Sustainable Management of Surfing Breaks - An Overview

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ABSTRACT

Surfers constitute a coastal interest group that has historically been ignored in coastal management. As the social, economic and environmental benefits of high-quality surfing breaks are being realised, surfers are increasingly being consulted during the planning phase of coastal projects. Surfers can benefit from Integrated Coastal Zone Management (ICZM) practices that include environmental impact assessments on surfing wave quality and balance the coastal space requirements of various coastal user groups. This paper presents examples of surfing breaks that have been both improved and compromised by coastal development. Coastal management practices that can be utilised to ensure surfing breaks are sustainably managed are outlined. The paper advocates detailed and standardised assessments of environmental impacts of coastal development on the quality of surfing waves. The types of environmental data that are important for protection of surfing breaks are identified, and it is suggested that existing environmental data can be reinterpreted in the context of surfing breaks to develop surfing wave climates and show general changes over time to surfing breaks. However, it is argued that for detailed understanding of the mechanics of surfing breaks the collection of surfing specific baseline information on surfing breaks at risk of modification is required, in order to preserve the quality of surfing waves. Although local and central governments in some areas act to ensure the protection of surfing breaks, it is not generally formalised in legislation or coastal management plans. It is recommended that further research investigates ideal management techniques to promote sustainable management of surfing breaks for different resource management frameworks.

ADDITIONAL INDEX WORDS: *surfing reefs, coastal space, recreational space, coastal amenity, ICZM, environmental impact assessment, EIA, AEE, GIS, surf tourism.*

INTRODUCTION

Coastal Management is a complex issue and many interest groups influence how our coastlines are maintained. Sensible coastal development is essential because a significant percentage of the world's population lives near the coast, leading to pressure on resources. Preserving natural coastal resources presents many challenges that must be balanced against the benefits of development (NELSEN and HOWD, 1996). It is commonly believed that around 50 percent of the world's population lives within 1 km of the coast (SMALL and ROBERT, 2003), and that migration towards the coast is continuing (GOLDBERG, 1994). There is evidence to show that the percentage of people living near the coast is smaller than commonly believed because of the different measurement techniques used (SMALL and ROBERT, 2003). However, it is agreed that the population is dense and therefore human infrastructure requirements mean that the modification of coastlines happens in most developed locations.

Although in a perfect world, nature's balance would dictate shoreline and inlet positions, beach widths, sediment transport patterns and other coastal issues, this rarely happens. Historically there has tended to be a single-issue (e.g. protection of expensive real estate) or single-sector (e.g. marine transportation) management approach applied in coastal engineering projects. This approach has often left stakeholders with less political voice having their opinions ignored. One such example is recreational surfers where significant numbers of surfing breaks have been modified by coastal development (e.g. PRATTE, 1987; NELSEN and HOWD, 1996; MEAD *et al.*, 2003a). This is not surprising given, as FRENCH (1997) describes, there are few environments that have not been impacted to some degree by humans. Activities such as construction of seawalls (Saint Clair, Dunedin, New Zealand), jetties (Mission Bay Jetties, San Diego, California), boating infrastructure (Manu Bay, Raglan, New Zealand), piers (Oil Piers, Ventura, California) and beach nourishment ("The Cove" Sandy Beach, New Jersey) all change the coastal environments. Whether the change is for better or worse, after the alteration the environment ceases to be natural and has some degree of artificiality (FRENCH, 1997). Although sometimes the engineering effects are positive on surfing wave quality (e.g. Superbank, Tweed Heads, Gold Coast, Australia), more often the surfing breaks are compromised (e.g. Saint Clair, Dunedin, New Zealand), or even destroyed (e.g. El Sugundo, California). Even though coastal management has now reached a mature stage where multiple-use coastal management objectives are set, there is still very little emphasis placed on the protection of surfing breaks and no wide spread use of standardised environmental impact assessments (EIA) that include consideration of surfing breaks.

Surfing, while long considered a fringe sport, has developed into a US$10 billion p.a. industry (mid-1990s; BUCKLEY, 2002a) with over 10 million participants worldwide and a 12-16 % growth rate per annum in surfer numbers (ORAMS 1999; BUCKLEY, 2002a). The presence of a high-quality surfing break is of enormous social and economic value to a coastal community (BREEDVELD, 1995; AUGUSTIN 1998, GOUGH, 1999; BLACK *et al.*, 2000; BAILY and LYONS, 2003; BUCKLEY, 2002a; SCARFE *et al.*, 2003a; WEIGHT, 2003). Surf tourism is tied to the specific features of the natural landscapes and is largely separate from the cultures of the host communities, but has strong economic links to the global fashion and entertainment industries (BUCKLEY, 2002a). Yet in some countries, the protection of surfing breaks that provide both recreational benefits and support this growing industry, is not practised at a government level (SCARFE *et al.*, 2003a). Even in places like Southern California, which is regarded as one of the main centres of modern surfing culture and is home to many of the world's largest surfing companies, surfers have little political say in the management of their playground. The rapid rise in coastal populations and the increasing popularity of surfing has led to increased pressure on surfing locations worldwide. This phenomenon is particularly apparent in Southern California, with a dense coastal population, a large number of surfers and conflict for coastal space. The conflict is usually with vessel navigation and other infrastructure rather than other recreational users. In Australia, however, many of the political decision makers are surfers and they actively seek to improve the recreational value of their coasts. The Gold Coast, Queensland, Australia, also known as *'Surfers Paradise'*, has embraced surfing as demonstrated by the construction of the Narrowneck artificial surfing reef (HUTT *et al.*, 1999) and the Tweed Heads sand by-passing project (DYSON *et al.,* 2001; PHILLIPS, *et al.,* 2004).

The focus of this paper is to show the need for sustainable management practices around surfing breaks, and demonstrate how Integrated Coastal Zone Management (ICZM) can be used to protect surfing breaks. One of the key legislative requirements discussed in this paper that can help to ensure surfing break sustainability is environmental impact assessment (EIA). Sustainable management of surfing breaks is discussed relative to New Zealand's Resource Management Act 1991 (RMA) and provisions within that Act (e.g. for a New Zealand Coastal Policy Statement) to provide an example of how sustainable management can be incorporated into environmental planning statements, plans and policies. The RMA attempts, although some say optimistically (RENNIE, 2000; WOOD, 2003), to incorporate ICZM and sustainable management into environmental law. This paper also presents methods and tools for undertaking detailed EIAs of coastal activities on surfing breaks. Trends in coastal engineering that can be of benefit to surfing communities are discussed and it is argued that innovative coastal engineering designs, which work more harmoniously with the environment, can result in multiple benefits to multiple user groups. In order to facilitate the sustainable management of surfing breaks, this paper outlines issues for coastal management plans and discusses storage and interpretation of environmental information in geographic information systems (GIS).

CASE STUDIES

No detailed methodological studies have been found specifically on the impacts of coastal activities on existing surfing breaks in the peer-reviewed coastal literature. Although peer-reviewed papers on surfing breaks exist (e.g. WALKER *et al.*, 1972; BATTALIO, 1994; AUGUSTIN 1998; RAICHLE, 1998; RIDER 1998; HUTT *et al.*, 1999; SAYCE *et al*, 1999; MEAD and BLACK, 1999; 2001a, b and c), most literature on surfing and coastal processes has been focused on designing artificial surfing reefs (ASRs, e.g. WALKER, 1974a and b; DALLY, 1989; BUTTON, 1991; MEAD and BLACK, 1999; BLACK, 2001a and b; HUTT *et al.*, 2001; SCARFE *et al.*, 2002), or demonstrating how a surfing breaks work (e.g. BATTALIO, 1994; RAICHLE, 1998; MEAD and BLACK, 1999; BUONAIUTO and KRAUS; 2003). A few non-peer reviewed publications on surfing break protection are available (e.g. WALKER and PALMER, 1972; BLACK *et al.*, 1998; NELSEN and HOWD, 1996; SCARFE *et al.*, 2003b; MEAD *et al.*, 2004b) but it is still a new area of coastal research. For instance, BLACK *et al.* (1998a) undertook an impact assessment that considered the effects of a boat ramp and breakwater extension on an existing break in Auckland, New Zealand (the extensions were eventually not undertaken). More recently, a technical report on the physical processes around jetties that can create surfable waves was undertaken by SCARFE *et al.* (2003b) but the conclusions are yet to be incorporated into any jetty developments. MEAD *et al.* (2004b) reviewed the environmental impacts on inshore surfing conditions at Palm Beach, Gold Coast, Australia, of a series of offshore submerged reefs resulting in the abandonment of the project due to the negative impacts for surfing amenity. This EIA however was not required by the formal permitting process and was independently funded by local residents.

Every year the quality of surfing breaks are compromised by coastal engineering projects that do not include recreational surfing as a consideration in the design process, and this is not surprising considering the lack of attention the subject has received in the literature.

Although water quality is an important issue for surfers for health reasons, this paper is focused on activities that modify the physical processes around surfing breaks and their effects on the 'surfability (Dally, 1989)'of surfing waves. The main types of activities and structures observed on the coastline that can alter the wave quality include, but are not limited to:

1. Seawalls
2. Dredging
3. Dumping of dredge spoil
4. Groynes
5. Artificial nourishment
6. Jetty construction or extensions
7. Breakwaters
8. Boat ramps
9. Port or marina development
10. Outfall pipelines
11. Piers

Some case studies are presented here to show some of the types of impacts human activities can have on surfing breaks.

Case Study 1 – Manu Bay Boat Ramp, Raglan New Zealand

The Raglan headland (Figure 1) is a unique surfing break where the dominant southerly swells are refracted and 'organized' to produce clean surfing waves from a westerly direction at the surfing breaks. The waves peel perfectly for surfing along the bolder/reef shoreline and the location has been extensively studied by several researchers (HUTT, 1997; SAYCE, 1997; HUTT *et al*., 2001; MEAD, 2001; MOORES, 2001; SCARFE, 2002, PHILLIPS *et al*, 1999; 2001; 2003a and b; 2004). However, the construction of a breakwater and boat ramp in the 1960s at the end of Manu Bay surfing break has shortened the length of the ride by up to 100 m during certain conditions. The detrimental effect was caused by two activities. Firstly, according to discussions with local residents the reef was either dredged or dynamited or both, creating a hole that stops waves breaking. Secondly, the constructed breakwater blocks wave energy. The exact details of the construction have not been found and it is likely that the pre-construction bathymetry was not recorded during the project so the precise impacts can only be theorised. At the time of construction all environmental permits were obtained and the boat ramp was built legally. Although EIAs were beginning to be used 30 years ago (WOOD, 2003), it would have been extremely optimistic for serious consideration to be given to any negative impacts on surfing waves of the boat ramp.

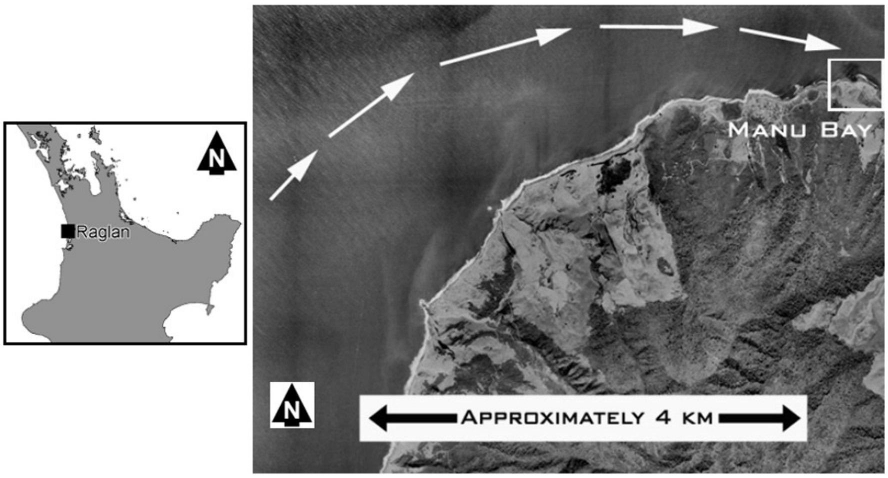

Figure 1: Location of the Raglan Headland

Although the way that surfing waves transform is complex (see BLACK, 2001a; MEAD, 2003; SCARFE *et al.*, 2003a), it can be generally stated that waves break along contours relative to the wave height. Offshore focusing (BEAMSLEY and BLACK, 2003; MEAD *et al.*, 2003b) and varying seabed gradients complicate the breaking location, but for this discussion it is assumed that waves break along a single contour. Figure 2 shows the contours of the end of the surfing ride at Manu Bay from a survey by SCARFE (2002) and SCARFE *et al.* (2002). The waves generally break along the shore parallel contours and the large hole that has been created can be clearly seen to the south of the boat ramp in this survey. As a result of the breakwater's presence, an area of deep water has also been created to the north of the boat ramp breakwater. During large swell conditions, strong wave driven currents, which would normally flow down the headland unimpeded, are directed offshore by the breakwater, resulting in a hole created possibly by scour. Thus, the breakwater affects the coastal processes in two ways (i) the sand and smaller gravels are directed offshore to create a hole to the north of the boat ramp breakwater, and (ii) the larger rocks and boulders cannot move past the breakwater, which has lead to erosion to the south of the boat ramp that is currently controlled by a failing seawall. The presence of the hole means that the water depth is now too deep for wave breaking and the surfing ride ends prematurely.

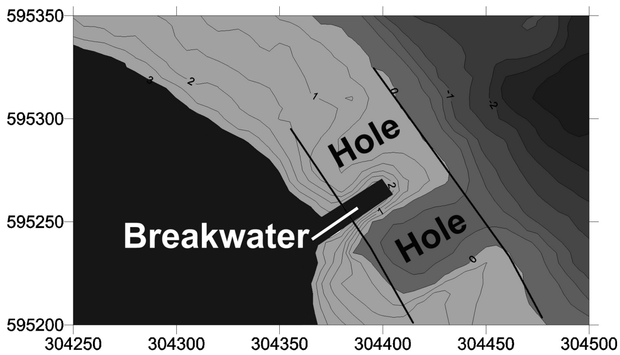

Figure 2: Contours at the end of the surfing ride at Manu Bay from a survey by SCARFE (2002).

The dark lines in Figure 2 depict the reconstructed position of the original contours. To determine the effects in more detail the exact magnitude of the holes would need to be determined with 100 % bottom coverage multibeam surveying (HUGHES-CLARK *et al.*, 1996), as well as an understanding of the current patterns and suspended sediment levels. The work of PHILLIPS *et al.* (1999; 2001; 2003 and 2004) on sediment transport around the Raglan headland would make a significant contribution to such a study.

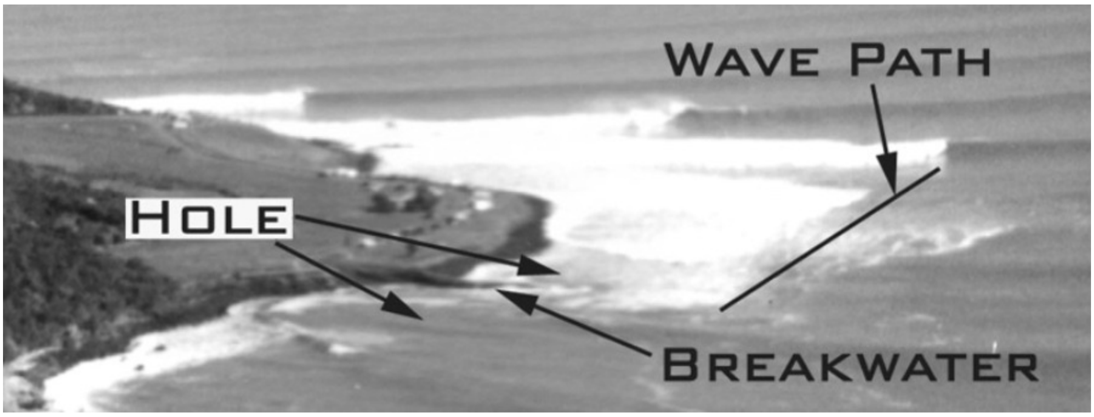

Figure 3: Photo clearly showing the impacts of the boat ramp breakwater construction on the surfing ride.

Figure 3, from SCARFE *et al.* (2002), clearly shows the impacts of the boat ramp breakwater construction on the surfing ride. The breakwater has blocked the wave energy completely. Offshore of the breakwater, the hole has caused the wave to stop breaking. One of the most famous surfing films of the sixties, *Endless Summer*, includes footage of Manu Bay in its natural state before modification and shows waves breaking beyond the current boat ramp position (PHILLIPS *et al.*, 2004). The modification was made before sustainable management practices were written into New Zealand legislation and therefore no EIA on the effects to the natural landform that creates the surfing waves would have been considered. Also, the science required to undertake this type of EIA is only now becoming adequate. The current New Zealand 'effects-based' resource management legislation would have required effects to be avoided, remedied or mitigated. Given the outstanding nature of the original break and its importance to the local community, the break may well have been given a greater level of importance through contemporary coastal management planning. It is likely that other issues such as the cultural significance of Manu Bay to the local Iwi (indigenous people) would also be given more detailed investigation if such a project was initiated today.

Case Study 2 - Mission Bay Jetties, San Diego, California

The jetties that stabilize the entrance to Mission Bay (Figure 4) are examples of a common type of coastal modification that can have positive or negative impacts on surfing wave quality (SCARFE *et al.*, 2003b). In this case, the northern jetty is a consistent and high quality surfing break that can have good waves even when the beach to the north has relatively poor conditions (SCARFE *et al.*, 2003b). The waves at this jetty peel for a significantly longer time than at the beach and break with higher intensity. The take-off point is reasonably consistent, whereas the beach breaks are very "shifty" and the wave peak and breaking location varies. Predictable, clean waves where the break point peels along the wave crest at a surfable speed are desired by surfers (DALLY, 1989; HUTT, 1997; SCARFE *et al.*, 2003a). More detailed literature reviews on desirable characteristics of surfing waves can be found in BLACK (2001a), MEAD (2003) and SCARFE *et al.* (2003a).

The southern jetty is significantly less consistent because it is orientated differently to the dominant wave conditions and has different nearshore bathymetry to the northern side. The orientation of the jetty to the dominant wave direction has a large impact on the surfing conditions (SCARFE *et al.*, 2003b) and this is evident at Mission Bay Jetties. The open angle of the northern jetty allows the wave crest to compress against the jetty wall, focusing wave energy. Whereas the southern jetty actually shadows wave energy for the dominant swell conditions. The northern jetty has been categorised by SCARFE *et al.* (2003b) as a Type 1 jetty (Figure 5) where a long jetty wall and delta absent inlet cause surfing waves to peel along the sand fillet against the jetty.

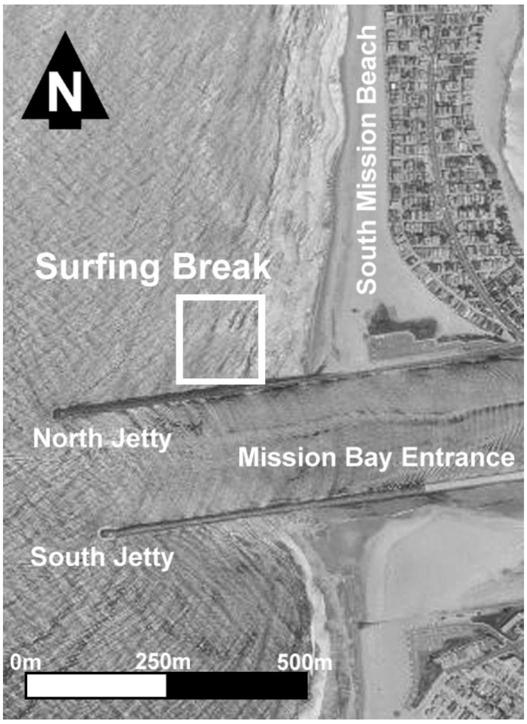

Figure 4: The jetty that stabilizes the entrance to Mission Bay, San Diego, California.

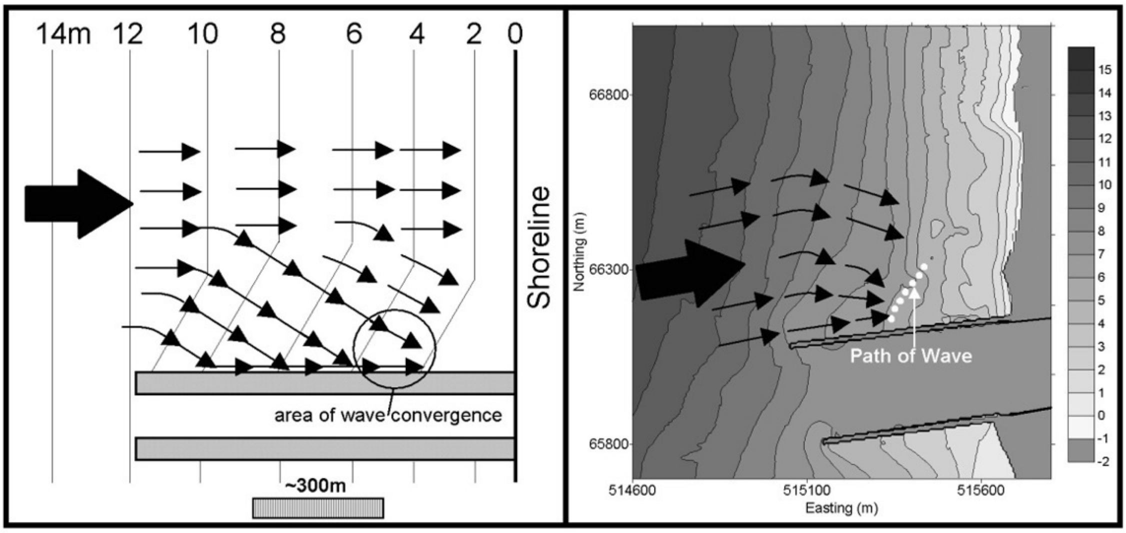

Figure 5: The northern jetty at Mission Bay, San Diego, California.

Case Study 3 – Ponce De Leon Inlet Jetties, Florida (New Smyrna Inlet)

Good surfing waves in Florida are rare because of the relatively low energy wave climate in the region. However, features such as the Ponce De Leon inlet jetties (Figure 6) and the reasonably large delta formation (Figure 7) help to focus the small wave heights and stabilise the wave breaking location to create more consistent surfing bars and waves. The delta is termed a *focus* under the Mead and BLACK (2001a and b) surfing break component categorisation scheme and is a critical preconditioning component of the surfing break. Waves at Smyrna can be significantly larger than at neighbouring beaches (RANDY RICHENBERG, *pers. comm.*) and this is due to the macro-scale (SCARFE *et al.,* 2003a) focus component.

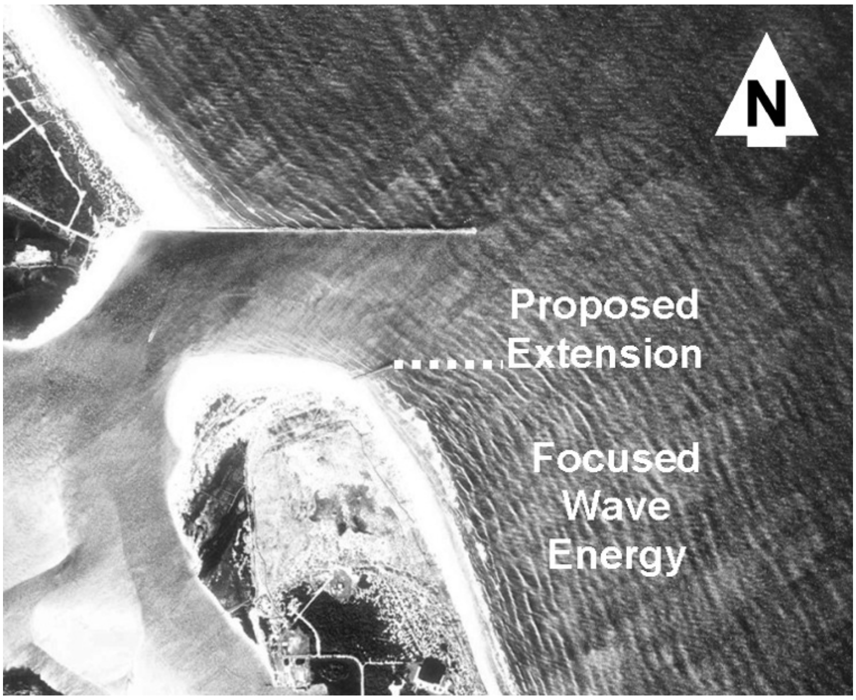

Figure 6: Ponce De Leon inlet jetty, Florida.

Although research relating sand bars and rip formations to surfing has not been undertaken as yet, the general processes that create waves at New Smyrna Inlet can be hypothesised from previous research. SCARFE *et al.* (2003a and b) state that in order for waves to peel suitably for surfing there needs to be a gradient in the wave height and/or contours oblique to the incoming wave crests. It is expected that during larger wave events with complicated spectrums (Figure 8) that the surfing bars and rips form. The best surfing conditions will then occur during clean swells and the organised swell will focus over the delta (Figure 9), before breaking on the bars rips created during the stormier events. A secondary and less significant process is wave focusing and rotation over the inshore bars. The bars and the focusing will satisfy SCARFE *et al.*'s (2003a and b) two requirements for peeling waves. Firstly, the bars, as well as the delta, will cause wave height gradients through wave focusing. Secondly, the bars and rips will also provide oblique contours for waves to break over by rotating the wave and also because the bars can be oblique to the wave crest.

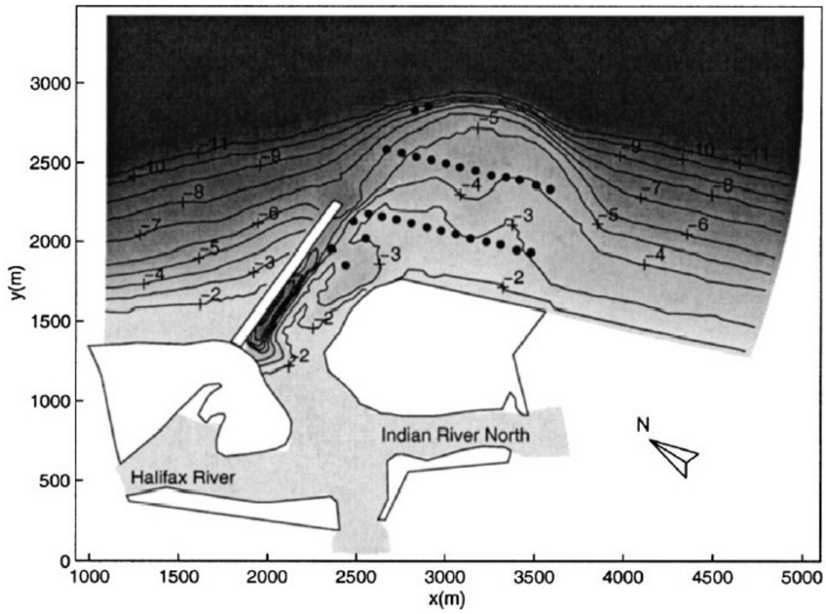

Figure 7: Large delta formation.

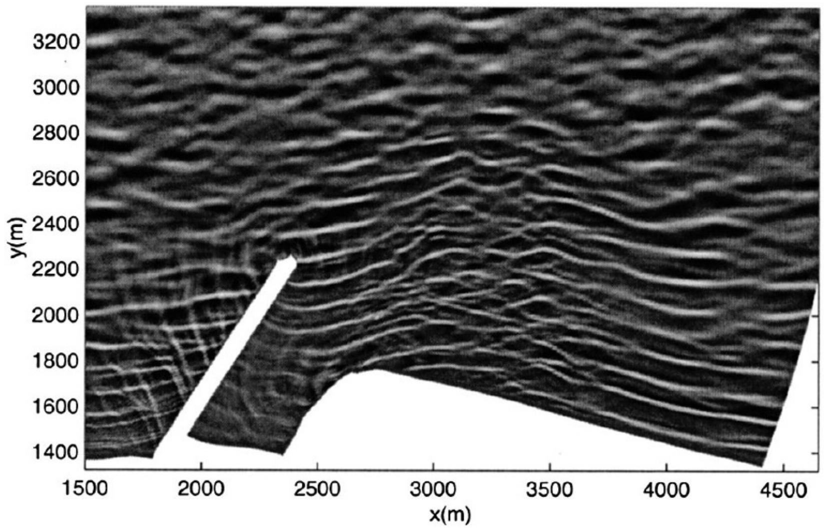

Figure 8: Formation of surfing bars and rips.

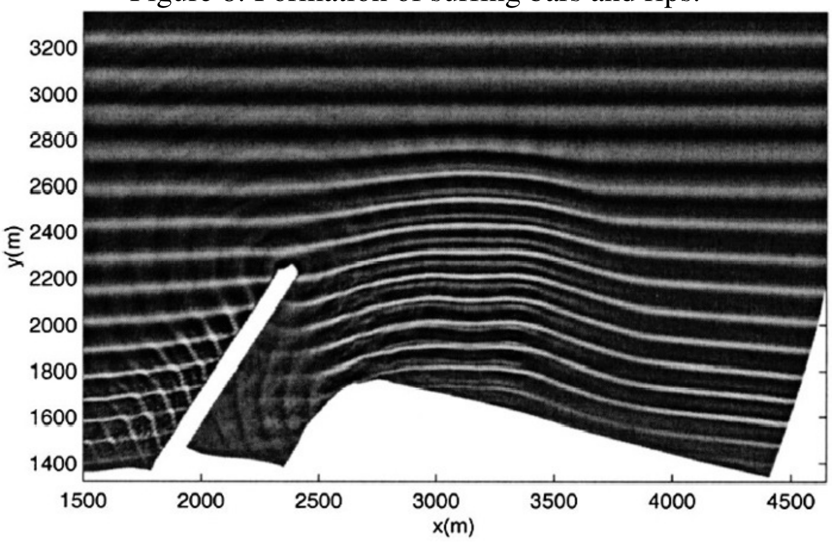

Figure 9: Organised swell focussing over the delta.

An extension to the southern jetty of approximately 300 m is planned (HARKINS *et al.*, 1997; TAYLOR *et al.*, 1997) that might cause an overall degradation in surfing wave quality (MICHAEL WALTHER, Coastal Tech, Vero Beach, FL, *pers. comm.*). The specific cause of the degradation is that the proposed jetty will shadow the beach. The extension is planned to help stabilize the entrance channel, reduce north jetty maintenance costs and decrease the transfer of sand into the inlet from the south and the preliminary study suggested surfing impacts would be minimal (TOM R. MARTIN, Jacksonville District, U.S.A.C.E, *pers. comm.*). The conflicting opinions of the impacts to the surfing break have resulted in a review of the project impacts on surfing conditions. The review, yet unpublished, found that the main surfing area 100-300 m south of the jetty will be unaffected but surf conditions up to about 50 meters south of the southern jetty will be impacted depending on swell direction (TOM R. MARTIN, *pers. comm.*). More consultation with the local surfing community and a detailed EIA using standardised method into the impacts on surfing early on in the project could have minimised any conflict between surfers and developers as well as enabled development of non-traditional engineering alternatives if the project looked likely to impact surfing conditions. Detailed consideration of surfing impacts this late in the project lifecycle will either make changes to the design more expensive or unlikely. If all of the issues associated with the surfing break were raised earlier in the project timeline, it is more likely that the final design could have enhanced rather than possibly degrade surfing amenity. Early public consultation, a key part of EIA, would have identified such possibilities and resulted in support for rather, than opposition to, the project. Incorporation of surfing amenities in the relevant coastal policies could also ensure that this kind of situation does not occur in the future.

Case Study 4 - Palm Beach, Gold Coast, Australia

Three large-scale offshore reefs were planned as coastal protection devices at Palm Beach, an important surfing beach on the Gold Coast (TOMLINSON *et al*., 2003). Its importance is echoed by the fact that it is home of three of the current top 10 professional surfers on the World Tour. The EIA concluded that inshore surfing conditions would be un-affected by the presence of the three reefs along the beach. An independent review is used for this section to show how a trivial surfing EIA resulted in last minute abandoning of the project (MEAD *et al.*, 2004b). Although the project attempted to develop an integrated and multifunctional coastal management strategy (TOMLINSON *et al*., 2003) it was obvious that the public participation aspect of this strategy was insufficient.

At the time of writing, the construction of the first of the three reefs has been indefinitely postponed and the Gold Coast City Council (GCCC) has stated that construction will not go ahead without the consent of the local stakeholders. This is similar to the situation described at Ponce Inlet, where inadequate preliminary consultation led to conflict, and in this case abandonment of the project moments before construction began. Contradictions in the EIA and insufficient evidence of impacts of the design on surfing lead the local stakeholder group's allegations that the reef's presence would significantly impact on the quality of the surf along Palm Beach.

Griffith University's design and EIA of the Palm Beach Protection Strategy was found to be deficient, contradictory, and failed to relate existing scientific literature to the design (MEAD *et al.*, 2004b). Local concerns were poorly answered with a fact sheet with questions and answers that were unsupported with evidence, badly researched and often incorrect with respect to existing knowledge of oceanography and surfing wave parameters (MEAD *et al.*, 2004b). One example of this was the repeated statement that the reefs would not impact on surfing quality. Since the 250 m long reef's primary functional design is to break waves prior to them breaking on the beach, it is impossible that the reefs will not have an impact on the inshore surfing waves. Modelling simulations and review of existing literature demonstrated that the waves that break on the reef as well as those passing over the reef would be significantly modified and have significant negative impact on the existing surfing in the area (MEAD *et al.*, 2004b).

Two main points were brought out of this case. Firstly is the lack of requirement for surfing amenity to be taken into account in coastal protection projects. In later meetings, it was suggested by the GCCC engineer that surfing amenity should be incorporated into State policy to ensure that the Palm Beach situation did not occur in the future (J. MCGRATH, *pers. comm.*). Secondly, it identified the need to utilise the large resource of existing information to design structures that are in harmony with, or will enhance, the surfing conditions while still protecting the beach. The Narrowneck reef (HUTT *et al.*, 1999), at Surfer's Paradise to the north of Palm Beach, is a good example of this type of multi-purpose structure and the proposed multi-purpose reef in Dubai has demonstrated that very effective multi-purpose reef designs (for coastal protection and surfing) can be developed by using the abundant published information and numerical modelling (MOCKE *et al.*, 2003).

INTEGRATED COASTAL ZONE MANAGEMENT (ICZM)

Shortcomings in coastal policy, planning and management caused by competing sectors or activities have been highlighted in international literature over the past three decades and the cases described above exemplify some of the problems that can occur. It is now generally accepted that the philosophies of Agenda 21 (UNITED NATIONS, 1992) and the concept of Integrated Coastal Zone Management (ICZM), Integrated Coastal Area Management (ICAM) or Integrated Coastal Management (ICM), are a desirable avenue to appropriately consider many of the issues (CICIN-SAIN, 1993b; RENNIE, 2000; HEALY and WANG, 2004). The term ICZM has been adopted in this paper, and readers are referred to HEALY and WANG (2004) for presentation of different definitions of the term.

The aims of efficient ICZM practices are to establish and maintain the best use and sustainable levels of development and activity use in the coastal zone, and, over a period of time, improve the physical status of the coastal environment in accordance with certain commonly held and agreed norms (HEALY *et al.,* 2001). One of the most important aspects of ICZM is that it is forward looking (HEALY and WANG, 2004) and aims to preserve resources for future generations, and this definition is extended here to also include surfing breaks. Problems that have been identified in the absence of ICZM include:

- unnecessarily reactive management (responding after the fact to problems which should have been anticipated and avoided);
- cumulative impacts (where the many small decisions made by different levels of government add up to major problems for the coastal environment);
- transfer of problems from one sector to another;

- predominance of short-term economic interests (often at the expense of nature and the environment, and in many cases having a negative long term economic or social impact); and
- fragmented geographical planning (lack of co-ordination between managers of land and marine areas, managers of different economic activities, or neighboring communities bordering a single coastal ecosystem) (HEALY and WANG, 2004).

Although efforts of individuals and organizations for environmental causes can have excellent results, these can be reactive attempts to protect a threatened natural resource. For the case of surfing breaks it is recommended that a more proactive and preventative approach, such as legislation and practises incorporating ICZM and sustainable management philosophies be used. For the best environmental result, recognition is required of the specific natural resource in coastal plans and environmental legislature to facilitate the protection of environmental assets. For example, a coastal plan that identifies surfing break locations, the physical processes that cause the quality waves to form and the threats to the wave quality, gives greater weighting to any concerns that a coastal project may jeopardize the break. Effective coastal management planning can help to protect surfing breaks by providing structured avenues for the concerns of surfers to be directed. A model for such an approach can be found in New Zealand's Resource Management Act 1991 (RMA). This regulatory approach is recommended generally for coastal management at various national and international levels by GOLDBERG (1994) to minimise conflict due to competing for coastal zone space. GOLDBERG (1994) also suggests that regulation should also exist where currently there is no conflict to pre-empt possible future conflict. Spain is used as an example where 42 % of the coastline (at time of publication) is unoccupied and laws and policies have been formulated to minimise unregulated development.

Sustainability is an underlying paradigm of ICZM and New Zealand's Resource Management Act 1991 was among the first significant pieces of environmental legislation that has adopted "sustainability" as the cornerstone of its coastal management regime. The purpose of the Act is to "*to promote the sustainable management of natural and physical resources*". The Act controls all activities related to environmental resources and binds both private and government sectors to its statutory requirements. Many of the philosophies behind the Act have been espoused in Agenda 21 (HEALY and WANG, 2004) and the Act is used here to demonstrate some provision for protection of surfing breaks within an existing resource management framework. Chapter 17 of Agenda 21 emphasises a precautionary and anticipatory approach rather than a reactive approach. The concept *inter alia,* is embraced and suggests "applying preventive and precautionary approaches during project planning and implementation" (HEALY and WANG, 2004; WOOD, 2003). Sustainable management is defined in Section 5 of the RMA as:

> *Managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while:*
> a. *sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;*
> b. *safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*

c. *avoiding, remedying, or mitigating any adverse effects of activities on the environment.*

This contrasts with the aims of traditional ICZM practices that seek to establish and maintain the *best* use and sustainable levels of *development* and *activity*. New Zealand's sustainable management approach, however, does not attempt to identify the 'best' uses or encourage development, other than indirectly. It seeks to achieve best use through public participation processes that identify tiers of biophysical 'bottom-lines'. If developers can carry out their activity without adversely affecting those bottom lines, then they can proceed with the appropriate level of development. Basically, no development is allowed seaward of the level of mean high water of spring tides unless a rule in a plan specifically allows the adverse effects associated with that development. If the plan does not allow those effects, but does not specifically prohibit them, then a permit can be obtained for the activity. For example, surfing on natural breaks is permitted because the adverse environmental effects are so low, limited to the visual appearance of surfers. The release of pollutants, for example if suntan oil was highly damaging (ORAMS, 1999) into the water could come as easily from swimmers as from surfers. Thus it would not be appropriate to ban the activity of surfing to prevent suntan oil pollution. An effects-based regime would control the use of sunscreen rather than activities where sunscreen may be worn. Another example is tributyltin (TBT) which is an effect antifouling paint for boats. TBT is one of the most toxic anthropogenic compounds introduced into marine waters (GOLDBERG, 1994) but banning boating would not be an appropriate action to stop the effects of the toxin.

The effects-based planning approach of the RMA therefore requires people to analyse the adverse biophysical effects of uses and developments before they occur. This means requiring some form of EIA. The local community can have its views as to what are acceptable and unacceptable adverse effects addressed in the coastal plan. Specific projects are identified as needing or not needing permits through the developers carrying out an EIA. If the developers decide that the EIA does not show any effects that need a permit, then they can proceed to develop, but if they are wrong in their conclusion they may find that their development is stopped by the local government. They are therefore wiser to pass their assessment through the local government, who if it agrees that the effects are too minor to need a permit, can issue a Certificate of Compliance (CoC). If the local government considers the effects do not qualify for a CoC then a permit must be obtained and this could require a full public hearing (RENNIE and MAKGILL, 2003). The best use in terms of social development receives very little weight in New Zealand. Such matters are left to "the market" to decide on the basis that the market is the most efficient means of allocating resources and development. What the RMA does achieve, however, is that the developer with environmental effects has a greater incentive to invest in technology to avoid the adverse effects. If those effects cannot be avoided then they must be remedied or mitigated. Among the mitigation methods might be slightly more expensive designs that enable surfing amenities to be retained or improved.

Traditionally ICZM tended to identify best use on the basis of segregating areas of conflicting activity and where those conflicts could not be resolved by segregation, then relying on lobby groups armed with either public opinion or cost-benefit analyses to win the day as to the best use. Ecosystem services could be too easily discounted from everyday decision-making in the face of short-term cost-benefit based arguments of relatively high economic returns to a community from major engineering works. The RMA therefore offers a more powerfully biophysical effects-basis to achieving ICZM than did traditional ICZM. It does this on the basis of EIAs.

For effective ICZM that includes surfing amenity there needs to be legislative frameworks for surfers objections to coastal activities to be considered. GOLDBERG (1994) stresses the need for both natural and social scientists to communicate with bureaucracies for effective development of such regulation. An avenue suggested by GOLDBERG (1994) to facilitate this communication is an advisory committee made up of professionals involved with environmental problems. In the case of sustainable management of surfing breaks, at a local level this could be surfers, government officials, engineers and scientists who in turn are part of a larger more nationally focused committee. The committees could guide the creation and improvement of regional and local surfing management plans. Using New Zealand as an example, the local committees could act to incorporate surfing into the regional coastal management plans, which are guided by the national coastal policy statement that the nationally focused committee is involved in defining.

ENVIRONMENTAL IMPACT ASSESSMENTS (EIA)

If EIAs are to be a useful process in advocating the preservation of natural surfing breaks or the development/maintenance of artificial ones, then it is important that they incorporate appropriate methods and models. Here we summarise the nature of EIAs and their methods and suggest some processes, strategies and tools that should be incorporated into EIAs. A standardised step by step methodology is beyond the scope of this overview paper and will be the subject of future research.

EIAs have been around for over 30 years (WOOD, 2003) and yet there remains considerable debate over their purpose and the role of science in EIA (BARTLETT and KURIAN 1999, CASHMORE, 2004). For the purposes of this article we accept the view that EIA is an anticipatory, participatory, integrative environmental management tool to provide decision makers with an indication of consequences of their actions (WOOD, 2003). They involve an investigation into the effects of an activity on the environment and are a central tenet of ICZM (HEALY and WANG, 2004). There are over 100 EIA systems worldwide and although they differ in detail, the basic principles are similar (WOOD, 2003). They are usually required by law as part of the environmental permitting for an activity and are a very tangible step in the ICZM process. All potential effects, to all sectors of the environment need to be considered in detail so the impacts can be avoided, remedied or mitigated. The impact assessments and predictions must include expert scientific evidence and may include contributions from traditional environmental knowledge systems. They may well require a level of rigour that is defendable in court and the less uncertainty in the data used, and the more rigorous the processes followed is, the greater the likelihood of success. The information from the EIA is used by decision makers to determine if an activity is allowable and also to impose any conditions on the approvals granted. The extent to which they may empower particular stakeholders, for instance surfers, may well depend on the degree to which surfer’s can provide scientifically rigorous assessment criteria and processes for assessing the impacts of activities on surfing and of surfing on other activities. In this article our focus is on developing criteria for standardised scientific assessment of the biophysical environment.

The information from the EIA is used by decision makers to determine if an activity is allowable and also to impose any conditions on the coastal permit. In the case of surfing breaks, a baseline understanding of the processes and bathymetric features that produce the surfing waves is required. The EIA must then predict probable, and improbable, but highly significant, changes caused by the activity to the seafloor features that create the surfing waves. In addition, the assessment should consider any shadowing or focusing of wave energy to the surfing break.

Although the impacts of an activity on environmental assets such as seal colonies, shellfish or sediment transport are automatic and generally detailed in EIAs, impacts on surfing breaks have traditionally been ignored. For example, FRIHY (2001) in a review of EIA in coastal projects makes no mention of surfing. Where impacts on surfing have been acknowledged they have been reviewed superficially. Statements such as 'there will be no negative effects to surfing wave quality' are often made without any scientific rationale (MEAD, *et al.*, 2004). There has been a lack of examples of how EIAs for surfing breaks should be undertaken, and until recently, the physical processes that transform ordinary waves into surfing waves were not very well understood. Now surfing science research, motivated initially to develop design parameters for artificial surfing reefs, can be applied also to the preservation of surfing breaks (SCARFE *et al.*, 2003a). This section will outline the important information that should be included in EIAs for surfing breaks as well as describing the EIA process.

An excellent example of a poor EIA on surfing conditions was presented in NELSEN and HOWD (1996). This resulted in a developer being required to pay compensation for the destruction of a surfing break. The surfing break in El Segundo was an example of two interest groups with conflicting coastal user space requirements. Chevron's El Segundo oil refinery was at threat from erosion and sought permits for construction of a groyne to retain sediment. Local surfers also required use of the same coastal space for recreational surfing. Several experts on coastal processes predicted no negative impacts to surfing with the possibility of an improvement to surfing conditions (NELSEN and HOWD, 1996). Surfrider Foundation, acting on behalf of local surfers, raised concerns with the groyne construction in spite of the experts assessment. This resulted in the Californian Coastal Commission (CCC) allowing permitting with a unique condition that if the initial EIA was incorrect and the surfing conditions were impacted, funds had to be provided by Chevron to mitigate with an artificial surfing reef (ASR) (NELSEN and HOWD, 1996). Unfortunately for the surfers the El Segundo ASR never significantly improved surfing conditions (BORRERO and NELSEN, 2003) because the design and construction techniques were still only basically understood. A detailed EIA and alternative design considerations that included ICZM philosophies could have resulted in a positive outcome for surfers and no cash settlements required by the developer.

EIA Process

Various EIA processes have been suggested, with variations often reflecting the different backgrounds of their authors (MORGAN, 1998). There are three main components to EIA: the process (methodology), methods and techniques (MORGAN, 1998). EIA can be applied to policies, plans and programmes, where it is usually known as strategic environmental assessment (SEA), or to projects. The processes need not vary substantively between SEA and EIA, but the nature of policies and plans places constraints on applicable methods and techniques and in this report we focus on EIA for projects. The EIA process for a project generally contains the following iterative steps:

1. Selection of scheme concept
2. Determining whether, or what type of EIA is necessary in a particular case (also called screening)
3. Deciding on the topics to be covered in the EIA (scoping – this may precede screening)
4. Preparing the EIA report
5. Peer and public review of the EIA report to check its adequacy (this may be repeated or revisited during appeals of the decision)
6. Making a decision on the proposal, using the EIA report, as well as expressing opinions about the project and usually applying conditions or specifying constraints on the project.
7. (Re) designing the selected proposal
8. Construction
9. Monitoring the impacts of the project during and after construction.

Public participation is an integral part of most forms of EIA and may occur at most stages of the process (WOOD, 2003; SADLER, 1996). WOOD (2003) suggests consideration of alternative means of achieving objectives as step one of the EIA process. In practice, developers usually have a commercial objective that pre-empts such considerations and a more practical approach would be to consider alternative means of achieving objectives during the screening or scoping stages. After all if a project will not have negative effects there would not be a requirement to provide alternative designs. Unfortunately this results in realistic alternatives not being considered sufficiently early and proponents become too committed to the project to consider anything other than similar alternatives. For instance, the fundamental function of a marina is to provide parking space for boats. Marina proponents will often consider only alternative marina designs, scales and management practices rather than consider whether a land-based facility (e.g. a boat stack) might provide an alternative means of parking boats with fewer adverse impacts.

Although public participation is seen as integral to EIAs (and SEAs), the range of mechanisms that can be used to implement participatory processes vary considerably and some members of the community may be overlooked (ROBERTS, 1995; MORGAN, 1998). For example, it is unlikely at the moment that many, if any, plans worldwide identify surfing breaks as a fragile environmental asset. Even though legislation such as the RMA does identify protection of unique natural landforms as a matter of national importance (surfing breaks can be grouped under this description), surfing breaks are not specifically identified in the New Zealand Coastal Policy Statement or Coastal Management Plans. The only way that they will be considered in decision-making is if the impacts on them are identified during the EIA of projects. If there are no open public participation procedures in such EIAs, then surfers are reliant on raising objections through legal procedures when avenues exist. It is also important to recognise that during the consultation process alternative designs should be proposed and interest groups, such as surfers, should be consulted to determine if the new design solves issues or raises new ones. A method for reducing opposition to activities during the EIA process is mitigation. When there are negative impacts to surfing breaks and the activity is still permitted, mitigation of the impacts should be undertaken. WOOD (2003) discussed a range of possible mitigation measures in a mitigation hierarchy:

1. Avoidance at source
2. Minimise at source
3. Abatement on site
4. Abatement at receptor
5. Repair
6. Compensation in kind
7. Other compensation and enhancement

Any decision to mitigate should not be made lightly. In fact, some cynics of artificial surfing reef technology are justifiably wary because mitigation with a reef may appear an easy option when surfing wave quality is threatened. Over time natural surfing breaks could be replaced with artificial reefs. In come instances this maybe desirable such as when an average quality surfing break is destroyed and replaced with a higher quality, more consistent artificial reef. However, mitigation should never be considered as a viable option when the destruction of a natural, unique and high quality break is shown to be likely in an EIA.

EIA Methods and Techniques

The methods employed in the EIA process should be designed with two main criteria in mind: adding rigour to the process, and effectively communicating the nature of the effects. Four basic methods have been developed over the years as aids to EIA: checklists, overlays, matrices and networks. Each of these has advantages and disadvantages and each has evolved and become more technically and technologically sophisticated. Overlays, for instance, popularised originally by McHARG (1969) have now been largely overtaken by Geographic Information Systems (GIS). Checklists, however, provide a simple method for impact identification and ensuring that important effects are not overlooked. These may be general (able to cover any project and environmental type), generic, or specific (a 'one-off' checklist designed for a particular project or setting) (LEE, 1989; MORGAN, 1998). The generic checklist is the type of most interest to us in that it can be designed for a particular type of project (e.g. new artificial surfing reefs) or for types of environment (e.g. natural surfing breaks). They could also address existing artificial surfing breaks. For example, Ponce De Leon inlet jetties where the break has been created as an incidental consequence of artificial modification of the environment. They are able to be developed for social and biophysical effects and for SEA as well as EIA use.

Matrices tend to be sophisticated versions of checklists, but make transparent, in tabular format, the cause-effect assumptions of linkages between specific actions undertaken during a project and their assumed effects. They also underpin multi-criteria evaluations. Networks, however, can show cause-effect relationships diagrammatically and provide the basis for systems modelling. Among the keys to effective use of any of these methods in ICZM is the identification and collection of relevant data (FRIHY, 2001; TIWI, 2004). Our research suggests a generic checklist of the information requirements for EIAs relevant to the effects of activities on surfing breaks could easily be used in conjunction with GIS overlay methods as a basic initial tool for protecting surfing breaks.

Details of matrices and networks for surfing break EIAs is beyond the scope of this overview paper and but be based the generic checklist presented in this paper.

EIA Checklist

In order to undertake an EIA for an activity on a surfing break firstly there needs to be a baseline understanding of why the surfing break produces surfable waves. Although the general features may be common knowledge, such as there is a reef where the waves break or the jetties make the surf, the specific components (MEAD and BLACK, 1999, 2001a and b) and processes that make the surfing break must be understood and related to current surfing science literature. Then any effects to the seabed shape or focusing/shadowing of wave energy from the proposed activity must be related to the surfing wave quality. Different wave and tide conditions must also be investigated because the impacts may be limited to, or accentuated by certain conditions. It is beyond the scope of this paper to detail the specifics of each type of information that should be included in a surfing EIA. However, a list of the various factors that should be considered and related to credible literature has been compiled. It is expected over time that this list will become more comprehensive, but currently it includes:

- Bathymetry
- Wave climate (inshore and offshore)
- Sediment transport pathways and grain sizes within littoral cell
- Wave refraction
- Peel angles
- Breaker Intensity
- Surfer numbers and seasonal variations
- Precise location of surfing rides
- Tidal patterns and long term water level trends
- Wind patterns
- Relating the surfing break to surfer skill level
- Storm surge
- Number of surfable says per year or surfing wave/wind climate
- Wave and tide induced current patterns

Overlay Techniques - GIS

Overlay techniques have been around for quite some time but the widespread use in recent years of GIS has enabled more powerful analysis of spatial data. GIS allows different types of information to be stored, interpreted and related to each other, resulting in a better understanding of the environmental system than through analysis of the data without the spatial software tool. Information about surfing breaks can also be stored and interpreted with GIS. It enables the effects of changes in bathymetry to be visualised in relation to surfer type and surfer use under different swell conditions, wind directions and weather. Appropriate bathymetric and modelling techniques can be combined with other GIS-based information to fully understand environmental process occurring around a surfing break.

Utilizing existing data for a surfing GIS serves two benefits. Firstly, environmental data is expensive to obtain funding to collect specifically for management of surfing breaks would be difficult in many areas. Secondly, reuse and re-interpretation of existing environmental data reduces the cost per-project of collecting the data because the data is used repeatedly. However, for detailed surfing break studies data must be collect specifically for the project. Examples of the types of biophysical environmental information that could be stored in a surfing GIS include:

- Surfing break component schematics
- Bathymetry/Digital Elevation Models (DTM)/Digital Terrain Models (DTM)
- Bathymetry data (XYZ with metadata)
- Numerical modeling images for different oceanographic conditions
- Sediment transport patterns
- Sediment grain size data
- Wave data
- Side scan images
- Oblique photos of surfing waves
- Video of surfing waves
- Aerial photos showing shoreline position and wave refraction
- Links to pdf documents
- Water quality data
- Tidal data
- Current data

It is important to recognise that while some spatial data can be readily collected at short notice, data on people's use of areas may be much less readily available. Well-prepared surfing interest groups should invest in collecting such data on an ongoing basis so that it is readily available in case their surfing breaks are threatened. Techniques for gathering such information are available, although still somewhat experimental (e.g. THOMSON, 2003; POLETTE and RAUCI, 2003; KLEIN *et al.,* 2003). An example of an environmental surfing organisation is the Surfrider Foundation and they are utilising GIS technology to store information about the location, access to, and water quality around surfing breaks. This information supports their mandate to protect surfing breaks and the rights of surfers to utilize the resource. To date there is no known large scale organised GIS collating geophysical data. Although Surfrider is working with the National Parks Service to locate all the surfing breaks in the National Parks, and collect information on number of users (CHAD NELSEN, Surfrider Foundation *pers. comm.)* and this could later be extended to geophysical information. An example of another non-surfing GIS that uses environmental information for coastal management decision making is discussed in JIANG *et al.* (2004) and this type of project could be used to design a surfing GIS system.

TRENDS IN COASTAL ENGINEERING

Conventionally used coastal engineering structures such as groynes, seawalls, jetties, and detached breakwaters are not considered by many as a holistic method of engineering coastlines (e.g. KOMAR and MCDOUGAL, 1988; PILKEY and WRIGHT, 1988; SCHWARTZ, 1990; SCARFE, 1999; BLACK, 2001b; BLACK and MEAD, 2001). For instance, the main objective of a seawall is to protect land from eroding and being lost to the sea, but it does not always retain the beach seaward of the wall. However, the loss of recreational and visual amenity by changing the beach from a dunes system to a seawall is significant. Recreational amenity is lost because often seawalls result in narrower beaches, as the erosion continues and is often accelerated by reflected wave energy from the seawall. Hard rock structures such as groynes, breakwaters and jetties are also disliked by some because of their unnatural appearance, or as WOOD (2003) states, their 'artificialness'. For surfers, the backwash created by the wave reflections off seawalls can destroy surfing rides by stopping the waves from breaking properly. St Clair Seawall, Dunedin, New Zealand is an example of a seawall that has degraded the quality of the surf, particularly at high tide because of reflections of waves off the seawall. The deteriorating seawall has recently been replaced with a similar, non-holistic, simple, land protecting design that fails to enhance any recreational amenity. A more modern and progressive answer to fixing the failing seawall would have resulted in improved visual aesthetics and recreational amenity. Now the investment in the seawall means that the opportunity is lost for another 50-100 years when the seawall fails again.

Negative responses to traditional engineering practices are driving the development of engineering methods that work with, rather than against, nature and benefit multiple user groups. Practices that take into account more than one objective and include visual amenity, biological enhancement and recreational concerns will continue to develop. It is expected as more detailed environmental impact assessments of coastal projects on surfing breaks are undertaken, weaknesses in traditional engineering technology will be highlighted and there will be an effort to include secondary objectives (such as recreational surfing, biological enhancement, sheltered swimming, etc.) into engineering designs. As multiple objectives are taken into account, innovative holistic engineering techniques such as wave rotating structures, submerged reefs, submerged groynes and stabilized artificial nourishment may be seen to be the preferable solutions to many coastal engineering problems. An example of a project attempting to integrate multiple benefits is discussed in HEALY *et al.* (2002). The project's main objective was to redesign a coastal port but the project also included amenity values as an ancillary redesign consideration. Surfing enhancement also was considered but is yet to be given any detailed design consideration.

One example of an innovative technique is the artificial surfing reef concept. Although the technology is still in the early development stage, acceptance of artificial surfing reefs is also growing and there have been over 20 feasibility studies completed worldwide. Various detailed reef designs projects have also been undertaken in Opunake (BLACK *et al.*, 2004), Lyall Bay (MEAD *et al.*, 2001) and Mount Maunganui (MEAD and BLACK, 1999; GOUGH, 1999) in New Zealand; Narrowneck (HUTT *et al.*, 1999), Noosa (BLACK, *et al.*, 2001), Geraldton (MEAD *et al.*, 2004a) and Cable Station (PATTIARATCHI, 2000 and 2002) Australia; Borth, Newquay (CHALLINOR, 2003) and Bournemouth (BLACK *et al.*, 2000), England as well as Ventura (MEAD *et al.*, 2003a) and El Segundo (MOFFATT and NICHOL ENGINEERS, 1989; NELSEN and HOWD, 1996; BORRERO and NELSEN, 2003), in California. Of these projects, construction began for Narrowneck in 1999 and has been very successful in terms of coastal protection. Even though the surfing quality has been significantly enhanced, the conditions are not yet being optimised due to the construction techniques used (the reef is still undergoing periodic construction to further enhance the surfing conditions, and has not yet reached the design shape). Lyall Bay and Mount Maunganui have been granted permits for construction, with construction tender documents released for Mount Maunganui. Opunake is in the final permitting stages and has full financial support if permitting is successful. Construction for a multi-purpose reef at Ventura, California, is scheduled for the fall of 2005 and permitting is presently underway. The Ventura project is part of the U.S.A.C.E Section 227 program for innovative and non-traditional erosion control methods and demonstrates a willingness of the U.S.A.C.E to improve on traditional engineering practices. The Cable Station reef is now one of the better surfing breaks in the Perth metropolitan area, although it is interesting to note that performance monitoring by PATTIARATCHI (2002) did not assess how well the surfing waves form or the number of days that the reef was surfed. Instead the report focused on the number of days per year that waves break on the reef, which is a very poor estimate of number of surfable days because not all breaking waves can be surfed.

Different countries have different approaches to coastal engineering. Some countries opt for hard engineering practices while others choose softer methods that work closely with the natural environment. Many of the common hard engineering practices employed today are implemented verbatim from textbooks with little creative or innovative ideas and sometimes lack of understanding of physical processes. Although barriers exist, global trends in coastal engineering are tending to work with nature and maximize visual, ecological and recreational benefits. GEORGE (2004) in a discussion of artificial surfing breaks listed numerous coastal engineering projects in the USA that had inadvertently improved the quality of surfing waves, or indeed created a surfing break where one did not previously exist. The number of these *'happy accidents* (GEORGE, 2004)*'* compared with the number of engineering projects was not addressed but it is likely that with a few design improvements many more of the coastal engineering projects in the USA could have improved surfing amenity. Many more examples of *'happy accidents'* exist worldwide, yet there remains limited credible scientific research on how the engineering projects improved the surf quality (SCARFE, 2003b). At one end of the scale artificial surfing reef technology is attempting to create new surfing breaks where there are none. At the other end of the scale, traditional engineering practises on occasion improve surfing wave quality yet there seems little effort to link the two and subtly modify traditional designs to ensure benefits to surfing amenity. The artificial surfing breaks in the USA listed by GEORGE (2004) are:

> *Humboldt Jetties, Fort Point, Sharp Park Pier, Princeton Jetties, Santa Cruz Harbourmouth, Moss Landing, Cayucos Pier, Morro Rock, South Jetty, Pismo Pier, Sandspit, Oil Piers, Ventura Dredge, Hollywood-by-the-Sea, POP Pier, Venice Jetties, Hammerland, Manhattan Beach Pier, Hermosa Beach Pier, Redondo Breakwall, Seal Beach, Huntington Beach Pier, River Jetties, all of Newport Beach, Wedge, San Clemente Pier, Del Mar Jetties, Oceanside Jetties, Oceanside Pier, Warm Water Jetty, Ponto, Scripps Pier, South Mission Jetty, Ocean Beach Pier, Imperial Beach Pier, Sandy Hook, Sea Girl, Manasquan Inlet, Bay Head, Casino Pier, Seaside Heights, States Avenues, Ventnor Pier, Margate Pier, Ocean City, all of Virginia Beach, all of Cape Hatteras, Jacksonville Beach, Ormand Beach Pier, Ponce Inlet, Cocoa Beach, Canaveral Pier, Sebastian Inlet, Palm Beach Jetties, South Beach, Galveston Jetties, J. B. Luby Pier, Bob Hall Pier, Fish Pass, South Padre Island, Ala Moana and Kaisers.*

It should be noted, that while these projects have created surfing breaks, in many cases they have led to negative downcoast impacts. The mitigation of downcoast impacts is one of the main advantages of offshore submerged reefs for coastal protection; since a gap between the reef and the beach is maintained the littoral system is slightly modified rather than 'interrupted'.

CONCLUSIONS

Globally coastal environments are under threat, especially with the trend for people to migrate towards the coast from rural areas (HEALY and WANG, 2004). The associated new infrastructure demands as populations increase reinforce the need for ICZM and protection of fragile and scarce environmental assets such as surfing breaks. Tourism associated with the coast is also extremely important and the tourism niche of many coastal communities is recreational surfing (BUCKLEY, 2002a and b). There are over 10 million surfers worldwide and a third of these are cash-rich and time-poor (BUCKLEY, 2002a) making them potentially highly lucrative tourists. The flow-on economic benefits have been shown to be significant and include revenue from such activities as purchasing a snack at a store, buying fuel, renting accommodation, buying surfing equipment, spending on other local tourism activities and increasing the value of coastal property. In the Indo-Pacific Islands adventure tourism such as surfing is providing a more environmentally sustainable economic revenue than activities such as logging and plantation agriculture (BUCKLEY, 2002a).

Coastal tourism is a major component of total global tourism (MILLER, 1993 in HEALY and WANG, 2004), which has become the largest global industry since the new millennium (HEALY and WANG, 2004), and this tourism places high stress on the coastal zone (GOLDBERG, 1994) Surfing makes up a significant component of the worldwide adventure tourism market (BUCKLEY, 2002a) and sustainable management of surfing breaks will become a more important issue as pressure on these finite resources increases. GOLDBERG (1994) has argued that a lack of integrated planning and management is likely to result in depletion of the coastal environmental resources and long term negative economic trends. Evidence exists to indicate that tourists are increasingly interested in higher quality tourism experiences (HEALY and WANG, 2004) and therefore localities with the highest quality surfing wave quality and natural character will continue to be premium surfing tourism destinations.

This paper has presented a wide range of general issues about sustainable management of surfing breaks. Case studies of surfing breaks that have been both improved and compromised by coastal development have been presented to illustrate the need to nurture the fragile natural features. The case studies have not come from detailed and well funded studies and do not claim to exactly quantify the precise effects. Rather they present examples of different types of coastal activities that can affect surfing breaks in order to create discourse in scientific literature that can be used as a base for future EIA projects. It is argued that the requirement of ICZM to balance the needs of various interest groups can be better achieved through innovative and non-traditional coastal engineering practices that provide multiple benefits to many users. The artificial surfing reef concept is used as an example of a technique that aims to provide multiple benefits.

The EIA process is suggested here as the best method to address surfer concerns relating to assessing impacts of coastal developments on surfing breaks. Various common activities that can affect surfing wave quality are presented and a list of the variables that must be taken into account during a detailed surfing EIA is also provided. Although the information required will vary for specific projects, the basic EIA process remains similar. Clearly the processes and features that create the surfing waves must be understood so that any impacts of the activity to those features and processes must be addressed. Various EIA tools have been discussed including overlays, checklists, matrices and networks. It is essential that EIAs are based on the now significant volume of science on surfing research. References provided in this paper should provide a trail to most of the important documentation on surfing science and sociology to date. Surfing sociology (e.g. PRESTON-WHYTE, 2002; RIDER, 1998) seems to be a growing field that may help to link the surfing science to society, and this may contribute to resolve some of the complicated resource management questions that continue to occur with surfing breaks.

In summary, in order to sustainable manage surfing breaks there needs to be two main improvements to ICZM practises. Firstly, an appropriate legislative framework. Without the appropriate avenues for surfers, objections to coastal activities will be limited to protest actions that may or may not be heard by environmental permitting agencies. Secondly, the collection and reinterpretation of geophysical data on surfing breaks that is related to the scientific literature on the subject.

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