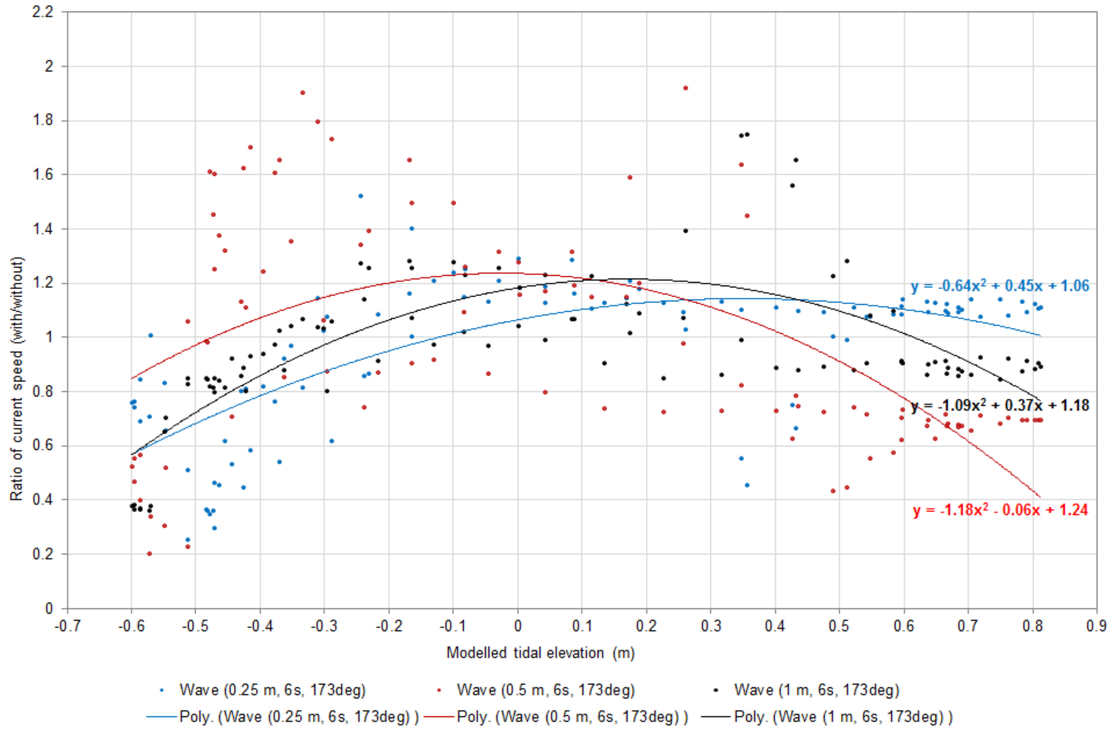

Figure (6.20). Scatter data of the ratio between the modelled current magnitudes (ms^{-1}) in the 'without ASR' model and 'with ASR' model, as a function of tidal elevation (m). A second order polynomial curve relationship is fitted to describe the general trends in the data.

the curved trend in these datasets.

Generally, all the low tide ratios are <1 and shows that the ASR is providing shelter at 25 m offshore. The 0.25 m wave height pass over the ASR without breaking after -0.2 m waterlevel and therefore there is little amelioration in the wave height. The wave remains unbroken until the shoreline. The 1 m wave height is broken over the ASR in shallow waterlevel conditions, however there is a marked increase in the ratio when waterlevels are between -0.4 m and 0.2 m as most ratio are >1, with higher waterlevels (>0.2 m) the ratio falls to <1 and the ASR is providing shelter to the bathing water area. The 0.25 m and 1.0 m curves are similar in shape, however the 0.5 m curve differs there is greater disparity between the with ASR and without ASR current data and therefore the ratio is greater. In this simulation the 0.5 m wave is creating more current in this specific area, the wave energy is being focused after the ASR as it is able to pass over it unbroken in water level >-0.5 m. The curve in the data is quicker to fall off with the increasing tide and this effect is reduced to <1 at around water level 0.3 m, after which there is enough water depth for the 0.5 m wave to pass over the ASR and travel to the shoreline before breaking.

6.6 Discussion

This chapter utilises a numerical model to investigate the impact of an artificial surfing reef on nearshore hydrodynamics. A particular focus was on the impact the ASR has on local hydrodynamics and the potential for rip current generation in the vicinity of the ASR. The understanding of current patterns is essential to management of risk at the coastline, both in terms of coastal protection and for the public safety, particularly water users. It is necessary for managers, coastguard and RNLI lifesavers to have full information about the potential for the structure to form rip currents, narrow strong currents that move seaward in the surfzone (Shepard and Inman, 1950; Bowen, 1969; MacMahan et al., 2006; Mendonca et al., 2012) under certain environmental conditions.

The numerical model MIKE21 performed well under the set-up conditions described, it is a well known commercial model that has been shown to perform well in a variety of situations, and the flexible mesh suits the nearshore coastal environment. The calibration with the measured pressure transducer data shows that the MIKE21 SW module to be replicating the wave transformation well. The wave heights and currents investigated in this study were of appropriate magnitude and the patterns were represented well when compared to the literature. Limitations to the model were the depth limited element, as the circulation could be further investigated with a 3D model although beyond the work for this study it would be an interesting investigation for future ASRs design and planning.

6.6.1 Impact to wave climate

The results presented are consistent with the physical and numerical model work by Ranasinghe et al. (2010) where they illustrate 2- to 4-celled circulation patterns occurring around submerged breakwaters (Figure 6.9) with varying wave height and increasing distance offshore. Modelling the water level at its highest extent shows that the 2-celled pattern is weakest in velocity at the high tide. The velocities are weakened in the higher water level (1 mODN) scenario compared to the relatively stronger velocities in low (-1 mODN) water level scenario. The results of the simulations of Boscombe ASR reflect observations in the literature and, although weak due to the limited local wave climate, reveal this circulation pattern acting at Boscombe nearshore coastal environment.

The presence of a gyre at the location of the erosion near the foot of the structure, the location of the gyre coinsides with the steepening of the bathymetry leeward of the ASR (as described in Chapter 4). The groynes on Boscombe beach could enhance this offshore movement of water during stormy weather and cause further erosion at the structure. The failure of the ASR in Kovalam, India was attributed to return flow and an associated rip current undermining or scouring the base of the structure (verbal communication with the local project construction team). The design did not take into consideration the volume of water overtopping the ASR and onto the beach during monsoon conditions. The Boscombe ASR is further offshore and is not exposed to the same extreme environments conditions, however it is necessary that during rare storm events are considered, and set-up and return flow (rip currents) are accurately calculated for the design.

The ASR is successful in ameliorating the mean wave height for bathers at lower tides, however during high tide conditions the mean wave height can pass over the structure unbroken. In larger energy events, the ASR will provide breaking and therefore ameliorates the wave energy in the leeward area of the ASR. Johnson (2006) provides a simple relationship that can be used in wave models for modelling wave transmission and wave energy decay over submerged breakwaters. They highlight various studies e.g. Seabook and Hall (1998) who show that the transmission coefficient over a submerged breakwater depends primarily on the relative freeboard (or relative submergence) and secondarily on other parameters. This is consistent with the parameter Johnson studied, γ_2 (Gamma2), which is used in the wave breaking description of numerical wave models for submerged breakwaters, which is dependent on the relative submergence.

6.6.2 Impact to hydrodynamics and scour effects

Dean (1997) found that a detached breakwater modifies both wave and curent fields landward of the breakwater, with the modificaltions depending substantially on the creast elevation relative to still water level. With higher relatvive crest elevations (emergent breakwaters), such as the Boscombe ASR at low tide, wave heights and currents in the breakwater lee are both reduced. Dean (1997) goes on to describe how the reduction in wave height was not sufficient to offset the increased sediment transporting capacity of the currents, resulting in scour landward of the breakwater. A similar effect is occuring with the Boscombe ASR, although the wave height is reduced in the leeward area the increased currents that are associated with an increased surface elevation where water cannot readily return offshore and is forced around the ASR exposing a clay seabed. Other non-ASR effects on the dissipation of energy around a reef stucture are wave breaking, bottom friction and wave-wave interaction (Dean et al., 1997). With an increased surface elevation in the leeward area of the ASR as the driving force behind much of the increased current and therefore scour at the toe of the structure as sediment is entrained and carried away from the site. As the structure is a suitable distance offshore, the scouring of the seabed is observed only locally and not at the shoreline (as observed in Chapter 4).

Due to the presence of the reef no return flow near the bottom can compensate for the water masses accumulated behind the reef due to wave set up. The return flow is hampered by the incoming waves, enhanced longshore currents and tidal effect could therefore evolve with an associated erosion potential. Dean's (1997) research concluded with this recommendation: comprehensive designs must consider the full range of hydrodynamic and breakwater parameters, and sedimentary effects and must be based on an understanding of mechanisms that are not fully understood at present. The same advice is highly recommended today as the few studies that have been carried out still have not fully quantified all the effects of hydrodynamics at low crested breakwaters and reefs.

> "When a structure is placed in a marine environment, the presence of the structure will change the flow pattern in its immediate neighbourhood, resulting in one or more of the following phenomena: the contraction of flow, the formation of a horseshoe vortex infront of the structure; the formation of lee-wake vortices (with aor without vortex shedding) behind the structure; the generation of turbulence; the occurence of refraction and diffraction of waves; the occurence of wave breaking; and the pressure differentials in the soil that may produce "quick" condition/liquiefaction allowing material to be carried off by currents. These changes usually cause an increase in the local sediment transport capacity and thus lead to scour " (Sumer et al., 2001)

Ranasinghe and Turner (2006) gave a comprehansive review of the state of art in submerged construction stating that many submerged structures resulted in shoreline erosion on their lee-side (Cceres et al., 2010). The traditional formulation for predicting shoreline behaviour after the construction of a submerged breakwater is based mainly on the physical dimensions of the structure, as Black and Andrews (2001) paper discussed the length and distance from the shoreline, others such as Pilarczyk (2003), also take into consideration the wave transmission coefficient (Cceres et al., 2010). These models are limited due to the number of different parameters needed to calculate the sediment transport behaviour induced by a structure, up to 14 (Hanson and Kraus, 1990; Cceres et al., 2010). Overtopping of the ASR is the dominant process that is driving currents. As Zanuttigh

(Zanuttigh and Martinelli, 2008) discusses that energy transmission due to overtopping is highly non-linear and shows energy peaks at super-harmonics induced by the impulsive overtopping volumes hitting the water body in the lee of the structure. This impulse force drives the currents in the leeward section, as seen in the model results presented for Boscombe ASR.

In the DELOS project, to investigate the use of low crested structures (LCSs) in combination with beach nourishment schemes, Lamberti (2005). DELOS describes how when planning semi-submerged low crested structures (in this case an array as opposed to the ASR) maintainence should be planned for the vulnerable parts, such as gaps and roundheads, where strong currents are responsible for erosion. The project authors note that the deeply submerged LCSs have little impact on the coastline where as emergent LCSs show the formation of satients and tombolos, depending on the distance from the shoreline. Of particular note is a reference to Elmer, UK where Lamberti (2005) describe how the tidal currents control the salient development and the overall performance of the scheme. There is much similarity with these results and the Boscombe ASR observations and model results, the lack of salient development or beach widening as hoped during the design and planning stages could be due to accelerated tidal currents that suspends sediment and moves it to areas away from the lee area. The controlling or limiting factor in salient growth will be the strength of the current, whether tidal during ebb and flood conditions, or wave driven currents during the mid- to high tide when waves are breaking on or near the reef. This is reflected in Lamberti (2005) where they report that there are two significantly different hydrodynamic conditions in the incidence wave energy. Under low wave energy the tidal currents are dominant, however flow reversal appears under higher energy conditions (Pope, 1997).

Scour in coastal engineering has not received the same attention as fluvial scour around bridge piers, for example. More focus on the scour around marine structures due to waves has been made in the review papers by Sumer and Fredsoe (1999; 2001). The effect of waves and wave-induced current running along the face of a rubble-mound seawall Al Sooyung on the Korean coast has been studied using numerical models, Kim et al. (1998) show that both reflected waves and compression of streamlines play an important role in scour processes (Sumer et al., 2001). The resulting current fluxes show two important features (confirmed by experimental results): a) a gyre in front of the structure which is the “degenerated” version of the twin recirculation cells in front of a fully reflective structure (associated witto the standing wave), and b) a significant (and therefore nonnegligible) mass flus through the permeable structure (depending, of course, on porosity) (Sumer et al., 2001). The tools and models suggested in the literature, for example Sumer (2001), can be used to provide guidance for design purposes on the scour development at this type of structure on a sand bed. There use of wave models for solving wave motion, flow through the structure, and circulation currents in front of the breakwater, provides a tool for extending the laboratory results to different wave conditions and bed profiles.

6.6.3 Surfability

Wave-current interaction can negatively effect the surfability as waves break prematurely due to underlying currents. Caceres (2010) suggests the use of a channel through the main structure that allows the rip current to pass offshore and therefore reduce the impact of wave-current interaction, greatly improving the surfability when compared to a solid reef structure in laboratory tests. This channel could be designed to enhance the surfer experience as it is reflective of a natural reef situation, whilst allowing the surfer to pass offshore more easily. As Mendonca (2012) points out, currents at a reef are of vital consideration for the surfability of the breaking waves as they can negatively affect the wave stability. Whilst rip currents are used by surfers to move offshore in calm areas between breaking waves over sandbars on natural beaches, they can also remove energy from the wave thereby shortening the ride length. Wave breaking occurs due to the turbulence at the rip current. Henriquez (2004) observed in an experimental laboratory model that approximately 20% of the wave ride was negatively affected by the rip currents driven by wave breaking over the reef. With the rip current flowing seaward, waves are breaking further offshore and intern there is a reduction in peel angles, potentially too low for surfing (van Ettinger, 2005; Mendonca et al., 2012). During larger wave conditions these effects will be enhanced as more water overtopping and greater return flows occur. Therefore, when designing an ASR consideration must be given to the risk of rip currents from both a beach safety and surfing amenity perspective. Similarly to Mendonca (2012), for cases where there is a normal angle of approach there is stable wave breaking and little wave-current interaction, when waves approach at an angle the incoming wave meets the return flow rip current and effect the breaking significantly by making the waves steeper and breaking in an unstable way.

6.6.4 Implications for public safety

The ASR is more hazardous from the currents generated near the structure, however it is unlikely that novice surfers or bathers will venture 150 m offshore to this area. There is a chance that the rip currents at Boscombe associated with the groynes and ASR could move water users offshore. The currents have been shown by the research in this chapter to be greater than 0.5 ms^{-1} in some modelled scenarios. Average rip currents flow speeds are typically between 1 and 2 mph (0.45-0.89 m/s), but they fluctuate over time, and can exceed 4 mph (1.79 m/s) during pulses. The RNLI (2013) state that 21% of all rip incidents between 2006-2011 were involving topographic rips (2629 incidents), either geological or man-made; that rips with physical obsructions are likely to be a major factor in coastal drowning.

Rip currents are responsible for 67% of all individuals rescued by lifeguards on UK beaches, representing the greatest environmental risk to water users; 66% of all rip incidents were male (Woodward 2013). Approximately 100 people die from drowning associated with rip currents each year in the United States, and 80% of surf rescues in the USA are as a result of rip currents; 89% are male (Gensini and Ashley 2010). Klein et al. (2003) found that 90% of beach rescues in southern Brazil were associated with rip currents and 64% of victims were men. Since 1949 when recordings begun, it is estimated that Australian lifesavers have rescued 300,000 people from the New South Wales surf, 90% of those rescues were associated with rip currents (Short, 2007). In all studies, there is a notable gender difference in rip current victim data. Woodward et al (2013) report teenagers (aged 13-17 years) to be the most likely demographic to be involved in a rip current incident. This research into lifeguard incident data from 2006-2011 highlights the activities most commonly associated with rip current are bodyboarding at 53% (n.3065), swimming (26%, n.1483), and surfing (20%, n.1172). Lifeguards record equipment hazards associated with incidents; inexperience accounts for 57% of all incidents (35% not recorded) with a breakdown of 32% of all bodyboarding incidents, 14% of surfing incidents and 11% of swimming incidents. Experience will dramatically affect the response of a water-user to the rip current, enabling informed decision making, reducing panic and saving energy (RNLI, 2013).

Data from the literature and online sources are combined with the likely swim or paddel ability of various users in Table 6.3 in order to understand the implications of the flows discussed in this research. Additionally, the safety considerations for each user group is

Different users	Mean velocity estimates (ms^{-1})	References	Safety considerations
Paddeller and bather	0.45	Average human swim speed	Likely to stay in the shallows and not venture out in large wave events. Consideration for hidden rip current at low tide and panic if they loose the bottom (bar-trough morphology). ASR marketed as a safe and sheltered area, there will be increased bathers in the lee area.
Distance swimmer	1.83	400m world freestyle record (2013)	Rip currents fluctuate overtime and can exceed 2 ms^{-1}; even elite swimmers would have difficulty. Unlikely to be in the lee area.
Bodyboarder (BB)	1 to 4	Estimated using speeds needed to paddle into waves and take-off speeds, short bursts only.	Learning to catch waves is easier on a BB than on a surfboard, but the paddling is much harder due to the shape of the BB and only short bursts are possible. The fins worn in this sport are short and paddling is also required. BB are more buoyant with less power therefore more likely to be caught out by rip currents. Most appreciative of the Boscombe ASR construction.
Surfer (Longboard)	1 to 4	Estimated using speeds needed to paddle into waves and take-off speeds, short bursts only.	Beginner to intermediate surfers, more likely to be inexperienced in the water. Tthe board as a boyancy device but are liable to unleash the board in favour of swimming (due to inexperience). Not as interested in the ASR construction.
Surfer (Short board)	4 to 8 (Tube wave 8+)	Estimated using speeds needed to paddle into waves and take-off speeds, short bursts only.	Likely to be more experienced water users that have progressed to short board surfing. However, teenagers are likely to be in this category due to being light and needing less board volume; poor judgement and inexperience in this demographic. Interested in the Boscombe ASR, this is the main market group.
Stand-up Paddle-boarder (SUP)	1.50-4.25	Based on race statistics	Less likely to be interested in the ASR from a surfing perspective. The SUP rider is high and more likely to see the rip, if experienced, and has more over all power to avoid this danger.
SCUBA diver and Snorkeller	Up to 0.5	Based on SCUBA websites	Currents can accelerate air use and exhaust the diver. A half knot current speed (0.5 ms^{-1}) could dislodge a mask and cause confusion. Down or up currents should be carefully considered before encouraging diving at an ASR.

Table (6.3). The safety considerations of different types of beach and ASR user. This table was compiled from sport websites and scientific research including; DRIBS project by Plymouth University and the RNLI (2013), Scott (2009), Woodward et al (2013) and Sandwell (2015).

commented on in the table. Encouraging novice and beginner surfers into the same area as bathers and children will create increased crowding in one area and increase the lifeguard incident statistics, as introduced in Chapter 4. As the results from Woodward et al (2013) highlight, youth and inexperience in open water are major factors for incidents associated with rip currents. Additionally, the type of boardsport will account for additional dangers. Houser (2015) discusses how surf and rip currents pose the greatest hazard to those at the beach (i.e., under high-energy conditions), there is not necessarily an increase in submersions since fewer people choose or are allowed by lifeguards to enter the water. The greatest hazard to beach users may occur under perceived nonthreatening or moderately threatening conditions when more enter the water with greater confidence.These issues should be carefully considered in the design and marketing of future ASRs, with particular attention given to rip currents in mid-energy conditions and storms conditions in summer months. Particle tracting can be an effective method in numerical models to simulate a floating object in the rip, the velocity of the particle can be related to novice water users.

The implications for swimmer and novice surfer safety will be further discussed in Chapter 7 where direct users of the Boscombe ASR are questioned regarding their experiences and opinions. When designing future ASRs, warning signs should be designed to reflect the real dangers of the reef and education aimed at teenagers and young adults. Providing the public with as much information as possible about the currents in the lee area and closer to the structure. In terms of wave height, observations and simulations indicate ameliorated wave field leeward of the ASR, supporting the claim that the reef does provide a sheltered zone for swimmers and bathers. However, the ASR is enhancing the mean offshore flow in the area.

6.7 Conclusions

The numerical modelling presented highlights divergent and convergent current cells within the hydrodynamic model results, whilst these divergent currents illustrate only the potential for erosion we are able to understand the cause for the scour at the toe and lack of change at the visible shoreline. The Boscombe ASR is a suitable distance from the shoreline to avoid either erosion or accretion impacts that may be inferred from these current fluxes. The physical processes surrounding semi-submerged geotextile structures depend on the dimensions and distance from the shoreline, this will determine their interaction with hydrodynamic and morphodymic fluxes.

Through the use of the numerical model a better understanding of the hydrodynamic current circulation patterns at Boscombe ASR. In terms of wave height, observations and simulations indicate an ameliorated wave field leeward of the ASR, supporting the claim that the reef does provide a sheltered zone for swimmers and bathers. The pre- and post-construction simulations highlight changes to the rip currents associated with the groynes and ASR, this is a safety concern for bathers and inexperienced surfers. The nearshore hydrodynamics are altered by the ASR, this is more prevalent at certain tidal states (flood and ebbing tide) and with wave heights greater than 0.25m, and therefore consideration should be given to return flow (rip currents). Better understanding of the ASR and the potential safety implications to the public (both for surfers and bathers) under a variety of environmental conditions are highlighted.

The following two chapters introduce the socio-perception studies in this research, the first of these chapters follows and studies the direct users of the Boscombe ASR through interviews within the surf community, the second studies the indirect users, the stakeholders and coastal community. The demographics of the groups are presented and discussed alongside their perceptions and opinions towards the Boscombe ASR.

Chapter 7

The surf community evaluation of Boscombe ASR

Figure (7.1). Surfing at Boscombe ASR, UK

7.1 Introduction

The Boscombe ASR sole target audience was surfers, the direct users. It is inherently important to understand whether the surfers are benefiting from the reefs construction. The perception and opinion of the UK surf community to ASR projects is essential to capture. There was a limited stakeholder consultation process in the original feasibility design stages but the surfing community are a vocal group in the media. Limited data exists concerning expenditure of surfing related tourism in UK. Most surfers internationally are not associated with an organisation. Research recording seafront visitors (to be further discussed in Chapter 8) found that surfers are attracted by local environmental conditions or surfing events. These results indicated that a more detailed investigation into UK surfer opinions and perceptions of ASR technology was required to determine the need for surfing reefs as a tourism attraction.

Surfers Against Sewage (SAS) were unable to provide official statistics of their membership numbers over time due to the resources needed to process the data, however they provided this statement: “We have approximately 7,000 members currently, it wouldn’t have been too far off that in 2010 (maybe 6,000). I’d imagine the 600,000 figure is the number of surfers in the UK, not SAS members” (Cummins, 2013). The last sentence is in response to a question regarding the number of SAS members after reading an article that stated that “SAS represents 600,000 UK water users” (Siegle, 2010). In this same article, Tagholm (one of the founders of SAS) states that “In effect we represent hundreds of thousands of leisure water users, and many different people surf including doctors and lawyers. They don’t necessarily drive VW vans, and they’re all over the country” (Siegle, 2010). As an example of the number of interested parties, the surfers against sewage POW (Protect Our Waves) campaign generated 10,000 signatures to highlight the value of surfing. The total number of UK adults participating in surfing in 2008 has been estimated by Royal Yachting Association (RYA) to be 500,000 (Arkenford, 2012). The SAS, RYA and Surfing GB all agree on a similar estimate of the number of surfers currently participating in the sport in the UK, approximately 500,000 in 2013.

As shown in Chapter 4, the Seafront Ranger data highlights that the regeneration and ASR construction of Boscombe has seen surfing in the local area increase from 29,164 surfers in 2008 (pre-ASR) to 32,310 surfers in 2009 (post-ASR). These records have not been made available after 2009 due to political reasons and the structural failures. It has to be noted that surfing at Boscombe is more popular since the regeneration of the seafront and addition of the ASR, surfing is taking place predominantly at the beach break however, not on the ASR. At Boscombe alone there were 16,619 surfers at the beach break compared to 808 surfing the ASR in 2009 before the damage to the ASR was discovered; the data shows an order of magnitude in popularity of the surf spot.

SAS identified a need for better economic information about surfing within the UK, both nationally and regionally (Surfers Against Sewage, 2013b). The organisation campaign for local authorities to acknowledge that ocean waves have an inherent natural capital value; they are vital in transporting energy around the planet and dramatically influence our coastal processes (Surfers Against Sewage, 2013a). Essentially surf breaks have a high intrinsic value among water sports communities. In 2001, a study estimated the value of surfing to Cornwall at £64 million per annum (Cornwall Enterprise, 2001). According to the survey surfers spend 8.5% more per head than other visitors in Cornwall (Cornwall Enterprise, 2001). Ove Arup Ltd. (2001) predicted the annual expenditure is £830 per person per annum if you include visiting costs. The British Surfing Association (BSA) found that on average members spent £831 on surfing holidays (based on 72% of the BSA members who took a surfing holiday in 1997, of which 40% stayed in Britain). Trisurf (2008) estimated the value of surfing for the North Devon region at £54m per annum. Globally there have been economic studies for world renowned surfing waves that are the location for big wave surfing and international competitions. For example, a report on Trestles, California by Surfrider International found that the wave had an economic impact of $4.2 m (Nelson, 2007), Maverick's in Half Moon Bay, California concludes nearly US$24 m is generated per year due to 420,000 visitors per year (Save The Waves Coalition, 2009), and Mundaka, Spain has an estimated positive economic impact of up to $4.5 m per year to the local economy through direct income and the creation of 95 jobs (Murphy and Bernal, 2008).

The aim of this chapter is to evaluate the benefits and burdens of ASR construction to surfers from a social, economic and environmental perspective using social perception analysis. To understand why surfers are choosing to surf the beach break over the ASR, and their experience of surfing the ASR. In this chapter the perceptions and opinions of the direct users of ASRs are evaluated with regard to the perceived success of the Boscombe ASR project and impacts for the surfing community. The objectives are:

- To provide a comparative study of the social demographics of the UK surf respondents with other previous studies.
- Analyse the opinions of the surf community in Boscombe regarding the ASR.
- Provide a thematic framework of the benefits and burdens of the ASR at Boscombe.

The data collection method is described and three distinct sections describe the results; firstly, the demographics of the respondents of the surf community are provided in a comparative study, secondly, the opinions of the surf community about the reef as a surfing break are presented and finally, a thematic review of the perceptions of the Boscombe ASR, and ASR technology is provided. A discussion of the results with recommendations to the future use of ASR technology is provided in the conclusions.

7.2 Methods

7.2.1 Data Collection

To understand the socio-demographics of the surfing community in the UK and to capture the opinions of surfers regarding ASRs, the UK surf community were invited to complete an online questionnaire (Appendix B; The UK waverider survey). The survey was available for two months online and attached to two social network websites (Facebook and Twitter) and a surf prediction website (www.magicseaweed.com), alongside email to share the questionnaire around the surfing community. The questionnaire was designed to understand the demographics of the surf community in the UK as this is the main market for the project, as well as the reaction to the ASR concept.

The UK Waverider Survey was initially advertised on 30th January 2012 and further promoted throughout the first weeks. In a short article respondents were invited to participate in the survey by following a link to an on-line google document. The data collected represents surfers from the UK. The online survey remained active for 56 days. Further advertisement of the survey was stopped after an initial examination of the results showed repetitive responses and no new comments were being made. It also became apparent in this initial review of the responses that there was an element of survey fatigue regarding the ASR. Bournemouth and Southampton University and school students were using the ASR as a case study for questionnaire design and analysis in various geography and sports courses, alongside various dissertations and thesis. Although these data were captured and reported on, they remain unpublished.

7.2.2 Comparative study

To meet objective 1, a comparative study of socio-demographic statistics of surfers and waveriders calculated by two independent studies is provided with the addition of the research collected in this study; one from the Gold Coast, Australia (Lazarow and Nelsen, 2007) and the other from California, USA (Nelson, 2007). A table was created to compare of the demographics of the surf community in the UK against those in the US and Australia, where the emphasis on surf tourism is generally more advanced.

7.2.3 Analysis of surfer opinions

In the analysis of the opinions and perceptions of the surf community regarding the Boscombe ASR direct users were asked a series of questions using a point scoring system. Respondents were asked to complete eight Likert scale questions to ascertain their opinion of artificial surf reefs. A point system of 2 to -2 was assigned to the Likert scale of strongly agree (2), agree (1), uncertain (0), disagree (-1) and strongly disagree (-2). The reaction of the respondent is coded with a negative score when they give a negative response, and vice versa. Therefore from 8 questions it is possible to attain a score ranging between -16 to 16 points indicating an extremely negative and an extremely positive reaction, respectively. Questions were balanced to avoid bias; 50% of questions were posed in a negative voice and 50% were posed in a positive voice. An overall score for each respondent was generated by their response to the questions and comments throughout the survey.

7.2.4 Thematic framework

Nvivo9 was used to analyse the qualitative responses collected in the UK waverider survey. The tool enables the user to explore and analyse qualitative data and open ended responses. NVivo9 provides a sophisticated workspace that lets you works through identifying themes in research material (QSR, 2011). Themes were highlighted under economic, social or ecological perspective. These were further coded as either positive and defined as benefit, or negative and defined as a cost. This enabled a thematic framework to be produced to further investigate the responses provided by direct users (Objective 3).

Some responses were written in short-hand where letters, particularly vowels, are missed out of words. It is presumed that this was due to the respondents using tablets or smart phones to complete the questionnaire thereby provoking this form of abbreviated text-speak. In order to make the sentences coherent some editing was needed; spell checking and re-writing in long-hand. Otherwise, the majority of responses remain unedited.

7.3 Results

7.3.1 Comparative study of the socio-demographics of surfers

Respondents to the questionnaire numbered 767 in total, 721 of which were waveriders from the UK and Northern Ireland and are only analysed for this study. The UK waveriders use different equipment to surf waves; this sample contained a majority of short-board riders (n = 493), with longboard (n = 126) and bodyboard (n = 72) surfers. Other sports represented by the survey were stand-up paddle boarding, body surfing, wind and kite surfing. The use of the word 'surfer' is used to describe all those whose ride waves, regardless of their board choice or sports name.

This study shows that UK surfers are comparable in age (Table 7.1) to their western counterparts in California, USA (Nelson, 2007) and on the Gold Coast, Australia (Lazarow and Nelsen, 2007). These independent studies are conducted on groups of surfers, and while not directly related to ASR construction, are two of few other social studies of large groups of surfers. It is important to understand the global context of the data being collected. The average age is 32, based on mid-range analysis, ranging from 18 to over 74 reflecting surfing as a sport popular with those well into their retirement years. The lowest percentage of female surfers was represented in the UK survey. This may reflect where the survey was advertised or the ASR generally may not captured the interest of women. The low female participation in surfing is relatively similar to that observed in California and on the Gold Coast (Lazarow, 2011). The UK surfing community is also comparable to surfers in the USA in terms of education and employment, but differs considerably to Australia. UK surfers have a high level of education with a mean of 69% achieving university degrees or above. The UK surfers seemingly achieve a higher employed rate with 78% in full time employment and a further 19% in full time education.

In comparison to the cost of living and income in these countries, UK surfers are the low earners compared to their counterparts in Australia and the USA; with an estimated average income of £26,581 (mid-range values were used to estimate the mean). Surfers from the USA earn the highest, with the Australian income at the lowest. The respondents to the UK waverider survey mostly surfed a few times per week, returned home or to a friends between surfing sessions (free as opposed to staying overnight at hotels or B&Bs) and driving was their main form of travel (either alone or with friends). The UK surfer is spending less but travelling more; surfers estimated they spend on average £980 per annum (mid-range values were used to estimate the mean) including accommodation, travel costs, eating/drinking, equipment, accessories, and clothing. When calculated by multiplying the amount spent per surf session by the number of surf sessions per annum the estimation is £2,040 per annum, twice that of the respondent's estimation. However, it is still lower than the expenditure by USA and Australian surfers (Table 7.1). Respondents are willing to travel for long periods to find good surf; average 84 km (mid-range values were used to estimate the mean) for an everyday surf and average of 248 km (mid-range values were used to estimate the mean) for a weekend surf session. The inconsistent nature of UK surf conditions explains why UK surfers need to travel further to obtain surfable waves. Since UK surfers travel the furthest but spend the least on surfing per annum, they are spending on fuel as opposed to accommodation and food.

Socio-demographics	Surfer case studies Trestles Beach, CA, USA	 Gold Coast, AUZ	 Boscombe ASR, UK
Year	2007	2007	2012
No. Respondents	973	471	721
Method	Web-survey	Web + face-to-face survey	Web-survey
Average age (over 18s only)	36 years	54% are <36 years	32 years (64% are <34years)
Gender (male)	92%	90%	96%
Education (graduated)	65%	35%	69%
Income (median household)	£35,000-49,000*	£28,000-41,000*	£20-29,999
Unemployed	1%	2%	2%
Fully Employed	76%	21%	78% (+19% full time education)
Experience level (Hutt scale of surfing)	84% high level of experience	43% advanced	35% advanced
No. sessions / week	3	2.5	'few times a week'
Distance travelled to surf session	36.8 km	60% = 10 km or less	84 km (weekend 248 km)
Surf sessions / year	109	104	97
Expenditure / surf session	£16-28*	£13-22*	£21 (weekend £33)
Expenditure / year (costs x surf sessions per year)	£3,960*	£2,360*	£2,040 (mean estimation = £980)

Table (7.1). Comparative analysis of socio-demographic results from the UK waverider survey 2012 (adapted from Lazarow (2011)). Comparative statistics collected by previous socio-economic studies on surfers in California, USA (Nelson, 2007) and on the Gold Coast, Australia (Lazarow and Nelsen, 2007). *Exchange rate used from 01/06/2011 www.xe.com.

7.3.2 Opinions of the ASR as a surfing break

The surf community were asked to rate both the surf reef and the beach break at Boscombe for surfability between 1 and 10 (1 being the lowest). Both surfing breaks received poor scores, with the beach rated slightly higher than the ASR for surfability. The mean and modal response for the beach break was 3, with 28% of respondents. The modal response for the ASR was 1 with 36% of respondents rating the artificial surf reef the lowest on the scale (Figure 7.2). The mean score from all respondents for the ASR was 2.7, only slightly lower than the surfability of the beach. The steep take-off zone makes stand-up surfing difficult at the reef, only those with higher experience are likely to find the reef satisfying. The reliance on the state of tide and inconsistent swell reaching Boscombe cause the ASR to break infrequently, even less regularly than the beach break.

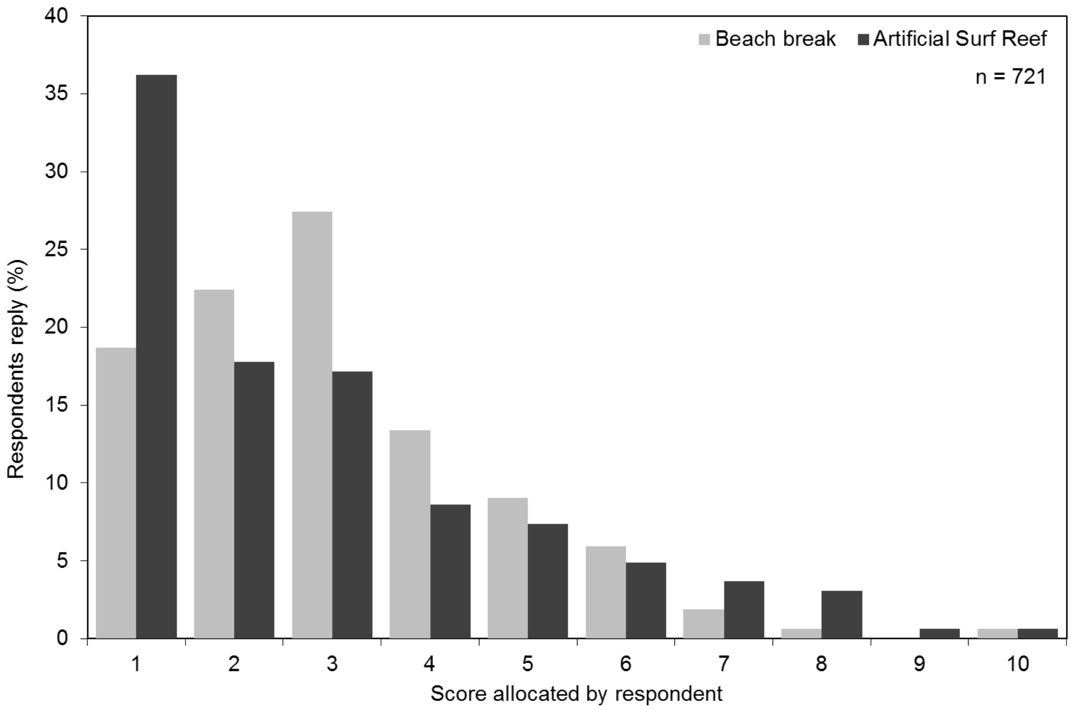

Figure (7.2). Likert scores given by surf respondents when asked to rate the ASR surf break and the Boscombe beach break where 1 = poor surfing break, and 10 = perfect surfing break (n=721).

Despite the low scores for the beach break and the ASR the results from Likert scale questioning illustrate an overall positive attitude towards ASR technology from all surfers who took part in the survey (Figure 7.3). The agreement to the three out of four positive statements illustrates there is strong support for the technology. However, the surf community are cautious about the technology and agree that more research is needed in order to create surfable waves. The surf community understand that the Boscombe reef was not popular with local residents and whilst they disagree that there would be impact on the natural surfing conditions, there is an overall neutral response to the idea of coastal modification with ASRs. The surf community remains cautious and support further construction with more research and site investigation.

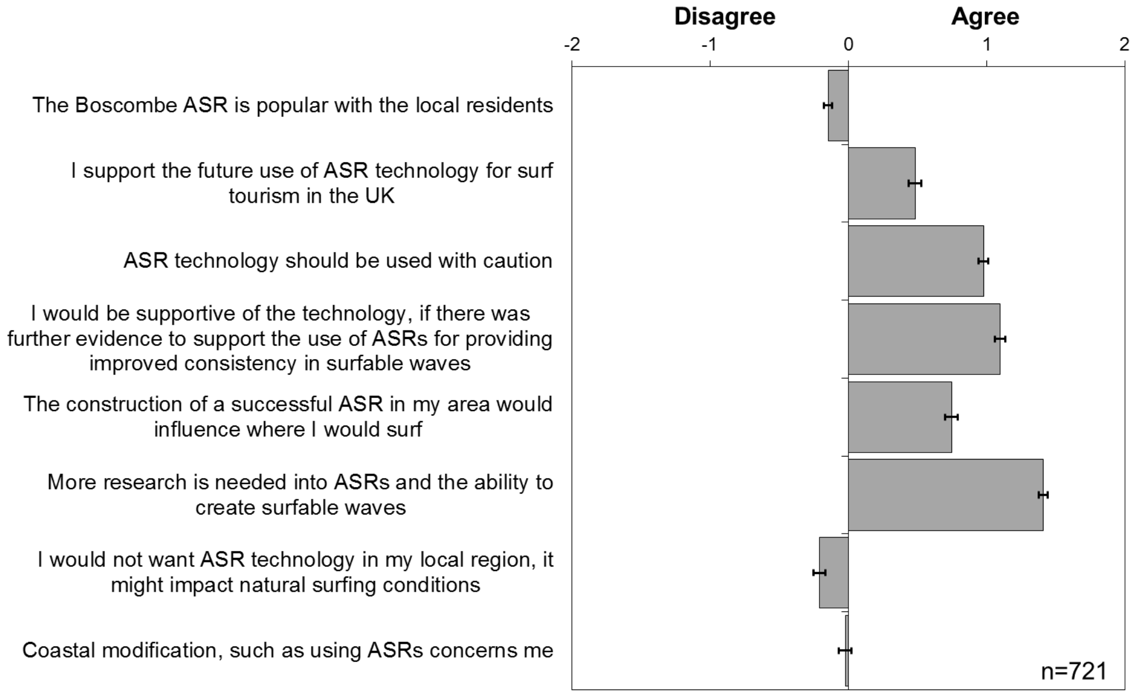

Figure (7.3). Bar chart illustrating mean response with error bars showing variation (standard deviation) for the eight Likert style questions for the surf community who responded to the UK Waverider survey in 2012 (n=767), including those who lived aboard.

The eight Likert questions responses were summed for each participant to give a "Likert score". The highest the ASR could have scored in this analysis is 16 with a very positive attitude towards the ASR, and the lowest score is -16 giving a highly negative attitude towards the ASR. This score was used to produce a histogram (Figure 7.4) to shows the attitude towards ASRs. The graph illustrates a normal distribution, slightly skewed towards the negative (n = 721). The modal response of 2 and mean of 1.36 (SD = 4.00). Although the predominant response is positive in support for surf reefs, there are those in the surf community who are quite negative towards the technology and this is reflected by the skewness.

It is important to understand whether the respondents who had no direct experience of surfing the reef and the impact of the ASR project at the site, had the same opinion of the ASR project as those who have surfed there (local surfers or traveling surf respondents). Further analysis was carried out to address the possibility that a negative perspective of

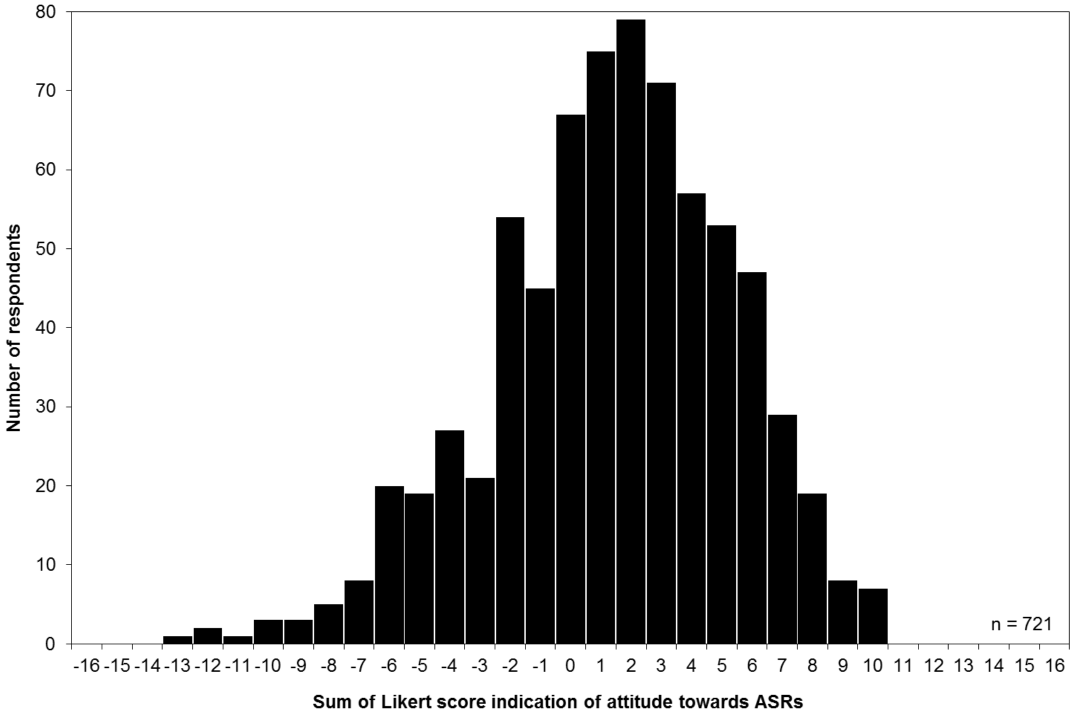

Figure (7.4). Histogram showing scores to eight Likert scaled questions regarding the attitude towards ASRs. The -16 (no support) to 16 scale (support), n=721.

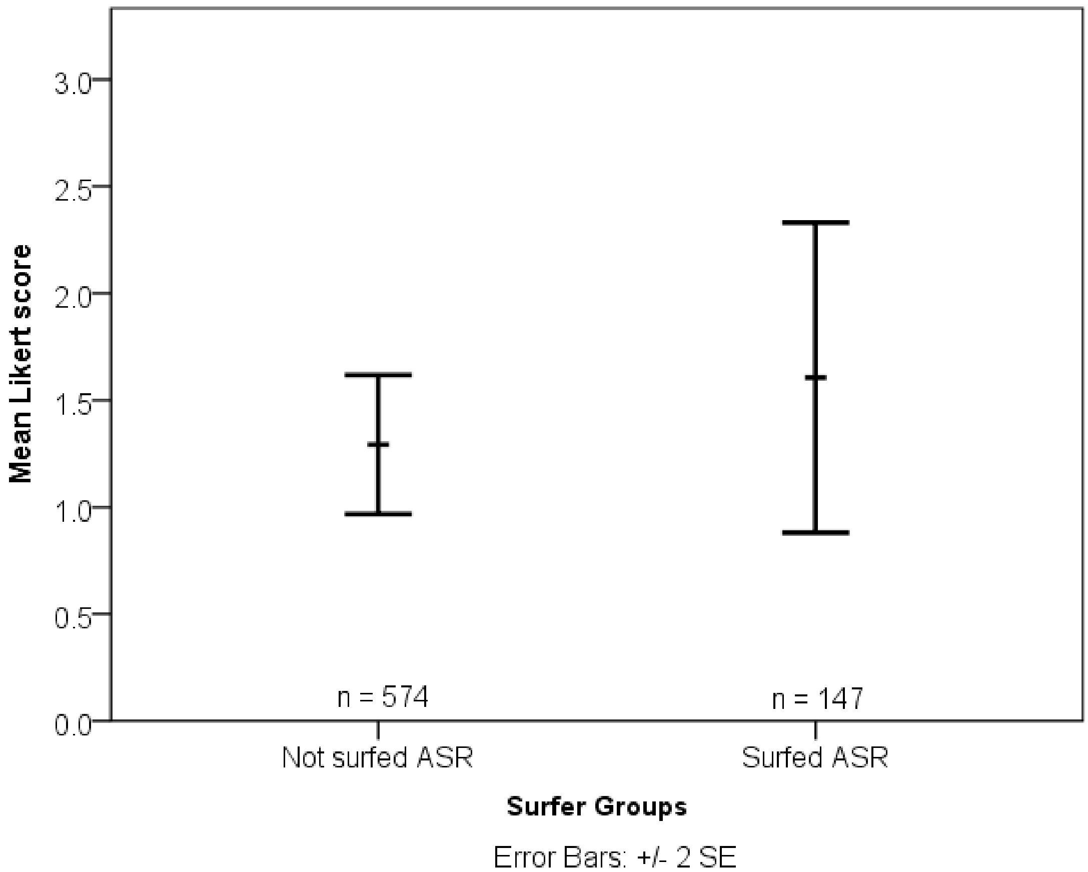

Figure (7.5). Mean likert score response (standard error) of the direct users that had surfed the Boscombe ASR at least once (n=147), and those respondents that had not surfed the ASR (n=574).

the ASR had been gained from what surfers read in the press or by word of mouth. The respondents were split into two groups and tested for statistical significance in their responses; those that had surfed the ASR at least once, and those had not. Figure 7.5 illustrates the mean score for the Likert questions are similar for both the groups; 1.61 (SE = 0.363) for those that had surfed the ASR, and 1.29 (SE = 0.163) for those that had not surfed the ASR. Indicating a slightly higher but more varying score for respondents who had surfed the ASR. The stand-up surfers are less satisfied with the ASR, compared to the bodyboarders who are generally more positive about the ASR. There is more negativity towards the ASR in the group with no experience surfing the ASR. Therefore the hypothesis is put forward that the opinion and perception of the ASR by the group that had not surfed the ASR has been influenced by word-of-mouth and negative media coverage of the project.

Score	Sum of squares	df	Mean square	F-statistic	P-value
Between groups	11.45	1	11.45	0.71	0.40
Within groups	1151.95	719	16.02		
Total	11527.40	720			

Table (7.2). Test for significance between mean Likert scores all groups (n = 721); SPSS output from the analysis of variance at 0.05 significance level.

In order to test if this is the case a one-way analysis of variance (ANOVA) was performed to test for significant difference between the two groups. The hypothesis (H_1) that the mean score of surfers that have experience surfing the ASR and those that have not surfed the ASR are not similar. The null hypothesis (H_0) is that the mean scores are similar, and that they are independent. The results (Table 7.2) show that since the P-value (0.40) greater than the 0.05 significance level the null hypothesis is accepted; that there is no relationship between the two means and conclude that there is significant strength in the P-value to support this statement. The F-statistic (this is the same as the student t-test result) indicates that there is no relationship between the means of the two groups at the 5% significance level (0.72¿0.05). Therefore, those with second hand information do have similar response to the ASR to those with direct experience of the site, these groups are not significantly different.

7.3.3 Thematic framework

The thematic framework provides quantitative assessment of the written responses given by the surf community. Comments are broken down into three main categories; economic, social and environmental. The comments are marked for generally positive responses (benefit) or negative (burden) responses. Overall, surf community respondents made 1973 burden related comments to the 1390 benefit related comments. These responses are reported in Table 7.3, and later in this chapter the benefits and burdens are presented and discussed in more detail (Also see Tables A1 to A4 in Appendix C). A similar count for economic and social themed comments is noted. A greater difference in the environment comments with respondents generally perceiving the ASR as an environmental concern. The most results do indicate economic and social benefits of the ASR. Overall however the burdens outweigh the benefits.

The following sections will explore at the economic, social and environmental benefits and burdens in further detail. Quotes are given to help illustrate the surf community response when asked what they perceive are the advantages and disadvantages of the Boscombe ASR. The last section will explore other themes (Table A5 in Appendix C) that appeared in the research that do not easily fit under these headings, but contain key messages from the research.

General framework	Burden	Benefit
Social	366	384
Economic	555	629
Environmental	212	73
Total	1133	1086

Table (7.3). Thematic framework of counts of qualitative responses regarding the perceived advantages and disadvantages of ASRs from UK surfers (n = 721).

7.3.3.1 Social benefits and burdens

The social theme received the highest number of comments (n = 1184); 555 burden and 629 benefit related comments (Table A1 and A2 in Appendix C). 317 benefit comments from the surf community were related to the waves being ‘better’ (meaning more surfable) for surfing/bodyboarding or had the ‘potential to be better’. ‘Better’ in this context were comments on the quality of the waves, consistency or the frequency of surfable wave in the area, or the power of the wave. This includes all respondents who mentioned theoretically or potentially better quality surfing waves, consistency of waves, for bodyboarding or surfing. Other respondents regard the ASR as having the potential to improve the shape of the wave and the consistency with which it breaks. The surf community emphasise that through using ASR technology "it may possibly increase the number of surfable days in the winter", "create a better face to ride and better form to the peak of the wave", or even a "high class break". Most surfers like the concept of the ASR "providing a different style of wave to the area" and many mention "variation" as an advantage of ASR construction. They associate this with increasing surfer skill "A higher performance wave would raise the local standard of surfing", along the same lines it is noted that "Better waves to raise better UK Surfing standards" generally. The view by many of the surfing community that have not surfed the ASR is that the technology will provide "Consistent barrelling and good peeling waves". The surf community enjoy the idea of "Creating a more challenging wave" and one writes "Consistency in wave conditions, and a safer break which is more regulated and better for beginners".

Surfers draw attention to when the reef breaks, stating the local and visiting surfers are not of the standard to surf the aggressively breaking wave e.g. "it doesn't work by the sound of it - or rather it works too well i.e. the average longboarder weekend warrior can't surf it". They describe the wave as "heavy" or "too heavy for surfers - better for experienced surfers or spongers [bodyboarders]". Some respondents acknowledge that they have not got experience of surfing the site but describe what they have heard in the surf community, that it is not good for surfing but better for bodyboarding. Another surfer writes "My perception is that it is a failure as a location for stand up surfing. The technology doesn't seem to work and it seemed a strange choice in terms of swell and wind patterns."

Bodyboard surfers have benefited from this addition at Boscombe and respondents (n = 115) mention increased surfability for this board sport. Bodyboarder prefer steep, heavy waves and refer to them as wedge shaped waves. They enjoy a rush from the drop down the face of the breaking wave. Stand-up surfers have to be highly proficient and quick to their feet to enjoy wave conditions like this, most will find this very steep breaking frustrating and loose interest quickly. Respondents comments confirm that the ASR provides additional amenity from the perspective of bodyboarding, and some detail the type of wave that is produced and how it benefits bodyboarding; "the reef was built to help magnify the often small swell available on the South Coast. From what I have seen this seems to have worked but the wave it produces is not suitable for many stand-up surfers due it being steep and hollow. However as a body boarder, and after reading reports of the reef by body boarders, the ASR has created a great wave for body boarding and has produced one of the best venues for this surfing discipline on the whole South Coast. A positive thing for an often overlooked form of wave riding".

A local natural reef break just 40 km from Boscombe is used as a comparison by surfers (n = 3) to illustrate that there are naturally working breaks in the area that form surfable waves from the incoming swell conditions; "When conditions prevail at Boscombe ASR, it is a poor comparison in surfing to other local reef spots such as Kimmeridge". A surfer makes this comparison with the occurrence of surfing conditions at Kimmeridge Reef to estimate the basic economic return on £3.2m; "There are not the swell conditions in the English Channel that make a reef consistently break. Say, if Kimmeridge (nearby), that gets slightly better swell conditions, breaks 30 times a year in clean conditions, Boscombe would probably be half that. Thus you would only find, even if the reef did work, 15 surfable days (in reasonable conditions) per year. Even at £1,000 a day that's quite a long pay back! We mostly get wind swell here and grovally [sic] conditions which is fine for a beach break but no good for a reef."

Another surfer lists the promises or claims made initially in the project, as they understood them, regarding the ASR and why they feel hard done by: "In my opinion, the reef has not fulfilled ANY of the things we were told it would: 1. It has not increased the number of surf able days, in fact most days it does not break; 2. The ride is shorter than we expected; 3. Wave height (when it's working) is not significantly improved; 4. A complete waste of money from a surfing point of view, and 5. The car parking has all but disappeared with the development of the flats on the site of the old car park, so the beach receives less visitors than before."

Other respondents have a more balanced perspective of the project in their analysis of the ASR, focusing more on the inaccuracy of the claims made in early stages of the project. One respondent writes "when the reef was in construction media made the hype around the surf being much better was too great and people's perception of how much better it would be got distorted. This meant that when the reef was finished and when the reef 'didn't do anything' because the conditions were not right, people thought that the reef was a waste of money." Another respondent comments on the inaccuracy of the initial claims for surfing "It cost a lot of money and doesn't live up to the promises made before construction about increasing the number of surfable days, and increasing wave height compared to the beach. It doesn't offer anything for learners as hoped."

While the ASR may not have provided the expected outcome in terms of surfability, the project certainly raised awareness for UK surfing; 43 respondents mention increased surf popularity. The ASR is also seen as having the ability to aid surfers training and skill set. Surf access is mentioned (n = 26) as a perceived advantage of the ASR project, the concept of having a new surfing resource as well as the natural one is welcomed. Some relate this social benefit to there being an environmental benefit as well for example "provides a low carbon, local amenity". The surf community value the project as an improved recreation activity (n = 55). The active encouragement of outdoor activities is seen as a positive and healthy step forward that the surfers recognise. Despite concerns expressed regarding overcrowding respondents seem to be positive regarding people taking up the sport and the encouragement of surfing and other watersports. A respondent recognises potentially beneficial aspects of the ASR construction for the surfing community and for the sport: "It is really positive that money is being spent on a sport that I feel gets little attention out of its close knit community. It's a rapidly growing sport, and people are taking it up for numerous reasons such as the health aspect, being in the sea, the lifestyle."

Whilst some in the surf community view the ASR as a positive and innovative step, some respondents view the addition as an embarrassment to the town (n = 49) and raise concern regarding the negative impact to the towns reputation. This is related to the council, its members, or the surf community that have been made to look foolish by the media. Some stretch this further and associate the project to the wider UK surf scene by stating that the ASR "makes British surfing look like a joke". The aesthetic impact of the ASR is mentioned (n = 11) in association with the embarrassment surfers feel for the area, the visual impact on the beach and surrounding sea views.

A respondent draws differences from a local surfer compared to the travelling surfer attracted to the area. Ultimately, the latter are the surfers bringing money into the area: "Rideable surf is by its nature a scarce commodity. Enhancing the supply by creating proper bottom contour increases the accessibility of the sport in general and the quality of the experience for the typical user. There will always be a place for iconoclasts who choose to go on adventure but the day-in day-out rider needs reliable high quality surf. To the extent that investment in surf infrastructure draws people in to an enjoyable experience there will be increased frictional spend merely from being in the area. Some people will chose to live closer to consistent waves and this can have a positive impact on the urban environment, sophisticated users will be drawn to the improved break and not only holiday on location, but perhaps choose to live full-time in the area."

Respondents allude to the redevelopment of the seafront rather than directly to the

ASR itself (n = 107). They describe the area as previously run down and welcome the change from the redevelopment: "Rejuvenation of the Boscombe seafront area, good bar and restaurants, pier has been updated, a nicer beach front all around mainly due to the reef being constructed. The reef has become secondary to the success of the redevelopment; it has become a nice place to go in the summer / winter and with your family." The surf community comment on the ASR as a focal point for the regeneration project (n = 12) thereby giving the town a new identity. The social problems that Bournemouth Borough Council were up against "It has definitely brought so much attention to the area, positive attention to Boscombe seafront which before was very run down and full of social problems such as drugs and alcohol. The regeneration of the seafront alongside the construction of the reef has been brilliant and many more people visit here. Definitely raised the profile of the area even though the reef doesn't work and that has been brilliant for local businesses as well as the local community. Less good for surfers as the water is a lot more crowded now." And "The gentrification of a very run down, seedy area of Boscombe that had been allowed to deteriorate by lack of investment. It is now a delight to go to the beach again... even though there are very few good waves. A great restaurant and surf shop. Activities and events on the beach... great Volleyball!".

Respondents say the reef is "dangerous" and refer to gaps in the reef structure that could damage equipment (n = 92). There is a general view that the reef itself "could cause injury" or secondary effects of gradients in flow around the structure that cause rip currents or increased turbidity in the water. A respondent writes about the "safety issues, currents and undertow created by shifting of the geotextile bags". The closure of the ASR added to this concern comments such as "it is dangerous and it has been condemned" highlight the concern the surf community have regarding the structure. Others express a concern for liability and governance issues surrounding the structure. Direct users express concern and regard the "lack of knowledge about reef movement and subsequent safety issues" as a real problem. Some surfers explain that the reef is also damaging their equipment with surfboard fins being stuck in the reef; "you have a long paddle out compared to the local breaks, quite strong rips around the break, it is very shallow, in my opinion dangerously shallow (I perceive the local reef breaks as safer), the marketing of the reef seems to be for surfers of all abilities when in reality it's for intermediate to advanced surfers only."

Publicity is mentioned as an economic benefit of the Boscombe ASR, however this is also linked strongly by the surf community as a social cost: 197 respondents mention

Figure (7.6). Illustrating the possibility of overcrowding at the Boscombe ASR with one small "take-off" zone

"crowding" or "overcrowding" in the water as a disadvantage of the ASR construction. This reflects the inherent association with publicity from the media coverage of the ASR and crowding in the water. The respondents express concern for the limited size of the area where the surfers can take-off at the break. Another link the surfers make is to "commercialisation of surfing" in that the popularity of the sport is making surfing at the site problematic due to many novice surfers interrupting local surfers who know the site and more advanced surfers. More simply the dangers associated with increased numbers of surfers in the sea are a concern.

> "I think when you create areas supposed to be superior to other spots in the area you attract the wrong type of crowd e.g. inexperienced surfers, who will make the line-up dangerous and unpleasant to surf. Reef break line-ups work on a strong code of unwritten etiquette, which many of the surf tourists that Boscombe might attract do not understand. Then the reef becomes a liability for local rescue services and for the reputation of the construction."

A total of 71 respondents comment on the ASR impact on the natural surfing conditions at Boscombe beach break and emphasise concern for the changes to the sediment on the beach. The 44 respondents mention localism as another problem created by ASR construction. Respondents (n = 34) also mention increased traffic and parking costs at the site and say this problem is adding to localism issues at Boscombe. All of which cause additional pressure to the amount of surfers in any location. When describing Boscombe specifically one respondent writes "localism was always a big thing there" and another "local residents object due to increased parking and localism". The surf community associate surf etiquette with localism, as they describe how uninitiated novice surfers are more likely to be the cause of this issue in the water. The concern for this clash between local and travelling surfers is mentioned by both those that have been to Boscombe and those that have not been to the site; the burden of increased numbers of surfers, causing violence and unease. Other surfers suggest a means to modify this problem is inherent in ASR design e.g. "Any truly successful solution will create multiple take-offs that hold in a variety of conditions and provide a range of difficulty, and does so in a way that fits in to the environment so that the individual isn't even aware that the area has been modified."

> "The reef has had significant cost and was carried out without full input of the surfing community. There is general consensus amongst local surfers that the reef has been constructed in the wrong place etc. thus showing that the public consultation (if any) was not extensive enough or did not take the views seriously"

> "There is a difference between perceived and actual. Any surfer worth his salt could have told the council that a reef can only improve the waves that Boscombe already get. So on the 3 or 4 days a year when Boscombe gets a decent swell then provided the tide is right for the swell window then the reef will produce good waves. Now if those 3 or 4 days coincide with a weekend then you will get surfers travelling to the area to surf it. Unfortunately Boscombe does not get many waves and so has little to improve on. Advantage: if on those 3 or 4 days coincide with a weekend then you will get surfers travelling to the area to surf it."

7.3.3.2 Economic benefits and burdens

There is a strong recognition from the surf community that the ASR has potential economic burdens and benefits (Table A3 in Appendix C), with 750 comments made under this theme. Reasons behind the comments are not always clear, although respondents were invited to expand on comments many chose to write short explanations, if any. Many respondents have not visited Boscombe but they had heard about the ASR project; 20% had visited the site and surfed the ASR, whereas 96% had heard about Boscombe ASR through the media or marketing. Considering this, 384 respondents (53%) stated that there were economic benefits to ASR construction.

Respondent comments range from brief statements to more detailed responses discussing the means in which an economic benefits may have been observed. General statements were common responses, for example surfers would simply write “tourism” as an advantage to the ASR construction. Comments indicate that the surf community do see the reef as a potential economic benefit to the town. Specific comments regarding how ASRs could bring a positive contribution to the local economy by “enhancing” or “encouraging” new surf tourism. Respondents made the observation that surfers will be encouraged to spend more once they have been attracted to the area with the provision of high end shops and restaurants. The more detailed responses indicate how respondents are making a connection between the ASR and the surf scene, and the potential for increasing tourism based revenue. This was the most common economic benefit with 120 responses of this theme. Respondents also make a correlation between increased tourist numbers and jobs.

Another surfer reflects on the fact that inherent to the ASR project was “the redevelopment of the local area (Honeycombe chine), increasing revenue in the area and local business opportunity.” He recognises that the “’the project has regenerated the whole area, and allowed the council to sell the land to businesses”. The surf community are aware that Boscombe was not previously noted as an investment site and now “it appears to have put Boscombe on the map for investment and regeneration of other types”. The redevelopment project has affected the cost of living in the area, positive comments regarding the value of housing and real estate as an outcome of the ASR construction. Although some respondents are more negative in their reaction to the construction and increased house prices; “Developers have made a killing selling ‘surf’ reef flats and apartments. These were never intended for use by surfers of course.” Generally, respondents feel that the Boscombe reef project might have been more of a marketing strategy for the town, e.g new flats constructed by Barratt’s Homes and new luxury end properties with sea views, rather than focused on the encouragement of surfing at the site: “The main advantages seem to be property development and very little to do with surfing”.

Publicity generated by the ASR for Boscombe and the regeneration work at the seafront are mentioned by 104 respondents. Surfers are quick to relate the publicity from the ASR and consequent tourism. The “advertising” has simply meant that more people know that Boscombe is a destination for a British seaside holiday. Inherent to drawing the surf related tourism is the marketing and advertising of the beach suggest some respondents. One surfer comments that “[the ASR] has generated a lot of media interest and it was one of the most talked about things in British surfing at the time". Tourism gain through visitors attracted to the beach to observe surfing rather than to participate is another avenue through which the economy might be enhanced. Boscombe is also seen as "a good place for people to come and watch surfers performing" given the promenade, narrow beach and relatively close vicinity of the cafes.

The surf community recognise that the ASR helped "raise the profile of the place". Generally, the "re-branding and gentrification of the Boscombe area" is seen as a positive outcome of the ASR project noting that the ASR "drew publicity to a struggling area". A common response is that the ASR provided momentum to the seafront regeneration project at Boscombe. A respondent notes that "the publicity generated from the installation of the reef has helped in the regeneration of the Boscombe seafront and some of the surrounding area" whilst others point out that "it has been a catalyst for regeneration and provided a great deal of positive PR (public relations)". A respondent even goes as far as to say that the ASR improved the "poor reputation of the town". One specific positive comment that mentions the themes discussed succinctly; "The huge amount of investment into the local area has encouraged new successful businesses to operate in the area. There is an increase in surf related tourism as a result of these enterprises. This has led to an increased awareness of surfing nationally".

However, the surfing community note that the publicity was not all positive, some are unhappy with additional attention to the natural surfing break. Comments regarding the media portrayal of the project and the attention the reef received in the press was not on the whole positive "bad publicity from surfers as all I've spoken too think it's a waste of time and complete waste of money". Some surfers see the ASR and the advertising "purely mechanism to drag unsuspecting punters down to Bournemouth."

The initial construction costs of the ASR project are of deep concern to the surf community; 215 respondents commented on the overall cost of the project, and wasting public money. The project is seen as an expensive burden to tax payers, not only for the initial construction but for the on-going maintenance. The ASR project is seen by some as not giving any real benefit to the redevelopment of the seafront. The closure of the ASR so soon after it was completed has angered users and respondents point out that there can be no economic gain due to the repairs that need to be completed. Comments from the surf community regarding the increased burden to taxpayers and tourists arose during the survey (n = 96). More detailed responses noted economic costs specifically regarding the increased prices at the seafront and local people having to pay holiday prices all year round.

> "The advantages of the reef are not directly linked to surfing. The significant advantage of the reefs construction comes from the focal point of regeneration of Boscombe seafront, which has been very successful with considerable money directed to an area suffering from being old and tired. The new seafront promenade is popular with tourists and locals alike more so than the surfing community. Cafes and restaurants as well as a few shops provide consistent attraction to a smartly designed sea front; I feel little attention is given to the reef by most beach users in the area. From the surfing communities point of view the increased media interests in the project and sport can only be positive and help generate much needed funding into the sport."

7.3.3.3 Environmental benefits and burdens

Environmental burdens related comments numbered 212 during the survey; these ranged from general comments regarding damage to the environment and skyline, physical coastal impacts on the shoreline and sediment, disadvantage to local ecology, wildlife and fisheries, altering nature and dumping plastic in the sea, and the increased rubbish and litter from increased visitors. Environmental benefits of the ASR were noted by the surfers as positive outcome of the project (n = 73); these include aiding coastal protection through accretion or reduction of erosion, and beneficial habitat for marine life and fisheries. The surf community perceived a 1:3 benefit to burden ratio (Table A4 in Appendix C).

Comments regarding the reef providing beneficial "coastal protection" were made by 37 respondents. Other examples of the notion that the ASR could be used as a tool for littoral management for example; "can help with coastal management", "prevention of coastal erosion" and "reduced effect of longshore drift". However, 82 surfers perceive the ASR as a potential cause of coastal erosion using expressions such as "uncertain effects on the marine /coastal environment". The "altered coastline and dangerous rips and currents" are noted by surfers as environmental impacts at the ASR. Some comments are scientific in their response, whilst others use more common language. Some respondents (n = 37) are under the impression that the reef was built with coastal protection benefits in mind and see an advantage; "to negate the need for the groynes, which are costly to maintain" and another "far more preferable to a coastal defence/management system to something like groynes and presumably cheaper in the long term". The surf community recognise the potential for changes in beach geomorphology. However, the physical structure of the ASR is commented on by surf respondents as a cause for concern:

> "The sand bag construction of the reef is also concerning people apparently, there are reports again being passed round via word of mouth and through the Internet that there is extensive underscoring of the reef resulting in caves appearing in the footings. The concern is for the permanence of the reef."

Surfers are knowledgeable in their discussion of ocean topics, showing compassion generally for nature and wildlife; "I like the idea of it being used as a nursery or shelter for marine life, and being able to be used for marine biology research". Similar numbers of comments reflect the ASR project as a burden (n = 43) or benefit (n = 36) to marine life. This reflects a possible uncertainty surrounding the impact of the ASR to ecology. Respondents use simple comments e.g. "provide wildlife with a home" to more technical terminology "development of marine eco-systems" to describe how biota might thrive or aggregate to the Boscombe ASR. The reef is perceived as having "environmental benefits" and habitat creation is seen as positive for "encouraging marine life". It is clear that some in the surfing community recognise that an aim of a project such as Boscombe ASR might be to "help marine life around and on the reef" be that through just noting the word "fishery" or more detailed notes describing how the reef might "help with coastal ecosystems and coastal management". However, not all surfers write favourably about the reef and some express concern to the burden to ecology. Statements such as "negative effect on marine life in the area", "danger to wild marine life" or "may damage natural ecosystems" are common. Whilst others see the construction process and related changes to the seabed as having a negative impact two respondents have direct experience snorkelling on the reef and report otherwise; "before the closure of the ASR the increase in marine life made for some good diving/ snorkelling". Another respondent writes: "While the reef has failed to deliver as a surfable wave it is a good snorkelling place and should be used by a dive school. I have spent many an early morning in the spring and summer seeing spider craps and sea bass to my surprise."

Generally, there seem to be two attitudes about environmental impacts from the surf community towards the ASR. The more common response (n =28), expresses caution and views altering nature as a negative impact that should not occur as they are "not natural" or "unnatural, danger to wild marine life". One respondent goes as far as to say "the notion is ethically and environmentally unsound". Usually the respondents are concerned and worry that there will be an interruption to nature: "the unquantifiable nature of the intervention is concerning, especially when it is primarily concerned with providing a recreational benefit that seems to surpass any environmental benefit". The other attitude is that changes to the natural coastline in favour of new surf breaks is positive, if new surfing amenity is provided even if it disrupts wildlife. The development of the ASR technology is seen by some as more ominous as competition at the coastline increases the use of ASRs as mitigation tools for destroying natural sand banks and rock reefs.

Pollution is mentioned as a direct reflection of increased tourism and surf traffic at the coastal resort. A Boscombe surfer writes; "The disadvantages are; the influx of surfers into the area would make the surf spots crowded and more competitive, the added waste and pollution brought with the influx of people, the cost of the whole process and the added costs of delays". Whilst some recognise that the geotextile bags are a polymer and have the potential for pollution, others are unsure of the material and write "as long as all materials used are eco-friendly" and "caution should be exercised regarding the material used to construct the reef". Another respondent shows understanding of the problems associated with marine construction and writes "It runs the risk of upsetting sea life although I presume that risk is marginal. I presume there is a risk of disrupting the distribution of sand on the beach, affecting water-flow etc."

7.3.3.4 Other Comments regarding ASR

There were a number of perceived impacts that do not easily fit under the themes discussed previously but are still worth noting (Table A5 in Appendix C). They have been split into positive and negative impacts of the ASR project. These might be direct experiences or indirect outcomes, i.e. problems learnt through word of mouth. The response that the "ASR at Boscombe doesn't work" were the most common statements in the survey, 295 comments of this nature were made. These statements mostly reflect the perceived failure of the ASR in the fact that surfable waves were not produced consistently. Some are more articulate in their response and attempt to explain their response; "the surfing benefits are limited by the consistency of the wave, the length of ride and imperfections in the wave form (particular sections of the wave which break too quickly to be passed)."

The surf community reflect on multiple issues with the project from the design, the construction through to the end product. Inconsistent or unpredictable nature of the Boscombe ASR is also communicated as a disadvantage by 109 respondents. A surfer sums up his experiences at Boscombe:

> "From a purely selfish surfing perspective it has worsened due to parking, crowds and diminished wave quality. It has highlighted the inadequacy of the local council's ability to deliver the project and manage the finances with ASR suitably. They play down the failure of the reef and offset against the success of the regeneration. I feel that these two do not mitigate each other and that the regeneration could have occurred anyhow with the right publicity. The reef itself has failed to deliver any surfing upside."

However, others were positive and found advantages in the Boscombe ASR project. Respondents discussed the wave theory (n = 197), innovation (n = 26) and research into alternative materials (n = 20) that had gone into the ASR construction. The project is seen by as a trial run or test case for possible further ASR construction in the country. Some see the reef as an innovative step towards developing artificial wave technology. Boscombe ASR is a new example of how surfing could possibly become a focus for the attention of councils. The respondents comment on the progression of geotextile technology to allow the ASRs to be manipulated and altered according to location.

Location of the ASR is reported as a disadvantage due to the small wave climate in Boscombe by 189 respondents from the surf community. The reasons are typically associated with the location of the ASR in the UK rather than the position or orientation to the incoming predominant waves, although a few surfers do mention the latter point. Most surfers would have liked to have seen the ASR constructed in a location, such as Newquay, Cornwall. Surfers commented on the reduction of shelter from south-westerly winds, cause by the shortening of the pier during the regeneration works, as a key problem in the ASR location.

The ASR design is mentioned as a disadvantage to the project by 173 respondents. The general consensus was that further research was needed into both the technology and materials for construction, and the process of project management. The contractual agreement was broken between ASR Ltd. and the council, and it was not made clear how and why the project lost in time and expense. It is apparent that the surf community and general public were aware of this and voiced concerned for the lack of transparency in the ASR project. The management of surfer and public expectation was mentioned by 137 respondents and comments are linked closely with the design of the ASR.

7.3.4 Relationship between themes

A cluster analysis was performed on the themes to highlight the similarity of the phrases used by the surf community respondents. The results were simplified (some of the less commonly mentioned themes have been removed) and illustrated as a dendrogram (Figure 7.7). Pearson's correlation coefficient is the statistical metric used to calculate similarity between themes. Themes that have a higher degree of similarity based on the occurrence and frequency of words are shown clustered together in the same branch and different items are further apart. As an example, when asked for the perceived disadvantages of the Boscombe ASR, respondents might frequently write "crowding" and "localism" at the surf break, the analysis therefore links or clusters these together.

The benefits and burdens are clearly separate although the themes from the previous section are dispersed through the diagram. Relationship links are made between concerns for the ASR altering nature and the funding of future ASR projects, as the Boscombe project was not seen as a success by many outside and within the surfing community. The burdens to the environment are linked with both the ecological and physical impacts to the coastline. The affect of the ASR on the natural surfing wave (Boscombe beach break) is linked to the potential danger the ASR poses to humans (as previously discussed in Chapter 6). The visual impact of the reef is discussed alongside the liability issue (i.e. through injury on the reef or rip currents) and concern is raised by the surf community regarding responsibility if someone was injured on the reef. Other relationship links exist between respondents mentioning the ASR being closed, the burden of the construction and perceived time and money wasted on the project. This highlights the concern by the surf community for the long-term financial impact to the council, taxpayers and tourists.

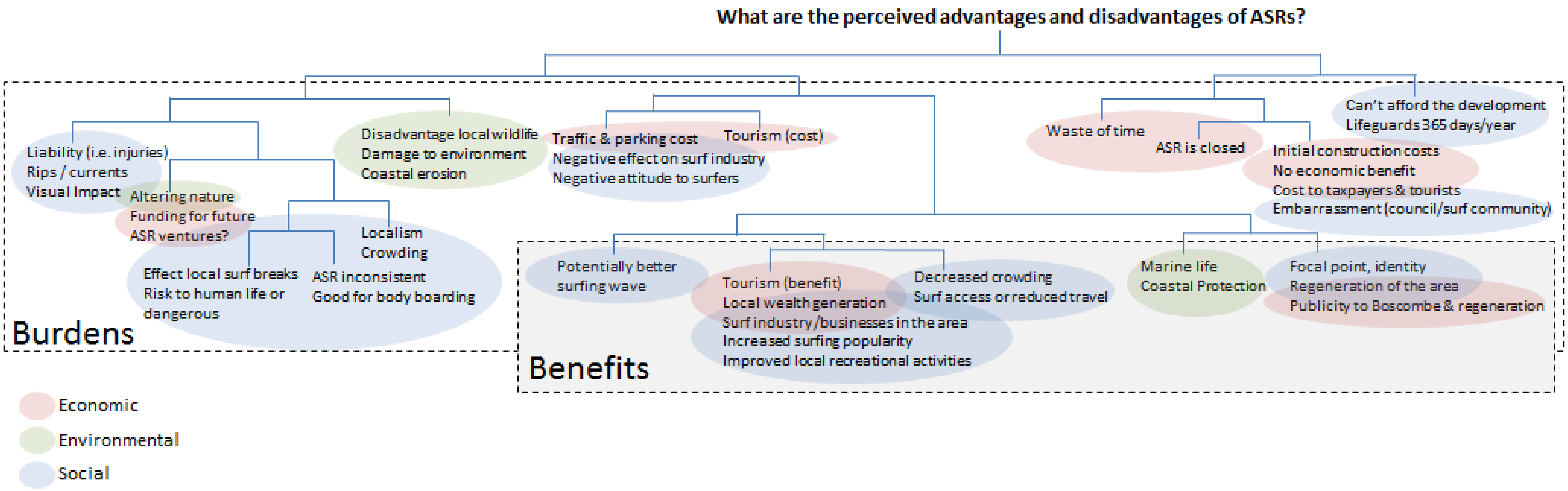

Figure (7.7). Vertical dendrogram of themes (economic, environmental and social) clustered by word similarity in NVivo 9; common words are ignored in this analysis allowing relationship links between themes to be investigated.

Relationship links (Figure 7.7) were highlighted between the benefits for tourism, local wealth generation and business growth in Boscombe. The relationship of the ASR being a focal point or identity for Boscombe's seafront regeneration project comes out clearly in the analysis, as well as the association with the publicity the ASR generated for Boscombe as a newly revamped tourist destination. The marine life and the coastal protection were environmental benefits that were closely linked. The potential for a better surfing wave was associated with the increased tourism, economic benefits and overall benefits to the sport. Decreased crowding, and the reduced time for travel were given by surfers as perceived advantages of the ASR construction. The popularity of surfing is thought to be increased and improved recreational facilities (such as the addition of volleyball nets and showers) are referred to as a benefit of the ASR.

7.4 Discussion

As introduced in the case study (Chapter 4), the Boscombe seafront was a deprived area much like the main town centre, and not a tourist destination. However, surfing did occur at Boscombe Beach and Pier, as shown in the surfer statistics collected by the seafront rangers. The main motivation for change at Boscombe seafront was the ASR, the seafront would have been redesigned and renovated but not with surfing in mind. The ASR is thought to have provided media attention, advertising opportunities and become a tourist attraction. This section discusses how the ASR has impacted the surf community and what the consequences have been to the direct users. The physical change of putting the structure into the ocean has inherent implications to the natural surf break. The ASR changed the surfing commodity in Boscombe, this section of research examines whether the surf scene in Boscombe has benefited from the construction. The opinions and perceptions of the surfing community are discussed in themes in order for comparisons to be drawn with other studies. These themes are: demographics (age breakdown and gender); education, employment and earnings; travel and expenditure; attitude towards the ASR; safety of the ASR; novelty of the structure; the environmental and ethical implications; the impact on tourism; planning and consultation.

7.4.1 Demographics: age and gender

The figures recorded for this survey are comparative with the literature regarding surfer age and gender. The majority of respondents are in their 30s or the mean age lies between 30-40 years. Buckley (2002) acknowledges in his study of surfers the Indo-Pacific Islands participant age can span across all generations, the largest growth in recent years seems to focus on younger individuals (Reynolds and Hirtz, 2012). Research in Australia and the US also highlight average age of surfers in their 30s but a wide range of ages participating in the sport (Dolnicar and Fluker, 2003b; Lazarow and Nelsen, 2007; Nelson, 2007). It has to be noted that this does not include the under 18s due to the ethical procedure of a guardian being present in order to interview them. It would be timely and therefore expensive to include this age group in this retrospective research. However, it is recommended that future planning of ASR construction should include this demographic as the sport is a safe and healthy popular sport with local children (approximately 12-18 years of age) in coastal communities. The consideration of the future generation of beach users will add to ownership of a project and reduce conflict for the council in the future. It is important to consider carefully the governance of the ASR from a safety aspect, as discussed in Chapter 6 males and teenagers are most vulnerable to rip current incidents.

The findings in Australia (Lazarow and Nelsen, 2007) and the USA (Nelson, 2007) are similar to the figures of female participation in UK surfing (Table 7.1). It is understandable that there might be a lag effect in female participation in the sport since the surf scene explosion occurred decades earlier (in the 1960s) in these retrospective countries compared to the UK (where a rapid interest in surfing wasn't seen until the early 1990s). Other studies on surfers also have relatively low female participation (Buckley, 2002; Dolnicar and Fluker, 2003a). There is limited research based on the social studies of surfers yet research does focus on surfing as a 'man's sport'. Articles have been written about how surfing leads to 'masculinity' (Waitt and Warren, 2008; Evers, 2009). Farmer's (Farmer, 1992) study suggests that surfing also might be an activity for only one gender. In research on surfers in USA, an adequate number of female surfers were not available and therefore not included in the results (Reynolds and Hirtz, 2012). Pearson (1982) writes that historically women were not known to surf, however this has since been disputed. Traditional Hawaiian women were known to surf: "surfing was not the sole preserve of men, but an oceanic spiritual activity where both sexes would surf together" (Southernden, 2005). Women are participating despite the perception that surfing is male dominated (Henderson and Webber, 1977).

Up until the 1990s, the focus remained firmly on men's professional surfing, men's surf fashion and technological advancements in surfboard design, with shorter boards becoming increasingly popular (Southernden, 2005; Young, 2008; Fendlt and Wilson, 2012). By the end of the 1990s, more attention was drawn to females on boards and women's surfing was receiving increased interest (Southernden, 2005; Young, 2008; Fendlt and Wilson, 2012). The last decade has seen women's professional surfing sponsorship improve in the UK. Fendlt and Wilson (2012) write that while a small body of research has investigated aspects of surf tourism in relation to surf culture, motivations for surf travel and other applications to social theory, women's voices seem to remain neglected (Buckley, 2002; Dolnicar and Fluker, 2003a, 2004; Fluker, 2002; Ponting, 2009). The study of female tourists is in general still largely underdeveloped, and empirical studies are needed to understand the knowledge gaps in female tourists motivations, constraints and experiences (Harris and Wilson, 2007; Fendlt and Wilson, 2012). It is recommended that more emphasis be placed on capturing the opinions and perceptions of both genders in sport tourism equally.

7.4.2 Demographics: education, employment and earnings

Research findings show that the UK surfer is well educated, has full or part-time employment and earns over the average UK income. In Boscombe, 41% of 18-74 year olds are employed in technical occupations, managerial professional or associate professional work. The Bournemouth council ward residents have below average qualifications, compared to national statistics (Bournemouth Borough Council, 2011). Surfing has become a respected sport reaching a broad spectrum of society (Huges Dit Ciles, 2009). Surfers are not the media portrayed stereotype of a school "drop-out" (Mead and Black, 2002). Oram and Valverde 1994 wrote that "today's surfers include doctors, attorney, CEOs and even a 1993 Nobel Prize winning scientist". However, there is a lingering prejudice that persists over the surfing community associated with their abilities and even social habits (Siegle, 2010). Booth exposes a plurality of Australian surfer that include the soul-searcher, the rebel and clean-cut professional (Waitt and Warren, 2008; Booth, 2001, 2004). More recently, Reynolds and Hirtz (2012) found that in their US based study participants viewed themselves as conservative in their lifestyles and values. The results support these findings, the surfing community who responded to this survey have strong employment (78%)

and qualifications statistics, greater than the national average implying an understanding for education and strive for work. Regardless of the activity or semantics, adventure travel participants seek to engage in active pursuits because they are authentic, unique, interesting, educational, and exciting (ATTA, 2010; Loverseed, 1997; Jackson et al., 2001; Reynolds and Hirtz, 2012). The study presented in this chapter and literature suggest that the surfing community are able to provide valid and educated responses to a consultation process.

7.4.3 Demographics: travel and expenditure

Although many UK respondents are employed where there is no surf or close access to beaches, they are willing to travel extended distances to surf. Huges (2009) notes that business people and city folk, previously attracted to the city breaks offered in Europe and other international locations, are tending towards exploring Britain's own natural environment. Results presented indicate that UK surfers have similar demographics to surfers in other countries, but there are differences in distance travelled and expenditure annually. These factors are fundamental in predicting the return from a new surfing amenity and in cost:benefit calculations.

Spending between countries varies greatly, as well as what they are spending on. The less willing the surf community are to depart with cash, the less likely surfers travelling to surf the ASR will directly benefit the coastal community. The UK surf community appears to have less disposable income, than surfers from the USA or Australia. However, with an average distance of 84 km the UK surfer travels more than twice that of the US surfer (Nelson, 2007) and 8 times further to find surf than the Australian surfer (Lazarow and Nelsen, 2007). Location of employment, good surfing conditions and the fickle wave climate in the UK cause this increased travel. Surfers living outside of Cornwall and Devon travel long distances, these are notably areas of reduced industry and opportunity for graduate positions is low. As the surf community are spending money on travelling in particular on fuel, they are unlikely to spend on food, clothing, and other nonessential items at the coastline.

The mean income for the surf community is also less than the USA and Australia, the UK surfer has less spare money to spend in the town after travel expenses. It is logical that as surfers are travelling further they are spending more on fuel rather than on accommodation and meals. The tourist surfer is the one that enhances the economy not the local surfer. Dolnicar and Fluker (2003a) discover unique market segments of the surfer including those that are “price conscious safety seekers”, “price conscious adventurers”, “luxury surfers”, “ambivalent”, and “radical adventurers” further illustrating the variety of character and personality within the surf community (Reynolds and Hirtz, 2012). UK surfers might be seen as price conscious when travelling for surf, either in the week or at the weekend. The UK surfer will act differently whilst travelling abroad, however this is considered beyond the scope of this study.

7.4.4 Attitude to ASR

The surf community do have a positive attitude to ASR construction according to the Likert question responses. Even though Boscombe ASR was not popular or considered particularly successful, surfers are still interested in the concept of ASRs. This is interesting given that the project at Boscombe was over budget and perceived as underachieving by the majority in the surf community. As introduced in Chapter 4, the initial construction cost was inflated above the original quote and the original cost:benefit prediction (1:20) is not realistic. The increased popularity of the newly regenerated Boscombe seafront has driven up prices in turn dispelling surfers; increased traffic, decreased parking availability and increased parking prices. Additionally, there are few examples where the technology has been very successful giving an impression of general optimism towards the development of more effective ASR design. Narrowneck ASR, Australia can be perceived a success as its primary aim was coastal protection and it has benefited scuba and fishing tourism (Jackson et al., 2005, 2007). Surfing is possible at Narrowneck despite familiar complaints of inconsistency. Despite this, the surf community in the UK still remain interested and optimistic about ASR technology and the possibility for creating artificial breaks in the marine environment.

Most of the negative responses towards the Boscombe ASR are associated with design and its perceived ineffectiveness. The shape, consistency, power and quality of a new surfing amenity were all brought into question. According to the results, both groups of surfers (those that had, and those that had not surfed the ASR) had the same opinion of the surf break so we can be confident in discussing the group results together. Surfers remain positive toward the ASR concept, however rated Boscombe ASR poorly. It is important to note that the beach break was also rated very low, although slightly better than the ASR. The discussion about surfability in Section 6.6.3 discusses the reasons for the poor wave form and inconsistency. Concerns surrounding the ASR location and the geotextile SFCs were common responses. The surf community seemed to perceive the project as a failure that could have been avoided if the designers and council had consulted those with more local knowledge of the surfing conditions. The errors made in the location choice and design flaws at Boscombe provide important lessons for future projects.

7.4.5 Health and Safety

A well-documented point raised in the cluster analysis of the dangers associated with surfing at the ASR and the issue of liability and responsibility if somebody was to be seriously injured. This was discussed previously in Chapter 5 in relation to the materials used and in Chapter 6 in relation to the potential for rip current enhancement. Health and safety is an important aspect of planning coastal works; materials, crest elevation and location to the shoreline all influence risk. Secondary effects such as rip currents and exposure of submerged sections of the structure between waves needs to be considered in the design process (Jackson et al., 2001). Since the ASR has been deemed unsafe and closed to the public Bournemouth Borough Council are removed from responsibility. It is questionable as to whether they were liable if a serious accident had occurred in current UK law. Safety is increasingly important to avoid injury and litigation from the increasing number of surfers (Jackson et al., 2002). The structure is still a magnet for the surf community, even with bags missing from the crest of the structure, this poses a risk to those who are not local to the area or have good knowledge of the sea. Few coastal protection or improvement projects have addressed the issue of surf amenity and safety (Jackson et al., 2002). Coastal engineering has historically altered, created or destroyed surf amenity or created dangerous conditions for surfers (Scarfe et al., 2009b). In other cases, inadvertently, coastal works have improved the surf conditions for some surfers but with a high risk factor, for example at the San Sebastian Inlet, US "First Peak" (Slotkin et al., 2009), "Supertubes", Portugal and Gold Coast, Australia "Superbanks".

Issues associated with surfer safety arise from equipment (own or another's) or misjudgment of personal capability in the water and around wave driven currents. Hay et al. (2009) investigate recreational surfing injuries in Cornwall, UK where they sampled 212 patients and found 90% with minor injuries (lacerations, bruising, fractures and sprains) and 10% with serious injuries (requiring hospital admission). They find a higher than expected occurrence of shoulder dislocations, and discuss spinal and neck sprains, as well as fractures to the limbs, skull and spine in the study. The study recommends the increased use of protective headgear to be considered. The more experienced surfer surfing on larger waves has a higher relative risk of injury (Nathanson et al., 2002) but the most common reason surfers cite is that there is simply "no need" for headgear (Taylor et al., 2005). Clearly, surfing poses a serious and therefore potentially life threatening risk to those participating in the sport. However, there is an unwritten acceptance of personal risk when entering the natural environment as a surfer.

The natural risk taken by a surfer is shifted if the environment has been altered to create a new surf break, liability might be shifted towards those who invested in or designed the structure. Boscombe ASR presents a unique coastal management challenge in Europe for which there is no precedent and little pre-existing management capacity (Fletcher, 2011). The research conducted by Hay et al. (2009) illustrates the danger to surfers, especially the novice and low ability wave rider. It was described in Section 6.6.4 that teenagers and males are more likely to suffer an incident in the water. It should be considered then that novice surfers on the ASRs are encouraged to protect themselves e.g. by wear head protection as collision with the ASR is more likely than when surfing at the beach. There are lifeguards watching the ASR at Boscombe 365 days of the year, this is vital to avoid more serious injury or death. Day to day governance of the ASR must be undertaken by trained lifeguards who appreciate the ability of the surfers paddling out to the ASR. Other governance challenges that will face the Boscombe ASR amongst others include overcrowding, a lack of surf skill and etiquette amongst visitors, conflict between different users and localism (Fletcher, 2011).

7.4.6 Novelty

The results from this research support the suggestion that a novelty period attract the attention of surfers nationally and, depending of the success, the ASR would be taken up as a surfing destination or abandoned in favour of natural, more consistent surfing breaks. The discussed "novelty factor" of the Boscombe ASR wore off after 6-12 months (Fletcher, 2011; Rendle and Esteves, 2010). In Chapter Section 3.6, the Boscombe Seafront Ranger data and the RNLI data was introduced highlighting tourism trends. Increasing numbers of tourists came to the beach area in the summer months, which then plateaued. The initial increase of surfers attracted during the summer and autumn months peaked during 2010, after which a decline in numbers was observed. This secondary data supports this socio-perception research and highlights the short lived interest in the ASR. The frustrations of the Boscombe ASR being inconsistent are reflected strongly in the negativity towards the project from the surf community and hence why there was a short novelty period.

When wave do break at the ASR, particularly when the ASR was well formed near its completion date overcrowding became an issue. Since the ASR breaks infrequently there has been a loss of interest in the break and surfers are tending to ignore the surf spot in favour of their local or normal break. There are less travelling surfers at the ASR break, however there are more surfers generally along the beach break. There are two focal points described by Fletcher et al. (2011) as regions that will suffer from overcrowding and where conflict between users and potential accidents are more likely; the Boscombe ASR itself and in the lee area of the reef. The reef is not being used by novice surfers, the distance offshore and the infrequence of breaking mean it is unlikely to draw the attention of travelling surfers with little or no experience. However, the risks associated with the area in the lee of the ASR are apparent in the RNLI incident data as introduced in Chapter 4 and discussed further in Section 6.6.4. The increase in tourist number is reflected in the number of incidents attended to by RNLI lifeguards at the coast. The numbers are increased both at the east and west sides of Boscombe Pier however the more popular lee section of the reef is where accidents occur more frequently. The danger and the misconceptions of safety to novice surfers at the ASR 2011 should also be extended to the lee area of the ASR where collision and rip associated incidents are possible.

7.4.7 Environment and Ethics

The perceived environmental implications surrounding the ASR outweigh any perceived positive benefits. The physical changes to the seabed such as coastal erosion and potential or observed changes to the beach break were notable concerns. These are real concerns as this research highlights change to the geomorphology in Chapter 5. Direct users of the ASR did not comment on any benefit to coastal management or protection. Marketing or initial advertising is thought to impact these comments, all from respondents who had not visited Boscombe. Respondents expressed the benefits an ASR may have for biodiversity or fisheries, again these are tentative comments that had little direct observational backing. Concern is equally expressed for the potential damage to marine ecosystems or life on the seabed. Theoretically, man-made structures can provide the main function but not all the functions of a natural break/reef i.e. 3D complexity for fish populations (Bortone, 2006). Research regarding the use of geotextile material in providing a complex and stable habitat for marine growth is poor, more emphasis is placed on rock, concrete and metal in the literature (Chapter 2). This discussion will be continued with the fishers and anglers responses in Chapter 8.

The surf community globally regard the lack of research into ASR technology a significant concern, that the structures may prove to damage natural surfing waves. Some waves break only under specific swell and wind direction at the site making the occurrence of surfable waves rare but special, almost spiritual to surfers. Other natural reef breaks provide more consistent surfing (a local example would be Kimmeridge, Dorset), however these reefs are exposed to a more suitable wave climate and bathymetry. Surfing that is provided by these natural sites is referred to as "cultural services" when discussions of ecosystem services arise, they are combined with non-commercial fishing and other recreational amenity (Fisher et al., 2009). To effectively include surfing amenities in coastal management of ecosystem services, there needs to be legislative frameworks for considering surfer's objections to coastal activities (Scarfe et al., 2009b).

Additionally, even if ASRs are proven to be successful, they could be used to replace a natural surfing wave interrupted by industrial coastal engineering. Mitigation for natural break damage using an ASR elsewhere in the region. Recent years have seen numerous attempts to protect surfing waves and stretches of coastline that are traditionally sites for surfing across the world. Similar to the Marine Protected Area (MPA) concept in Europe, the next few decades will see surf breaks being protected, as they are becoming elsewhere in the world by Surfrider Foundation (US and Australia). National surfing reserves (NSR) implemented by Farmer and Short 2007 are described as being "recognised by the NSR-Australia and the local community for the quality and consistency of its surf and its long-term and on-going relationship between the surf and surfers, [which extends to] the beach and the adjacent surf zone, [and to have] features that intrinsically enhance aspects of the surfing experience, including structures such as surf clubs or places considered sacred by surfers for a particular reason". This definition could be extended to include wave breaking, preconditioning, and sheltering of a surfing break (Scarfe et al., 2009b). Another study that comments on how "the tradition of the beach is not yet understood or accepted in intellectual terms, although it is instinctively endorsed by the vast majority of Australians" (Dutton, 1985), this is also true to UK surfers. The additional non-market value ecosystem services such as well-being, health and happiness; are provided by the redevelopment of the seafront and the provision of amenity. It is has not been clear that the ASR has provided these benefits directly. We know little about the full value of surfing to individuals and to communities in any formal sense (Lazarow and Nelsen, 2007).

The process of replicating nature has associated ethical implications, the design of new "artificial" surfing breaks have therefore become an interesting argument in the surfing community. Some representative bodies for surfers i.e. Surfrider (global) and Surfers Against Sewage (UK) (Wheaton, 2007) are unsure of their position towards ASR technology for three core reasons. Firstly, the unknown impact the new ASR may have on the natural local surf break; damaging one surf wave to create another, the fundamental design issues and environmental concerns. Secondly, an ethical dilemma is posed on the development of ASRs through replacing natural capital with man-made capital. ASR construction might be perceived as an uncertain trade-off and whether the loss is justified by the benefits of all the new artificial services provided. The overarching view is that surfing is, and always has been natural; it is about closeness to the natural environment by its very essence and should remain that way. Finally, as discussed previously, the consequential loss of surfing amenity by human intervention would be replaced with an artificial reef structure. This mitigation has already happened unsuccessfully in El Segundo, California in 2000 where Chevron replaced the lost amenity (due to the construction of an oil refinery) with an ASR (Nelson, 1996; Nelson and Howd, 1996; Borrero and Nelson, 2003), the reef was subsequently removed after partially sinking. The ability to reproduce natural environments with ASRs is yet to be trialled (Scarfe, 2008).

Direct users comment on the visual impact of Boscombe ASR; most respondents found the ASR aesthetically unacceptable. Unappealing to visitors, the ASR is covered in brown-green algae and since the crest of the structure breaches the surface it is visible from the beach. The unnatural appearance of the geotextiles is viewed as unattractive compared to the surrounding sand beach area. Sustainability in the surfing industry is regularly coming into question. There is a drive to use more natural materials such as wood for boards and alternative polymers to the neoprene used in wetsuit manufacture. The shift away from plastic based products is highly desirable throughout the community, the ASR construction of a polymer based geotextile goes against this and has proven to break up in the marine environment. From an ethical perspective the issues surrounding the use of artificial structures is not reflective of the fundamental nature and origins of surfing of preserving the environment. The ASR construction caused disruption locally and the clear up of the site was poor; cable ties, ropes, tools and other debris were discarded onto the seabed. Future environmental impact assessments (EIAs) of coastal and offshore engineering can now be based on the now-significant volume of science on surfing research (Scarfe et al., 2009b).

7.4.8 Impact on Tourism

Seen by some in the surf community as a trial run or test case, the project has been hailed as innovative and much needed publicity for the seafront regeneration project. The increased tourism in Boscombe might not be directly linked to the ASR however, there is increased interest in the site from the growing novice surf community. The advertising and promotion of the revitalised surfing destination, the surf schools that provide lessons, reduced travel for many in the south of England rather than Cornwall or Devon and gentler surf for learner surfers. The Bournemouth region has always been a popular destination for holiday makers, this additional amenity appeals to all ages of holiday maker and is an novel focal point for the seafront. Unfortunately, the project image was poorly managed which has reflected on the surf community and other stakeholders in Boscombe. Wider implications for the perceived success of the project in other stakeholder groups and seafront visitors is discussed in Chapter 8. Respondents feel that poor management decisions have given the general ASR concept a bad reputation.

Surfability of waves depend on the surfers skill as well as the wave formation. Different conditions are needed for different wave riding sports. The skill level of the surfers targeted and the need for safety for all surf users also has a large impact on where the perfect surf is located (Jackson et al., 2001). The level of UK surfing and many different forms of wave riding is partly due to the inconstancy of the wave climate and the bathymetry along the coast, when compared to US and Australian counterparts. Stand-up surfers (short and longboarders) are more negative about Boscombe ASR and refer to it as a bodyboarders wave. This is often commented on in a derogatory manner due to the expectations for consistent stand-up surfable waves. As Jackson et al (2001) points out the ‘perfect’ surfing wave for one group of surfers may not be suitable for another group. The ASR designers were expert medium to short board surfers that consider the ‘perfect’ wave to be a challenging hollow, plunging wave. However, surfers use a multitude of surf craft with different performance that require different skills and types of waves. Some stand-up surfers are unable to surf the Boscombe reef partly due to the steep wave face and short ride length, it is frustrating for a novice or intermediate stand-up surfer due to the level of ability needed to ride the break (Davidson, 2010). It is suggested that the level of surfing ability required is higher than that in the original design i.e. 7 or 8 as opposed to 5 or 6 on the Hutt classification of surfing breaks and ability (Hutt and Black, 2001). This has alienated some of the more novice surfers keen to use the new facility and caused frustration in the surf community.

Bodyboarders were more positive about Boscombe ASR, seeing the wave as a new venue for their sport. Generally, bodyboarding is an overlooked sport, with stand-up surfing taking more attention due to media driven image and the number of participants in stand-up surfing. Waitt and Warren (2008) discuss the macho approach by stand-up surfers towards bodyboard surfers as "failed men". This unfortunate attitude in the surfing community was apparent in this research. However, the potential for variation provided by the wedge shaped bodyboarding wave that was created by the ASR and a new challenge in Boscombe. Increasing the variety and different forms of wave riding available would benefit the UK surfer's skill and ability levels. Inconsistency in regular swell conditions and locality of surfers to ideal bathymetry for the creation of surfable waves. Perfected ASR technology on a much larger scale (ASR footprint) may provide an associated increase in surfing standard due to an increased frequency of consistently surfable waves.

The cluster analysis indicates how surf tourism is often associated with surf related issues such as localism, due partly to overcrowding at a location. These phenomena are well discussed in the literature (Ishiwate, 2002; Young, 2000; Waitt and Warren, 2008; Scarfe et al., 2009b; Fletcher, 2011); the ownership of a surfbreak has been known to cause verbal abuse towards outsiders, even physical violence in the water at particularly crowded breaks. Whilst tourism is seen by the coastal community as a benefit of increased tourism from the surf industry, local water users are often not as positive about increased numbers in the water. Physical injuries could therefore be caused by accident (e.g. collision head with surfboard) or deliberate aggressive behaviour (e.g. fighting arises due to perceived ownership of a surf break and overcrowding pressures from travelling surfers). This occurs where there is one small "take-off" area (from where the surfer paddles / stands up on the wave) and the competition for the wave causes tension. This is a common problem in the surf community reported initially in 1970's Hawaii where Eddie Rotnman founded 'Da Hui' a gang to protect culture and the native surf etiquette. This 'locals only' attitude spans across boarders and between nations. These problems described by the surf community are similar to those predicted by Fletcher et al. (2011) who describes the likely governance challenges that will face the Boscombe ASR; overcrowding, a lack of surf skill and etiquette amongst visitor, conflict between different users and localism. They found that localism would be exasperated by a difference in attitude and behaviour between locals and visitors using the ASR.

7.4.9 Planning and consultation

Recent studies into the implementation and management of marine protected areas (MPAs) and MPA networks are reflective of the ASR project. MPAs are recognised as being an effective and necessary conservation tool for protecting marine biodiversity and providing a base for the sustainable management of marine resources (Rees and Rodwell, 2012; Kelleher, 1999; Sobel and Dahlgren, 2004). In order to improve the status of the UK oceans and seas, a legal framework is being developed; Marine Plans, guided by the Marine Policy Statement (HM Government 2011) will enable the designation of a new type of MPA called a Marine Conservation Zone (MCZ) (Rees and Rodwell, 2012). Through aligning MCZ objectives with fishery objectives and collaborative monitoring programmes, it is possible to create systems for the co-management of marine resources and maintain a sustainable fishing industry (Rees and Rodwell, 2012).

UK surfers have been interviewed in retrospect for this research, as opposed to a consultation during the planning stages. Results presented here indicate that surfers want to be more involved with the Boscombe ASR and any further artificial wave development. As with the MPA example, the success of a surf reef will be dependent on the interaction of the direct users of the facility and how well it is managed. The functionality misconception was that the surf will always be good regardless of the prevailing meteorological and oceanographic conditions (Fletcher, 2011). Management of expectations within the surf community could be achieved through ongoing consultation with the surfing community throughout a project lifetime. As with the MPA, managers who miss out the social context in management decisions and fail to acknowledge the unique nature of fishing activities and responses to change are risking the future ability of MPAs to meet all stakeholder needs (Rees and Rodwell, 2012).

To calculate a true estimation of surfing benefits at Boscombe ASR has not been possible due to the short life span of the project. During the 18 months that the ASR was open for surfing, the project was not considered successful by surfers as they indicate they are unlikely to return to surf the ASR. The project was deemed a failure in the media since there was little positive response generally from the surf community. The world class surfing break at Mundaka, Spain is an example of how a small rural coastal community (population of 1900 people) can benefit from a well-developed surf tourism market where it is estimated the total economic impact is $3 million per annum (Murphy and Bernal, 2008). This valuation however does not include any valuation of surfers enjoyment, pleasure or cultural aspects therefore the socio-economic value would be far greater. An economic tool combining economic assessment with measurement of the participant's value of the activity is necessary for surfing to be seen as a viable part of coastal economics and its impact considered in any development plans (Murphy and Bernal, 2008). It is suggested that future projects should consider carefully in early stages of the project how this might be considered and included in the valuation of surfing sites before and after constructing an ASR.

7.5 Conclusions

In this chapter a comparative study of the social demographics of the direct users, that is the UK surf respondents, was provided and compared to other similar studies. The majority of respondents are 30-40 years, well educated, have employment, and earn over the average UK income. The results supports the literature that the surfing community is educated and qualified, therefore able to provide valid and educated responses to a consultation process. In terms of travel and expenditure, UK surfers are travelling greater distances to participate in their sport compared to their US and Australian counterparts, spending far greater on fuel and reducing spending power at the coast.

The perceptions and opinions of the surf community were analysed and a thematic framework of the benefits and burdens is provided. The study of direct users highlight that the regeneration brought with it some enhancement to the tourism industry, but the ASR construction did not enhance the surfing experience. Boscombe is now on the surf map and the ASR generated some initial general interest from the surf community. The lack of consistency and wave quality has meant this interest has not been sustained. The surf community believe the ASR has provided a marketing opportunity for the town and seafront surf shops. Generally, the surfing community remain positive about future development and construction of ASRs in Europe and globally. Emphasis is placed on greater research into the local area and inclusion of the community, both direct users and indirect users in the design stages. The community feel that with stakeholder consultation many of the pitfalls of ASR construction could be avoided, particularly in physical design and environmental conditions. The attitude of most surfers is that although they are interested in ASR technology, the direct users would not appreciate an ASR at their local beach as many fear it would interfere with the natural breaking waves.

The final analytical chapter follows which addresses the indirect users of Boscombe ASR; the stakeholders including those that were predicted to benefit from the ASR construction. Primary data is collected through a series of surveys and interviews and the results presented and discussed.

Chapter 8

The coastal community response to the Boscombe ASR

8.1 Introduction

The ASR was built primarily for surfing, however claims have also been made regarding the benefits of the structure to the wider coastal community. As discussed in Chapter 1, a wide range of claims regarding ASRs and geotextile technology were made, from ecological enhancement to shoreline stabilisation. Claims regarding the economic potential of ASRs and economic contribution from surf tourism are a particularly powerful selling tool aimed at local councils. Business people, entrepreneurs and residents may have been enthused by ASR construction due to marketing claims; "multi-purpose soft reefs and surfing greatly increase tourism and property values" (ASR Ltd., 2009). If proven to be successful and these claims can be substantiated, ASRs offer an exciting innovative new commodity both in terms of coastal management and social use.

> "International high-powered studies by reputable agencies all over the world show that multi-purpose soft reefs bring 10-80 times their full construction cost back to the community; through better, safer beaches, coastal protection and visitor spending" (ASR Ltd., 2009).

In Chapter 7, direct users were the target beneficiaries for the ASR project surveyed using a questionnaire. This chapter concerns the indirect users of the ASR, stakeholders that may be impacted by the project such as Boscombe residents, seafront visitors and business stakeholders. Essentially, this research aims to quantify the social and any percieved economic value the ASR may have for stakeholders. The objectives of this chapter are to:

- Determine changes in attitude towards the ASR using time series analysis of seafront visitors, both residential and tourist.
- Evaluate public perception and opinion of the Boscombe ASR in terms of benefits to local stakeholders and economic change.
- Quantify the social value of the Boscombe ASR to the wider (non-surfing) tourism industry and fisheries.

There have been social and economic benefits claimed regarding the construction of Boscombe ASR . However, the impacts from installing an ASR are not widely discussed in the literature. Like any man-made coastal structure, an ASR has the potential to alter the coastal community and business dynamics in both positive and negative ways. Whilst some stakeholders benefit from the ASR construction, there is a risk that any benefits are outweighed by the burden to others in the community. This chapter addresses the need for further engagement with the community and the necessity for the encouraging support for ASR development through the stakeholder consultation. Boscombe ASR has numerous stakeholders, including fishers, interested in this area of the coastline and the ecosystem services it provides. There are clearly great opportunities for stakeholders to benefit, however without consultation with the community the true range of perception and opinion cannot be taken into consideration.

In general, surfing has been shown to enhance coastal economies through additional opportunities that arise for the tourism industry (Butt, 2010). The results of a 2004 survey conducted by the Cornwall County Council and the South West Regional Development Agency in the UK showed visiting surfers spend approximately 8.5% more in Cornwall than the average visitor (Butt, 2010). The study showed the surfing industry turnover was £64 million in Cornwall, about 20% more than the sailing industry and twice as much as the golf industry. Similarly, a Spanish study in 2008 investigated the impacts of surfing on the small coastal community of Mundaka (population size 2000), where they showed surfing attracts 30,000 visitors to the town per annum, supports 95 jobs and contributes up to US$3.4 million £1.9 million per annum (Murphy and Bernal, 2008). A study of the confluence of surf tourism, ASRs and environmental sustainability in Florida found that the overall average daily spend per surf visit is about US$60 (Slotkin et al., 2008). This is consistent with other similar studies in the US (Nelson, 2007) and on the Gold Coast, Australia (Lazarow and Nelsen, 2007). Lazarow (2011) also gives a global estimation for the value of surfing at US$15.5 billion calculated from the three largest international surf companies based solely on surf equipment and clothing alone. It is clear that surfers spend money on equipment, travel and accommodation given good natural surf conditions. The question remains as to whether this can be replicated by creating new man-made surfing amenities.

There are few references to the socio-economic impacts of ASRs in the literature. In a cost-benefit analysis for the Northern Gold Coast Beach Protection Strategy (NGCBPS) (Raybould and Mules, 1999), a project amounting to AUS$8 million which included both beach nourishment and the construction of an ASR, a high economic return value of 1:60 was estimated. The benefits were attributed to the protection of the beach face from cyclones and storms which in turn protected against loss of valuable tourism revenue. This high cost:benefit ratio is often misquoted in ASR Ltd. sales literature (ASR Ltd., 2006) as the achieved cost:benefit ratio of the Narrowneck ASR. However, the ASR was only part of the overall NGCBPS, and there have been no economic studies that evaluate the ASR directly. Evidence of the benefits of the ASR itself is lacking (Slotkin et al., 2008). It has been acknowledged that the transfer of surf tourism activity from other popular surfing locations on the Gold Coast to Narrowneck would mean that "there would be no net benefit to the region" (Raybould and Mules, 1998). It remains to be resolved as to whether the Narrowneck ASR was successful in generating an economic benefit to the region directly through surfing since diving and fishing at the ASR is reportedly more popular.

Slotkin et al (2009) highlight that the assessment of sustainability of surfing is hampered by the paucity of economic data and the subjective interpretation of success . These same issues arise whilst addressing the economics of ASRs. The benefits of ASR construction to the local community are therefore debatable and heavily reliant on economic monitoring pre- and post-construction. An independent assessment of the proposal for an ASR in Florida significantly undermines the claim of a 1:4 cost:benefit ratio (Slotkin et al., 2008) . The authors state that the project recreational benefits were unlikely to justify costs since uncertainty surrounded the economic benefits of holding surf competitions at the site; the original economic analysis presumed to take these competitions as a matter of fact. In a proposed ASR project for Geraldton in Western Australia, it was claimed that Narrowneck ASR could generate $1.5 million per annum through tourism, with 97%

of this income being re-spent within the city (Rafanelli, 2004). However, no cost:benefit ratio was estimated and there was no discussion of potential income from the ASR after the first year. This reef has not been constructed and so no figures exist to support this optimistic claim.

Described in this chapter are two methods for collecting data on the opinions and perceptions of the coastal community: a) a quick-fire interview of visitors at Boscombe Seafront over a three year period, and b) a detailed structured interview aimed at business and enterprising stakeholders collected over a 3 month period. The methodology section outlines the objectives, survey design and provides detail on the two sampling techniques used for data collection for this chapter. The results section follows that explores seafront visitor (both residential and tourist) results; the distances they have travelled, the duration of their stay in Boscombe, the reason for choosing Boscombe seafront, and their expenditure when visiting. This reflects changes in behaviour of visitors over a three year period post-construction. Following this, results from the business and local stakeholder survey are examined. A thematic review is presented to ascertain the opinions and perceptions of business and other interested stakeholders. The discussion brings these two sets of results together.

8.2 Methods

8.2.1 Interview design

Two interviews were designed; 1) a face-to-face survey was developed to determine the temporal changes in both attitude towards the ASR by Boscombe's seafront visitors and this group's expenditure pattern at the seafront (Appendix B.B), and 2) the Boscombe business interview was aimed at understanding local business people and other stakeholders opinions of the ASR and any economic benefit they have received since the ASR construction and whether there were temporal changes, respondents completed this survey either online or face-to-face (Appendix B.C). The face-to-face survey interview was employed due to its simplicity, cost efficiency and ease of being replicable quarterly. The questionnaires used for interviews were submitted to the University of Plymouth ethics committee, approval was recieved to conduct this research in the UK.

Pilot studies of both surveys were undertaken within the Marine and Coastal Policy research group at Plymouth University and with a test group of 50 stakeholders at Boscombe

Seafront. The results revealed that respondents were reluctant to be questioned for more than 5 minutes, particularly those doing watersports in the winter. The final survey was shortened to quickly elicit key data required. A pilot study revealed 100% resident visitors to the town centre none of whom were attracted to the area due to developments at the seafront. The town centre is dilapidated and does not hold much interest for tourists, therefore visitors to the town were not questioned as part of this survey. The Boscombe business interview was also piloted with three Boscombe stakeholders to gain feedback of on the questions from the perspective of those working in Boscombe; a surf shop owner, restaurant employee and a hotelier. Response from the pilot group from Boscombe indicated that the necessity to divulge financial details would put business respondents off, these questions were consequentially made optional to gain a better response rate.

Seafront visitors are described simply as anyone walking along the seafront location. They are further defined as resident (less than 2 miles from Boscombe) or tourist (greater than 2 miles from Boscombe). The visitor may be at the seafront for recreational or work purposes, some were passing through (i.e. walking or cycling) whilst others were visiting Boscombe seafront purposefully. The two mile radius is given as a guide when communicating with respondents as it encompasses Boscombe residents living along the coast and inland. The town centre is approximately 1 mile (2.2 km) inland from the seafront and urban sprawl extends another mile north of the centre. Temporary residents are defined as second home owners living for short periods in Boscombe, usually in holiday periods. The data were collected was: distance travelled to Boscombe, duration of stay (if staying in Boscombe), expenditure per day, and reasons for visiting the seafront and basic demographic information. Respondents were asked to estimate their daily expenditure per person including; food, accommodation, transport, entertainment, parking, shopping expenses, and any other costs incurred. From the reasons for visiting it was possible to differentiate between those who had come due to the regeneration of the seafront and those who had been attracted by the ASR. All participants to this survey were randomly selected and interviewed by the author.

The Boscombe stakeholder survey required more detailed responses and took approximately 30 minutes to complete the interview. The stakeholder interview was designed to collect data to realise any economic implications of the ASR and the opinions and perceptions of stakeholders. Five main groups were identified as most impacted by the Boscombe ASR; fishers, hospitality, shops, sea users and other. Data collected was specific to the groups but included general socio-demographics, history of business or background interest in Boscombe, details of the business or activity and how this has changed both temporally and spatially, net income and profit changes. Likert scale questions were used to gather opinions and perceptions of the ASR, and opportunities to express perceived advantages (benefits) and disadvantages (costs) of the ASR, and to expand on answers were present throughout the interview.

8.2.2 Data collection and analysis

For the seafront visitor survey, 10 surveys were conducted between December 2009 and August 2012 and represent one survey per season. These quarterly surveys represent a 32 month time frame starting shortly after the construction of the ASR was completed in November 2009. The surveys were carried out on Boscombe beachfront promenade; a 50 m stretch between the pier and the ASR. The location was chosen due to the locality of amenities such as parking, shops, restaurants and beach side facilities as well as vicinity to the Boscombe ASR. All visitors to the seafront were approached and asked if they would be willing to answer a few questions regarding tourism at the seafront. The data collection took between 2 to 3 hours between 12:00 and 15:00 hours for every survey session.

Interviews were conducted over a three month period between 1st February 2012 and 1st May 2012 for the business survey. This period was chosen to avoid the peak trade period of the year more time could be given to responding to the questions in the interview. The combination of using web-based and face-to-face interviews enabled as many stakeholders to engage as possible. Advertising for the survey and an invitation to be included in the research was made through television (BBC news southwest), radio (local independent) and social network sites (Twitter and Facebook). Invitation through email was conducted at the specific target groups. A representative group of at least 5 individuals per stakeholder group was considered a feasible and realistic sample size given the size of Boscombe and the number of businesses, this was achieved is all the main stakeholder groups. Where the total population of the group was unclear, respondents were asked to provide contact details of individuals who fit the sampling requirements. This snowballing technique (described by Oppenheim, 1992) enabled a higher response rate to be achieved. This was particularly the case for the ‘commercial fishers’ and ‘sea user’ groups where individuals were problematic to talk to online or face-to-face without an introduction.

A thematic review of the qualitative responses in the business interviews were carried out to address objective 3. This process is similar to the thematic review described in Chapter 7, allowing comparisons to be drawn between the direct users of the ASR and the indirect users. The respondents were requested to expand on answers they provided, particularly after being asked a series of Likert scale questions. They were also gived the opportunity to provide any perceived advantages and disadvantages the Boscombe ASR may have created for their business or activity. The results were grouped into themes using NVivo9; economic, environmental and social. The benefits and costs of each of these themes were then analysed.

Microsoft Excel and SPSS were used to analyse the quantitative data collected. To enable statistical analysis, the mid-range value was used for variables such as expenditure per day and income by taking the arithmetic mean of the maximum and minimum value of the range to obtain a single expenditure value per range (Dodge et al., 2003). Regression analysis was performed where appropriate in order to highlight general trends in data. Further numerical and statistical exploration of the data was conducted with SPSS to perform analysis of variance (ANOVA) and further explore the data.

8.2.3 Boundary conditions

The seafront visitor research was limited by the availability of surfers (and watersports enthusiasts) at the time of the surveys, the online surf questionnaire was later designed to capture this group (as presented in Chapter 7). There is an indication of seasonality influencing in the seafront visitor survey data set, which is to be expected. The global recession may be a confounding influence on the low expenditure of visitors in Boscombe. The socio-economic value of ASR construction to a local community is yet to be fully understood and further research is required. Since the novelty factor for the ASR at Boscombe dropped rapidly whilst tourism continues to be strong (as discussed in Chapter 4 and 7), the surveys focused on whether the same level of tourist attraction could be achieved without the construction of an ASR. Though limited to a short 32 month period, the findings of this study provide clear indications of attitudes towards Boscombe ASR in the period soon after construction until after the ASR closure.

Additional boundary conditions are associated with questionnaire fatigue of some businesses and residents, the local University students had also been surveying. The ASR and regeneration at the seafront has also been a popular topic with undergraduate projects. The stakeholders I approached had developed a strong "leave me alone" attitude towards the end of the collection period. Some stakeholders felt that they could not respond to the survey stating that the “ASR does not impact my business”. After prompting this as an important result I would like to capture some stakeholders did then respond, but the majority felt it was not worth their time. A clear boundary condittion of this data collection process was getting stakeholders to engage and take the view their business is important enough to warrant having an opinion.

This study represents an investigation into the potential of ASRs to enhance a local economy through tourism. It found that while the ASR project provided a focal point for the regeneration of Boscombe Seafront, it was the regeneration itself that drove the additional economic benefit felt by local businesses. The two projects are impossible to seperate and provide economic analysis for the ASR, however this study finds alternative ways to understand the social and economic impacts of the ASR through perception analysis. These impacts remained at the coastline and have not been felt in the town centre.

8.3 Seafront visitor results

This first survey captured tourists and residents at Boscombe seafront in order to satisfy the first objective; to determine changes in attitude towards the ASR using time series analysis of seafront visitors, both to the residential and tourist visitors. It also goes some way towards addressing the second objective; to evaluate public perception and opinion of the Boscombe ASR in terms of benefits to local stakeholders and economic change. Objective 2 will be further investigated with the business survey in Section 8.4.

8.3.1 Socio-demographic of seafront visitors

A total of 523 respondents were questioned randomly during 10 survey sessions. Approximately 1 in 4 of the visitors approached completed the survey. Those reluctant to be questioned were predominantly the older generation and parents with young children. There was no pseudo replication in the data. Respondents were questioned on a random basis by the same interviewer. None of the respondents mentioned that they had previously participated. The mean age of visitors to Boscombe seafront was 43.4 years (sd = 43.2). The modal age category was 25-34 with 23.9% of respondents in this age group (Figure 8.1a). There was a gender bias towards men with 61.8% male (n = 323) and 38.2% female (n = 200) respondents. 51% were tourists, 44% were residents and 5%

temporary residents. To determine whether there where changes in visitors to the seafront overtime (objective 1), these data are divided into seasons to illustrate potential seasonal fluctuations in visitors number (Figure 8.1b). The summer and winter months attract 50% or more tourists to the seafront. The autumn had fewest tourist visitors. A large temporary resident population is observed during summer months representing Boscombe's second homeowners.

8.3.2 Distance travelled

The non-resident respondents were questioned on how far they had travelled. Overall, 27% had travelled from the local area (classed as 2-15 miles) and 73% had travelled >15 miles. These data are given for the individual surveys (Figure 8.1c). No clear temporal trend is apparent in the distance travelled by respondents, although seasonal fluctuations are apparent. In the Summer 2011 survey there is a rise in the number of respondents in the >150 mile group, some of whom were visitors from outside the UK. There are more seafront visitors from the 2 to 60 mile radius during the autumn and winter month surveys. In general, higher proportions of visitors to Boscombe seafront in the >60 mile radius were recorded during the spring and summer months. The Summer 2012 survey does not reflect this same pattern and the proportion of visitors travelling >100 mile has reduced since Summer 2010 and 2011.

8.3.3 Duration of stay in Boscombe

Findings indicate that 80% of respondents were visiting Boscombe for less than 1 day (Figure 8.1d). Predictably, visitor overnight trips are impacted by seasonality; summer months are more likely to see visitor's trips being extended from a few hours to a period of days or weeks. An increase in duration of stay (respondents staying >1 night) was observed during the spring/summer seasons from 2010, 2011 and 2012; from 25% to 26% to 36%, respectively. However, an overall decrease in duration of stay (respondents staying >1 night) was observed during the autumn/winter season from 2010, 2011 and 2012; from 14%, 10% to 8%, respectively.

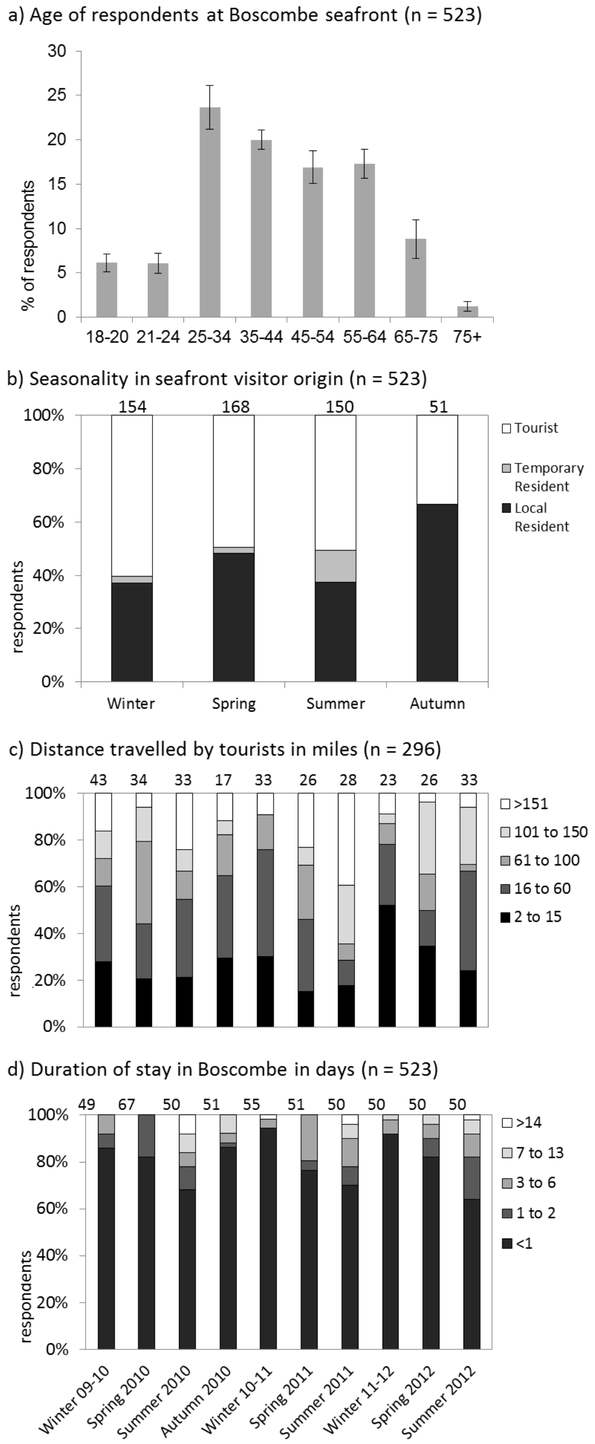

Figure (8.1). Socio-demographic results of the Boscombe seafront visitors survey; a) Age of respondents as percentage with standard error of the mean (SEM), b) Seasonality in seafront visitor origin, whether tourist or resident, c) The distance travelled by the tourists and temporary residents, in miles, and d) The duration of stay of all respondents in days.

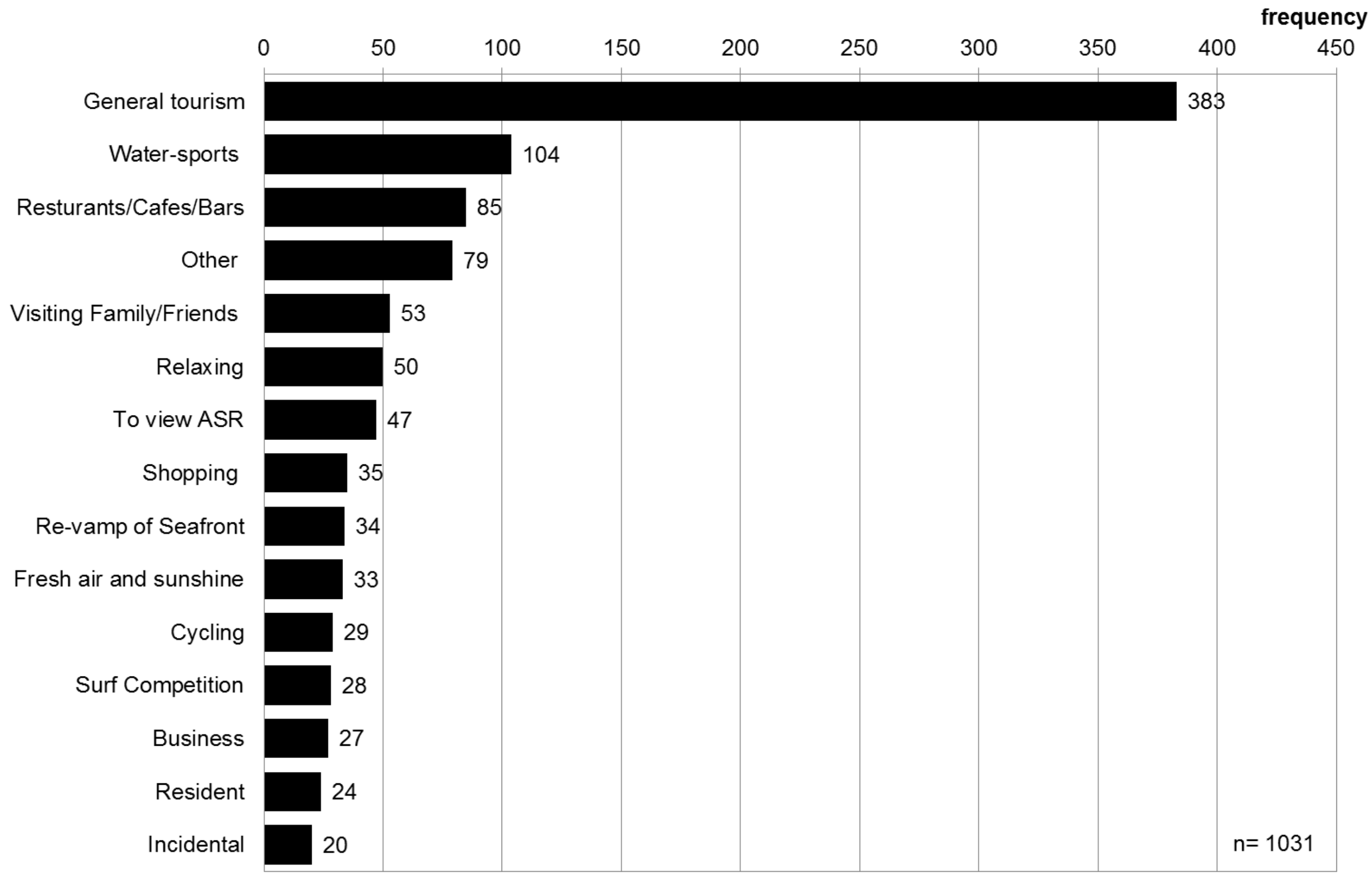

Figure (8.2). Ranked frequency table for the reasons given by respondents for visiting Boscombe seafront. Each respondent could give a maximum of three reasons.

8.3.4 Reasons for visiting Boscombe seafront

To evaluate public perception and opinion of the Boscombe ASR in terms of social benefits to local stakeholders and economic change (objective 2) seafront visitors were asked for three reasons for visiting the seafront. This gave an indication to the main attraction of the seafront to visitors. Respondents gave a total of 1031 responses, not all respondents could think of three reasons when put on the spot. 37% gave "general tourism" (e.g. walking, taking the fresh air, looking at the sea) as a reason to visit the seafront (Figure 8.2). There is a general increase in trend in the attraction of "general tourism" over the 32 month period (Figure 8.3a). The natural aesthetic attraction of the seafront are key to tourism and consistent with drawing visitors to the coast such as "fresh air", "open space" and "to take in the views".

"Watersports" were mentioned as an attraction by 19% of respondents (Figure 8.2). This category varied from families paddling and swimming (21%) to respondents partaking in more extreme sports such as kayaking or surfing activities. Of these, longboard stand-up surfing was the most popular water sport (26% of the water sports), followed by short board stand-up surfing (20%) and body boarding (14%).

Over the 32 month period studied, 4.5% of respondents provided the Boscombe ASR as a reason for their visit to Boscombe seafront. However, 85% of those respondents that replied "To view the ASR" were in the first two surveys (Winter 2009-10 and Spring 2010) indicating that there was initial interest in the ASR from seafront visitors, both local residents and tourists (Figure 8.2). Respondents replied 85 times that they had come to use the restaurants, cafes or bars and to shop, compared to 47 times the ASR was mentioned, for surfing use or as a tourist attraction. The initial interest dwindled to between zero and two respondents mentioning the reef in each survey after spring 2010. The ASR was not mentioned at all in the last three surveys. This decreased in interest is highlighted with sharply decreasing trends in reasons such as "To view the ASR" and "Renovation of the seafront" in attracting visitors to the beach front (Figure 8.3c and d). The "Restaurants/Cafes/Bars" category had a strong positive trend over the three year period (Figure 8.3b). Respondents (n = 25) that replied in the "other" group (Figure 8.2) included attractions such as watching the football (in the pub or football ground), skateboarding, attending a wedding, spear fishing, and photography.

Length of stay	Number of water-sport respondents	Number of respondents in range				
		£0-5	£6-10	£11-20	£21-50	£50+
Stay few hours	88	56	13	12	7	
Overnight (1-2 days)	3			1	2	
3-4 days	2	1			1	
5-6 days						
1 week	7	2	1		2	2

Table (8.1). Duration of stay in Boscombe for watersport enthusiasts and their associated daily expenditure category (n=100).

8.3.5 Visitor expenditure

Respondents who partake in water sports at Boscombe (n = 100) included amongst others long, short and bodyboard surfers (60%), swimmers/paddlers (21%), bodysurfers (5%), windsurfers (3%) and kayakers (3%). Water sports respondents are less likely to stay overnight (Table 8.1), preferring to stay a few hours and return the following day (12% responded they would stay 1 night or more). The surfer market is neither affluent nor willing to spend; with 73% spending under £10 and 59% saying they would spend £0-5 during their visit to Boscombe (Table 8.1). Of the total survey population (n = 523), 2% said that they were attracted to the seafront for water sports and would be staying overnight or longer. Of these respondents, 66% are spending £10 or more per day in Boscombe.

	Number of responses	Mean expenditure £(± sd)		
		Low	Middle	High
Tourists and temporary residents	295 (57.4%)	14.5 (± 23)	22.0 (± 31)	26.0 (± 28)
Residents	228 (43.6%)	2.5 (± 5)	5.6 (± 7)	8.8 (± 9)

Table (8.2). Mean expenditure estimates calculated using the low, middle and high values of expenditure ranges for all Boscombe seafront visitor respondents (n = 25), residents, tourists and temporary residents.

Expenditure estimates were calculated for all Boscombe seafront visitor respondents (n = 523). To understand the potential extremes in the data the low, middle and high value of each expenditure range were considered (Table 8.2). The low estimate provides information based on the assumption that the respondent has spent at the bottom end of the expenditure range and so provides a conservative estimate. The high estimate is calculated using the highest value in the range. These expenditure estimates are averaged over the 10 surveys to illustrate the general trend. Taking the middle values, tourists and temporary residents were found to have an estimated mean daily expenditure at the seafront of £22 per person (sd = 31) (Table 8.2). Residents had a significantly lower daily expenditure of £5.6 per person (sd = 7). The ratio of resident to tourist expenditure at Boscombe seafront is approximately 1:4 based on the mean expenditure of each group over the 10 surveys.

Using the mid-range values for each survey, temporal information on mean expenditure of visitor groups was calculated. Results show that 96% of Boscombe residents do not spend more than £20 per day at the seafront and approximately 75% of residents spend less than £5 per day (Fig. 8.4b). Comparably, 38% of tourists will spend less than £5 per day, with increased expenditure during the spring and summer seasons (Fig. 8.4a). Resident expenditure decreases and become less variable over the survey period. Results indicate an increase in the tourist visitor and temporary resident expenditures at the seafront during the first two summer seasons; from £22 (sd = 29) during the first summer post-construction in summer 2010 to £57 (sd = 72) in summer 2011 (Fig. 8.4c). Interestingly, the most recent summer survey (Summer 2012) shows that non-resident expenditure decreased to £23 (sd = 34). The high variation in expenditure can be explained by some visitors paying for accommodation whilst other tourist visitors visit family and friends and have no accommodation expenditure. The highest mid-range resident expenditure of £9 (sd = 13) was observed in the first survey (Winter 2009-10) (Fig. 8.4d). However, a similar pattern is observed to the tourist expenditure as the most recent survey (Summer 2012) indicates the lowest mid-range expenditure for the residents (£2.50, sd = 3).

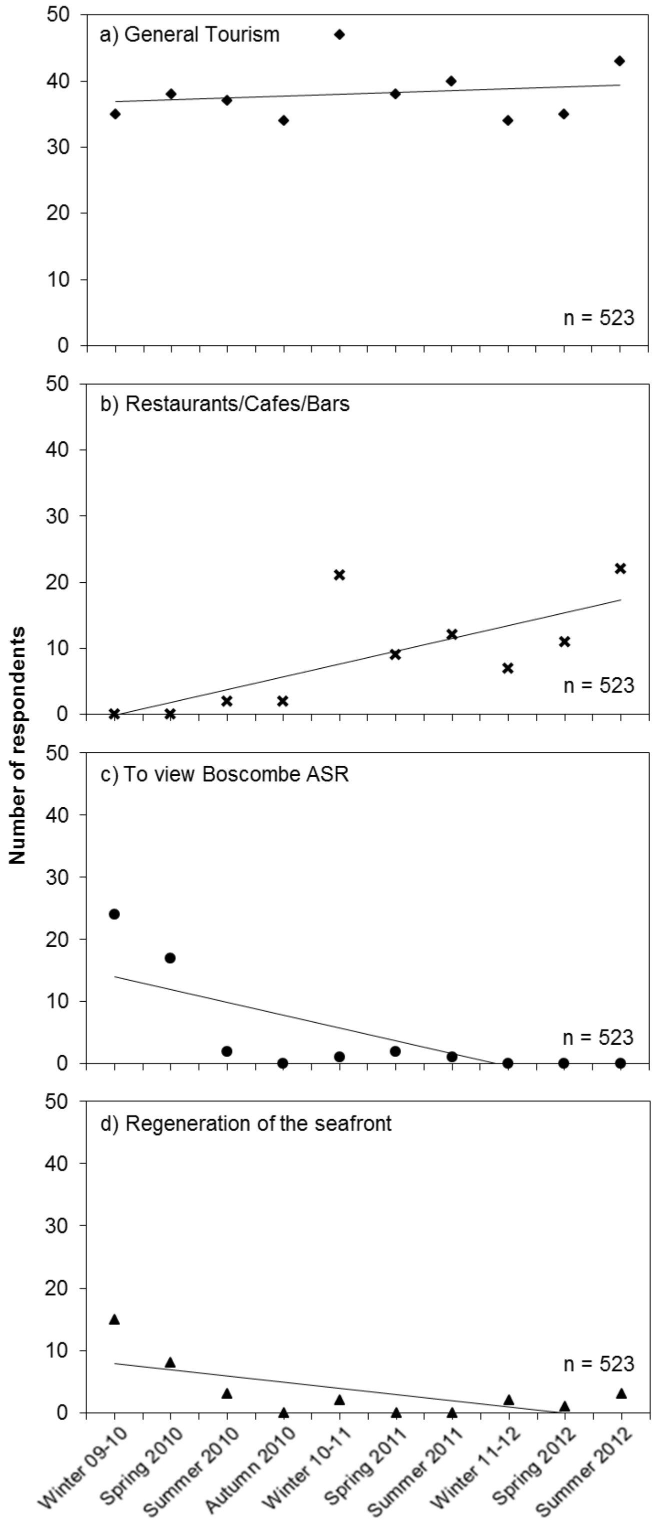

Figure (8.3). Reasons provided for visiting the seafront in the Boscombe seafront visitor survey. The key reasons for visiting of interest to this study and how they have changed over time; a) general tourism, b) the restaurants, cafes and bars, c) to view the Boscombe ASR, and d) to see the regeneration of the seafront.

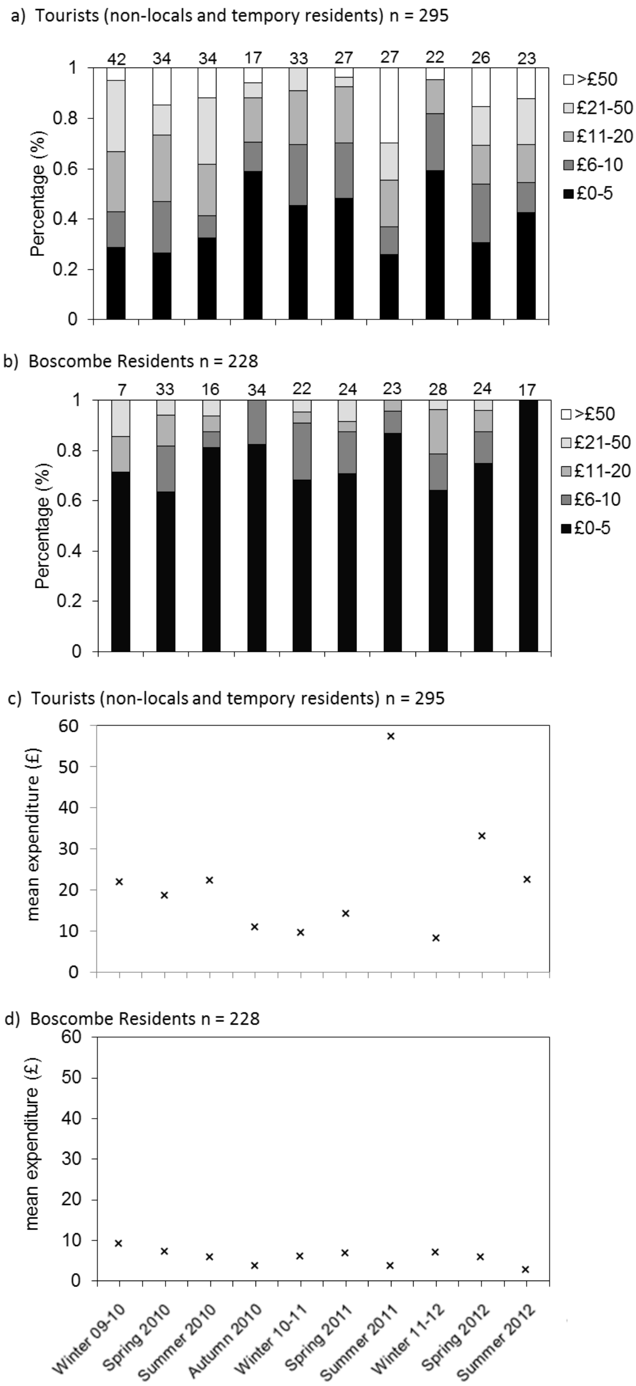

Figure (8.4). Expenditure per person of all 10 survey at Boscombe seafront; a) tourists responses (non-locals and temporary residents) and b) Boscombe residents (living in under a 2 mile radius of the seafront) responses. Mean expenditure (£) calculated using the mid-point analysis for each survey for c) tourists responses and d) the Boscombe residents responses.

	Commercial fishers	Hospitality	Shop owners	Sea users	Others	Total
Number of respondents (n)	10	14	6	8	8	46
Gender (% male)	100%	50%	83%	100%	88%	80%
Mean age (years)	39.1 (±11.2)	45.5 (±15.4)	45.5 (±17.9)	51.5 (±14.3)	39.5 (±11.1)	44.1 (±14.8)
Education (completed college or further education)	50%	93%	50%	88%	100%	78%
Mean income (£)	32,000 (±18,466)	29,000 (±10,832)	25,000 (±12,910)	20,000 (±10,000)	36,250 (±20,879)	28,695 (±15,929)
Response rate	42% from Poole 100% from Mudeford	24%	7%	29%	n/a	n/a

Table (8.3). Social demographics of stakeholders interviewed (n = 46), aimed at business and enterprise in Boscombe. Mean and standard deviation provided where appropriate.

8.4 Boscombe business results

8.4.1 Socio-demographic of business respondents

The business stakeholder respondents (n = 46) represented the diverse range of businesses in Boscombe (Table 8.3). The mean age of all 46 respondents was 44 years (sd = 15). The majority of respondents were men (80%), representing a gender imbalance. The only respondent group that had a balanced gender split (50%) was the hospitality sector. The majority of respondents (78%) gone on to further education after secondary school including vocational diplomas and technical training . The 'others' group and 'hospitality' services had the highest number of respondents completing further education with 100% and 93%, respectively. The mean income of the all Boscombe business respondents is £28,695 (sd = 15,929). The lowest earners were the sea users and highest earners were the 'others' and 'commercial fishers' (Table 8.3).

The commercial fishers landed at Poole or Mudeford, a total of 10 responded through being interviewed. An equal rate of response came from each of these locations. All fishers questioned carried out fishing activities in Poole Bay, this was a criteria of the research. Fishers who landed catch at Poole but fished offshore (or in other waters) were not included as they consider themselves unaffected by the changes to Boscombe seafront and construction of the ASR. There has been a decline in vessel numbers at Poole since 2000 from 625 to 482 vessels registered in 2012; this amounts to 23% decrease in vessel activity (personal communication Howes (2011)). Vessel registered to land commercial catch at Pool quay total 79 (Table 8.4), however in practice there are not more than 12 commercial fishing vessels (estimated by the fishers at Poole quay). A similar pattern emerges at Mudeford quay where only 5 vessels are actively fishing commercially (estimated by fishers in Mudeford). Therefore of the fishers in Poole a 42% response rate was achieved, and in Mudeford a 100% response rate was achieved.

Fishers were in the industry for a considerable time, for an average of 19 years ($\pm$9.4). The majority of fishers (70%) owned their vessel, the remaining 30% crewed vessels for other fishers. Since vessels and catch size are small, most are operate as a one man venture. Nine vessels were set up for static pots and, or net fishing and one vessel was capable of dredge fishing. The average income range of fishers is £32,000 ($\pm$18,466). The average income is above the 2011 median UK income at £26,200 (Office for National Statistics, 2011). Income from Poole Bay fisheries was approximated by fishers, the average was

49% (±29) of their total income. Days spent fishing in Poole Bay averaged at 177 days (±126). When asked about fishing effort respondents were asked for top three landed catch. Majority of fishing effort is aimed at lobster and crab (n = 10), Dover sole (5), sea bass (4) and cuttlefish (3), but also includes whelks (1), oysters (1), plaice (1) and turbot (1).

Type of fishing	Poole Harbour	Poole Bay	Christchurch
Actively Fishing	1	12	7
Shellfish / Potting only	11	23	5
Multipurpose vessels	2	16	2

Table (8.4). The 79 vessels that are registered to land catch at Poole, where they typically fish and what type of fishing activity is usual for the vessel. The boats vary from occasional to daily fishing activity (personal communication Howes (2011))

The Boscombe businesses surveyed (n = 28) were subdivided into the following groups based on business sector; hospitality, shop and others. The average ownership of a business varied greatly, with a mean 12.4 years (±13.8). Size of business is consistently small with 27 micro businesses (<10 employees, not exceeding £5.6m) and one small business (<50 employees, not exceeding £5.6m). The types of business ranged greatly; bars, restaurants, and cafes, hotels and bed & breakfasts, surf shops, a music store, an online website, a florist and a hair salon. Of the respondents that owned a business in the hospitality sector 79% claimed seasonality whereas just 33% of shop owners observed any seasonality in their industry.

The response rate to the business stakeholders interviewed varied, not all business sectors responded with the same enthusiasm to share their experiences as with other sectors. An achievable response rate was considered to be 10% sample of a group population, and ensuring there was no possibility of bias (Oppenheim, 1992). This was achieved in most respondent groups; the commercial fishers, sea users and hospitality groups had a strong response rate (Table 8.4). A 100% response rate was achieved for the two surf businesses on the seafront. Not all the shops are directly linked to the seafront and surfing, some owners were less enthusiastic due to the ASR having little influence on their business i.e. "The reef does not affect the shops in town and so I see no reason to filling in this survey", another politely declined "unfortunately, the survey doesn't apply to us because we have only been trading since November 2011, in a pure sense we have no comparison to draw on". Taking time to complete an interview on the subject was also deemed by many as "a waste of time" and seen as "a comical idea that the reef was built to enhance the town as much as the seafront". The town is still considered by shop owners to have very "few tourists" and many consider the centre to be "in a dilapidated state therefore there is no tourism to speak of". However, a response rate of 7% was achieved, calculated based on the number of shop businesses in Boscombe using an internet search (n = 82).

The 'sea user' respondents (n = 8) comprising of charter boat skippers (charter operators) whose main work are coastal tours or specialist recreation such as angling and SCUBA diving. Charter operators partake in some commercial work i.e. water sampling, local piers, bathymetry surveys and diving. Charter operators represent another section of indirect tourism that is hoped to be enhanced by the provision of an ASR. There are 28 anglers and fishers registered to the Poole Charter Boat Association, 8 of which responded to the survey. This provided a response rate of 29%. Reasons given in email responses for not being interviewed included: "Can't see that this has been of much benefit to anybody, the position of [the ASR] has not interfered with my charter business, nor benefited it". Another respondent gives feedback in an email but does not wish to be interviewed;

> "No charter boats are using the reef for sport diving customers. It is unlikely that divers visit the reef from the shore, owing to the distance from the shore. Very occasional snorkelers visit the reef, usually in the summer holidays."

8.4.2 Perception analysis

The thematic review of all Boscombe business stakeholders perceptions of the ASR grouped together enabled general trends and common themes that run through the business community to be highlighted. Tables in Appendix C A6 and A7 show the cost and benefit comments from stakeholders split into themes from all qualitative responses from the business survey. Overall, 211 cost related comments were made by the Boscombe stakeholders compared to 42 benefit related comments.

Understandably from the business community's perspective, the economic costs had the most focus for comments overall (Table in Appendix C A6); cost:benefit ratio was approximately 3:1. Comments mainly concerned the construction cost (n = 29), the poor image and publicity for Boscombe (n = 20), and wasted council resources (n = 13). Benefits to the local economy included the regeneration of the seafront (n = 7), and the regeneration caused increased income (n = 7) were discussed. Although there was negative publicity surrounding the Boscombe ASR project, some stakeholders believe that "not all publicity is bad" (n = 4), "the ASR project had exaggerated claims" (n = 7) and "does not deliver claims to boost tourism in the winter months".

Social and environmental comments were fewer but diverse in nature (Table in Appendix C A7). The cost benefit ratio was lower in this combined group at 10:1, the stakeholders struggled to find benefits of the ASR. Positive comments were made regarding the general ASR concept of the project (n = 5) i.e. the ASR makes the "beach area look more interesting" and that the project is a "great idea". As in Chapter 7 with the direct users, the many comments related to the issue of the ASR being "inconsistent" for surfing or "not working" (n = 29). Some stakeholders considered the ASR to be "no benefit to the area" (n = 16), that "more coastal research was needed" (n = 5) and that "structure is hazardous" (n = 9). The physical position of the ASR is commented on as it may prove to be a "hazard to navigation" (n = 4). Whilst others considered the ASR to be "in the wrong location" (n = 4). Sentiments that are all familiar from the analysis of the direct user information.

From the fishers there were reported disturbances to the seabed during construction (n = 5) for example "aggravation of building it - barges during the construction process in the fishing area". Additional concern was expressed by respondents regarding the material and sediment lost from the geotextile containers for example; "I have a shed full of bags of [geotextile] material from fishing equipment", and "since the ASR was put in place an increased in sand in pots has increased around the area, costing time and money - making life harder." Another fisher write about the disturbances and materials from the ASR construction:

> "What with the beach replenishment, dredging and ASR (not just original works but now sand from the broken bags) there has been a lot of upheaval. Material from the reef has wrapped around propeller causing £600 and £1700 worth of damage in two separate incidents. The council is refusing to reimburse fishermen, [the council's] advice is to sue ASR Ltd. but they can not be contacted. This is too costly however for fishermen and [would cost] more than the damage."

8.4.3 Opinions of the Boscombe ASR

The first set of Likert scale questions were posed to all 46 respondents. Likert asked subjects to place themselves on an attitude scale continuum for each statement; from 'strongly agree' to 'strongly disagree' (Oppenheim, 1992). An overall Likert score was generated for the stakeholder's opinion of the Boscombe ASR; scores are based on 13 questions with strongly agree to strongly disagree (-2,-1,0,1,2) as the response, plus 1 question (-1,0,1) therefore total range is -27 to 27. The questions posed were "To what extent do you agree with these statements?" (e.g. Figure 8.6) and "Please respond to the following statements" (Figures 8.8 and 8.10).

Overall, the mean response is fairly neutral at 0.304 ($\pm$6.712) but the large standard error indicates variability in the data (Figure 8.5). The variance in the scores indicates that there are some respondents with more positive outlook on the project. The most positive Likert score came from the 'others' group (mean=4.63, $\pm$4.32)because any additional tourism and amenity benefits would benefit this group directly. The greatest difference in opinion (Figure 8.5) was seen in the shops owners group due to the divide in benefit from the ASR i.e. the seafront shops compared to the town shops.

Respondent groups had varying Likert scores, however the standard error is large for all groups. The sea users and fishers have a similarly negative outlook on the ASR project with mean Likert scores of -3.63 and -2.3, respectively. Hospitality, shops and others all share a positive outlook on the ASR project overall, with mean responses of 1.5, 1.33 and 4.63, respectively. To understand whether there is a significant difference between the mean Likert scores of each group, a one-way ANOVA (analysis of variance) was performed on the data using the more powerful statistical test; the uni-variate generalised linear model using the Tukey post hoc approach in SPSS. The respondent group sizes are greater than 5 and the variance between the different groups is similar therefore there is minor impact on type I errors. Under the null hypothesis that all group means are similar and that there is no significant difference, we expect the ratio of these (the F statistic) to equal 1 if there is significant difference. As the F is 2.266 ($>$1), we accept the null hypothesis and conclude there is no significant difference between the means of the group Likert scores (Table 8.5). The significance, or P-value is 0.079 ($>$0.05) therefore we accept the null hypothesis, and conclude that there is no significant difference between the group means. Further examination of the comparison of group mean scores highlights a marginal significant difference (P = 0.091) at a 90% confidence level between the 'sea users' and 'others' groups (Table 8.6).

Results from the commercial fishers (n = 10) imply that much of the fishing activity remains unchanged. The data show that in Poole Bay since 2010 there has been a slight increase in fishing effort (Figure 8.6a) and the annual catch has generally been decreasing, with the largest decrease observed in 2011 (Figure 8.6b). Overall, net income and profit

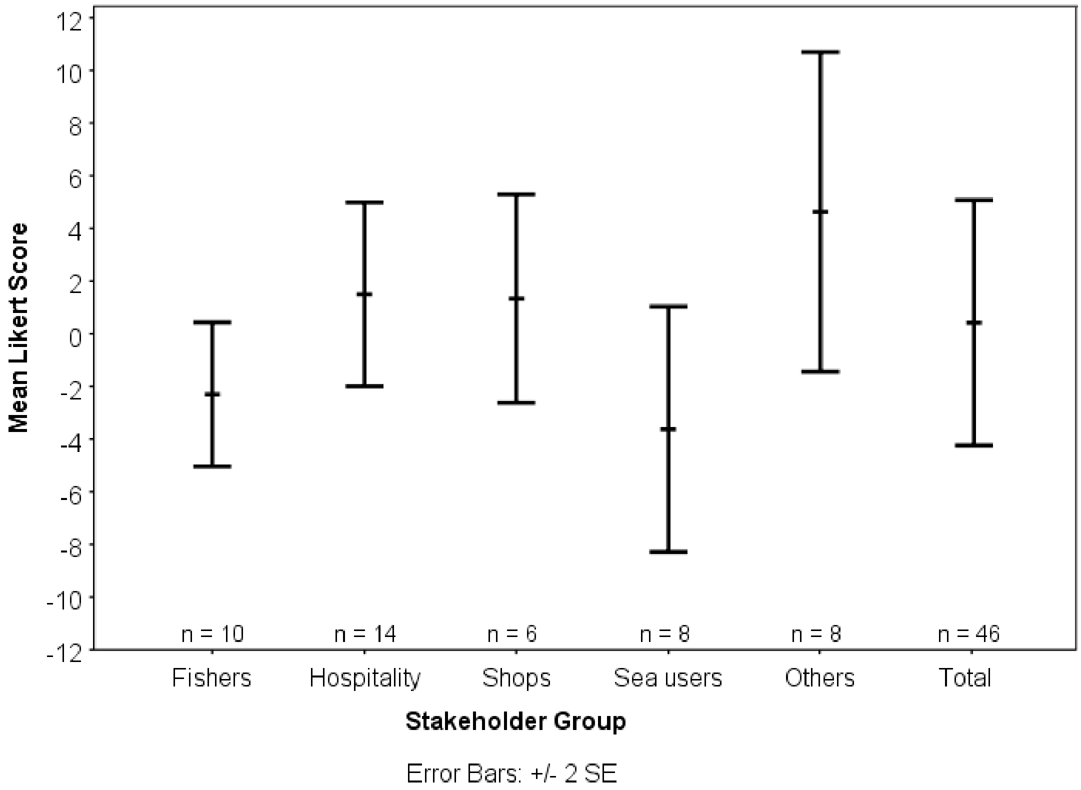

Figure (8.5). Mean likert score plot illustrating the mean opinion (with +/- 2 standard error) for the different respondent groups of business stakeholders.

Source	Type III sum of squares	df	Mean square	F-statistic	P-value
Stakeholder group	367.056	4	91.764	2.266	0.079
Error	1660.683	41	40.504		
Total	2032.000	46			
Corrected total	2027.739	45			

Table (8.5). Test for significance between mean Likert scores all groups (n = 46); SPSS output from the general linear model, uni-variate analysis of variance, Tukey HSD post hoc approach. R^2 = 0.181 (Adjusted R^2 = 0.101).

from fishing is slightly decreasing, however the variance indicates that this is not the case for all fishers (Figure 8.7a). The abundance and biodiversity of commercially important fish species remains unchanged in Poole Bay since the construction of the Boscombe ASR. These large scale temporal changes are not attributed to the ASR construction but to more general issues effecting the fishing industry (such as increased fuel prices and decreased fishing stocks). Commercial fishers do not agree with the claim that the ASR improves fishing or creates habitat (Figure 8.7b). They do agree that the ASR structure has proved to aggregate fish and crustacean. However, this is seen as a negative impact since the reef is a "no-go-zone" these fish are sheltered from the fishers nets and lines. Fishers claim the "ASR is a nuisance" to their activities, the "fishing grounds have been

(I) Stakeholder group		Mean difference (I-J)	Std. Error	P-value	95% Confidence Interval Lower Bound	Upper Bound
Fishers	Hospitality	-3.80	2.635	0.605	-11.32	3.72
	Shops	-3.63	3.287	0.803	-13.01	5.74
	Sea users	1.33	3.019	0.992	-7.29	9.94
	Others	-6.93	3.019	0.168	-15.54	1.69
Hospitality	Fishers	3.80	2.635	0.605	-3.72	11.32
	Shops	0.17	3.105	1.000	-8.69	9.03
	Sea users	5.13	2.821	0.378	-2.92	13.17
	Others	-3.13	2.821	0.801	-11.17	4.92
Shops	Fishers	3.63	3.287	0.803	-5.74	13.01
	Hospitality	-0.17	3.105	1.000	-9.03	8.69
	Sea users	4.96	3.437	0.604	-4.85	14.76
	Others	-3.29	3.437	0.872	-13.10	6.51
Sea users	Fishers	-1.33	3.019	0.992	-9.94	7.29
	Hospitality	-5.13	2.821	0.378	-13.17	2.92
	Shops	-4.96	3.437	0.604	-14.76	4.85
	Others	-8.25	3.182	0.091	-17.33	0.83
Others	Fishers	6.93	3.019	0.168	-1.69	15.54
	Hospitality	3.13	2.821	0.801	-4.92	11.17
	Shops	3.29	3.437	0.872	-6.51	13.10
	Sea users	8.25	3.182	0.091	-0.83	17.33

Table (8.6). Multiple comparisons test for significance between mean Likert scores from all respondents groups (n=46); SPSS summary from general linear model, uni-variate analysis of variance, Tukey HSD post hoc approach. Based on observed means. The mean square error = 40.504.

damaged" and the "no-go-zone interrupts activities".

In statements regarding the advantages of the ASR, two fishers stated that "it apparently creates new habitats encouraging new life" and "a new feature for fish". Otherwise, fishers were the second most negative group (as Likert score highlights in Figure 8.5) calling the structure hazardous and damaging to the fishery; "The no go area has stopped us fishing a prime cuttlefish area and there are some that are very annoyed. There are some considering vandalism to speed up the removal of the reef", alongside "danger to vessels, it's a hazardous area, decreased fishing area (although it is a small area, it has wide impact)." Concerns are raised regarding the geotextile material; "The structure of the reef is falling apart. This is leading to fabric being wrapped around props and gear. If the reef had been constructed of rocks it would have attracted fish but in its present form it is just a hazard." Another fisher comments more broardly in his response; "[The ASR] takes up ground where we'd normally be fishing. Waste of time and money. There's more surfing waves at the Boscombe pier than at the ASR."

Stakeholders (n = 46) were invited to comment provide feedback on the Boscombe ASR. Two simple overview questions were proposed to all respondents, the results are shown in figure 8.8. The stakeholders surveyed find the ASR is not generating an income

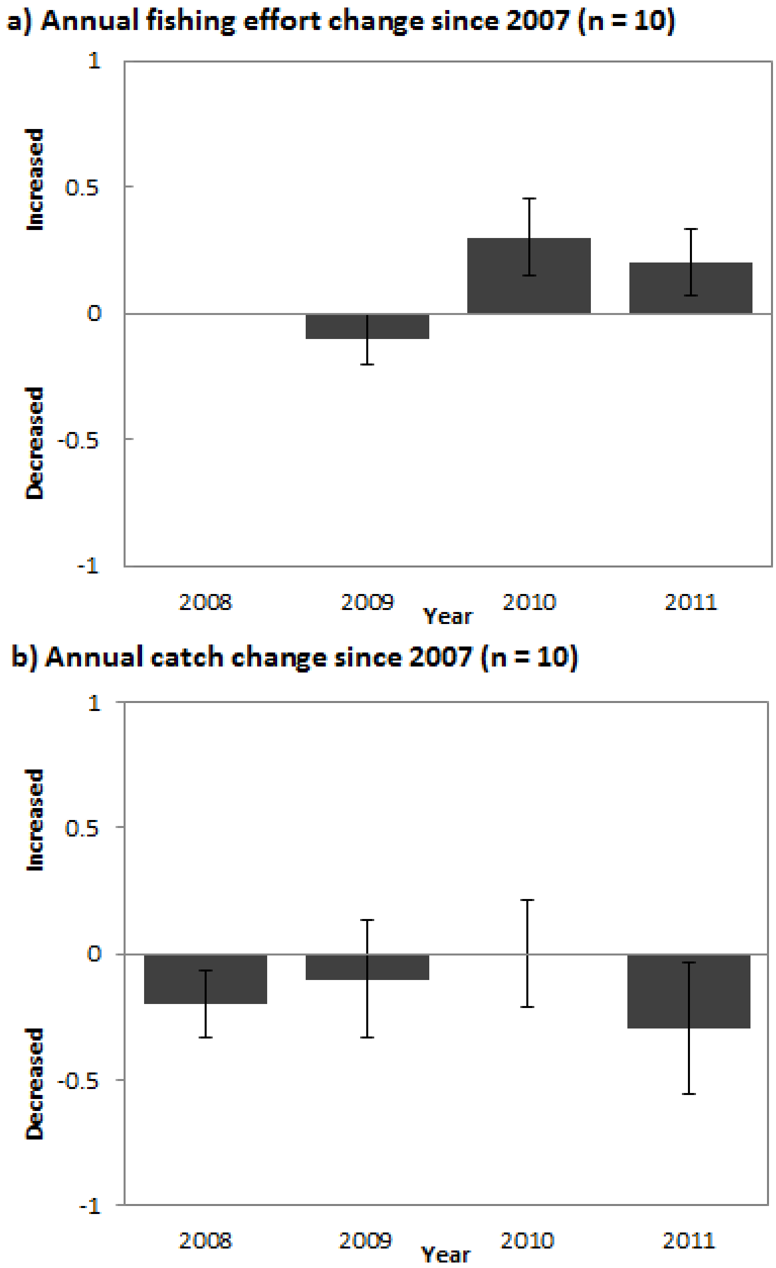

Figure (8.6). The fishing community in Poole Bay were asked their opinion of the Boscombe ASR using Likert scale questions to establish; a) any change in annual fishing effort since 2007, and b) any change to catch size since 2007

for Boscombes local economy. The data show the respondents do not agree with the statement that the money generated through the sale of a car park to a property developer was spent wisely on an ASR, and that the money would have been better spent elsewhere in the town.

Since 2009, business stakeholders (n = 28) have seen customer numbers, enquires by the public, repeat custom and annual turnover profit all increase (Figure 8.9a). The daily expenditure of customers and annual net profit however have not changed since 2009. The stakeholders do not agree that it is the ASR construction that has benefited their industry.

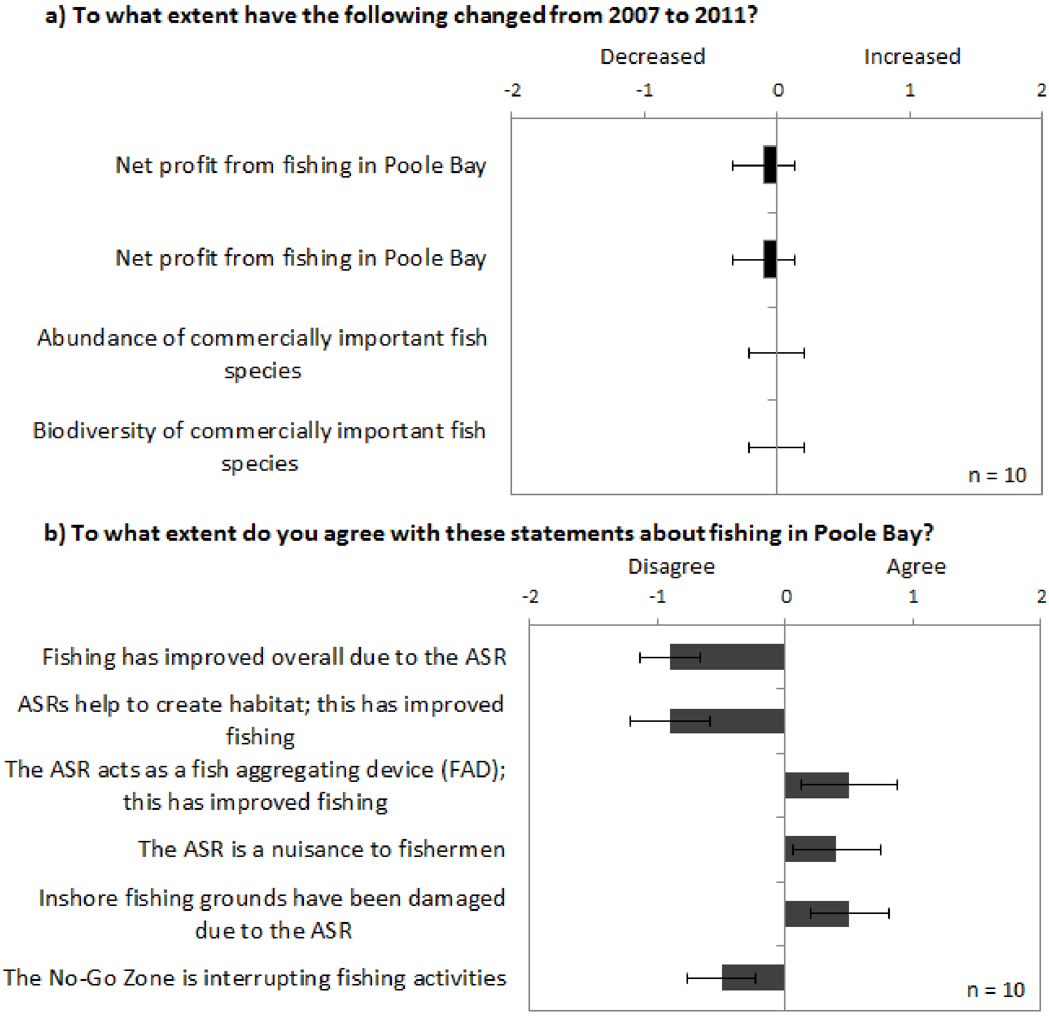

Figure (8.7). The fishing community in Poole Bay were asked their opinion of the Boscombe ASR using Likert scale questions to establish; a) how the specifics of fishing activity have changed over time, and b) whether the fishing community relate any positive changes to fishing with the ASR construction.

The ASR is not seen as attracting customers to Boscombe, the respondents (n =20) do not use the ASR for marketing and stakeholders generally believe that the ASR is poor publicity for the town (Figure 8.9b). The ASR is generally commented on in a negative manner by the stakeholders (n = 46), the more detailed questioning (Figure 8.10) shows that the ASR has not got the support from the business community. Future use of the geotextile ASR technology and ASRs in general should be approached with caution and have further research. The statement which invoked the most agreement was “the ASR was a failure in creating consistent surfable waves”. The statement which invoked the most disagreement from stakeholders was “the ASR has had a direct positive influence on my lifestyle”, this implies that the ASR has had little impact on Boscombe business.

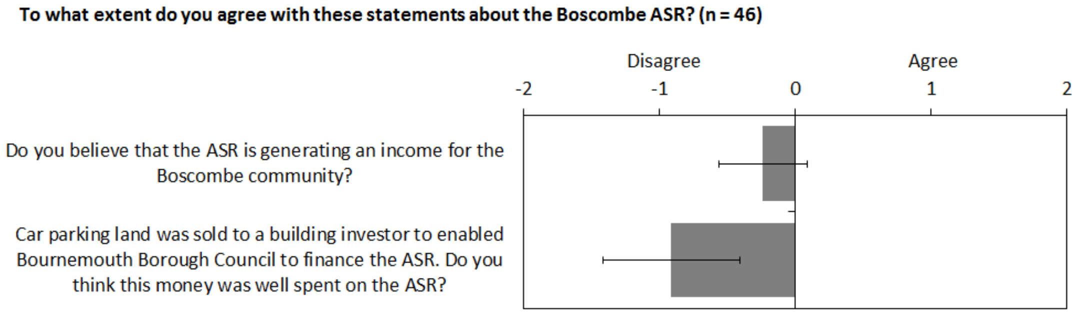

Figure (8.8). Boscombe stakeholders were asked their opinion of the Boscombe ASR using Likert scale questions to establish whether the ASR is generating income and worth the construction expense.

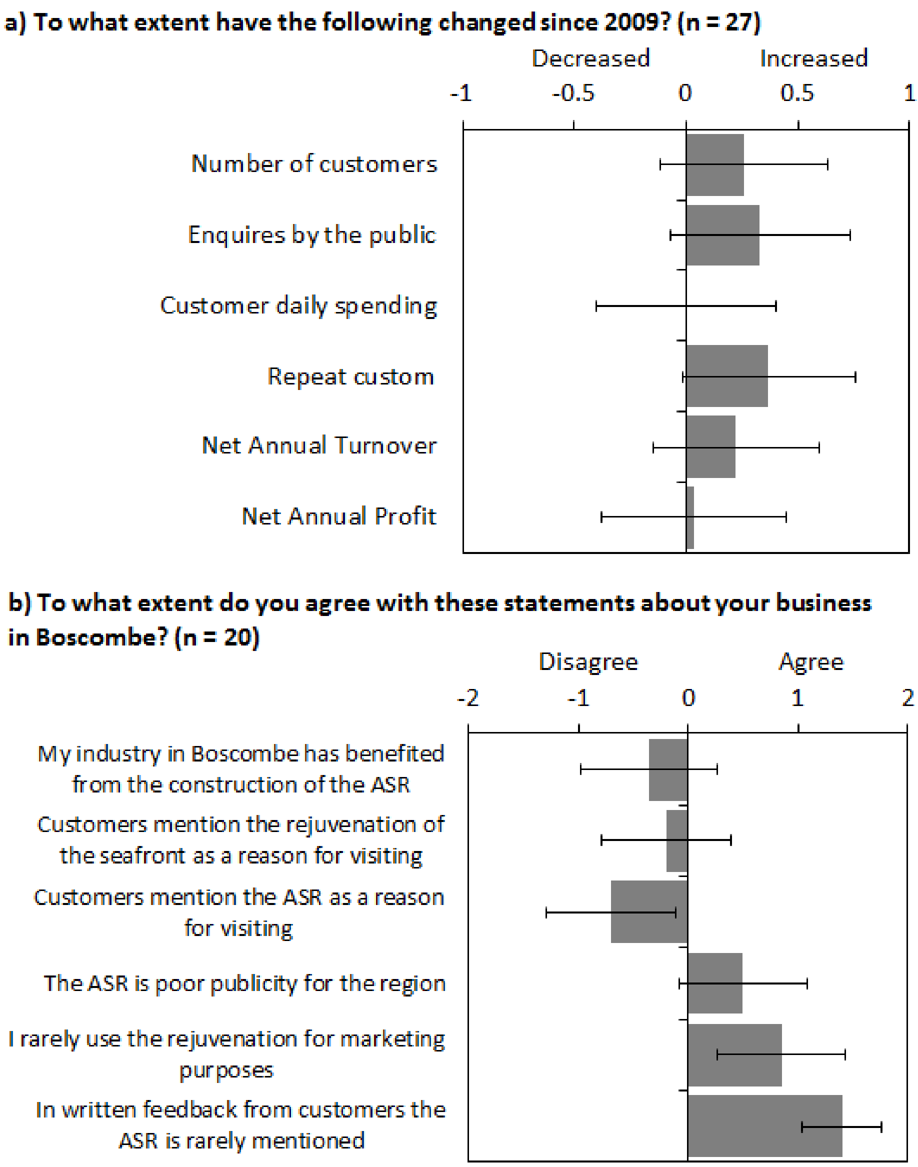

Figure (8.9). Boscombe stakeholders were asked their opinion of the Boscombe ASR using Likert scale questions to establish; a) how the specifics of the stakeholders business has changed since 2009 (n = 28), and b) whether the business community relate any positive changes to the economy with the ASR construction (n = 20).

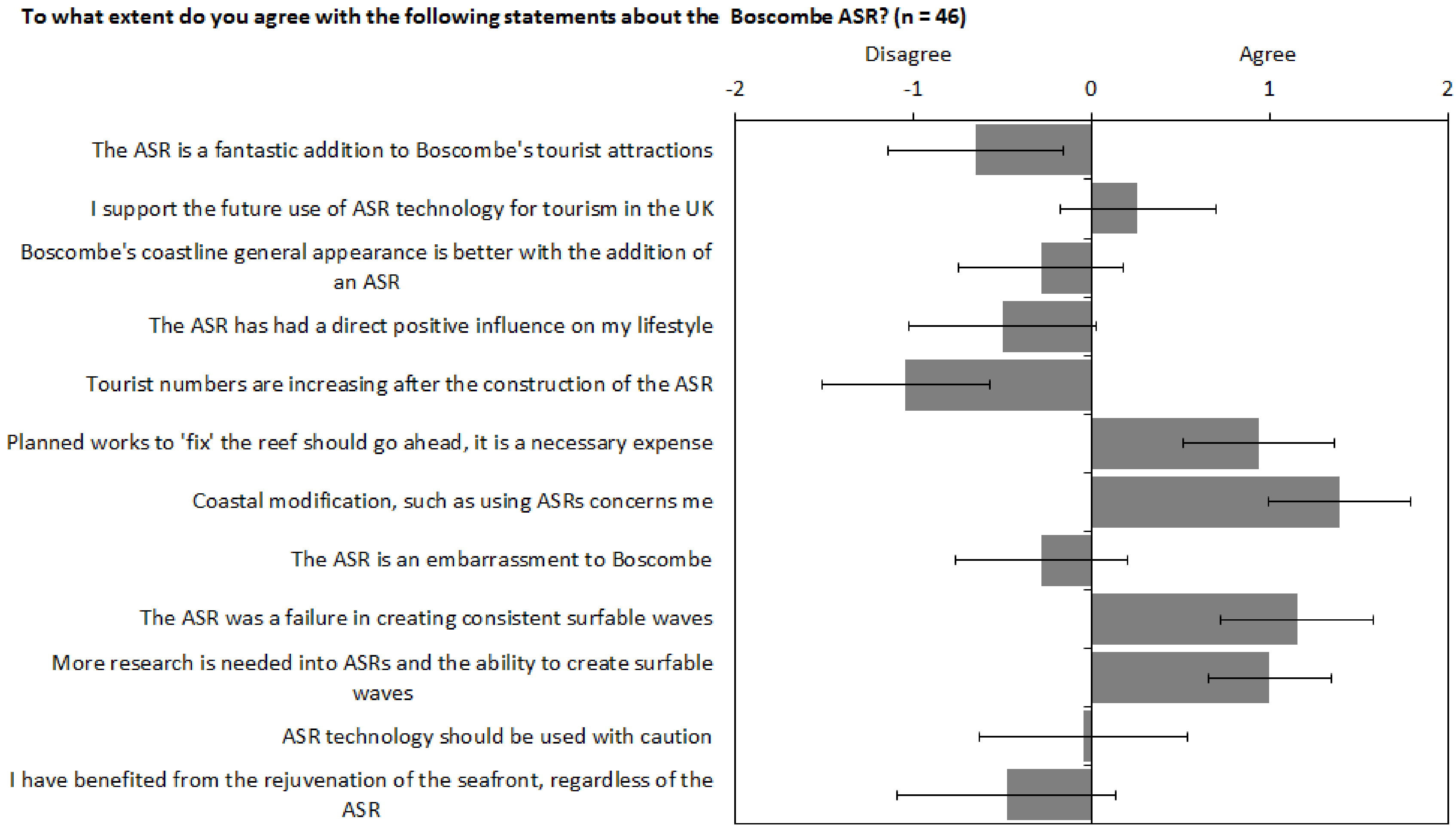

Figure (8.10). Boscombe stakeholders were asked their opinion of the Boscombe ASR using Likert scale questions to establish whether the ASR has been a positive addition for the local economy.

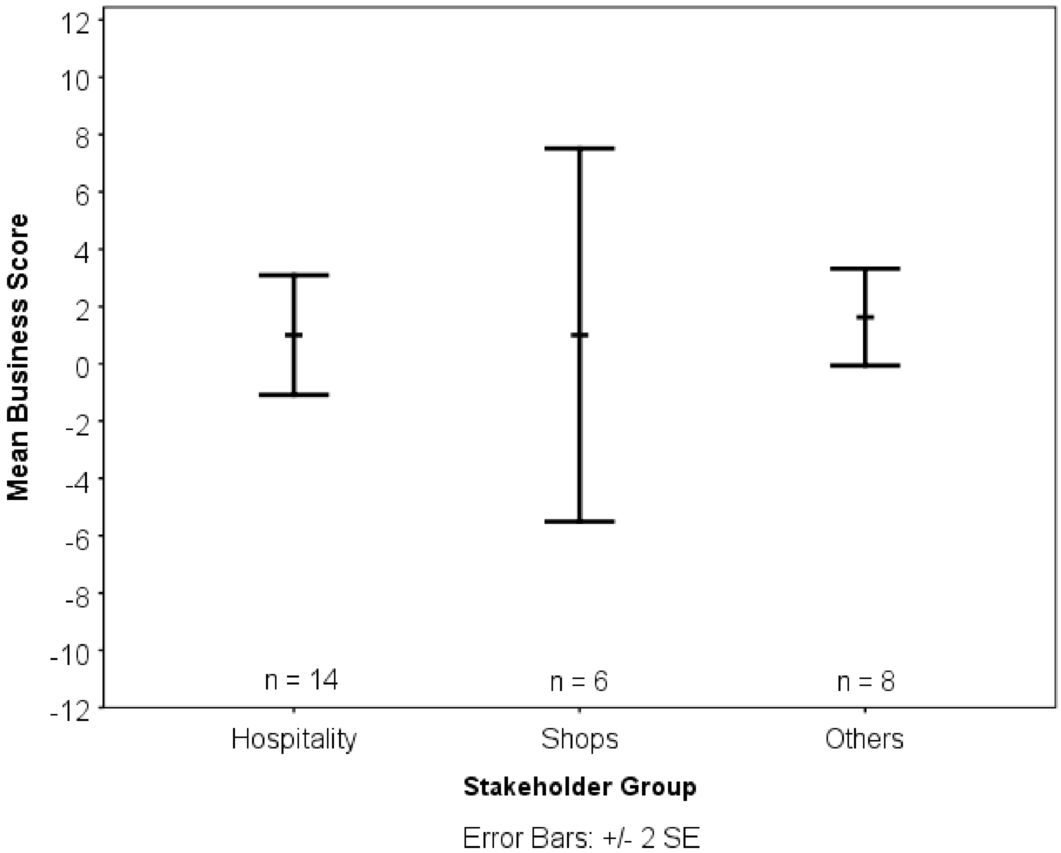

Figure (8.11). Mean likert score plot illustrating business indicator scores of the different stakeholder groups (n = 28). The groups include hospitality (mean=1.00, ±3.90), shop owners (mean=1.00, ±7.97), and others (mean=1.63, ±2.88) all of whom answered the same questions with a maximum/minimum score of +/-39.

Source	Type III sum of squares	df	Mean square	F-statistic	P-value
Stakeholder group	2.232	2	1.116	0.050	0.951
Error	555.875	25	22.235		
Total	597.000	28			
Corrected total	558.107	27			

Table (8.7). Test for significance between mean business Likert scores all groups (n = 28); SPSS output from the general linear model, uni-variate analysis of variance, Tukey HSD post hoc approach. R^2 = 0.004 (Adjusted R^2 = -0.076).

The second set of Likert scale questions inquires how typical indicators of business have changed since 2009. These business indicators are listed in Figure 8.9a and include number of customers, customer expenditure, net turnover and net profit. ‘Hospitality’, ‘shop owners’ and ‘others’ answered these questions (n = 28). There are 6 questions with options ranging from significantly decreased to significantly increased (-2,-1,0,1,2). Therefore the range of scores is between -12 to 12. Since 2009, there was an overall slight increase in business indicators, apart from customer daily spending which has decreased.

(I) Stakeholder group		Mean difference (I-J)	Std. Error	P-value	95% Confidence Interval	
					Lower Bound	Upper Bound
					Lower Bound	Upper Bound
Hospitality	Shops	0.00	2.301	1.000	-5.73	5.73
	Others	-0.63	2.090	0.952	-5.83	4.58
Shops	Hospitality	0.00	2.301	1.000	-5.73	5.73
	Others	-0.63	2.547	0.967	-6.97	5.72
Others	Hospitality	0.63	2.090	0.952	-4.58	5.83
	Shops	0.63	2.547	0.967	-5.72	6.97

Table (8.8). Multiple comparisons test for significance between mean Likert scores from all respondents groups (n=28); SPSS summary from general linear model, uni-variate analysis of variance, Tukey HSD post hoc approach. Based on observed means. The error term is Mean Square(Error) = 22.235.

The mean score for all groups is 1.17 (SD = 4.546) showing this generally positive response. The mean score for each group of respondents is shown in Figure 8.11. The mean for the ‘others’ group is 1.63 (SD = 2.39), higher than the mean score for those in ‘hospitality’ (mean = 1.00, SD = 3.90) and ‘shop owners’ (mean = 1.00, SD = 7.97).

In order to understand whether the means are significantly different from one another a one-way ANOVA was performed. Under the null hypothesis that all means are the same, we expect the ratio of these (the F-statistic) to equal 1. As the F-statistic = 0.05 and the P-value = 0.951, considerably greater than the significance level (0.05), the null hypothesis is retained and conclude that there is no significant difference between the stakeholder group mean Likert scores (Table 8.7). The further break down of the uni-variate ANOVA (Table 8.8) highlights the lack of difference between the group means.

The ‘hospitality’ group (n = 14) were most vocal and keen to put their thoughts forward in this survey of business. There is a mix of positive responses to the regeneration, amid opinions the ASR was an unnecessary addition to the seafront. However, most stakeholder opinion is that the addition of the ASR was excessive in cost and feel disappointed by the projects overall performance; “it would have been extremely helpful if the ASR had been successful and we all (I am a director of Boscombe Spa Resort Ltd a co-operative of 12 hotels in Boscombe) feel badly let down by ASR and the Council.” The stakeholders feel that “until the ASR performs as marketed, very little benefit to the hotel trade. Most watersport enthusiasts are day visitors”. Another hotelier comments that the “surf reef is not working properly, it was hoped this would have extended our season, the seafront is lovely but so are a lot of other seafronts, these days resorts need a gimmick, a specific reason, something to draw visitors to your resort, a nice seafront is not enough.” And similarly, “it does not deliver and in fact is now obsolete with notices everywhere telling people not to use it. It has never bought us business in the time it has been open and has not given us the boost in the winter months we had hoped for." This hotelier gives a more detailed incite to his experiences at Boscombe seafront:

> "No advantages [to my business] from the ASR, the seafront regeneration has been wonderful and hats off to the people who have invested there and made it so great for locals and tourists alike. Whilst the Barretts conversion was controversial it has enhanced the seafront. Everything about Boscombe seafront has been managed and marketed by the people there and the surf reef has been a failure in what it set out to deliver and in fact hardly worked and now is a no go area for anyone to use. We do have a fabulous watersports area now due to the commitment of the surfing community and the expansion into lessons and other watersports like paddle boarding, kayaks etc."

Other themes from hospitality include the economic divide between the seafront and town centre, the negative publicity generated by the ASR and thoughts that Boscombe should have focused on families rather than surfers in its rebranding; "the development down the beach front has caused the divide between the beach and the town to grow even larger - there has been no visible rejuvenation in the high street if anything a marked decline" and "surfing and the reef make Boscombe a laughing stock, this is a family resort and the area would have been better served with a protected swimming area for children."

Similarly, a common theme from the shop owners (n = 6) the lack of changes that had occurred in the town centre since the ASR construction "no changes" and "doesn't affect the business at all, surfers can't use the reef anyway as it was broken after two winters". It is noted that this is a particularly common comment from those inland, in the town centre; "no advantage on the high street/Boscombe centre". However, the shop owners located at the seafront were more positive "much more interest in the area and first time tourists to the area are flocking to Boscombe beach more than Bournemouth". The shop owners do note a "general improvement to area and the quality of customers has improved", and they have observed "increases tourism, so trade and awareness of the local area is raised".

There was one positive quote from the 'sea users' group (n = 8) implying the ASR created habitat for fish; "good for the fish, a new home for them". Otherwise, sea users were generally negative; "waste of time/money" or "unsafe". A charter boat operator reflects on the cost and effort taken up in the project "Total waste of time. Rate payers in Bournemouth suffer; useless for what it is designed for, doesn't even perform as a surfing break." The sea users are mostly charter boat operators and therefore have a practical approach in their responses; "hydrographic information should be thoroughly researched prior to these projects" and "the surf reef is a poorly conceived concept lacking the essential ingredient of an ocean swell, simple mechanics is not understood by those who signed up to it." Interestingly, the angler's response is negative given the fishermen thought the ASR acts as an aggregating device for fish; "a waste of money and shouldn't be considered for angling" and "shown to be unusable for fishing". A charter boat operator that takes SCUBA divers out comments that the ASR has "made no difference", he also adds that "the site is too shallow and uninteresting to divers given the natural interest and wrecks in the local area".

In the 'other' stakeholders group (n = 8) interviewed some focused on the publicity generated by the surf reef. One stakeholder places a positive spin on this "it is a great topic to cover on my website, unfortunately it is usually bad news but it does generate interest for my website" and similarly "the surf reef has been good in encouraging interest to the area of Boscombe. If anything I would say it has helped to put Boscombe on the map". Another views this as unbalanced given the other tourist attractions available "negative publicity, [Boscombe is] laughing stock for all things bad, and there has been no coverage/publicity for all the good things Boscombe has to offer". One respondent views the ASR project as a stimulus for the general regeneration and, since Boscombe beach has been "awarded 'Best Beach and Garden in Bournemouth' area now, 365 day lifeguards make the beach safer for visitors and excellent seafront facilities". The ASR plans were greeted with enthusiasm and interest from the public, due to the economic claims. These benefits have not filtered through to the coastal community, the respondents feel let down by the project; "we were quite excited when we first heard about the surf reef as we thought it would generate additional trade outside of high season, but it did not." One respondent provides more detail of how the ASR project has impacted his backpacker hostel business:

> "As we run a backpacker hostel for young international visitors we would expect some interest from guests and potential guests. I cannot recall a single enquiry relating to the surf reef at any point since it opened. The only comments we have had about the reef are in the form of comments/jokes about how poor it is both as a project and a facility. The reef has become an embarrassment and a financial liability. It has been suggested that coastal experts

gave advice, before construction commenced, that the reef was being sited in an inappropriate location. If this is true, the project was doomed to failure from the outset and the money could have been better spent on some other tourist attraction."

8.5 Discussion

In this chapter it is shown that the socio-economic claims made in original design documentation of Boscombe ASR lacked supporting evidence to the statement that the ASR would significantly enhance or "increase the local economy" (ASR Ltd., 2006, 2007; Black et al., 2000). The Boscombe ASR has gained public attention through the media (BBC News, 2009) providing a centrepiece for advertising and marketing at the resort (Bournemouth Tourism PR Department, 2009) and helped the marketing of Boscombe as a surf destination. Boscombe's shops, restaurants and bars often use "surf" or "reef" in their branding. There is no evidence for the predicted cost:benefit figures that have been quoted in the reports. In this discussion the results provided from the study will be address in relation to the literature and coastal management in UK seaside towns. It has proved impossible to value the ASR project and to differentiate from the regeneration of the Boscombe Seafront.

In 2001, the English Tourism Council report on seaside destinations, "Sea Changes" (English Tourism Council, 2001), it stated that many seaside destinations fail to live up to modern expectations and needed to diversify by attracting new industry and improving transport links (Barrow, 2009). Since then, UK seaside resorts have been experiencing a revival: "a significant group of British seaside resorts have defied predictions of doom and decay, and emerged as twenty-first century success stories" (Walton, 2007). UK holiday makers staying overnight are spending almost a quarter (23%) more money at the English coastline in 2011 than 2010 (CSMA, 2011). According to the findings of Cornish Enterprise 2001, the trend has resulted in 21% more holiday makers staying overnight at seaside resorts. "After a decline in popularity in the 1990s the British seaside has been reinventing itself; high end tourism had seen a particular increase with upmarket boutiques, antique shops, art galleries and Michelin starred restaurants frequently setting up shop in seaside resorts" (CSMA, 2011).

The revival of coastal resorts as stylish and upmarket places to frequent, alongside a fashionable beach-surf image, has been shown to spin higher expenditure amongst tourists. For example, Barrow 2009 discusses how building points of difference (such as facilities for business tourism, or a reputation for 'foodies' or 'surfies') can mean a positive future for the seaside community, even in times of economic difficulties. A report examining the contribution of water sports in Cornwall finds that surfing culture does have wider economic benefits than the direct participation in the sport itself (Cornwall Enterprise, 2001). It is difficult to establish how many visitors come to the coast to watch surfing but this form of spectator tourism is also considered important when examining the economic impacts of surfing to the area. Hundreds of thousands of spectators can be drawn to professional surfing events and competitions causing regions of the world's coastlines to be redesigned with not only surfers in mind but also the spectators (Augustin, 1998). Boscombe lends itself as a natural competition site due to the promenade and the pier which provide ideal spectator stations.

8.5.1 Economic boost to the seafront vs town

There is little reflection of an economic boost in the town centre from either the ASR construction or the regeneration project. There is also limited impact from the project in the wider coastal community. The regeneration project did however aid an economic boost for Boscombe's seafront region, the ASR had little to do with the increase in numbers of tourists visiting the site after 6 months. A cultural divide now exists and separates classes and age groups are apparent due to the increased cost at the seafront. The seafront properties have increased in value which has displaced residents as cost of living increased. The results presented here show that the initial interest in Boscombe ASR increased through 2009, a novelty factor that wore off after 6 months. Visitor spending has increased however, but watersports enthusiasts are not shown to be high spenders (also highlighted in Chapter 7).

The ASR provided a focal point for the regeneration project, the funding was secured partly on the marketing potential. Financial investment in the area was fuelled by the seafront regeneration and associated economy growth. Economic estimates by the council claim the regeneration benefits were £41.5m GVA in addition to an estimated £10m in international marketing due to press coverage and media attention (MacWilliam, 2011). These figures appear in media documents and verbal accounts only, not quantified independently. The claim regarding marketing has been explained as free advertising for the Boscombe site through the press and other media, rather than direct economic gain for local business. The hospitality and shop owners interviewed in this research have not reported an economic enhancement to the area, as the original claims suggested there would be. In an online interview, Local Councillor and Cabinet Member for Economy and Tourism, Rod Cooper said: “The contribution the reef has made to the reputation of Boscombe as a destination cannot be underestimated” (Jenkins Marine, 2011; BBC News, 2011). Respondents stated that, despite the regeneration of the area, they would have preferred the Council to invest the £3.1 million spent on Boscombe ASR elsewhere in the town. The study highlighted that only businesses within 250 m of the ASR have benefited financially, others experienced zero net growth.

Although the ASR is impossible to differentiate from the regeneration at the seafront, it is possible to analyse the results and understand the experiences of the local business community. There are four areas that are highlighted as important for increasing economic and social benefits within the community, the Boscombe ASR project has had an impact on all of them in varying degrees of success: 1) The ability to create and support opportunities for income generation and general improvement. This has been proven along the seafront area, two thriving surfshops and many cafes, restaurants and bars that have benefited from the redeveloped area. However, these are not directly related to the ASR and the community argue that the redevelopment alone would have enabled similar successes. 2) Re-establishing the Boscombe area as popular tourist destination. The ASR certainly caused media attention and was initially a great selling point for the new redevelopment of the seafront. The brief positive followed by increasingly negative media attention became an embarrassment to the council and frustrating for the local community, this is reflected in the negative way the ASR is described. It is impossible to confirm whether the free advertising by the media was a success or hampered the projects popularity, there is certainly a spike in visitor numbers after which it plateaus. To sustain this interest the ASR project needed to be a success. 3) The provision of employment opportunities were created such as lifeguarding, shop, cafe and bar work. The job count is varied as some report a positive, beneficial result from the seafront regeneration and others reflect the seasons have been hampered by the UK recession. The ASR project cannot claim to have created jobs directly, however the combined seafront projects at Boscombe have provided opportunities. 4) The increase of community initiatives and general moral in the area. The Boscombe ASR provided an opportunity for the community, developers and tourism representatives in the council to come together to create something innovative and unique. It seems that there was neither communication nor transparency in this project for this to occur, low moral associated with the project. There was no ownership within the community; the business and surfing community could have been united to work with developers to design a more appropriate marine leisure attraction with the space and resources.

8.5.2 A shift in community and culture

The public and business stakeholders are generally protective of a place, the aesthetics of their surroundings and they do not want to see it impaired. Most would like to see the present beach front surviving for future generations to enjoy. Stakeholders do not like the change to a previously aesthetically pleasing view, whether it is natural or unnatural. The community are used to their surrounding environment and are often resistance to change is encountered by developers. Sense of place is a natural human attachment which coexists with the sense of belonging to a place. The community together or individually feel ownership for an area or view and will strive to protect it. The ASR in Boscombe did represent a shift in focus for this coastal community. The economically sound project failed to meet the expectations of the developers, the council and the community. As described in Chapter 5, the ASR crest is 0.5 m above the design height therefore the visual impact is greater than planned. The coastal community consider their seafront has been altered by the ASR without any economic benefit from the ASR. The visual aesthetics of a place are important to residents and visitors alike, they ascribe a high value to seascapes.

Seafronts represent the culture-nature interface between land and sea (Jeans, 1990). They represent a space where humans can interact with the marine environment without the necessity for seaworthy vessels. For some this is a piece of land to work from every day, for others it is a recreational area. The coast and seafront are important in society, and the value place on this area is high. The cultures tastes and preferences of tourists to the seafront may influence the landscape that emerge around these leisure spaces (Preston-Whyte, 2001). Boscombe is a reflection of this; as recreational activities changed historically the council has updated the seafront with modern innovations whilst retaining a traditional image.

The notion of leisure tourism carries with it the assumptions that people differentiate and categorise it in their minds (Preston-Whyte, 2001). At Boscombe Seafront the beach is categorised to differentiate between stakeholders based on the activity they partake in. Some stakeholders take a progressive attitude towards change at the coast, others are more conservative. If an activity forms a livelihood (e.g. fishers and charter boat operators) then income maybe threatened by change. Physical change to the natural environment concerns stakeholders impairing their enjoyment of their activity. For example walkers are keen that the countryside and paths are maintained for aesthetic reasons, they visually enjoy the landscape and coastal views. "The subjective partitioning gains credibility when sufficient people agree on the principle activities that define it. Once defined, it becomes part of the social and cultural domain" (Preston-Whyte, 2001). This apparent shift in seafront and coastal waters use may take time to adjust to as the "sea-scape" changes. Increased numbers of surfers, tourists attracted by the shops, bars and cafes, and the ASR itself exposed at most stages of the tide are all changes likely to impact those who treasure the unitturupted seaview from Boscombe to the horizon. Whilst some stakeholder groups welcombe coastal change, others may take longer to accept the visual impacts and displacement caused by the ASR construction.

The change in tourist profile must be managed carefully to avoid segragating the original users of the coastal space. As discussed in Chapter 7, direct users felt that the natural wave had been interrupted replaced with an intermittent bodyboarding wave. Segregation creates conflict, this must be avoided in order to maintain order between water users. Zoning off areas for bathing and surfing separately had been shown to aid this and lifeguards have long used the technique to manage swimmers. There are key safety implications for encouraging surfers and bathers to use the same space as discussed in Chapters 6 and 7 where increased injury from collisions are likely with novice surfers.

Smith's (2004) case study on Southend-on-Sea describes the 'buzz word' for the 1990's was undoubtedly the concept of sustainability, not lease in the field of tourism development, and how its successor for the 2000's is the phenomena of cultural regeneration and changing urban landscapes. However, the study discusses how the extent to which regeneration through cultural development and the revival of tourism is the solution for declining resorts is open to debate. The regeneration of a seaside is described by "the three R's of seaside renaissance"; regeneration, revitalisation and reinvention (Table 8.9). The process is described as multifaceted as it appears that activities need to be carried out incrementally. For example, it is difficult to focus on economic regeneration, especially the attraction of business investment or new tourism markets before the destination has been revitalised physically. There will be few jobs without significant investment in new attractions and facilities. Similarly, reinvention in terms of image, identity and rebranding really can be achieved only once a quality product is in place (Smith, 2004).

The Boscombe regeneration project followed this process and the focus of economic

Regeneration	The diversification and strengthening of the local economy through tourism, culture and leisure services. This includes employment creation, the development of SMEs (small and medium sized enterprises) and boosting visitor expenditure and multiplier effects.
Revitalisation	Product enhancement, including the upgrading of infrastructure and local facilities, environmental improvements and town centre renaissance.
Reinvention	Product innovation, including the development of new attractions, rebranding, image enhancement and the creation of a distinct place identity.

Table (8.9). The three 'R's of seaside renaissance, taken from Smith (2004)

regeneration that initially focussed on the ASR, is now firmly based around other aspects such as the natural views and newly refurbished pier. The ASR rarely gets mentioned, apart from in occasional press releases regarding its physical stability. Interestingly, much of the rebranding of Boscombe carried out before the ASR was completed and deemed successful. This is premature considering the unknowns in the project, stakeholders claim their investments were wasted as travelling surfers did not turn up in the numbers expected. This is reitterated by the direct user reserarch where it was shown that UK surfers were low spenders and rated the ASR poorly.

Policy and planning documents for regeneration now tend to focus on prioritising local community needs (Smith, 2004). In Boscombe the idea of the regeneration of the seafront and provision of a surfing reef would provide the community with an improved public space. Public space provides a venue for chance encounters, which serves to strengthen community bonds (Talen, 1999). The focal point of this regeneration project was the ASR, distinguishing it from other regeneration projects around the country. The concept of providing neighbourhood gathering places to give "heart to the community" (Langdon, 1994), and serve as a counter pressure to community fragmentation when public spaces are privatised (Talen, 1999). Some low incombe members of the community feel they are being squeezed out financially through gentrification, other users feel physically disturbed by the no-go-zones for boats. As discussed in Chapter 7, the local surfers complain of overcrowded by travelling surfers, and that they have lost control of their surfing location.

The idea of creating a new surfing facility should be taken as a form of creating a new public space for a community. Public spaces in the form of parks and civic centre also serve as symbols of civic pride and sense of place which promote the notion of community (Talen, 1999). It must promote the notion of community, and will therefore be held with pride by the residents. If public spaces are a pleasure to inhabit, they will be used, and their usefulness as promoters of sense of community with flourish (Talen, 1999). In this sense, if the ASR is successful in not only providing a new amenity for surfing but a place to meet regularly and to provide opportunity for chance encounters, then community bonds will be strengthened. Sense of place is created simply by paying attention to sense of space through proper design and placement of public space (Duany and Plater-Zyberk, 1992). This is true of natural surfing breaks globally, the way a central park is used in the city the beach and ocean is used to meet in the coastal township. This can be related to both ASR construction and coastal adaptation. By interfering with an established social meeting place for local residents the project risks impacting sense of community and upsetting the balance that exists. The addition of an ASR could provided an additional public space, a place to meet and thereby enhancing the coastal community if managed correctly.

8.5.3 Disturbance to marine activities: No-go-zone

Disturbances to marine activities were felt by all sea users. Problems that occurred include changes to bathymetry (as described in Chapter 5), increased sand suspension and sedimentation (fishers' pots impacted), prolific seaweed growth, geotextile material debris causing problems for boats, poorly marked no-go-zone for vessels and navigational hazards. These disturbances were not made clear in advance to the local sea users, neither explained nor broardly discussed. This could be achieved through communication and transparency with stakeholders.

The ASR was not a positive feature for fishers, anglers or anglers. Initial claims regarding enhancement to habitat and increasing catch are unsubstantiated according to the fishers and angling community. The fishers are not convinced the ASR is capable of increasing productivity in local fisheries. The ASR does seem to be a positive feature for spearfishers hunting spider crab under the geotextile SFC. Both the commercial fishers and the sports angler groups rate the ASR poorly because there are better natural reefs and boat wrecks locally. The same reasons are given when discussing the ASR as a potential diving location; visibility is low and there is little life compared to the natural sites. Attracting snorkelling and SCUBA diving tourism at Boscombe is not necessarily a positive when there are surfers in the water (as discussed in Chapter 6 and 7). Concerns for rip currents and conflict over the water space with the increasing diversity of activity in an already crowded area. Risks collision incidents, injury and the potential for liability claims are high.

There is discussion of vandalism amongst the business stakeholders and fishers. These stakeholder groups have different reasons for seeing the removal of the Boscombe ASR. The act of deliberate vandalism is seen as a means to speed up this process and encourage the council to remove the structure. During the surveys made for this research, the fishers detail how the ASR was deliberately vandalised by dragging trawling gear over the surface of the structure in order to damage the top bags of the ASR. One business group respondent states that "fishermen claim to have deliberately sabotaged the ASR by bragging about dragging trawl gear across the top of the ASR to speed up its removal". The reason for the geotextile bag failure is vague, the council claim it was caused by accidental boat damage. However, vandalism is a real consideration for exposed geotextile projects of this nature; the geotextiles are delicate and require all parties to be considerate of them.

8.5.4 Stakeholder engagement

Highlighted in both the results from the direct users (Chapter 7) and the indirect users (Chapter 8) the community engagement was poor before the Boscombe ASR construction. The stakeholder reaction to their involvement in the project is generally one of confusion. The vast majority were not represented nor did they have a good interaction, if any, with the designers and planners. The wider Boscombe community thought the ASR project suffered "poor publicity, embarrassment and liability for the council, the project remains unfinished and stakeholders are left not knowing what will happen to the ASR". There was generally a negative view of the project due to the ASR closure (Chapter 5). The coastal community are unsure of the ability of the ASR to attract surfers or encourage economic growth.

> "Since the reef has been deemed unsafe and closed to surfers the council have technically removed themselves from any responsibility. It is questionable as to whether they were liable in the first place however the now incomplete structure is still a magnet for the surf community even with bags missing from the structure, this poses a risk to those who are not local to the area or have good knowledge of the sea".

Liability and safety at the ASR remain of key interest to the coastal community. The dangers associated with the ASR and who would is responsible for any repairs seemed to be outstanding at the time of writing. Alternative plans for the ASR and the surrounding area have been floated in the media but little has occurred to make the ASR project success. Fletcher (2011) suggested that planners communicate better with Boscombe stakeholders to alleviate misunderstanding regarding the ASR project. Any perceived under performance of the ASR and associated negative publicity may reduce visitor numbers and compromise the anticipated economic benefits. It was suggested that expectations should be managed to minimise this risk occurring (Fletcher, 2011). That advice was not followed and the project continued to be discussed in council offices with little stakeholder engagement. Many stakeholders feel their opinions went unheard and have a negative attitude towards the future success of the Boscombe ASR. The management of expectations is crucial for a coastal community when establishing an ASR. There is a need to balance the support for an ASR whilst avoiding unrealistically high expectations of eventual performance (Slotkin et al., 2008).

8.5.5 Comparison of opinion: the direct and indirect users

Responses from the direct users (Chapter 7) were reflected in the results from the indirect users. Boscombe has a small vocal community who appear to interact well between the various stakeholders groups, the surfers particularly reflected the concerns of the others in the wider coastal community as many of them work in the immediate and surrounding area and have similar values. One of the main cause of concern was the lack of engagement with the surf community that had been conducted previously to the ASR construction, and that what was a purportedly negative attitude in using the Boscombe site as a location for the ASR. There were similar comments from all respondent groups regarding "location issues and stakeholder displacement; did the council not listen to external advice on location?" The construction of ASRs at coastal resorts should be undertaken with caution. There is clearly no guarantee that their economic effects will be positive, and there is a danger that artificial reefs will be constructed in circumstances which do not justify them (Whitmarsh and Pickering, 2000). In Boscombe it is commonly considered that any other installation could have been chosen, that the resources would have been better invested in the deprived town centre area. Alternatively, spent on an art installation, education center or water feature accessible to the whole community.

Other key similarities that were commonly discussed by both the direct and indirect users are:

- The economic impacts to the community, the initial cost and resources used to construct the Boscombe ASR.

- The premature closure and unfinished appearance of the project; the poor surfability and consistency.

- The poor publicity and image for Boscombe in the press and media.

- Lack of engagement with the community.

- Alteration to the environment: mainly from an aesthetics perspective of the surrounding area in the case of the indirect users.

- Further research is needed particularly to the environmental disturbance and for impacts to fishing and fisheries.

Whilst there are similarities between these two groups, there are obvious differences, particularly in the assignment of benefits from the ASR project; the coastal community responses are generally more negative than the surfer community. The perception and opinions of the coastal community are pessimistic compared to the direct users who are optimistic about the future use of geotextile and ASR technology. The type of comments are different in attitude; the project remains a burden or sore point for the indirect users, rather than one that could be changed or developed for the better. The surfers are interested in the ability to alter the coastal environment for the better and engage in discussions regarding the future use of ASRs, however there is little interest from the coastal community in similar conversations. The attitude "it's failed once, why would anyone try it again" will be a tough reputation to alter, particularly in the UK. Given the unfortunate press coverage regarding the structural failures and premature closure the ASR construction is perceived a high risk project. The surfing community however are not against the idea. It is perceived as an innovative and exciting possibility to create artificial waves. In recent years the focus has turned to wave machines developing inland brownfield sites areas e.g. Surf Snowdonia, Weber Wave Pools, Wavegarden and The Wave Bristol. These projects offer more in terms of surf consistency and experience, less environmental damage and no inturruption of natural surfing waves, however they come at a financial cost to the surfer.

8.6 Conclusions

In this chapter the change in attitude by seafront visitors towards the Boscombe ASR was captured overtime. Business stakeholder opinions and perceptions of the project were captured using a structured interview. The ASR had an initial added novelty value of interest for Boscombe seafront visitors, with the increase in numbers of tourists visiting the site to see the ASR peaking at 6 months. The regeneration project was shown to aid the local economy for Boscombe's seafront region, however it is difficult to seperate any economic benefits directly from the ASR. The socio-perception analysis highlighted little reflection of any economic boost in Boscombe town centre from the ASR construction, or from the regeneration project. Limited impact from the project was felt in the wider coastal community. The visual aesthetics of a place are important to residents and visitors alike, they ascribe a high value to seascapes. The coastal community feel their seafront has been visually altered by the ASR, inturrupting the view to the horizon.

The engagement of the coastal community was poor before and after the Boscombe ASR construction. The stakeholder understanding and reaction the project is generally one of confusion. The coastal community are unsure of the ability of the project to attract surfers and consider it bad for tourism. Coastal planners failed to communicate with stakeholders causing unrealistically high expectations of ASR performance, from a surfing and economic perspective. The ASR structure is of little value to the fishers, divers or anglers as claimed. Initial claims regarding marine life and habitat are unsubstantiated according to fishers and the angling community. There is still potential for conflict over the water space, increasing activity in an already crowded area of water could result in injury and liability claims.

In the following synthesis chapter common themes in the thesis are gathered together and discussed. Key points that impact the management and implementation of policy surrounding ASR and recommendations for their future use in the marine environment are opened up and links are proposed between the analytical chapters. In the following chapter the DPSIR framework is reintroduced as the structure of this synthesis chapter; the response to the impacts the ASR has had on the local environment and socio-economics are discussed. Recommendations are given for future ASR construction projects, monitoring strategies and a discussion of policy and guidance.

Chapter 9

Synthesis and Discussion

This chapter aims to bring together the multidisciplinary topics of research and draw link between the contributions made in each of the analytical chapters. The consideration for current principles in coastal management and tools for understanding change have been utilised here, namely the ICZM and DPSIR frameworks. The output of this chapter are given as recommendations for future ASR projects based on the data from this research, protocols to regulate implementation and standards for monitoring studies are defined.

9.1 ICZM and DPSIR framework

This section focuses back to the frameworks described in Chapter 3. The ICZM used predominantly for sustainable management of the coastal system. It is mainly observational data which informs ICZM since it is harder to include the perception and opinions of stakeholders, the assumptions of designer and contractors, and any power struggles in the wider government. The beliefs and agendas of different stakeholder groups are also hard to include, such as the local council, the direct users and wider coastal community. The DPSIR framework is a useful analysis tool to understand the causal chain from an identified problem to the best response. The DPSIR can be used to identify the links between sub-tasks within the ICZM, for example a pressure-state relationship. It is proposed that the DPSIR framework can be utilised to collect, asses and represent these social topics together alongside the measurable data. A diagnostic analysis can be performed using the DPSIR framework to build evidence regarding a part or area that is not functioning sustainably in the wider ICZM. Allowing the governance, environmental and socio-perception analysis to be brought together, discussed and better understood.

Figure 9.1 illustrates the DPSIR framework (as introduced in Chapter 3) with additional areas of interest that have been highlighted throughout the research. This is related to the environmental state changes, the opinions and perceptions of the coastal community regarding the observed impacts and any implications of the Boscombe ASR construction. If the ASR had been a success there would be little need to change policy, although valuable lessons can be learnt from this novel project.

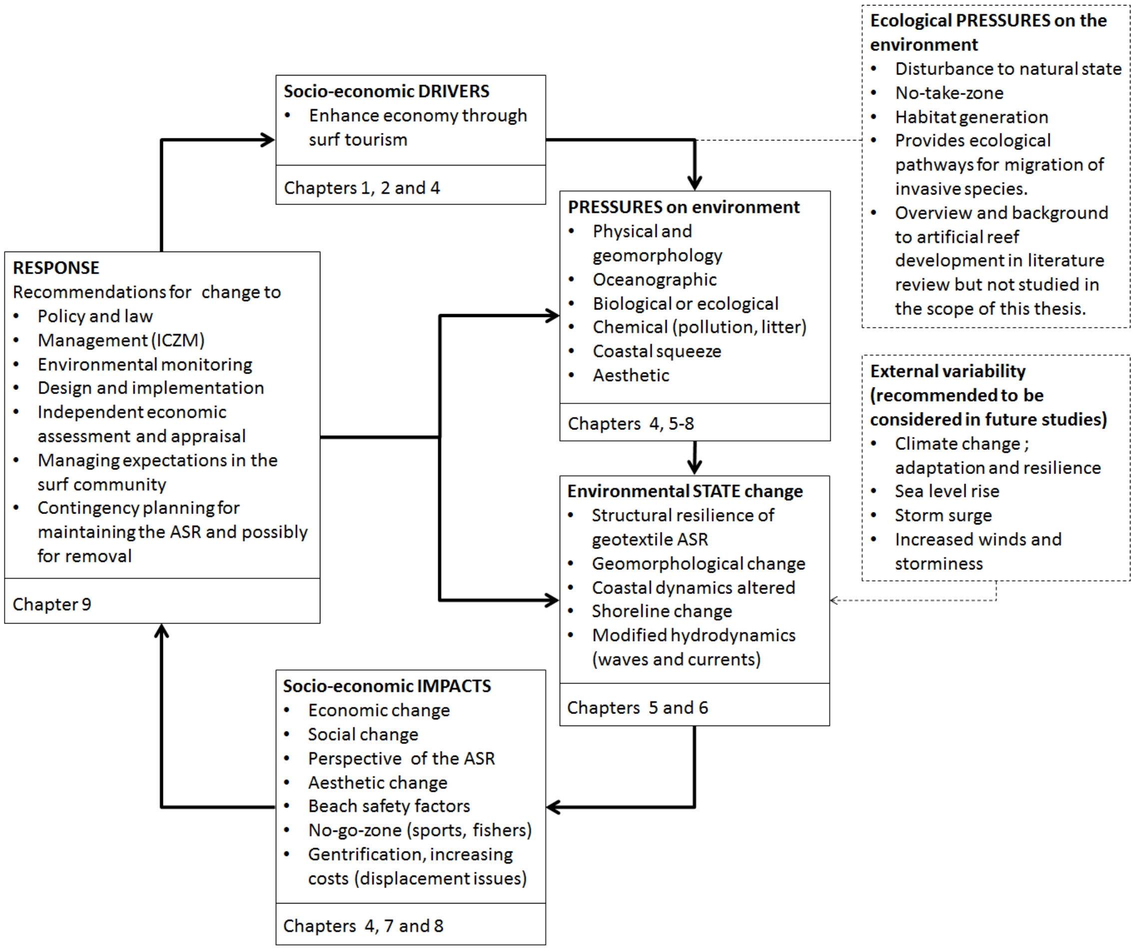

Figure (9.1). The DPSIR framework, adapted from Mangi (2007), showing the socio-economic drivers creating environmental pressures, which lead to changes in the state of the environment that have socio-economic impacts. The policy response are formulated from this research to aid understanding and mitigate against damage or re-orientate the drivers or pressures.

The main driver for the project is the enhancement of the economy through the increased surf tourism generated by the ASR. The surf community recognised this as an innovative marketing opportunity and remain interested in the technology, however express a not-in-my-backyard attitude to future ASR projects. The surf community and wider stakeholders agree that the media attention surrounding the ASR put Boscombe on the surf map, generating initial interest from the surf community and a longer term interest from the general tourism market. However, this initial novelty period diminished after six months.

The pressures on the environment have been investigated and the environmental state changes identified. The physical environmental change was covered in Chapters 5 and 6. Data analysed enabled a detailed picture of the coastal dynamics to be realised through changes in the ASR's structure, geomorphology and at the shoreline, and through the modified hydrodynamics. The Boscombe ASR was investigated for the effect on the shoreline leeward of the structure. The results showed that there was no impact due to the distance of the ASR from the shoreline, that neither erosion or accretion was taking place. There was some minor scouring effects at the toe of the structure, both to the lee and seaward sides. Up to 0.5 m erosion was observed on the side exposed to the greatest swell and lee side, and between 0.25 m and 0.5 m on the sheltered sides. There is more evidence of variance leeward of the structure, compared to the relatively stable surrounding beach. The claim that the ASR was increasing the volume of sediment leeward of the ASR and creating a salient feature has not been supported by this research. However, the lee area was becoming more stable (neither accreting nor eroding), over longer timescales.

The impact of Boscombe ASR on local hydrodynamics was evaluated using a spectral wave and hydrodynamic model. The modelling highlights divergent and convergent current circulation cells, whilst these divergent currents illustrate only the potential for erosion they indicate the reason for scour at the toe and the lack of change at the shoreline. The pre- and post- construction simulations show that the original claims of the contractors were not correct regarding the Boscombe ASR. The wave height reaching the shore was shown to be ameliorated by the ASR. However, the ASR does not always create a safer area for bathers as it alters and enhances current patterns. The nearshore hydrodynamics were altered by the ASR in the numerical model, this is more prevalent during flood and ebbing tide, with wave heights greater than 0.25 m. Consideration should be given to enhanced return flow or rip currents in the vacinity of the ASR and in the surf zone. The surf community expressed concern for rip current enhancement under larger wave conditions (Chapter 7), this was identified and expressed early on in the original project planning but dismissed.

The socio-perception analysis provided valuable insight to the perceived economic impacts. In terms of the benefits to local stakeholders and visual impacts, Boscombe ASR was perceived to perform poorly. Coastal community represent in the decision making process of the ASR design and construction was negligible, and that the project was not popular after construction. The wider surf community would like to have been consulted in the design process. The project has driven unrealistic expectations within the business community therefore the performance of the ASR, was considered poor. Specifically, in forming surfable waves and attracting new surf tourism revenue. A lack of transparency during the marketing campaign was discussed by both the direct and indirect users. Original cost:benefit ratio estimate 1:20 was widely reported to the coastal community, business stakeholders are quick to quote this and say it did not materialise. It is apparent that there was misunderstanding of the final design objectives in both user groups and even with the owner, at the local council.

Where the educated surf community are realistic in their expectations of the local sea conditions, other members of the public who are not aware of wave climate are often misled into grander expectations. The preconception of the generation of waves for surfing is common surrounding the ASR structures. It is obvious that there is some misguidance in stakeholder education during feasibility phases. The key findings of this research are summarised here:

- Surfers rate the Boscombe ASR very poorly as a surf break.
- Initial interest in Boscombe ASR increased from 2009 to 2010.
- The novelty factor of the ASR wore off after 6 months and interest declined.
- Visitor spending has generally increased in Boscombe, attributed to the general tourism attracted by the regeneration of the seafront (water sports enthusiasts were not shown to be high spenders).
- Fishing in Poole Bay remains largely unchanged; neither benefited catch nor any great displacement issues. The SFC failures did impact fishing activity.
- The majority of stakeholders felt a recent positive impact to business related to general regeneration of the area but do not associate the ASR.
- Only seafront businesses have seen benefits from marketing surrounding the regeneration and ASR, this has not been felt in the town centre.

The visual impact of the ASR at Boscombe is a well discussed problem, both in this research and in the media. The final constructed crest height is higher than the design crest height and the structure is visible at low tide. The community felt that the seafront has been altered by the ASR and are not complimentary. The visual aspects are important to residents and visitors alike, they ascribe a high value to seascapes, and all respondents in this study who mentioned aesthetic value felt the Boscombe seascape has been reduced by the addition of the ASR.

Recommendations in the next section are the Response in the DPSIR framework, these recommendation are suggested for the future construction of ASRs and similar structures such as ARs for habitat creation and submerged breakwaters for coastal protection. The responses in this case study are mainly in the form of the recommendations to coastal managers and decision makers, but also can be used by the coastal community for general information.

9.2 Recommendations

The initial momentum for this research was the growing interest in ASR technology globally, and more recently in the UK. This combined with the understandable weight being given to using ASR technology to control conflicts during coastal developments, and assist in coastal management decision making around surfing breaks (Scarfe et al., 2009a). For example, where a development might impinge on a natural surfing area, an alternative artificial wave could be offered that could enhance the surfing experience. This is contested by the surf community but in the light of global sea level rise, coastal engineers are looking for alternative sustainable options that consider the expectations of all marine users. ASRs potentially hold an exciting opportunity for those that are interested in innovative or alternative coastal design protection schemes.

The following are recommendations for future consideration in design and feasibility studies for ASR construction. In order to logically provide the recommendations from this research, the timeline for the Boscombe ASR from Section 4.2 (Table 4.1) is revisited. A simplified version of this timeline is presented in Figure 9.2. The timeline is used to focus this section and to provide structure to the recommendations for future ASR construction. This is includes the full life cycle of the ASR, from conception to removal.

9.2.1 Feasibility Study

The ASR concept and preliminary design phase of any coastal engineering project should ask some basic questions to ascertain the necessity of a project. If the natural surf amenity can be made more accessible or safer for beginners, this might be preferential and cost

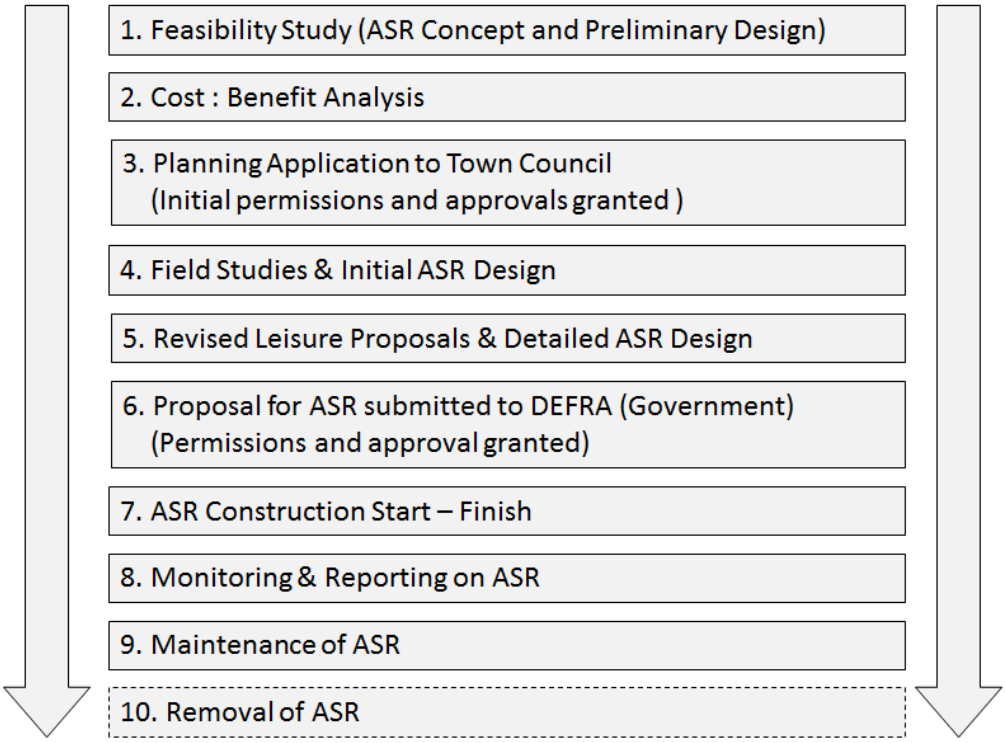

Figure (9.2). Simplified timeline of the planning and construction of Boscombe ASR.

effective. Resources could be focused elsewhere in the community enhancing the tourist amenity by providing additional services or government grants for small businesses.

Results from from Chapter 8 suggest that the impact of the regeneration of Boscombe seafront is a greater influence on the coastal economy than Boscombe ASR, which didn't attract visitors directly after 6 months. The ASR did not aid the local economy after 2011 as it is no longer attracting interest due to closure. The research findings contradict the original feasibility assessments and design documentation that state the ASR would directly enhance surf tourism (ASR Ltd., 2006). Responses indicated that people instead visit for walking or have lunch at the seafront. This is supported by figures released by the Bournemouth Borough Council highlighting a move away from decline towards a phase of regeneration. Since 2008, visitor numbers and house prices have increased by 32% and 25%, respectively (Bournemouth Borough Council, 2011). Also, the reduction of antisocial behaviour incidents by 40% since 2007 (Bournemouth Borough Council, 2011) indicates a safer community. The findings suggest that long term economic and social benefits from the gentrification and attraction of the surf community may be achieved through regeneration and modernising alone. Planners could aim to attract visitors who simply desire the associated lifestyle when visiting a new surf destination, by designing a fashionable surf scene and cafe culture on the seafront.

The results in this study may have been quite different had the surf community been involved from the outset and had ownership of the project. The surf community place emphasis on greater research for any future ASR project. They suggest that the local environmental conditions should be better considered and further inclusion of the coastal community to avoid the design errors. Understanding how this very niche type of marine construction impacts surfing can be achieved by recording the opinion of those in the sport. For an ASR project to genuinely to attract the surf community, there should be period of consultation with local and travelling surfers asking what they require from a new surf break. Consultations must be factual or lean towards a conservative prediction of the surfing conditions expected. There should be transparency regarding the costs and historic problems associated with the geotextile SFCs, this will give stakeholders supporting information to aid their understanding from which to provide more educated feedback.

During design and construction phases consideration should be given to relevant legislation and agreements applicable to areas such as conservation, fisheries, navigation and waste management. Guidelines should be followed for specifically built structures and, where they do not exist, best practice methods can be adopted. For example, the DEFRA policy on the construction of coastal defence schemes required the scheme to be environmentally acceptable, technically sound, economically viable and where possible have multiple benefits (Gardiner, 1999).

9.2.2 Cost : Benefit Analysis

Social-economic research was hampered by the lack of baseline data regarding the seafront area. The difficulty in establishing an economic baseline post-construction and regeneration proved impossible as data regarding the project remained politically sensitive. Additionally, separating the ASR from the overall regeneration of the seafront meant that it was difficult to quantify the success or failure of the project. Baseline information would have helped differentiate between the benefits derived from Boscombe ASR and those from the regeneration project. An assessment should be conducted to address if the regeneration alone could achieve the increased tourism success, as many stakeholders claim, thereby saving the council over £3m. The research findings presented do indicate that an affluent surfer market is not being attracted during quieter autumn and winter months and does not support claims of the original cost:benefit study.

Highly speculative benefits that were included in the original cost:benefit assessment should not be relied on if they are not the primary focus of the project. It is possible that some potential economic losses could be offset by some indirect or non-market benefits such as surf spectator tourism, or a protected area for safer swimming. Until these additional benefits can be proven as a positive benefit, the claims remain unsubstantiated. Any related cost:benefit studies of a new surfing facility should reflect the tourist or travelling surfer expenditure only, not those surfers who are already in the council catchment as they do not add anything new to the economy. Local people may be encouraged to the sport by the construction, however if they live locally they will spend far less than the travelling surfer. Future studies should detail surfer spending when at their destination, without the inclusion of fuel which can be bought outside the area.

Three clear themes were identified during this research; the carrying capacity of the ASR, localism at the beach and in the water, and safety issues surrounding the ASR and rips currents. Encouraging tourism to a location increases spatial pressure from an environmental and social perspective. The cost:benefit ratio should be adjusted to reflect the true carrying capacity of the ASR, that is the true of surfers the ASR can possibly handle, safely. The issue of safety is an important consideration in terms of collisions, localism created with an increase of visiting surfers, and with novice surfers encouraged into rip currents. Investigating the level and perceived level of localism in the area is highly recommended: is the location a suitable choice to alleviate any localism issues, or might it be enhanced by ASR construction? Consideration must be given to governing the level of localism if novice and non-local surfers are being attracted to the beach. Additionally, the consistency, surfability, tides, and daylight hours should be factored into the carrying capacity calculation. It is unrealistic to assume that the ASR could attract large numbers of surfers on a daily basis.

In the original economic cost:benefit analysis a presumption was made regarding the sediment needed for the SFCs: "since ASRs use mineral-based construction materials such as sand they require little or no processing" **??**. However, the processing of the sand at Boscombe was necessary as the sediment delivered was mixed and not fine enough for the machinery used to pump. Processing sediment created weeks of delays for the project, additional costs, and the larger grain size remained on the beach post-construction. The grain size was mentioned by some stakeholders during this research (Chapter 8), particularly with the seafront visitors who noticed the change in the sand and the aesthetics of finer sand. Although not planned, it has been argued that the larger sediment size aided the stabilisation of the beach and is not a concern to coastal managers. Consideration for the sediment used in geotextile SFCs is critical. The procurement of suitable sediment should be carefully considered to ensure movement and scour is reduced inside the SFC. All effects for beach morphology should be considered; excess construction materials, fluctuations in the original sediments, dredge operations offshore for "topping-up", scour at base etc. The costs related to detailed investigations are minimal compared to the remobilisation of the construction team for maintenance or even removal of the ASR structure.

Weather down-time additionally caused a sink for resources, this was originally accounted for but vastly underestimated. Experience from local coastal engineering firms should be sought. All predictions of costs and known potential delays should be shared with the client and coastal community; transparency is essential in this process and will reduce conflict in later monitoring stages. Thoughtful design should include physical and numerical modelling that aids the understand of sediment migration during and post construction. All stakeholders should be made aware of any potential changes to their environment, so they can make an educated decision regarding the introduction of an ASR.

9.2.3 Planning Application to Town Council

In order for planning applications to be taken seriously, future ASR projects need to be investigated with the principles of ICZM in mind. The Boscombe ASR did not fit well into the wider shoreline management plans, but had some short lived success as an addition for novelty and marketing. Project success and longevity depends on the ASR being incorporated into the shoreline management plan, as well as reviewing the sustainability of the services it could provide. This research has highlighted unsubstantiated claims regarding ASRs, therefore independent assessment is advised. Planners and decision makers should carefully review the design and all environmental, socio-economic and socio-perception assessments before making a decision.

A detailed overview of the risk to human life should be the utmost concern. This information should be publicly available and help to inform lifeguards at an early stage. More effort to contact a wider diversity and background of stakeholders, with valuable experience should be included. Fletcher (2011) explored ASRs from the perspective of governance by reviewing the anticipated challenges facing the Boscombe ASR, UK. He found that the success of the reef project would be based on balancing a three way tension between; elevated visitor numbers resulting from an intentional policy to attract surfers to Boscombe, the need to ensure surf safety as far as is possible, and the need to generate a genuine surfing experience.

This research showed that when engaged the direct and indirect user groups were eager to interact and communicate their thoughts. Boscombe ASR was an innovative and original project in Europe which attracted wide spread interest, for different reasons the coastal community were passionate about this project. There were multiple opportunities when Boscombe ASR designers could have included stakeholder opinions for a more successful and cost effective project, particularly with reference to local hydrodynamics and wind climate during construction phase. Direct users remained positive about creating artificial surfing waves and are interested in the potential for further ASR projects. Future ASR projects are advised to address the gap in discussions between surfers, fishers and scientists; where an independent group is best placed to bring separate stakeholder groups together.

Communication and consultation with the surfing community at an early stage is essential to ensure inclusion, ownership and transparency of the surfing community throughout a project like this. Unfortunately this was limited and there was a feeling of exclusion and ignoring local opinions and concerns when they were expressed. In Boscombe the ASR was designed as a tourist attraction to produce a "surfable" wave for surfers and spectators. However, Davidson's (2010) analysis and this research suggest that the ASR has failed to achieve improved surfing conditions. Future projects of this nature need to clearly assess and then communicate with stakeholders under what environmental conditions (swell, tides and wind) the ASR will form "surfable" waves order to avoid the perception of failure. ASRs have the potential to provide a tourist attraction for coastal economies but interest from surfers may not be long lasting if the technology does not support design claims of an improved surfing experience. It should also be clear which type of surfer the construction will appeal to. Offshore ASR construction is for the experienced surfer and not those new to the sport. This misconception is the main reason for lack of return visitors to the Boscombe ASR.

The management of expectations by the local governing body is crucial for establishing an ASR. Media attention to such projects can often produce unrealistic expectations in the community. Poor media communication caused assumptions in the press and coastal community regarding the size and consistency of waves at Boscombe ASR beyond the initial design scope. Many that invested in their existing businesses feel deceived by the council and the designers of the ASR as they made no clear increase in income from the addition of the ASR. There is a need to balance the support for an ASR whilst avoiding unrealistically high expectations of eventual performance (Slotkin et al., 2008). Shand (2011) discusses a misalignment between community perception of ASRs and the wave form that can be achieved. Management of expectation should be undertaken at planning stages by the council and engineers, this will prove valuable if the project meets or exceeds expectation.

9.2.4 Field Studies & Initial ASR Design

Characterisation of the physical, biological, social and economic environment needs to be conducted during feasibility, design and pre-construction stages to serve as a baseline from which environmental impacts are quantified. The field studies should inform all stages of this process, conducting them after the planning application caused other stages to be poorly informed. Estimates are not a wise replacement for observation data. The failure of the geotextile SFCs was directly linked to the hydraulic forcing and circulation at the ASR. The cost of the ASR more than doubled due weather down time miscalculations. The monitoring of a project site previous to any planned construction would allow better baseline understanding of hydrodynamics and coastal processes.

As described in the tables in Appendix D, environmental assessment pre-construction should include: topography and bathymetry of the beach, nearshore and reef areas with measurements of seasonal variability, sediment sampling, subsurface geology review, local biota and seasonality, metocean data with climate change predictions, and baseline social and economic data. Additionally, future research plans should evaluate local hydrodynamics and the potential for rip current generation or enhancement of weaker natural current systems. The implications for swimmer and novice surfer safety should be incorporated into design testing.

Alternative construction choices for ASRs should be considered; geotextile research is at an early stage, further research is required to understand the resistance to hydraulic reworking and abrasion within SFCs. Shand (2011) suggests that whilst the concept of ASRs should not be dismissed altogether, but that geotextile ASR technology currently being employed is too expensive for construction on the scale needed for success. Quality surfing waves in nature have generally been preconditioned (wave shoaling and focusing) over a number of wave lengths (Mead and Black, 2000; Shand, 2011) over large bathymetric changes. Boscombe ASR has a small footprint compared to the scale of natural surfing breaks, subsequently limiting what it can deliver as a surfing break. Marketing of ASRs should focus on their innovative and experimental design.

9.2.5 Revised Leisure Proposals & Detailed ASR Design

After the initial design has been put forward to the local planning committee the design should be revised to include the stakeholder, council and results from field and modelling studies. If observed data is not available, then a full modelling assessments can inform design. The effects of wind on the surfability of waves should not be underestimated. Modelling investigations should represent both common and storm conditions. As mentioned previously, the detailed design of the ASR should include a specification for the SFC fill to avoid unnecessary processing and sorting pre-fill.

The correct choice of geotextile is essential, the geotextile SFCs fail for a variety of reasons including seam weakness, damage during construction, environmental stresses (hydraulic and UV), and are susceptible to vandalism. Careful consideration should be given to the local stakeholders and renegotiation maybe required. For example, if there is a strong opposition this could lead to vandalism. The environmental constraints are project specific and should reflect the social or political problems in the area. Detailed design by competent engineers with experience in offshore environments with the chosen construction material is essential.

Few studies have investigated the effect of ASRs on the shoreline, but parallels can been drawn with the study of submerged breakwaters (Ranasinghe and Turner, 2004; Ranasinghe et al., 2006, 2010). Considerably more temporal research is needed to assess the impact of scour or accretion at the shoreline, as well as other parameters such as the performance of ASRs and longshore coastal erosion over decade periods. At Boscombe, there is considerable exposure of the clay underlying the beach sand veneer due to scouring. The shoreline remained stable throughout the period of this research, with no detrimental impact. An inaccurate claim was made by the designers that the beach had been widened by the ASR presence. Changing the aims to coastal protection in this manner caused the project to be viewed as a failure by the coastal community.

This research highlights benefits of the ASR project, as well as areas that need attention and improvement if future projects are to be successful. Engaging multiple ecosystem services is key to making these projects successful. There are key niche areas of research that need detailed specialist attention, such as the attraction vs production debate. Boscombe ASR did not prove useful in enhancing commercial fisheries. Future ASR projects might benefit from aiming for a particular area of commercial fishing, as opposed to this blanket claim. Alternatively, the ASR could form part of a marine protected area (MPA) but this prevents marketing for sport fishing. Consideration should be given for potential conflict between anglers and surfers. Steps should be taken to minimise crowding and resolve conflict before construction.

The detailed design process should be iterative with physical and numerical model testing, it should be discussed with foucs groups in the coastal community to gain feedback.

9.2.6 Proposal for ASR, submitted to government

The national regulatory body should be able to provide an objective review of the proposed plans. In the UK, Department of Environment, Fisheries and Rural Affairs (DEFRA) gave permission for the Boscombe ASR. Regulations and guidelines, if they exist, vary between countries. There were no regulations that specifically guide or controlled the construction and little information by which to assess the impact. Implementing protocols of good practice for geotextile SFCs and ASRs will provide support in regulating the construction of ASRs, and define the standards for monitoring studies pre- and post-construction.

There are numerous legal questions associated with ASRs, relating to their location, construction, operation and decommissioning (Pickering, 2000). Currently, the purpose of an AR will dictate the legislation or policy surrounding it. This will vary across Europe as member state will have additional internal policy governing their use. Pickering (2000) and Whitmarsh (1997) stand out as leading authors in the subject of AR construction legislation in British and European waters. They rightly state that it is imperative that the current growth of interest in ARs is matched by corresponding development in the law applying to such structures. No AR should be placed in the marine environment without authorisation or regulation by the competent authorities. The legal requirements for permits and permissions vary widely across Europe; no two countries have the same approach to licensing AR deployment (Jensen et al., 2000b).

Ultimately, the decision to install an ASR or AR should only be agreed with the correct licensing completed and when the environmental and socio-economic impact assessments have been evaluated. In this process, due account should be taken of the precautionary principle and the best environmental practice. The guidelines on ARs from the OSPAR convention (OSPAR, 1999) state that authorisations for constructing ARs should:

- a) specify the responsibility for carrying out any management measures and monitoring activities required and for publishing reports on the results of any such monitoring; and
- b) specify the owner of the artificial reef and the person liable for meeting claims for future damage caused by those structures and the arrangements under which such claims can be pursued against the person liable.

The deployment of artificial reefs must not constitute an unreasonable interference of the right of innocent passage by vessels of other states through territorial waters (Honein, 1991). The provisions in respect of the safety of navigation reflect international commitments under the United Nations Convention on the Law of the Sea 1982 (UNCLOS). In many countries this is supplemented by a public right of navigation by the citizens of the coastal state (which in the UK is a right to wander, subject only to measures for ensuring the safety of navigation). Additionally, consultations by the MMO (Marine Management Organisation) with the Environment Agency, CEFAS and the Crown Estate are required by DEFRA in order to produce a 'consent license to dump at sea' under the 1985 Food and Environmental Protection Act (FEPA). The MMO consult with smaller bodies and organisation alongside stakeholders to ensure the best possible decision is reached. As licensing authority the MMO (then MFA) consented to undertake the construction of an ASR at Boscombe under Part II of the FEPA 1985 (MFA, 2009) alongside the Coastal Protection Act 1949. The FEPA license authorised the deposition of materials (substances or articles) associated with the Boscombe ASR construction namely; sand, plastic and synthetic, and 'other'. The international and EU science community do not wish the term artificial reef to be used in association with harm to the environment (Jensen et al., 2000b). The association with pollution is not positive, therefore the legislation for reef construction should be considered completely separately.

The UK Marine and Coastal Access Act 2009 provides the legal mechanism to ensure clean, healthy, safe, productive and biologically diverse oceans and seas by putting in place a new system for improved management and protection of the marine and coastal environment. This act has come into play since the construction of the Boscombe ASR. Past acts have favoured gaining permission to get construct or build at sea, but there were flaws in this legislation and construction projects have not been monitored or governed properly, and accountability has been lacking. The Marine and Coastal Access Act 2009 favours sustainable development so, unless there is a reason not to go ahead with the construction, a license will be granted so that development continues. This is a positive and negative instrument for ASR designers and coastal planners. Some might see the application process as a hindrance, however it prevents important areas of the project being overlooked or poorly planned, such as the under resourced budget and construction plan for the Boscombe ASR project. The positive argument is that only well managed, reviewed, designed and planned projects will go forward, promoting successful engagement with stakeholders and the public.

Discussions surrounding the degradation of the reef with time should apply the precautionary principle as there is a lack of scientific research on the full environmental impact of the polymer used in geotextile SFCs. It is important that ASR licensing should follow some simple policy guidelines including a robust licensing process based on sound scientific findings and the establishment of pre-construction baselines. The licensing process and reporting should be objective and not written by those with commercial interest in the project. This would help avoid criticism from stakeholders and increase transparency.

9.2.7 ASR Construction

It is essential that project management and construction are carried out by those experienced in marine construction. Accurate calculation of weather downtime and prediction of construction problems that may be encountered should be budgeted. An ASR should be constructed with it's lifetime in mind, from the initial placement of geotextile SFCs to their planned removal (at 25-40 years in the case of Boscombe ASR). Additionally, a good understanding the hydrodynamic circulation at the construction site is important to the ensuring scour and undermining are reduced and prevented in future projects.

At Boscombe, the compression and settling within the geotextile SFCs created an uneven distribution of sediment and the term pillowing was coined due to appearance. It is thought the increased strain on the seams of neighbouring SFCs was induced by the void created after one failed. A number of causes for the damages were raised, none of which have been categorically proven to be the exact cause for the damage; it became apparent that the containers were not filled to the capacity specified in the original design documents, and that one or more of the containers were missing from the original designs.

The construction team stated that the incorrect grain size had been provided by the council and that the distribution of grain size was inconsistent, therefore hampering the filling of the geotextile containers.

The guidelines that exist previous to the Boscombe ASR (OSPAR, 1997), legal documents and associated implications are unclear causing conflicting interpretation. Few countries have explicit legal provisions governing ARs or ecosystem rehabilitation structures. There are even fewer regulations that guide or control the construction of ASRs. The Guideline for the Placement of Artificial Reefs written after the London Convention (2009) provides an up dated approach to constructing reefs for biological and fisheries purposes, and even touches on amenity uses such as surfing and stakeholder engagement. However, these guidelines are outdated with the Boscombe ASR experience. New guidance is needed for all stages of the construction process and the owner is accountable for monitoring and maintenance, and for end of life removal. New guidelines should highlight best practice procedures in design and construction, coordinate stakeholder engagement meetings and standards for recording biological, physical and socio-economic data.

9.2.8 Monitoring & Reporting on ASR

Post-construction monitoring is needed to regularly measure pressures and any environmental state change and socio-economic impacts. With clear definition of the project aims in place, and baseline data pre-construction to measure impacts and performance against monitoring will provide a useful tool for maintanence. Monitoring will identify minor problems early and dictate potential structural alterations, maintenance or complete removal. Any major changes should be acted upon and an previously identified maintenance team mobilized.

Clear criteria should be used to assess the performance of ASRs in terms of the project aims, for example the ASRs ability to generate surfing waves, or advance the shoreline, or create habitat. If claims are to be made for any additional benefits, it is recommended that observations are reported in the timescales of years to incorporate seasonality. Suggestions for the criteria used to establish a baseline pre-construction and assess performance and monitor impacts are provided in two tables, the physical environmental monitoring is presented in Appendix D Table A1 and the ecological and socio-economic monitoring is presented in Appendix D Table A2. The tables include suggestions for the frequency and survey method a project manager or coastal planner might utilise.

The standard of monitoring and construction is currently poor, this needs to be modernised and standardised through collaboration of engineers and scientists. The installation of an ASR should be followed by appropriate short, medium and long-term monitoring; 5 years seems sufficient time for a relatively stable biological community to develop (Jensen et al., 2000a) therefore monitoring should surpass this. To ensure impartial judgment, survey and analysis should be conducted by independent parties. It is suggested that any sampling designs are checked with a professional of a suitable independent organisation to ensure pseudo-replication is avoided and provide qualitative, robust information that is non-bias and reliable. The results of monitoring studies must be documented and reported in ways accessible to the wider audience of stakeholders.

Three main benefits arise from establishing monitoring programs. First, to assure compliance with the conditions defined in the authorising permit, laws and regulations. Secondly, to provide an assessment of the predicted performance against the original aims of the project, and ensure the ASR meets general standards and expectations. And thirdly, to provide evidence that support future improvements of reef design and performance. The suggested monitoring protocol in Appendix D provides reliable ways of quantifying the impacts and measure performance of ASRs, which can be easily adapted to suit local specificity globally. The monitor protocol proposed is by no means exhausted and should be adapted and developed. Project managers would be best advised to seek input from an independent organisation with local knowledge in order to adopt the most appropriate methodology and investigate other potential environmental impacts.

9.2.9 Maintenance & Removal of ASR

Repairs and general maintenance of the ASR should be performed as soon as problems are discovered, delay will result in SFC failure as observed in the Boscombe ASR project. It took years of deciding what to do with the failed Boscombe ASR before a decision was made. There was no contingency plan and budget in place for full removal and restoration of site. The cost of removal needs to be factored in at the design stage of an ASR. In the event that the ASR fails to deliver or begins to disintegrate at the end of its design lifespan, as has happened with two of the ASR projects to date (e.g. Pratte's Reef, an ASR in California and Mt. Managui ASR in New Zealand).

The monitoring, inspection program and repair plan should be established as part of the initial design and feasibility studies. A contracted team should be assigned to this work. The replacement or addition of entire individual containers may be required if damages are too severe for patching, port holes are particular area of weakness. It is essential that the knowledge gained in the field from monitoring the performance of SFC systems is used to improve the designs of the container shapes, seams, and fill ports (ADB, 2008). Therefore, it is advised that this information is made publicly available for future geotextile manufacturers, designers and construction teams. Typical repairs include field sewing, gluing, and the heat welding of seams and materials, adding new materials to cover the damaged areas when necessary. Better advise from manufacturers regarding patching tears and ports is required to support future designs.

Chapter 10

Conclusions

The study presented in this thesis discusses the topic of Artificial Surf Reefs through the use of a specific case study constructed at Boscombe, UK. With the main aim to provide an impartial and independent study into the environmental, social and economic impacts of an ASR. The research presented is therefore multidisciplinary in nature, the separate components utilise key techniques from the geophysical, numerical modelling and socio-economic disciplines are combined to present a significant contribution to the knowledge and understanding of Artificial Surf Reefs. Whilst previous studies have focused on one of these disciplines, there are no independent detailed studies of a constructed ASR utilising an multidisciplinary approach; for example the impact of submerged breakwaters on shoreline migration (Ranasinghe et al., 2006), or the economic impact of surfing to a coastal community (Murphy and Bernal, 2008). The ASR concept and structures are still in their development infancy, the subject has recieved cursery independent review in the literture. There have been few sucessful projects, those that have survived structurally in the ocean are not being used primarily for surfing. The Boscombe ASR is an example of high overspend, poor management and construction, loss of geotextile SFC and users deem the project a failure. The consequences of not correctly planning, managing and overseeing the construction has resulted in a poorly viewed project of limited success. All stages of this project could have benefited from thoughtful planning, thereby avoiding this outcome. If lessons are to be learnt from this project then the planning and manangement are key areas of the process that need addressing. Ensuring that any future ASR projects are securely intergrated with the coastal zone management plan will provide sustainability and more likely sucess. The DPSIR framework approach can be used during the monitoring and reporting stages to highlight and address the causes of problems arising from the project. This framework enables the various disciplines to be discussed in relation to each other; links can be identified between the environmental, social and economic impacts of the ASR construction. Following strict planning and guidelines for construction will increase the success of the ASR. The final crest height of the Boscombe ASR was 0.5 m higher than the final design height, this is a fundamental design flaw that should not be occuring in modern coastal engineering practice. It is suggested that guidelines are written based on this research for the design and construcion process of an ASR. The recommendations and guidelines for ASR monitoring pre and post construction are provided by this research. The emphasis for future projects should be in the final design and in monitoring, baseline field data should be collected to understand the environmental state change and socio-economic impacts. Planning and government proposals should be accompanied by extensive stakeholder engagement ensuring transparancy for the project and ownership within the coastal community. The exclusion of stakeholders at key decision points created distrust and misunderstanding towards the Boscombe ASR project. Avoiding unrealistic expectations within the surfing community and wider coastal community was discussed throughout this research, and by others in the literature (Slotkin et al., 2008; Shand, 2011; Fletcher, 2011). Shand (2011) goes on to discuss the size of the ASR is a fundamental problem to the sucess of these projects to date, to deliver the consistency of wave form for surfing they need to be large and have multiple take off points. This research agrees with these statements, the issue of poor surfability would be improved by a greater area to manipulate the bathymetry. However this would come at a greatly increased cost in geotextile SFCs, which the current construction method is certainly not capable of delievering successfully. It would be recommended in this case that an alternative construction material was used that is resilient to the marine environment and readily adaptable given poor performance. Further testing of materials, both geotextile SFCs and alternatives, are required for the successful advancement of ASR technology.

Throughout this study there has understandably been interest in the performance of the ASR from a surfing perspective. Davidson's (2010) research at 6-month's post-construction highlights that the reef performs loosely to the original design, meeting four out of eleven performance criteria (surfability, wave form, peel angle and wave height amplification) and partly meeting a further two (ride length and physical shape). The results presented in this thesis would reduce this since the wave form and surfability were reduced after the ASR lost shape and reduced in volume. Results from questioning the direct users of the ASR highlight poor overall performance. The frequency and consistency of surfing at the beach break surpasses the ASR break. The ASR breaks rarely and when it does is very crowded, the wave is steep and heavy meaning it is considered an intermediate to expert break as a surfer needs to stand-up quickly. There are reports of overcrowding and therefore increased localism as the beach became more crowded over the lifespan of the ASR. This research has added to the limited discussion about artificial surf reefs and compliments the broard literature on artificial reefs. The thesis provides a useful reference for those interested in the construction of an artificial surfing facility and considerably widens the current information and material regarding tourist amenity structures available to coastal engineers, planners and managers. It warns against the over exageration and misleading claims of the ability to create artificial waves particularly where stakeholders are concerned. This research is valuable in defining new protocols for policy and regulation, and providing guidelines for the construction and monitoring of future ASR projects. The discussion suggests a number of areas for considerable research across the associated diciplines.

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Appendices

Appendix A

Model runs and outputs

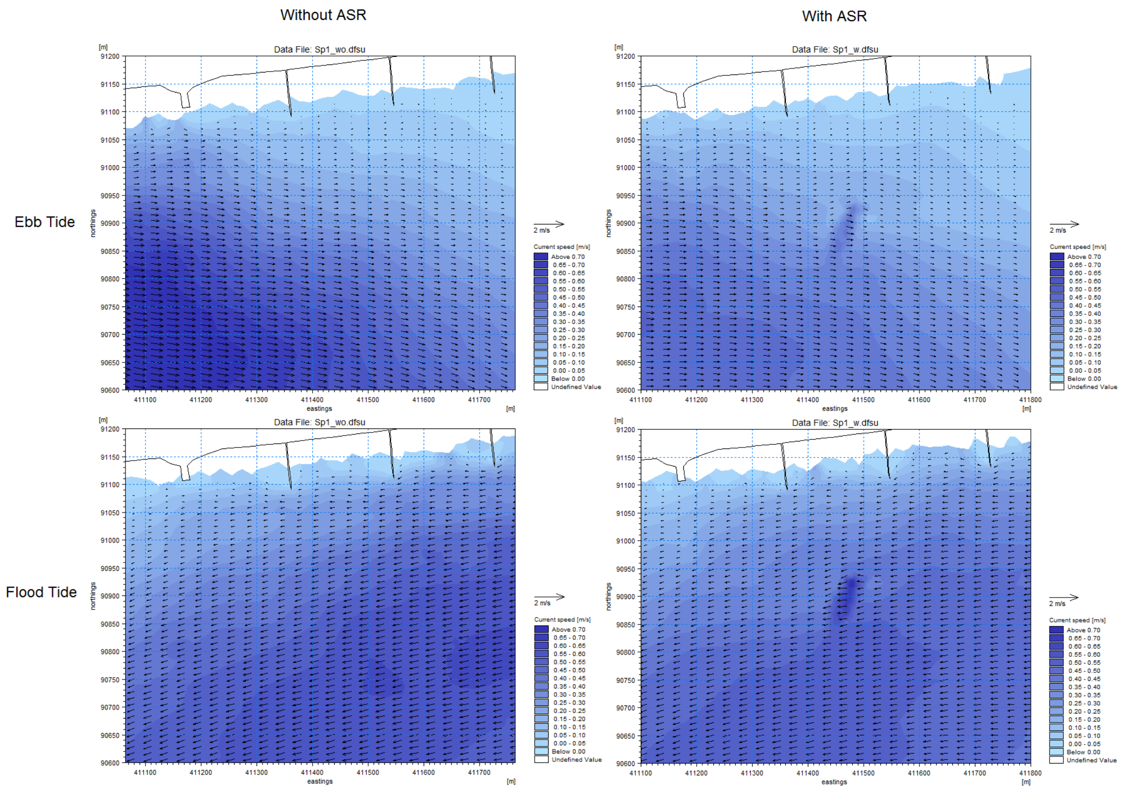

Figure (A1). Mid ebb and flood tide for the peak spring tide model run 1 (calm conditions, zero waves), with and without the ASR in the mesh bathymetry.

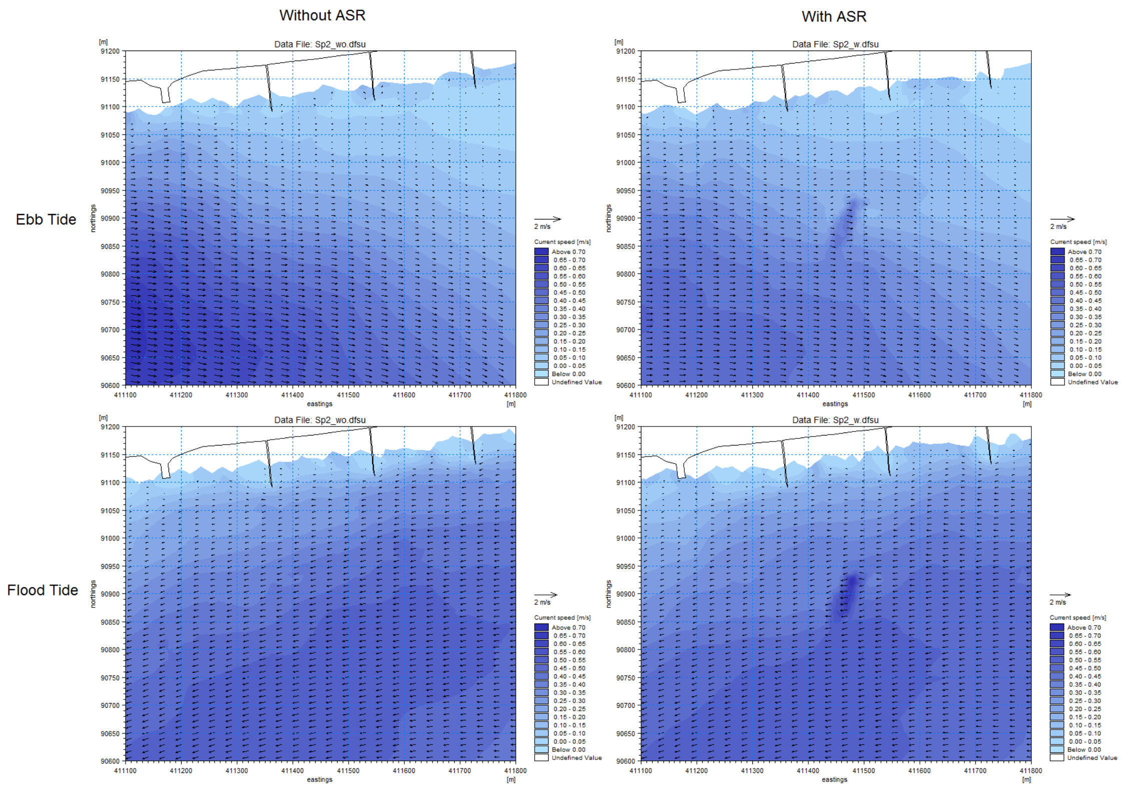

Figure (A2). Mid ebb and flood tide for the peak spring tide model run 2 (calm conditions, 0.25 m wave height, 6 s period, shore parallel wave direction 173^o wave direction), with and without the ASR in the mesh bathymetry.

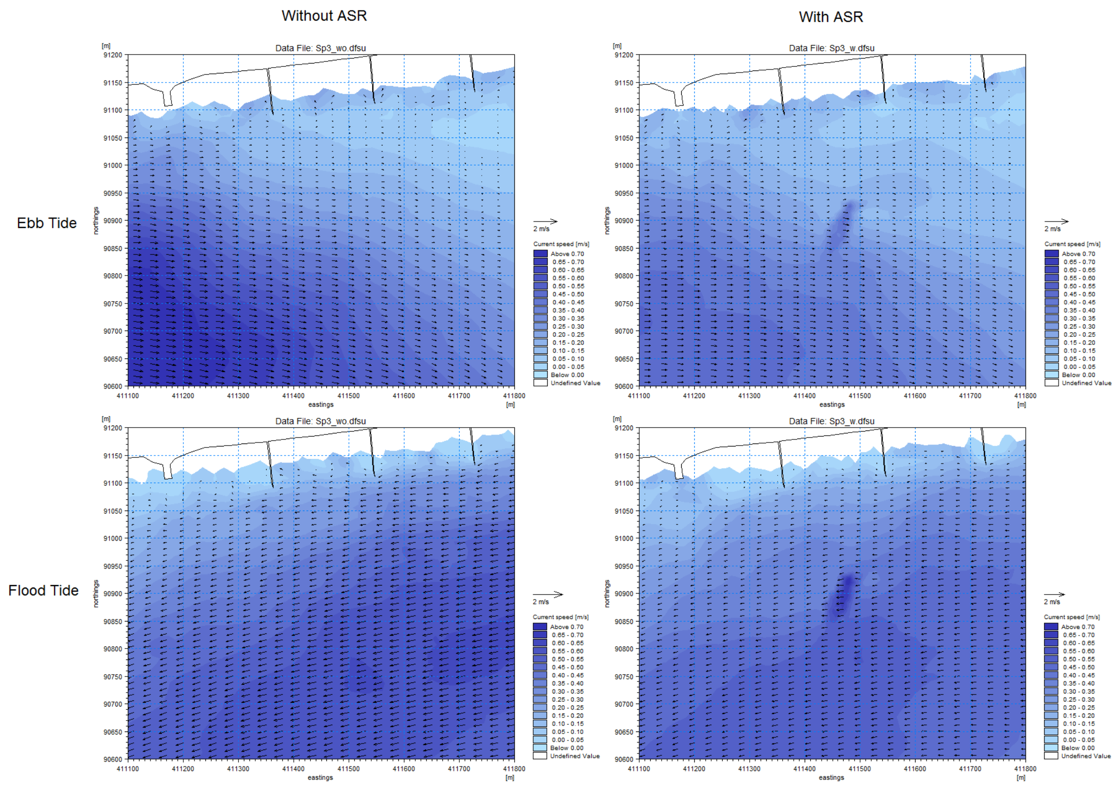

Figure (A3). Mid ebb and flood tide for the peak spring tide model run 3 (rough conditions, 0.5 m wave height, 6 s period, shore parallel wave direction 173^o), with and without the ASR in the mesh bathymetry.

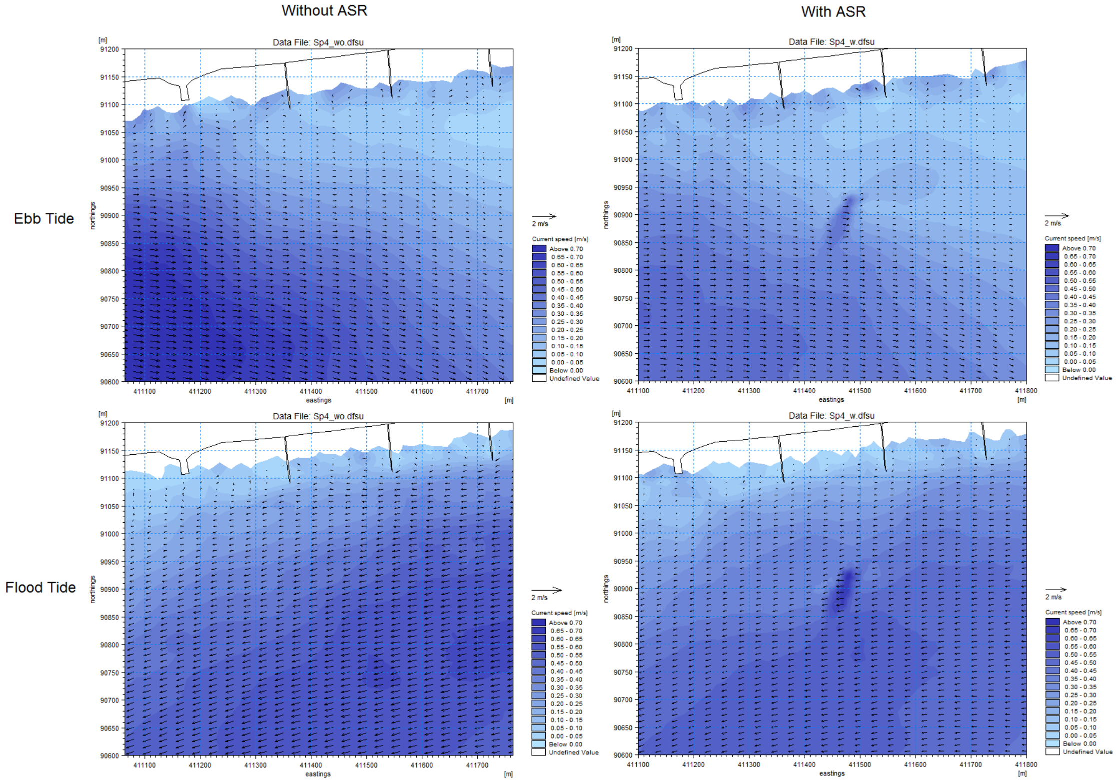

Figure (A4). Mid ebb and flood tide for the peak spring tide model run 4 (surf conditions, 0.5 m wave height, 10 s period, shore parallel wave direction 173^o), with and without the ASR in the mesh bathymetry.

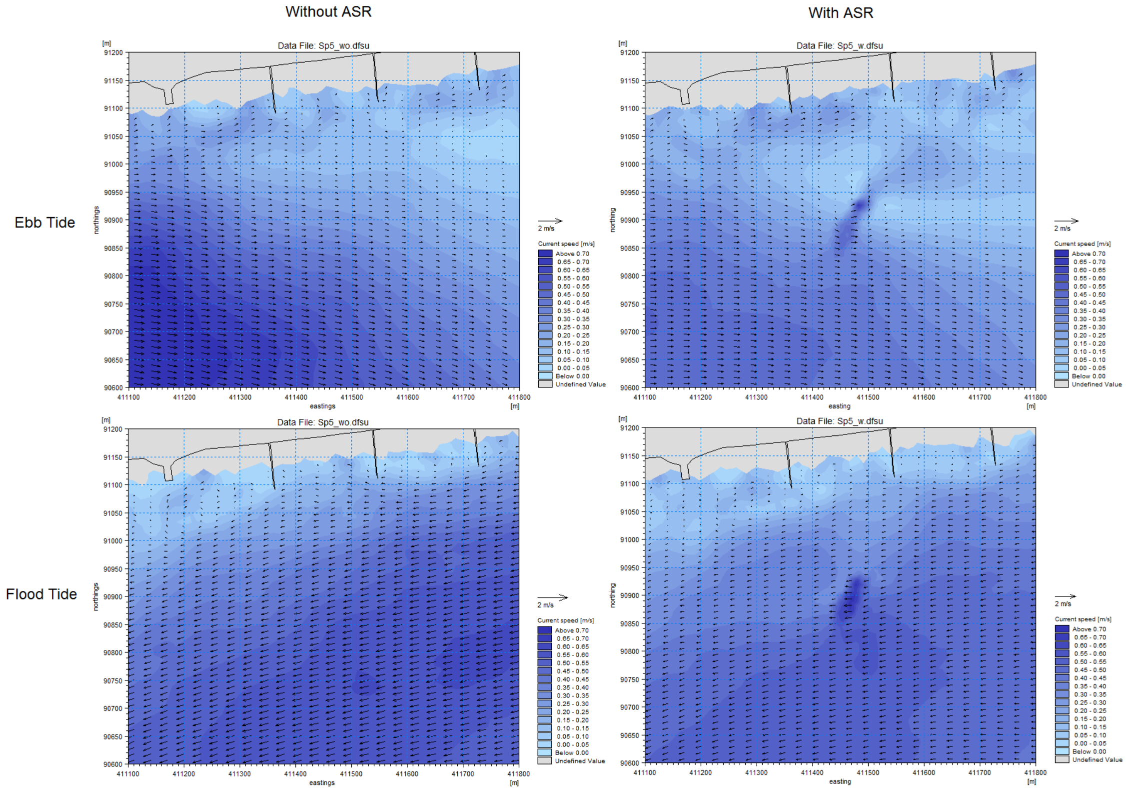

Figure (A5). Mid ebb and flood tide for the peak spring tide model run 5 (rough conditions, 1.0 m wave height, 6 s period, shore parallel wave direction 173^o), with and without the ASR in the mesh bathymetry.

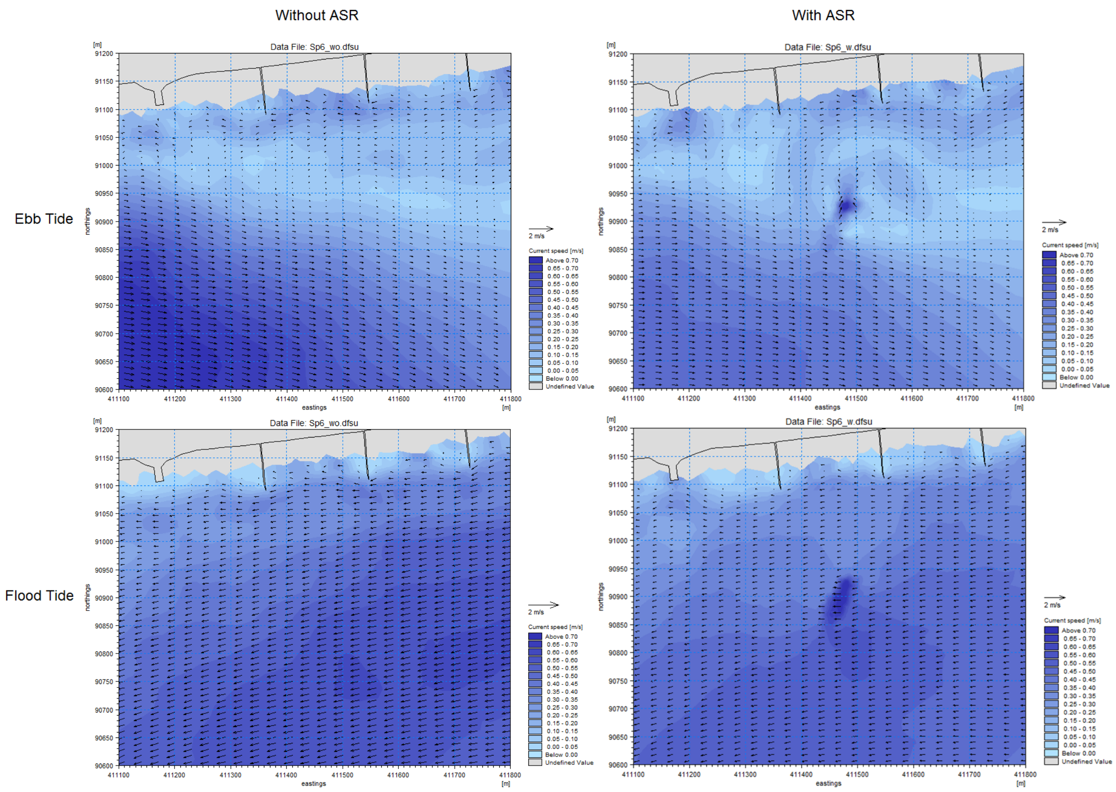

Figure (A6). Mid ebb and flood tide for the peak spring tide model run 6 (rough conditions, 0.5 m wave height, 6 s period, oblique wave direction 150^o), with and without the ASR in the mesh bathymetry.

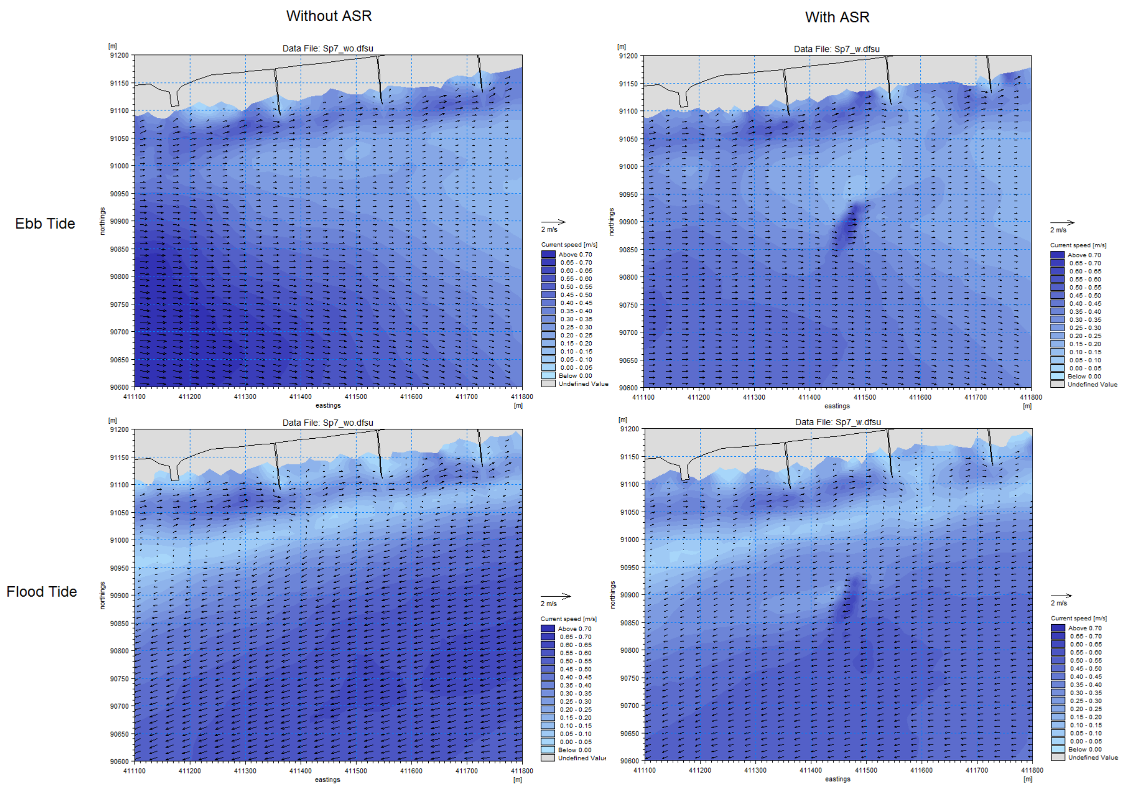

Figure (A7). Mid ebb and flood tide for the peak spring tide model run 7 (rough conditions, 0.5 m wave height, 6 s period, oblique wave direction 220^o), with and without the ASR in the mesh bathymetry.

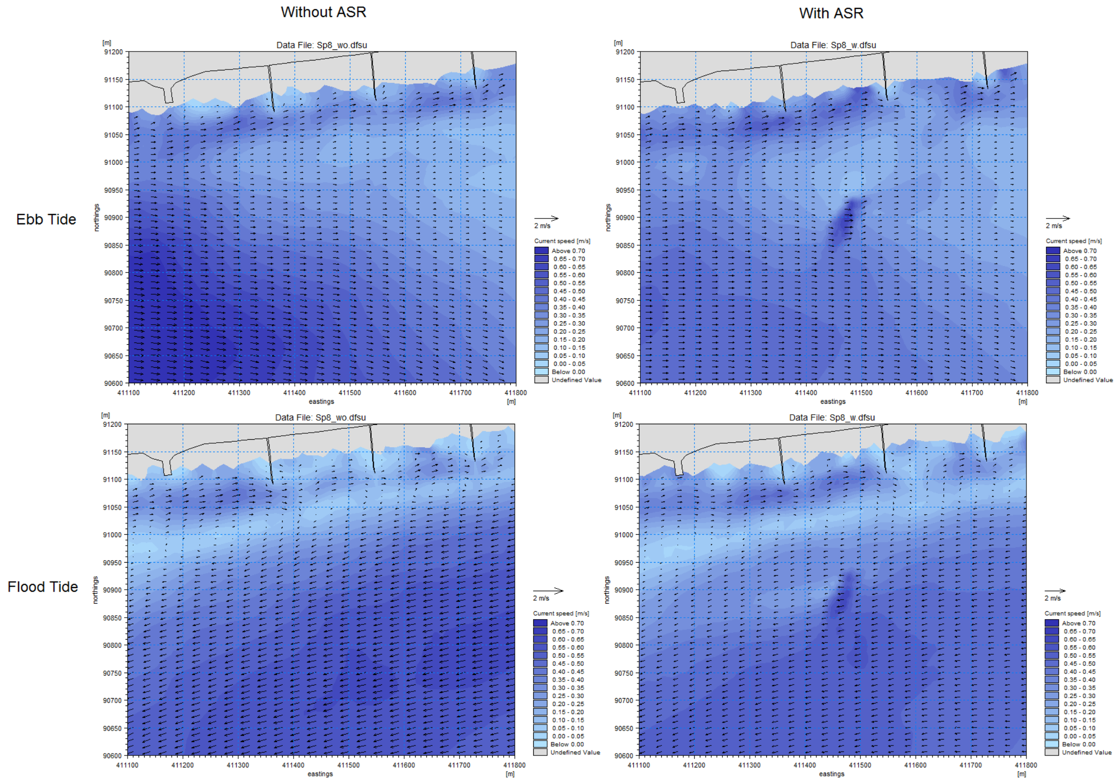

Figure (A8). Mid ebb and flood tide for the peak spring tide model run 8 (rough conditions, 0.5 m wave height, 6 s period, oblique wave direction 200^o), with and without the ASR in the mesh bathymetry.

Appendix B

Questionnaire and Interviews

A Direct users questionnaire: The UK Waverider Survey

Hello and Thank you for your interest in this research into the UK Waveriders!
Your opinion matters and your honest responses are incredibly important if the results are to truly reflect the surfing community. We understand your time is valuable the questionnaire should not take long to complete (15 minutes), there are 4 short sections. Answers given will remain confidential. By taking part in this questionnaire you are consenting to the use of the data you provide for the purpose of this research.
In this study ”surfing” is described as travelling along the face of a wave using any shape of board or with the body alone. With Europes first Artificial Surfing Reef (ASR) constructed in Boscombe, Dorset in 2009 and further interest in other European countries, this independent research aims to extract an economic value for ASR construction. Your responses to this questionnaire will give detailed background information into the socio-economic impacts of the surfing industry and whether structures such as these are justified considering the variety of natural surf breaks already in the UK. Understanding wide and varied opinions from the surfing community regarding the Boscombe ASR is important and needs to be voiced in the correct manner.
Thank you in advance for your participation!

Emma

Questions? contact Emma Rendle at The University of Plymouth (emma.rendle@plymouth.ac.uk)
Required

Please indicate that you give consent to use information for use in research and you understand your right to withdraw by checking the 'yes' box. Please note you can only withdraw from this research if you have provided your name and email address in the appropriate places.

- Yes, I understand the consent procedure and right to withdraw.

Please indicate that you are over 18 by checking the 'yes' box * Please note this research is aimed at adults, aged 18 and over.

- Yes, I am over 18.

A. Surfing Ability

A1. What is your predominant surfing activity? *

- Surfing Short-board
- Surfing Longboard
- Surfing Bodyboard
- Stand-Up Paddleboard (SUP)
- Windsurfing
- Kite Surfing
- Body Surfing
- Other:

A2. Please indicate your level of surfing based on the standard Hutt Scale for surfing * Surfing is defined as those who ride the face of waves, using whatever means. Therefore please apply the scale below according to your sport (all forms of boardsports, including body surfing)

- Beginner surfer (not yet able to ride the face of a wave; simply move forward as the wave advances)
- Learner surfer (able to successfully ride laterally along the crest of a wave)

- Surfer has developed the skill to generate speed by pumping on the face of the wave
- Surfer beginning to initiate and execute standard surfing manoeuvres on occasion
- Surfer can execute standard manoeuvres consecutively on a single wave
- Surfer able to execute standard manoeuvres consecutively; execute advanced manoeuvres on occasion
- Top amateur surfer (able to consecutively execute advanced manoeuvres)
- Professional surfer (able to consecutively execute advanced manoeuvres)

A3. How many years have you been surfing? * Less than 1, 1-5, 6-10, 11-15, 16-20, 21-25, 26-30, 31+

A4. Rank your 3 MOST SURFED surfbreaks in the UK (1=most often) * If you do not want to disclose location by name please write region and type i.e. 1=N.Cornwall beach break, 2=S.Devon point break, 3=S.Devon beach break

A5. Rank your TOP 3 UK surfbreaks (answers can be repeated from above) * as above

A6. Rank your TOP 3 INTERNATIONAL surfbreaks (answers can be repeated from above) * as above

B. Frequency of Surfing

B1. How often do you surf? *

- Daily
- Few times a week
- Once a week
- Once a fortnight
- Once a month
- Quarterly
- Once/ or twice a year maybe
- Annual UK surf trip only (every day for trip duration)

- Other:

B2. If you surf the same break two days in a row do you normally; *

- Go for one day or a few hours only
- Return home and come back the next day
- Stay over with friends (i.e. free accommodation)
- Sleep in your van/car, free camp (i.e. free accommodation)
- Stay at a campsite (i.e. pay for accommodation)
- Stay in a hotel or B&B (i.e. pay for accommodation)
- Other:

B3. On average, how much do you spend PER DAY on a typical, everyday surf trip? * include accommodation, travel costs, eating/drinking, equipment, accessories, clothing etc.

B5. What do you estimate your total expenditure PER YEAR on UK surfing * include accommodation, travel costs, eating/drinking, equipment, accessories, clothing etc.

C. Willingness to travel

C1. What is the main means of travel to your most surfed break? *

- Walk
- Public transport (bus, train etc)
- Drive alone
- Drive with friends (car share)
- Other:

C3. On average, how much do you spend PER DAY on a UK short break surf surf trip? * include accommodation, travel costs, eating/drinking, equipment, accessories, clothing etc.

C4. How far are you willing to travel to go surfing during a typical working week? * i.e.

before or after work, university or school.
C5. How far are you willing to travel to go surfing during a typical weekend or short break? *

D. Artificial Surfing Reefs (ASR)

An Artificial Surfing Reef was built in Boscombe in Dorset in 2009 in order to enhance the consistency of surfable waves and to attract surf tourism to the town, both novices and competent surfers alike. The ASR cost 3.1 million and has been in the centre of an argument regarding spending public money. It is also considered by the local council as the centre piece of a rejuvenation project to enhance the seafront and promote tourism.
D1. Had you heard about the ASR at Boscombe, UK previous to this survey? * Yes / No
D2. Have you ever surfed, or tried to surf the beach at Boscombe? * Yes / No
D3. If YES, how do you rate the Boscombe Beach as a surfing break? On a scale of 1 to 10, where 1=poor performance and 10=top world class break.
1 2 3 4 5 6 7 8 9 10
D4. If Yes, do you surf more frequently at Boscombe Beach since to the rejuvenation of the seafront and improved beach facilities?
Yes / No / The same
D5. Please comment on surfing at Boscombe Beach generally.
D6. Have you ever surfed, or tried to surf the ASR at Boscombe? * Yes / No
D7. If YES, how many times?
D8. If YES, how do you rate the ASR as a surfing break? On a scale of 1 to 10, where 1=poor performance and 10=top world class break.
1 2 3 4 5 6 7 8 9 10
D9. Please provide details about the ASR surf session/s you experienced If possible, provide dates, swell/wave conditions, wind state, your experiences for safety and that of other surfers around you, enjoyment factor, length of ride, lefts or right rides?
D10. Please respond to the following comments: * Even if you have never seen the technology, we are interested in your opinion Strongly Agree, Agree Uncertain, Disagree, Strongly disagree

- The ASR at Boscombe is popular with the local residents
- Coastal modification, such as using ASRs concerns me

- I support the future use of ASR technology for surf tourism in the UK
- More research is needed into ASRs and the ability to create surfable waves
- ASR technology should be used with caution
- The construction of a successful ASR in my area would influence where I would surf
- I would not want ASR technology in my local region for fear of the effect to surfing conditions
- If there was further evidence to support the use of ASRs for providing improved consistency in surfable waves, I would be supportive of the technology

D11. In your opinion, what are the perceived ADVANTAGES of Boscombe Artificial Surfing Reef? *

D12. In your opinion, what are the perceived DISADVANTAGES of Boscombe Artificial Surfing Reef? *

E. SOCIO-DEMOGRAPHICS

Please provide your location and, if you would be interested in being contacted in future rounds of this research, please provide your contact details. This information will remain anonymous and will not be passed on to other parties.

E1. Name

E2. Nationality *

E3. City/Town *

E4. Country *

E5. ZIP / Postcode *

E6. Email Address

E7. Phone Number

E8. Please indicate your age *

18-25, 26-33, 34-41, 42-49, 50-57, 58-65, 66-73, 74+

E9. Please indicate your gender *

Male Female

E10. What is the highest level of education you have completed? *

- Secondary Education/High School

- Diploma, Vocational or Technical Training
- University or College Graduate
- Postgraduate
- Other:

E11. Please indicate your employment status *

- Employed
- Unemployed
- Full-time Student (School)
- Part-time Student (School)
- Full-time Student (University/Collage)
- Part-time Student (University/Collage)
- Other:

E12. Please indicate your annual income * including DSS and benefits

B Indirect users interview: Seafront Visitors

Tourism; Boscombe Seafront

Reference Number:

Please allow a few minutes to complete this questionnaire and return the completed form to the person/establishment from whom/where you obtained it. Retain the last page for contacts and your reference number.

1. Are you local to Boscombe? (please tick one)

[ ] Local Boscombe Resident (less than 2 miles) [ ] Temporary Resident (Holiday Home) [ ] Not Local Resident (more than 2 miles)

If you are a local or temporary resident; continue to Question 2.

If you are NOT local;

How far have you travelled (miles)? [ ] 2-5 [ ] 5-15 [ ] 15-40 [ ] 40-60 [ ] 60-100 [ ]100-150 [ ]150+

How long will you stay in Boscombe? [ ] Few hours (i.e. not overnight) [ ] 1-2 days (overnight) [ ] 3-4 days [ ] 5-6 days [ ] 1 week [ ] 2 weeks [ ] More than 2 weeks

2. Approximately, what has been the Average Cost per Day of your trip to Boscombe Seafront/Beach? (Total including food, accommodation, fuel, transport, entertainment, parking, shopping expenses and any other costs incurred). [ ] 0 [ ] up to 5 [ ] 6-10 [ ] 11-20 [ ] 21-50 [ ] 51-75 [ ] 76-100 [ ] 100-150 [ ] 200+

3. What are the 3 Primary Reasons for your visit to Boscombe Seafront/Beach?

[ ] Resident (Permanent/full-time address) [ ] Business (In the Boscombe/Bournemouth area) [ ] Incidental (Just passing) [ ] General tourism (Beach attractions, walking etc) [ ] Visiting Family/Friends [ ] Water-sports [ ] To view New Artificial Surfing Reef [ ] Shopping [ ] Relaxing [ ] To view the re-vamp of Boscombe seafront (heard in the media) [ ] Other

4. Will you participate in Water Sports whilst visiting Boscombe Beach?

[ ] Yes [ ] No

If YES, Which Water Sport primarily attracted you here? (Please tick one)

[ ] Stand-up Surfing short-board [ ] Stand-up Surfing long-board [ ] Paddle boarding [ ] Body Boarding [ ] Windsurfing [ ] Swimming [ ] Paddling/Bathing [ ] Body Surfing [ ] SCUBA diving [ ] Kayaking/Canoeing [ ] Fishing from boat [ ] Fishing from Pier [ ] Other

5. Gender [ ] Male [ ] Female

6. Age [ ]18-20 [ ] 21-24 [ ] 25-34 [ ] 35-44 [ ] 45-54 [ ] 55-64 [ ] 65-74 [ ] 75+

Thank you for your time! Please tear below information off and retain for your records

Reference Number:

If you are dissatisfied with the way the research is conducted, please contact the principal investigator in the first instance; Emma Rendle at emma.rendle@plymouth.ac.uk or on 01752 584735. If you feel the problem has not been resolved please contact the secretary to the Faculty of Science Human Ethics Committee, Mrs Paula Simson on 01752 232984. Principal Investigator Emma Rendle Aim of research This questionnaire investigates the interests of people visiting Boscombe Beach for use in PhD project research Benefits of proposed research Data collected will be used in on-going monitoring and development of coastal management procedures and social-economic impacts Right to withdraw Please understand that if you wish to be withdrawn from the research at any stage, and ask for data to be destroyed you are free to do so. Description of risks The Principal Investigator of this work will have attempted, as far as possible, to avoid any risks, and that safety and health risks will have been separately assessed by appropriate authorities (e.g. under COSHH regulations) Anonymity is guaranteed, unless expressed otherwise (you will not be asked for your name, address or personal details)

C Indirect users interview: Social-economic impacts of Artificial Surfing Reefs

Thank you for your interest in participating with this research. With Europes first Artificial Surfing Reef (ASR) constructed in Boscombe, Dorset in 2009 and further interest in Wales and Cornwall, alongside other European countries, this independent research aims to extract an economic value. Your responses to this questionnaire will give detailed background information into the socio-economic impacts of these structures. When completing the following questionnaire please try to fill in the questionnaire as honestly and thoroughly as possible. We understand your time is valuable and we have therefore developed a questionnaire which should not take long to complete (15 minutes). Your opinion matters and your responses are therefore incredibly important if the results are to truly reflect the stakeholder community. Answers given will remain confidential. By taking part in this questionnaire you are consenting to the use of the data you provide for the purpose of this research. Thank you in advance for your participation.
Emma
Questions? Please contact Emma Rendle at The University of Plymouth (emma.rendle@plymouth.ac.u
Required

Please indicate that you give consent to use information for use in research and you understand your right to withdraw by checking the 'yes' box * Please note you can only withdraw from this research if you have provided your name and email address in the appropriate places.

- Yes, I understand the consent procedure and right to withdraw.

Please indicate that you are over 18 by checking the 'yes' box. * Please note this research is aimed at adults, aged 18 and over.

- Yes, I am over 18.

What is your interest in Boscombe, Dorset? * Please just fill the one section that best describes your stakeholder interest.

- Commercial Fisherman
- Sea Users: Surfers, Sailors, Divers, Anglers, Swimmers
- Hospitality services
- Local Store Owner
- Other:

A. Commercial Fishermen

A1. Do you ever fish in Poole Bay? *

Yes / No

A2. How long have you been a fisherman in Poole Bay? *

A3. Do you have your own boat, or employed as crew? *

- Own Boat
- Work as Crew
- Other:

A4. Please name the port you usually land your catch *

A5. How would you describe your normal fishing gear? *

A6. Please expand on your choice for gear (A5)

A7. What are the top three main species that you target? *

A8. Please estimate the number of days spent fishing in Poole Bay in 2007 *

A9. How has this changed in recent years? *

Tick: Significantly increased, Increased, Stayed the same, Decreased, Significantly decreased

- 2008
- 2009
- 2010

- 2011

A10. Please explain any changes in number of days spent fishing in Poole Bay.

A11. In recent years how have your catches in Poole Bay changed since 2007? * Tick: Significantly increased, Increased, Stayed the same, Decreased, Significantly decreased

- 2008
- 2009
- 2010
- 2011

A12 Please explain any changes in catches since 2007.

A13 On average, what is your current Net Annual Income from fishing? *

A14. What percentage of your fishing net income comes from Poole Bay? * please write as a percentage of your net annual income

A15. To what extent have the following changed from 2007 to 2011? *

Tick: Significantly increased, Increased, Stayed the same, Decreased, Significantly decreased

- Net income from fishing in Poole Bay
- Net profit from fishing in Poole Bay
- Abundance of commercially important fish species
- Biodiversity of commercially important fish species

A16. What has influenced these changes? Please use this space to expand on the previous question.

A17. To what extent do you agree with these statements about fishing in Poole Bay? *

Tick: Strongly agree, Agree, Uncertain, Disagree, Strongly disagree

- Fishing has improved overall due to the ASR
- ASRs help to create habitat, this has improved fishing
- The ASR is a nuisance to fishermen
- Inshore fishing grounds have been damaged due to the ASR

- The No-Go Zone is interrupting fishing activities
- The ASR acts as a fish aggravating device; this has improved fishing

A18. In your opinion, what are the ADVANTAGES of the Artificial Surfing Reef to the fishing industry?
A19. In your opinion, what are the DISADVANTAGES of the Artificial Surfing Reef to the fishing industry?

B. Sea Users: Surfers, Sailors, Divers, Anglers, Swimmers

Sea Users only to complete this section - please complete only the sections that apply to you, use the continue button at the bottom of the page to continue through the survey.
B1. What is your activity as a Sea User? * please supply us with more than one questionnaire if you participate in more than one of these activities

- Sailing
- Angling
- Diving
- Swimming
- Kayaking/Canoeing
- Surfing
- Other:

B2. Do you belong to an association or club? *
Yes / No
B3. Name of Club
B4. Club postcode. Please write town/city if postcode is unknown
B5. Rank your 3 MOST visited UK sites for your activity (1=most often) * Please be specific, however if you do not want to disclose a location by name please write region and type. i.e. an example from a diver might be 1=S.Cornwall Wall, 2=E.Dorest 20m Wreck, 3=S.Devon Cove
B6. Rank your TOP 3 UK sites for your activity (1=most often) * answers can be repeated for the previous question

B7. How many days in total did you spend on your activity in 2010? *

B8. How many days did you spend on your activity in Boscombe and Poole Bay in 2010? *

B9. With relation to your activity, please comment on how the following have changed since the ASR construction; * The Boscombe Artificial Reef and Rejuvenation project was completed 03/11/09. Tick: Significantly increased, Increased, Stayed the same, Decreased, Significantly decreased.

- Days spent at Boscombe
- Hours spent whilst visiting Boscombe
- Money spent whilst visiting Boscombe
- Willingness to travel to Boscombe

B10. What has influenced these changes?

B11. When you visit Poole Bay do you normally; *

- Go for one day or a few hours only
- Return home and come back the next day
- Stay over with friends (i.e. free accommodation)
- Sleep in your van/car, free camp (i.e. free accommodation)
- Stay at a campsite (i.e.pay for accommodation)
- Stay in a hotel or B&B (i.e.pay for accommodation)
- Other:

B12. Approximately, what do you spend per year of your activity? * Including transport, parking, accommodation, food and drink, fuel, boat hire, bait, equipment, air, accessories, clothing etc.

B13. Approximately, what percentage of this do you spend in Poole Bay and Boscombe? *

B14. Have you ever tried to use the ASR for your activity? *

Yes No

B15. If Yes, how many times?

B16. How would you rate the ASR as a site for your activity? on a scale of 1 to 10, where 1=poor site performance and 10=top world class site, for your sport.

1 2 3 4 5 6 7 8 9 10

B17. Please respond to the following comments: *

Tick: Strongly agree, Agree, Uncertain, Disagree, Strongly disagree

- The Boscombe ASR influence where I go as a sea user.
- New facilities provided by the rejuvenation project is the only reason I go to Boscombe, not the ASR.
- Since the construction of the ASR I avoid Boscombe.
- Boscombe seafront is a great location for my sport naturally, it did not need an ASR.
- I understand the ASR was built with my sport in mind.
- I consider the ASRs to be safe.

B18. In your opinion, what are ADVANTAGES of the Artificial Surfing Reef for sea users? *

B19. In your opinion, what are DISADVANTAGES of the Artificial Surfing Reef for sea users? *

C. Hospitality Services

Hospitality services only to complete this section - please complete only the sections that apply to you, use the continue button at the bottom of the page to continue through the survey.

C1. Name of Business

C2. Postcode of Business *

C3. How many years have you owned the business, based in the Boscombe area? *

C4. Size of Business (Staff Headcount, Turnover) * According to the latest government SME definition, ceilings within recommendation (2003/361/EC) for each enterprise category

- Medium (¡250, not exceeding 22.8m)
- Small (¡50, not exceeding 5.6m)

- Micro (¡10, not exceeding 5.6m)

C5. What services does your business provide? * please check all boxes to describe services fully.

- Hotel/B&B
- Camping
- Caravan Park
- Restaurant
- Caf/coffee shop
- Bar/Public House
- Other:

C6. Do you consider your business to be seasonal? * i.e. significantly more customers in one season than another.
Yes / No
C7. How many full-time equivalent staff did you have in 2010? *
C8. What was your Net Annual Turnover in 2010? *
C9. Please estimate the average spend, per customer, per day in 2010? * If seasonal, give as two figures (average for summer and average for winter)
C10. Please estimate the average number of customers, per day in 2010? * If seasonal, give as two figures (average for summer and average for winter)
C11. How have the following indicators changed since 2009? * The Boscombe Artificial Reef and Rejuvenation project was completed 03/11/09.
Tick: Significantly increasing, Increasing, Stayed the same, Decreasing, Significantly decreasing.

- Hotel/B&B
- Number of customers
- Enquires by the public
- Customer daily spending
- Repeat custom

- Net Annual Turnover
- Net Annual Profit

C12. In your opinion, what are the reasons for these changes?

C13. Please indicate below how many of your customers you consider to be drawn to Boscombe for the following *

Tick: None, Few, Some, Half, Majority.

- Surfing or specific watersport
- Diving
- Angling
- Business
- General beach tourism
- Relaxing
- Walking
- Cycling

C14. To what extent do you agree with these statements? *

Tick: Strongly agree, Agree, Uncertain, Disagree, Strongly disagree.

- The hospitality industry in Boscombe has benefited from the construction of the ASR
- Customers mention the rejuvenation of the seafront as a reason for visiting
- Customers mention the ASR as a reason for visiting
- The ASR is poor publicity for the region
- I rarely use the rejuvenation for marketing purposes
- In written feedback from customers the ASR is rarely mentioned

C15. In your opinion, what are ADVANTAGES of the Artificial Surfing Reef on the hospitality industry? *

C16. In your opinion, what are DISADVANTAGES of the Artificial Surfing Reef on the hospitality industry? *

D. Local Store Owner

Store Owners only to complete this section - please complete only the sections that apply to you, use the continue button at the bottom of the page to continue through the survey.

D1. Name of Business

D2. Postcode of Business

D3. How many years have you owned the business, in the Boscombe area? *

D4. Size of Business (Staff Headcount, Turnover) * According to the lastest government SME definition, ceilings within recommendation (2003/361/EC) for each enterprise category.

- Medium (¡250, not exceeding 22.8m)
- Small (¡50, not exceeding 5.6m)
- Micro (¡10, not exceeding 5.6m)

D5. What services does your business provide? * please help us understand your business better.

- Newsagents
- General groceries
- Surf and Kit Hire
- Dive and Kit Hire
- Angling/fishing
- Multiple-sports hire
- Charter boat operator
- Other:

D6. Do you consider your business to be seasonal? * i.e. significantly more customers in one season than another.

Yes No D7. How many full-time equivalent staff did you have in 2010? *

D8. What was your Net Annual Turnover in 2010? *

D9. Please estimate the average spend, per customer, per day in 2010? * If seasonal, give as two figures (average for summer and average for winter)
D10. Please estimate the average number of customers, per day in 2010? * If seasonal, give as two figures (average for summer and average for winter)
D11. How have the following indicators changed since 2009? * The Boscombe Artificial Reef and Rejuvenation project was completed 03/11/09.
Tick: Significantly increasing, Increasing, Stayed the same, Decreasing, Significantly decreasing.

- Number of customers
- Enquires by the public
- Customer daily spending
- Repeat custom
- Net Annual Turnover
- Net Annual Profit

D12. In your opinion, what are the reasons for these changes?
D13. Please indicate below how many of your customers you consider to be drawn to Boscombe for the following: *
Tick: None, Few, Some, Half, Majority.

- Surfing or specific watersport
- Diving
- Angling
- Business
- General beach tourism
- Relaxing
- Walking
- Cycling

D14. Does your business benefit directly from changes at the seafront? * i.e. does your business organise trips/lessons/hire equipment at the beach or sell products to tourists.

Yes / No

D15. If yes, please help us to understand your business by ticking the following and providing some details in ’other’.

- Diving, experienced
- Diving, lessons
- Angling
- Surf - equipment hire
- Surfing - seafront lessons
- Site seeing
- Bird watching
- Educational trips
- Other:

D16. To what extent do you agree with these statements? *

Tick: Strongly agree, Agree, Uncertain, Disagree, Strongly disagree.

- The local stores in Boscombe have benefited from the construction of the ASR
- Customers mention the rejuvenation of the seafront as a reason for visiting
- Customers mention the ASR as a reason for visiting
- The ASR is poor publicity for the region
- I rarely use the rejuvenation for marketing purposes
- In written feedback from customers the ASR is rarely mentioned

D17. In your opinion, what are ADVANTAGES of the Artificial Surfing Reef to local store owners? *

D18. In your opinion, what are DISADVANTAGES of the Artificial Surfing Reef to local store owners? *

E. Others

E1. Please explain your interest in Boscombe, Dorset *
What services does your business/organisation provide?
E2. Name of Business/Organisation (if you own one)
E3. Postcode of Business/Organisation (if you own one)
E4. Size of Business (Staff Headcount, Turnover) According to the latest government SME definition, ceilings within recommendation (2003/361/EC) for each enterprise category

- Medium (¡250, not exceeding 22.8m)
- Small (¡50, not exceeding 5.6m)
- Micro (¡10, not exceeding 5.6m)

E5. What was your Net Annual Turnover in 2010?
E6. How have the following indicators changed since 2009? The Boscombe Artificial Reef and Rejuvenation project was completed 03/11/09
Tick: Significantly increasing, Increasing, Stayed the same, Decreasing, Significantly decreasing.

- Number of customers
- Enquires by the public
- Customer daily spending
- Repeat custom
- Net Annual Turnover
- Net Annual Profit

E7. In your opinion, what are the reasons for these changes?
E8. Does your business benefit directly from changes at the seafront? i.e. does your business organise trips/lessons/hire equipment at the beach or sell products to tourists.
Yes / No
E9. In your opinion, what are ADVANTAGES of the Artificial Surfing Reef to your business/organisation?

E10. In your opinion, what are DISADVANTAGES of the Artificial Surfing Reef to your business/organisation?

F. Artificial Surfing Reefs (ASR) Your Views

All respondents are asked to please complete this section.

F1. Do you believe that the ASR is generating an income for the Boscombe community? *

Yes / No / Unsure

F2. Car parking land was sold to a building investor to enabled Bournemouth Borough Council to finance the ASR. Do you think this money was well spent on the ASR? *

Tick: Very well spent, Well spent, Unsure, Poorly spent, Very poorly spent.

F3. Please explain your answer *

F4. Please respond to the following comments: *

Tick: Strongly Agree, Agree, Uncertain, Disagree, Strongly disagree.

- The ASR is a fantastic addition to Boscombe's tourist attractions.
- Coastal modification, such as using ASRs concerns me
- I support the future use of ASR technology for tourism in the UK
- Boscombe's coastline general appearance is better with the addition of an ASR
- The ASR has had a direct positive influence on my lifestyle
- The ASR is an embarrassment to Boscombe
- The ASR was a failure in creating consistent surfable waves
- Tourist numbers are increasing after the construction of the ASR
- More research is needed into ASRs and the ability to create surfable waves
- ASR technology should be used with caution
- I have benefited from the rejuvenation of the seafront, regardless of the ASR
- Planned works to 'fix' the reef should go ahead, it is a necessary expense

F5. Please use this space to give any additional information, comments and views regarding the Artificial Surfing Reef.

G. About you (Socio-demographics)

All respondents are asked to please complete this section Please provide your location and, if you would be interested in being contacted in future rounds of this research, please provide your contact details. This information will remain anonymous and will not be passed on to other parties.

G1. Name

G2. Nationality *

G3. City/Town *

G4. Country *

G5. ZIP/Postal Code *

G7. Email Address

G8. Phone Number

G9. Please indicate your age *

- 18-25
- 26-33
- 34-41
- 42-49
- 50-57
- 58-65
- 66-73
- 74+

G10. Please indicate your gender *

Male Female

G11. What is the highest level of education you have completed? *

- Secondary Education/High School
- Diploma, Vocational or Technical Training

- University or College Graduate
- Postgraduate
- Other:

G12. Please indicate your employment status *

- Employed
- Unemployed
- Full-time Student (School)
- Part-time Student (School)
- Full-time Student (University/Collage)
- Part-time Student (University/Collage)
- Other:

G13. Please indicate your income * including DSS.

Appendix C

Socio-perception Responses

A Direct users: surf community responses

A.1 Social

A.2 Economic

A.3 Environmental

A.4 Advantages and Disadvantages

> "Important data and research can be recorded, and used to develop a better understanding of how ASR's work. And with that information we could possibly create good or great working waves throughout the UK. Potentially through research findings we could better understand what makes the perfect artificial reef, and eventually create one as a blueprint enabling us to expand the surfing playgrounds of the world."

> "An excellent opportunity for this new technology to be used in this country and these conditions. I think that with sand bags having the option of being adjusted (removing or pumping in more sand) was an excellent option to produce an excellent end product. With a better managed construction and maintenance contract the final result could have been tweaked every few years to improve the wave quality as more knowledge of the local conditions was understood."

Burden related themes	N	Example comments
Overcrowding (water)	197	Crowds are always bad, publicity is bad inasmuch as it increases crowds Crowding - dangers associated It is dangerous, and has led to overcrowding of all the other nearby surf spots due to more people taking up surfing Potential of crowding if there is surf breaking on the reef as it is a very small area
Risk to human life	92	Dangerous rips and currents Could snag leashes It is in the wrong place. It has made part of the beach dangerous. It doesn't improve the quality of the surf on a day to day basis, only on extremely rare occasions It doesn't work as well as it could or often enough, I'm not sure why, but it looks much too shallow. I've also heard it's a bit dangerous as peeling surfers have got the nose of their boards caught in the sandbags and snapped.
Impact local surf break	71	Possibility of effecting current surfing spots Ruined the break Destruction of natural surf breaks Could have a negative effect on the oceans natural surfable waves and habitat
Embarrassment	49	Makes Bournemouth a joke in the eyes of the surfing community It has ridiculed and de-valued Bournemouth/Boscombe, surfing and surfers and ASRs The disadvantage is mainly for the local council who look a bit foolish because they didn't research it properly
Localism	44	Crowded wave, and locals not wanting increased numbers of surfers unaware of etiquette / sharing waves If it worked consistently would be overcrowded and there would be conflict in the water with people in experienced in surfing etiquette potentially more aggression in the water? Local surfers unhappy with the influx of non-locals.
Increased cost of living	44	Price hike in local shops and parking Increased parking prices, newly built apartment blocks, which are don't fit the environment. Increased car traffic, instead of developed public transport. The cost of maintaining the area and ASR would have to be offset against any increase in local revenue. Disturbance to locals ie parking / litter / noise Increased cost of local services, shops, parking, etc. it's pretty much £5 a pint in Urban beach
Negative impact, local surf industry	17	Done more harm than good for the local surf industry Sorted surf shop getting the monopoly on selling surf gear (Bournemouth surf centre shut down not long after sorted opened up their shop on the front
Negative attitude to surfers	14	From a human population point of view, if the demographic majority in Boscombe were generally of a non-surfing background then this may cause some anxiety from the perceived change of lifestyle expected from such a venture Local people that do not agree with the ASR give you grief about being a surfer there. Some people tend to think that surf tourism is associated with social problems such as youth behaving less appropriately
Commercialism	13	Commercialisation of surfing I also don't like the idea of more big businesses getting involved with surfing which must be inevitable with ASRs Exploitation of surfing
Visual impact	9	At low tide it can be seen breaching the surface and has become an object of local ridicule. It is ugly. It makes the council and those involved look like they wasted a lot of money
Liability (i.e. injuries)	5	Rips in front of the reef close to shore are lethal to kids on some days In terms of liability I imagine people who injure themselves on the reef will be able to seek compensation from those who constructed the reef which is not an issue with a non-manmade reef
Total	555	

Table (A1). Thematic review of qualitative responses regarding the social disadvantages (burdens) of ASRs from UK surfers (n = 721).

B Indirect users: coastal community responses

Benefit related themes	N	Example comments
Potentially better surfing, waves or consistency	202	Better shape to wave, more consistency, providing better and more reliable surfing conditions.
		Presumably to improve swell and improve consistency.
		Better waves, more often.
		In theory, it should improve the wave quality in the area.
		A better quality of wave for the area/region.
Good for body boarding	115	Production of an unusual wave suitable for advanced body boarders (there are few equivalents along the south coast).
		I have heard extensive criticism of the quality of wave that it has created. From a surfers point of view it doesn't sound like a successful project. It does look like a good body boarder wave though!
Regeneration of area	107	Boscombe making it a nicer, safer and cleaner place.
		Boscombe had become run down, huge drug problems, theft, violence etc. With the reef a lot of development time has been spent in.
Improve local recreational facilities	55	Having a more consistent wave would encourage more surfing locally, improving the standard of surfers locally, and improving the recreational activities available to people in the area.
		Encourage outdoor activity.
		Promoting healthy lifestyles.
Decreased crowding elsewhere	54	Keeps people away from other breaks.
		It may thin out the crowd at the pier.
		Having an extra break means surfers are spread out more, meaning less crowding.
		If it worked it would keep travelling surfers away from more prestigious breaks on the S. and S.W. coasts.
Increased UK surfing popularity	43	More interest in surfing, more support for surf GB.
		It also makes people more aware of the surfing community in the UK.
		It would be great to have a good clean wave to practice on and could aid the improvement of the level of surfing in the UK.
		A focus for surfing and associated water sports activity in the area.
		Improve surfing skill (due to more waves).
Ease of access for surf, or reduced travel	26	As someone in London, it means I can potentially surf with half the drive as if I was heading for Devon or Cornwall.
		Shorter commuting times to get a wave, as opposed to having to drive to Devon/Cornwall.
Town focal point, new identity	12	Raise profile of Boscombe areas as a vibrant coastal are with a 'surfer cool' perception.
		Tourism, great idea, brings English surf more into mainstream English culture, brings more innovation into the UK.
Lifeguards all year round	11	Higher lifeguard presence in the area.
Improved angling	3	Good fishing!
Safe for swimming	1	Lagoon area with calmer water between reef and beach.
Total	629	

Table (A2). Thematic review of qualitative responses regarding the social advantages (benefits) of ASRs from UK surfers (n = 721).

Burden related themes	N	Example comments
Initial construction costs	215	Cost too much money!
		A massive waste of money.
		An expensive monstrosity.
		Extremely costly to build and maintain.
Cost to taxpayers and tourists	39	Money and costs to us locals
		High costs at beach.
		It has ruined the natural break by the pier and brought money to the area that the council seem to think everyone can afford i.e. £15 per day parking and £3.50 for a coffee.
No economic benefit	38	It cost a lot for little improvement to the seafront.
		Huge overspend on construction and repair using public money.
		The council charging either directly, or indirectly as tax, to fund the repairs to the project.
Funding for future ASRs will be difficult	23	May make sourcing funding difficult for future ventures.
		I fear that the the way the council, media, etc have reacted will put off any other councils taking such a step for a long time (especially in times of austerity).
Waste of time (financial costs to the town)	19	Huge waste of time.
		Bad press and public relations due to the problems with the reef.
Loss of surf tourism	16	Too busy, natural marine environment damaged, too commercial for me.
		Too many visitors in the area, causing some local surfers to go elsewhere.
ASR is closed	16	It being 'closed'.
		The fact that it is sectioned off and not allowed to ride anymore.
Total	366	
Benefit related themes		
Tourism	120	Stimulating the local economy (you only need to go to North Devon spots to see how many surfers turn up and spend money in the local area).
		Good for the local business. Should help create jobs. Bring more money into the area
		Help the council with tidying up the scruffy areas. Keeping the beaches clean and safe.
		Improved image of Boscombe/Bournemouth with both surfers and non-surfers
Publicity to Boscombe	104	Increased the profile of Boscombe as a surf spot due to all the publicity.
		More people have heard of the location.
		The reef has brought attention to the area with the publicity surrounding it.
Local wealth generation	96	House prices have risen in the area.
		Money for local businesses and surrounding community.
		Selling of real estate.
Surf industry/business in the area	64	In theory it should help promote surf tourism in the area, driving local businesses and employment.
		Increased spending by traveling surfers in the local area.
		Will bring extra surfers to the area and possibly create more business in the local area.
Total	384	

Table (A3). Thematic review of the qualitative responses regarding economic costs and benefits of ASRs from UK surfers (n = 721).

Burden related themes	N	Example comments
Coastal erosion	82	Disruption to the local coastal geomorphology. Changes to the pattern of sediment transport/transfer, leading to changes in coastal erosion and deposition rates
		Risks for coastal erosion
		Increased erosion elsewhere
Damage to the environment	52	changes the natural coastal environment - we are unsure of the effects
Marine life	43	possible or unknown impact on marine life
		Disrupt local ecology
		A knock-on effect to wildlife
		Alteration of a natural habitat
Altering nature	28	Damage to the natural environment, through interfering with nature
		It isn't natural, but that doesn't really matter as long as the waves are good
		It takes away that aspect of natural environment
Pollution	7	Litter and noise
		It is likely to have a long and expensive legacy of plastic pollution once the bags are damaged or destroyed
		Breakdown of reef or materials contributing to coastal pollution
Total	212	
Benefit related themes		
Coastal protection	37	Protecting the coastline
		Coastal defence
		The Boscombe Reef advantages are in the salient formation in the lee of the structure, stabilising the shoreline and reducing the need for non-sustainable wooden groynes
		Potentially prevent further erosion of the beach front. It has also opened the conversation about alternatives to rock armour and projects where the cheapest option is the one that gets passed, rather than the one that might be best for the area.
Marine life	36	Sea life
		Wildlife
		Creation of habitat
Total	73	

Table (A4). Thematic review of qualitative responses regarding the environmental benefits and burdens of ASRs from UK surfers (n = 721).

Disadvantages of ASR	N	Example comments
Does not work	295	Failed to produce waves as per design. Hasn't actually fulfilled its potential. Nothing, it failed. I hear it is bad.
Location choice was poor, lack of swell	189	The reef was put in a poor location, not enough swell in the area to make the reef work. The ASR was placed in an area subject to inconsistent and low quality swells. It was never going to work even if the ASR had done what it was meant to the area doesn't receive enough consistent swell for it to result in high levels of surf tourism. An ASR would be much better in places like Newquay town beaches where swell is consistent yet the waves are poor quality and close out.
Design is not effective	173	No-one has yet perfected the creation of a surfing wave in the natural environment. Technology is not proven, more research needed. The organisation and severe delays reflected very badly on the project. Choice of reef building materials, the fact that they have moved.
Contractual agreement, management of expectations	137	Poor design / contract management between Bournemouth Council and ASR Ltd. The Council appears to have been persuaded by the charismatic promoter / builder of it without further consultation with other technically qualified coastal engineers who surf. Over-hype. Has not met expectations. The ASR has not provided consistent waves in the way that might have been expected.
Inconsistent surf break	109	Inconsistency. It doesn't work regularly enough. Waves too violent and unpredictable.
Ethically unsound	28	The notion is ethically and environmentally unsound. If I lived near Bournemouth I would fish, sail, windsurf, SUP etc. on what I hear are the many poor or flat days. Profiteering through surfing.
Boating hazard	7	All reefs can be a problem if they are shallow enough to inconvenience boating traffic. Has become a hazard.
Precedent for natural break mitigation	7	I think it can create a bit of a worrying precedent; if breaks can be made around the coast then it is possible that if a coastal development destroys a natural break, then it can 'mitigate' this by building an ASR Legitimises the destruction of other breaks if another can just be 'created' where pleased.
Prices increased	4	Price hike in local shops and parking. Prices and the mass-marketing of surfing as a sport, surfing will become like skiing (surf passes/prices for admission).
Total	949	
Advantages of ASR	**N**	**Example comments**
Theoretically better quality or consistency (uncertain responses)	197	In theory, it should improve the wave quality in the area. Higher class surf break. Better wave shape and length. Better quality waves maybe.
Benefit tourism industry and local economy	61	Attracting more tourism from UK and overseas surfers. It was supposed to create a more consistent/larger wave to generate more surf tourism but I believe that it works only occasionally.
Trial run or test case	26	Innovative. Great trial run
Alternative coastal protection materials	20	The main advantage seems to be that it has stimulated discussions such as this and exposure of this technology should hopefully lead to further research.
Total	304	

Table (A5). The disadvantages and advantages of the Boscombe ASR with count per theme and example respondent comments (n = 721)

Theme	Cost	N	Benefit	N
Economic	Exaggerated initial cost for construction	29	ASR lead to regeneration	7
	Poor publicity or image for Boscombe	20	Regeneration caused increase income	7
	Resources better spent elsewhere	13	The ASR has benefited the seafront area only	4
	Project remains unfinished	8	Interest or private investment in area	4
	Geotextile failure (bags, material)	7	Novelty factor, tourist curiosity	4
	ASR Ltd. exaggerated initial claims (no tourism boost in winter months)	7	Increases tourism (better trade and general awareness of the local area)	4
	Increased cost of living (car parking, council tax)	6	Negative publicity, but all publicity is good	4
	Financial issues for Boscombe due to ASR and regeneration	3	More affluent clientele	3
	Tourism in town is reduced since ASR and regeneration at the beach	3	If surfable, ASR may be an advantage	1
	Decreased in fishing area (ASR has wide impact on fishing grounds)	3		
	Investment in the area has ceased	3		
	Poor contractual agreement with ASR Ltd.	3		
	Poor choice of construction materials	2		
	Does not deliver claims, no boost in the winter months	4		
	Lifeguards all year is unnecessary and expensive	2		
	Customer base unaffected	2		
	Flats remain unsold	1		
Total		110		38

Table (A6). Business stakeholder economic comments compiled from qualitative responses within the structured interview.

Theme	Cost	N	Benefit	N
Social	ASR is not surfable	29	ASR is an interesting concept	5
	No benefit to area	16	Quality of beach services	1
	It's a hazardous area	9	Good waves, when conditions are right	1
	Maybe a navigation hazard	4	Public interest in watersports	1
	Takes up beach or sea (no-go-zone)	3		
	We all feel badly let down by ASR and Council	3		
	Divide (socio-economic) between seafront and the town centre	2		
	Surfers do not pay for staying, park in vans in street	1		
	Not as many hotels for tourists general nature of the area has changed	1		
	Not enough information about the project for locals	1		
Environmental	More coastal research needed	5	Creates new habitat for fish	3
	Sand from structure	5		
	Disturbance to the seabed	5		
	Material from structure	4		
	The ASR is in the wrong location	4		
	The structure does not improve fishing grounds	3		
	Introduction of seaweed	3		
	Not good for angling	3		
Total		101		11

Table (A7). Business stakeholder social and environmental comments compiled from qualitative responses within the structured interview.

Appendix D

Monitoring ASRs

Aspect	Reason to monitor	Method and frequency of monitoring
Structural assessment	Integrity of the geotextile containers and the ASR structure (correspondence with planned design, durability, physical stability and structural integrity).	Quarterly bathymetry surveying (ideally SWATH high resolution or single beam) to assess final ASR design and effects of subsidence and resilience in the first year, if stable after the first 3 years reduce to one annual post-winter survey. Quarterly visual inspections (SCUBA or ROV) to assess integrity and durability of the geotextile SFCs. More frequently if deemed necessary (e.g. following collision incident with propellers).
Sediment characteristics	Assess changes in sediment characteristics at the beach, nearshore and adjacent to the reef. Assessment of the effects of accretion in the lee of the reef and erosion/scouring Link with the biological monitoring; coarser grain sizes produce a harsher, more abrasive environment, habitat change for benthic species causes altered biodiversity.	Sediment sampling can be conducted using transects and at predetermined locations in the nearshore and at defined distances from the reef. Can be conducted with beach topography and nearshore bathymetry. Surface scrapes or shallow coring using SCUBA or spring loaded box grabs, remotely operated from boat or kayak. It is preferable that samples are geo-referenced for replication. Sediment grain size analysis can be repeated seasonally for the first 3 years, and then annually.
Beach and nearshore morphology	Measuring changes in coastal topography/bathymetry allows assessing the ASR performance in enhancing coastal protection; widening the beach or accretion at the shoreline. Identifying impacts to the coastal zone, intertidal area and swash zone. Important in understanding the impact to the wider sediment cell, potential for associated erosion.	Several methods can be used to measure beach topography (e.g. total station, RTK-DGPS, laser scanner, video monitoring and LiDAR). The technique chosen must be accurate, repeatable and comparable. Beach topography should be measured at the lowest tide, quarterly in the first three years and then annually. It might be necessary to measure an area that is away from the direct influence of the reef to assess the influence of natural changes in wave climate. Detailed bathymetric surveys should be conducted at least annually. Pre and post-storm surveys can be conducted to observe the recovery rate of the leeward area of beach.
Oceanographic and meteorological observations	Data used for monitoring changes in natural environmental conditions, these are essential for interpreting changes in coastal morphology bathymetry and for identifying ideal conditions for surfing.	Wave characteristics (height, period and direction), wind (speed and direction), water level (tides and surges). Continuous data collection using wave buoys deployed locally, meteorological stations where feasible, and water levels by installing a tide gauge or pressure sensors.
Wave and current characteristics	Examine wave focusing and breaking on the reef alongside local hydrodynamic patterns. Waves and currents can be examined with numerical or physical modelling pre-construction, then compared with observations	Measurement of the angle of wave incidence on the reef relative to measured surfer tracks (collected with video or surfer-mounted GPS). Modelling can be used with the bathymetry and real data collected from wave buoys. Assess whether the enhanced waves meets design aims and expectations. Revisit annually in the first three years to ensure consistency, if successfully meeting aims then only review again in year 10 for improvements and maintenance.

Table (A1). Suggestions for the criteria used to establish a baseline pre-construction, to assess performance, and then monitor the physical environmental impacts of an ASR project.

Aspect	Reason to monitor	Method and frequency of monitoring
Biodiversity and biomass	Biomass/ abundance, species richness, diversity and community structure. Quantitative monitoring of number of species and individuals using standard biological survey methods (at ASR and Control site pre and post construction). Indicators of biomass increase such as growth rates of fish, fecundity of reef-associated fish, and survivorship of juveniles around artificial reefs. Labour intensive study but needed if claims of fisheries enhancement are important to the project.	Several methods can be used and the most adequate depends on local characteristics the most suitable will depend on project and location as they range in speed and cost: annual fixed quadrate surveys (SCUBA), annual towed HD video transects, dropdown cameras or ROV from a boat or kayak, baited video sampling (frame mounted camera to observe mobile species), trammel netting etc. The frequency of surveying depends on the method used. Other considerations might include a study of bird diversity and population. To obtain comparable results pre-construction surveys should be taken for baseline figures, followed by a review after construction at 1, 3 and 10 year intervals.
Surfability or surfing performance	Reef performance with respect to the original performance based contract and the aims of the project, an assessment of the surf quality. Reef usage to ascertain whether the reef is being surfed and the environmental conditions under which surfing on the reef are taking place.	Ride angle, length, speed and direction can be estimated using an experienced surfer with a Global Positioning System (GPS) recording position during surfing sessions to assess the surfability of a break. Beach rangers or beach lifeguards collect data to generate tourism statistics (secondary data). Questionnaires and interviews can be used for collecting surfers perception (primary data). Quarterly in the first three years, review at 10 years to consider the need for upgrade and maintenance.
Social-economic impacts	Quantitative description of the annual revenue and net benefits generated by the ASR. Assessment of the novelty factor of an ASR, the variability in interest over time. Changes to local community, society and perceptions; impact to property market, availability of jobs, income and benefits realised by the tourism industry. Quantify socio-economic impacts. Predicted verses actual cost:benefit ratio.	Questionnaire utilising a range of sampling techniques e.g. face-to-face or social media, interviewing all stakeholders. Perception and opinion changes over time. Close interaction with fishers using participation methods to engage on economic impacts on fisheries. Contingent Valuation Method (CMV) and the Travel Cost Method (TCM) to evaluate costs incurred by reef users, and willingness to pay (WTP) for recreational enjoyment, and hence the value of the reef (Whitmarsh and Pickering, 2000). Pre-construction cost:benefit and engagement of stakeholders for baseline figures, followed by a detailed review after construction at 1, 3 and 10 year intervals.
Bacterial and chemical analysis	Water quality analysis to protect primary users of the ASR, and to avoid liability if surfers are encouraged to use a new facility in poor quality bathing waters.	Water Quality testing can be carried out through monthly water samples before and after construction, providing baseline and regular monitored assurance for bacterial levels. This should be done for at least 1 year previous to construction and for the entire lifetime of the project. Results should be published and open access, where there are concerns these need to be adequately addressed or have a warning system in place for a pollution events.

Table (A2). Suggestions for the criteria used to establish a baseline pre-construction, to assess performance, and then to monitor the ecological and socio-economic impacts of an ASR project.