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From beaches to beach environments: linking the ecology, human-use and management of beaches in Australia

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Abstract

Beaches are very important to Australians but are presently threatened by several forms of environmental degradation. Beach management has traditionally concentrated on geomorphic hazards and the recreational human-use of beaches, but has largely ignored the ecological and broader environmental values of beaches. In this paper beaches are conceived as multidimensional environmental systems — 'beach environments' — that are nested within larger coastal systems and comprised of interacting natural, socio-cultural and management systems. These three component systems of beach environments have usually been considered separately. It is argued that a focus on both the component systems of beach environments and interactions among these systems is necessary for improvements in the management, conservation and overall environmental quality of beaches. Interactions among natural, socio-cultural and management systems are specified in a simple model of beach environments. A brief review of our knowledge on these interactions indicates that fundamental information is lacking in Australia and the ramifications are potentially severe. The concept of beach environments provides an appropriate context for the collection of relevant information, the collaboration necessary between researchers and managers and a new setting for beach environmental management. Several opportunities are outlined for beach management.

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1. Introduction

'The beach' is a national icon in Australia and a recognisable beach culture is indicative of the high value Australians place on beaches [1]. Beaches are typically viewed in physical and cultural terms in Australia, as natural places of 'sun, sea, surf and sand' that support various hedonistic socio-cultural activities [2]. But beaches are also recognisable ecosystems that provide various services and have many ecological values. There are signs that the environment of Australian beaches is being degraded because of waste disposal problems, over-engineering, invasion of exotic flora, urbanization and over-development [3–5]. In Sydney, New South Wales (NSW), the quality of water on beaches for bathing has been a major environmental issue for the general public over recent years [6–8]. In response to the public health issues caused by sewage pollution, the 'Beachwatch' program presently conducts water sampling at 70 sites on ocean beaches in the greater Sydney region [9]. Global climate change and sea level rise also threatens greater storminess and significant changes in the position of beaches in the long term [10]. Due to their popularity, importance, and legislative and policy imperatives, Australian beaches require effective management to prevent further environmental degradation.

Beach management in Australia has largely concentrated on two activities. Firstly, protecting the coast and property from the geomorphic hazards associated with beach erosion and flooding. And, secondly, providing for the recreational use of beaches (including clean water for swimming). This 'hazards-and-playgrounds' view of beach management is pervasive in Australia. For instance Eric Bird, a geomorphologist with a vast experience of beaches in Australia and elsewhere, recently described the aims of beach management thus: "Beach management seeks to maintain or improve a beach as a recreational resource and a means of coast protection, while providing facilities that meet the needs as aspirations of those that use the beach [11]".

Clearly, a broader conception of beaches and beach management is required to address beach degradation. This conception must acknowledge that beaches are multidimensional environmental systems — 'beach environments' — rather than unidimensional physical systems or recreational playgrounds. From this broader perspective, there are two major ways of improving the quality of beach environments. The first is by deepening our understanding of the many components that comprise beach environments. This is the focus of ongoing disciplinary research into beaches, for example investigations of beach organisms or analyses of management arrangements.

This paper explores a second approach to improving beach environments — by improving our comprehension and awareness of the linkages among the various systems comprising beach environments. This idea is examined by initially outlining a model of beach environments which elaborates these linkages. I then briefly review our understanding of the linkages among the systems comprising beach environments and the possible consequences of ignoring them. Finally I consider ways of improving our understanding of these linkages and sketch a new setting for beach management to facilitate this improvement. The focus is generally on Australian ocean beaches and particularly the situation in the east-coast state of New South Wales (NSW).

2. A model of beach environments

Beach environments are multidimensional environmental systems that are nested within larger coastal systems and comprised of interacting natural, socio-cultural, and management systems (Fig. 1).

The natural (or biophysical) systems of beach environments consist of the biota, sediments and water occurring on beaches, their interactions and the ecological processes and physical processes that shape them. These systems extend from the shoreward limit of active dune systems, which may occur up to about 1 km shoreward of the high-water mark, seaward to the water depth at which average size waves move sediment shorewards — this offshore limit occurs between about 1 and 3 km offshore in water depths of about 20 m in NSW [13]. Thus the natural systems of beaches include both terrestrial and marine constituents, and occur in the broader context of catchments, littoral cells and oceanic processes.

The socio-cultural systems of beach environments are comprised of the many, varied and interacting human uses of beaches. People use beaches for a range of commercial and recreational purposes. Commercial activities include sand mining, development for housing or infrastructure, waste dumping, tourism, surf carnivals and fishing. Recreational activities include sunbathing, sightseeing, angling, swimming, surfing and boating. Beaches are also indirectly 'used' as a socio-cultural icon.

The management systems of beach environments encompass many interacting government agencies, non-government organizations, statutes, policies and programs. Environmental management is the style of management that most easily fits within the 'management systems' component of beach environments (Fig. 1) because other forms of management often focus only on a specific use, resource or economic sector [14,15].

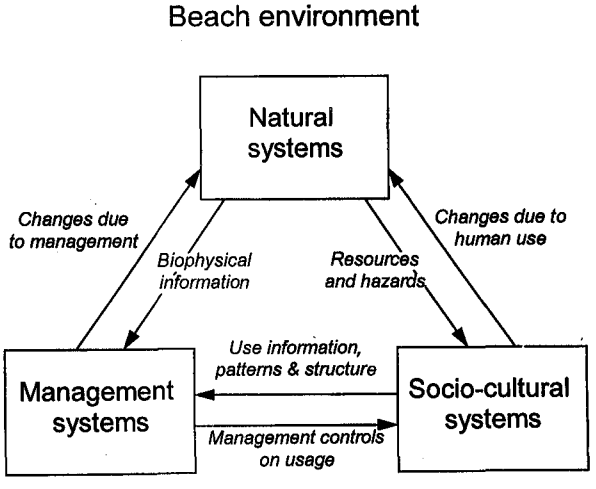

Fig. 1. Simple conceptual model of beach environments showing the three major component systems (boxes) and linkages among them (arrows and italicized text). Adapted from a general model for coastal management [12].

Other terms often used in this sense in the literature include 'holistic', 'comprehensive', 'integrated', and 'ecosystem' management [16]. The environmental management of beaches contains elements of coastal management, natural resource management, pollution control, land-use planning, nature conservation and environmental planning. Policy and legislative frameworks establish ecologically sustainable development as the overarching goal for beach management in NSW, but there is no specific policy to effectively guide the environmental management of beaches [17]. Within this framework, beach management relies on a variety of both legal and non-legal tools and techniques.

Interactions occur both within and among the systems comprising beach environments. The natural sciences such as ecology and geomorphology consider interactions within natural systems. Interactions within the socio-cultural systems of beaches are the domain of the social sciences such as geography and psychology. Interactions within management systems are the concern of political scientists and managers in general. Research in each of these domains is necessary to improve our overall understanding of beach environments. The model of beach environments presented here provides the context necessary for a proper understanding of any of the component systems.

The focus of this paper is, however, on the linkages and relationships among the systems comprising beach environments. The model of beach environments used here explicitly specifies the interactions among these systems (Fig. 1). Such interactions result in a flow of resources and hazards from the natural to the socio-cultural systems of beach environments. The natural systems of beach environments are changed by the human-uses they support and also by the manipulations imposed by management. Management usually seeks to control human-use and makes decisions based on information about the patterns, processes, structures and effects of human-use, and biophysical information obtained directly from natural systems. Thus, in seeking to maintain natural systems and provide for human use, the linkages/interactions among all component systems of the beach environment must be considered.

3. Present knowledge

Each of the component systems of beach environments and each linkage among the systems has many facets. Our present understanding of these systems and their interactions is variable. Here I briefly consider our present knowledge of the six linkages among the three component systems of beach environments (Fig. 1). These fall into three groups: (1) linkages that result in changes to natural systems; (2) linkages that affect the human-use of beaches; and (3) linkages that provide information for management. These three groups are considered in turn.

3.1. Linkages that result in changes to natural systems

Changes to the natural systems of beach environments are caused by interactions with socio-cultural systems and management systems (Fig. 1).

3.1.1. Socio-cultural systems → natural systems

Many activities carried out by people result in changes to the biophysical environment of beaches (Fig. 1). Some of these activities are general, such as water pollution, whereas as others directly impinge on beach environments. Much is known about those activities that affect the physical beach [11] but we have a less thorough understanding of the influence of human activities on beach organisms.

People interact with the biota of beaches in many ways, with exploitative and non-exploitative interactions forming two broad classes. Non-exploitative interactions are those where people do not directly seek to collect beach organisms, and the variety of these interactions far outnumber the variety of exploitative interactions. Non-exploitative interactions include the use of off-road vehicles (ORVs) and trampling by pedestrians which can affect dune flora [18–20], supralittoral/dune fauna [21,22] and birds [23–27]. These activities seem to have little effect on individual intertidal invertebrates, except for the potential for night time use of ORVs on beaches to result in large kills of ghost crabs foraging in the intertidal zone [22,28].

Effects of the massive trampling that metropolitan beaches may endure either seasonally or year-round remains largely unexamined. But a study in Chile found no differences in the abundance of several species of intertidal invertebrates between the two halves of a beach before or after a fence was temporarily erected to deny people access to one-half of the beach [29]. Unfortunately this study only ran over 9 weeks and more research is generally required on this topic.

Sand mining — for minerals or the sand itself — also affects beach biota. Mineral sand mining was widespread on the east coast of Australia, mainly between 1950 and 1980 and has resulted in the reshaping of many beaches [30]. Mining, industrial activity and beach nourishment can result in the dumping of sediments on beaches, which may affect biota [31,32]. The increasing deposition of oil and litter on beaches has resulted in increasing amounts of beach cleaning [33] which may affect beach organisms due to the removal of habitats and/or food such as beach wrack (e.g. cast-up seaweed).

By far the major *exploitative* interactions between people and beach organisms are commercial and recreational fishing and the collection of other beach organisms for decoration, bait or food. Commercial fishing activities are common, but recent studies indicate that recreational fishing (angling) and collecting of invertebrates can be more prevalent in terms of effort, harvest and value for some species caught on beaches [34]. To date, most studies of harvesting have focussed on rocky shores [35–37], shore-angling which has not distinguished beaches and rocky shores [38–40], or angling on mixed sandy and rocky shores [41,42]. Studies focusing on the harvesting of organisms from sandy beaches are becoming available [43–45]. To date these studies only describe variation in the harvesting of particular species of fish and/or invertebrates from particular sandy beaches. Much more work is needed to enable prediction of harvesting patterns.

Lack of understanding of this interaction between the socio-cultural and natural systems of beaches can result in unacceptable changes to the natural environment of beaches. This is most likely to occur through poor planning and management that do not consider the effects of beach use on natural systems and/or allow overexploitation

of natural resources. The lack of information available on this linkage could exacerbate the situation.

3.1.2. Management systems → natural systems

Management may directly implement programs for improvement of the natural environment of beaches or regulate activities (such as those discussed above) that may cause 'unacceptable' changes to natural systems (Fig. 1). These two classes of management interventions may be termed 'direct' or 'indirect', respectively.

The broad types of direct management interventions in the biophysical environment of beaches in Australia are known, but particular cases are not necessarily well documented. Briefly, again most is known about direct management interventions in the physical environment of beaches, especially using hard and soft engineering approaches [11,46]. This is usually done to protect infrastructure of beaches rather than the natural environment, but it affects the natural environment in various ways depending on the methods used. Cleaning of beach sediments is widely practised on beaches heavily used for recreation but may have the unfortunate side effects of removing sand and beach organisms, and compacting areas of the beach [11]. Management of water quality on beaches is an ongoing problem near major cities due to oceanic or estuarine sewage and stormwater disposal that may affect natural systems. Management of the physical environment of beaches can be useful in protecting ecosystems such as wetlands in areas adjacent to beaches and also for protecting beach habitat.

Direct management of the ecological resources of beaches is less prominent. There are plans for recovery of threatened species of birds nesting on beaches and attempts to control invasive weeds on sand-dunes, but most management of the ecological resources of beaches is done indirectly through the regulation of human activities. In terms of conservation, substantial numbers of beaches in NSW are now contained in terrestrial or marine protected areas, but rarely both. The terrestrial areas (above high-water mark) of about 240 of the 721 NSW ocean beaches are presently contained in National Parks, and the marine areas (below high-water mark) of about 100 NSW ocean beaches are presently contained in Marine Protected Areas. The management requirements and appropriate within-reserve zoning for these beaches are presently unclear.

Being ignorant of the likely direct effects of management on natural systems can result in beach engineering problems (such as unforeseen beach recession), complications due to waste disposal, and ecological problems such as overexploited fish stocks, threatened species and invasive weeds.

3.2. Linkages that affect the human-use of beaches

The human-use of beaches is facilitated and constrained by both the natural systems and management systems of beach environments (Fig. 1).

3.2.1. Natural systems → socio-cultural systems

Beaches supply a mixture of resources and hazards to people (Fig. 1). Resources include land, natural open space, aesthetic landscapes/seascapes, surf, clean water, fish

and shellfish, ecological habitat, sand and dunefields that provide for a variety of human activities and desires. Studies have yet to examine the supply, demand and economic values of beach resources, although a small amount of information is available on tourism demand for beaches. Approximately one-third (810 000) of international tourists visit Sydney's beaches but only 7% (175 000) visit beaches outside Sydney [47]. The gross economic value of beach tourism and recreation was recently estimated at $M 637 or 57% of the total gross economic value of the tourism and recreation resources of public lands on the northern quarter of the NSW coast [48]. Strategic studies of the supply, demand and economic values of beach resources are required in Australia, at both regional and local scales. Lack of appreciation of actual demand can lead to general problems due to overuse of resources which manifest in various ways such as the overdevelopment of beaches for tourism which may alienate beaches from other types of users.

The hazards of beaches include erosion, flooding, rip currents, poor water quality and biological hazards. Much is known about hazards caused by the physical characteristics and processes of beaches in some areas of Australia. Physical characteristics and associated hazards of beaches for swimming have been described for the States of NSW [13] and Victoria [49] as part of the ongoing Australian Beach Safety and Management Program. The NSW Coastline Management Program and the supporting Coastline Management Manual [50] also concentrate heavily on the physical hazards of beaches [17]. Lack of understanding of hazards can lead to beach recession, poor safeguards for public safety, poorly located development/infrastructure and unwise/expensive protective works. Bad outcomes from engineering approaches to hazard reduction have led to more emphasis on non-structural approaches such as beach nourishment and planning set-backs.

3.2.2. Management systems → socio-cultural systems

Management often seeks to regulate the human use of beaches. Regulation of commercial activities such as sand-mining are quite clear, but regulation of recreational use is less strict. In Australia, the main management response to increasing amounts of recreational use of beaches has been to continue beach development and the provision of infrastructure in a largely ad hoc fashion. A good outcome of the cultural tradition of beach use in Australia has been the maintenance of beaches, especially the marine areas of beaches (below the high-water mark), in public ownership and explicit requirements that public access to beaches is not to be blocked by hind-beach development [54].

It has often been the case that management responds to issues in the human use of beaches, and regulation has been reactive rather than strategic. This is clear in both the protection of poorly situated property and infrastructure from beach erosion, and the development of beach areas in line with increasing public demand, but with little regard to wider effects. Further the actual outcomes of attempts at regulation are rarely measured and it is generally perceived that regulation of the exploitation of natural resources is ineffective due to enforcement difficulties. For example, 17 000 shellfish (*Donax deltoides* or 'pipis') were confiscated (including 3200 from one vehicle)

by government authorities from fishers on one NSW beach when the legal bag-limit of 50 pipis per person per day was able to be enforced [52].

Lack of understanding of this linkage will mainly lead to poor regulation of socio-cultural activities on beaches. This may affect one or more user groups and may flow onto natural systems.

3.3. Linkages that provide information for management

Information for the management of beach environments is obtained from both natural and socio-cultural systems (Fig. 1). Further, management must have a good knowledge of interactions between the socio-cultural systems and natural systems of beach environments to be effective. These interactions have been discussed above, but the implications for management are considered further here.

3.3.1. Natural systems → management systems

Information on the biophysical environment of beaches is required for management (Fig. 1). At present, our understanding of the biophysical attributes of beaches is well developed on the physical side and poorly developed on the biological side. We now have a good understanding of the physical/geomorphological characteristics of Australian beaches and the processes controlling these characteristics [11,13,49,53–61]. This understanding of physical beach processes is the basis of the various management responses to erosion and flooding hazards [46].

Management of the ecological resources of Australian beaches is hampered by a lack of local information. The ecology of beach organisms has received little attention in Australia with research effort in coastal ecology focussed on coral reefs and rocky shores/reefs [62]. Recent reviews of the ecology of sandy beaches in Australia have concluded that 'there remains much to be learned about exposed, ocean beaches [63]' and that there "is a continuing need for further, basic information on the biology and ecology of beach organisms, because knowledge of Australian beach fauna is so sparse [64]". There is an ever expanding worldwide literature available on beach ecology [65–67] but, unfortunately, the design of many studies has been poor [68] and the Australian situation may be somewhat different so that our knowledge is less advanced than it appears at face value.

There is an increasing information-base on the ecology of Australian beaches with work done since the early 1980s [55,69–79] now being added to by recent papers mainly on intertidal invertebrates [68,80–86] and some work on fish [87]. At this stage, most studies are descriptive and concentrate on structural aspects of ecology. They should provide the necessary basis for future investigations of the ecological function of beaches and their biota. Unfortunately, the ecology of some groups of beach organisms has been quite neglected in Australia. Birds have received little attention despite some observations of the importance of beaches to migratory waders in particular areas of Australia and elsewhere [88,89]. Similarly, dune fauna has received little attention in Australia but a review of overseas work is available [90].

Lack of information on some components of the natural systems of beach environments will increase the probability of poor management. The bias in information

towards the physical attributes of beaches means that they will be more often considered in management than the ecological attributes of beaches. This may be a reasonable first step because the maintenance of habitat is necessary for conserving biota. Overall, however, the ecological attributes of beaches will continue to be ignored until more information is available or until crises arise.

3.3.2. Socio-cultural systems → management systems

Beach management requires knowledge of the human use of beaches, especially information on any patterns in human use (Fig. 1). Knowledge of both exploitative and non-exploitative activities is required. Human exploitation of beach biota are discussed above and non-exploitative beach use is discussed here.

Many studies of the human-use of beaches focus on attendance patterns of non-exploitative beach users, both in Australia [91–93] and elsewhere [94–99]. There is undoubtedly also a huge 'grey literature' of many reports on recreational beach use performed by local beach management and planning authorities interested in the provision of facilities [91,92,95].

In terms of patterns in beach attendance, it has been established that large numbers of people participate in recreational activities on beaches adjacent to metropolitan areas [38,91,92,98]. Of greater interest is the finding that spatial variation in beach attendance can vary enormously among beaches. For example, one study recorded < 10 to almost 300 people per km during one Sunday in summer on 29 beach areas near Perth, the capital city of Western Australia [92]. Similarly, another study recorded approximately 40–2400 people per km during the annual summer holiday period on 17 sandy beaches near Cape Town in South Africa [98]. Beach users are also patchily distributed within beaches, with aggregations of people near beach entrances, facilities, and lifeguard areas [45,100].

Spatial variation in beach attendance has been attributed to many factors including differences in the provision of facilities, the presence of lifeguards, accessibility (including car parking), the characteristics of surrounding development, and the physical characteristics of the beach such as surf conditions [69,92,95–97,101]. A 'distance-decay effect' — where the beach attendance rates of suburbs or other areas declines with distance from a particular beach — has explained about 20% of the variation in beach attendance in the few studies using statistical analyses [91–93]. Socioeconomic variables such as income, age, car ownership and education have each explained $< 10\%$ of the variation in beach attendance in these studies, despite non-statistical analyses suggesting that they modify the effects of distance [91,96]. Multiple regressions using both distance and socio-economic variables appear to have been ignored.

Temporal variation in beach attendance has also been observed, and on several scales: within days, among days within weeks and seasons, among seasons, and during holiday periods [38,91,92,95,102]. Explanations usually include daily and seasonal weather patterns, variations in day-length and public holidays, but good analyses are not yet available. Thus, investigations of spatial and temporal patterns in beach attendance are far from conclusive.

Lack of understanding of this linkage provides a poor basis for management. The studies cited above suggest that there is much spatial and temporal variability in

beach attendance. But seasonal cycles in beach attendance and crowding on peak days should be predictable and therefore amenable to management.

3.3.3. Understanding the interactions of natural systems and socio-cultural systems for management of natural systems

As discussed above, management may cause changes to the natural systems of beach environments either directly or indirectly. Indirect management operates through two linkages, regulating the human activities of beaches and noting how this actually leads to changes in the natural systems of beaches. The above discussion concentrates on particular linkages between pairs of component systems. But, it is obvious that the many interactions among and within the components of beach environments operate concurrently. Changes to natural systems can occur through processes occurring within the systems, changes in human-use of the systems, and/or direct management interventions in the natural system. Feedback loops also mean that management decisions may have undesirable consequences. For example, the decision to develop a beach may cause changes in natural systems such that the availability of natural resources change (e.g. landscapes and biota). This may undesirably alter the socio-cultural systems and the very human uses that the development aimed to facilitate in some way. Ultimately, the interactions between particular components systems of beach environments need to be considered in the context of the total beach environment and the many interactions both within and among the component systems.

4. Improving linkages among the components of beach environments

The main messages of this paper are that our perception of beaches should be broadened to encompass 'beach environments', that we need a good understanding of the linkages among the major component systems of beach environments for management and maintenance of the environmental quality of beaches, and that our present understanding of many of these linkages is inadequate.

The brief review presented above indicates that interactions among each of the natural, socio-cultural and management systems comprising beach environments are poorly understood. This is a fundamental problem for beach management. In particular, there is a pressing need for information on interactions among the ecology, human-use and management of Australian beaches. This need is partly caused by a lack of disciplinary knowledge on the major components of beach environments themselves — the natural, socio-cultural and management systems. Fundamental quantitative information is needed on the patterns of distribution and abundance of beach biota, the spatial and temporal dynamics of beach biota at various scales, the actions of ecological processes, and methods for monitoring populations and assemblages of beach organisms. Similarly, basic quantitative information on the human-use of beaches, including spatial and temporal variation and patterns in beach-use, remain to be considered at several scales. Finally, the structure, function and adequacy of present management systems also need further investigation.

As well as generally informing management, this knowledge of beach ecology, the human-use of beaches and beach management is required to inform work on the 'impacts' of human-use and management interventions. To paraphrase Ludwig [103], 'bad ecology leads to bad policy'. The remainder of this paper examines how we can improve our understanding of the linkages among and within the component systems of beach environments.

A focus on beach environments, and particularly the interactions among the major systems comprising beach environments, provides the necessary context to guide research and management. The concept of beach environments provides a basis for synthesising our information-base and thereby identifying critical gaps in knowledge. Focusing on the interactions among the components of beach environments sets a research agenda and provides an appropriate framework for investigations most useful to management. Under this framework, the development of tools for the investigation and monitoring of beach environments become important research projects.

A focus on the interactions among the components of beach environments should also facilitate the construction of simple predictive models. These are required so we can predict what will happen to the natural and/or socio-cultural systems of beaches as a result of a management intervention or a natural change. These models could be similar to the simple models that have proven very useful in the management of eutrophication of freshwater lakes [104,105]. For beaches, simple models are required to predict three main types of variables: (1) ecological variables such as the numbers of species; (2) patterns in human activities; and (3) the effects of human activities on beach biota.

Our well-developed knowledge of the physical characteristics of beaches could serve as the basis for constructing the required predictive models. The physical characteristics of beaches seem to be useful predictors of bathing hazards [13,106,107], angling effort and fish harvests [43], the distribution, abundance and species richness of invertebrates [108,109], and the structure of foredune vegetation [55]. Coupling information on the physical characteristics of beaches with knowledge of potential patterns in the human-use of beaches would provide powerful tools for strategic planning and achievement of the ecologically sustainable development of beaches. For example, accurate prediction of patterns in the distribution and abundance of beach biota would provide good information for conservation planning, such as for beaches contained in the large marine parks recently declared in NSW. Combining these predictions with knowledge of the effects on biota of the recreational use of beaches would allow reasonable trade-offs to be made between beach conservation and development. Similarly, accurate predictions of beach attendance coupled with the safety ratings now available for each beach in NSW [13] would enable assessment of safe locations for future coastal development and the rational allocation of public-safety resources [107]. Further, knowledge of angling patterns and patterns in non-exploitative beach-use is the basis of managing these somewhat conflicting activities.

Attributes besides the physical characteristics of beaches may be important for some components of the beach biota and for non-exploitative human-use of beaches.

For instance, the frequency of human disturbance may be important in determining the distribution and abundance of birds breeding on beaches [23]. Patterns in the non-exploitative human-use of beaches are likely to be influenced by socioeconomic variables such as proximity to towns. This information remains to be uncovered, and models including both biophysical and socioeconomic factors are probably necessary. The models are probably best built on bioregional scales, such as for sandy beaches on the southeast coast of Australia which have broadly similar physical characteristics and hydrodynamic climate.

It is a complex and time-consuming process to obtain detailed quantitative information on the state and dynamics of beach biota, on the human-use of beaches, to develop tools for investigation and monitoring (e.g. rapid assessment techniques and research protocols), to detail interactions among components of beach environments, and to develop even simple predictive models. Basic disciplinary and interdisciplinary research by universities and other research institutions is one way to ease this problem. At this time of decreasing funding for basic research, however, other approaches are required to help use acquire the necessary understanding of beach environments. These approaches largely rest on a new setting for beach management, which is sketched below.

4.1. A new setting for beach management

A new setting for beach management can be achieved through the consideration of beach environments. The concept of beach environments explicitly incorporates management systems and recognizes the roles of the natural and social sciences in management. The concept also links and integrates management systems with the natural and socio-cultural systems of beaches. Importantly, the concept of beach environments clearly recognises that managers, social scientists and natural scientists are all stakeholders in beach environmental management, together with the community in general. With its explicit consideration of interactions among natural, socio-cultural and management systems, the concept of beach environments should help to broaden the goals and approaches of beach management.

Techniques are needed for the linking of research and management required under the concept of beach environments. Linking research and management is known to be problematic. Chua [110] blamed 'defective perception' of both researchers and managers, and suggested that researchers orient their research towards pressing management needs. Underwood [111] suggested that researchers take the lead and actively identify and study future management issues. What seems to be actually needed is a better partnership between research and management agencies. This could take several forms, but all involve better dialogue and collaboration between researchers and managers. Some guidelines for collaboration in environmental planning and management are available [112]. Research could then focus on identifying, prioritizing and filling the relevant information needs. This is difficult to achieve in situations of reactive management because it requires collaborative strategic analyses, support of research, evaluation of activities and constructive feedback — all of these are very time-consuming.

There are presently six main opportunities in NSW to achieve better collaboration between researchers and managers and thereby improve beach management and/or improve the quality of beach environments. These opportunities arise in (1) local area management; (2) coastal conservation programs; (3) management plans; and (4) programs dedicated to beach environments; (5) designing tools and indicators for beach environmental management; and (6) evaluation of existing and future management interventions.

Local area management: In NSW, environmental management is increasingly being devolved to local government and mechanisms for improving the management of beach environments need to be devised for this setting. Area-based local councils are being given extensive powers and responsibilities, from decisions on development applications, formulation of strategic planning instruments, reporting on the state of the local environment, and implementation of management plans and programs. Unfortunately local government also suffers from a lack of human and financial resources leading to a lack of management and technical capacity. External consultants or personnel from other spheres of government are often used to perform technical work on a project-by-project basis.

However, capacity for the generation of local information and its application needs to be built at the local government level if this devolution of responsibility for environmental management is to become workable and successful. This problem is identified in the recent national coastal policy [113] and will require dedicated assistance over the long-term. However, despite the numerous responsibilities and prescriptions for local government contained in the latest NSW coastal policy [51], the need for capacity building was not recognized. Capacity building at the local government level is specifically required for beach management and is probably best achieved within the existing coastal management framework in NSW and many other Australian states. Techniques for capacity building include skill transfer during collaborative projects, university courses, focussed short-courses, workshops and working groups [114].

Local communities are also increasingly active in beach management through community-based programs such as 'Dune Care' and 'Coast Care'. These programs potentially allow implementation of localized beach management projects important to the community, capacity building of the local community, and effective collaboration with management agencies.

Coastal conservation programs: A National Representative System of Marine Protected Areas (NRSMPA) is presently being investigated in Australia through a Commonwealth government based program run in conjunction with State government conservation and fisheries agencies. This program offers two main opportunities for improving beach environments. The first opportunity is the generation of new ecological information on beaches to guide the selection of marine protected areas and within-reserve zoning. The NSW Fisheries department was collecting such information but results are presently unknown. The second opportunity is to address the key issue of trade-offs between the recreational and coastal defence uses of beaches versus environmental needs. This requires an analysis of the effects of socio-cultural systems and management systems on the natural systems of beach environments. It therefore

requires inputs from both managers and researchers. The danger with this program is that the conservation needs of beaches will be ignored as knowledge of other coastal ecosystems is better developed and proponents for their conservation are more vocal.

Management plans: Many types of management plans can apply to beaches under present legislation in NSW. These range from general zoning plans commonly developed under the environmental planning legislation, to coastal management plans that can be developed for individual beaches or groups of beaches in local government areas. Coastal management plans typically focus on local scales, on beaches heavily used for recreation, or on geomorphic hazards because the plans are developed by local councils under the guidance of the NSW Coastline Hazard Policy [115]. A focus on beach environments could, however, be used to expand the scope and scale of these management plans and also to develop a broader policy basis for beach management. This opportunity requires consideration of the development, review, implementation and evaluation of coastal management.

Programs dedicated to beach environments: There are presently many coastal programs affecting beaches in NSW [17]. These programs are broadly concerned with the conservation and rehabilitation of ecosystems, maintenance of aesthetics, dune stabilization, hazard reduction and protection of coastal property, and providing for recreational use and tourism. Various government agencies or non-government organizations run these programs. Some of the programs are specific to beaches whilst others are coastal in scope. The concept of beach environments would provide the context necessary for these individual programs and would help ensure that each program contributed to an overall improvement in beach environments. Programs specific to beaches such as the Australian Beach Safety and Management Program (which presently concentrates on surf life saving), have great potential to be developed into programs that provide a focus and leadership for beach environmental management.

Designing tools and indicators for beach environmental management: Tools and indicators for the measurement of the quality of beach environments are needed for management. The NSW Environment Protection Authority used water quality (faecal coliforms) on Sydney beaches as a quality indicator in its assessment of the state of the NSW environment [116]. Whilst this is a nice quantitative measure and the data is readily available, it focuses on public health and human amenity issues but tells us little of the ecological environment of beaches throughout NSW. Ultimately, a suite of indicators and tools are needed to indicate the state and dynamics of many more facets of the beach environment, including those of our management systems!

Evaluation of existing and future management interventions: Evaluation of management interventions in beach environments is essential and could occur in many ways and using many different criteria. The concept of beach environments, however, could be used to provide context to any evaluation so that the fundamental evaluative criterion was an improvement in the beach environment. Such evaluations would often require a partnership between managers and researchers. It would require managers to pose their interventions in terms of hypotheses and the development of evaluation programs during the formulation of management interventions. Rather than being seen a test for managers that is controlled by researchers, evaluation needs

to be seen as a way of learning from management interventions. As such, evaluation has the potential to provide valuable feedback on the development of tools and indicators and the operation of beach management programs.

5. Conclusions

Emphasis is presently being placed on environmental and coastal management in Australia. This emphasis provides many general opportunities to improve beach environmental management, but to take these opportunities and achieve successful environmental outcomes will require a broadening of our perspective of beaches. Taking the opportunities presented in this paper to improve beach environments will not be easy. However, the concept of beach environments presented here and the focus on the interactions among and within the major components of beach environments that it engenders provide an appropriate context for the collection and synthesis of relevant information, collaboration between researchers and managers, and a new setting for beach environmental management. To take these opportunities, beach managers and researchers will have to be adaptive, flexible and collaborative. This should provide the basis for success in improving the overall quality of beach environments.

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