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Appendix 2 – Research proposal
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Development of a Spatial Framework to Measure the Sustainability of Small Boat Harbours in Western Australia

Research Proposal

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Abstract
Sustainable development of boat harbours and other coastal infrastructure is a key to maintaining a balance between environmental, economic and social goals for integrated coastal zone management. There is a demand for more boating harbours and facilities as the population growth in metropolitan coastal areas continues to increase. However, no quantitative measure has been developed for evaluating the overall sustainability of boat harbours and there is no standard set of sustainability indicators on which to make an informed evaluation. The aim of the research is to develop a spatial framework to measure sustainability of boat harbours in Western Australia. To measure this, sustainability indicators for each harbour will need to be defined by using both quantitative (e.g. water quality testing, collation of economic figures, and collation of spatial information to provide an assessment of environmental indicators i.e. benthic habitats) and qualitative methods (e.g. conducting stakeholder and community surveys to capture local knowledge from the general boating community). A simple model known as the ‘triangle model’ will be used to measure the environmental, economic and social values or indexes based on a multi-criteria method. This framework will allow us to form baseline monitoring indicators that will be useful for decision-making purposes.

1. Introductory Statement
Population is increasing in coastal areas, which can lead to increased demand for boating facilities and other coastal development, and as a consequence, adding pressure to the coast and the quality of the marine and adjacent ecosystems. Policies on sustainable development have been applied to a number of boat harbours within Australia and overseas. However, a standard framework to measure and evaluate the sustainability of small boat harbours has not been developed at a local scale in Western Australia (WA). Sustainable development for any
activity is defined as an integration of the needs of the environment, society and economy, whilst achieving a suitable balance between these components over the long-term.

Therefore, this project’s focus is to establish a framework to evaluate the environmental, social and economic sustainability of small boat harbours to provide for measuring an important component of integrated coastal zone management. The project will address the following questions: How can we measure sustainability? What indicators will be used? And have we achieved sustainability?

2. Background

2.1 Setting the scene for Western Australia - Significance of sustainable boat harbour development

Harbours used for recreational and commercial boating are a growing sector worldwide which, without the appropriate management can lead to significant environmental, social and economic impacts in the coastal zone. Measuring and evaluating these impacts depend on establishing reliable sustainability indicators. Sustainability, discussed in this review, is defined as the management of environmental, economic and social impacts. Thus, the development of sustainability indicators is becoming increasingly important as it provides a mechanism for the measurement of the effectiveness of management within boat harbours.

There are a number of approaches that can be used to define and analyse these indicators, such as conducting environmental impact assessments, multi-criteria analysis, taking part in stakeholder groups and participatory surveys, and using geographic information system (GIS). Establishing a standard framework will allow an effective measure to evaluate the sustainability of boat harbours. It will also help identify management needs and manage boating pressures. In a previous study, a conceptual model, used by Xu et al. (2006), was applied to quantify the sustainability status and trends of economic development in China. The model used was a triangle model, where three indexes, economic development, resource-energy consumption and environmental pollution, were calculated based on weighing factors for the selected indicators of interest (Xu et al., 2006). This approach has not been applied to boat harbours in WA.
Based on the Australian census records, Perth recorded a population growth change of 9% in WA in the last decade (ABS, 2013). WA recorded the highest growth increase in Australia, followed by the next highest growth in Queensland and Northern Territory (ABS, 2013). To cater for this growth, upgrades or new construction of boating facilities are currently being planned. With increased anthropogenic marine activity, comes a concern for water quality, fisheries and a requirement for ongoing monitoring of marine life.

To develop this framework, a cross-section of the Department of Transport managed small craft infrastructure within WA will be examined. Due to the population increase and demands for more boating facilities in WA, the following Department of Transport’s managed boat harbours along the northern coastline from Fremantle to Two Rocks will be explored – Fremantle Fishing Boat Harbour, Hillarys Boat Harbour, Ocean Reef Boat Harbour, Two Rocks Marina, to be managed by the Department of Transport in 2014, and Mindarie Keys which is privately owned and managed. These boat harbours service a similar population base within the Perth metropolitan region, and therefore will aid in comparative analysis. For this study, a boat harbour is defined as “an area of protected navigable waters where boats can shelter and where boat-to-shore (and vice versa) transfers of people or goods can be made” (Development Control Policy 1.8, Western Australian Planning Commission, 2012).

Further, this review discusses the impacts and issues of harbour development, and the development of appropriate sustainability indicators for the environmental, social and economic aspects. A review of the common tools and approaches used to measure and evaluate sustainability will be discussed. The triangle model is proposed as an effective method to set a spatial framework for evaluating the sustainability of these boat harbours. The indicators used in this model will establish baseline criteria conditions for sustainability (environmental) monitoring.

2.2 Impacts of harbour development and sustainability issues
Boat harbours are an important asset for tourism, recreation, and the economy. One of the significant direct impacts is the loss of benthic habitat due to the construction of breakwaters and dredging of the boat harbour basin and channel. Demands for growing infrastructure, such as the construction of coastal resorts, harbours, roads and jetties, has resulted in loss of habitat and biodiversity in many coastal and marine areas (Davenport and Davenport, 2006).
Also, the loss of natural public beaches is often replaced by a new or safe beach within the harbour (Hobbs et al., 1990). Further, unsuitable design of coastal recreational facilities such as hard structures and earth embankment jetties, for example at the Red Sea, can block littoral currents, thus changing the hydrodynamic regime, setting down-drift erosion to adjacent beaches (Frihy et al., 2006).

Within WA, there was pressure for harbour development in Perth due to the America’s Cup Challenge. For example, Fremantle Fishing Boat Harbour, Hillarys Boat Harbour and Mindarie Keys were originally built or intended for the America’s Cup Challenge event (MacKenzie, 1986; Department of Transport, 2011). This event was notably one of the biggest in WA. Another factor is that environmental regulations have changed and that regulatory framework has become increasingly tight over the last three decades since the Environmental Protection Act 1986 came into effect. Increased harbour facilities within the Perth’s coastal metropolitan areas are due to the population growth in Perth, thus placing more pressures and demands for more boating facilities, such as the recent boardwalk upgrade at Hillarys Boat Harbour, the new floating boat pens at the Fremantle Fishing Boat Harbour which were completed in 2009, and a new boardwalk access behind Little Creatures in Fremantle (Department of Transport, 2011).

Harbour developments and their expansions have had indirect impacts on the aquatic environment as a result of increased human use. For example, the development of Hillarys Boat Harbour resulted in increased access to Boyinaboat Reef by recreational divers, and consequently led to the area being fished out (Hobbs et al., 1990). The Department of Conservation and Land Management then issued a ban on spear fishing for the area (Hobbs et al., 1990). Furthermore, the abalone fishing community living within the Ocean Reef Boat Harbour claimed that stocks near the harbour facility have declined since the harbour development, suggesting the harbour gave way to increased access for over-overfishing or modifications in sediment patterns (Hobbs et al., 1990).

At local and regional scales, coastal erosion, siltation, and seaweed accumulation are common problems occurring in harbours. To ensure the safety of boaters, the harbour’s seafloor must be regularly dredged to maintain a safe and navigable waterway. For example, beaches in the Two Rocks Marina area had erosion problems before and after its construction. Erosion at the
northern end of the marina is approximately 20,000 m$^3$ per year, with sand accreting to the
south at about the same rate, causing siltation of the original fishing boat moorings (Hobbs et al., 1990). Harbours can become traps for sand and seaweed. For example, Hillarys Boat Harbour requires manual removal to prevent odours from decaying seaweed and degrading water quality.

Fuel and oil spills from boaters have an impact on water quality, although minor incidents have occurred within recreational boat harbours, such as in Two Rocks. When 50 tonnes of oil was split in Fremantle waters in 1986 due to an oil pipeline fracture from BP Pty Ltd, oil flowed into the Fremantle stormwater drains, then into the Fishing Boat Harbour and accumulated on Garden Island (Environmental Protection Authority, 1986). “The Fremantle Oil Spill Inquiry” was established by the Environmental Protection Authority to report on the oil spill and provide further environmental protection measures (Environmental Protection Authority, 1986).

2.3 Development of a Sustainability Framework to assess small boat harbours around the world, Australia and in Western Australia

2.3.1 Sustainability concept – Environment, Social and Economics

The concept of sustainability has become widely known and understood over recent decades. Worldwide recognition came as a result of a report published in 1987 by the World Commission on Environment and Development, entitled “Our Common Future”. Norway’s Prime Minister and the Chair of the Commission, Gro Harlem Brundtland, stated today’s generally accepted definition of sustainability as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). However, this definition is broad, and a precise and commonly accepted definition is still lacking (Radermacher, 1999; Phillis and Riantiatsaholinaina, 2001; Cummins and McKenna, 2010). Increasing awareness of sustainability was shown by the United Nations Conference on Environment and Development 1992, held in Rio de Janeiro, and local level action was adopted by Agenda 21. Furthermore, at the Copenhagen Summit and in the Treaty of Amsterdam of 1997, the three pillars of sustainable development - environmental, economic and socio-cultural, were formed. In most countries around the world, particularly developing countries such as China, Malaysia and India, the situation for the environment and over-population is still an issue. To
assess the progress made since Rio in terms of sustainable development, five key areas – water, energy, health, agricultural productivity and biodiversity, were identified during the World Summit on Sustainable Development held in Johannesburg in 2002; where by 2015, people without access to basic sanitary facilities is to be halved, negative impacts on human health will be minimised, fish stocks must be restored, the loss of biodiversity will be stopped, and national sustainability strategies will be developed (Plan of Implementation of the World Summit on Sustainable Development, United Nations, 2002). This raises concerns particularly if the increase in boating facilities in an unmanaged environment may add further direct or indirect impacts on the coastal and marine environment.

Although the concept of sustainability development is broad, covering a range of environmental issues, linkages between sustainability and integrated coastal zone management (ICZM) is needed. ICZM is a process for achieving sustainable development and protection of marine resources by taking into account all conflicting interests and uses. This is generally a well-accepted process, with acknowledged concepts of ICZM developed by Cicin-Sain and Knecht (1998). For example, Cummins and McKenna (2010) outline that capacity building approach is important for integrating coastal research with policy, and highlights principles of sustainability science into ICZM, to help guide ICZM researchers, practitioners and policy makers. They propose principles such as establishing the need to resolve sustainable development issues by a problem-driven agenda, particularly at a local level ICZM, work with stakeholder groups as part of social learning, and implement an interdisciplinary approach (Cummins and McKenna, 2010). As a result, increased awareness of management options for specific problems, such as recreational carrying capacity, was reported for Cork Harbour in Ireland, also, a local Integrated Harbour Management Strategy for Cork Harbour was adopted (Cummins and McKenna, 2010).

2.3.2 Deriving sustainability indicators
The use and development of sustainability indicators at all scales is becoming increasingly important. Sustainability indicators are parameters that will quantitatively or qualitatively measure and facilitate progress towards a range of environmental, social and economic goals. A well-defined indicator(s) will ensure an accurate measurement and evaluation of sustainable development. For example, a set of criteria was used to evaluate sustainability indicators at a local scale (see Table 1) (Reed, 2006). Reed (2006) presented a methodological framework

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that summarises best practice for developing and applying sustainability indicators using an adaptive learning process (Figure 1). This process starts with defining relevant stakeholders as a crucial step, along with identifying problems, strategies, and sustainability indicators, where indicators would be tested and applied using both qualitative and quantitative methods (Reed 2006). Reed (2006) highlights the use of data from different sources during the evaluation phase, and this process provides an understanding of the interactions between environmental, social and economic systems required to assist local sustainable development activities. Although a number of reviews on sustainability indicators have been conducted (Moldan and Billharz, 1997; International Institute for Sustainable Development, 2000; Swart et al., 2002; Reed, 2006; Håkanson and Blenckner, 2008; Moldan et al., 2012; Marques et al., 2013) more work in improving the development of sustainability indicators is needed (International Institute for Sustainable Development, 2000; Reed, 2006; Cummins and McKenna, 2010; Marques et al., 2013).

Table 1. Criteria to evaluate sustainability indicators at local scale (taken from Reed, 2006)

<table>
<thead>
<tr>
<th><strong>Objectivity criteria</strong></th>
<th><strong>Ease of use criteria</strong></th>
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<tbody>
<tr>
<td>Be accurate and bias free</td>
<td>Be easily measured</td>
</tr>
<tr>
<td>Be reliable and consistent over space and time</td>
<td>Make use of available data</td>
</tr>
<tr>
<td>Assess trends over time</td>
<td>Have social appeal and resonance</td>
</tr>
<tr>
<td>Provide early warning of detrimental change</td>
<td>Be cost effective to measure</td>
</tr>
<tr>
<td>Be representative of system variability</td>
<td>Be rapid to measure</td>
</tr>
<tr>
<td>Provide timely information</td>
<td>Be clear and unambiguous, easy to understand and interpret</td>
</tr>
<tr>
<td>Be scientifically robust and credible</td>
<td>Simplify complex phenomena and facilitate communication of information</td>
</tr>
<tr>
<td>Be verifiable and replicable</td>
<td>Be limited in number</td>
</tr>
<tr>
<td>Be relevant to the local system/environment</td>
<td>Use existing data</td>
</tr>
<tr>
<td>Sensitive to system stresses or the changes it is meant to indicate</td>
<td>Measure what is important to stakeholders</td>
</tr>
<tr>
<td>Have a target level, baseline or threshold against which to measure them</td>
<td>Be easily accessible to decision-makers</td>
</tr>
<tr>
<td></td>
<td>Be diverse to meet the requirements of different users</td>
</tr>
<tr>
<td></td>
<td>Be linked to practical action</td>
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<td></td>
<td>Be developed by the end-users</td>
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</table>
Cummins and McKenna (2010) highlight the need for public involvement and capacity building in sustainability science, which is a critical element of ICZM. Conducting surveys is one way to establish sustainability indicators. However, low levels of participation has been observed among stakeholders possibly due to their unwillingness to answer survey questions, and lack of funding or participatory approaches to develop and implement sustainability indicators (Blackstock et al., 2007; Areizaga et al., 2012; Marques et al., 2013). Despite this, the advantage of undertaking these surveys is that local knowledge can be captured. Boating surveys or questionnaires either voluntary or by providing an incentive to gather more data aimed at a particular interest group, have been conducted by many researchers or organisations i.e. Silver and Campbell (2005), Kopke et al. (2006), Areizaga et al. (2012), and Dalton and Thompson (2013). Much of the participatory surveys have resulted in increased
community awareness of the environment and an enhanced capacity to improve environmental conditions and management needs (Fraser, 2002; Cummins and McKenna, 2010). However, community’s social values may change over time, thus goals may need to be re-defined in response to changing needs and priorities. Therefore, a solid sustainability indicator framework process, such as an adaptive learning framework presented by Reed (2006) (Figure 1), is vital for the development of successful indicators.

Sustainability indicators help to establish baselines for future monitoring which would allow for observing trends and to identify thresholds over which problems become critical. However, it is often difficult to identify thresholds due to the dynamic nature of the environment (Gunderson and Holling, 2002). Despite the difficulty, Håkanson and Blenckner (2008) used a simple set of indicators to assess water quality at all local, medium and broad scales for a number of sites in Europe with detailed modelled outputs for determining critical thresholds for each indicator, including Secchi depth (a standard measure of water clarity), chlorophyll-a concentrations (a simple, operational, standard measure of algal biomass), oxygen saturation in the deep-water zone (regulating the survival of an important functional group, the zoobenthos), and macrophyte cover (or biomass; as a measure of coastal productivity; the “biological value” of the coastal area). Most of these indicators are used in monitoring water quality across many boat harbours in WA, as part of the ongoing environmental monitoring conditions set forth by the Environmental Protection Authority.

2.3.3 Frameworks and tools for measuring sustainability

There are a number of frameworks and tools that cater for site-specific requirements, or based on data availability, or focused on different environmental areas, i.e. marine or terrestrial (e.g. Kopke et al., 2006; Balaguer, 2011; Collin et al., 2011; Lozoya et al., 2011; Sanchez and Morrison-Saunders, 2011; Areizaga et al., 2012; Busch et al., 2012; Convertino et al., 2013). The first comprehensive sustainability strategy for Australia was prepared by the State Government of WA, which documents a number of approaches relevant to WA to aid in decision making (Government of WA, 2003). Such tools currently used are economic valuation of environmental and social assets and services, multi-criteria assessment, applying regulation and legislative framework, community-based solutions and Environmental Impact Assessments (EIA) (see Table 2).
For example, EIA is a widely used and accepted tool used by many coastal developers or organisations that are engaged in landuse activities in Australia. EIA plays a vital role in providing ongoing adaptive environmental management. It is used to identify the necessary environmental precautions and alternative approaches to reduce or eliminate environmental effects (Sadler, 1996; Sanchez and Morrison-Saunders, 2011). The advantage of using this tool is that it is a site-specific approach, where EIAs can help identify the necessary indicators at a local scale and to aid legislative condition monitoring requirements as authorised by the State and / or Federal Australian governments. For example, EIA was conducted at Fremantle Fishing Boat Harbour in WA whilst undergoing environmental approvals for the proposed harbour expansion in 1984 to cater for the America’s Cup Challenge. Environmental conditions were established by the Environmental Protection Authority, following a water quality monitoring programme, using the indicators identified in the EIA and the proponent’s commitments that were necessary for water quality monitoring (Department of Marine and Harbours, 1989).

GIS is another common tool, and is increasingly used in coastal management over the recent years, to aid in display and analysis of geographically based information (Stojanovic et al., 2010; Balaguer, 2011; Collin et al., 2011; Lozoya et al., 2011; Busch et al., 2012). As information technology is becoming more central to decision-making processes, GIS is a valuable spatial management tool to guide management and policy making decisions. For example, tools in GIS such as generating 3D points in space using data collected from light detection and ranging (LiDAR) technology can be used for analysing sea bed depths and / or mapping benthic habitat areas (Collin et al., 2011). Based on geo-statistical analyses, classification of benthic habitat using bathymetric LiDAR, as shown in a study by Collin et al. (2011), resulted in an overall accuracy of 93.3% using 12 benthic parameter bands (LiDAR waveforms). The use of this technology can aid in the measure of sustainability indicators, such as calculating the extent or volume of critical benthic habitat areas near boat harbours or other coastal development. This measure would be useful to assess the sustainability of the marine environment when coastal development is likely to cause a hazard or risk to the coastal and marine habitat.
<table>
<thead>
<tr>
<th>Sustainability area</th>
<th>Tools and approach</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td>Environment</td>
<td>Environmental Impact Assessment (EIA) - evaluates potential environmental impacts of large development projects with the aim to reduce the negative effects. This may involve the use of criteria weighting, cost-benefit analysis, and field surveys.</td>
<td>Sadler, 1996; Sanchez and Morrison-Saunders, 2011</td>
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<td></td>
<td>Geographic Information System (GIS) - a tool to aid display and analysis of geographically based information, e.g. using LiDAR for benthic habitat mapping</td>
<td>Stojanovic et al., 2010; Balaguer, 2011; Collin et al., 2011; Lozoya et al., 2011; Busch et al., 2012</td>
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<tr>
<td>Social</td>
<td>Community development processes - are community-based solutions through development approaches that recognise and value diversity of the community to obtain local knowledge, e.g. conducting community and stakeholder surveys.</td>
<td>Fraser, 2002; Kopke et al., 2006; Blackstock et al., 2007; Arceo and Granados-Barba, 2010; Cummins and McKenna, 2010; Areizaga et al., 2012; Dalton and Thompson, 2013</td>
</tr>
<tr>
<td>Economic</td>
<td>Cost-Benefit Analysis (CBA) - evaluates public or private investment proposals by weighing the costs of the project against the expected benefits</td>
<td>Busch et al., 2012</td>
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<td></td>
<td>Millennium Economic Framework - an ecosystem service approach used to quantify benefits that humans obtain from ecosystems such as food, water and recreational opportunities</td>
<td>Millennium Ecosystem Assessment, 2005</td>
</tr>
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<td></td>
<td>System of Environmental-Economic Accounts (SEEA) - a standard classification scheme developed by the United Nations Statistics Division (UNSD), consists of a set of Gross Domestic Product (GDP) indicators used to assess sustainability and human well being</td>
<td>UNSD et al., 2003; Haines-Young and Potschin, 2010</td>
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<td></td>
<td>Multi-Criteria Analysis (MCA) - assessment of options by listing criteria, measuring these where possible or rating them where not, weighting the criteria through community involvement, and providing integrated options from the analysis</td>
<td>Brouwer and van Ek, 2004; Greening and Bernow, 2004; Xu et al., 2006; Garmendia et al., 2010; Garfi et al., 2011; Wood et al., 2012; Convertino et al., 2013</td>
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<td></td>
<td>Risk Analysis - is the assessment of potential damages in a particular event(s), e.g. beach hazard, flood</td>
<td>Lozoya et al., 2011; Wood et al., 2012</td>
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<tr>
<td></td>
<td>Strategic and statutory plans, i.e. legislative Acts and policies</td>
<td>Government of WA, 2003</td>
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<td></td>
<td>Vulnerability Analysis - evaluates the vulnerability and capability of human environment systems to changes, e.g. coastline vulnerability to erosion</td>
<td>Kelly, 2000; Dixon et al., 2003; O'Brien et al., 2004; Devoy, 2008; Meur-Péré et al., 2008</td>
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</table>
Coastal hazards caused by natural factors, e.g. storms, or by human activities can lead to strong impacts on societies. This can lead to economic damages and loss of human lives (Pérez-Maqueo et al., 2007). These hazards can be quantified to assess risk at a beach. For example, in a coastal hazard study by Lozoya et al. (2011), water quality or pollution, storm-induced erosion, storm-induced flood, storm-induced erosion, storm-induced floods, long-term erosion, river floods, jellyfish, and human uses, were identified as the main hazards or measureable indicators at S’Abanell beach, located along the Spanish Mediterranean coast. Coastal hazard intensity was calculated based on different landuse types using GIS, with river floods being identified as the most hazardous factor at S’Abanell beach (Lozoya et al., 2011). An economic evaluation was also conducted to determine non-market values for S’Abanell beach. This is a commonly used approach when environmental and social information are not available. Based on the economic evaluation, the most highly valued was recreation and aesthetic values, while coastal habitat, spiritual and historic values were least important (Lozoya et al., 2011). However, this assessment used limited bio-physical and socio-economic data (Lozoya et al., 2011), and therefore the study does not show a complete assessment of sustainability.

The economy has played a large part in society for a long time, and various models in the past have been used to address economics, with a minor part of environmental frameworks to assess economic evaluation to manage ecosystems. However, recent economic studies are being used to address more environmental concerns. For example, the Millennium Ecosystem Assessment is an ecosystem service approach used to quantify benefits that humans obtain from ecosystems, such as food, water purification and recreational opportunities (Millennium Ecosystem Assessment, 2005). This framework is developed to assign monetary values to ecosystem services for the purposes of a cost-benefit analysis and to drive political and economic decisions, i.e. for decision-making support. For example, mapping total economic values based on flood patterns illustrates how the monetary value of land and ecosystem services may differ over time due to the dynamic environment, i.e. greater flood risk leads to increased land insurance cost and reduced biodiversity (Busch et al., 2012). Further, in an economic study, biotic diversity (i.e. seabird) was greatly impacted by the development of offshore wind farms in Germany, thus reducing the seabird diversity (Busch et al., 2012). Ecological indicators (energy cycling, nutrient cycling, storage capacity, nutrient loss, abiotic heterogeneity, biotic diversity, and organisation) were analysed for this study, using seabird,
fish and climate GIS data, and questionnaires were received from more than 350 local residents (Busch et al., 2012). The evaluation of ecological impacts based on economic data gathered for Busch et al.'s (2012) study, was rated on a relative scale from -2 to +2, with +2 being strongly impacted, for ease of comparison, based on expert estimations by Busch et al. (2012).

Rating scales are commonly used for measuring and evaluating sustainability indicators in preparation of developing a strategy or action plan for future monitoring, e.g. the Australian National Action Plan for Salinity under the Natural Heritage Trust. For example, the most commonly used approach is a multi-criteria decision analysis, which is a structured decision-making process that quantitatively evaluates metrics or sustainability indicators that are ranked or weighed according to a set of criteria, based on a specified project criteria, expert opinions, and stakeholder preferences (Garfi et al., 2011; Wood et al., 2012; Convertino et al., 2013). This type of approach is used by many coastal managers for risk analysis to provide better management and policy making decisions, as seen in much of the literature (Thayer et al., 2005; Garmendia et al., 2010; Lozoya et al., 2011; Wood et al., 2012; Convertino et al., 2013). Formulae have been used to calculate the overall utility for each metric, for example Convertino et al. (2013) uses a selection of metrics and formulae for a multi-criteria analysis for ecosystem restoration programs, however, metric selection can be complex when left in the judgement of stakeholders, and the assumptions to treat metrics being independent and utilise the additive equation form, which is a widely used formula. Furthermore, ranking values may vary across different stakeholders and there is no standard method to assign the ranking.

However, a combination of different types of questionnaires, such as semi-structured interviews, household surveys, and stakeholder surveys, can be used to identify sustainability indicators, and the responses can be ranked accordingly (e.g. Fraser, 2002; Kopke et al., 2006; Blackstock et al., 2007; Arceo and Granados-Barba, 2010; Cummins and McKenna, 2010; Areizaga et al., 2012; Dalton and Thompson, 2013). In Mexico, indicators of interest were evaluated by using a radial model, known as ‘amoeba’, which estimated a sustainability index of 45.9% for a protected reef system in Mexico (Figure 2) (Arceo and Granados-Barba, 2010). The amoeba model shows a sustainability graph for each indicator based on a given rating scale, allowing a comprehensive comparison of the advantages and limitations of each
indicator under evaluation. This model is predominantly used in agricultural studies, but recently used for coastal management as a decision support tool (Meur-Féree et al., 2008; Arceo and Granados-Barba, 2010).

Figure 2. An example of a radial amoeba diagram showing the indicators and the area covered (taken from Arceo and Granados-Barba, 2010).

A complete model that covers the three pillars of sustainability and that allows for flexibility and ease of use is the triangle model concept. This model was proposed by Xu et al. (2006) to evaluate economic development across 31 political regions in China (Figure 3). Weighting criteria were also used in a triangle model concept for evaluating the status and trends of sustainability. The model was based on three indexes, an economic development index, a resource and energy consumption index and an environmental pollution index (Xu et al., 2006). Further, data was obtained from year books which easily fed into the triangle model by applying data normalisation, weighting factors, and then calculating the three indexes. By plotting the index values in a triangle model, Xu et al. (2006) found that economic
development in the year 2000 showed a relatively weak sustainability status. The model was able to successfully evaluate the sustainability status of economic development across the 31 regions. The advantage of using this model is due to its simplicity and visual representation. It allows comparison of sustainability values of different sampling sites, and plots these values into one model, thus providing an overall picture of a site’s status, rather than applying the comprehensive evaluation of individual indicators using the amoeba model. Further, the model allows for flexibility in selecting individual sustainability indicators to suit a particular area of study or based on data availability.

Figure 3. The Triangle model, where EDI: economic development index; EPI: environmental pollution index; RECI: resource and energy consumption index (taken from Xu et al., 2006).
2.4 The proof is in the Triangle – How can the triangle model address sustainability for small boat harbour developments

The existing State sustainability strategy developed by the State Government of WA provides an overarching framework for WA. Further, ministerial conditions set out by the Environmental Protection Authority for boat harbour developments provide legally binding environmental targets or indicators. The use of the triangle model can quantify and evaluate the sustainability status, not just from an economic point of view, but also environmentally and socially. This will also explore the gaps or limitations of sustainability indicators, and possibly re-evaluate the indicators and the conditions set by the Environmental Protection Authority. The model is flexible in its use, being able to define sustainability in a spatial context. It provides a framework that can help government, industry and policy makers, and can be replicated to measure sustainability for other boat harbours in WA.

2.5 Conclusion

In conclusion, impacts of harbour developments, both direct and indirect, have resulted in loss of marine habitat due to dredging, over-fishing, etc. Demands for boating facilities are increasing due to the increased population, with a focus on Perth, that is experiencing the highest population growth change over the last decade in Australia overall. The development of sustainability indicators is important because it provides a framework for monitoring and evaluation. A general framework to address sustainability for WA and at a global scale has been discussed. A number of tools have been used to evaluate sustainability, however, there is no specific guide on which model should be used for any activity due to changes in sustainability indicators i.e. changes in community’s social values, or changes in the environment i.e. floods. More specifically, there is no current standard method for assessing or quantifying the sustainability status of boat harbours in WA. The triangle model is a promising spatial management tool for coastal managers or developers, scientists and policy decision makers, and will be used in this study to measure the sustainability of boat harbours in WA.

3. Aims and objectives

The aim of the project is to develop a spatial framework to measure the overall sustainability of small boat harbours in WA. The objectives to support the aim are as follows:

- Identify a theoretical framework for measuring the sustainability of boat harbours,
• Identify sustainability indicators required to measure environmental, social and economic parameters:
  - What are they?
  - How are they identified?
  - How do we measure them?
  - Why do we need them?, and
• Measure, evaluate and compare the sustainability of up to five small boat harbours within WA.

4. Significance and outcomes
This project hopes to develop a conceptual framework and set of metrics to measure the sustainable development and management of small boat harbours, with a focus on the environmental, social and economic components. A standard set of sustainability indicators will be identified and will form a baseline for future monitoring. This will guide better management and policy-making decisions. For example, investments can be targeted to support indicators that are performing poorly. Therefore, management will be strategic and necessary to provide for ongoing sustainable development. The outcome of this project will be to establish a useful management framework tool that can be used to evaluate the success of boat harbours, answering the question 'have we achieved sustainability?' This tool can be adopted and utilised by a range of Stakeholders (including private developers, boating industry and clubs, government and indigenous groups) and the general community for public consultation, monitoring and management purposes.

5. Methodology
5.1 Study Sites
Due to the population increase and demands for more boating facilities in WA, the following boat harbours will be explored and are discussed below – Fremantle Fishing Boat Harbour, Hillarys Boat Harbour, Ocean Reef Boat Harbour, Mindarie Keys and Two Rocks Marina.

5.1.1 Fremantle Fishing Boat Harbour
Fremantle Fishing Boat Harbour is located approximately 20 km west of Perth and is the main facility for the fishing and marine industry in WA. With a fishing industry dating back to the 1800’s and its first jetty built in 1919, the harbour now caters for approximately 540
commercial and recreational vessels (Department of Transport, 2011). The first boat pens at the harbour to house fishing boats were constructed in 1969 (Department of Transport, 2011). Major changes to the harbour occurred in 1984 to cater for boating demands of the America’s Cup Challenge in 1987. This included expanding the harbour to construct the adjacent Challenger Harbour, construction of sheet piled wharfs, car parking, buildings, fish receival depots, fuelling stations for the fishing industry and a number of retail and food outlets (Department of Transport, 2011). The Fremantle Fishing Boat Harbour is vital to the commercial marine and industry, recreation and tourism, and being centrally located to the Fremantle CBD, has a significant influence on the economy and cultural values of Fremantle.

5.1.2 Hillarys Boat Harbour
Hillarys Boat Harbour, formerly known as the Sorrento boat harbour, was also built to provide for the America’s Cup Challenge. Located approximately 30 km north of Fremantle, the harbour has over 450 public boat pens, a service wharf and six boat launching ramps (Department of Transport, 2011). There is also an artificial beach constructed within the harbour, picnic areas, restaurants and cafes, apartment type accommodation, and is home to one of the biggest tourist destinations in WA, the Aquarium of WA (AQWA). A recent $20 million upgrade at the harbour in 2010 involved the construction of a pedestrian boardwalk and bascule bridge to provide access between the northern and southern side of the harbour (Department of Transport, 2011).

5.1.3 Ocean Reef Boat Harbour
Ocean Reef Boat Harbour consists of a small boat launching facility, and is located approximately 6.5 km north of Hillarys. The harbour was constructed in 1978, with additional boat ramps added in 1986, and was originally built to make use of the existing constructed groynes and effluent pipeline (Hobbs et al., 1990). Further development at the harbour is under consideration (Baird, M., pers. comms., Manager of Maritime Planning, Department of Transport, 2013).

5.1.4 Mindarie Keys
Mindarie Keys is a small boat harbour located approximately 11.5 km north of Ocean Reef Boat Harbour. The harbour was constructed in 1988 and was opened to the public in 1989 (Hobbs et al., 1990). Although the harbour was originally intended to be constructed before
the America’s Cup Challenge, environmental approvals were not received until after due to environmental and harbour planning concerns (MacKenzie, 1986). The development of the harbour involved the excavation from a nearby existing foredune and construction of two breakwaters extending approximately 200 m out from the shoreline, with the aim to protect the harbour from direct ocean swells (Hobbs et al., 1990). The proponent for the development is Smith Corporation Pty Ltd, and they submitted an Environmental Review and Management Programme (ERMP) in 1985 which was then assessed by the Environmental Protection Authority. However, no post construction monitoring was done, and the monitoring programme indicated that water quality was not significantly different from predicted levels (Hobbs et al., 1990).

5.1.5 Two Rocks Marina
Built in 1972, Two Rocks Marina is located approximately 30 km north of Mindarie Keys. Although originally a privately owned marina facility by Yanchep Estates Pty Ltd, the marina will be managed and owned by the Department of Transport in 2014. The marina consists of an embayment formed by two breakwaters extending out from the shoreline. A legal agreement between the developer (Yanchep Estates Pty Ltd) and the State government was made, in which a number of legally binding conditions were established, including seaweed wrack management and mooring control (Yanchep Estates Pty Ltd and State Lands, 1972).

5.2 Identifying and measuring sustainability
To develop a theoretical framework for the general management of boat harbours, collation of existing data, field work, an online boating participant survey, and community and stakeholder surveys will be conducted to identify the relevant sustainability indicators for environment, social and economic. Indicators will be developed and managed within a GIS framework to aid in the establishment of a suitable methodology and analytic approach. The use of the triangle model, i.e. based on a study from Xu et al. (2006), and multi-criteria analysis, will be used to assess the indicators and to calculate the environmental, social and economic indexes, and the overall measure of sustainability for each boat harbour.

5.2.1 Environmental monitoring
Stakeholder meetings will be conducted to identify measurable environmental indicators, e.g. water quality – pH, chlorophyll-α, nitrogen and phosphorus, hydrocarbon level, benthic
habitat, seagrass productivity, and sea-level rise. Existing data on water quality, oceanographic and hydrographic records will be gathered. Some data may be available for most boat harbours, if not, systematic sampling of sediments and/or water quality will be conducted, with measurements taken over different seasons, or alternatively, with budget approval from the Department of Transport, a licenced contractor may be engaged to collect and test samples in a nationally accredited laboratory (NATA).

5.2.2 Social effects
A boating participant survey starting in May 2013, funded by the Department of Transport, will be used to provide results to address socio-economic indicators. The following measurable social indicators will be used in this study, but are not limited to: e.g. population census, health epidemics, number of fishing licenses, and number of registered recreational vessels. This is a monthly online survey distributed over the course of a year, with repeats every two or three years. Stakeholder and community (including private developers, boating industry and clubs, government and indigenous groups) questionnaires may also be prepared to address the community’s boating concerns relating to sustainability.

5.2.3 Economic assessment
The online boating survey, as mentioned above, and stakeholder survey will be used to identify or address these economic indicators, but are not limited to, land value, harbour revenue, level of employment, and fishery. Other economic data will be obtained from the Australian Bureau of Statistics (ABS).
6 Timetable

The project will be undertaken part-time due to full-time work commitments. Starting date is February 2013 and completing in June 2014.

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7 Budget

Project costs are funded by the Department of Transport, along with a $5000 per year study scholarship. *Subject to the Department’s approval.

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References


Western Australian Planning Commission, 2012. Development Control Policy 1.8 Canal estates and artificial waterway developments, State of Western Australia, Perth


24

9 Appendix – Reference style
Reference style from the Ocean & Coastal Management journal.
Adaptive-participative sustainability indicators in marine protected areas: Design and communication

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ABSTRACT
Recently there has been an effort to put in practice integrated management plans in Marine Protected Areas (MPA) not only because of their high natural and cultural importance but also due to usual conflicts related to local activities. These plans should include the use of adaptive sustainability indicators that reflect stakeholders concerns, and community interests, allowing a better assessment, management and reporting. An adequate set of indicators for the MPA should help their managers to improve management policies in order to achieve better decision making processes. This study aimed to develop a set of adaptive-participative sustainability indicators (SDI) for the assessment, management and reporting of MPAs that include, through the all process, the participation of local stakeholders at every levels, integrating the stakeholders knowledge and perceptions about the SDI meaning and a self-assessment of the SDI state produced also by the stakeholders. The proposed approach was tested in Luiz Saldanha’s Marine Park, located in South East of Portugal between the municipalities of Sesimbra and Setúbal. The framework to design the SDI comprised four phases: i) an international analysis of SDI sets for coastal zones and MPAs; ii) a participatory process, where the stakeholders had the possibility to state their concerns through an online and face to face questionnaire surveys about the strengths and weaknesses of the MPA; iii) an analysis conducted by a team of experts to reach a set of indicators that include the main relevant aspects of environmental, socioeconomic, and governance issues, taking into account the information from the first two phases and iv) a workshop and questionnaires held to assess the stakeholders’ global views and perception about the selected set of indicators and each indicator’s relative importance. This study showed the importance of a dynamic participative process involving the local stakeholders. It is concluded that this methodology allows a better understanding of each indicator by the local stakeholders and how it could respond to their concerns. It should also help the MPA managers, to define the most suitable management actions and monitor the management plan itself.

1. Introduction

In order to measure sustainable development it is vital to use tools that can both measure and facilitate progress towards a broad range of environmental, socioeconomic and governance goals. During the decade of 1990 there was an exponential increase in programs that intended to propose sustainable development indicators (SDI). Most of supra-national bodies state that the development of SDIs was necessary to provide solid bases for decision making at all levels and also to contribute to self regulating sustainability of integrated environmental and development systems (Mitchell, 1996; Reed et al., 2006). These SDI should help us to gather, analyse and use information for managers to make better decisions, measuring progress, and monitoring feedback mechanisms (Scipioni et al., 2008). Also, in order to reach a better set of SDI, their design and development should integrate an open and effective communication and a broad participation process, including a continuous, iterative and adaptive procedure that provides ongoing support in the decision-making process (Hardi and Zand, 1997; Reed, 2008; Ramos, 2009; Coelho et al., 2010; Mascarenhas et al., 2010). As stressed by Reed et al. (2006), the majority of the actual indicator systems are based on a top-down
processes from the public point of view, assuming that are “weak” and “strong” actors with different roles. This finding a shown a need to deal with non-traditional aspects of sustainability assessment and reporting, facing new challenges of stakeholders engagement, namely about the meaning and important of sustainability indicators for an effective, management of MPA. Participatory approaches to develop and implement SDI are not enough. They should have effective impact on the policies and management plans of the MPA, and involved stakeholders should see how their contributions have affected the strategic or operational actions. Also this kind of adaptive-participative approach should be stimulated within the MPA decision-makers communities and put into practice their usefulness. At last an SDI revisions and evaluation should be conducted at all the stages of the adaptive-participative approach to allow a continuous improvement.

In future developments the methodology could be tested in other MPA to allow comparisons and cross-validation of the adopted methodology. Also stakeholder could active participate and be involved in the indicator assessment. Volunteer monitoring could become an integral part of the effort to assess the sustainability of an MPA. Government agencies, often strapped by financial limitations, have found that volunteer programs can provide high-quality, reliable data to supplement their own monitoring programs (e.g. water quality).

Acknowledgments

We would like to express our thanks for the financial support of the Fundação Calouste Gulbenkian and Oceano of Lisbon, Portugal. We would like as well to acknowledge the valuable support of the anonymous reviewers.


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Appendix 3 – Formatting and referencing style guide

Journal of Ocean and Coastal Management
Coastal state indicators to assess the morphological development of the Holland coast due to natural and anthropogenic pressure factors

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A R T I C L E   I N F O

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A B S T R A C T

The description of the state and possible changes of a physical system, through an objective, simple and standard methodology is becoming a daily requirement for coastal managers. The implementation of national and international regulations is in fact nearly fully based on the use of such indicators. On the other hand, scientists spend a considerable effort into trying to express and understand the physical processes underlying a certain system, but often they do not put the necessary effort to translate them into useful indicators which can be used by coastal managers. This paper tries to close the existing gap between scientists and coastal managers by describing the morphological development of the Holland coast through an indicator approach. In particular, three indicators have been chosen to quantify three different coastal functions, i.e. the short-term safety, the medium term safety and the available space for nature and recreation. The dynamics of the indicators have been quantified in relation to the external pressure factors determining those changes. Those relations provide simple rules of thumb which can be used by coastal managers to quantify the effects of specific actions (e.g. implementation of nourishments), to assess the impact of changes in the natural forcing (e.g. due to climate change), or as a basis for cost-benefit analysis.

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1. Introduction

Coastal state indicators have been widely used in recent years in different disciplines related to oceanography, marine ecology, biology and coastal engineering. Coastal managers supported by scientists feel an increasing pressure from national and international authorities to define those indicators. For example, the European Water Framework Directive (Directive, 2000/60/EC) and the most recent European Marine Strategy Framework Directive (Directive, 2008/56/EC) are based on the definition of Good Environmental Status, completely described by a number of targets and indicators. Indicators are used to monitor environmental issues and, as management tools, to assess the effectiveness of policies, by measuring the progresses towards a certain target.

On the other hand, the information provided by scientists is often too complicated and the communication between scientists and coastal managers very ineffective (Van Koningsveld et al., 2005; Ojeda-Martínez et al., 2009). The scientific community is mainly working on very detailed aspects of one specific problem, while managers are interested in the holistic view, with a lower degree of detail, of the entire physical system. Stojanovic et al. (2009) suggested that ‘communication’ between scientists and stakeholders should be preferred to ‘dissemination’, involving a two-way transfer of information and they indicated as an example to reach this objective the set-up of ‘coastal partnerships’.

Considerable efforts to improve this situation has been made for example in the CoastView European project (Davidson et al., 2007). Video-derived coastal state indicators have been applied for monitoring the coastline evolution (Kroon et al., 2007), the level of beach-use and the beach safety (Jiménez et al., 2007).

The present investigation aims at describing and quantifying the morphological development of the Holland coast through an indicator approach, in a way that can support coastal managers. At first, the main natural and anthropogenic external pressure factors are depicted. This is followed by choosing three indicators to quantify possible changes to three different coastal functions represented by the short-term safety, the medium term safety and the available

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http://dx.doi.org/10.1016/j.ocecoaman.2013.09.015
4.3. Relations between indicators

Besides the effects of external pressure factors on the indicators, possible relations between indicators were investigated. These relations could help coastal managers to estimate values for one indicator based on a different one, whenever data are not available to compute the first one explicitly.

Fig. 11a shows how variations in MCL position can affect the probability of failure. The Figure shows that a seaward shift in MCL of 100 m, can lead to a decrease in probability of breaching of 1.2 orders of magnitude in logarithmic scale. Fig. 11b shows the relation between shifts in dune foot position and the probability of breaching. A seaward shift in dune foot position of 100 m has the potential to reduce the probability of breaching of about one order of magnitude. Those relations can be explained considering that a seaward shift of the MCL or of the dune foot position corresponds to an increase in sediment volumes at the shore and in the dune area, and as a consequence to an increase in safety level shown by a decrease in probability of breaching.

5. Discussions and conclusions

The present paper focuses on the identification of a number of coastal state indicators which describe and quantify the morphological development of the Holland coast. The overall morphological development of the coast has been described as a sum of pressure factors corresponding to long-term trends, yearly storminess and effects of nourishments. Relations between external pressure factors and indicators, and between different indicators were identified. The three chosen indicators (probability of breaching, MCL and dune foot position) were linked to three different coastal functions, and indicators, and between different indicators were identified. The chosen three indicators (probability of breaching, MCL and dune foot position) were linked to three different coastal functions, i.e. short term safety, medium-term safety and available space for nature and recreation.

A number of relations between indicators and external pressure factors (storminess and nourishment volumes) were identified and are summarized in Table 2. The Table shows both the slope of the regression line, identifying the relation between the indicators, and the confidence interval which defines the range within which this slope might vary.

Those relations provide easy-to-use rules of thumb for coastal managers, to assess the impact of external actions (e.g. nourishments) on certain functions (e.g. safety). They are of course not exact and are subjected to a certain degree of variability described by the confidence interval. Nevertheless, they can be the basis for simple cost-benefit analysis, for example replacing the nourishment volume with the actual nourishment cost, and their effect on the function with their monetized value. As an example, assuming an average cost for a nourishment of 5 €/m³, and considering a stretch of coast of 10 km, with an investment of 5 M€ spread on a 10-year time window, we can nourish the coastline with about 0.02 × 10 × 0.000 m—20 000 m³ at the end of 10-year period in which the investment will take place.

Also, the effects of possible changes in the natural pressure factor (e.g. storminess), for example due to climate change, can be easily estimated using these relations. Nevertheless, the effects of nourishment was found to be by far the most dominant process on the morphological development.

The coefficients in the relations presented above are clearly determined for the Holland coast case and depend on several local parameters such as the slope of the cross-shore profile, the wave climate, the hydrodynamic conditions, the grain size diameter, etc. The fact that relations could be determined for this case study allows scientists to translate them to their specific situation, in support of the decision making process of coastal managers responsible for the region.

Acknowledgements

This work has been done in the framework of the KPP-B&O Kust, financed by the Waterdienst (Rijkswaterstaat, The Netherlands). The authors would like to thank Gemma Ramaekers (Waterdienst), Dr. Ankie Bruens, Dr. Jan Mulder and Dr. Katherine Cronin (Deltas) for their comments and suggestions which resulted in an improved manuscript.

References


