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Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing

Leanne C. Cullen-Unsworth^{a,*}, Lina Mtwana Nordlund^b, Jessica Paddock^c, Susan Baker^d, Len J. McKenzie^e, Richard K.F. Unsworth^f

^aSustainable Places Research Institute, Cardiff University, 33 Park Place, Cardiff CF10 3BA, UK

^bWestern Indian Ocean – Community, Awareness, Research, and Environment (WIO CARE), P.O. Box 4199, Zanzibar, Tanzania

^cClimate Change Consortium of Wales at Cardiff School of Social Sciences and School of Earth and Ocean Sciences, Cardiff University, Cardiff, UK

^dCardiff School of Social Sciences and Sustainable Places Research Institute, Cardiff University, Cardiff, UK

^eCentre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Cairns, Queensland 4870, Australia

^fSeagrass Ecosystem Research Group, College of Science, Wallace Building, Swansea University, Swansea SA2 8PP, UK

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ABSTRACT

Seagrass ecosystems are diminishing worldwide and repeated studies confirm a lack of appreciation for the value of these systems. In order to highlight their value we provide the first discussion of seagrass meadows as a coupled social–ecological system on a global scale. We consider the impact of a declining resource on people, including those for whom seagrass meadows are utilised for income generation and a source of food security through fisheries support. Case studies from across the globe are used to demonstrate the intricate relationship between seagrass meadows and people that highlight the multi-functional role of seagrasses in human wellbeing. While each case underscores unique issues, these examples simultaneously reveal social–ecological coupling that transcends cultural and geographical boundaries. We conclude that understanding seagrass meadows as a coupled social–ecological system is crucial in carving pathways for social and ecological resilience in light of current patterns of local to global environmental change.

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1. Introduction

There is growing understanding of the links between ecological systems and social processes. The dynamics of these intrinsically linked, ‘coupled’ systems are seen to be determined by the feedback loops operating among them (e.g. [Holling, 1973](#); [Folke et al., 2010](#)). While there are different understandings of how the term ‘coupled’ can be understood, the term can, in the first instance, be used to refer to the links between natural and social systems. This is where the properties of social systems are in some sense linked to the properties of natural systems *on which the social system depends* ([Adger, 2000](#)). This understanding has been used to explore social systems that depend on a single ecosystem or a single natural resource, such as a mining or fishing community. Research has explored vulnerabilities in resource dependent economies and societies and exposed the links between natural resource depletion over time and economic decline within communities. This has highlighted the link between community decline

and unsustainable methods of natural resource management ([Adger et al., 2005](#); [Baker, 2006](#); [Liu et al., 2007](#)).

Policy makers have also taken note of the relationship between ecological systems and social processes. The UN Millennium Ecosystem Assessment ([MEA, 2005](#)) and the more recent UK National Ecosystem Assessment ([NEA, 2011](#)), for example, have highlighted human dependence on ecosystems for life support, wellbeing and socio-economic development. Such reports have also stressed how vulnerable these systems are to change and degradation caused by certain human activities. The more recent focus on ecosystem services and their accompanying ecosystem assessments resonate with the perspective that society depends on natural systems, providing a way of looking at this relationship in economic terms. Despite advances in the understanding of the links between social processes and ecological systems, more in-depth, theoretical and empirical investigation is required.

It is well known that coastal and island communities provide a clear example of the interactions between societies and nature, where people both depend on the marine environment to provide their basic life needs and where the marine environment is proving to be highly vulnerable in the face of social pressures. However, less is known about seagrass meadows as examples of this coupled relationship. In addition, seagrasses are valuable ecosystem service

* Corresponding author. Tel.: +44 2920879366.

E-mail address: Cullen-UnsworthLC@cardiff.ac.uk (L.C. Cullen-Unsworth).

providers which are often marginalised or missing from the global conservation agenda (Kenworthy et al., 2006; Duarte et al., 2008; Unsworth and Cullen, 2010; Nordlund, 2012). Therefore, in this paper, we shift empirical focus from a general discussion on the marine environment to a particular examination of the coupled social and ecological functions of seagrass meadows.

Seagrass meadows are important for their ecological functions and ecosystem services such as their role in food web dynamics, seascape interactions and ecological resilience potential (e.g. Duarte, 2002; Moberg and Rönnbäck, 2003). Coastal communities across the globe rely on seagrass meadows directly for food and livelihoods (de la Torre-Castro and Rönnbäck, 2004; Nordlund et al., 2010; Unsworth et al., 2010), but indirect services also include the cultural benefits obtained from seagrass meadows (Felger et al., 1980; Wyllie-Echeverria and Cox, 2000; de la Torre-Castro and Rönnbäck, 2004; Shokri et al., 2009). From temperate to tropical climates, seagrasses have been shown to create supportive conditions for other marine habitats and fisheries, stabilise the sea floor as well as effectively sequester carbon (Jackson et al., 2001; Orth et al., 2006; Fourqurean et al., 2012). The nearshore and inter-tidal location of seagrasses generally enables easy human access and multiple uses as well as exposing seagrass meadows to both terrestrial and marine based threats.

This paper explores the multi-functional role of seagrasses in their provision of services fundamental to human society. We apply a coupled view of the interactions between social systems and ecological processes as they relate to seagrasses, identifying both the social and ecological values of seagrass meadows and the dynamic interactions between them. This enables us, in turn, to identify the unintended consequences arising as a result of often externally driven stressors that cause imbalances in this relationship. Specifically we address the importance of seagrass meadows for food security and economic development across a range of local communities with varying levels of dependence on marine resources. We discuss resilience of this coupled social–ecological system, taking account of the management status of seagrass ecosystems and exploring the local to global implications of their conservation status. We argue that the dynamic relationship between society and ecosystems creates a variety of opportunities and problems for diverse communities in different places and times. To explore these interactions we present seven regional case studies, each of which highlights the intricate relationships between seagrasses and people.

2. Methods

This exploration uses a range of case studies conducted by the authors from 2001 to 2013, in different locations across the globe. The case studies are geographically, politically and culturally diverse and include tropical, sub-tropical and temperate seagrass systems from both developed and developing countries (Fig. 1).

The case studies used mixed, qualitative methods of data collection, including household surveys, elite and key informant interviews, focus groups, participant observation, market surveys, gleaning surveys, and seagrass habitat, invertebrate and fish assessments. The authors have been conducting detailed research at all of the locations (except Turks and Caicos and Inhaca Island) for at least 2 years. The Turks and Caicos Islands have been studied by the authors in detail during 2013 only and Inhaca, in detail, during 2005/2006. The authors have worked in the Wakatobi since 2004, Zanzibar since 2007, Green Island since 1992, Porth Dinllaen since 2011, and Laucala Bay, Fiji Islands since 2001.

3. Case studies

3.1. Wakatobi, Indonesia

The Wakatobi National Park (WNP) is centred in the Coral Triangle and comprises a range of marine ecosystems with high marine biodiversity (e.g. Pet-Soede et al., 2003; Unsworth et al., 2009) but suffering extensive anthropogenic overexploitation (Unsworth et al., 2010). Marine resources in WNP are heavily relied upon for food, raw materials and income (Cullen-Unsworth et al., 2011). The area has extensive reef and seagrass systems and is heavily exploited by a variety of fishery activities (Cullen, 2007; Cullen et al., 2007). Seagrass covers at least 1000 ha and is dominated by *Thalassia hemprichii*, *Enhalus acoroides*, *Syringodium isoetifolium* and *Halophila ovalis*.

WNP is home to a culturally diverse population of approximately 80,000 people including both islanders (known locally as *Pulo*) and traditionally nomadic sea people (known locally as *Bajo*). *Pulo* and *Bajo* communities have different cultural backgrounds, beliefs, values and levels of dependence on natural resources (Sather, 1997; Tomascik et al., 1997; Cullen et al., 2007; Pilgrim et al., 2008; Cullen, 2009). A forced shift from traditional nomadic lifestyles to a more sedentary lifestyle meant that *Bajo* peoples developed semi-permanent settlements in the shallow intertidal or subtidal areas in coastal regions but they remain predominantly fisher people and intertidal gleaners with highly limited livelihood alternatives (Cullen, 2007). In the WNP *Bajo* settlements are specifically located over shallow subtidal to intertidal seagrass meadows.

Seagrass in WNP is of high economic importance; particularly for its provision of critical habitat for fish and invertebrate species of subsistence, commercial and recreational value, as well as the provision of habitat for endangered Dugong and Green Turtle. At low tide intertidal seagrasses are exploited by men, women and children gathering a major portion of their daily nutrition. The reliance of fishers in WNP on seagrass meadows demonstrates their importance for both income and food security, but they also represent a source of spiritual fulfilment, with lives and lifestyles intricately interlinked to the seagrass system. Seagrass areas are also used for seaweed cultivation.

Data highlights that seagrass meadows represent a reliable and accessible fishing resource when other resources, such as coral reefs, are inaccessible (e.g. during poor weather). Most invertebrate gleaning (e.g. clams, sea cucumber and conch) activity (82%) is conducted within the intertidal and shallow subtidal seagrass meadows, but the role of gleaning is changing rapidly. A household survey in 2005 (Cullen, 2007) outlined gleaning as a supplementary food gathering or recreational activity with no households dependent on gleaned products as their main food source. Conversely in 2012, several *Bajo* households stated gleaned products as their primary source of protein with seagrass gleaning also viewed as a “backup livelihood” when food or money is scarce. Survey data from 2005 to 2006 demonstrates that 60% of invertebrate collectors utilise seagrass habitat, with seagrass remaining the preferential habitat for finfish for 40% of fishers (Unsworth et al., 2010). Approximately 70% of households preferentially consume fish from seagrass habitats; this is in contrast to around 20% who preferentially consume reef fish (Cullen, 2010; Unsworth et al., 2010).

Seagrass meadows in WNP are an essential resource base for local people contributing significantly to their wellbeing through the provision of fishing grounds, substrate for seaweed cultivation, nutrient cycling and, for the *Bajo*, a place to live. But these habitats are suffering from increasing anthropogenic pressures. Destructive fishing practices and overexploitation, particularly the use of static

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