A conceptual model of impacts of environmental change on human well-being

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Abstract

Human well-being is dependent on goods and services provided by well-functioning ecosystems. Changes in ecosystem status and integrity can therefore impact directly and indirectly on human well-being. However, neither current measures of ecosystem health nor methods to value ecosystem services incorporate methods to assess impacts of changes in ecosystem health on human well-being. Assessment of these impacts is potentially useful in improving the sustainability of coastal management decision making. This paper presents a conceptual model developed to identify the potential links between ecosystem condition and human well-being. Based on existing literature, it is hypothesised that changes in coastal ecosystem condition may affect aspects of social and community relations through affecting people's sense of place, degree of involvement in the community and the extent to which they undertake recreation in the coastal environment. Changes in these aspects of social relations can have flow-on impacts on social capital, social networks, levels of trust and physical and mental health. Changes in ecosystem condition may also have more direct impacts on human health, through bacterial contamination of recreational waters, the presence of toxicants in seafood, or through the presence of toxic algal blooms in recreational waters. Regional economic production is also affected by changes in coastal ecosystems, through changes in the production of fishing, aquaculture and tourism industries. The conceptual model provides a basis for the development of a dynamic systems model to assess the impacts of changes in ecosystem health on human well-being. This information is necessary to ensure that decisions regarding the use of natural ecosystems are well-informed and therefore appropriate.

Introduction

Humans have a wide and profound influence on most of the world's ecosystems today and are responsible for managing most of the world's resources. Despite our increasing awareness of the negative impacts that many of our activities have on these ecosystems, in many cases we continue use natural resources at a faster rate than they are replenished (Daily, 1997).

One of the reasons for this is that humans tend to manage systems according to the benefit we perceive we could derive from them. This benefit has traditionally been measured only in terms of dollar values as this is the most widely understood unit of measure for value. It is also easily compared with economic costs and benefits. As most ecosystem goods and services are not currently traded in economic markets a dollar value must be estimated using valuation techniques such as contingent valuation, choice modelling, travel cost, replacement value and hedonic pricing techniques (Commonwealth of Australia, 1995).

Economic values estimated using these techniques rely on either revealed or stated preferences of individuals as an expression of value. All of these valuation techniques rely on the assumption

that the individual preferences represent the gain in well-being that a person expects to get from the specific service and that the monetary value obtained therefore represents this gain in well-being. Some of the problems with this assumption are reviewed in Sagoff (2000; 2003) and Cox (submitted). In fact, well-being is dependent on a number of factors, including health, social and family relations and freedom (Trewin, 2001).

It would therefore be useful to be able to assess the effects of ecosystems on more direct measures of human well-being that do not rely on the assumptions inherent in economic valuation techniques. One possible way to do this is to use a dynamic systems model that incorporates aspects of ecosystem condition and human well-being and identifies the links between them. One of the first and most important steps in any type of modelling is the development of a conceptual model, which identifies the components, scope and scale of the model (Grant, 1998).

The aim of this paper is therefore to develop a conceptual model that details the effects of changes in ecosystem condition on human well-being and that will form the basis for the development of a quantitative dynamic model. A general model including different ecosystem types and regions would be extremely complex; therefore the model proposed here will focus specifically on coastal aquatic ecosystems using information from case study regions in Queensland as the basis of the model. Coastal ecosystems play an important part in the lives of many Australians; approximately 87% of Queenslanders live within 50km of the coast (Australian Bureau of Statistics, 2002) and the coastal population is still increasing rapidly (Department of Local Government and Planning, 2002). Coastal ecosystems are also the most productive per unit area of all systems on the planet (Costanza, 1993; Costanza et al., 1997).

The first part of the paper will include a general definition of well-being and will focus on aspects of human well-being that could potentially be affected by coastal ecosystems. The second section will look at the ecosystem health indicators included in the model and the final section will provide some information on the conceptual model as a whole.

Frameworks for measuring human well-being

There are numerous existing frameworks and indicators for measuring human well-being or quality of life. The Australian Bureau of Statistics (ABS), which is responsible for reporting on well-being in Australia, defines well-being as 'a state of health or sufficiency in all aspects of life' and recognizes eight areas of concern as relevant to quality of life in Australia: health, family and community, education and training, work, economic resources, housing, crime and justice, culture and leisure (Trewin, 2001). Of these eight areas of concern, health, family and community, work, economic resources and culture and leisure are potentially measurably affected by coastal environments. As the aim of this model is not to assess effects on well-being as a whole, but rather the effects of changes in ecosystem health on specific aspects of well-being, only these components of well-being are considered in this model. The next sections summarise the main indicators for each of these aspects of well-being and describe the potential links with ecosystem health. Social capital (incorporating family and community and culture and leisure) is described first, followed by economic production and human health.

Social capital

Social capital is defined by the ABS as the "layer of commonly held social value, beliefs and attitudes that lies beneath individual behaviour and encourages transactions that result in greater well-being for society" (Trewin, 2001). The term "social capital" was brought to prominence in the literature by Putnam's study into the effectiveness of governance in southern Italy (Putnam et al., 1993), although the theory of social capital and benefits of social cohesion had been described earlier (Coleman, 1988; Egolf et al., 1992). Putnam found that some regions in Italy had greater levels of community participation in government, more effective institutions and that healthier and wealthier populations than other regions. The differences observed between these towns was attributed to differences in social capital. The concept of social capital includes aspects of communication, participation, networks, equality, reciprocity, cooperation and trust between residents. Since this time there have been many studies that have shown clear relationships between aspects of social capital and other measures of well-being such as health, crime rates and economic production (Kennedy and Kawachi, 1998; Lomas, 1998; Kawachi et al., 1999; Svendsen and Svendsen, 2000; Uphoff and Wijayaratna, 2000). In this study, social capital is used as a general term to include several aspects of social well-being: sense of place, community involvement, networks, social interaction, trust, equality and norms of mutual aid and reciprocity. Although there are many other indicators of social well-being, these particular indicators were included in this model as they are potentially affected by ecosystem condition and can be measured.

Recreation

Recreation, while not usually considered part of social capital, is an important component of social well-being as it provides many benefits, including benefits to physical and mental health, self-identity, skill development and learning, spirituality, social cohesion and community satisfaction (Driver et al., 1991). Coastal environments are an important part of many people's recreation in Queensland and the presence of healthy coastal ecosystems provides numerous opportunities for recreation. The presence of natural, open space contributes to the likelihood of people undertaking recreation in the area. Neff et al. (2000) found that a natural setting was one characteristic related to people undertaking regular exercise and that the environmental setting was important in maintaining regular activity. MacDougall et al. (1997) found that in Adelaide, satisfaction with recreational facilities (sport facilities, meeting places and parks) was positively related to activity levels. Similarly, perception of environmental quality may affect the type of recreation undertaken; for example, a perception of good water quality is more likely to result in people swimming in waterways (Smith et al., 1995a; Pendleton et al., 2001). Recreation in coastal areas is likely to increase casual social interaction with strangers or acquaintances, increase social networks by providing opportunities for social interaction with friends and relatives, reinforce positive feelings of sense of place and relieve mental fatigue. The benefits of these are described in the following sections.

Sense of Place

There are a number of definitions of sense of place, but the most encompassing is the relationship between people and spatial settings (Jorgensen and Stedman, 2001). Sense of place can include a person's attachment to a place, their dependence on a place, identification and satisfaction with a place and sense of belonging to a place (Shamai, 1991). Sense of place can exist over a variety of

spatial scales, from a house to a country, but is usually measured on the scale of neighbourhoods or cities. Both social and physical aspects of place are important – attachment may be to the people or community living in a place, to aspects of the physical environment itself, or to both (Cantrill, 1998).

Sense of place is an important component of well-being as it forms part of an individual's identity and contributes to the creation of a group, neighbourhood or cultural identity (Williams et al., 1992; Chipuer and Pretty, 1999). Sense of place may also be linked with other aspects of well-being. For example, communities in Alaska that had stronger place attachment were found to be more cohesive and had a higher perceived quality of life (Brown et al., 2002).

The physical environment is hypothesised to contribute to an individual's sense of place in recreational settings. Factors likely to affect the development of sense of place include features endemic to the local environment, personal and communal experiences and perceptions of the environment and information on the local environment from media and interpersonal networks (Williams et al., 1992; Cantrill, 1998; Chipuer and Pretty, 1999; Horwitz et al., 2001).

Community Involvement

Community involvement refers to the extent to which individuals are involved in community activities such as local clubs, environmental and volunteer groups. It is an important indicator of civic participation, which has been found to be linked with lower crime rates and higher levels of institutional support of local communities (Kawachi, 1999). Greater community participation may also lead directly to improved community facilities and local environment (Sobels et al., 2001). For the individual, involvement in community activities is likely to increase social networks, increase personal skills, self esteem and identity and attachment to place. In turn, good health, self esteem and personal skills also increases individuals' capacity to become involved in the local community. Impetus to become involved in community activities may result from having a strong sense of place, or attachment to the local area, which is directly influenced by the local ecosystems. Involvement of community members in local activities may also be self-reinforcing; as individuals observe that other community members are involved in and committed to a group or activities, they may become more willing to join and participate.

Social interaction

Social interaction is an important component of social well-being as it is through personal interaction that individuals develop trust and supportive networks (Lochner et al., 1999; Svendsen and Svendsen, 2000). Both of these are important components of social capital and have been found to be correlated with health (see sections on trust and networks). Coastal ecosystems are likely to contribute to social interaction through the provision of common space that is aesthetically pleasing, attracts residents and provides a convenient setting for casual contact. For example, in city neighbourhoods it has been found that common spaces with trees and greenery were preferred by residents over barren spaces and that the presence of greenery led to a greater use of common spaces and face to face social contact (Kuo et al., 1998; Kweon et al., 1998). Casual face to face contact was in turn important in providing opportunities for the development of social relationships and neighbours who had face to face contact were more likely to develop and maintain social ties. It is also possible that increased social interaction may also lead to conflict, particularly where there is competition for resources (usually space), but this has not been extensively studied. Although the influence of coastal ecosystems on interaction and social ties has not been examined directly, it is reasonable to assume from these studies that

coastal environments would also be preferred over environments dominated by human artefacts and that the presence of healthy coastal environments could lead to greater social interaction.

Networks
Social networks are important for well-being as they contribute directly to physical and mental health. For example, Romans et al. (1992) found higher psychiatric morbidity in women with lower levels of social support. In a nine-year study, it was found that the mortality risk was more than twice as high for the most isolated people compared with those with the most social contacts irrespective of health at the beginning of the study (Berkman and Syme, 1979). Participants with more diverse social ties were four times less likely to develop cold symptoms after exposure to rhinoviruses than people with less diverse social ties (Cohen et al., 1997). Literature reviews of nineteen studies also suggested that individuals with social support had lower blood pressure levels and higher immune responses; in hypertensive people social support led to better blood pressure regulation (Uchino et al., 1999).
Support networks may comprise family members and friends. Networks of friends can be formed or increased through social interaction and by involvement in local community activities. Family networks may also be reinforced through frequent social contact. Both social contact and involvement in community activities may be influenced by local ecosystem condition.

Trust, equality and norms of reciprocity
Trust, equality and norms of reciprocity are commonly used indicators of social capital and have been found to be significantly correlated with crime rates and health. Lower levels of trust of other people in the community (interpersonal trust) have been found to be associated with higher total mortality due to most causes of death including heart disease, malignant neoplasms, stroke, accident and infant mortality and also with higher levels of violent crime (Kawachi, 1999; Lochner et al., 1999; Rosenfeld et al., 2001). Measures of social capital, including trust, were correlated with homicide rates at a regional scale, even while controlling for reciprocal effects (Rosenfeld et al., 2001). Income equality has been found to be related to public health; Kawachi et al. (1999) found that a one percent increase in income inequality was associated with an increase in the death rate by two to three percent. It is hypothesised that communities with greater social capital, as measured by levels of trust, equality and reciprocity, are more likely to have effective institutions to maintain law and order and are more likely to have stronger informal social controls, resulting in lower crime rates and better health outcomes (Lochner et al., 1999; Rosenfeld et al., 2001). Kawachi et al. (1999) also hypothesises that noticeable inequalities in a society may produce resentment and that this may disrupt the 'social fabric' of a community.
Coastal ecosystems may influence trust, equality and reciprocity indirectly, through increased social interaction and social networks and involvement in community activities (Kawachi, 1999). Trust and reciprocity are developed primarily through face to face interaction (Svendsen and Svendsen, 2000) and it is hypothesised here that recreation in coastal environments contributes to casual social interaction and formation of social networks and therefore to the development of trust, perceived equality and norms of reciprocity.

Economic resources

Coastal ecosystems provide resources that contribute directly to a region's economic production and therefore to the livelihoods, employment and incomes of the residents. The economic

production and employment of a region can therefore be used as indicators of the economic well-being of the residents in the region. For industries that are directly dependent on natural resources, production and employment may also be used as measures of dependence of residents on those resources. The three main industries that are likely to benefit from, and rely directly on coastal ecosystems in Queensland are aquaculture, commercial and recreational fishing and tourism. The dependence of each of these industries on coastal ecosystem health will be discussed in this section.

Aquaculture

The most common types of aquaculture currently practised in the coastal zone in Australia are of prawns, oysters and fish. Aquaculture of these species is dependent on a supply of clean water, larvae, genetic diversity and fish feed from coastal ecosystems.

Prawn and fish aquaculture relies on the collection of gravid females from the wild for broodstock, on good water quality of the intake water and on the production of fish feed from wild caught fish (Battaglene and Fielder, 1997; Lobegeiger, 2001). Where effluent from prawn or fish aquaculture is not treated prior to release, aquaculture also depends on the nutrient and sediment filtration and nutrient recycling capabilities of the surrounding estuarine and coastal systems (Lebel et al., 2002). The genetic diversity of wild caught broodstock is also important in maintaining resistance to disease and general health of the stock (Battaglene and Fielder, 1997).

Farming of oysters or other shellfish also depends very much on the condition of the coastal system – oysters feed on natural populations of phytoplankton and require good water quality (low in faecal contaminants and shellfish diseases) for grow-out and commercial sale (Folke and Kautsky, 1989; Beattie and Dexter, 2002). Oyster spat are also obtained by settlement of larvae from wild populations (Lobegeiger, 2001). Oysters are also grown for pearls and mother of pearl in north Queensland; survival of these oysters is also dependent on good water quality and in particular, a lack of disease. In recent years the depletion of the natural stock of some pearl oysters has limited production (Lobegeiger, 2001).

Commercial and recreational fishing

Commercial and recreational fishing are dependent on an abundant fisheries resource, which in turn is dependent on good water quality, the availability of nursery habitats for juvenile fish and genetic diversity in fish populations. Mangrove estuaries provide an important nursery habitat function for many marine and estuarine fish and crustaceans (Rönnbäck, 1999). Approximately 34% of species found in estuaries in the Gulf of Carpentaria were found to be dependent on estuaries as a principal habitat for at least one part of their life cycle; making up at least half of the total fish biomass. A further 12% of species were estuarine opportunists and came into the estuaries to feed (Blaber et al., 1989). Mangroves provide good nursery habitat as they provide abundant trophic resources due to freshwater inflow, nutrient trapping and tidal mixing and the relatively high turbidity (compared with marine systems) and structural complexity provide refuge from predators, as well as multiple spatial and trophic niches for exploitation (Baran and Hambrey, 1998).

The fishing industry also depends on good water quality, as high concentrations of toxicants in the water can render the fish inedible or unsaleable and frequent algal blooms can inhibit fishing and may also result in the presence of algal toxins in fish (Osborne et al., 2001).

Tourism

Tourism in coastal areas is dependent on visitors' perceptions of water quality and ecosystem health. In most cases, it is the vision of clear and pristine waters, with an abundance of marine life and water-based recreational activities, that lures visitors to coastal destinations (Peterson and Lubchenco, 1997; Hall, 2001). Tourism is a growing industry and the marine environment one of the fastest growing segments of the tourism industry (Hall, 2001). In a survey of visitors to the Caloundra region in Queensland, (Tourism Queensland, 2003) it was found that the most appealing aspect for visitors was the beach or coast, followed by the scenery or natural landscape. Similarly, in an earlier study of visitors to Port Douglas, (Savage, 1988) found that 22% of respondents said that the reef was a primary attractor for them to visit the region and 29% said that scenery attracted them to the region. (Shafer et al., 1998) reported that for visitors to the Great Barrier Reef, one of the aspects of the trip that most influenced their enjoyment was the natural environment (specifically the coral and fish). Estuaries also support tourism, particularly for wader bird viewing (Peterson and Lubchenco, 1997). For tourism, it is the perception of the condition of the coastal ecosystems, more than the actual condition, that is important in determining the success of the industry. The process of forming perceptions of the condition of coastal areas is not well understood, but is likely to be related to personal experience, word of mouth, media coverage and information from travel agents.

Human health indicators

Health is an important part of well-being as many other aspects of quality of life can be negatively affected by poor health. Health is also important at the community level, as a healthy population incurs less burden on health and support services, has greater potential to develop and manage change and improvement and is more productive. Measures of individual and community human health are therefore important indicators of well-being. Six health areas have been identified as National Health Priority Areas in Australia; cardiovascular disease, cancer, injury prevention, mental health, diabetes and asthma (Glover and Tennant, 1999). Of these, cardiovascular disease, cancer and mental health are potentially affected by the condition of coastal ecosystems. Potential links between ecosystem condition and mental health will be summarised first, followed by effects on physical health.

Mental health

The condition of the physical environment and, in particular, the naturalness of an area, can potentially affect the degree of mental fatigue experienced by people living in that area. Several authors have shown that exposure to natural environments has restorative effects on mental fatigue and mood. Experiencing a natural setting, either directly (walking through parkland), or indirectly (watching video tapes of natural scenes) may result in faster recovery from a stressful event, better cognitive performance and higher scores on happiness and positive effect scales compared with experiencing an urban setting (Hartig et al., 1991; Ulrich et al., 1991). Thinking about past outdoor recreation experiences may also have positive effects such as decreased nervousness, irritability, distress, tense muscles, racing heart and headaches, compared with recalling stressful events or using passive relaxation techniques (Tarrant, 1996).

Longer term effects of natural scenery have also been shown. Patients assigned to a hospital room with a view of a natural setting had shorter stays in hospital and used less painkillers than patients with a view of a brick building wall (Ulrich, 1984). Residents in buildings with less vegetation

reported more aggression and violence and had higher levels of mental fatigue than those in identical buildings surrounded by trees and grass (Kuo and Sullivan, 2001). Environmental degradation may also be associated with higher levels of stress, feelings of marginalisation, lower self-esteem, feelings of hopelessness and helplessness and lower levels of problem solving and support seeking (Van Haaften and Van de Vijver, 1999; Horwitz et al., 2001).

As mentioned in the section above, recreation in natural areas is likely to lead to increased exercise, which has also been linked with improved mental health. Lawlor and Hopker (2001) reviewed several randomised controlled studies and reported that people exercising were less depressed than those who did not exercise and that the difference was similar to that obtained using standard cognitive therapy techniques. Glenister (1996) in an earlier review of clinical studies also found that there were improvements in mental health following exercise treatments, although the results were not consistent across all studies and some results were only short-term.

Given the results of the literature described above it is reasonable to hypothesise that the presence of natural environments in good condition could reduce stress and mental fatigue in residents. This effect would be mediated by the residents' perceptions of the environment and the amount of time that they spent in the natural areas.

Physical health

There are several mechanisms through which the natural environment can affect human physical health. The most commonly discussed mechanisms are through bacterial contamination, toxins in seafood and toxic algal blooms (Boesch, 2000), but coastal environments may also provide a setting for exercise and contribute to fitness and overall health. The existence of nearby coastal areas in good condition has the potential to influence the amount of recreation residents undertake and therefore the type and amount of exercise (Ball et al., 2001). A park environment was one of several exercise trail characteristics that encouraged people to walk for exercise in a statewide study (Ball et al., 2001). Bauman et al. (1999) found that people who resided closer to the coast in New South Wales were less likely to be sedentary and more likely to report vigorous levels of physical activity than those who lived inland. Exercise is well known to reduce the likelihood of premature mortality and morbidity through reducing the risk of cardiovascular disease, colon cancer, non-insulin dependent diabetes mellitus, obesity, osteoporosis and depression and anxiety (Neff et al., 2000). Exercise may also have some mental health benefits (see previous section). Coastal areas in good condition may therefore promote better health if people are more likely to undertake recreation in these areas.

Toxicants (pesticides and heavy metals) have the potential to affect human health through direct exposure (skin contact) and through ingestion of contaminated seafood (World Health Organization, 1996; Montgomery and Needleman, 1997). High concentrations of lead in ingested food can have negative effects on the nervous system, adults may experience hypertension and kidney dysfunction and developmental effects in children can be severe. Dietary exposure to cadmium can result in kidney and lung damage. Mercury consumption can cause neurotoxic effects and damage to gastrointestinal organs. Long-term exposure to high concentrations of arsenic can increase cancer risk (World Health Organization, 1996). Consumption of foods contaminated with polychlorinated compounds (DDT, other organochlorine chemicals) may result in developmental deficiencies in children and these chemicals also appear to be carcinogenic at high doses (Smith and Gangolli, 2002). These metals and pesticides have been found to occur in low concentrations in the marine environment (Haynes and Johnson, 2000) and may therefore pose a potential health risk to humans.

Bacterial and viral contamination of coastal waters can lead to illnesses including gastroenteritis, dysentery, diarrhoea, vomiting and respiratory infections in users of the waters (Corbett et al., 1993; Henrickson et al., 2001). Corbett et al. (1993) found that swimmers at Sydney beaches were more likely to develop respiratory, ear and eye symptoms than non-swimmers and that there was a small linear relationship between counts of faecal bacteria and symptoms. Bacterial contamination may be derived from sewage effluent, users of the waterway, livestock and wildlife and pathogens indigenous to waterways (World Health Organisation, 2001).

Contamination of shellfish by bacteria and viruses can also cause health problems. The consumption of contaminated shellfish is particularly problematic, as shellfish bioaccumulate some toxins and bacteria and they are typically eaten raw (Healthy Rivers Commission, 2003). In 1997 a hepatitis A outbreak in Wallis Lake, NSW, resulted from the consumption of contaminated oysters (Healthy Rivers Commission, 2003). Gastrointestinal illnesses, respiratory paralysis and neurological effects can also result from consumption of shellfish contaminated with toxin-producing dinoflagellates (Australia New Zealand Food Authority, 2001).

Cyanobacterial blooms are a potential result of poor water quality (Henrickson et al., 2001; Pitois et al., 2001) and toxic blooms can have negative effects on human health, especially when recreational activities are undertaken in the area of a bloom. Potential health problems that can result from contact with toxic cyanobacteria include skin rashes, asthma-like symptoms, diarrhoea, vomiting and ulcers (Pilotto et al., 1997). *Lyngbya majuscula* blooms have had some effects on human health in Queensland, including irritation of skin, eyes and respiratory function (Osborne et al., 2001). Swimmers have recorded dermatitis after swimming in areas with *Lyngbya* blooms and toxic effects may also occur as a result of accidental consumption of *Lyngbya*, or by consumption of fish or other animals that have consumed *Lyngbya*.

It is clear from the summary above that coastal ecosystems with poor ecosystem health have the potential to negatively affect the health (and therefore well-being) of residents in the area, while ecosystems in good condition may promote healthy behaviours and positive attitudes.

Ecosystem Health Indicators

There are many potential indicators of ecosystem health. In this study, the focus will be on those indicators that have been identified as having a direct link with the social, economic and health aspects of human well-being. As the aim of the conceptual model is to identify linkages between ecosystem health and human well-being, the indicators of ecosystem health will not be combined to form a overall index of ecosystem health. It is therefore considered to be more important to identify and use indicators that are potentially related to human well-being than to identify indicators that would form a comprehensive overall measure of ecosystem health. From the discussion above, it is clear that human health is potentially affected by algal blooms, toxicants, and bacterial contamination; economic production is dependent on ecosystem productivity and diversity, habitat and water quality; and social capital may be influenced by community perceptions of ecosystems, which are in turn influenced by all the above-mentioned indicators, as well as the available information and understanding of the ecosystem. These are therefore included in the model as indicators of ecosystem health. As the interactions between these aspects of ecosystem health and human well-being have been discussed in section two, this section will describe the indicators briefly and discuss interactions between these components of ecosystem health.

The effects of algal blooms on human health are described in the previous section. Algal blooms can also impact on fisheries, as fish may avoid algal blooms, fishers may be unable to work in algal bloom areas due to health concerns, or the seafood caught may be unsaleable due to community concerns of the effects of the bloom. Algal blooms are also often very visible to the local community and the presence of an algal bloom is likely to negatively impact perceptions of the quality of the environment and therefore its perceived suitability as a site for recreation. Algal blooms may be a result of poor water quality and excess nutrients in particular, and may cause other changes in coastal ecosystems such as changes in habitat, community composition and biomass and changes in other aspects of water quality (Cloern, 2001).

Toxicants (typically metals and pesticides) in water, sediment and aquatic life impact directly on human health through seafood consumption. Toxicants can also affect the growth and development of sensitive species and may therefore decrease the overall community structure, productivity and diversity of the system (Crompton, 1997).

The productivity and diversity of the system are used here as indicators specifically in relation to their effects on fishing, aquaculture and tourism. They are likely to be affected by water quality (including toxicants, algal blooms and bacterial contamination), habitat extent and quality as well as other factors such as hydrodynamics and resource management. Productivity and diversity are also important in terms of the capacity of the system to withstand perturbations (Costanza and Mageau, 1999).

The extent and quality of coastal habitat (such as mangrove, seagrass and reef areas) has a direct effect on the productivity and diversity of the system (Jenkins and Wheatley, 1998; Rönnbäck, 1999). Habitat may also add significantly to the aesthetic appeal of a coastal area; riparian vegetation is likely to contribute to the overall perceived naturalness of an area and be preferred by visitors over man-made structures such as concrete walls (Nasar, 1987; Smith et al., 1995b).

Physical water quality includes characteristics such as turbidity, temperature, nutrient status, bacterial contamination and salinity. These characteristics are important for aquaculture and fisheries, which are dependent on clean water. Physical water quality can also affect the quality and extent of habitat; for example, elevated turbidity levels can reduce the extent of seagrass beds and elevated nutrients can cause excess algal growth, which may lead to smothering of other habitats such as coral reefs. Poor water quality can also lead to algal blooms and may affect the productivity and diversity of the system.

Ecosystem information refers to the available scientific and local knowledge about the condition of coastal waterways. It is an important indicator as it affects the management of the system and the perception of the health of the system that is held by the general public. The communication of the known information, through government, scientific and community oganisations, as well as through general media, is also important in influencing both management decisions and public opinions. Ecosystem information is related to all indicators of ecosystem health described above.

The perception of ecosystem condition held by the general public is very important as it is the perceived condition of the coastal waterways, rather than the actual condition, that influences people's behaviour (Smith et al., 1995a). The extent to which the local waterways contribute to a positive sense of place, the willingness of the community to become involved in local environmental groups and the amount and type of recreation (including tourism) and fishing undertaken in the coastal zone are all potentially influenced by individuals' perceptions of the quality of the environment. For example, people may be reluctant to swim in water that is seen to be 'dirty' (Smith et al., 1995a).

Common perception of water quality may be influenced by several factors, including people's own observations, opinions or observations of friends or family and information from various sources, including media, community or environmental groups, government and scientists. Each of these sources may present information differently and be influenced by different types of information. Individuals' own perceptions of water quality, for example, are likely to be strongly influenced by visual and olfactory components of water quality (Smith et al., 1995a). Individuals' perceptions may also be related to what they perceive as being natural – for example, individuals often rate brown water as being 'polluted' or 'unclean'; however, if the cause of the colour is known to be natural (for example, as a result of natural humic staining), people may find the water quality to be more acceptable (Smith et al., 1995b). Assessment of water quality may also be related to the overall perceptions of the waterbody –for example, a waterbody in a natural setting may be classified as cleaner than one in an urban setting, regardless of the actual water quality at the time (Smith et al., 1995b). Perception of water quality is therefore influenced both by the available ecosystem information and by individuals' own perceptions of each of the ecosystem health indicators.

Conceptual model

As is clear from the discussion in the previous sections, the interactions between human well-being and ecosystem health are extremely complex. Details of these interactions have, to date, been spread throughout the literature of disparate scientific disciplines. To gain a real understanding of the dependence of human well-being on ecosystem health, a single coherent framework is required that identifies all the significant components of the system and their interactions in a clear and easily understood way. It is also important to be able to describe the interactions in terms of their direction, shape and strength and to test the sensitivity of the response of one parameter to changes in other parameters or assumptions in order to gauge the effect of various scenarios. The construction of a dynamic systems model is one way to do this (Grant, 1998; Cox et al., submitted).

Developing a conceptual model is one of the most important steps in the development of a systems model (Grant, 1998). A conceptual model is necessary to identify all the important components and interactions that need to be included and helps to clarify the scale and scope of the model. It can also be a useful first communication tool and, as it is relatively simple to understand and construct and can be developed in conjunction with stakeholders or decision makers. Of course, the conceptual model can continue to be modified according to results of data collection. The conceptual model forms an important guide in focussing data collection, as it can be used to identify indicators and links that are well understood and those that require further research. In this case, the effects of ecosystem health on physical health and on economic production can be relatively easily modelled using existing water quality and economic data, existing information and guidelines on health risks and existing regional economic models. However, the impacts of coastal systems on aspects of social capital and mental health are less well understood and require further research and data collection.

The conceptual model developed to demonstrate the effects of coastal ecosystem health on the aspects of human well-being described above is presented in Figure 1. The diagram presented here shows only the main effects and links in the model; there are several other factors that will also be included in the final quantitative model (for example, income, age, sex, length of residence may affect several of the social indicators). These and some interactions between

indicators of ecosystem health are not shown in the diagram to maintain clarity. The conceptual model includes links between individual aspects of ecosystem health and human well-being, rather than attempting to estimate effects on an overall index of well-being. It is considered that, at least in the early stages of model development, it is more effective to concentrate on effects on individual indicators, as the interactions are clearer and information could be lost in the process of combining indicators into one index.

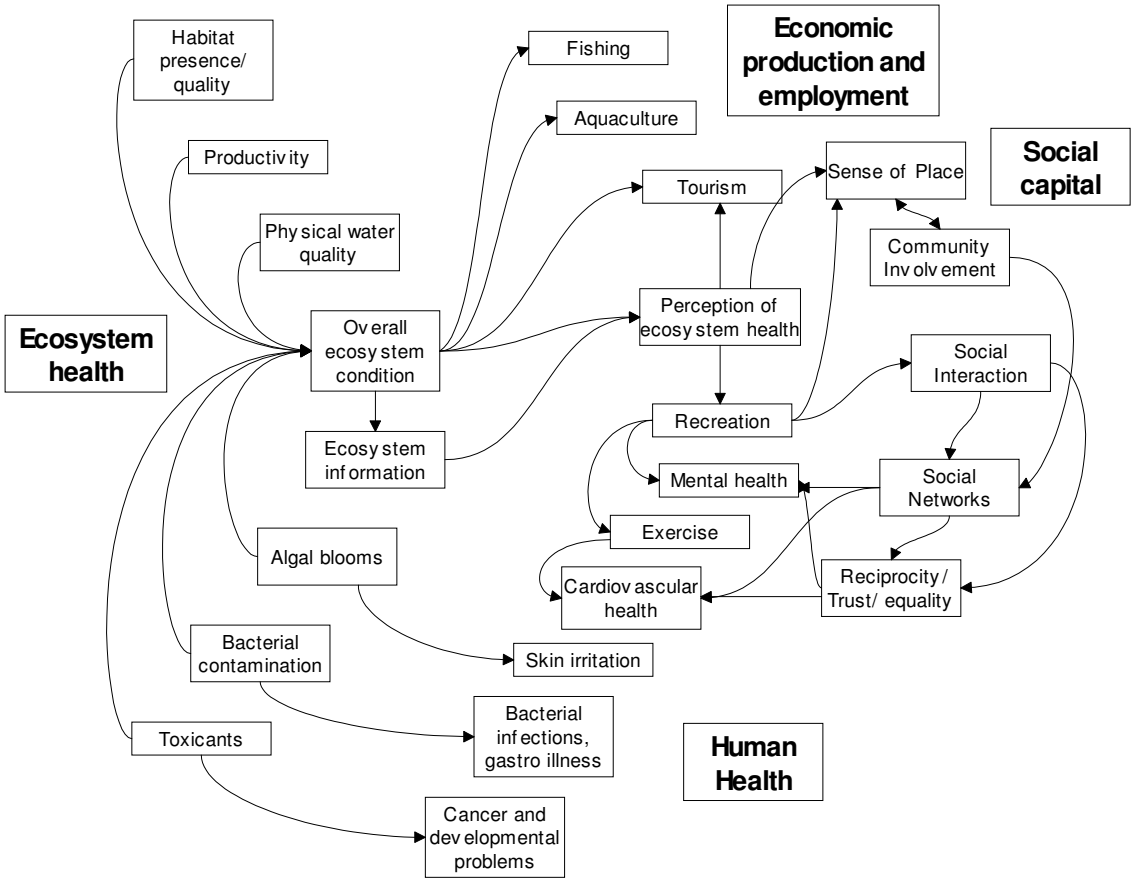

Figure 1. Conceptual model detailing the effects of coastal ecosystem health on aspects of human well-being.

Conclusions

Coastal management (indeed, resource management in general) is currently lacking an understanding of the potential impacts of our management decisions on the well-being of the local people and communities. Such an understanding is important as much of human management of ecosystems is human-centric and focussed on the benefits that we expect to derive from ecosystems. Current techniques attempt to address this issue through estimating monetary values of ecosystems and assuming that the monetary value derived is equivalent to human welfare. Although this can be a useful technique, we believe that it is inappropriate in many situations as it does not address the implications for wider aspects of human well-being. We have presented a conceptual model that details the potential links between coastal ecosystem

health and human well-being, as a first step towards developing a dynamic systems model that can be used to predict the impacts of changes in coastal ecosystem condition on human well-being. Better understanding of the effects of environmental change on the human community is essential in improving our management of ecosystems. Although some of the links described in this paper are specific to coastal ecosystems, the general framework could easily be applied to other ecosystem types.

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