Ecosystem service values and societal settings for coral reef governance

PhD thesis submitted by
Christina Chemtai Hicks,
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Australian Research Council Centre of Excellence for Coral Reef Studies
and the School of Business
James Cook University
Townsville, Australia, 4811

Primary supervisors: Prof Terry Hughes**,** Dr Josh Cinner
Co-supervisors: Prof Natalie Stoeckl, Prof Bob Pressey

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Your smile, our memories, forever in our hearts

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Abstract

People receive a range of benefits from nature, which are often referred to as ecosystem services – a term popularized by the Millennium Ecosystem Assessment (MA 2005). Those engaging with this new way of thinking about ecosystems, seek practical solutions to environmental decline, and specifically, solutions that link people with nature. Many core ecosystem service concepts emerged predominantly from the ecological sciences, but this new branch of literature also drew on environmental economics (particularly that branch which deals with non-market valuation methods) to demonstrate the importance of the benefits provided by nature.

Ecosystem service scientists thus explicitly focus on the relationship between people and nature, the aim being to influence the way people behave. However, ecosystem service science is yet to fully engage with many of the social sciences that examine values and behavior. For example, socio-cultural and motivational components of value are lacking from ecosystem service assessments. Further, although it is evident that people benefit from nature in different ways and to different degrees, current approaches do not always recognize this social differentiation, or its influence on behavior. Thus, while the last decade has seen considerable growth in the adoption of ecosystem service concepts by research programs, development agencies, funding bodies, and national policies, there is no generally accepted framework for integrating ecosystems service values into decision making.

In this thesis, I therefore set out to develop a better understanding of how people benefit from and value ecosystem services; and to determine how this knowledge could be integrated into the analysis and development of policy. To do so, I visited, and collected data from, 28 coral reef fishing communities in four countries across the western Indian Ocean (WIO): Kenya, Madagascar, Tanzania, and Seychelles, and drew on political science, social psychology, and welfare economics to address five objectives, specifically to:

1. establish what ecosystem services have been assigned monetary estimates of 'value' and to ascertain the implication of this work;

2. develop and apply a framework that allows one to evaluate the potential outcome of a set of rules, taking resource users' ecosystem service values and their social characteristics into consideration;
3. examine ecosystem service priorities and interactions at different levels of decision making;
4. integrate socio-cultural and motivational components of value to determine why bundles and trade-offs emerge;
5. establish how different people benefit from a supply of ecosystem services.

Objective one is addressed in chapter two, where I report on the results of a semi-quantitative meta-analysis of the coral reef valuation literature. Here I found a diversity of ecosystem services had been 'valued' (i.e. assessed in monetary terms). However, studies tended to focus on one or two services at a time, and different services tended to be 'valued' using fundamentally incomparable methods. Thus comparisons could not be made across study, or service. All of the valuation studies contained in the review measured the benefits flowing to specific beneficiaries and at a specific scale. However, this information was not always readily apparent. Furthermore, differences in the ability of beneficiaries to pay (i.e. comparing wealthier with less wealthy individuals) created apparent differences in ecosystem service values. In other words, many of the observed differences in 'value' were found to be an artifact of method. This analysis thus highlighted the need for ecosystem service assessments to: a) measure multiple ecosystem services; b) employ similar valuation methods; and c) acknowledge whose values are being counted.

As a result of this review, and in the remainder of my thesis I examined multiple ecosystem services, using methods applied consistently across all services, and clearly articulated whose values were being counted. To do this I collected qualitative and quantitative data about people's ecosystem service priorities, their underlying motivations, and their contextual characteristics via focus group and interviews with resource users, managers, and scientists.

To meet objective two, I developed an analytical framework, incorporating values, contextual characteristics, and behavior to determine the outcome of policy options. I applied this framework to a case study in the Seychelles in chapter three, which illustrated

how different resource users prioritized fundamentally different ecosystem services and how these differences were associated with specific social characteristics. A key finding here, therefore, was that ecosystem service values and resource users' contextual characteristics together determine how people are likely to behave under alternate policy options.

I therefore used insights from chapter three's case-study to guide my data collection activities and analysis for the remaining chapters of my thesis. In chapter four, I looked at ecosystem service priorities at different levels of decision making (objective 3). I found both similarities and differences in the priorities of different actors (fishers, managers, and scientists). Most interesting however, were the marked differences in the bundles and trade-offs associated with different actors' ecosystem service priorities. Specifically, the interactions associated with fishers' ecosystem service priorities were almost entirely distinct from scientists. For example, fishers considered fishery and habitat values to trade-off with one another, where scientists did not see an interaction. Managers however, overlapped with both fishers and scientists on a number of perceived bundles and trade-offs, suggesting a potential role for managers in navigating trade-offs and brokering agreement.

In chapter five I integrated concepts from social psychology on human values as motivations (objective 4), finding that people's motivational goals for valuing ecosystem services aligned with the most commonly used measures of value-types from social psychology. This relationship implies ecosystem services are structurally related: specific services are close to one another, whereas others are in opposition. This lends insight into why bundles and trade-offs in ecosystem service priorities emerge. The distribution in ecosystem services can therefore be understood from their underlying motivations. Critically, I found this same distribution in the independent assessments of ecosystem service priorities.

Finally objective 5 focused on the fact that the benefits which people gain and the values they assign to ecosystem services are likely to be dependent on their *ability* to benefit from a given supply of ecosystem services. In other words: people benefit from nature when they have access to it. Access manifests in many ways. For example, people may need legal access before they can benefit from a resource. In the same way people may need certain

knowledge, or technology, or they may need to attain a certain status in society before they can benefit. As reported in chapter six, I found that access mechanisms were strongly related to how people perceive benefits from ecosystem services. Social and institutional access mechanisms, in particular, were found to explain most of the benefits people perceived.

Throughout my thesis, trade-offs and bundles emerged as a critical component of people's ecosystem service priorities. Common trade-offs emerged that align with the literature (e.g. supporting with provisioning services) suggesting trade-offs may be absolute. Bundles however, were more variable. The distribution in people's ecosystems service priorities can be understood from their underlying motivations, and are associated with specific social and institutional characteristics. Furthermore, the ability of people to benefit, and therefore value a variety of ecosystem services is also associated with social and institutional characteristics that enable them to access resources. The mutability of bundles and the influence that social characteristics have, may provide tools that managers can employ in brokering decisions over the management of ecosystem services. My PhD has thus highlighted the importance of incorporating social theory into ecosystem service science and the potential for addressing bundles and trade-offs in people's ecosystem service values.

Contributions during PhD

Peer-reviewed publications

Hicks C.C., McClanahan T.R., Cinner J.E., Hills J.M. (2009) Trade-offs in values assigned to ecological goods and services associated with different coral reef management strategies. Ecology and Society 14: 10.

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[1] Chapter two

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[2] Chapter four
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Chapter 1

Introduction

Chapter 1. Introduction

The world is facing a natural resource crisis precipitated by natural, climatic, and anthropogenic stressors that are predicted to increase in frequency and intensity; (Barnosky et al. 2012; Hughes et al. 2007; IPCC 2007; Acheson 2006; Chapin et al. 2000;). A consequence of these pressures is a loss in the provision and value of the goods and services that humans derive from nature. These goods and services, or ecosystem services, refer to the benefits that people receive from nature (MA 2005); and can include: direct benefits (such as food); indirect benefits (such as regulating the climate); intangible benefits (such as a good feeling from knowing nature exists); and the benefit of knowing that we continue to have the option to benefit from goods and services into the future (Stoeckl et al. 2011; Freeman 2003; Bateman et al. 2002).

1.1. An emerging philosophy

The Millennium ecosystem assessment (MA 2005; 2003) catalyzed an ecosystem services approach that represented a practical response to the trend toward environmental decline. The concept of ecosystem services seeks to link the functioning of ecosystems to human well-being (Figure 1.1.). Scientists believed that reframing ecosystem function and biodiversity and highlighting its importance to humans would increase public consciousness of the importance of biodiversity[4] (Ehrlich & Wilson 1991; Ehrlich & Mooney 1983). The underlying rationale was that if people could be made fully aware of the benefits provided by nature, they would incorporate those benefits into decision making (by governments, companies, and individuals) and people would behave in a manner that conserves an optimal amount of nature. Ecosystem benefits have previously been classified in a number of ways based on functions (de Groot et al. 2002), descriptions (Moberg & Folke 1999), or how people use the benefits (Bateman et al.

[4] References to nature's services, concerns over how people interact with nature, and the need to maintain areas of nature have been echoed in various forms through the years (e.g. Plato, Wordsworth, Malthus, Marx, Leopold, Marsh). For a brief history on natural capital and environmental thinking on nature see Hicks et al (2010).many of the ideas in ecosystem services reflect developments in economics (e.g. Pearce & Turner 1989, Krutilla 1967, Freeman 2003, Arrow et al. 1995).

2002)[5]. Building on these ideas and focusing on function, the Millennium ecosystem assessment (MA 2003) identified four distinct categories of ecosystem services benefits, organized along functional lines: provisioning[6], regulating[7], supporting[8], and cultural[9] services (Figure 1.1). In the past decade an ecosystem services approach has gained significant support from research, government, and international institutions because it forms a compelling and rational model that has clear, practical applications (Martin et al. 2010).

This approach tends to assume a linear, causal, relationship between the environment, people's values, and outcomes (Figure 1.2). The environment (ecosystem processes and functions) produces services that are of benefit to humans and thus valued (Figure 1.2). These values influence human behavior, which in turn creates an outcome (Figure 1.2). This causal relationship suggests if science can demonstrate the importance of nature then people will 'value' the environment 'appropriately' and behave 'rationally' to conserve an optimal amount of nature. Simplified heuristics are invaluable for tackling complex problems but, the robustness of this relationship has been put into question. Many measures of human wellbeing are steady or increasing despite considerable evidence that the environment is in decline (Barnosky et al. 2012; Raudsepp-Hearne et al. 2010b).

[5] Environmental economics classifies good or services into use values (include direct consumptive uses- such as food from a fishery; as well as indirect non consumptive uses –such as enjoyment from recreation) and non-use values (which refer to the importance attributed to the simple existence of something that is not used) (Bateman et al. 2002).

[6] Provisioning services reflect goods and services produced in the ecosystem and include food, water, timber, and fibre.

[7] Regulating services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes, for example coastal protection.

[8] Supporting services represents the ecological processes that underlie the functioning of the ecosystem and include soil formation, photosynthesis, and nutrient cycling.

[9] Cultural services are "The non-material benefits people obtain from ecosystems" and they that provide recreational, aesthetic, cognitive, and spiritual benefits" (MA 2003)

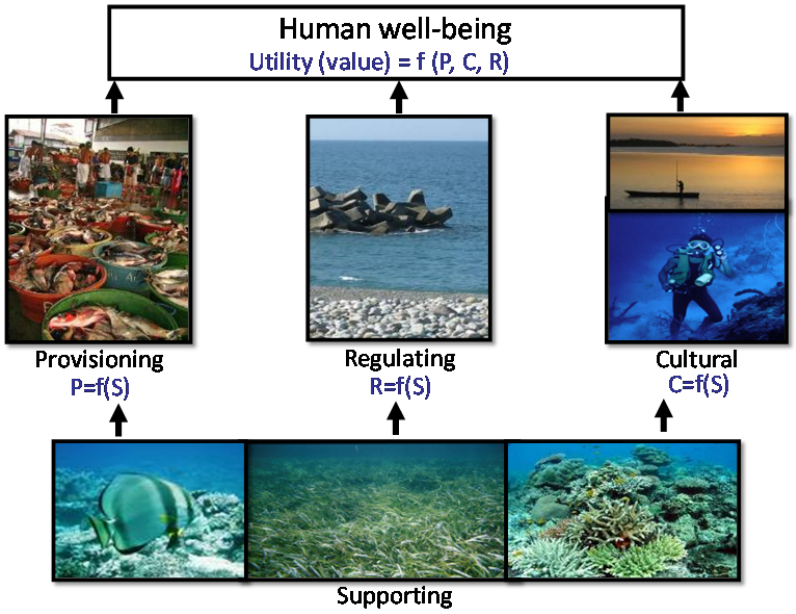


Figure 1.1 A conceptual framework showing the four ecosystem service categories.
The Millennium Ecosystem assessment (MA 2003) categorizes benefits into four distinct groups that serve to link ecosystem processes and function to human well being. Supporting services represent the ecological processes that underlie the functioning of the ecosystem and include soil formation, photosynthesis, and nutrient cycling. Supporting services are necessary for the provision of the other three categories of services provisioning, regulating and cultural. Provisioning services reflect the products that we gain from ecosystems and include food, water, timber, and fiber. Regulating services result from the capacity of ecosystems to regulate our environment and include climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes, for example coastal protection. Cultural services are the non-material benefits people obtain from ecosystems that provide recreational, aesthetic, cognitive, and spiritual benefits (MA 2003).

Figure 1.2 Causal pathway between the environment, human values, and management outcomes.
The ecosystem processes and functions of the environment are expected to generate ecosystem services that are of benefit to people. People are therefore expected to value these ecosystem services. Valuing ecosystem services is expected to motivate human action to produce an outcome where by an optimal amount of nature is conserved or used sustainably Adapted from deGroot et al 2009.

Consequently, a number of assumptions inherent in this huerestic are beginning to be questioned (Carpenter et al. 2009). Here I highlight three key areas of investigation; first, although it is not generally questioned that ecosystem processes and functions are of benefit to people, it is less clear how biodiversity contributes to this benefit (Mace et al. 2011). Second, if we accept that ecosystems produce benefits to people in general, it is not clear how these benefits are socially differentiated (i.e. do different people benefit in different ways) (Daw et al. 2011). Third, if we can demonstrate a benefit to people, resulting in ecosystem service value, it is not clear whether people's values will lead to a change in behavior (Seymour et al. 2010). A number of ecologists are exploring the relationship between biodiversity and ecosystem function, process, and service (Mace et al. 2011; Kremen 2005). But if ecosystem service science is to inform decision-making processes as intended, it needs to develop a more robust understanding of how people benefit and behave in nature (Turner et al. 2010; Daily et al. 2009; Fisher et al. 2008). Fortunately, ecosystem service science can be complemented by parallel fields of research that examine social phenomena, develop social theory, and determine people's likely responses to a set of policy choices. For example, environmental economics, human ecology, and anthropology investigate the ways in which individual and social values relate to or are dependent on the environment. Social psychology, behavioral economics, and human geography examine the way people's behavior, and behavior intentions, are influenced by individual values, social values, and key contextual characteristics. Political science evaluates how and in what way institutions[10] affect people' behavior.

The aim of my thesis is, therefore, to develop a better understanding of how people benefit from and value ecosystem services; and to determine how this knowledge can be integrated into the analysis and development of policy. In the next section, I will highlight four key gaps that limit the influence ecosystem service science can have on decision making:

- A coherent framework integrating ecosystem service values into decision making is lacking.

[10] Institutions are the shared sets of rules (formal and informal e.g. norms) that individuals (or organisations) in a given setting are expected to adhere to (discussed on page 29).

- Interactions between different services are generally not addressed.
- Socio-cultural and motivational components of value are seldom considered.
- Social differentiation in how people benefit is not always acknowledged.

I then address these gaps in my thesis, seeking to fulfill the following five objectives, namely to:

1. establish what ecosystem services have been assigned monetary estimates of 'value' and to ascertain the implication of this work
2. develop and apply a framework to evaluate the potential outcome of a set of rules taking resource users' ecosystem service values and their social characteristics into consideration;
3. examine ecosystem service priorities and interactions at different levels of decision making.
4. integrate socio-cultural and motivational components of value to determine why bundles and trade-offs emerge; and to
5. establish how different people benefit from a supply of ecosystem services.

1.2. Progress in quantifying ecosystem service benefits

Ecosystem service benefits are generally thought of as ecosystem service values. However, there is considerable variation in how values are conceptualized and measured. Values about ecosystem services can be divided into different domains (de Groot et al. 2010; MA 2003); for example, ecological, economic, and socio-cultural values.

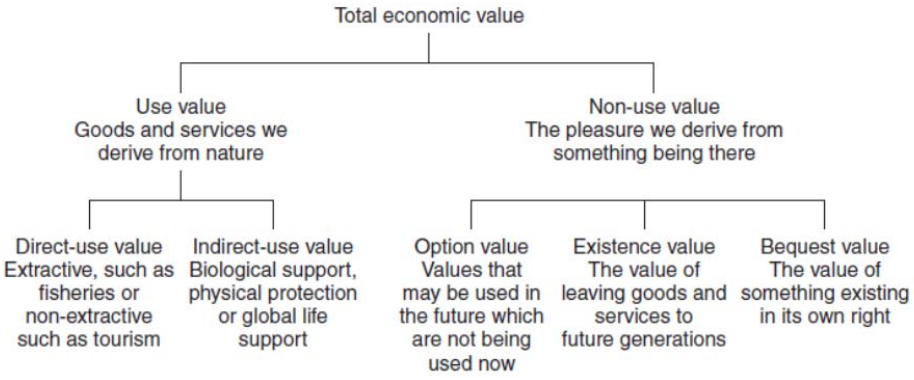
1.2.1. Ecological concepts of values

Ecosystem service science emerged predominantly from the ecological sciences generating concepts linking biodiversity, ecosystem function, process, and service.. Ecological values thus attempt to capture the state of an ecosystem and are generally measured with ecological indicators representing supporting services (Kremen 2005). For example, indicators obtained through functional and biodiversity approaches (e.g. species diversity, functional abundance, and functional redundancy (Nystrom et al. 2008; Kremen 2005; Chapin et al. 1998) capture

some of the supporting services, which are known to underpin the very existence of all other services. Although biodiversity is often equated with or viewed as an ecosystem service, both biodiversity and ecosystem services are complex concepts, and many ecologists are worried that current efforts to integrate these concepts fail to accurately represent ecological science (Mace et al. 2011; Kremen 2005).

1.2.2. Economic concepts of value

Environmental and resource economics have well-developed methodologies that seek to quantify the benefits nature provides to humans (Bateman et al. 2002; Arrow & Solow 1993). These approaches have been used in policy for nearly a century; for example, the benefit of clean air was first accounted for in the 1920's with the introduction of a Pigouvian tax, designed to penalize polluters and attempt to influence their behavior (Pigou 1920). Because environmental economics had an established history in accounting for environmental benefits see (Bateman et al. 2002; Pearce & Turner 1989), it was natural for ecosystem services to draw on economic valuation approaches (e.g. Sukhdev et al. 2010; Turner et al. 2008; Cesar et al. 2003; Costanza et al. 1997). Although there are some differences between economic and ecosystem service concepts of values terminologies and approaches are often used interchangeably (see chapter 2). Environmental economics classifies the benefits associated with the environment into use and non-use values, use values can be further split into direct and indirect use values (Hicks et al. 2010a; Moberg and Folke 1999; Spurgeon 1992; Freeman 2003). Direct use values relate to goods and services that can be consumed directly (e.g. fishery goods), indirect use values relate to functions and services that are enjoyed indirectly (e.g. habitat control), and non use values include existence (e.g. the value in knowing something is there even is it is not currently, and never will be used.) and bequest (e.g. the value in knowing our children will be able to benefit from something) values (Figure x). A final category, option, can be classified as a use and/or a non-use value, as it refers to all the values that may be used in the future which are not being used now (Fig. x).



In welfare economics the price of a commodity will be determined by the relationship between the quantity available and the demand for that commodity. True welfare estimates of the value of environmental goods are therefore based on people's demand for the environmental good in question, at a given quantity of supply. Real or hypothetical demand curves are constructed based on subjective preference theory of value where value originates in the minds of individuals. For example, a demand curve can be based on quantities of a good bought or sold in a market (e.g. for fishery or recreation), alternatively where markets do not exist a hypothetical demand curve can be constructed using an approach where individuals are asked how much they would be willing to pay (WTP) for an additional unit of the good in question, or willing to accept (WTA) to lose a unit of the good in question (e.g. for bequest). The difference between WTP and WTA is theoretically greatest when there is less substitutability, and in most cases in which hypothetical demand curves are constructed the divergence between WTP and WTA is small (Bateman et al., 2002).

1.2.3. Socio-cultural concepts of value

Socio-cultural values capture a diversity of meanings, for example they may capture people's cultural identity and the degree to which that relates to ecosystems (Stedman 2002, 2003), or they may reflect an individual's motivations in context of their needs and constraints (Rokeach 2008; Schwartz 1994; Kluckhohn et al. 1961). In psychological theory, values are an expression of people's motivational goals or desires, in context of their needs and constraints (Rockeach 2008; 1973; Schwartz 1992; Kluckhohn 1961). In other words, values are what people desire

and why; and therefore, are a strong indication of behavior (Song et al. 2013). Similar to an ecosystem services or environmental economics approach it is generally accepted that a small number of stable values exist (Rockeach 1973, Hofsted 2011). For example, in a widely adopted framework, Schwartz (1992) identified ten basic human value types (Benevolence; Universalism; Self Direction; Stimulation; Hedonism; Achievement; Power; Security; Tradition; Conformity) that cluster into four domains (*traditionalism*, *openness to change*, *self-transcendence*, and *self-enhancement*). In addition to identifying value types, scholars have developed and applied various value-measurement systems that quantify the extent to which individuals prioritize the identified values as a guiding principle in their lives (e.g. Schwartz 1996, Rockeach 1973; Morris 1956; Vernon & Allport 1931). However, ecosystem service assessments tend to focus on ecological or economic value domains, rather than socio-cultural, a focus that is largely attributed to the field's origins (Spash 2012; 1999).

Ecological concepts of value tend to be used to quantify supporting services and are generally treated independently of other types of value (economic and socio-cultural) and categories of service (provisioning, regulating, and cultural). Economic concepts of value can be used to measure provisioning, cultural, and regulating services. For example, provisioning services, which include the benefits gained from a fishery, are often calculated using a market value approach based on the price and quantity sold in a market setting (Hicks et al. 2009; Bateman et al. 2002). Regulating services, such as coastal protection, can be calculated using a damages avoided approach that values the infrastructure protected; or a replacement cost approach that calculates the cost of constructing an artificial structure, such as a coastal wall, that would provide the same coastal protection (Hicks et al. 2009; Bateman et al. 2002). Cultural services such as recreation can be quantified using a travel cost method (Hicks et al 2009). However, different components of these the same services can equally be measured using socio-cultural concepts of value. For example, we can examine how people prioritize cultural, provisioning, and regulating services as well what motivated them to assign those priorities. An emerging literature on cultural services and values has begun to better integrate broader social science theories and concepts into ecosystem service research (Satz et al. 2013; Daniel et al. 2012; Chan et al. 2012). This work is attempting to disentangle the way cultural services are conceptualized

and to provide new frameworks and approaches designed to account for these services within ecosystem assessments. However, ecosystem services science is dependent on an accurate understanding of, and ability to anticipate social phenomenon – i.e. how individuals and societies are likely to behave towards nature. Socio-cultural and motivational components of value therefore need to be considered beyond cultural services.

Although economic valuation approaches are widely used and well accepted (Arrow & Solow 1993). They, they remain contentious and their ethics debated within economics (Spash & Aslaksen 2012; Peterson et al. 2010 Stoeckl et al. in review). This is in part because the power structures in actual markets distort prices (Kapp 1970) Furthermore, because the majority of economic valuations generate dollar estimates of people's preferences, these estimates face the additional challenge that they cannot be independent of income. Environmental valuations are therefore at least partially determined by the ability of people to pay rather than only by resource scarcity and/or benefit flows (Stoeckl et al. in review). Those who are able to pay more will seem to have a greater demand. A number of weighting systems have been developed to redress this balance; however, they have failed to gain any traction and therefore valuation approaches remain biased. An additional challenge faced by both psychologists and economists results from the tendency to pool and average individual values to determine social measures of value. This process of aggregation tends to overshadow within culture variation (Hitlin & Piliavin 2004) and makes assumptions about how individuals behave in groups (Vant 2009). Consequently, there is no ideal or unique way to combine individual choices to obtain a group choice (Arrow 1951). Furthermore, there is the risk that those individuals whose values are not represented by the mean will be marginalized in decision-making processes (Pagiola et al., 2005).

Ecosystems are complex, interdependent systems; scientists therefore acknowledge the need to assess multiple ecosystem services simultaneously (Raudsepp-Hearne et al. 2010a; Carpenter et al. 2009; MA 2005; Foley et al. 2005). This suggests ecosystem service assessments should include economic, ecological, and socio-cultural values (de Groot et al. 2010). However, the different value domains represent divergent disciplines that differ in how knowledge is seen to

be formed – i.e. in their methodologies. Integrating fundamentally different approaches to knowledge formation would require methodological pluralism which can be both challenging and contentious (Spash 2012; Norgaard 1989). This has resulted in many researchers focusing on one or two services that tend to be most apparent or easily measurable; such as fishery or recreation (MA 2005; Hicks 2011). The inclusion of ecosystem in decision making processes is therefore often based on measurability rather than on a reflection of people's priorities or motivations. There is a clear gap in ecosystem service assessments where a better understanding and integration of socio-cultural and motivational values is needed.

In chapter two I therefore focus on objective 1, conducting a quantitative review of the literature to establish what ecosystem services have been estimated and the implications of this work. This review focuses on the western Indian Ocean where my thesis is based.

1.3. Frameworks to inform decision making

Ecosystem service science is intended to inform a decision making process and ultimately influence how people interact with nature (Daily et al. 2009; Fisher et al. 2008). Decision makers, who guide how people interact with nature, employ a limited set of tools[11] or rules[12]. Decision makers therefore need to be able to evaluate the potential outcome their choice of rules will have. In order to inform a decision making process, ecosystem service values need to be integrated into a broader evaluative framework.

Frameworks are heuristic tools that help to identify the critical components of a system (Ostrom 2011; Ostrom & Ostrom 2011). A framework can provide an overarching language that allows the analyst to combine multiple, compatible, theories when exploring complex phenomena. Multiple frameworks have been applied to the analysis of ecosystem services (Nahlik et al. 2012). Existing frameworks tend to be built on an ecological base, integrating economic components of the system (Armsworth et al. 2009; Daily et al. 2009), although recent iterations including social components (Chan et al. 2012). However, these frameworks tend to

[11] Tools can be thought of as a management action- i.e. restrict fishing

[12] Rules are shared understandings among those involved that refer to enforced prescriptions about what actions (or states of the world) are required, prohibited, or permitted.

be conceptual so do not identify data useful for the analysis of human well-being (Nahlik et al. 2012). Furthermore, influencing human behavior is a social phenomenon and ecologically based frameworks fail to account for the differences that exist between people, or the interactions inherent in social systems. The Institutional analysis and development framework (IAD) was built on the analysis of social actors and as such may provide a valuable tool to link ecosystem service science with decision making processes (Ostrom 1990).

The shared sets of rules (formal and informal e.g. norms) that individuals (or organizations) in a given setting are expected to adhere to represents an institution[13] (Crawford & Ostrom 1995). These rules dictate how individuals may or may not behave; who they can interact with; the roles individuals occupy; and how decisions are made. An institution can therefore refer to a local fishing community, a regional management organization or a national government. Ostrom and colleagues (Ostrom 2011; Crawford & Ostrom 1995; Ostrom 1990) developed an institutional analysis and development (IAD) framework (fig 1.3) for assessing how the rules adopted by individuals and/or organizations address their problems and lead to desired outcomes (Imperial 1999). The IAD is a well-established, robust framework that is well suited to examining challenges of collective action, strategic behavior and choices (Koontz 2005). This framework has been applied to the analysis of different empirical settings addressing various issues, such as metropolitan organization, theory and sustenance of public goods, privatization and most notably- the governance of common-pool resources (Ostrom 2010; 1994).

[13] There is a great deal of variation regarding what an institution is but our definition can include a formal management body (Kenya's fisheries department) or informal management bodies (for example lead by a village elder). Both types adhere to formal rules, fishing cannot occur within a park, illegal gears may not be used, and informal rules, women do not fish).

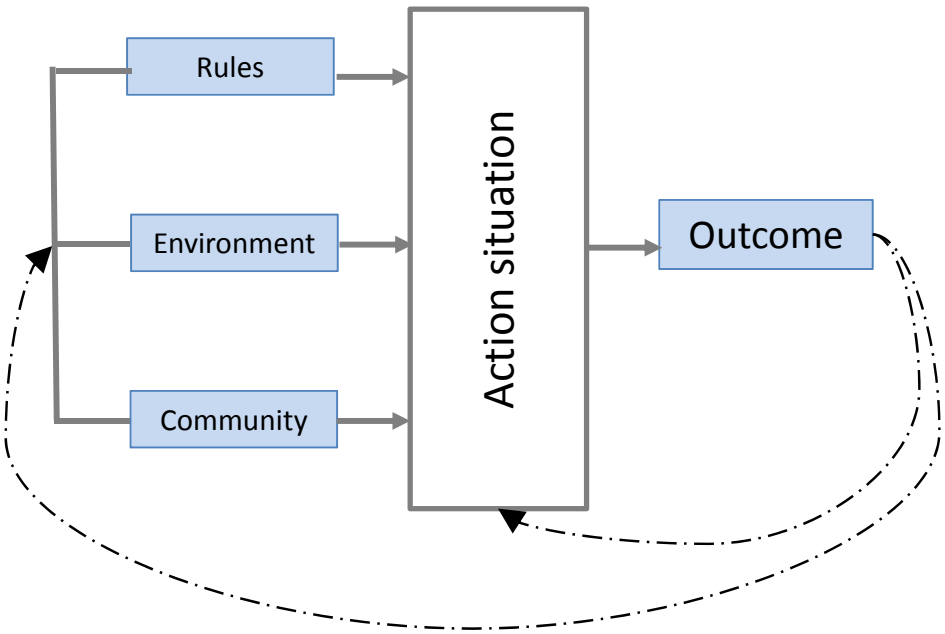


Figure 1.3 An Institutional analysis and development framework
This framework can be used as a heuristic to assess the likely outcome of a given set of rules in a specific setting. Alternatively this framework can guide the development of rules in a specific setting in order to achieve a desirable outcome. Analysis occurs at the action situation level which contains the actors and the setting. The setting is influenced by the environment, the rules, and the community. The outcome in turn influences the action situation, the environment, community and rules. Adapted from Ostrom (2011).

The IAD consists of an action situation, the biophysical environment, the community, rules in use, and an outcome (Fig 1.3). The action situation is the core conceptual unit of the IAD framework. It represents the social spaces where individuals interact, exchange goods and services, solve problems, dominate one another, or fight (Ostrom & Ostrom 2011; Ostrom 2011; 2009; 1999). The action situation is affected by the characteristics of the biophysical environment, the community in which an action situation is located, and the rules in use (Ostrom 1994). Actors are the individuals within a community that are influenced, or influence, the rules. Actors exist in the action situation, but remain analytically distinct from the setting.

IAD analysts tend to use an implicit or explicit theory or model of human behavior to make inferences about the likely behavior of an actor in a situation, and consequently the outcome. In doing so the analyst makes assumptions about how and what the actors value, what resources, information, and beliefs they have; what their information-processing capabilities

are; and how they make decisions (Ostrom 2011; Ostrom 2009). The most well-established formal model of individual behavior used in institutional analysis is *homo economicus,* as developed in neoclassical economics and game theory (Ostrom 2011). *Homo economicus*, assumes actors have well-ordered and articulated preferences; complete information; and that they maximize the net value of expected returns to themselves. Although, these assumptions are controversial and being challenged on many fronts, most ecosystem service assessments and policy uptake are influenced by *homo economicus* (Martin et al. 2010; Peterson et al. 2010).

Many institutional analysts use broader conceptions of individual actors that account for social costs and benefits (Williamson 1979); incomplete information (bounded rationality) (Simon 1972); and selective learning (fallible learners) (Ostrom 2011). Although the IAD allows for these broader concepts of individual actors, analysts are still bound by specific models of human behavior that make *a priori* assumptions about people's values (Ostrom 2011). This means that the IAD does not consider different values, motives, preferences, and beliefs that different actors may have (Fidleman, 2006). The IAD is clearly an important framework, capable of improving ecosystem sciences capacity to understand and account for many influences on human behavior but would benefit from a broader concept of value.

I therefore adapt the IAD to an ecosystem services context and integrate a broader concept of people's ecosystem service values. Specifically, I expand the action situation to include actors, their values, their social characteristics, and their intended behavior. In this way I intend to account for additional influences on the way people are likely to behave and (Figure 1.4.). Implicit in achieving an outcome is the need for rules to influence the behavior of the relevant actors. People's values, and their social characteristics, influence their behavior. To illustrate these relationships, I briefly provide an example from coral reef fisheries which is the system the work in my thesis is based on. Conservation objectives are often designed on coral reefs using rules that prohibit fishing in certain areas (Graham et al. 2011). However, people who prioritize fishery values above all else are unlikely to want to stop fishing. Similarly, fishers who have no alternative sources of food or income are equally unlikely to want to stop fishing. Although concepts and measurements of value, particularly within economics, are increasingly

incorporating social characteristics (e.g. through bounded rationality and fallible learners) I have chosen to retain social characteristics as a separate category to allow me to draw on alternate theories. This adaptation of the IAD is flexible enough to allow for broader concepts of value; it does not require the analyst to prescribe to one specific concept of human behavior and allows multiple theories of value to be represented and tested.

To meet objective two, I therefore apply this framework (in chapter three) to a case-study on the Seychelles where I explore the likely outcome of a set of rules when actor's values and social characteristics are taken into consideration. I define the rules based on two commonly adopted policy options (a decentralized and incentive based approach to fisheries management). I examine actor's values through a broad economic lens of values as priorities (Bateman et al. 2002), and their social characteristics through the lens of common property theory (Ostrom 2007a, b).

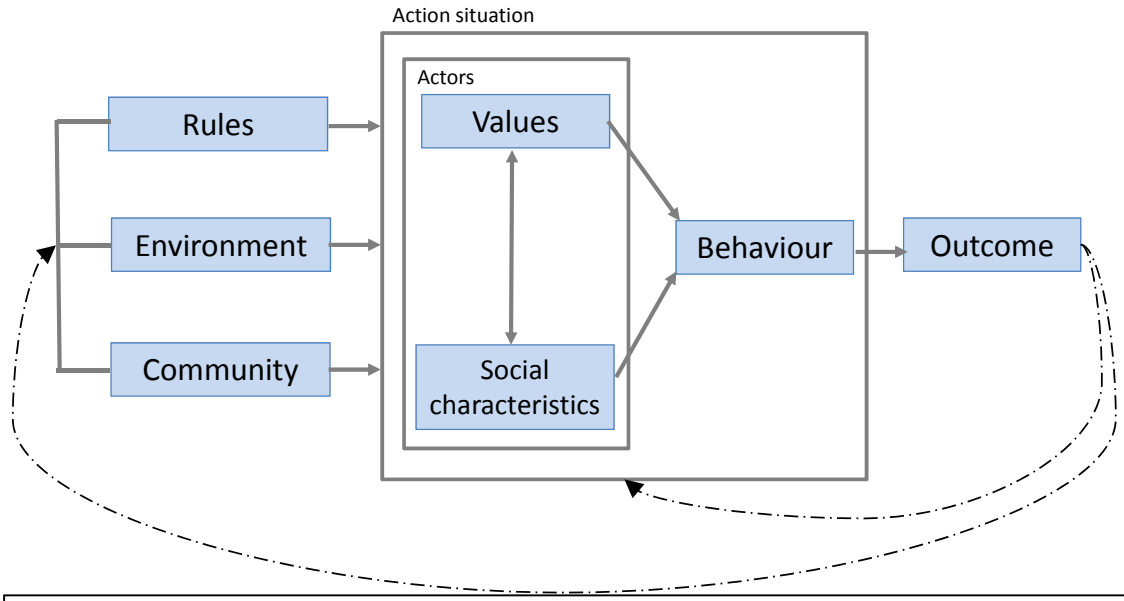


Figure 1.4 Value-centric IAD frame work.
This framework can be used as a heuristic to assess the likely outcome a given set of rules in a specific setting are likely to achieve, where actors hold specific ecosystem service values and reflect certain social characteristics. Analysis occurs at the action situation level, which contains the actors and the setting. The setting is influenced by the environment, the rules, and the community. The actors possess specific ecosystem service values and certain social characteristics influence actors' ability to benefit from specific ecosystem service values; the combination influences their behavior which creates an outcome. The outcome in turn influences the action situation, the environment, community and rules

1.4. Different levels of decision making

In reality, an action situation does not occur in isolation, but is linked to and influenced by other action situations. This can be at the same level of decision-making (involving, for example different stakeholder groups or adjacent communities), or it may involve higher and lower levels of decision-making (for example, local and national resource management policies). The IAD framework consequently identifies three stages where rules are made: the operational choice level; the collective choice level; and the constitutional choice level (Ostrom & Ostrom 2011) (Figure 1.5). The top level is the constitutional choice level (Figure 1.5), where rules for the collective choice level are made and set. These rules, for example, dictate who is allowed to participate in the collective choice level and who is allowed to represent and articulate the preferences of various sectors of society. The second level is the collective choice level, at this level rules for the operational choice level are made and set (e.g. what gears fishers are allowed to use, who is allowed to fish), usually in a group setting (Figure 1.5) (e.g. in a community committee or regional management committee).The lowest level of decisionmaking and action is the operational choice level. At this level, decisions influence how people interact with their resources (for example a fisher decides to fish his usual spot) (Figure 1.5). Each stage involves a set of actors using a set of rules, interacting with their community and environment, to develop an outcome or new set of rules.

To illustrate these three levels, I briefly provide an example from Kenya, one of the study locations in this thesis. Historically in Kenya, ministerial departments were responsible for commissioning research that would inform how fishing should be formally controlled. This represents a centralized approach to rule making where the ministerial departments represent the constitutional choice level, the scientists and managers that they commission to research the topic represent the collective choice level, and the resource users who were required to adhere to the resultant rules represent the operational choice level. In 2005, a new law was written for the fishing sector that devolves power down to local representatives (Cinner et al. 2012a).

This new legislation makes it possible for local fishing communities to make and set rules concerning how resources are used. Although the government remains the constitutional choice level, the local communities can make up both the collective choice and the operational choice level. Of course, this is the case for formal rule making. When considering informal rules, under both scenarios (centralized and decentralized), all three levels of decision making tend to occur within the local communities.

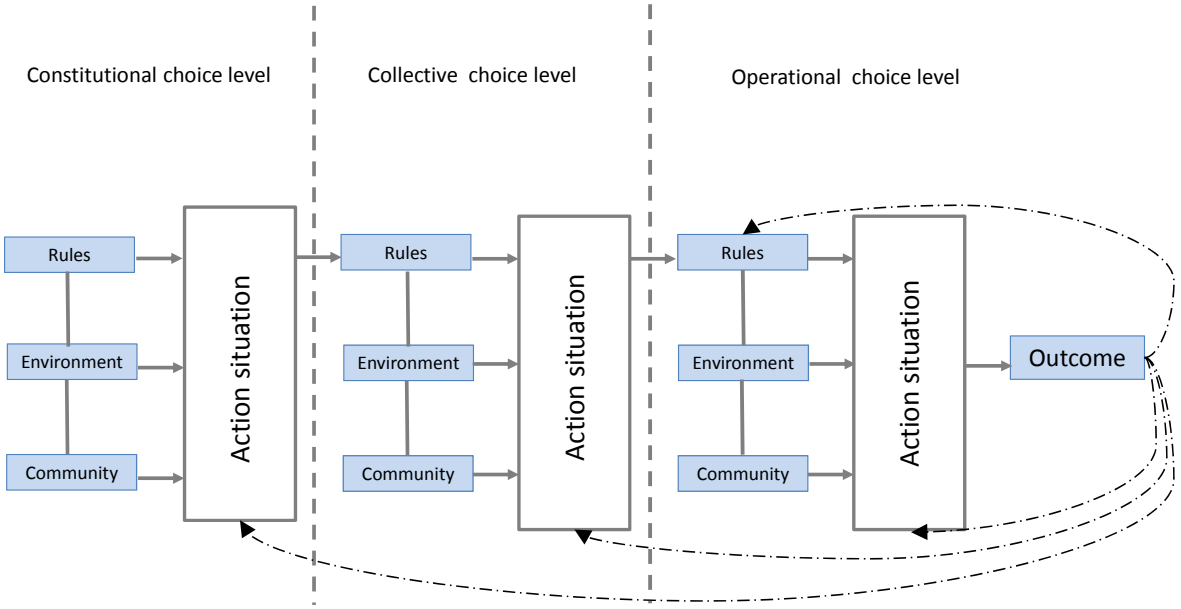


Figure 1.5 Levels of institutional analysis. Adapted from Ostrom (1999).

Rule-making happens at three institutional levels the operational choice level; the collective choice level; and the constitutional choice level. The lowest level of decision making and action is the collective choice level. At this level decisions influence how resources are used. The second level is the collective choice level where operational choice rules are made and set, usually in a group setting (eg community committee or regional management committee). The third and top level is the constitutional choice level. Here collective choice rules are made and set. These rules for example dictate who is allowed to participate in the collective choice level, and who is allowed to represent and articulate the preferences of various sectors of society. The outcomes of the operational choice level feedback to affect the environment, community, and rules in the collective choice level; as well as the action situation at all three levels.

A starting point for assessing how of a set of rules lead to outcomes, would be to define the set of rules in terms of the rules as well as the actors involved informing those rules (Ostrom & Ostrom 2011). I therefore expand my original framework (Figure 1.3) that focuses on resource users[14] and the rules employed to influence how they extract resources, to include the decision makers[15] who are involved in making and setting the rules that guide how resources are extracted (Figure 1.6).

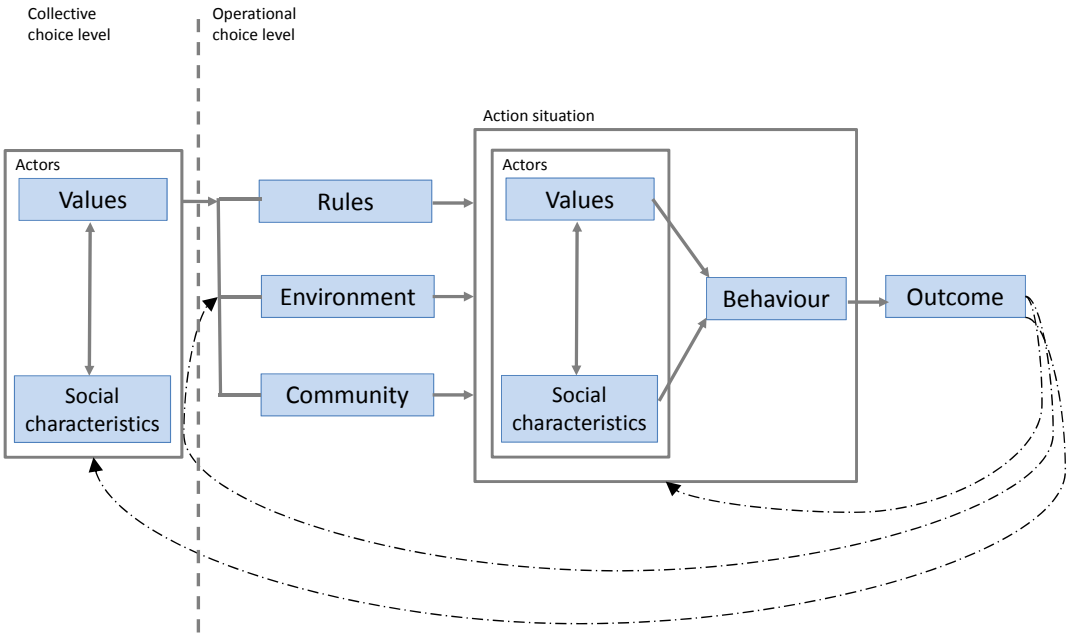


Figure 1.6 Expanded value centric frame work.

I expand my framework to account for differences between the actor's values and perceptions at two levels of decision making. The suitability of the rules developed by decision makers (collective choice level) for the resource users (operational choice level) will depend on how these groups of actors perceive and value ecosystem services.

[14] Operational choice level
[15] Collective choice level

The suitability of rules, perceived costs, benefits, and therefore potential outcomes, will depend on whether the actors involved in setting the rules and those required to change their behavior to adhere to the rules share a common vision, or mental model, of how the environment is valued and understood.

I address this issue in chapter four – which focuses on objective 3. Here, I examine ecosystem service priorities and interactions at different levels of decision making. I examine actor's values through a broad economic lens of values as priorities (Bateman et al. 2002)

1.5. Values as priorities and values as motivations

A number of disciplines focus on developing an understanding of how values influence behavior- most notably the fields of psychology and economics (Rokeach 2008; Rohan 2000; Becker 1996; Becker 1989) However, the concept of value differs across disciplines and individuals. Psychologists consider values to be expressions of people's motivational goals or desires - such as benevolence[16] and hedonism[17] - in context of their needs and constraints (Schwartz 1992; Rokeach 1973; Kluckhohn et al. 1961). As people grow they learn to express their values, and through interactions with others they learn which are compatible, and which come in conflict with each other thus developing an implicit network of meanings for their values (Schwartz 1992). There is general consensus that a small number of stable and widely shared values exist (Rokeach 2008; Manfredo et al. 2003; Rohan 2000), and although priorities assigned to those values may differ, the structure of the human value system is universal (Schwartz 1994; 1992)

Economists generally view value from a self-interest perspective where individuals act to maximize their gains. Value is sometimes calculated as the dollar (or equivalent) exchange value of any good or service. In an economic sense, value is thus a relative concept. The value of 'x' can be assessed by determining how much of y someone is willing to give up to get 'x'. Value establishes the idea of a measure of pleasure felt when engaging with a good or service. This could involve using a good or service directly; for example eating fish; or indirectly (for example

[16] Benevolence: Preservation and enhancement of the welfare of people with whom one is in frequent personal contact

[17] Hedonism: Pleasure and sensuous gratification for oneself

going for a walk or swim in nature). It can also refer to the pleasure we derive from just knowing something exists (such as beautiful coral reefs) (Freeman 2003; Bateman et al. 2002). Although value refers to a measure of pleasure it does not prescribe what motivated that pleasure. The common assumption is that pleasure is driven by selfish goals, but it does allow for alternate goals and does appreciate values can be less tangible that those described above (Stiglitz 2000). This view of value therefore does not necessarily exclude the alternate motivations for value often covered by psychologists.

The substantial body of research on socio-cultural and psychological components of value, capturing people's motivational goals and how they relate to behavior, is seldom connected to ecosystem service science; creating a critical gap in the field's understanding of human decisions and behavior (Spash 2012; Dietz et al. 2005; Rohan 2000; Stern & Dietz 1994).

I begin to fill this gap in chapter five, where I apply a psychological theory of human values to the analysis of nine ecosystem services to address objective 4. In doing so I examine the motivations behind ecosystem service values and determine why bundles and trade-offs in ecosystem service priorities may emerge.

1.6. An entitlements approach for the analysis ecosystem service benefits

Endogenous and exogenous values

The majority of this thesis treats values as endogenous- deriving from within an individual. However there is significant evidence to suggest that people are both shaped by and shape their environment. I therefore devote the final section of this thesis to examining the extent to which the values and preferences people hold are influenced by their broad social institutions. Considerable progress has been made in behavioral economics accounting for behavior that fails to be explained by the derived value estimates. This approach has the additional benefit of accounting for influences on peoples' behavior that are yet to be, or unable to be, incorporated into concepts of value.

People's ecosystem service values are likely to be influenced by whether, and to what extent, they benefit from nature. The ability of people to benefit from, and thus value their environment, has been examined in many contexts through the lens of entitlements theory (Sikor & Nguyen 2007; Adger & Kelly 1999; Leach et al. 1999; Sen 1981). Emerging through the analysis of famines, Sen (1981) first noted that famines are about people not having access to enough food, rather than there being an insufficient quantity of food. In the same way, people are likely to value ecosystem services because they are 'able' to benefit from them rather than simply because ecosystem services are present. Entitlements are therefore "the alternate set of utilities (benefits) derived from environmental (ecosystem) goods and services over which actors have legitimate and effective control" (Leach et al. 1999). An entitlements approach adds to an ecosystem services approach by examining the distribution of ecosystem service benefits across different people in society. The lack of social differentiation has been recently identified in the ecosystem services literature, drawing attention to the existence of winners and losers in ecosystem service provision and change (Daw et al. 2011). This distinction is particularly pertinent with the growth of payments for ecosystem service projects and aspirations for ecosystem services for poverty alleviation (Poverty Environment Initiative 2011; Pagiola et al. 2005).

An entitlements approach highlights social differentiation in people's access to ecosystem services. Perspectives from political ecology can add to this by analyzing how this social differentiation occurs. Ribot & Perusoe (2003) developed a theory of access which identified nine categories that shape processes and relations that enable people to benefit from things (e.g. people may be able to benefit through the position they hold, the knowledge they have). Components of access such as social capital (e.g., trust) (Dasgupta 2005), social relations (such as discrimination), and power (Becker & Becker 1996) have been previously shown to influence people's values.

I add to this work in chapter six where I use an extended entitlements approach and a theory of access to establish how people benefit from a supply of ecosystem services (objective 5). I

examine benefit through a broad economic lens of values as priorities (Bateman et al. 2002), and determine levels of access according to their social characteristics (Ribot & Peluso 2003).

1.7. Geographic context

I use coral reef fisheries as a lens to examine the relationship between rules, people's ecosystem service values, and their behavior. Coral reefs are amongst the most threatened ecosystems in the world (Bellwood & Hughes 2001). They are also located predominantly in low income countries (Donner & Potere 2007) where rapid population growth rates (Roberts 2011), changing consumption patterns, and emerging markets are taking a heavy toll on coastal resources (Berkes et al. 2006) . People in these contexts are likely to be heavily dependent on natural resources (Dasgupta 2007) and, because they do not generally have the capacity to adapt (Daw et al. 2012; Cinner et al. 2011; McClanahan et al. 2008) or resources to cope, they are likely to be the hardest hit by losses in the provision of their ecosystem services (Dasgupta 2007). Furthermore, these countries lack the resources necessary to implement wide-spread management. The combination of stressors, and lack of resources, makes the effective and efficient management of coral reefs a particularly pertinent challenge.

The coastal communities of countries in the western Indian Ocean tend to have low incomes and high levels of dependence on fishing (Cinner & David 2011; Cinner & Bodin 2010). The composition and condition of the coral reefs in these areas are well studied, and there is significant research uncovering the social mechanisms that lead to effective resource management in these communities. These communities therefore present an ideal lens through which I can investigate individuals' ecosystem service values. I collected qualitative and quantitative data about people's ecosystem service values via interviews with resource users in 28 communities across the western Indian Ocean (Figure 1.6). A general overview of these methods (including a detailed discussion of the questions and formation of focus groups, of the development of the questionnaire, and of the sampling procedures adopted) can be found in Appendix 9.2 and the relevant details will be covered in each chapter.

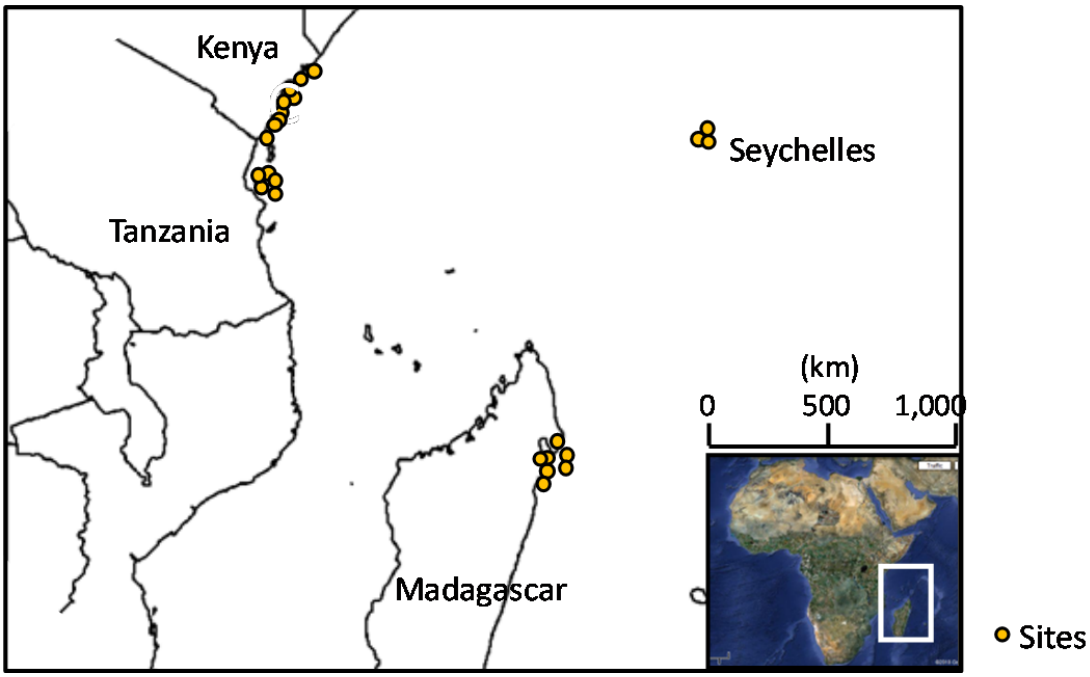


Figure 1.7 Map of study sites.
Western Indian Ocean region showing the 28 communities I visited across four countries, Kenya, Tanzania, Madagascar, and Seychelles.

1.8. Aims and Objectives - recap

The aim of my thesis is to develop a better understanding of how people benefit from and value ecosystem services; and to determine how this knowledge can be integrated into the analysis and development of policy. The introduction above identified four key gaps that limit the influence ecosystem service science can have on decision making.

- A coherent framework integrating ecosystem service values into decision making is lacking.
- Interactions between different services are generally not addressed.
- Socio-cultural and motivational components of value are seldom considered.
- Social differentiation in how people benefit is not acknowledged.

I address these gaps to achieve my aim by through the following five interrelated objectives.

1. Establish what ecosystem services have been assigned monetary estimates of 'value' and to ascertain the implication of this work.
2. Develop and apply a framework to evaluate the potential outcome of a set of rules taking resource users' ecosystem service values and their social characteristics into consideration?
3. Examine ecosystem service priorities and interactions at different levels of decision making.
4. Integrate socio-cultural and motivational components of value to determine why bundles and trade-offs emerge.
5. Establish how different people benefit from a supply of ecosystem services.

1.9. Thesis Outline

This thesis is presented as a series of chapters formatted for publication in peer-reviewed journals. Figure 1.6 shows the overall format of this thesis. Following this introduction, I start in chapter two with a meta-analytical review of the valuation literature in the western Indian Ocean; this chapter reflects what would be a literature review in a traditional thesis. The overarching methods of my thesis are included in Appendix 9.1, 9.2 but details of the relevant methods are contained in each data chapter. Chapter 3 tests my framework by applying it to a case study in the Seychelles to evaluate policy options. Chapters 4, 5, and 6 explore elements of the framework in further detail to develop theory relevant to ecosystem service science. Chapter 2 is a sole authored publication. Authorship of subsequent chapters for publication (chapters 3-6) is shared with members of my thesis committee, Josh Cinner (Chapters 3-6), Natalie Stoeckl (Chapters 3, 5), and three contributing authors Jan Robinson (Chapter 3), Nick Graham (Chapter 4), and Tim McClanahan (Chapter 5). The section below describes what is in each chapter and how it contributes to the overarching aim of the thesis.

I start off my thesis, in **chapter 2**, with a meta-analysis of coral reef valuation studies published in *Coastal Management*. I focus on the western Indian Ocean to determine which services are measured, what methods are used, and the scale at which assessments are made. This establishes a baseline for how ecosystem services are conceptualized and measured, and what

the implications of basing decisions on the existing data might be (Figure 1.7a). By identifying gaps in our knowledge and highlighting the implications of common assumptions this chapter informs my choice of methods for the subsequent data chapters. Consequently, for the rest of my thesis, to capture between service interactions, I examine a full range of ecosystem services; to enable comparison across services I apply consistent methods across all services, and to minimize the impact of power on values I measure benefits that flow to beneficiaries at the same scale.

Chapter three is in revision with *Ecology and Society.* Here, I conduct a case study of an artisanal fishery in Seychelles, where I apply my framework (Figure 1.7b), to evaluate whether two policy options, commonly adopted by institutions to control rates of exploitation in fisheries, lead to desired outcomes. This chapter allows me to test of the robustness of my framework and to illustrate that both resource users' values and social characteristics are critical in determining policy outcomes.

Chapter four is in review in *Global Environmental Change*. Here, I compare ecosystem service priorities at different levels of decision making (resource users, managers, and scientists). These actors are linked through the rules they either set (e.g. managers and scientists in the collective choice level) or are expected to adhere to (e.g. fishers in the operational choice level) (Figure 1.7c). This chapter shows that managers, scientists, and fishers prioritize ecosystem services differently. However, the greatest differences are reflected in the bundles and trade-offs associated with the different actors priorities.

In **chapter five**, I broaden conventional concepts of ecosystem service value by applying a psychological theory of human values to the analysis of ecosystem services (Figure 1.7a). In this chapter I examine the motivations behind ecosystem services values, explore how these align with psychological theory, and ask whether ecosystem service priorities can be understood from ecosystem service motivations. This chapter begins to develop a theory of why bundles and trade-offs in ecosystem service priorities emerge.

In **chapter six**, I use an extended entitlements approach to examine how people benefit from a supply of ecosystem services. In this chapter I explore the actor's box (values and social characteristics) (Figure 1.7d), to examine values as priorities, and determine levels of access according to various social characteristics. This chapter highlights that ecosystem benefits are not evenly distributed, but mediated by key access mechanisms. This approach allows one to identify factors that influence who benefits which are key determinants of the success of environmental policy.

I conclude in **chapter seven** where I identify recent developments in ecosystem services science and draw out some of the cross cutting themes that my thesis illuminates. Specifically, my research shows that ecosystem service values are inherently heterogeneous and interactions between ecosystem services are ubiquitous. These interactions result in bundles and trade-offs, that differ across actors, and levels of decision making. These bundles and trade-offs are driven by peoples motivations but manifest in people's priorities. Access mechanisms enable people to benefit from various ecosystem service bundles. Social mechanisms are likely to create the most divers opportunities in how people benefit, and managers have a potential role to play in mitigating the tensions inherent among actors.

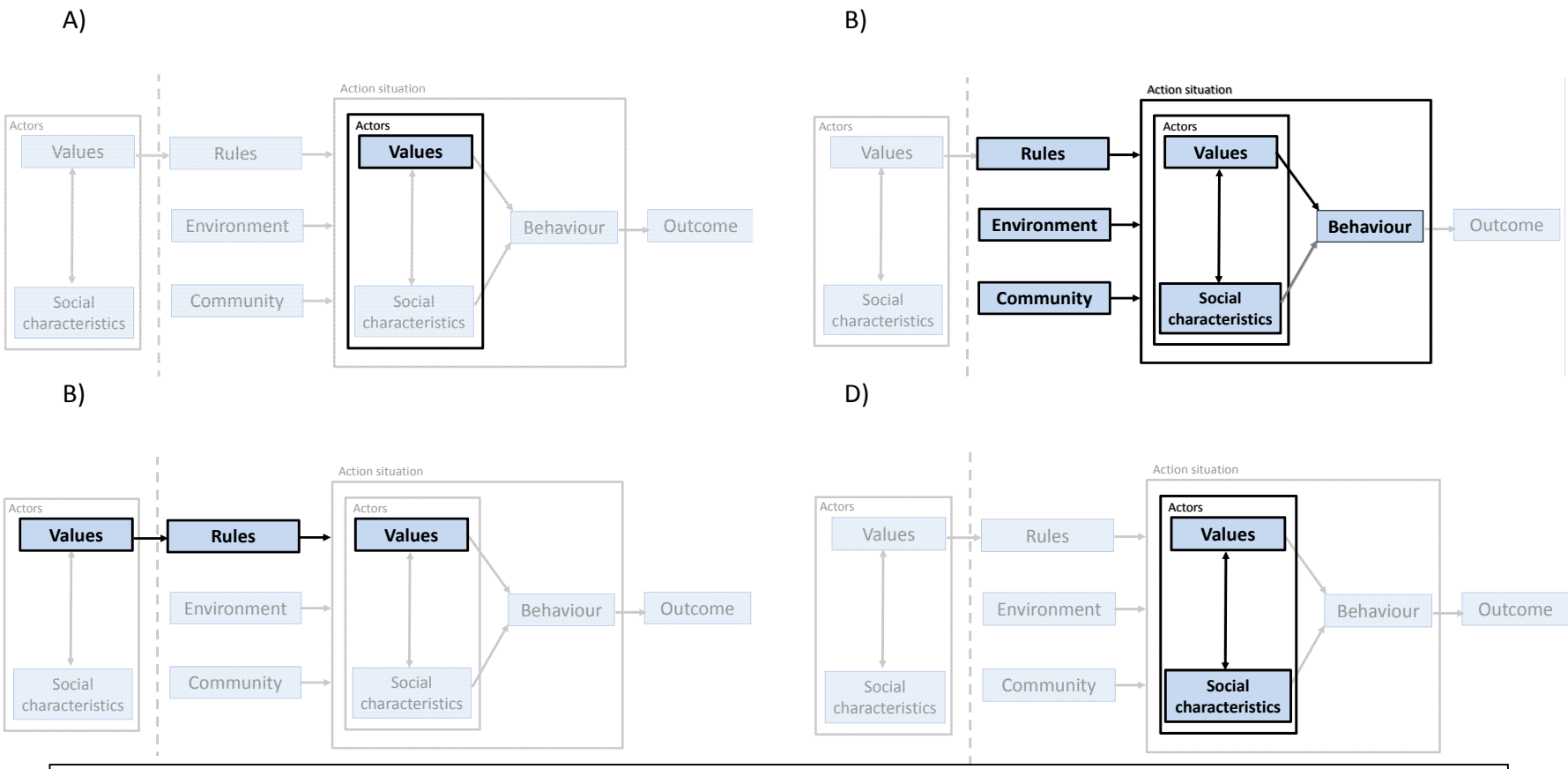


Figure 1.8 Overarching Framework

As applied in each chapter. A) Chapter 2 examines values as monetary estimates. Chapter 5 examines values as priorities and motivations. B) Chapter 3 evaluates the potential outcome of a set of rules taking values social characteristics into consideration. C) Chapter 4 examines values at different levels of decision making. D) Chapter 6 examines the influence of social characteristics on values.

Chapter 2

How do we value our reefs? Risks and trade-offs across scales in 'biomass based' economies.

Chapter 2. How do we value our reefs? Risks and trade-offs across scales in 'biomass based' economies.

Adapted from: C Hicks (2011) How do we value our reefs? Risks and trade-offs across scales in 'biomass based' economies. ***Coastal Management*** 39: 358-376

2.1. Abstract

This review examines monetary ecosystem services assessments from the western Indian Ocean to determine whether a sampling bias exists, what the implications of that bias may be, and what recommendations can be made for coral reef management. Results from the western Indian Ocean show that supporting services are underrepresented, whilst cultural and provisioning services, where clear markets exist, are overrepresented in both the number of studies conducted and values assigned. Different valuation methods were found to produce different results. These services are generally assessed using different methods meaning comparisons cannot be made across services. I found that, of the services measured in the western Indian Ocean, the largest number of flow to beneficiaries at a local scale. Therefore, the cumulative hypothetical value of ecosystem services is largest at this scale. However, the average value of a single service appears greatest, when flowing to beneficiaries at a global scale, creating biases in ecosystem service assessments. Furthermore, inconsistencies in classification and definition, particularly concerning regulating and option services exist. Findings suggest that if regional managers are to base their decisions concerning what to protect on current valuation studies, their choices are likely to result in unexpected and undesirable trade-offs. There is a need for; 1) new and standardized methods that adequately account for a full range of ecosystem services; 2) studies to consider multiple ecosystem services simultaneously and across scales; and finally 3) to acknowledge whose values are being counted and thus address how and why ecosystem services contribute to human well-being, under differing social contexts.

2.2. Introduction

Ecosystems provide us with a multitude of benefits, referred to as ecosystem services (MA 2005). Accounting for these benefits is the focus of ecosystems services research; a burgeoning, interdisciplinary and pragmatic field in the face of increasing pressures on our natural resource base (Chee 2004). The concept can be traced back to a number of disciplines, most notably ecology (Lindeman 1942) and economics (Krutilla 1967). Consequently multiple classifications and definitions, serving different purposes, exist to encompass the full range of benefits we gain from nature (MA 2005; Dasgupta 2007; Costanza 2008). Broader definitions allow for more inclusivity of values, and, as such, are often used for awareness. Narrower definitions, which limit what can be examined, serve more specific functions such as for accounting (for a review, see Patterson & Coelho 2009; Costanza 2008; deGroot et al. 2002). However, although the terminology may differ, it is important to note that the values identified by these frameworks are quite similar (Stoeckl et al. 2011).

Although an ecosystem services approach is relatively new, the rationale behind it can be linked to the development of other ideas including; the scarcity of natural capital eventually limiting economic growth (Becker et al. 2005; Arrow et al. 1995; Meadows et al. 1972; Malthus 1798; Smith 1776); environmentalism (Carson 1962); and more recently realizations that alternate forms of capital cannot be fully interchanged (Neumayer 1999). Environmental economists feel that the process of valuing natural resources makes the less obvious benefits we gain from nature explicit. In doing so, individuals and institutions become aware of the trade-offs involved in daily decisions and are therefore more likely to act in ways, or develop rules, that curb the loss of natural capital (Hicks et al. 2009; Ehrlich & Kennedy 2005; Pearce 2002). Consequently both scientists and practitioners are increasingly recognizing the worth of incorporating ecosystem service assessments into policy and management decision-making (TEEB 2008). Although we are adept at measuring land and agriculture, for which clear markets exist, it is not clear if we are adequately accounting for the full range of ecosystem services in our decision making processes (Dasgupta 2010; Dasgupta 2007).

One challenge is that values constitute diverse concepts to individuals from various disciplinary backgrounds. For example, from a neoclassical economics perspective, concepts of value are based on the optimum allocation of resources and efficiency; here something's value is based on its exchange value (Freeman 2003; Pearce 2002). In some areas, such as social psychology, concepts of value are broader, including more psychological and intrinsic qualities representing complex decision-making processes such as satisfaction, pleasure, feel-good, equity and sense of place. These values are often reflected as the contribution of a good or service to well-being; social, economic or environmental (Larson 2009; Diener & Suh 1997). Alternatively, within conservation circles value can refer to the rarity or importance of a species or ecosystem and thus its need for preservation (Pressey et al. 2007). Ecosystem service valuations may need to encompass all these aspects of value. Because motivations to account for ecosystem services differ, various valuation approaches have developed (see Bateman et al, 2002 and Willis et al. 1999 for detailed reviews). For example, financial accounting (Dasgupta 2010; Lange 2004), market and non-market based methods (Freeman, 2003; Turner et al., 1994), preference or deliberative approaches (Spash, 2008[a]) and biological irreplacibility or functional diversity approaches (Kremen 2005; Pressey et al. 1996). This multitude of options makes it difficult to know what the best approaches are for measuring and incorporating multiple ecosystem service values into decision making processes (Spash 2008[a]; 2008[b]). It is therefore clearly necessary to ascertain how values are being assessed within regions to help guide decisions that can be drawn from such assessments.

The need for advances in ecosystem services research is especially pertinent where individuals are most dependent on natural resources and most vulnerable to fluctuations in their provision (Paavola 2008). This is best illustrated in low-income countries, or "biomass based economies", where individuals predominantly work in economies that draw their production inputs from nature (Dasgupta 2007). For example, agriculture contributes 25% of GDP in low-income countries where 70% of the population live in rural villages. This compares to high-income countries, where agriculture contributes less than 5% of GDP and only 10% of the population live in the countryside (Dasgupta 2007). The disproportionate dependence on natural resources of the poor increases further within low-income countries. For example, a study in India has shown

whilst forest products contribute 7% to national GDP they contribute 57% to the 'GDP of the poor' (Dasgupta 2007). This indicates that the poor would be the hardest hit by biodiversity loss. Within these 'biomass based economies' many of the ecosystems people depend on are particularly vulnerable to the impacts of over exploitation and climate change. Coral reefs represent one of these vulnerable ecosystems presenting an interesting case study. What makes these challenges even greater is that, the majority of countries that have coral reefs are low-income countries which lack the resources, and alternatives, to invest in their protection (Donner & Potere 2007). The conservation of coral reefs, as with tropical rainforests, has therefore become a global challenge, reflected through international agreements and targets (Cop 10, 2011), with research focused on benefits delivered at various spatial and temporal scales. This potential refocusing of priorities from local needs to global benefits raises the issues of whose values are being considered?

This study seeks to review the valuation of coral reef ecosystem services in the Western Indian Ocean (WIO), an area particularly vulnerable to resource decline. Here, I present a quantitative summary of studies conducted in the region in order to address whether valuation studies are delivering relevant, meaningful science that has the capacity to inform local management or regional policy. Specifically I ask four questions; firstly, how much do we know about each of the categories of ecosystem services identified in the Millennium ecosystem assessment? Secondly, how are we assessing these services? Thirdly, whose values are we considering in these assessments? And finally, how do estimates from the WIO compare with estimates from the rest of the world?

2.3. Methods

Data collection- WIO

I used the Web of Knowledge^{TM} database, between September 2009 and March 2010, to search for published articles relating to or associated with coral reefs within the WIO region (Somalia, Kenya, Tanzania, Mozambique, Madagascar, Seychelles, Reunion and Comoros, Mauritius, Mayotte). Specific key word searches relating to valuations and ecosystem services did not return a sufficient number of studies. I therefore adopted a more manual approach where I entered

each of the ten countries, one by one as a keyword, AND the keywords “coral*” OR “reef*” OR “fish*” OR “marine*” OR “coast*”. I then screened the resulting titles followed by abstracts. If reference was made to ecosystem services or valuations, the paper was retained for analysis. From the selected articles a backward search (literature cited by the papers retrieved through keywords) and forward search (literature that cited the papers retrieved through keywords) of the literature was conducted and a similar screening of titles and abstracts conducted. Peer reviewed studies were supplemented by grey literature reports, obtained through the Google search engine. I only included reports if the source was well established and was considered to have undergone a process of review prior to publication (e.g. documents from well-known NGO’s and university thesis). I then screened the full papers of selected studies for empirical data. I retained for analysis, studies containing quantitative valuation data.

Ecosystem service Classification

I adopt the overarching classification as defined by the Millennium Ecosystem Assessment (MA 2003). This classification encompasses the full range of services considered in the region and allows me to assess how much is known about each of the categories. Ecosystem services are grouped into 4 categories; provisioning services which are the products obtained from ecosystems such as fisheries; regulating services which are the benefits obtained from the regulation of ecosystem processes such as coastal protection; cultural services which are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience and supporting services which are the services that are necessary for the production of all other ecosystem services such as habitat provision (MA 2005). I include ‘option’, as an additional category of service not covered by the four MA categories, as noted by Hein et al (2007). Although I adopt this classification, I retained as much as possible the ecosystem service terms from the original studies and readers are referred back to these studies for specific definitions. However, some reclassification was inevitable. As a result, I developed a definition of the hierarchies among services, Figure 2.1 shows how the services used in the individual studies, fit into those used in the WIO and global sections of this review, and how these subsequently fit into the MA framework. I also show how

the TEV framework (Freeman 2003) fits into in my adopted hierarchy, to illustrate the complementarities among frameworks.

Ecosystem service values and valuation methods

I examined how much was known, in the WIO, about each of the categories of ecosystem services identified by the MEA from distributions in the frequency and magnitude of estimates across ecosystem services measured. I established how we were measuring these ecosystem services in the WIO from distributions in the frequency and magnitude of estimates across methods used to assess the ecosystem services measured.

I recorded monetary values assigned to all measured ecosystem services, along with the site, valuation method used, date of study, document type, author's affiliation, study design and characteristics. I converted the monetary values (*v*) to a value per unit area (*V*) (Equation 2.1) using the study area provided. Where this area data was lacking I established the area using the available details of the study, other literature and information sources (i.e. World Resources Institute, Google maps, management databases).

$$V = \frac{v}{study\ area} \qquad \text{(Equation 2.1)}$$

I converted values per unit area (*V*) to US$ values using the exchange rate at time of publication (*y*) and adjusted for inflation based on the ratio of consumer price index (CPI) in 2010 to the consumer price index at date of publication (i) (Equation 2.2) (US bureau of Labour statistics, www.usinflationcalculator.com). It is worth noting that this approach may be influenced by yearly variations in market prices.

$$V_{2010} = V_i y_i \left(\frac{CPI_{2010}}{CPI_i}\right) \qquad \text{(Equation 2.2)}$$

Scale of beneficiaries

I developed a heuristic describing the governance scale which the ecosystem services flowed to (Figure2.2a). This heuristic allowed me to establish whose values were considered in WIO

valuation assessments. The flow is based on the assumption that an ecosystem service originates from a local reef and benefits stakeholders at different scales. I established the stakeholders who benefit from each ecosystem service based on the valuation methods used in the studies. I only consider three governance scales; local, representing stakeholders from the communities and towns in close proximity to the coral reef resource (< approximately 50km); national, representing stakeholders from other towns and cities including government and non-governmental organizations from each country; and global, representing stakeholders from outside countries including international government and non-governmental organizations. For example the recreation ecosystem service has the potential to benefit stakeholders' at all three scales. However, the methods employed in the studies examined, only consider the demand for recreation by international and national tourists. Furthermore, that demand is composed predominantly of international tourists. I therefore define valuation studies in the WIO to consider recreation as flowing primarily to beneficiaries (primary beneficiaries) at a global scale and secondarily to beneficiaries (secondary beneficiaries) at a national scale.

To demonstrate the implications this work may generate, I aggregated the ecosystem services that flow to beneficiaries at each of the three scales (local, national, global), in three ways[18]. This allowed me to investigate the implications of whose values are considered, on management and policy recommendations. Based on my heuristic, and the studies examined, I first calculated the number of ecosystem services, secondly the combined value of ecosystem services, and finally the average value of a single ecosystem service.

I calculated the number of ecosystem services (ESS) by counting the number of services flowing, a) primarily (Equation 2.3) and b) secondarily (Equation 2.4), to beneficiaries at an individual governance scale (e.g. at a local, national, or global scale).

[18] I have demonstrated that because of differences in methods, it is not correct to add across services. However, I have conducted this as a thought exercise to demonstrate the implications that this work could generate if the underlying approaches are not taken into consideration in decision making- a reasonable assumption (.e.g. see Costanza et al 1997). Even if the methods were comparable, simple linear aggregation may be insufficient and there are difficulties defining a single, well-defined service.

$$^{19}ESS_{aX} = n_{aX}$$

(Equation 2.3)

$$^{20}ESS_{bX} = n_{bX}$$

(Equation 2.4)

Where *a*=services that flow primarily, *b*= services that flow secondarily, *ESS*= ecosystem services supplied, *X*= local, national or global, *n*= number of different ecosystem service observations.

I calculated the aggregate value of ecosystem services (EV) at an individual governance scale by summing the means of all the ecosystem services that flow primarily to beneficiaries at that scale (Equation 2.4).

$$EV_{aX} = \sum ES_{aX} \qquad \text{(Equation 2.4)}$$

Where ES= mean of a single ecosystem service, EV= aggregate of individual ecosystem services,

I calculated the average value of a single ecosystem service (ESV) at an individual governance scale by dividing the aggregate value of ecosystem services (that flow primarily to individuals at that scale), by the number of ecosystem services (that flow primarily to individuals at that scale) (Equation 2.5).

$$^{21}ESV_{aX} = \frac{\sum ES_{aX}}{n_{aX}} \qquad \text{(Equation 2.5)}$$

Where ESV= average value of an individual ecosystem service

Global comparison

[19] As above footnote
[20] As above footnote
[21] As above footnote

I combined the WIO literature with literature from a global compilation of coral reef valuation studies (CI 2008) to establish how ecosystem service value estimates from the WIO compare with estimates from the rest of the world. I compared the value estimates assigned to ecosystem services in the global compilation with the value estimates assigned to those services in the WIO. Ecosystem services that were not included in both compilations were excluded from the analysis. When a single ecosystem service term encompassed more than one ecosystem service in the other compilation the broader definition was used and the mean of the lower level services was reported. For example biodiversity in the global dataset includes biodiversity benefit as well as habitat from the WIO dataset (according to my definition of hierarchy of classification; Figure2.1).

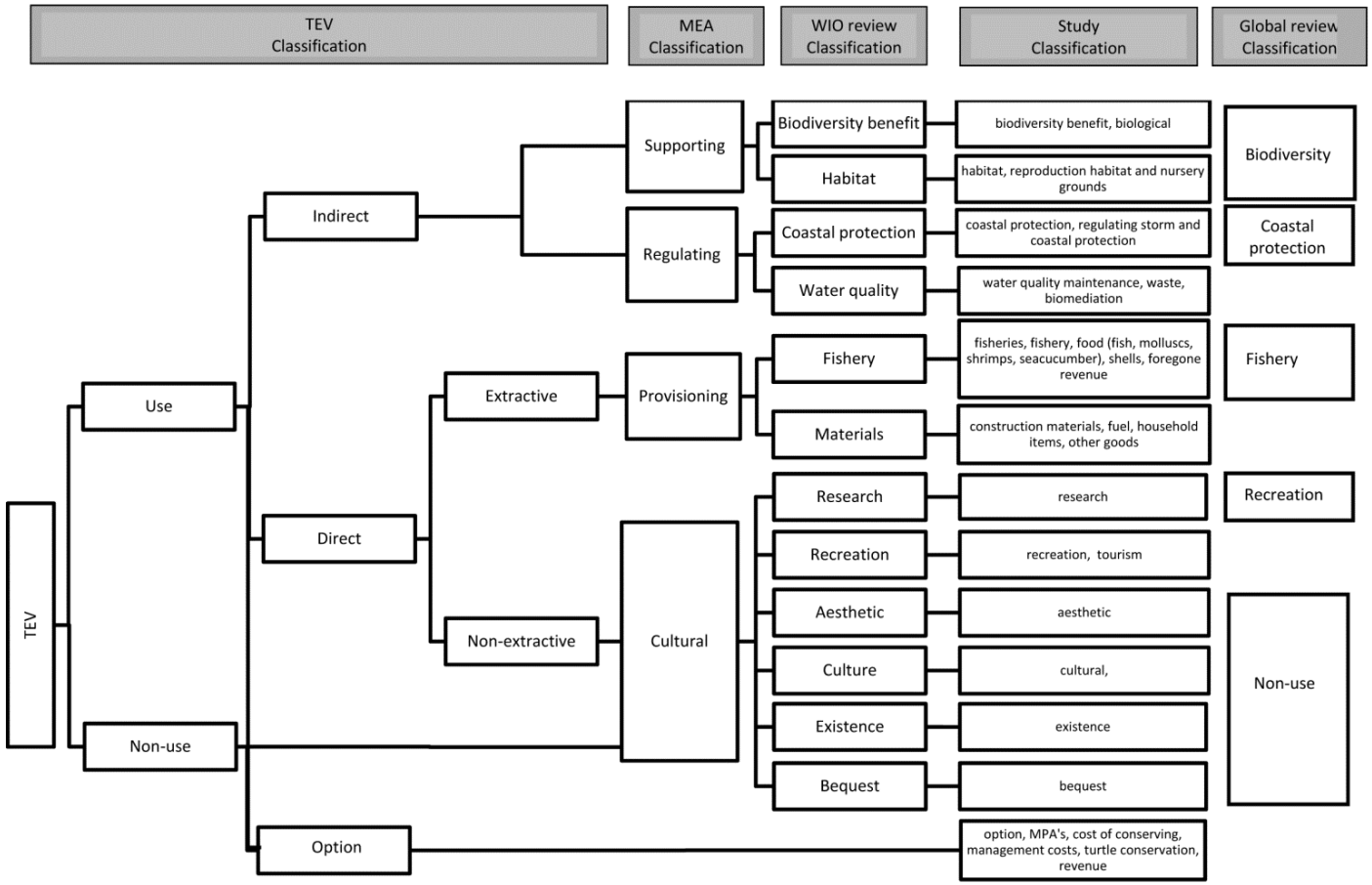


Figure 2.1 A definition of the hierarchies among services

An illustration of the relationships between the different classifications used, demonstrating how the services used in the original studies, fit into those used in the WIO and global reviews, and how these subsequently fit into the MEA and TEV frameworks.

Analysis

I tested the data for normality with the Kolmogorov-Smirnov test and Q- Q plots of the residuals (Field 2005) and assessed the homogeneity of variances with Levenes test (Field 2005). Because homogeneity of variances could not be established, I used the Kruskall-Wallis (Field 2005) test too look for differences in values across: 1) ecosystem services in the WIO, 2) valuation methods used, 3) scale of service provision, and 4) differences between services valued in the WIO and globally. I used Games-Howell (Field 2005) post hoc analyses to reveal which services were different within the WIO.

2.4. Results

Twenty-three studies incorporating 32 sites and 11 years, quantified 13 ecosystem services using nine methods in the WIO region. This resulted in 275 independent ecosystem service value estimates across five out of the ten countries in the region (Table 1.1 Appendix 9.5).

Ecosystem service values and valuation methods

Considerable differences existed in the value estimates across ecosystem services ($H_{12,199}$ 76.4; P=0.00) (Figure 2.2a). The estimates assigned to ecosystem services split into three broad groups (low, medium and high values) based on Games-Howell post hoc analysis. The cultural services *aesthetics* and *research*, and the regulating service *coastal protection* had high value estimates (*high value x* > Log 3) (Figure 2.2a). The supporting services *biodiversity* and *habitat,* and the provisioning service *materials* had low value estimates (*low value x* < Log 1) (Fig 2a). All other ecosystem services had medium value estimates (Log 3 > *medium value x* > Log 1) (Figure 2.2a) and included provisioning, regulating, cultural and option values. The cultural service *recreation*, provisioning service *fishery* and *option*, were estimated by the greatest number of studies (17, 8, and 7 respectively) (Figure 2.2a).

Table 2.1 table showing ecosystem services valued by country and year of study

Country	Services	Years	Studies [see Appendix 9.5]
WIO studies *(Somalia, Kenya, Tanzania, Mozambique, Madagascar, Seychelles, Reunion and Comoros, Mauritius, Mayotte)*			
Kenya	A, Bq, B, Cp, C, E, F, H, O, R, Wq, Rs	2000, 2001, 2002, 2007, 2009, 2010	1, 2, 3, 4, 5, 6
Madagascar	B, R	2003, 2006	7, 8
Mozambique	E, F, R	2004, 2008	9, 10
Seychelles	Cp, F, O, R	1991, 1997, 2002, 2003, 2004, 2005, 2007, 2009	1, 11, 12, 13, 14, 15, 16, 17
Tanzania	F, R, M	2000, 2002, 2005, 2007, 2009	1, 2, 18, 19, 20
Global studies *(Rest of World)*			
American Samoa	Cp, F, R	2004	21
Australia	R	2003	22
Belize Honduras	F	2001, 2005	23
Cambodia	F, R	2003	24
Ecuador	F, R	2000	25
Indonesia	Cp, F, R	2004, 2005, 2006	26, 27, 28
Jamaica	B, Cp, F, R	1998, 1999, 2000, 2008	29, 30, 31, 32
Malaysia	R	2004, 2005	33, 34
N Mariana Islands	Cp, F, N, R	2006	35
Netherlands Antilles	R	1995, 2007	36, 37
Philippines	F, R	2000, 2005, 2007	38, 39, 40
Sri Lanka	F	2005	41
St Lucia	R	2008	42
Tobago	R	2001, 2008	42
Thailand	R	2004	43
Turks and Caicos	B, Cp, F, R	2005	44
Venezuela	R	2007	45
Vietnam	F, O, R	2005	46

A- Aesthetic, Bq-Bequest, B-Biodiversity, Cp-Coastal Protection, C-Cultural, E-Existence, F-Fishery, H-habitat, O-Option, R-Recreation, N-Non-use**,** Wq- Water quality, Rs- Research, M- Materials

Differences also existed in the value estimates assigned across methods ($H_{7,199}$ 44.2; P=0.00). Financial (including market value), contingent valuation, and benefit transfer methods were used to value the greatest number of services (6, 5 and 5 respectively) (Figure 2.2a). The *coastal protection*, *recreation*, *fishery*, *biodiversity* and *option* values had been estimated by more than one method (Figure 2.2b). However, due to small sample sizes, I could only compare the estimates obtained across; all methods used for *coastal protection*, three of the four methods used to assess *recreation* and for two of the three methods used to assess *option.* There were significant differences across value estimates assigned to *coastal protection* ($H_{1,12}$ 11.7; P=0.00) and *recreation* ($H_{2,70}$ 6.9; P=0.03) (Figure 2.2b). Although methods used to assess *option* values appeared similar, this comparison did not include payments for ecosystem services which returned considerably lower values than the other two methods. The travel cost method which was used to measure *recreation*, returned considerably higher values than contingent valuation or financial methods, and benefit transfer was not included in this comparison (Figure 2.2b).

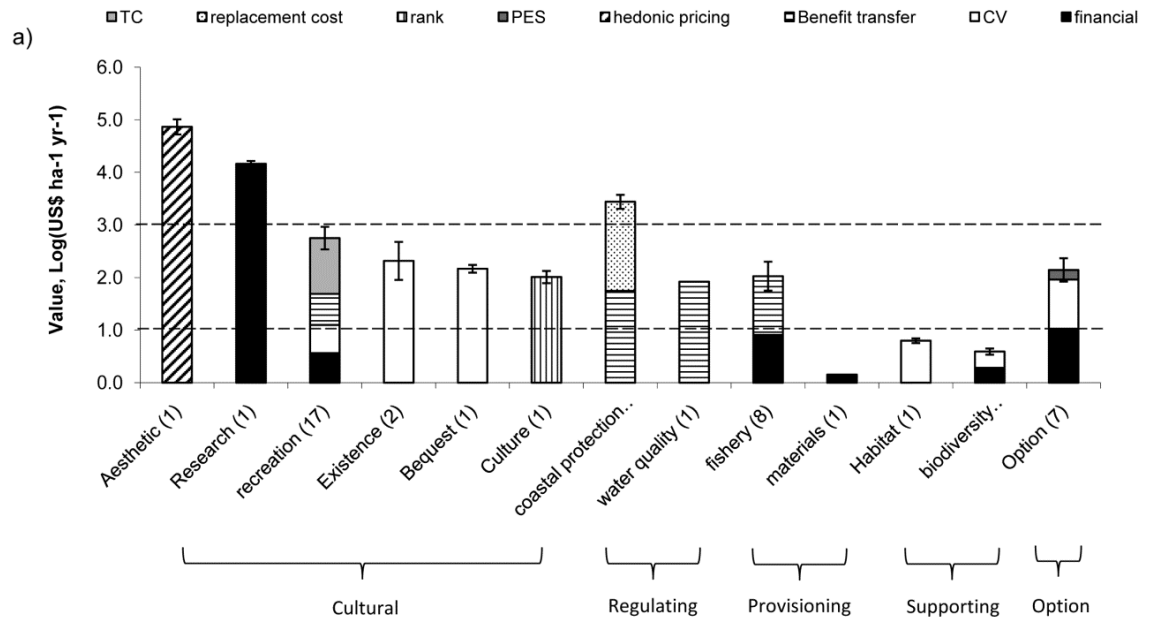


Figure 2.2a Ecosystem services estimated in the WIO, by different methods

Distribution of mean value estimates US$ Ha^{-1} yr^{-1} by ecosystem services showing proportions attributable to different methods. Error bars show standard errors of the mean, grey dotted line shows the James-Howell post hoc analysis cut off point for low, medium and high valued services. Services are ordered according to the MEA classification. TC= travel cost, PES=payment for ecosystem service, CV = contingent valuation. Numbers in brackets show the number of studies. BT- Benefit Transfer, RC- Replacement Cost, CV- Contingent Valuation, F- Financial, TC- Travel cost, PES- Payment for Ecosystem Services.

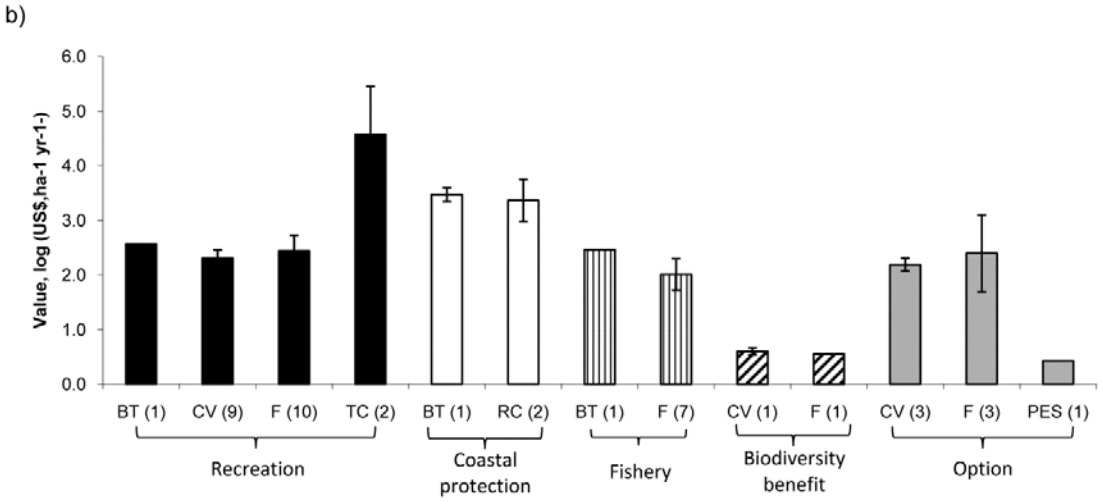


Figure 2.2b Ecosystem services estimated in the WIO, by different methods

Distribution of mean value estimates US$ Ha^{-1} yr^{-1} by different methods. Error bars show standard errors of the mean. Services are ordered according to the MEA classification. TC= travel cost, PES=payment for ecosystem service, CV = contingent valuation. Numbers in brackets show the number of studies. BT- Benefit Transfer, RC- Replacement Cost, CV- Contingent Valuation, F- Financial, TC- Travel cost, PES- Payment for Ecosystem Services.

Scale of beneficiaries

Nine services flowed to beneficiaries at a local scale; six of these were flowing primarily to beneficiaries at this scale (Figure 2.3). Nine services similarly flowed to beneficiaries at a national scale, although only four of these were flowing primarily to beneficiaries at this scale. Six services flowed to beneficiaries at a global scale only three of which were flowing primarily to beneficiaries at this scale (Figure 2.3).

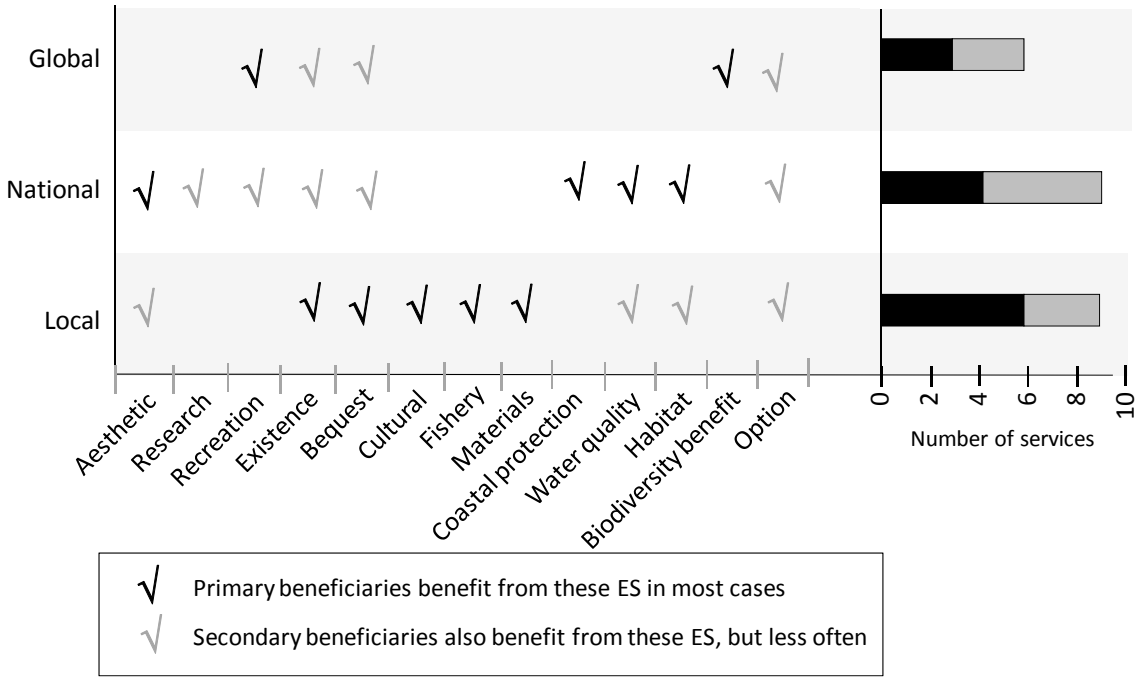


Figure 2.3 Ecosystem services flowing to beneficiaries at three scales (local, national, and global) Heuristic of the flow of ecosystem services to primary and secondary beneficiaries at a local, national and global scale; **a)** shows which ecosystem services flow to each scale, and **b)** shows the number of ecosystem services flowing

The combined value estimates of ecosystem services flowing primarily to beneficiaries at the three governance scales differed significantly ($H_{2,\ 273}$ 31.4; P=0.00) (Figure 2.4). The combined value estimates of ecosystem services was greatest when flowing primarily to beneficiaries at a local scale (US$ $Ha^{-1}Yr^{-1}$Log 12.49), followed by a national scale (US$ $Ha^{-1}Yr^{-1}$ Log 11.36) and lowest at a global scale (US$ $Ha^{-1}Yr^{-1}$ Log 7.96) (Figure 2.4).

The average value estimate of a single ecosystem service flowing primarily to beneficiaries at three governance scales differed significantly ($H_{2, 273}$ 5.7; P=0.05) (Figure 2.4). The average flow of a single ecosystem service was greater at a national scale (US$ $Ha^{-1}Yr^{-1}$ log 2.84) and global scale (US$ $Ha^{-1}Yr^{-1}$ log 2.08) than a local scale US$ $Ha^{-1}Yr^{-1}$ log 2.08 (Figure 2.4).

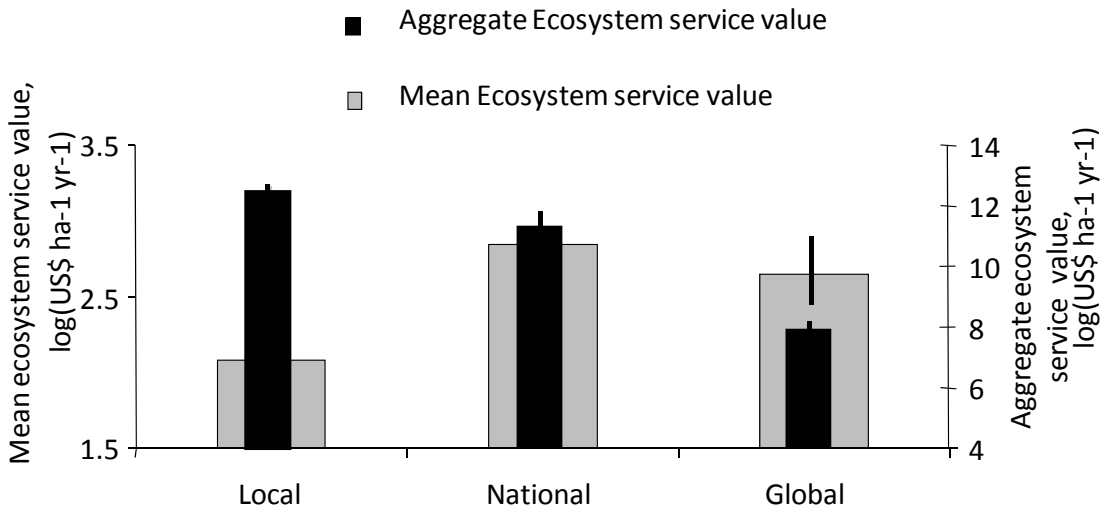


Figure 2.4. Ecosystem service value flowing to each scale
Average ecosystem service value estimate (US$ Ha^{-1} yr^{-1}) and the cumulative ecosystem service value estimate flowing to primary beneficiaries at a local, national and global scales. Error bars show standard errors of the mean.

Global comparisons

Six ecosystem services, producing 256 independent ecosystem service value estimates were available for comparison between the WIO and global studies (Table 2.1 Appendix 9.5). Fisheries, recreation, coastal protection and option estimates were reported in both WIO and global datasets. The global compilation had estimates for biodiversity, which encompassed both biodiversity benefit and habitat from the WIO dataset, and non-use, which encompassed aesthetic, bequest, cultural and existence, from the WIO dataset (Figure 2.4). Overall, values assigned to ecosystem services in the WIO did not differ significantly from those assigned globally ($H_{1, 255}$ 0.6; P=NS), although differences are apparent when looking at value estimates assigned to individual services. For example, biodiversity benefit is assigned a higher value in assessments

from the rest of the world ($H_{1, 24}$ 9.6; P=0.00) (Figure 2.5), whilst option values are assigned higher values in WIO assessments ($H_{1, 19}$ 3.1; P=0.07) (Figure 2.5). Although there is no significant difference between recreation, fishery and coastal protection values across both regions, coastal protection appears greater in studies from the WIO as do non-use values which due to a small sample size could not be tested for significance (Figure 2.5). Recreation and biodiversity are the most valuable services in assessments globally, whilst coastal protection and non-use services are the most valuable in assessments from the WIO region. Option is assigned the lowest value in the rest of the world, whilst biodiversity is in the WIO region (Figure 2.5).

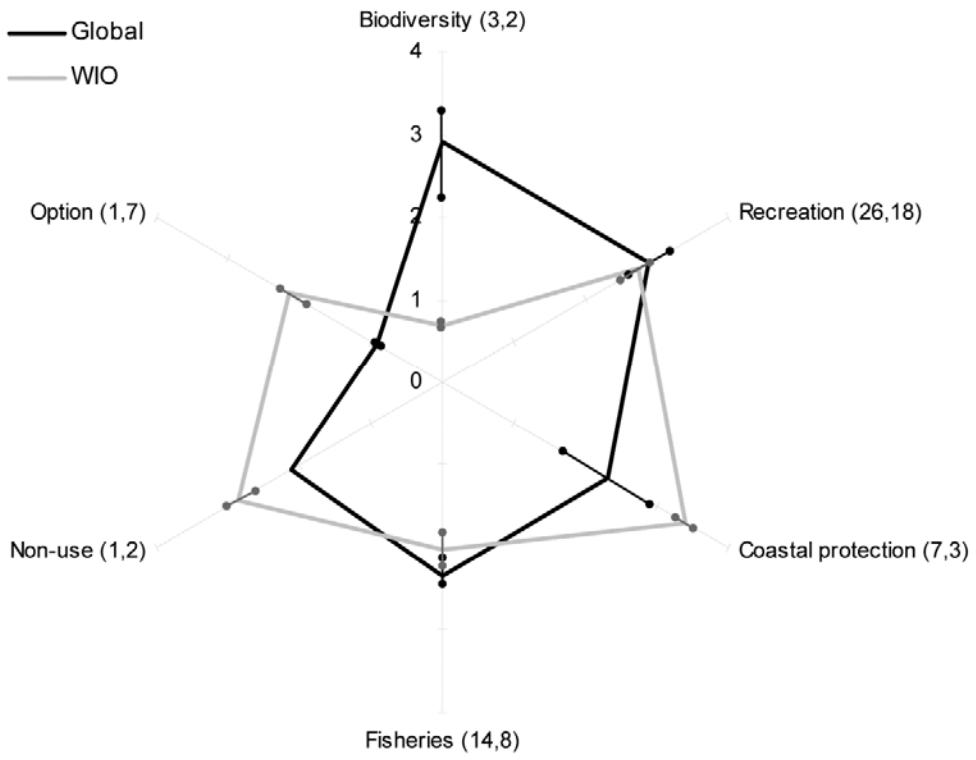


Figure 2.5 A comparison of WIO and global ecosystem service value estimates

Mean ecosystem service estimates US$ Ha^{-1} yr^{-1}, for the six ecosystem services measured by both studies conducted in the WIO and studies conducted in the rest of the world. Error bars show standard errors of the mean.

2.5. Discussion

Coral reefs are complex ecosystems with multiple services flowing to beneficiaries at multiple scales (Bennett et al. 2009). In this review I set out to assess whether coral reef valuation studies from the Western Indian Ocean (WIO) can inform policy and management. I asked, how much was known about each of the categories of ecosystem services, how these services were assessed, whose values were considered and whether estimates from the WIO were comparable with those from the rest of the world? A broad range of ecosystem services were estimated, using a variety of methods, flowing to beneficiaries at different scales. In this way WIO studies were similar to those in the rest of the world. The lowest value estimates were assigned to supporting services which were also estimated in the smallest number of studies. This implies that supporting services are under-represented in the WIO coral reef valuation literature. Where different methods assessed the same service they were found to produce different value estimates. Furthermore, different methods are often used to assess different services. This suggests it is wrong to compare value estimates across services; a dollar is not always a dollar. Of the ecosystem services measured, the largest number of services flow primarily to beneficiaries at a local scale. The cumulative value of ecosystem services is also largest when flowing to primary beneficiaries at a local scale. However, the average value of a single ecosystem service is smallest when flowing to primary beneficiaries at a local scale. The tendency of assessments to focus on single services leads to a bias, where the value of ecosystem services flowing to primary beneficiaries appears greater at a national or global scale than a local scale.

Coral reef valuation assessments from the WIO create biases across the categories of ecosystem services making it unlikely for decisions to be made which halt the loss of natural capital. By measuring services on a common basis, we imply that one service can be traded-off for another (Spash 2009; Vatn 2009; Holling & Meffe 1996). Provisioning, cultural, regulating, and supporting services were all included in valuation assessments. However, there was an overemphasis on valuing certain cultural services, particularly recreation, and a lack of studies addressing regulating and supporting services. Unlike terrestrial ecosystems, where provisioning services are assigned the greatest values (Raudsepp- Hearne et al. 2010), I found cultural services to be assigned the greatest values. The only measured supporting services, habitat and biodiversity, are

amongst the three least valued ecosystem services. This is despite the fact that supporting services are necessary for the continued provision of all other services. Therefore, theory suggests that the low values supporting services are assigned implies we should be trading supporting services off in favor of other more valuable services (Raudsepp-Hearne et al. 2010; Rodriguez et al. 2006). This is a dangerous situation, but is indeed the current *status quo,* where our ecosystem service preference is in the order of provisioning, regulating, cultural and lastly supporting services (Rodriguez et al. 2006; Foley et al. 2005) and we continue to degrade natural capital.

The under-representation of particularly supporting services is partly due to the lack of suitable methods which capture the function of these services. Where an economic demand exists, for example through a fish market or the tourism industry for some provisioning and cultural services, we have well developed methods establishing their worth. Supporting services differ as their value lies largely in our dependence on their supply. This difference influences the way supporting services contribute to our well-being. Provisioning, cultural and regulating services provide us with direct benefits (Stoeckl et al. 2011). For example, we directly benefit from having food (provisioning), from recreational enjoyment (cultural) and from the continued provision of clean water (regulating). However, whilst we may benefit from the knowledge that ecosystem processes are maintained, the greatest contribution to human well-being by supporting services is indirect, by ensuring that we continue to receive provisioning, cultural and regulating services. The challenge with measuring services that provide for other services, that are also being measured, is that we effectively measure their worth twice - known as double counting. The demand for supporting services would therefore need to be derived from the demand for the activities that depend on supporting services. But because of the indirect nature of this demand, it is likely that stakeholders do not have the knowledge necessary to fully comprehend our dependence on supporting services. Assessing these values may therefore require a secondary value system, which captures the supply of services that provide a system its life-support capacity, and thus identify what is critical capital (Spash 2008[a]; Gren et al. 1994). Accounting for the marginal change in overall wellbeing caused by changes in the function or supply of

supporting services, for example through joint production process, is therefore an area in much need of research.

There is no relation between the estimates assigned to the different ecosystem services across valuation studies in the WIO region. Five services had been measured using more than one valuation approach allowing us to assess how comparable different methods are. Although I was only able to test for differences in value estimates across three services, two of these showed differences and the graphical summaries suggest there are more differences across methods than similarities. This is not surprising as different methods calculate different components of value; therefore producing different results. For example, values may reflect prices such as with hedonic pricing, expenditures such as with a market value (prices x quantity), consumer surpluses such as with a travel cost approach (the amount a consumer would be willing to pay for a good over and above what is actually paid), total willingness to pay such as with some contingent valuations (expenditure + consumer surplus) or changes in any of these (Tisdell 2006). However, only three methods were used to assess more than one service, suggesting services are generally assessed by different methods. The combination of estimates differing across method and method differing across service means comparisons of value estimates cannot currently be made across services. Managers and decision makers need to be careful when using valuation studies as a dollar in one study can rarely be compared to a dollar in another.

Further biases are evident when we consider the scale to which measured services flow. Valuation assessments from the WIO put local beneficiaries, whom have a close dependence on coral reef resources, at risk of losing out to more powerful global and national interests (Norton-Griffiths 2010). Whether theories of value are based on utility maximization (Hausman 1992) or social choice (Etzioni 1988), value remains a subjective concept, therefore 'value to whom?' is an implicit question within any valuation process (Vatn 2009). As the choice of valuation method can influence value estimates, the scale and beneficiaries to whom the services flow can also significantly affect estimates of value and needs careful consideration when planning a valuation exercise. The majority of the world's reefs are situated in some of the lowest income countries (Donner and Potere 2007). Therefore, services assessed using global demand curves, such as

recreation, would reflect the greater ability to pay of the global community and would be assigned a greater value than for example fishery values, which are based on a predominantly local demand and markets. Of the studies examined in this review, the majority of services flow to primary beneficiaries at the local scale. Correspondingly, the cumulative value of ecosystem services is largest when flowing to primary beneficiaries at the local scale[22]. However, the average ecosystem service value is in fact smallest when flowing to primary beneficiaries at the local scale and greatest at the national or global scale, due to high values for services such as recreation. Although a large number of services were estimated, there was a tendency for individual studies to focus on single service assessments, over 50% of all studies only considered one service (see Lange & Jiddawi 2009; Andersson 2007). This is not unusual as the majority of assessments within the millennium ecosystem assessment (Rodriguez et al. 2005) only considered two services at a time. Decision makers, faced with a management choice between two individual services will therefore based on the data reviewed in this study, likely trade off, services that flow to local beneficiaries, in favor of services that flow to global beneficiaries. This is a common situation where the costs of conservation are often borne by those who have the least to gain (Chan et al. 2007).

Approaches are needed that consider the relationships between multiple ecosystem services (Bennett et al. 2009), providing decision makers with a broader suite of ecosystem service values, which incorporate the flow of ecosystem services to different scales (Stoeckl et al. 2011). However, inter-service interactions are complex and collecting data on multiple services costly. In addition, because ecosystem services originate from and flow to users across multiple spatial and temporal scales, conservation and management decisions struggle to incorporate this multi-scalar nature (Bennett et al. 2009). One difficulty is that the costs and benefits of managing ecosystem services seldom occur at the same scale. Whilst management may seek to maximize flows of a single service, such as biodiversity control to a global scale, the individuals who are required to change their behavior may operate at a local scale, and benefit from multiple services (Chan et al 2007). The logical outcome, based on the value estimates from the studies examined,

[22] Although I have demonstrated that because of differences in methods, it is not correct to add across services. I have conducted this as a thought exercise to demonstrate the implications that this work could generate if the underlying approaches are not taken into consideration in decision making.

is to prioritize global cultural services over local provisioning services. Indeed this is seen to happen in Kenya (Hicks et al. 2009), promoted by the market based land distribution model favoured by the World Bank (Fortin, 2005). Here, coastal tracts are sold to wealthy investors for beach side properties rather than retained for local fishers' beach access. Local fishers may potentially benefit from the recreation, aesthetic or coastal protection values being maximized. However, we would expect them to prioritize their physiological and safety needs above any conservation or aesthetic needs (Cinner & Pollnac 2004; Maslow 1970). These situations result in governments and local resource users subsidizing the costs. For example, again in Kenya, park user fees rarely cover the management and opportunity costs of conservation, where the benefits are indirect and external (Norton-Griffiths & Southey 1995). The benefits, as well as opportunity costs of these approaches are unevenly distributed with the benefits accruing to global or national, rather than local stakeholders, resulting in trade-offs across ecosystem services, stakeholders and scales. Ecosystem service bundles consider ecosystem services that often appear together under certain social ecological conditions (Raudsepp-Hearne et al. 2010). Such an approach would allow for the consideration of multiple ecosystem services without the need to value all of them and warrants investigation in the WIO region.

Although there is general agreement in the values assigned to ecosystem services by both global and WIO studies, it should be noted that sample size was low for some services. Biodiversity and option represent the two services where significant differences in value estimates are evident. Global studies assigned greater value estimates to biodiversity whilst WIO studies assigned marginally higher value estimates to option. These differences are likely due to inconsistent definitions across studies as well as differences in value. For example, Ruitenbeek and Cartier (1999) suggested basing biodiversity value on the levels of international support available to protect biodiversity, which could also represent the option value (Hundloe et al. 1987). Caution is necessary because when the distinction between two services becomes blurred, there is a potential for double counting ecosystem values. Double counting is an issue that receives considerable attention. Supporting services in particular pose a challenge as supporting services provide all other services. One key distinction between option and most other services is time**.** However, as we do not have markets over different time scales we rarely considered changes in

value over time (Dasgupta 2010), making this distinction problematic. Although studies use discount rates that incorporate the value a service will continue to have over time, these present purely financial views of natural capital (David et al. 2007) and fail to consider changes in preferences or value (Spash 2009). Developing approaches to consider these elements could go some way towards understanding the relationship between current and future biodiversity value.

2.6. Management implications

Despite the attempts of ecosystem service research to redress imbalances between uses and needs, the agenda is still set by more powerful global and national economic interests. Other than a few studies designed to address a specific management question, the available literature does not have the ability to provide robust management advice. Management requires the balancing of multiple priorities within complex socio-political situations. I therefore offer five recommendations that would improve the applicability of coral reef valuation studies for management across spatial and temporal scales. Firstly, we need to develop, test and incorporate suitable methods that account for changes in the supply of critical supporting services into the broader ecosystem services framework. Secondly, existing methods need to be improved and standardized for comparisons to be made across service assessments. Thirdly, studies need to be explicit about whose values are being counted thus acknowledging whose are not being counted. Approaches which assess a broad range of ecosystem services, simultaneously and across scales, are needed in the region. A better understanding of which ecosystem services commonly occur together would reduce the potential for unexpected and undesirable trade-offs. Fourthly, it is accepted that different classifications may be necessary for different applications of ecosystem services research (Costanza 2008). We therefore need to define and standardize the terminologies used, what considerations are pertinent to a WIO context and pay particular attention to option values. This is necessary within individual studies as well as for scientists collectively. Finally, a better understanding of how and why ecosystem services contribute to human well-being will aid in developing management recommendations. Social assessments carried out in conjunction with ecosystem service assessments would help us understand the conditions around which priorities for ecosystem

Chapter 3

Key ecosystem service values associated with a coral reef fishery and their implications for management

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Adapted from: CC Hicks N Stoeckl JE Cinner J Robinson (in revision) Key ecosystem service values associated with a coral reef fishery and their implications for management ***Ecology and Society***

3.1. Abstract

Fishers often behave in ways that were neither intended, nor anticipated, by managers or policy makers. Understanding the factors that motivate and constrain behavior is therefore necessary to develop effective policy. I therefore developed a framework, taking resource users' ecosystem service values and their social characteristics into consideration, to evaluate the potential outcome of two approaches to management and applied it to a case study of coral reef artisanal fishers in Seychelles. I conducted individual qualitative and quantitative questionnaires, to distinguish and estimate values associated with the fishery, and collect indicators of the local social context. I found that fishers identified a diversity of benefits associated with the fishery but either prioritized option or direct fishery values. Decentralized approaches to management were more likely to succeed where fishers had higher option values because these fishers reported higher levels of support, identified avenues to resolve conflicts and were more likely to be proactive if they felt a norm had been broken; all characteristics that have been previously shown to improve the likelihood of collective action. Because I found greater direct fishery values when income was lower, there are distributional implications associated with incentive based policies that impact income, and these approaches can create potentially perverse outcomes. A diversity of fisheries management approaches are needed to match the social complexity present; however, poverty alleviation should feature as both fisheries and conservation priorities, and successes in areas where the conditions are conducive to management is likely to produce benefits to fishers elsewhere.

3.2. Introduction

Effectively governing natural resources so that they are used sustainably is a formidable challenge for many societies. This is partly because problems relating to sustainable resource use are inherently interdisciplinary, requiring social, political, ecological, and economic considerations to be balanced (Ostrom et al. 2007; Jennings 2004). Fisheries management is a classic example of such an interdisciplinary challenge where managers and scientists face livelihood, conservation, and governance issues, all of which are inextricably linked (Allison et al. 2012; McClanahan & Hicks 2011; Hilborn et al. 2004). Small-scale fisheries pose a particular challenge because they are complex systems employing 95% of those engaged in the world's fisheries sector, 90% of whom are in developing countries (Béné et al. 2010; Mahon et al. 2008). Despite the disproportionate global dependence and high levels of complexity inherent to small-scale fisheries, they receive the smallest proportion of fisheries science efforts (Mahon 1997). Consequently, there is a growing urgency for viable solutions that will need to be tailored to the local socioeconomic context in which small scale fisheries operate (Cinner et al. 2012; Gutierrez et al. 2010; Ostrom 2007).

Fisheries management generally involves controlling capacity, access, or technology (McClanahan 2006; Jennings 2004). There are many tools for achieving these controls, but little agreement on what constitutes the best governance approach to implementation (Hilborn et al. 2004). Governance approaches generally lie along a continuum from centralized to decentralized. Decentralized approaches, generally include co-management or community-based management and can involve assigning property rights to the resource, are often preferred by sociologists and political scientists because they involve stakeholders in a social process (Fulton et al. 2011; Field & Field 2008; but see Blaikie 2006). Although decentralized approaches have gained in popularity, particularly for managing common property systems, (Gutierrez et al. 2010) their success is dependent on individuals interacting and negotiating to reach agreement on rules based on existing institutions, their values and levels of use. Evidently, successful common property management outcomes are more likely when the characteristics that enable collective action, such as trust, and specific institutional designs are present (Cinner et al. 2012; Cox et al. 2010; Ostrom 2009; Ostrom 1990).

Incentive policies, such as a tax on fishing or an incentive not to fish, can be designed within a decentralized system, but are more commonly used tools within centralized systems; centralized approaches tend to be preferred by economists due to their perceived lower transaction costs (Costello et al. 2010; Field & Field 2008). A new tax is likely to impact people's income by increasing the cost associated with fishing, yet analyses on the effectiveness of incentives are based on the impact of changes in relative price and tend to ignore any distributional implications (Meenakshi & Ray 1999; Flores & Carson 1997). If poorer households have a greater fishery demand than wealthier households then a tax that impacts income may increase fishery demand rather than reducing it. So although a preference for lower transaction costs is valid, ignoring distributional implications may result in cheap but ineffective policies. However, if this relationship between income and fishery demand holds true then poverty alleviation and biodiversity conservation efforts may be aligned, and improvements in either could benefit the other (Brashares et al. 2011).

Because managers and policy makers often do not understand the conditions that influence behavior, the way resource users behave is often unintended and unanticipated (Fulton et al. 2011). People benefit from nature in a number of ways, often conceptualized as receiving goods and services. Individuals' preferences for these goods and services are likely to differ even when their activities are similar. For example, coral reef fishers may prioritize the fishery, recreational, spiritual, or biodiversity benefits associated with the fishery differently to non-fishers. Human behavior is motivated by an individual's values and preferences (Becker 1976) therefore, designing effective policies requires the individuals involved in policy and rule making to understand the preferences and priorities of those likely to be affected. Neo-classical economics has been criticized for its narrow view of how values motivate behavior, but recent research in behavioral economics and beyond, has begun to incorporate psychological motivating characteristics such as rights, attitudes, beliefs, and norms (Kahneman & Thaler 2006, Spash 2008; Spash & Biel 2002; Ajzen 1991). Furthermore, there is a parallel area of research examining how certain contextual attributes influence behavior in natural resource systems (Ostrom 2009). For example, studies have shown that fisher's livelihood options,

wealth and group membership influence how likely an individual is to exit a declining fishery (Daw et al. 2012; Cinner et al. 2011).

Designing locally appropriate policies involves balancing a diversity of competing values with an understanding of the contextual characteristics that interact to affect behavior (Armsworth & Roughgarden 2001; Becker 1976). Decision makers need information on the values associated with an ecosystem as well as how these values relate to the social context they are set within. Yet, few studies have investigated the ways that management policies can be designed to reflect local socioeconomic conditions, including institutions, and individual values (Fulton et al. 2011). Using a case study of artisanal coral reef fishers in Seychelles, I first identify the values driving resource use by establishing the range of benefits fisher's associate with the fishery and quantifying the key values identified. Second, I establish whether local conditions are conducive to a decentralized approach to fisheries management by testing the hypothesis that the 'key fishery values are associated with the enabling characteristics of collective choice arrangements' (Ostrom 2007). Finally, I establish whether local conditions are conducive to the use of incentive based tools for fisheries management by determining how key fishery values are related to income (Brashares et al. 2011).

Seychelles context

The Seychelles is an archipelagic nation of 115 islands spread across a vast exclusive economic zone (EEZ) of 1.4 million km^2 in the western Indian Ocean. The population is small (87,000) and largely confined to the 3 largest islands. It is an upper middle income country (GNI per-capita: US$ 10,300), with tourism and fisheries constituting the principal economic sectors. Traditional small-scale fisheries are confined to the populated granitic islands, primarily Mahé, Praslin and La Digue, which are situated centrally on the large (41,400 km^2) and shallow (0-75 m) Mahé Plateau. Agriculture production is land-limited (total land area of 455 km^2) and fish contributes significantly to food and nutrition security. On independence from the UK in 1976, Seychelles adopted a socialist agenda with centralized state control of economic sectors. Consequently, fisheries management was largely top-down and decentralization of decision-making was limited.

Although some fish stocks in Seychelles are relatively healthy (McClanahan et al. 2011; Robinson et al. 2011), overcapacity is worsening and most small-scale fisheries remain open access and unmanaged in terms of input or output controls. Operational fisheries management plans do not exist and regulations are limited to licensing of commercial fishing vessels and nets, as well as mesh size limits for the trap fisheries. A proactive approach to destructive and unselective gears has been adopted, with trawls, explosives, and poisons prohibited, and beach seines phased out (Mees et al. 1998). There are a large number of small (ranging from <1 to 30 km^2) no-take reserves in the granitic islands, covering less than 2% of the inshore fishing grounds, which are managed by the state or NGOs. The trap fishery is the principal fishery operating in the inshore fishing grounds. The perceptions of benefits from these reserves by fishers are mixed and compliance varies from low to high depending on location (Daw et al. 2011; Robinson et al. 2011; Wood 2004).

Fisheries management in the Seychelles will remain largely centralized for the foreseeable future, relying on incentives and monitoring. However, as the country increasingly moves towards a market-based economy, fishers associations are receiving a degree of support by government and a program to introduce decentralized co-management for the inshore fisheries is ongoing (Daw et al. 2011).

3.3. Methods

Sampling

I used a combination of open ended and semi-structured questionnaires to interview inshore trap fishers about their socioeconomic conditions and the values associated with the fishery. I selected 36 respondents across the age and geographic range of those involved in the industry in Praslin and Mahé Islands based on local knowledge. Due to variations in working hours and the opportunistic nature of fishing, I used non-probability sampling techniques, including convenience and snowball sampling (Henry 1990). Those interviewed were all from different crews and represented ~80% of all trap fisher crews across the three inhabited islands in the Seychelles.

Non-monetary valuations

I used expert knowledge and focus groups to identify 12 values associated with the coral reef fishery under the total economic valuation classification system (see Chapter 1, Fig x). Direct use values included direct fishery, education, recreation, culture, medicine, and option. Indirect use values included biodiversity control, habitat refuge, coastal protection, and water quality maintenance. Non-use values included bequest, and existence. I used individual questionnaires to discuss, identify, and rank these values. Respondents were asked about their perception of each value, what each value represented to them, and whether they or someone they knew benefitted from the value. I asked about the importance of each value (rated on a three point scale: low importance, important, and very important) (Ronback et al. 2007). I used Kruskall-Wallis test to look for differences in mean rank values across all 12 values associated with the fishery. I used Games-Howell post hoc analysis to look for significant differences across categories and classify our values associated with the fishery as low, medium, and high importance (Field 2009, IMB SPSS Statistics 20). Only values associated with the fishery that were revealed by post hoc analysis to have a high value were retained for monetary valuation.

Monetary valuations

I designed a contingent valuation method (CVM) (Spash 2008; Bateman et al. 2002; Arrow et al. 1993) to assign monetary estimates to the values associated with Seychelles' coral reef fishery that were of high importance (direct fishery, option, and bequest) (Appendix 9.1). Such an approach, known as stated preference, is designed to ask people hypothetically, how much they would be willing to pay (WTP) for a good or service, or willing to accept (WTA) to for go having a good or service (See chapter 1 for a discussion of WTP relative to WTA). Respondents were presented with a hypothetical scenario asking how much compensation, per week, they would need to stop fishing, how much additional travelling time, per week, they were willing to incur to ensure others would be able to use the fishery if they chose, and how much additional travelling time, per week, they were willing to incur to ensure their children would be able to benefit from the fishery in whatever way they choose (Appendix 9.1) (Hicks et al. 2009). Responses were elicited through a bidding game with the lowest value offered first. Different

quantities offered to forego fishing were trialed in piloting to determine a suitable starting point (Turner et al. 2010; Hicks et al. 2009; Freeman 2003). In order to validate the use of a contingent valuation format in our setting, I also calculated direct fishery value estimates using a market valuation method based on the ex-vessel value (Hicks et al. 2009). The relationship between the contingent valuation and market valuation direct fishery value estimates were compared using Pearsons' correlation analysis, after testing the data for normality (see Appendix 9.1 for more details on methods).

Option and bequest values

An option value can be a use or non-use value and refers to the value in preserving the option of benefiting from something in the future; the bequest value refers to the value in knowing something will be there for future generations to benefit from (Bateman et al. 2002). The additional travelling time a fisher was willing to incur to preserve the bequest and option values associated with their fishery was converted to an annual and a proportional willingness to pay (WTP)**.** The annual WTP was established based on the additional travel time incurred; the fishers hourly catch rate and the price of fish. The proportional WTP was based on the additional travel time incurred in a year relative to the number of fishing hours in a year

$$Annual\ WTP_i = x \times y \times z \quad \text{(Equation 3.1)}$$

$$Proportional\ WTP_i = \frac{x}{a} \quad \text{(Equation 3.2)}$$

i= option or bequest; x= additional travel time incurred in a year; *y*= hourly catch rate; *z*= price of fish; *a*= number of fishing hours in a year.

Direct fishery value

The additional travelling time a fisher was willing to incur to preserve the bequest and option values associated with their fishery was converted to an annual and a proportional willingness to pay (WTP)**.** The annual WTP was established based on the additional travel time incurred;

the fishers hourly catch rate, and the price of fish. The proportional WTP was based on the additional travel time incurred in a year relative to the number of fishing hours in a year

The direct fishery value was calculated based on how much money a fisher was willing to accept (WTA), per day, to forgo fishing. The annual WTA was converted to an annual rate based on the number of days fished in a year. The proportional WTP was an individual's annual WTA as a proportion their fishing income.

$$Annual\ WTA_j = k \times l \quad \text{(Equation 3.3)}$$

$$Proportional\ WTA_j = \frac{Annual\ WTA_j}{m} \quad \text{(Equation 3.4)}$$

j= direct fishery value, k= amount willing to accept to give up fishing, *l*= fishing days in a year, m= annual fishing income

Contextual characteristics

I established if conditions are conducive for a decentralized approach to fisheries management using semi-structured questions to gather information on 16 actor attributes thought to influence the ability of communities to self-organize and collectively manage their resources (Ostrom 2011; 2009; 1990). Attributes were classified into six characteristics: 1) Social capital, which included information on participation in community ceremonies, community organizations, decisions and whether fishers felt supported and offered support; 2) Norms, which included responses to norm breaking; 3) Knowledge of social ecological systems/mental models which included ecological knowledge based on the importance of habitat structure and functional diversity; 4) Conflict resolution mechanisms, which included response taken when faced with fishery problems; 5) Importance of resource which included fishing effort, catch, occupational multiplicity, importance of fishing, dependents and household expenditure; and 6) Socio-economic attributes which included age and migration status (Table 3.1). I calculated income from the market value of fishers' reported catch to assess the distributional implications of an incentive-based fisheries policy. I coded responses to the questions relating to norms, social capital, ecological knowledge, conflict resolution, whether fishing was a

primary occupation, and migration status into a binary or categorical scale. I combined the responses to levels of support into a single metric using a principle component analysis (Cinner et al. 2011, Field 2009, IMB SPSS Statistics 20). All other attributes were reported as continuous numbers.

Table 3.1 User characteristic indicators measured, questions asked, and response type given, for each social characteristics used relating to the efficacy of management approaches.

Characteristic	Indicator	Questions asked	Response
Norms	Response to norm breaking	1. What would you do if you saw or heard of another fisher leaving traps overnight during the spawning season in a spawning site?	Qualitative response (classified)
Social capital	Ceremonies	1. Do you participate in any community events or ceremonies?	Yes/no
	Community orgs	1. Are you a member of any community or fisher organisations?	Yes/no
	Involvement in decisions	1. Are you involved in decisions concerning the marine environment?	Yes/no
		2. Do you feel involved in decisions concerning your community?	Yes/no
	Support	1. Do you feel supported by:	
		2. Are you willing to offer support to:	
		a. Other trap fishers?	Yes/no
		b. Other fishers	Yes/no
		c. The district administration?	Yes/no
		d. The government?	Yes/no
Knowledge of Social ecological system/ mental models	Ecological knowledge	1. Respondents were asked to choose between three pictures and descriptions of fishing grounds that differed based on fish composition, presence of key functional groups and abundance (all key functional groups present but lowest abundance, some key functional groups missing medium abundance, only herbivores present, high abundance).	A, B, C
		2. Respondents were presented with a hypothetical scenario based on Graham et al (2007) where a climatic event had affected the habitat structural complexity with a resultant decline in small bodied fish and asked how they would feel about this situation.	Happy, not affected, concerned
Conflict resolution mechanisms	Response to problem	1. Individuals were asked what they would do if they had a problem concerning the marine resources.	Qualitative response (classified)

Importance of resource	Effort	1. How many fishing trips do you go on in a week?	Number
		2. How many gear types do you use?	List, number
		3. How long do you spend fishing?	Hours
	Catch	1. What would your catch be on a fishing day that was:	
		a. Good	kg
		b. Average	kg
		c. Bad	kg
	Numb occupations	1. What jobs do you do that brings in money or food?	List, number
		2. What jobs do others in your household do that brings in money or food?	List, number
	Occupation	1. Is fishing your primary occupation?	Yes/no
	Dependents	1. How many people live in your house that are	
		a. Men	Number
		b. Women	Number
		c. Girls	Number
		d. Boys	Number
	Expenditure	1. In a fortnight how much do you spend on food and entertainment?	Rs/fortnight
Socio-economic attributes	Age	1. How old are you?	Age
	Migration status	1. Where you originally come from?	Here, this district, this Island, this country
		2. How long have you lived here?	Number of years

Data analysis

I used an analysis of variance (ANOVA) to test for differences in the estimates assigned to option, direct fishery and bequest values (Field 2009). Prior to this I used the Shapiro-wilks test to check my data for normality (Field 2009, IMB SPSS Statistics 20) and square root transformed the direct fishery value estimates to achieve normality. In stated preference monetary valuations a response value of zero, or a missing response, can occur for a number of possible reasons. I used the non monetary responses to check the validity of all zero or missing monetary responses. When a zero or missing response was associated with a high importance ranking, I assumed the respondent did not want to answer the question or did not understand the question and removed these values (Spash 2008). Estimates are calculated with and without the zero responses, for comparison, and the response rates are reported.

I used a redundancy analysis to test the hypothesis that 'key values associated with the fishery are associated with the enabling characteristics of collective action'. A redundancy analysis combines a multiple regression with an ordination to bring out the difference in two-dimensional space (ter Braak & Smilauer 2002, CANOCO 4.5; Legendre & Legendre 1998). This allowed us to examine associations between the dominant values associated with the fishery and the actor characteristics thought to influence the ability of communities to self-organize and collectively manage their resources. The independent variables (actor characteristics) identified from theory to be used in the redundancy analysis were reduced using an exploratory stepwise regression analysis to establish which actor characteristics contributed to the variation in option, direct fishery, and bequest values (Field 2009, IMB SPSS Statistics 20).

Distributional implications are often evaluated by looking at the income elasticity of demand which is a measure of how demand for a good changes with changes in income (Egbert 2002). Policies that restrict goods are thought to benefit the rich if demand for the good decreases with increases in income (Flores & Carson 1997). However, when dealing with a common resource, such as a fishery, there is a distinction between the income elasticity of demand and income elasticity of the environmental value (Ebert 2003). I therefore established whether local conditions were conducive to the use of incentive based tools by examining the effect of

income on proportional WTP/WTA for each of the key values associated with the fishery (option, direct fishery and bequest) (Flores & Carson 1997). I used proportional WTP to remove income from the WTP calculation. I examine how the key values associated with the fishery relate to income by regressing income separately against proportional WTP/WTA option, direct fishery and bequest values (Brashares et al. 2011).

3.4. Results

Value classification

Open ended questions revealed fisher's conceptualizations of the values associated with the fishery to be generally consistent with standard definitions. The exception was option values. Option was identified as the importance attached to the fact that others (who were not currently using the fishery) have a right of access. For example fishers stated that "the sea is for everyone" and "anyone can come from anywhere to use it [the sea]", that "it is wrong to restrict other's access". These opinions echo Grotius' (Grotius 1916) argument on the "freedom of the sea", that nobody has the right to deny others access, that doing so "destroy[s] the bond of human fellowship" removing "the opportunities for doing mutual service" implying a cultural component to this value.

Non-monetary valuations

Both non-use goods (bequest and existence) and two of the direct use goods (direct fishery and option), were estimated to be of high importance. Two direct use services (medicine, culture) were categorized as low. All other goods and services, which included two direct use services (education, recreation) and four indirect use services (biodiversity control, habitat refuge, coastal protection, water quality maintenance) were categorized as medium (Figure 3.1). Significant differences were found between low and high valued goods ($P<0.005$), but those of medium value could not be distinguished based on post hoc analysis.

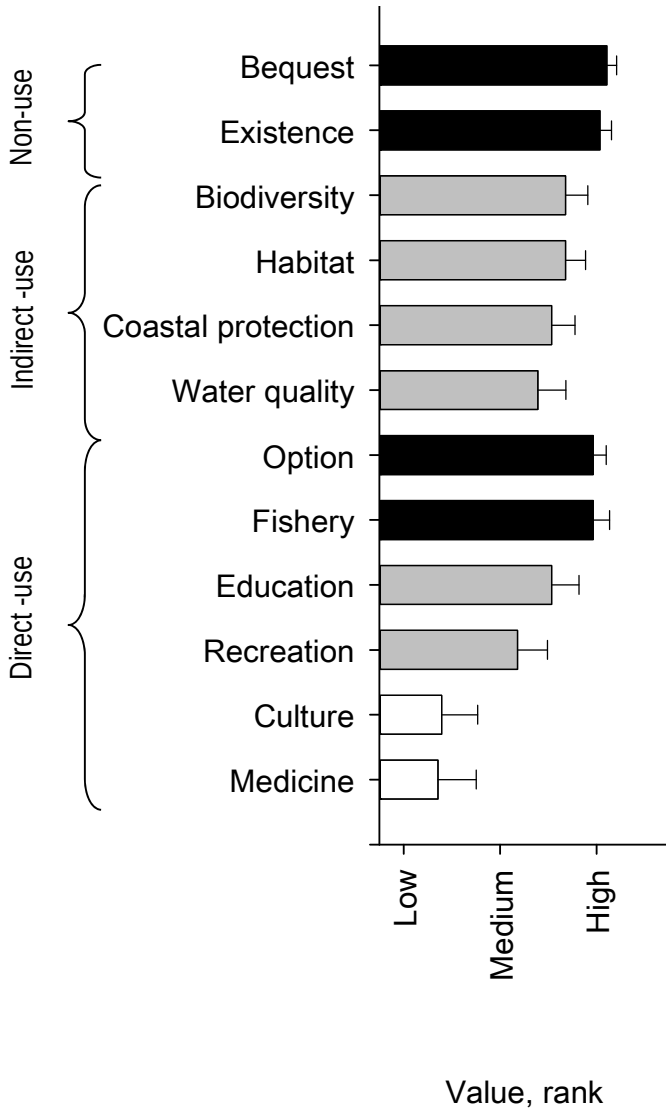

Figure 3.1 Average ecosystem service value (rank)
Average values assigned to all 12 identified ecosystem goods and services based on ranking high medium and low +/- standard errors of the mean. Differences based on James - Howell post hoc analysis, black represent services of high importance, grey medium importance and white low importance. Services of high importance are significantly different to those of low importance (P< 0.005). Fishery refers to direct fishery.

Average values assigned to all 12 identified ecosystem goods and services based on ranking high medium and low +/- standard errors of the mean. Differences based on James - Howell post hoc analysis, black represent services of high importance, grey medium importance and white low importance. Services of high importance are significantly different to those of low importance (P< 0.005).

Monetary valuations

Direct fishery, option, bequest and existence values were estimated using CVM. Both annual WTP/WTA estimates of option (US$18,124 SE 2,549) and direct fishery (US$ 18,527 SE 2,789) values were greater than the estimates of bequest (US$ 10,908 SE 1,228) value (P<0.005) (Figure 3.2). I do not report the existence value results as these produced a large number of protest bids (respondents refused to answer the question). Direct fishery, option and bequest value estimates received 3, 1 and 4 protest bids respectively. This represented 8%, 3% and 11% of responses and increased estimates by 9%, 3% and 13% for direct fishery, option and bequest values respectively.

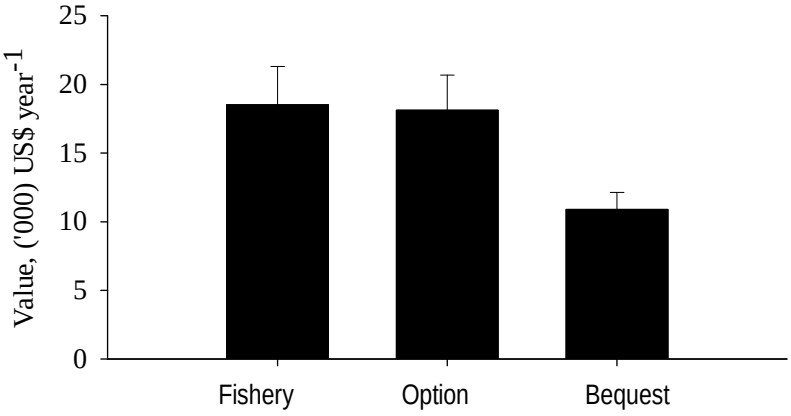

Figure 3.2 Average ecosystem service value (monetary)
Average values assigned to direct fishery, option and bequest values based on contingent valuations, +/- standard error of the mean.

Conditions conducive to decentralized management

Norms, participation in community organizations, levels of support, ecological knowledge, conflict resolution mechanisms, occupational multiplicity and household expenditure contributed to the variation in option, direct fishery and bequest values (P<0.01) (Table 3.2, Figure 3.3). The greatest variation in values was found between individuals who prioritized direct fishery values and those who prioritized option and bequest values (92% variation

explained by the first axis; C1). Individuals who prioritized option values were also distinct from those who prioritized bequest values (8% variation explained by the second axis; C2) (Figure 3.3). Bequest and option values were associated with enabling characteristics of collective choice arrangements. Individuals who valued the option and bequest aspects: 1) would take action when a norm was broken; 2) had access to conflict resolution mechanisms; and 3) felt supported by those involved in the fishery as fishers or managers and were willing to offer support to these stakeholders in return. Individuals with greater option values were also likely to have more household occupations and those with greater bequest values were also more likely to be involved in community organizations. Individuals who prioritized direct fishery values had: 1) fewer household occupations; 2) greater expenditures; 3) greater measures of ecological knowledge and; 4) lacked conflict resolution mechanisms (Figure 3.3).

Table 3.2 Exploratory stepwise regression analysis to establish which user characteristics contributed to the variation in option, direct fishery, and bequest values

	Option		Bequest		Direct fishery	
	F	p	F	p	F	p
Respond to norm breaking	-	NS	13.8	0.01	-	NS
Organizations	8.4	0.01	6.2	0.03	-	NS
Support	-	NS	6.9	0.03	-	NS
Biodiversity knowledge	-	NS	-	NS	5.2	0.04
Lack conflict resolution	5.6	0.03	-	NS	8.1	0.01
Expenditure	-	NS	-	NS	3.8	0.07
Occupation multiplicity	4.7	0.05	-	NS	NS	NS

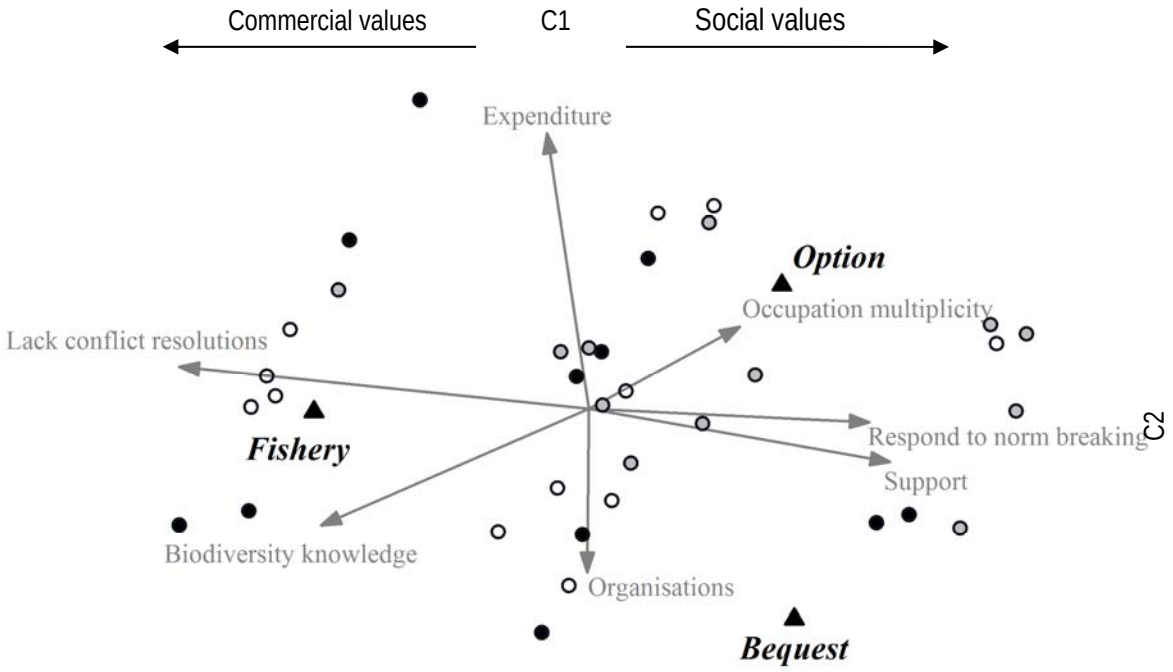

Figure 3.3 Variation in value explained by socio-economic characteristics
Redundancy analysis showing spatial distribution of fishers values and the associated fisher's socio-economic characteristics driving differences in distribution (C1=92%, C2=8% of variation; P=0.04).

Distributional implications of an incentive approach

An increase in household income was associated with a decrease in proportional WTA direct fishery values (p=0.002, F (1,34) =11.5, r^2= 0.29) and an increase in proportional WTP option values (p=0.004, F (1,32) =10.1, r^2= 0.26) (Figure 3.4). There was no relationship between household income and proportional WTP bequest values (P=0.82, F (1,31)= 0.05, r^2 = 0.02) (Figure 3.4).

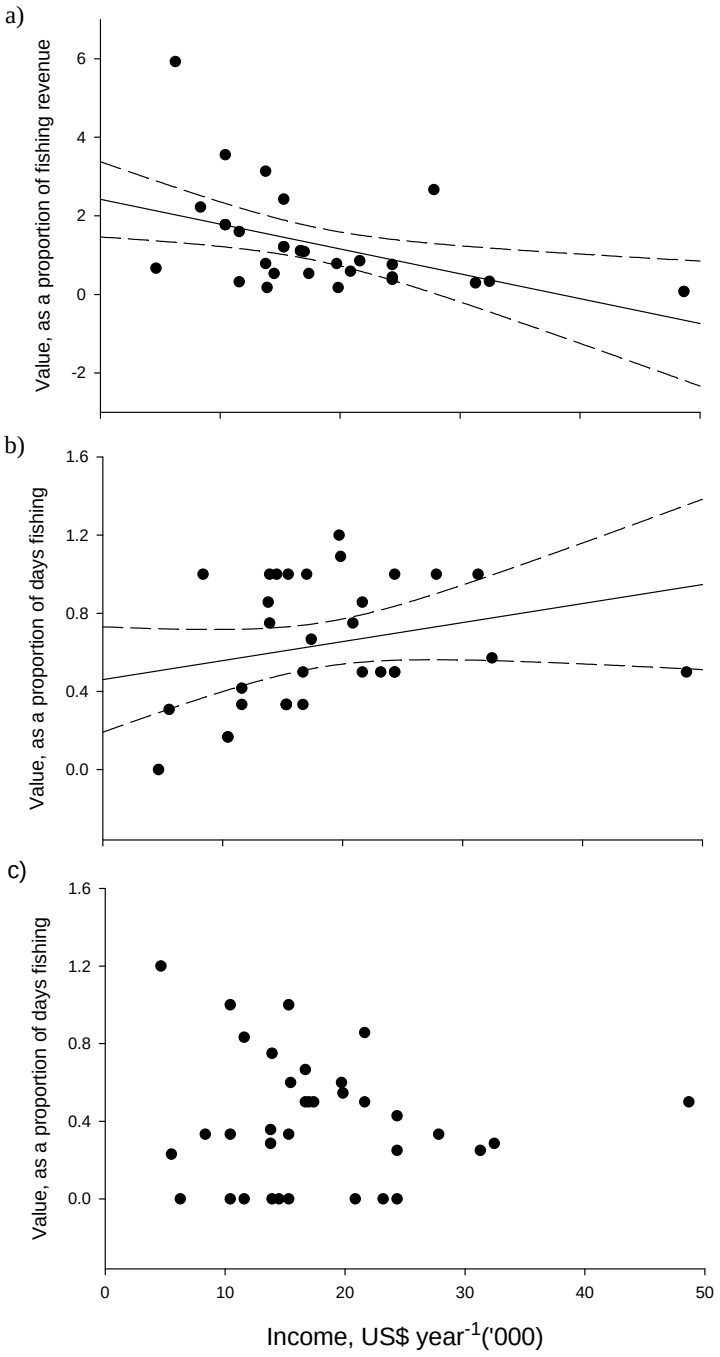

Figure 3.4 Variation in value explained by income

Estimated a) direct fishery, b) option and c) bequest values, as a proportion of days fishing, regressed against fishers income in US $ year^{-1} with 95% confidence intervals shown. A (p=0.002, F (1,34) =11.5, r^2= 0.29) (p=0.004, F (1,32) =10.1, r^2= 0.26) (P=0.82, F (1, 31)= 0.05, r^2 = 0.02)

3.5. Discussion

People make decisions and behave according to the values they hold and the structural features of their social setting (Ostrom 2011; Camerer 2003;). Azjen 1991I therefore set out to identify the values driving resource use in an artisanal coral reef fishery and, based on key contextual characteristics, determine whether conditions were conducive to a decentralized approach to fisheries management or the use of incentive based tools. Three key findings that have direct policy relevance were evident: 1) Fishers identified a broad range of values associated with the coral reef fishery, direct and non-use values were of greatest importance, and two salient values - option and direct fishery - received the highest value estimates; 2) Individuals who prioritized direct fishery values were distinct from individuals who prioritized option values; these differences were reflected in their social characteristics with individuals who prioritized option values more likely to engage in collective choice arrangements; 3) Individuals with lower incomes tended to have greater direct fishery values and lower option values creating distributional implications for the use of some incentive based tools.

My first key finding that Seychelles' inshore trap fishers identified a range of different values associated with their fishery illustrates the social complexity, and diversity of interests that may exist within groups of similar individuals (Fabinyi et al. 2010; Agrawal & Gibson 1999). Although the Seychelles inshore trap fishery represents a relatively homogenous group of male fishers who use the same gear and consider fishing to be their primary and usually sole occupation, the heterogeneity of values encountered suggests management needs to be inclusive of a range of benefits, rather than focus on individual objectives such as yield maximization or biodiversity conservation. Direct fishery, option, existence and bequest values were identified as more important than any indirect use values, such as water quality or biodiversity. Direct fishery, option, existence, and bequest values are not explicitly associated with environmental quality; however, they are dependent on the maintenance of a certain level of ecosystem health. The millennium ecosystem assessment (MA 2005), in an attempt to align environmental quality with human preferences, has championed efforts to reframe nature's services as the benefits they provide to humans. However, studies repeatedly find indirect use values (also characterized as regulating or supporting services) traded off in favor of direct use values (also

characterized as provisioning or cultural services) (Martín-López et al. 2012; Raudsepp-Hearne et al. 2010; Rodríguez et al. 2006; MA 2005). It is likely that this trade-off occurs because indirect use values occur over longer time periods than direct use values. For example, given the option of a benefit now (income from fishing), and an equal benefit in 5 years time (protecting habitat to that the fishery habitat will maintained in 5 years time), most people will prioritize the benefit now, especially if the benefit in 5 years has no market value. People are therefore likely to discount future benefits (indirect use values) in favor of more immediate benefits (direct use values). I also find that fishers prioritize direct and non use values over indirect use values suggesting a continued need for fisheries managers to explicitly incorporate ecosystem or environmental targets into management.

My second key finding distinguished fishers who prioritized direct fishery values from those who prioritized option values based on key social characteristics. Distinctions based on values and social characteristics enable an understanding of how individuals intend to behave (Azjen 1991) making it possible for managers to plan appropriate strategies. For example, decentralized fisheries management approaches rely on collective action, they need individuals to come together to make decisions concerning resource use, confident that those rules will be adhered to. Indicators of social capital such as support within a community (Pretty & Ward 2001), make it more likely that people will come together to make decisions and rules (Cox et al. 2010). Similarly, groups are more likely to stick to those rules, or norms, if they feel the rules are being monitored, they know what to do when a problem arises, and they feel they are enforced (Ostrom 2011; 2009; Cox et al. 2010; Rothstein 2005; Ostrom 1990). Fishers who prioritized option values reflected greater levels of support, identified avenues for resolving conflicts, and were more likely to be proactive in upholding an existing norm; characteristics that encourage individuals to come together for collective action. Therefore, if these individuals were interested in fisheries management, decentralized approaches would likely work.

Conversely, fishers who prioritized direct fishery values came from households with fewer occupations, lower incomes, and higher expenditures. Additional occupations represent other forms of income that a household can draw on in times of trouble; these households are

therefore less dependent on the resource. It is possible that the higher levels of dependence among fishers that prioritize direct fishery values, mean these fishers are focused on meeting their basic needs and less motivated to pursue other benefits, such as maintaining the option value of "the sea for everyone" (Chai & Moneta 2010; Engel 1857). This tendency to prioritize meeting basic needs (e.g. food and shelter) before individuals are motivated to fulfill any subsequent needs (e.g. conservation) has been reported elsewhere (Cinner & Pollnac 2004), and most notably in work on Maslow's hierarchy of needs theory from psychology (Maslow 1943). So, although the fishers with greater direct fishery values are in greater need of resource management, they are also less likely to engage in decentralized approaches. Alternate, complementary, strategies are needed for these individuals. It is possible that once individuals' most basic needs are met, they have the time to invest in the social interactions and reciprocal arrangements needed to build trust, co-ordinate negotiations, and reach decisions thus creating the conditions that are conducive to a decentralized policy approach.

My third key finding, that lower household incomes are associated with higher direct fishery values highlights the importance of considering the distributional implications of incentive based tools (Ebert 2003). Because poorer households have greater direct fishery values than wealthier households, the burden of a direct fishery values tax would fall disproportionately on the poor (Flores & Carson 1997). Incentive tools that impact income, such as taxes, run the additional risk of creating potentially perverse outcomes. For example, if a tax creates a decrease in income, which is associated with greater direct fishery values, then instead of a decline, we could observe an increase in the amount of fishing if the income effect of the tax outweighs the substitution/price effect. However, this is an empirical question for further research. This situation is analogous to a poverty trap; the poorer households become, the fewer options they have, so the less willing or capable they are of exiting the fishery and the more they ultimately need to fish (Daw et al. 2012; Cinner et al. 2011; Cinner 2011). It is also possible that stronger property rights may influence this relationship and alter the size of people's discount rates. Property rights are likely to provide people with a greater confidence that the resource will be there for them to benefit from rather than being exploited by others. However, because I found lower levels of income associated with higher direct fishery values,

poverty alleviation should be aligned with biodiversity conservation efforts so that improvements in one would benefit the other. Fisheries managers would therefore do well to focus on alleviating poverty where fisheries management proves challenging. Although I found direct fishery values to decrease with income, trends in fish consumption tend to increase with income (Pontecorvo et al. 2009; Brashares 2004). The different response of direct fishery values and fishery demand to changes in income create different distributional implications (Ebert 2003) that are inadequately considered in policy making decisions (Meenakshi & Ray 1999). It is likely that these differences between direct fishery values and fishery demand are linked to differences in the substitutability of fishery as a good (e.g. a choice of food where options exist) and fishery as a service (e.g. choice of occupation where limited options exist).

Although managers tend to opt for simple solutions to natural resource management, the diversity of values encountered in the Seychelles' fishery suggests that a diversity of management approaches are necessary (Ostrom 2007). The Seychelles' inshore trap fishery faces challenges in developing effective policy, yet there are some easy wins that can be taken advantage of that would serve to build trust and support for management; crucial first steps towards successful engagement and effective management. For example, individuals with greater option values were most likely to engage in decentralized approaches to management. These could include collaborations between the fishers and the fisheries authorities to facilitate a process for rule making and devolving power to fishers associations. It is worth noting that such a process is now under way in the Seychelles (UNDP) and should be applauded for its efforts. The individuals who prioritized direct fishery values were least likely to engage in decentralized approaches and would be the most impacted by a tax on the fishery. However, these individuals would still benefit from effective management in adjacent systems (McClanahan et al. 2008). Additional approaches should include poverty alleviation efforts and build characteristics associated with collective action. For example a long term objective could be to meet fishers' basic needs, build networks of support and community engagement, and invest in developing conflict resolution mechanisms and training. Other potential opportunities relate to the greater indicators of ecological knowledge associated with higher direct fishery values. When stakeholders think in similar ways they are more likely to reach agreement on

rules concerning the resource (Armitage et al. 2011; Cox et al. 2010; Ostrom 1990). A process where fisheries managers and resource users come together to agree on ecological targets is more likely to result in biodiversity success (Kenward 2011)

3.6. Conclusion

Although Seychelles' fisheries are in a better condition than much of the Western Indian Ocean (McClanahan et al. 2011), fisheries management should be proactive, and developing effective policies before decline is evident. No single approach will be effective across the whole fishery but addressing fishers basic needs should feature as both fisheries and conservation priorities. Incentives, such as taxes, may not be suitable because they impact income, possibly placing greater strain on fish resources. Other incentives, however that do not impact income may be feasible; such as group rights or payment for ecosystem services. Decentralized approaches may not receive support everywhere, but management can build on successes in areas where suitable levels of trust and support exist, and focus on building capacity in the characteristics that will make desirable approaches to management conducive in the future.

Chapter 4

Bundles and trade-offs in how managers, scientists, and fishers value coral reef ecosystem services

Chapter 4. Bundles and trade-offs in how managers, scientists, and fishers value coral reef ecosystem services

Adapted from: CC Hicks NAJ Graham JE Cinner (in press) Bundles and trade-offs in how managers, scientists, and fishers value coral reef ecosystem services ***Global Environmental Change***

4.1. Abstract

Managing ecosystems in a changing environment faces the challenge of balancing diverse competing perspectives on which ecosystem services (nature's benefits) to prioritize. Consequently, I measured and compared how stakeholders at different levels of decision making (managers, scientists and fishers) prioritize specific coral reef ecosystem services. The three stakeholder groups differed in how they prioritized ecosystem services, with fishers giving greater priority to fishery and education, managers giving greater priority to culture and scientists prioritizing coastal protection greater than the other stakeholders. Furthermore, within stakeholder groups, network analysis revealed bundles and tradeoffs in how ecosystem services were prioritized. Fishers' tradeoffs were between services of high priority, such as fishery and habitat. Conversely, scientists' tradeoffs occurred between services of high and low priority, such as habitat and culture. Managers had the greatest tendency to overlap with both fishers and scientists in interconnected priorities and may, therefore, play a brokering role, balancing both priorities and conflicts. I suggest that ecosystem service preference surveys can highlight key areas of agreement and conflict, both within and across stakeholder groups, to be addressed when communicating and prioritizing decisions.

4.2. Introduction

Societies are composed of individuals and groups that, because of diverse and often competing values and interests, often struggle to reach consensus-based decisions (Allison & Hobbs 2010; Verweij et al. 2006; Costanza 2000). Decision-makers are presented with a choice; represent the values of a few - perhaps a dominant group - or face the task of balancing diverse values and priorities. Conservation and natural resource managers strive to maintain intact or functioning landscapes, resisting or reversing environmental change. The task of managing these landscapes is exacerbated by the challenge of balancing priorities (McShane et al. 2011). This is in part because conservation is prioritized where threats to biodiversity are greatest (Pressey et al. 2007), in areas that are often inhabited by the poor, or that have significant economic potential (Adams & Hutton 2007; Adams et al. 2004). A failure to account for the diverse values encountered undermines conservation progress. For example, presenting only the values of a dominant economic interest potentially marginalize the most vulnerable sectors of society (Hicks et al. 2009), increasing inequality, and exacerbating environmental decline (Cinner et al. 2011). To be successful, natural resource management needs to integrate conservation priorities with the goals of local resource users. Therefore, natural resource scientists and practitioners need to engage in complex decision-making processes that can deal with multiple objectives and balance competing priorities (Ban et al. 2012; Berkes 2007; Tetlock 1986).

Ecosystem services refer to the benefits humans gain from nature (MA 2005). As a concept, ecosystem services incorporate diverse perspectives, balance ecological and human objectives, and have direct application and transferability to policy (Atkinson et al. 2012; Turner et al. 2010; Costanza et al. 1997). Furthermore, in accounting for the full range of benefits delivered by nature, ecosystem services research takes a holistic systems perspective capable of accounting for multiple benefits, and their interactions, simultaneously. Although human demand underpins ecosystem service concepts (Vira & Adams, 2009), stakeholder's preferences for ecosystem services are often overlooked in decision making with progress focused on obtaining objectively measurable, biophysical (e.g. Chan et al. 2012) or economic estimates (e.g. Martin-lopez et al. 2012; Boyd & Banzhaf 2007; Constanza et al. 1997).

Preferences are important because they reflect people's priorities and, together with the interpretation of the actions of others, help determine behavior (Costanza 2000; Kaplan 1985). Slow progress in incorporating preferences, and understanding behavior, has limited our ability to manage human-environment systems (Fulton et al. 2011).

Tradeoffs arise because people's interests vary and so they prioritize different aspects of the same system (Hicks et al. 2009). For example, a fisherman may prioritize the fish they can catch off a coral reef, a scientist may prioritize the knowledge they can gain from studying a coral reef, and a tourist may prioritize the diverse and colorful assemblages they can look at whilst snorkeling on a coral reef. Because resources are finite, (e.g. limited time or money) these differences will be reflected in the decisions people make, and influence the interactions they have with nature (Costanza 2000). Ecosystem services that tend to be prioritized together are referred to as bundles, whereas services that are prioritized at the expense of others create trade-offs (Martin-Lopez et al. 2012; Raudsepp-Hearne et al. 2010; Bennett et al. 2009). Bundles among stakeholders therefore represent areas of agreement, where people assign similar priorities to multiple ecosystem services. Conversely, trade-offs represent areas of conflict, where stakeholders assign different priorities to multiple ecosystem services. Bundles and trade-offs occur in space and time, and within and across stakeholder groups, creating different implications. Identifying bundles and trade-offs in stakeholder's preferences for ecosystem services should enable decision-makers to target opportunities where priorities align, and navigate or compensate for conflicts where priorities are in opposition.

Attempts to identify ecosystem service trade-offs have tended to ignore the distribution of benefits between groups and individuals within societies, thus failing to identify the winners and losers (Daw et al. 2011), and only a few studies have considered stakeholder's preferences for ecosystem services (Martin-Lopez et al. 2012). Therefore, in order to fill this gap, I examine the prioritization of coral reef ecosystem services within, and across, three stakeholder groups (scientists, managers, and fishers) in three western Indian Ocean countries. Coral reefs in this region provide vital food and livelihood security to some of the world's lowest income and most vulnerable people (Allison et al. 2009). Furthermore, this region has experienced some of the

worst effects of climate change on live coral and associated fish assemblages (Graham et al. 2008). Therefore, the need for effective management, and the juxtaposition of competing values, provides an ideal lens through which to ask: 1) Do fishers, managers, and scientists prioritize ecosystem services differently? 2) What ecosystem service bundles, and trade-offs, exist within fisher, manager and scientist stakeholder groups?

4.3. Methods

Sampling

I used a combination of focus groups and individual semi-structured questionnaires to interview fishers, managers, and scientists from three countries (Kenya, Tanzania, and Madagascar) in the western Indian Ocean (WIO) region about their preferences for coral reef ecosystems services. For the fishers, I conducted two preliminary qualitative focus groups, and 21 subsequent focus groups in each community - 6 communities in Madagascar, 6 in Tanzania, and 9 in Kenya. I obtained information from local fisher organizations on the age, primary gear used and place of residence for all registered fishers. I used this information to randomly select fishers across the age, gear and geographic range of all involved in the coral reef fishery (representing a stratified random sampling approach). After piloting the surveys in each country, I conducted 497 individual fisher interviews from the 21 fishing communities representing between 20% and 40% of the fishers from each community.

I obtained information from the Western Indian Ocean Marine Sciences Association (WIOMSA) - the regions professional organization for marine research and management - on the affiliations of managers and scientists in the region. I used non-probability sampling techniques including convenience and snowball sampling (Henry 1990) to approach scientists and managers who were delegates at the 2009 Western Indian Ocean Marine Sciences Association's (WIOMSA) biannual conference in Reunion, France. Delegates were asked where they worked and whether they worked as a scientist or manager. Only delegates working in Kenya, Tanzania, or Madagascar were included in this study. After piloting my surveys with managers and scientists, I conducted individual interviews with 17 scientists and 8 managers

representing 25%, 19%, and 19% of the managers and scientists from Kenya, Tanzania, and Madagascar attending the symposium.

Ecosystem service definitions

Expert elicitation

I used the millennium ecosystem assessment classification system as a starting point to frame the key benefits stakeholders are likely to associate with the coral reef ecosystem. For each country I conducted individual "expert" interviews with managers and scientists, to establish which of the MA benefits were most relevant to my study. These interviews discussed the relevance of the services, how the services were experienced, wording to describe the services and suitable photographs to convey the services. I then conducted a focus group, bringing together seven expert managers and scientists, who had experience working in Kenya, Tanzania and Madagascar. The purpose of this was to ensure the services, wording, and photographs to be used in the three countries were as consistent as possible.

Stakeholder elicitation

I conducted two initial fisher focus groups in Kenya with all gears in the fishery represented; these contained six and seven fishers. The fishers were first asked to discuss the benefits they associated with the coral reef ecosystem and their motivations for valuing them. I then introduced the benefits elicited from the expert interviews, and the selected photographs, and established whether there was agreement between fishers and experts on the services identified and whether the photographs were appropriate. Once I had a more definite group of benefits associated with the coral reef ecosystem I conducted larger focus groups in each of the communities surveyed (21). These focus groups were to ensure the benefits I had identified through fisher and expert consultations were appropriate and comprehensive, and that the wording and photographs used captured the meanings. The final selection included eight ecosystem services, with consistent definitions, but some different photographs were used across countries to better reflect the relevant context (i.e. cultural icons differed across countries). The final eight ecosystem services included one provisioning service (identified as

fishery), two regulating services (identified as coastal protection and sanitation), four cultural services (identified as culture, education, recreation, and bequest) (Chan et al. 2011; MA 2005; Krutilla 1967) and one supporting service (identified as habitat) (Kumar 2010) (Table 4.1). Ecosystem service assessments often omit supporting services, partly to avoid double counting, or subsume them in regulating services (Kumar et al. 2010). However, I do not attempt to aggregate values across services, and therefore double counting should not pose a problem. Furthermore, I felt it important to include supporting services in my perception based assessment because the implications of whether people prioritize provisioning or supporting services affect management decisions.

Table 4.1. Ecosystem services, photographs, and descriptions used in the valuation exercises

Service	Picture	Description
Fishery		This picture shows a fisher coming back from fishing with his catch which he may sell or used to feed his family. This illustrates the benefit we gain from the fish we catch and sell.
Habitat		This picture shows a healthy coral reef with many fish and places for the small fish to hide. This illustrates the benefits we gain from having a healthy coral reef habitat.
Coastal protection		This picture shows a rough sea and some trees washed away by the waves. The coral reef provides a barrier against the force of these waves. This illustrates the benefit we gain from having the reef buffer the force of the waves.
Sanitation		This picture shows women gutting and washing their fish. The sea takes away a lot of waste for us. This illustrates the benefit we gain from using the sea to wash and clean, knowing that when we come back tomorrow the waters will be clear again.
Tourism		This picture shows some tourists swimming and snorkelling, enjoying the marine environment. This illustrates the benefits we gain from being able to relax and enjoy the marine environment or having others come and enjoy it in this way.
Education		This picture shows some children learning about the sea. There is a lot of knowledge in the coral reef environment that school children come and learn about or scientists come and study. This picture illustrates the benefits we gain from the knowledge we have from the time we and our elders have spent in the marine environment.
Cultural		This picture shows a spiritual or cultural place related to the sea. Some people follow special traditions or norms involving the marine environment. This picture illustrates the benefits we gain from having cultural connections to the marine environment.
Bequest		This picture of children represents the future of the reefs. This illustrates the benefits we gain from knowing we will have healthy reefs that we can pass on to our children so that they can benefit from all the benefits that we do today.

Ecosystem service prioritization

I used individual semi-structured interviews to elicit stakeholder preferences for the eight identified ecosystem services. The interviews were piloted in each country to test the suitability of questions, structure, timing, and to ensure research assistants were comfortable in each setting. Respondents were provided with a photograph and brief description of each ecosystem service (developed in the focus groups; Table 4.1). The services were discussed with the respondents to establish a common understanding. I explained that I was interested in the respondents "personal preferences". I then asked the respondents to 1) rank the services, according to how important the services were (1-8); and 2) to rate the services, by distributing matches to be used as counters according to "where they would most like to see improvements". Managers and scientists were provided with 100 points to distribute across the services. I had to adjust the exercise for fishers, who were provided with 20 points in four installments to distribute across the services. This modification was made as 100 counters proved challenging to distribute in all instances (see Appendix 9.2).

Assigning rating weights

In the weighting exercise, a counter from the first installment of counters will necessarily carry more weight than a counter from the last installment. Therefore, to determine a suitable weighting to be assigned to each counter I ran an independent study to determine how much each successive round of counters contributed to respondents overall satisfaction with their distribution of counters. Respondents were provided with six photographs, each with a description that reflected aspects of their lives (e.g. family, job, health), and 12 counters (in four installments). I explained that I was interested in the respondents' preferences. I then asked the respondents to rate each aspect of their lives, by distributing counters, according to where they would most like to see an increase in the quantity or quality of that aspect. After the respondent had distributed each round of counters they were asked how satisfied they were with their distribution of counters. Their satisfaction score was recorded (% satisfaction), and they were provided with the next round of counters.

I ran a linear regression of satisfaction against round of counters to determine the relationship between round and extra satisfaction. Round of counters significantly predicted satisfaction in an exponential decay function (F= 220, P<0.001; $y=4.8^{-1.8x}$). I used the coefficients of the exponential decay function to calculate the weighting to be assigned to each round of counters (equation 1). The rating value estimates are therefore calculated based on equation 1 where a= counters, x= round (Appendix 9.4). Prior to the analysis I tested the data for normality and homogeneity of variances, and regressed the actual against predicted means (r2 = 0.98; F=52, P<0.001) to determine the validity of the relationship.

$$\sum_1^x a \times 4.8^{1.8x} \qquad \text{(Equation 4.1.)}$$

The rating and ranking responses were normalized, across all ecosystem services, to a common scale of 0-1.

The rating and ranking responses of the managers, scientists, and fishers were normalized to a common scale of 0-1. I used the ranking exercise to test for consistency between the manager and scientist rating and ranking responses. The relative importance of services obtained by rating and ranking was consistent across stakeholder group (P=0.001) (also see chapter 5 and Appendix 9.4).

Differences in ecosystem service prioritization, across stakeholder groups

Analysis

Broad variation in estimates assigned to ecosystem services priorities was first assessed using a hierarchical cluster analysis, which found the greatest variation in the data were across the three stakeholder groups, with little effect of country. I therefore focus on patterns within and between stakeholder groups. I looked for specific differences in ecosystem service prioritization, across stakeholder groups, using a MANOVA, followed by Tukey's HSD post hoc analysis. To illustrate these differences, I calculated an effect size on all eight ecosystem services for each two way combination of the three stakeholder groups (Equation 4.1).

$$Cohen's\ d = \frac{(v_{ai} - v_{aj})}{\frac{(Sv_{ai} + Sv_{aj})}{2}}$$

(Equation 4.1)

Where*:* v_{ai} = ecosystem service priority of the first stakeholder group*;* v_{aj} = ecosystem service priority of the second stakeholder group, S = standard deviation

Differences in ecosystem service prioritization, within stakeholder groups

Analysis

I looked for differences in ecosystem service prioritization, within stakeholder groups, using a one way ANOVA for each stakeholder group (Field 2009).

Bundles and trade-offs

A trade-off generally arises because two choices are incompatible with each other. For example you cannot simultaneously fish and stop fishing. Many approaches exist for quantifying trade-offs e.g. social cost benefit analysis, integrated cost benefit analysis (de Groot et al. 2010) and multi-criteria decision analysis (Brown et al. 2002). These are robust approaches, effective at engaging stakeholders in discussions over alternate options, that draw out trade-offs. However, people do not always consider the motivations or implications of their values and their resultant behavior (Bardi and Goodwin 2011; Schwartz 1996). This can create trade-offs that are not obvious, are not realized until they occur, or affect a minority. Therefore, rather than focus on the services of a high priority, that are likely to be discussed, I was interested in drawing out the important relationships that exist between all ecosystem services.

For each stakeholder group, I produced a correlation matrix based on a Pearson's correlation analysis looking at similarities and dissimilarities in the way ecosystem services were prioritized. A positive correlation between service A and B, suggests that the estimates assigned are more similar to each other than by chance alone (Legendre & Legendre 1998); individuals within a stakeholder group prioritize these services in the same way and they bundle together (Figure

4.1a) (i.e. both services are high, or both services are low, relative to the range of values each service receives). A negative correlation between the values assigned to service A and B, suggests the estimates assigned are less similar to each other than by chance alone (Legendre & Legendre 1998); individuals within a stakeholder group prioritize these services differently and a trade-off exists (Figure 4.1b) (i.e. when one service is high the other service is low, relative to the range of values each service receives).

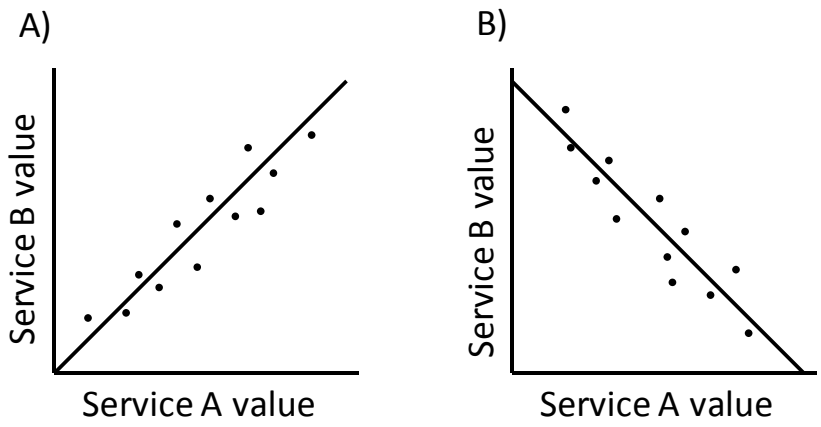

Figure 4.1 Bundles and trade-offs in ecosystem service priorities
Heuristic illustrating a) bundles and b) trade-offs. Two services that are positively correlated, bundle together; i.e. they are either both large or both small. Two services that are negatively correlated create a trade-off; i.e. when one is large the other is small.

Mapping bundles and trade-offs

I used network analysis (NA) to visualize the bundles and trade-offs in each stakeholder group and to determine key aspects of their interrelatedness. NA is the study of groups as networks of nodes connected by ties and provides methods to quantify the relations between nodes and the resultant network structure (Borgatti et al. 2009). Although network analysis is frequently used to study relationships between individuals, or groups of individuals (e.g. social network analysis see Ernston et al. 2009; Wasserman & Faust 1994), in the 1990's NA radiated into a great number of fields including physics and biology (e.g. Bascompte 2009), and continues to present new opportunities for interdisciplinary research (e.g. Bodin & Tengo, 2012). Consequently, the nodes of a network can represent organizations (Cohen et al. 2012),

occupations (Cinner & Bodin 2010), disciplines (Hicks et al. 2010), or species (Bascompte 2009). In the same way, the ties between the nodes can represent similarities (e.g. attribute), relations (e.g. kinship), interactions, or flows; and each combination of ties and nodes creates different outcomes for the network (Borgatti et al. 2009). I use NA to examine the relationships between ecosystem service priorities within each stakeholder group. Therefore, for each stakeholder group, I have eight nodes, each representing a different ecosystem service. My nodes are connected by ties that represent bundles, or trade-offs, in ecosystem service prioritization established from Pearson's correlation analysis.

I dichotomized each stakeholder group's Pearson's correlation matrix in UCINET version 6.365 (Borgatti et al. 2002). The cutoff points were selected to include the coefficients representing 40% of the strongest negative, and 40% of the strongest positive correlations for each stakeholder group. This produced two matrices for each stakeholder, one representing trade-offs (negative) and one representing bundles (positive). For each stakeholder group, I combined the positive and negative matrices in NetDraw (Borgatti 2002) to create a network representing stakeholders' bundles and tradeoffs in ecosystem service priorities. For each network, I calculated two types of centrality measures, degree and betweenness. Degree centrality is a measure of the number of connections between a service and all other services. Betweenness centrality is a measure of the number of shortest paths that run through a service representing the importance of a service for connecting other services that would otherwise be unconnected (Wasserman & Faust 1994).

4.4. Results

Differences in ecosystem service prioritization, across stakeholder groups

The first axis of the PCA (32.8% variation) distinguishes between fishers priorities and managers and scientists priorities, with fishers tending to prioritize fishery more than managers or scientists, who tended to prioritize coastal protection and culture more than fishers (Figure 4.2). The second axis of the PCA (21.3% variation) revealed a weaker distinction between managers and scientists priorities (Figure 4.2). These differences across stakeholders in the

values assigned to specific ecosystem services were confirmed with a MANOVA test (Wilk's value=0.01, $F_{8,39}$=10.2, P<0.0001) (Table 4.2). Post-hoc pairwise tests showed that fishers assigned significantly higher priorities to fishery than managers or scientists and significantly higher priorities to education than scientists (Table 4.2, Figure 4.3a,b). Similarly, managers assigned significantly higher priorities to culture than scientists or fishers and significantly higher priorities to bequest and coastal protection than fishers (Table 4.2, Figure 4.3a,c). Finally, scientists assigned significantly higher priorities to coastal protection than fishers or scientists, and significantly higher priorities to bequest, recreation and culture than fishers (Table 4.2, Figure 4.3b,c).

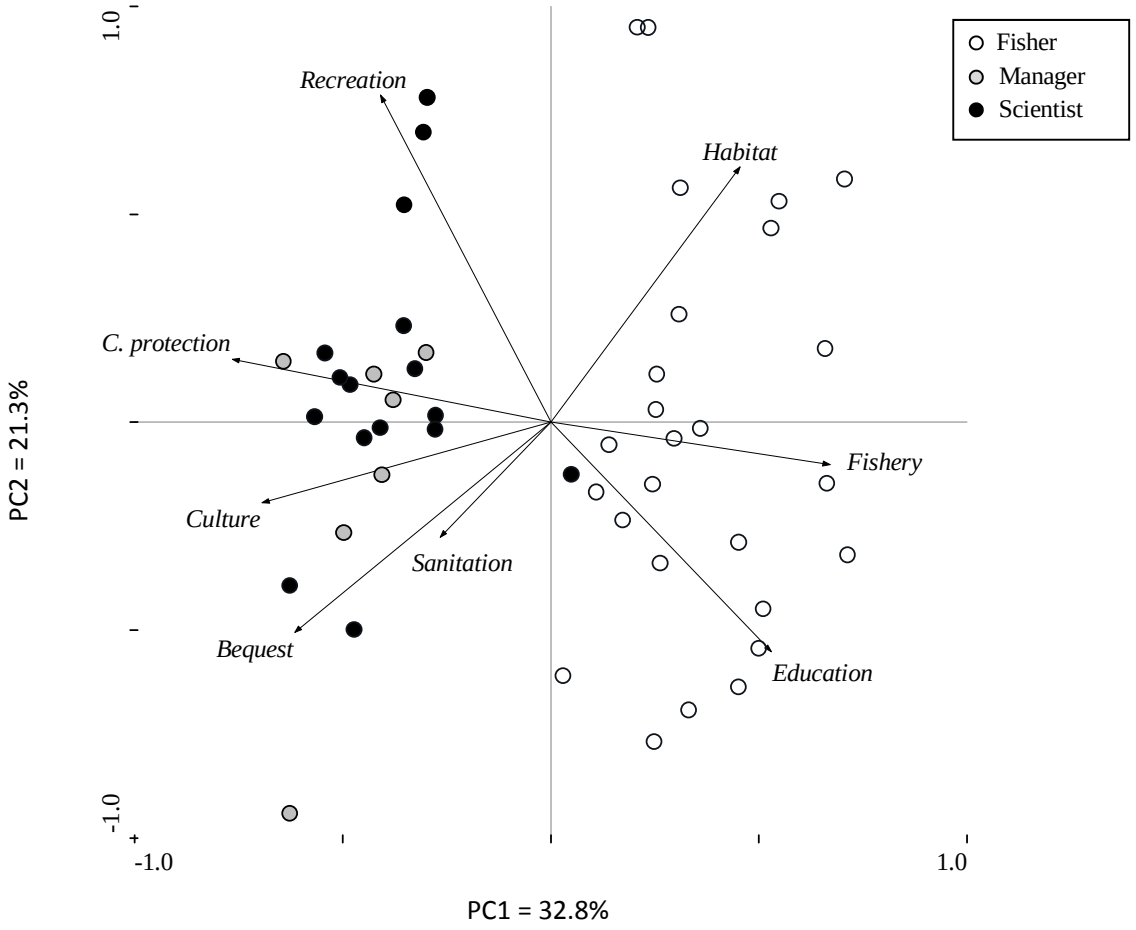

Figure 4.2 Distribution in ecosystem service priorities by stakeholder group
Principle component analysis showing the variation in ecosystem service values by stakeholder group.

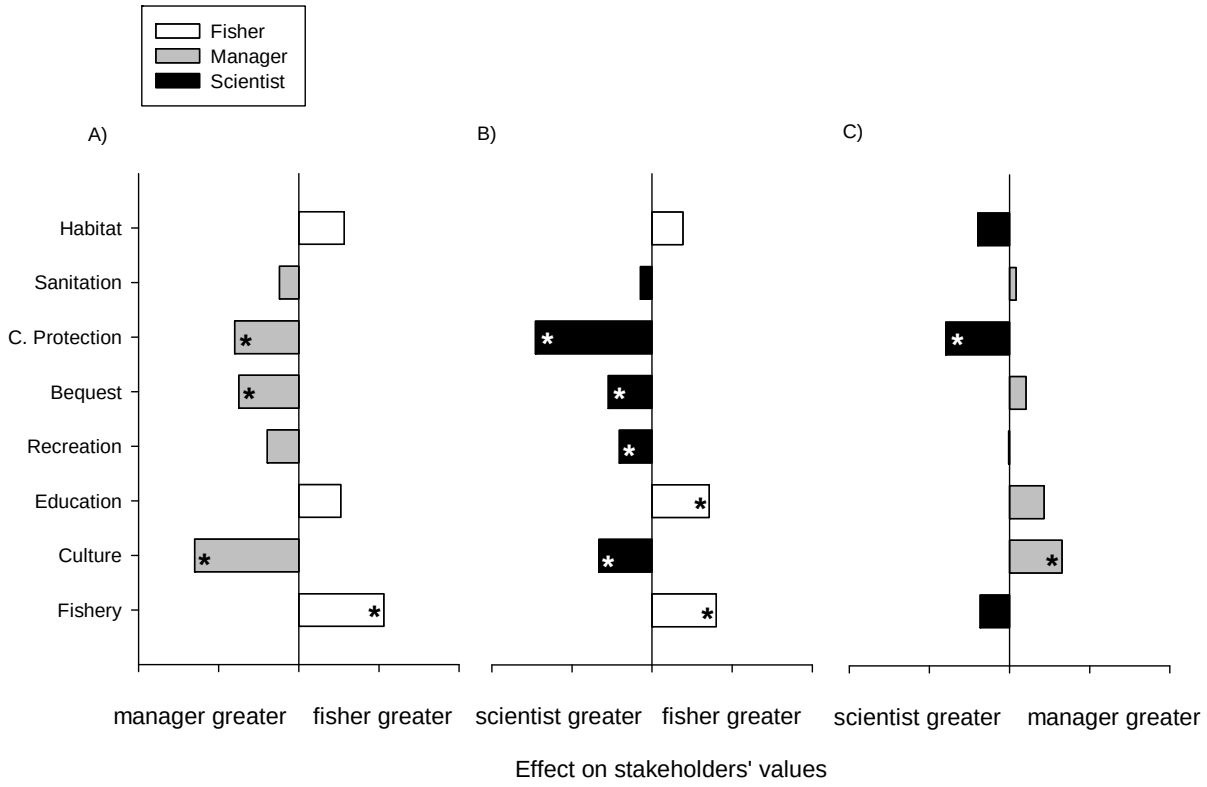

Figure 4.3 Two way comparison of ecosystem service priorities by stakeholder group
Differences in ecosystem service priorities between a) managers and fishers; b) scientists and fishers; and c) scientists and managers. Asterix shows where significant differences exist based on Tukey's HSD posthoc analysis (α= 0.05).

Differences in ecosystem service prioritization, within stakeholder group

Fishers assigned their highest priorities to fishery, habitat, and education, and their lowest priorities to culture and recreation ($F_{1,7}$=51.8, P=0.001, Table 4.3). Scientists assigned their highest priorities to fishery, habitat and coastal protection and their lowest priorities to culture and sanitation ($F_{1,7}$=10.0, P=0.001, Table 4.3). There were no significant differences in the priorities managers assigned to different ecosystem services ($F_{1,7}$=0.7, P=0.68, Table 4.3).

Table 4.2 Differences in ecosystem service priority across stakeholder group. Results from Tukey's HSD post hoc analysis to establish differences across stakeholders in each ecosystem service estimated. F= fishers, M= managers, S= scientists. MANOVA and Tukey's HSD post hoc analysis showing contribution to differences across stakeholders in ES values.

Ecosystem service	P	F	Tukey's HSD post hoc*
Fishery	0.000	$18.4_{46,2}$	F>M,S
Education	0.002	$7.3_{46,2}$	F>S
Bequest	0.000	$9.3_{46,2}$	F<M,S
Coastal protection	0.000	$38.3_{46,2}$	F<M<S
Culture	0.000	$17.8_{46,2}$	F<S<M
Recreation	0.010	$5.1_{46,2}$	F<S
Habitat	0.042	$3.4_{46,2}$	NS
Sanitation	0.382	$1.0_{46,2}$	NS

*Significant at < 0.05; F= fishers, M= managers, S= scientists

Table 4.3 Ecosystem service priority by stakeholder group. Mean normalized ecosystem service values for each stakeholder group with standard error of the means.

Ecosystem service	Fisher*	sem	Manager	sem	Scientist*	sem
Fishery	0.27	0.02	0.13	0.02	0.16	0.01
Culture	0.04	0.01	0.13	0.01	0.09	0.01
Education	0.19	0.01	0.14	0.01	0.12	0.01
Recreation	0.07	0.01	0.11	0.03	0.11	0.01
Bequest	0.09	0.01	0.14	0.01	0.12	0.01
C. Protection	0.08	0.01	0.11	0.01	0.14	0.01
Sanitation	0.08	0.01	0.10	0.02	0.10	0.01
Habitat	0.19	0.01	0.14	0.01	0.15	0.01

* Significant difference across ecosystem services at 0.001 significance

Table 4.4 Ecosystem service centralization metrics. Degree and betweenness measures for fisher, manager, and scientist networks showing ecosystem service prioritization

	Degree			Betweenness		
Ecosystem service	Fisher	Manager	Scientist	Fisher	Manager	Scientist
Bequest	3.0	1.0	0.0	1.3	0.0	0.0
C. Protection	2.0	4.0	3.0	0.0	4.0	0.0
Culture	2.0	1.0	5.0	0.0	0.0	5.3
Education	2.0	4.0	1.0	1.3	0.7	0.0
Fishery	4.0	1.0	1.0	13.0	0.0	0.0
Habitat	3.0	3.0	5.0	1.3	0.0	5.3
Recreation	3.0	4.0	4.0	1.0	0.7	0.3
Sanitation	3.0	4.0	3.0	10.0	0.7	0.0

Bundles and tradeoffs

There were three bundles in the fishers' network: recreation-habitat; sanitation- coastal protection; and fishery-bequest. Three trade-off ties were identified between the fishery-bequest and the recreation-habitat bundles, and both bundles also trade-off with education. The sanitation-coastal protection bundle only had trades-offs with culture and fishery (Figure 4.4a). Fishery is the service with the highest degree (4) and betweenness (13) centrality measures in the fishers' network (Table 4.4)

There were two main bundles in the managers' network: recreation-habitat; and coastal protection-sanitation-education. Five trade-off ties were identified between these two bundles. In addition, coastal protection traded-off with culture, and fishery traded-off with bequest (Figure 4.4b). Coastal protection had the highest degree (4) and betweenness (4) centrality measures in the managers' network (Table 4.4).

There were two main bundles in the Scientist s' network: recreation-habitat-coastal protection; and sanitation-culture. Five trade-off ties were identified between these two bundles. In addition, culture traded-off with fishery and habitat traded-off with education (Figure 4.4c). Culture and habitat are the two services with the highest degree (5, 5 respectively) and betweenness (5.3, 5.3) centrality measures in the scientists' network (Table 4.4).

The ecosystem service prioritization networks of all three stakeholder groups were associated with proportionally more tradeoffs than bundles (Figure 4.4). Fishers, managers and scientists all bundled habitat and recreation together, and found coastal protection to trade-off with culture (Figure 4.4). There was no other overlap between fishers and scientists ties. Managers, however, overlapped on an additional three trade-offs ties with scientists and two trade-offs ties with fishers (Figure 4.4).

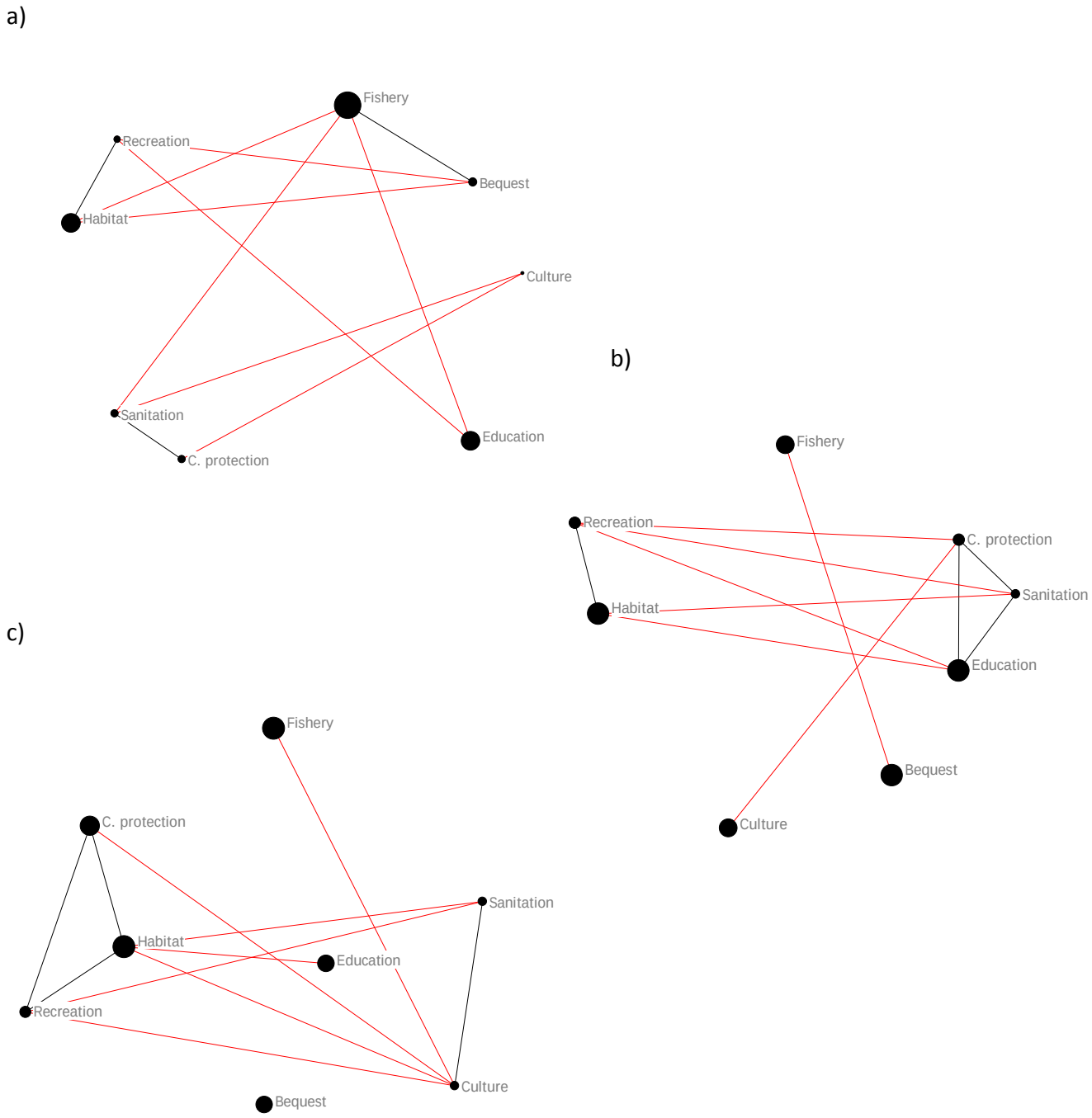

Figure 4.4 Bundles and Trade-offs in stakeholders' ecosystem service priorities
Network diagrams showing interactions among ecosystem services prioritized by **a)** fishers, **b)** managers **c)** scientists, based on Pearson's correlation analysis. Red lines indicate tradeoffs and black lines indicate bundles between services. Size of the node reflects average value assigned to each ecosystem service.

4.5. Discussion

Ecosystem service values depend on human preferences and demand, and not just the merits of the biological system, such as diversity and productivity (Vira & Adams 2009). Therefore, using a multi-country case study of coral reef fisheries, I set out to understand fishers', managers', and scientists' ecosystem service priorities, the interactions associated with their priorities, and what this may mean for dialogues intended to manage these complex ecosystems. Differences are evident across stakeholder groups in ecosystem service priorities. Fishery values distinguish fishers from managers and scientists; cultural values distinguish managers from fishers and scientists; and coastal protection values distinguish scientists from fishers and managers. Different patterns emerged when I examined within stakeholder group priorities that reflected distinct bundles and tradeoffs in stakeholders' preferences for ecosystem services. Interestingly, bundles and trade-offs identified by managers tended to reflect aspects of the patterns seen for both fishers and scientists, whereas the two latter groups were more distinct from one another. These associations are likely to result from different priorities and conceptual understandings of the system. Yet, because they reflect implicit rather than explicit preferences, these associations are rarely considered in decision-making (McRae &Whittington 1997).

Different groups of people derive benefits from different ecosystem services (Daw et al. 2011). Understanding these benefits and how different people value ecosystem services should help fishers, managers and scientists - the principal stakeholders involved in managing the WIO's coral reef ecosystems - reach agreement on how best to proceed. Fishers were most distinct from managers and scientists in their ecosystem service priorities. These differences were largely driven by fishers' tendencies to identify clear priorities, where managers and scientists would distribute their preferences more evenly. Fishers tended to prioritize fishery and education where managers and scientists prioritized culture, bequest, coastal protection and recreation. It is likely that fishers, who depend directly on the environment, are motivated to value ecosystem services to a greater extent by needs, than managers and scientists (Bardi & Goodwin 2011). Within the context of fishers' priorities, managers and scientists appear relatively similar; however, clear differences exist between the two, particularly for coastal

protection and cultural services. Despite these differences between fishers, managers and scientists, there are also areas of agreement, providing opportunities for dialogue to manage these systems for common goals.

Ecosystem service priorities within stakeholder groups revealed different associations to those found across stakeholder groups, suggesting ecosystem services provide different beneficiaries at different scales (Hein et al. 2006). I found distinct bundles and tradeoffs in stakeholders' preferences for ecosystem services that may result from conscious and sub conscious motivations (Bardi & Schwartz 2003; Schwartz 1996). Using insights from these bundles and tradeoffs, I explore three key policy-relevant implications of this research. First, identifying the bundles and tradeoffs associated with ecosystem service priorities illustrates how strategies that appear in the best interest of all stakeholders may result in unexpected or perverse outcomes. Bundles and tradeoffs associated with ecosystem service priorities, arise in part, from different stakeholder priorities and identify potential conflicts or opportunities that may arise in decision making processes. The dominant values of stakeholder groups may align, but still be associated with different interactions that ultimately impact how individuals behave (Kennedy et al. 2009). For example, because all stakeholder groups in my study reported habitat to be a high priority, improving habitat quality would seem a logical management objective. The group of scientists surveyed should be happy because habitat trades off with services that they consider a low priority. Managers and fishers however, are likely to be less satisfied because habitat trades off with services that they consider a high priority - education and fishery. A tradeoff between two services that are a high priority results from individuals prioritizing one or the other, not both. Therefore, investing in only one service has the potential to create conflicts and even marginalize certain individuals. Yet, decision-makers looking for consensus tend to focus on the strongest values neglecting potentially complex interactions that may lead to sub-optimal outcomes (Ostrom 1990; Platt 1973).

Second, identifying influences on people's ecosystem service priorities presents an opportunity for navigating conflicts or harnessing opportunities facing environmental decision making. Implicit perceptions of the environment influenced by institutions, education, and experience

have been shown to underlie people's values, preferences, and how they cluster in opinions (Kaplan 1985). I therefore propose two potential elements of the way people perceive ecosystem services that may be responsible for the bundles and tradeoffs I observed. First, people often perceive nature at different scales of time (Leopold & Schwartz 1989); this influences their time preferences – or how much they prefer something today over something at a later time. People who perceive the benefits of nature on shorter time scales are likely to prioritize immediate benefits over greater future benefits (Gollier 2002). The trade-off between fishery and habitat in the fishers network suggests fishers' have different time preferences. Some fishers prioritize an immediate return from increases in their fishery yield whereas others see the benefit of investing in the habitat for an improvement in the fishery in the long term. Strong property rights are likely to lower this trade-off because people develop a confidence in the future benefits. Second, people who perceive ecosystem services to be mutually exclusive are likely to consider prioritizing one at the expense of the other (Yoe 2011). I suggest the extent to which stakeholders perceive two ecosystem services as mutually exclusive will influence whether the pair of ecosystem services is a potential bundle or tradeoff. For example, recreation bundled with habitat in all stakeholder networks, indicating these services are unlikely to be perceived as mutually exclusive. This is likely to be because reef recreation, through the tourism industry, is widespread in the region and closely associated with healthy reefs for diving and snorkeling. Conversely, I found recreation to trade-off with education and bequest in the fishers' network. In the western Indian Ocean context and other similar locations tourism could present an appealing and lucrative alternative to learning about and maintaining local practices, knowledge, and traditions; and thus pose a threat to local cultures (Brown et al. 1997). This appeal may lead to the loss of local cultures, particularly in younger generations (Hill et al. 2011). When values and their associated trade-offs are the result of differences in perceptions or experience rather than needs and traits there is some potential for values to change (Bardi & Goodwin 2011). An understanding of the factors influencing key values and trade-offs can help managers decide on cues to introduce that could build a common understanding, challenge existing values, and begin a process of value change.

Finally, communication, which is important when trying to coordinate action (Ostmann 1998; Ostrom 1990), is easier when people think in similar ways (Verweij et al. 2006). The bundles and tradeoffs from the fishers' network were very different to those in the scientists' network. This could suggest that they would find it difficult to reach agreement on how to prioritize ecosystem services. These differences could be the result of different forms of knowledge common within these stakeholder groups (e.g. traditional ecological knowledge versus scientific or technical knowledge) (Pretty 2011). Managers however, whose network contained many of the same bundles and tradeoffs as the fishers' and scientists' networks may be better placed to anticipate or understand some of the opportunities and conflicts that fishers and scientists associate with their ecosystem service priorities. Although scientific research often informs environmental conservation, it is managers who in the end must balance research findings with local issues and priorities (Fazey et al. 2006). The ability of managers to balance the advice coming from scientists with their understanding of different stakeholders' priorities is expected to make them good negotiators around the issues of value and associated decisions.

4.6. Conclusions

Managing ecosystems involves understanding and potentially influencing complex human preferences. I find that stakeholders' priorities are often associated with implicit bundles and tradeoffs, potentially creating elusive opportunities and unexpected conflicts (McShane et al. 2011). To enable effective and equitable resource management, policy makers need to engage with the complexities associated with stakeholders' values and priorities. Such an approach needs stewards that are capable of navigating the conflicts and capitalizing on opportunities to reach consensus. I show that managers may be capable of playing such a role. This role could be furthered by introducing cues, through discussions, that address and challenge motivations behind the observed bundles and tradeoffs in ecosystem service preferences (Bardi & Goodwin 2011). A greater understanding of these motivations will help build a common understanding of ecosystem service priorities and help reduce conflicts over management decisions.

Chapter 5

Linking ecosystem services and human values theory

Chapter 5. Linking ecosystem services and human values theory

Adapted from: CC Hicks JE Cinner N Stoeckl T McClanahan (in prep) Linking ecosystem services and human values theory ***PNAS***

5.1. Abstract

Understanding how and why humans come to make the decisions they do remains a fundamental challenge for the future of our ecosystems. An increasing focus on ecosystem service concepts, generating information on how individuals benefit from the environment, reflects efforts to anticipate, and manage human behavior. I contribute to this knowledge by integrating socio-cultural and motivational components of value that may lend insights into why trade-offs occur. I examine ecosystem services through the lens of a human values theory to ask: 1) Are ecosystem service values prioritized in a consistent manner? 2) How do ecosystem service priorities relate to the variability of those priorities? 3) Are ecosystem service values related to each other in a consistent manner and as expected from psychological theory? Ecosystem service priorities exhibit a common hierarchy that is consistent across the western Indian Ocean countries studied. However, the consistency of this hierarchy should not mask considerable variation that exists in ecosystem service priorities. I found the greatest variation in ecosystem service values where marginal values (importance of a change) were greatest. Although ecosystem service values only represent a portion of broader human values I found compelling evidence that these values are motivated, and consequently orientated, as predicted by psychological values theory. Critically, the distribution of ecosystem service priorities mapped perfectly onto predictions from social psychology of how these values are structurally related, lending insight into why trade-offs are likely to emerge. Although ecosystem service categorizations appear relatively robust, distinctions exist between key cultural values, placing them in opposition to each other, that are not reflected in ecosystem service categorizations.

5.2. Introduction

People receive a range of benefits from nature, which are often referred to as ecosystem services. A new approach and scientific focus on ecosystem services was catalyzed by the Millennium Ecosystem Assessment (MA 2005), renewing appeals for a greater recognition of the connection between man and nature (Leopold & Schwartz 1989; Costanza 1989; Bruntland 1987). Built on science from the preceding two decades, ecosystem service concepts have helped to clarify the many ways that nature benefits people (e.g. Carpenter et al. 2009; Tallis et al. 2008; Daily 1997; Ehrlich & Mooney 1983). The MA (2003) classified these benefits into provisioning services (e.g. food), regulating services (e.g. coastal protection), cultural services (e.g. spiritual reflection) and supporting services (e.g. nutrient cycling). By describing how people relate to nature, ecosystem service approaches were intended to convey the essence of environmental sustainability and build support for conservation (Norgaard 2010; Daily 1997). At the core was an effort to influence the choices people make, so as to minimize their impact on nature. However, ecosystem service assessments have tended to adopt a narrow view of human behavior focusing on ecological (e.g Mace 2011; Kremen & Ostfeld 2005) or mainstream economic value domains (Spash 2012; Stoeckl et al. 2011; Bateman et al. 2010; Hicks et al. 2009). A substantial body of research on socio-cultural and psychological components of value, capturing people's motivational goals and how they relate to behavior, is seldom connected to ecosystem service science; creating a critical gap in the field's understanding of human behavior (Spash 2012; Dietz et al. 2005; Rohan 2004; Stern & Dietz 1994).

Many economists question assumptions of rationality (Kahneman & Thaler 2006); in doing so they account for social costs and benefits (Williamson 1979); incomplete information (bounded rationality) (Simon 1972); and selective learning (fallible learners) (Ostrom 2011; 2010; 1998). There is great potential for these broader concepts of value to be integrated with ecosystem service assessments. However, a tendency to make two basic assumptions tends to overlook the need to understand people's underlying motivations. First, ecosystem service assessments and the resultant policies, explicitly or implicitly, use a specific theory of human behavior that assumes people behave as economically rational beings - *homo economicus* (Martin et al. 2010; Peterson et al. 2010). *Homo economicus* assumes people have well ordered and articulated

preferences, they have complete information, and they maximize the net value of expected returns to themselves (Ostrom 2012). In an ecosystem services context, this would imply that all people are fully aware of all ecosystem service benefits, that individual ecosystem services are clearly more or less important than one another, and people act to influence society and its institutions to maximize the benefits of nature; thus ensuring sustainability and protection. The second assumption is that ecosystem service values are considered to be axiomatic - that is, specific values are better, more important, and intellectually defensible than others (Song et al. 2013; Kaltof & Satterfield 2005).

On the basis of *homo economicus*, the cause of environmental decline is attributed to the fact that people are not fully aware of the benefits they gain from nature (Costanza et al. 1997). The solution is therefore to make nature's benefits apparent, and because many ecological economists treat values as axiomic[23], this is done through expert led valuations (e.g. Sukhdev 2010; The Natural Capital Project). In some cases, people may respond accordingly, particularly in neoliberal economies, but modern environmental commons problems are only seldom solved through rational-behavior campaigns or engineering approaches (Robinson 2012; Rittel & Webber 1973). Despite considerable advances in ecosystem service science, understanding how and why people make the decisions they do regarding nature remains a fundamental challenge for social-ecological systems management. A broader understanding of ecosystem service values, capturing economic, ecological, socio-cultural, and psychological concepts of value is needed.

Psychology has much to offer to understand how humans behave in relation to the environment (Seymour et al. 2010; Manfredo et al. 2009), but is rarely applied to ecosystem services. In psychological theory, values are an expression of people's motivational goals or desires, in the context of their needs and constraints (Rockeach 2008; 1973; Schwartz 1992; Kluckhohn 1961). In other words, values are what people desire and why (Song et al. 2013). From a psychological perspective, ecosystem service values would express the benefits people desire from nature, and why they desire those benefits. For example, people may value

[23] *Homo economicus* does not necessarily assume values are axiomic.

spiritual reflection because they believe it restrains how people behave in nature (e.g. uphold traditional taboos) or that it develops a respect for nature (e.g. paying sacrifice to the sea) (Glaesel 1997; Schwartz 1994). Similarly, people may value coastal protection because it protects their homes and those of their community. Psychological theory has identified a small number of stable and widely shared value types that are the same the world over; and developed measurement systems to quantify relations between these value types (e.g. Rockeach 1973; Morris 1956; Vernon & Allport 1931). This research shows that people's values vary at an individual, community, and country scale (Dietz et al. 2005; Rohan 2004). However despite this variability, human values are prioritized such that specific values are consistently more important than others; these patterns have been found to hold across countries (Fisher & Schwartz 2011; Schwartz & Bardi 2001).

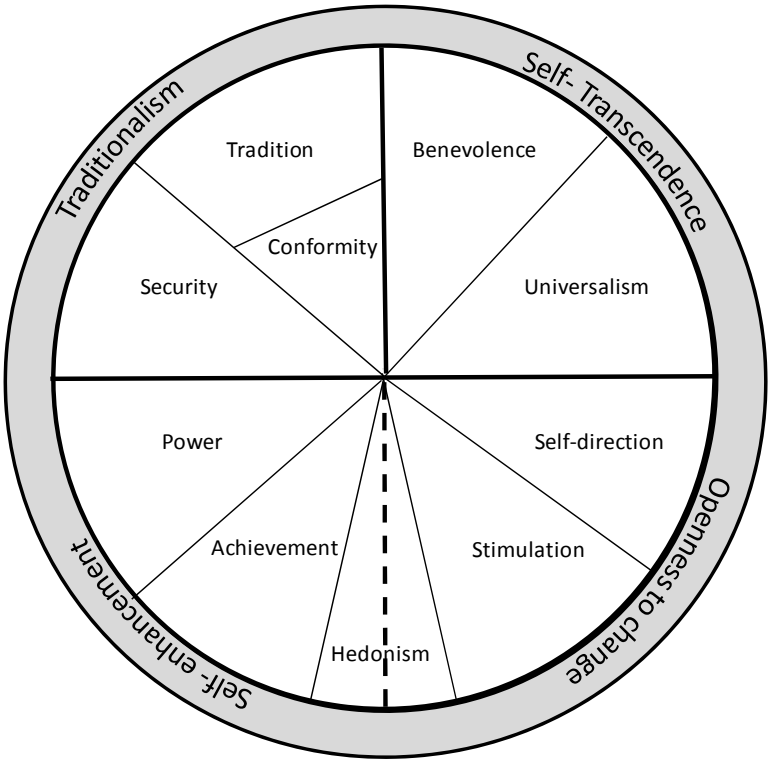

Figure 5.1Schwartz values wheel
Schwartz wheel, showing human values, and how they are structurally related to each other. Values are arranged around the wheel so that values adjacent to one another are similar and values opposite one another are in opposition to one another

Psychological values theory further suggests that values are structurally related to one another in a pattern that transcends spatial scales (Bardi et al 2011; Schwartz & Bardi 2001; Schwartz 1994; 1992). Some values are therefore similar and closely related, whereas other values are dissimilar and oppose one another (Davidov 2010). In a widely cited framework, Schwartz (1992) identified ten basic human value types (Benevolence; Universalism; Self direction; Stimulation; Hedonism; Achievement; Power; Security; Tradition; Conformity), that cluster into four domains (*traditionalism*, *openness to change*, *self-transcendence*, and *self-enhancement*) (Table 5.1). These value types have been shown to relate to each other in a consistent manner as though positioned around a wheel (Figure 5.1) (Davidov 2010; Bardi & Schwartz 2003, Schwartz & Bardi 2001; Schwartz 1994; 1992). People's priorities on adjacent value types are considered similar, while differences are accentuated when value types are opposite each other. The values reflected by spiritual reflection and coastal protection for example may be similar. However, if these values are in fact opposed to one another then activities that seek spiritual reflection are likely to obstruct activities that enhance coastal protection creating a potential trade-off. Trade-offs have been characterized in the ecosystem services and environmental change literature as an important yet often intractable phenomena (Vira et al. 2012; McShane et al. 2010). Values theory may provide an alternate perspective on how trade-offs may occur.

Ecosystem services are fundamentally about the relationships between people and nature. The outcomes of ecosystem service assessments seek to understand these relationships and influence the choices people make. But to influence these choices, ecosystem service science needs to move beyond measuring ecosystem services to examining the motivations behind people's preferences and how ecosystem services relate to one another. To begin to fill this gap, I apply a psychological theory of human values to the analysis of nine ecosystem services in 28 coral reef fishing communities across Kenya, Madagascar, Tanzania, and Seychelles (Figure 1.7). I use Schwartz's theory of human values (Schwartz 1994) to guide my study design and ask, across geographic scales:

1) Are specific ecosystem services consistently prioritised above others?
2) How do ecosystem service priorities relate to the variability of those priorities?

3) Are ecosystem service values related to each other in a consistent manner and as expected from psychological theory?

Using a combination of focus groups and semi-structured interviews with more than 400 resource users, I identified and conceptualized a range of ecosystem services, estimated the relative importance, and explored the motivational goals underlying each ecosystem service.

5.3. Methods

I used a combination of a qualitative and quantitative strategy to examine how coral reef ecosystem services were prioritized by resource users, and why. I obtained information from local fisher organizations, or the fisheries department, on the age, primary gear used and place of residence for all registered fishers at each community studied. I used this information to randomly select fishers across the age, gear, and geographic range of all involved in the coral reef fishery (representing a stratified random sampling approach). I conducted 28 focus groups and 400 individual semi-structured questionnaires representing between 20% and 40% of the fishers from 28 communities across Kenya, Tanzania, Madagascar, and Seychelles.

Ecosystem service conceptions and motivational goals

The qualitative component utilized focus groups to explore ecosystem service concepts and their motivational goals. This format was used to allow respondents to discuss ideas in depth and provide information based on a range of personal experiences.

I used the Millennium Ecosystem Assessment (MA 2003) classification system as a starting point to frame the range of coral reef ecosystem services. The focus groups explored and elicited the range of benefits that resource users identified with the coral reef environment. The final list contained nine ecosystem services including two provisioning services (fishery and materials), two regulating services (coastal protection and sanitation), one supporting service (habitat), and four cultural services (culture, education, recreation, and bequest). I developed a description, and identified a suitable photograph, for each ecosystem service to be used in the quantitative strategy below.

Next, I used the focus groups to explore and articulate why resource users thought the nine ecosystem services were important, and why they would prioritize them (i.e. to identify their motivational goals). I assigned the ecosystem service motivational goals to their relevant value type (Schwartz's 1994) by comparing the resource users' motivational goal to 58 items from the Schwartz value survey (SVS) (2008) that are typically used to measure Schwartz's (1994) 10 value types. For example, resource users prioritized fishery because they wanted: 1) an income; 2) to provide for their family; 3) to be seen as a skilled fisher; and 4) fish that they enjoyed eating. These motivations are similar to 'wealth', 'capable', 'preserving my image', and 'pleasure' from SVS, which reflect power, achievement, and hedonism values. Fishery therefore represents power, achievement, and hedonism values all of which are within the *self-enhancement* domain (Table 5.1). Similar to fishery, all ecosystem services were motivated by two or more of the values types; therefore, from here on I will refer to the relevant value domains (*traditionalism*, *openness to change*, *self-transcendence*, and *self-enhancement*), rather than the individual value type (e.g. power, achievement, benevolence) (Table 5.1).

Table 5.1. Ecosystem services, human values, and ecosystem service motivations. Ecosystem services are shown with their motivational goals and their classification into the 10 possible value types of Schwartz (1994).

Value domain	Ecosystem service[1]	Motivational goal[2]	Value type[3]	Definition[3]
Self transcendence	Sanitation	Safe and clean water for the community and environment	Benevolence - Universalism	**Benevolence:** Preservation and enhancement of the welfare of people with whom one is in frequent personal contact.
	Coastal protection	A safe fishing environment, safety for homes		
	Habitat	Maintaining ecosystem function to ensure continued productivity and provision of all ecosystem benefits for the ecosystem and for others in the community.	Universalism	**Universalism**: Understanding, appreciation, tolerance and protection for the welfare of all people and for nature.
Openness to change	Recreation	Harnessing ecosystem qualities for income (e.g. taking tourists snorkeling to see corals and fish); embracing and exploring new sources of income; a new economy; and fast paced lifestyle	Self Direction – Stimulation - Hedonism	**Self direction**: Independent thought and action—choosing, creating, exploring **Stimulation**: Excitement, novelty, and challenge in life. **Hedonism:** Pleasure and sensuous gratification for oneself
Self enhancement	Fishery	Harnessing the ecosystem for income and food; being a skilled fisherman; enjoying a fishers lifestyle	Hedonism – Achievement- Power	**Achievement:** personal success through demonstrating competence according to social standards **Power:** Social status and prestige, control or dominance over people and resources
	Materials	Harnessing the ecosystem for fuel and shelter		
Traditionalism	Bequest	Respect for future generations, leaving a legacy of to pass on place, meanings and a way of providing	Security - Tradition – Conformity	**Security:** safety, harmony and stability of society, of relationships, and of self. **Tradition:** Respect, commitment and acceptance of the customs and ideas that traditional culture or religion provide the self **Conformity:** Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms
	Culture	Maintaining traditions, beliefs, behaving appropriately		
	Education	Creating/ maintaining responsible and effective fishing practices		

Ecosystem service prioritization

The quantitative component utilized semi-structured interviews to estimate the relative importance (priorities), to each resource user, of each ecosystem service identified. I first provided each respondent with the photographs identified in the focus groups for each ecosystem service. I used the photograph and descriptions, also developed in the focus groups, to discuss and reach a common understanding of each ecosystem service (see chapter 4, Table 4.1). I next measured two concepts of value - marginal and total - for each ecosystem service. I take values to be expressions of people's preferences for the desirable (Rockeach 2008; Bateman et al. 2002; Kuckholm 1961); however, there is a distinction in economics between values that capture the desirable (total value), and those that capture a desired- or undesired-change (marginal value) (Bateman et al. 2002; Pearce & Turner 1989). I therefore explained to respondents that I was interested in the respondents' preferences. I then asked the respondents to: 1) rank the services, by arranging the photographs in order of importance to them, and 2) rate the services, by distributing counters according to where they would most like to see an increase in the quantity or quality of that service. Ranking estimates reflect total value priorities as they are independent of change, whereas rating estimates reflect marginal value priorities as they explicitly address the importance of a change. For the rating exercise, fishers were provided with 20 matches (in four installments) to be used as "counters" to distribute as they saw fit across the nine ecosystem services. For example, respondents could place all counters on one particular service or distribute them among several services. Any additional information on how the services were conceptualized, challenges arising in assigning priorities, or the rationale behind the respondents' prioritizations were recorded. Rating weights were assigned as in Chapter 4 and Appendix 9.4.

Analysis

Ecosystem service priorities

To examine whether specific ecosystem services were consistently prioritized above or below others in my cross sectional data across, I used a linear mixed model (LMM) that looked for

differences across ecosystem services in marginal and total value priorities. Country and community were set a-priori as random effects to account for inter country and inter community variations and to establish whether generalizations could be made beyond the inherent cross country differences. I ran pair-wise comparisons (least significant differences adjusted for multiple comparisons) to see where the differences in ecosystem service priorities lay. The LMM analysis was preceded by tests on the data for normality with Kolomogorov-Smirnov's test and homogeneity of variances using Levene's test (Field 2009).

Variability in ecosystem services estimates

To explore how much variation there was in the ordering of ecosystem service priorities, for both total and marginal values, I ran a LMM to test the effect that priority estimates have on the variation in value priority. Country and community were, once again, set a-priori as random effects to account for inter country and inter community variations. The effect of ecosystem service priority estimate on the variation in priority estimate was examined using linear regressions at a regional (WIO) scale, and 95% confidence intervals calculated around the slope.

Structure of ecosystem services

To examine the structure of ecosystem services I mapped the relationship between ecosystem services based on 1) motivational goals and 2) marginal and total value (priority) estimates. To map the ecosystem service relationships based on motivational goal, I placed each ecosystem service around Schwartz's (1994) wheel (Figure 5.1) according to the value domain identified in the focus groups (e.g. *traditionalism*, *openness to change*, *self-transcendence*, and *self-enhancement*) (Table 5.1). To map the ecosystem service relationship based on priority estimates, I ran a non-metric multidimensional scaling (MDS) (based on spearman's rank correlation coefficient) to look at the similarities in ecosystem service priority estimates across countries and communities (Clarke & Warwick 2001, PRIMER V6; Legendre & Legendre 1999).

5.4. Results

Ecosystem service priorities

Ecosystem service proprieties emerged such that certain ecosystem services were consistently more important than others and this pattern was largely consistent across total and marginal value estimates (Appendix 9.6). I therefore focus my results on the ordering of marginal ecosystem service priorities. There were four distinct groups of ecosystem services ($F_{8,3366} = 92$, $P<0.001$) (Figure 5.2). Fishery had the greatest priority; followed by habitat and education; coastal protection, sanitation, and bequest; finally, materials, recreation, and culture had the lowest priority (Figure 5.2). I found that the order of ecosystem service priorities was consistent across community, country, and region (AIC = -10,975, $F_{8,3366} = 92$, P=0.000; AIC = -10973, $F_{8,3366} = 92$, P=0.000; AIC = -10971, $F_{8,3366} = 92$, P=0.000).

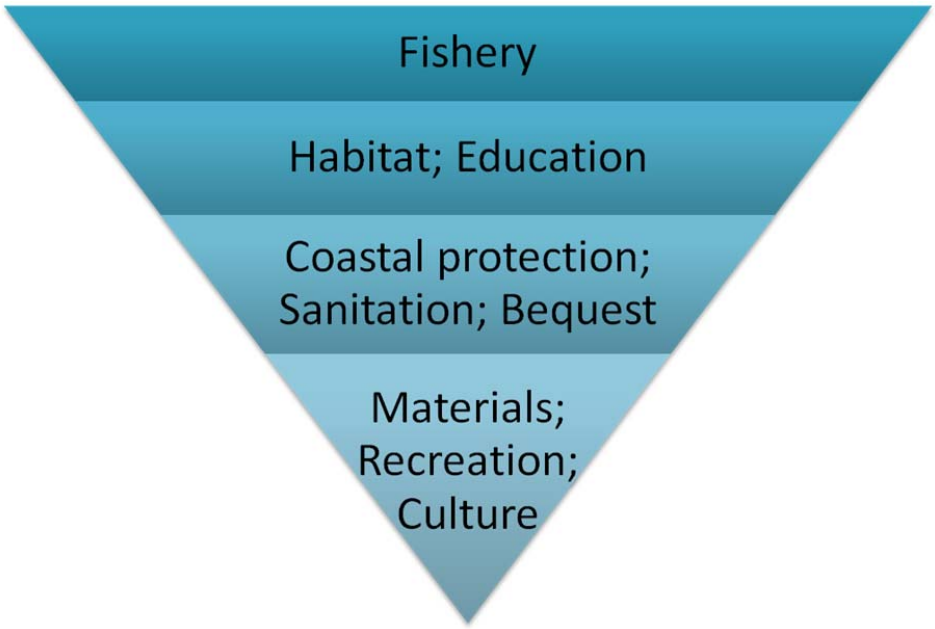

Figure 5.2. Coral reef ecosystem service priorities in the western Indian Ocean.
Mean marginal ecosystem service values for the whole western Indian Ocean based on ecosystem service priorities (appendix 1). Slices indicate significant differences between services, based on pair-wise comparisons and least significant differences $\alpha = 0.05$. There was no effect of country of community as random effects

Variability in ecosystem services estimates

There were striking differences in the variability of total and marginal ecosystem service priorities. An increase in marginal value priorities was associated with a decrease in variation in priorities (R_2 = 0.79; P <0.0001; $F_{1,34}$ = 133.2) (Figure 5.3a). Conversely, increase in total value priorities was associated with an increase in the variation of priorities (R_2 = 0.63; P <0.0001; $F_{1,34}$ = 57.4) (Figure 5.3b). These relationships were consistent at the community, country and regional scale (marginal estimates: AIC= 1509; $F_{2,250}$= 721; P=0.000; AIC= 1507; $F_{2,250}$= 722; P=0.000; AIC= 1505; $F_{2,223}$= 733; P=0.000; total estimates AIC= 1476; $F_{2,250}$= 49; P=0.000; AIC= 1476; $F_{2,246}$= 50; P=0.000; AIC= 1474; $F_{2,247}$= 50; P=0.000) (Appendix 9.6).

Structure of ecosystem services

Total and marginal ecosystem service priorities were motivated by the same goals and structured in a similar manner (Appendix 9.6). I therefore focus my results on the motivations and structure of marginal ecosystem service priorities.

The motivational goals identified in the focus groups determined four groupings of ecosystem services, that aligned with the broader value domains (*traditionalism, openness to change, self-enhancement,* and *self-transcendence)*, and were arranged around Schwartz (1994) values wheel (Figure 5.4a). The motivational goals of culture, education, and bequest reflected *traditionalism* values; the motivational goals of recreation reflected *openness to change* values. These two sets of values are situated in opposition to one another around Schwartz wheel (Figure 5.4a). The motivational goals of fishery and materials reflected *self-enhancement* values; the motivational goals of habitat, coastal protection, and sanitation reflected *self-transcendence* values. These two sets of values are situated in opposition to one another around Schwartz wheel (Figure 5.4a).

The distribution of ecosystem service priorities, based on independent quantitative MDS ordinations, established the same four groupings (Figure 5.4b). Furthermore, this ordination was consistent across country and community (Appendix 9.6).

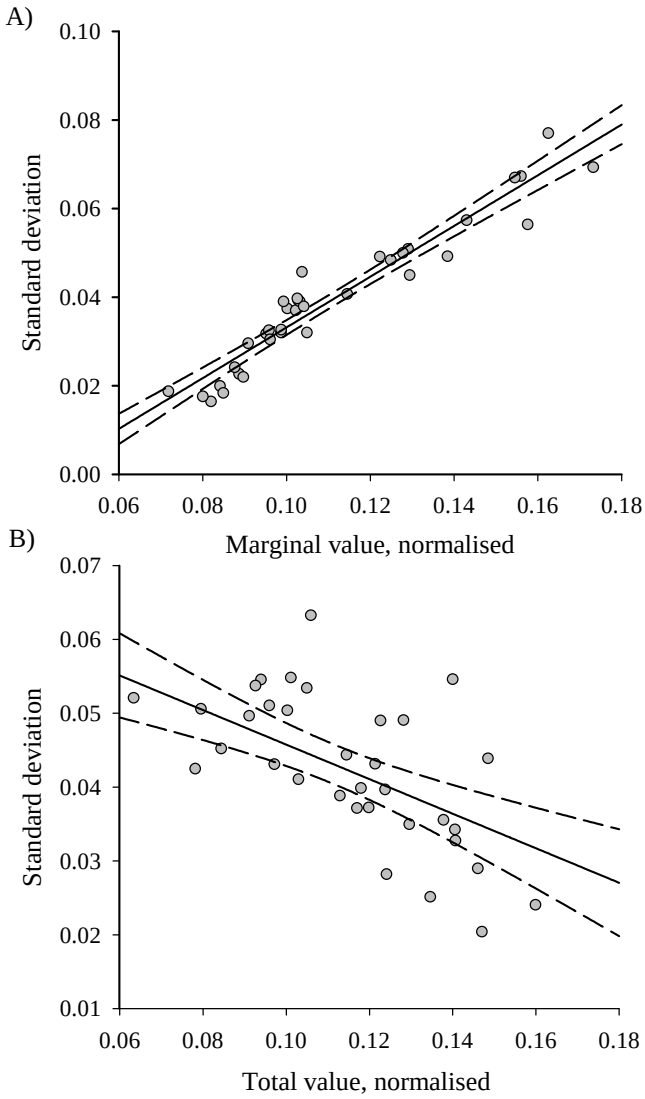

Figure 5.3 Variation in ecosystem service value
Standard deviation of value estimates as a function of **a)** marginal and **b)** total value estimates. Each dot represents a service for each country

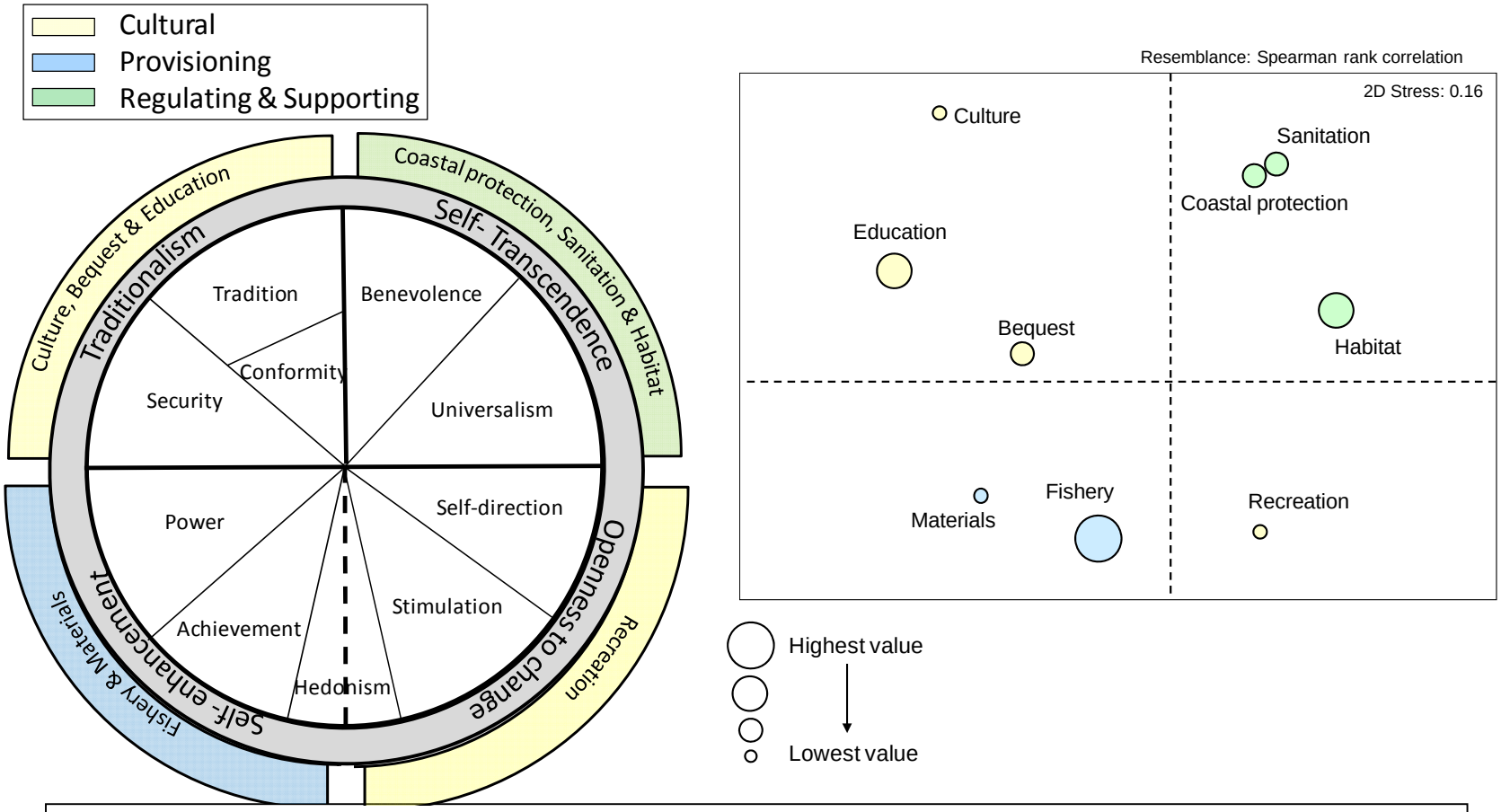

Figure 5.4 Ecosystem service value orientations

a) Inner two circles reflect Schwartz's value orientations, outer circle reflect resource user ecosystem service value motivations from qualitative focus groups. **b)** Similarities between quantitative ecosystem service value priorities. Quantitative MDS ordinations corroborate qualitative focus groups data.

5.5. Discussion

Understanding the values people hold, and how these values relate to one another, is a critical step towards influencing people's behavior (Dietz et al. 2005). I therefore applied a psychological theory of human values to the analysis of nine ecosystem services. This study represents a large-scale effort to connect an ecosystem services approach to a broader body of research on human values. Three key findings were evident from this work. First, I found ecosystem services across the western Indian Ocean communities and countries studied were prioritized such that certain services were consistently more important than others; again findings that are aligned with psychological theories of human value (Fischer & Schwartz 2011; Schwartz & Bardi 2001). Second, the consistency in which ecosystem services tend to be prioritized over others should not mask considerable variation in ecosystem service priorities that exists at finer spatial scales. This variation may not present a challenge for total values because the most important values are the least variable; people therefore broadly agree on what is important. However, the greatest variation in marginal values exists for those that are the most important. This suggests people disagree on how much of an impact a change in the most important values is likely to have. I have shown values to be heterogeneous, but analysts tend to aggregate individual values to determine societal values, particularly for policy purposes. Therefore, there is a risk that individuals will be marginalized if their values run counter to the mean. Finally, people's motivational goals for valuing ecosystem services align with the most commonly used measures of values type from social psychology (Dietz et al. 2005; Schwartz & Bilsky 1992; 1987 (Table 5.1). This means ecosystem service values reflect broader human values and should be managed as such. Critically, the distribution of ecosystem service priorities mapped perfectly onto predictions from social psychology of how these values are structurally related (Schwartz 1994; 1992) (Figure 5.4). These structural relations have implications for understanding trade-offs. Specific ecosystem services are consistently found to be close together, thus complimenting each other, whereas others consistently oppose one another. For example, fishery values are similar to education values but opposed to habitat values. Recreation values are similar to fishery and habitat values but opposed to bequest, education, and culture values.

What do people value?

Consistent with psychological theory, specific ecosystem services were consistently prioritized over others across all communities and countries studied from the WIO; patterns that were common to both marginal and total value priorities. Ecosystem services were organized in clusters, according to importance. Similarly, within the human values literature certain values are consistently more important than others. For example, at a societal level, *self-transcendence* (supporting and regulating) values are often most important, with *self-enhancement* values least important (Schwartz & Bardi 2001; Fisher & Schwartz 2001; Schwartz & Sagiv 1995). Although the ecosystem services literature suggests similar patterns, the services that tend to be favored are different to the values favored in the human values literature. In the ecosystem services literature, people tend to prioritize provisioning services (*self-enhancement*) and assign supporting services (*self-transcendence*) lower importance (Foley et al. 2005). The patterns I found in ecosystem service priorities was independent of either ecosystem service category (MA 2005) or value domain (Schwartz 1992). Instead, I found the three most important ecosystem services were fishery (a *self-enhancement* value or provisioning service); habitat (a *self-transcendence* value or supporting service); and education (a *traditionalism* value or cultural service). Conversely, I found the three least important services were materials (a *self-enhancement* value or provisioning service); culture (a *traditionalism* value or cultural service); and recreation (an *openess to change* value or cultural service).

A consistent pattern to ecosystem service priorities should not, however, mask considerable variation in that exists in ecosystem service priorities at smaller spatial scales. Psychologists and economists tend to aggregate individual values to determine social measures of value. However, aggregation can prove problematic as it tends to overshadow within culture variation (Hitlin & Piliavin 2004). Furthermore, aggregation makes assumptions about how individuals behave in groups (Vant 2009), consequently there is often no ideal or unique way to combine individual choices to obtain a group choice (Arrow 1951). I found variation in ecosystem service

priorities to be strongly associated with priority in the WIO, suggesting significant within country and community variation. Interestingly, marginal and total value priorities differed strikingly in relation to the variability in priorities. Marginal ecosystem services that were a high priority were more variable than marginal ecosystem services that were a low priority. The opposite was true for total values where ecosystem services of low a priority were more variable than ecosystem services of a high priority. This may be intuitive as total values align to a greater degree with values in psychology where salient values are considered to be enduring and stable (Bardi & Goodwin 2011; Manfredo et al. 2003; Rockeach 1973). However, these differences suggest people agree that habitat, fishery, and education are important (desirable), but they disagree to what extent a change in these services is Important (desirable or undesirable). It is possible that marginal value priorities predict behavior better than total value priorities (Seymour et al. 2010). Differences in marginal values can arise because people are more or less content with the services in question; they may believe different stakeholders are responsible for, or capable of, bringing about change to these services; or they may have different understandings of the causal agents of change to these services. The lack of agreement on whether change is necessary, or who is responsible, in natural resource systems can be problematic for environmental policy.

Is there a consistent structure to ecosystem service values?

Schwartz (1994; 1992) examined the content and relations between human values to propose, and validate, a universal structure to human values based on their motivational goals. I modified and adapted this approach to an ecosystem services context. All of the ecosystem service motivational goals I identified could be satisfactorily classified into the Schwartz (1994; 1992) value types. However, as individual ecosystem services were generally considered to be motivated by two or more of the values types I identified the value domain (Schwartz's 1992) relevant to each ecosystem service. Empirical studies of human values often find adjacent values to appear as a single value rather than distinct from each other (e.g. universalism and benevolence may be seen as one value rather than two distinct) (Davidov 2010). It is therefore reasonable that ecosystem services are also associated with more than one value type. Although I examined values that relate to nature, I chose to focus on the human values

literature rather than exploring specific environmental values. This is because environmental values fall within Schwartz's (1992) *self-transcendence* goals, and are therefore not distinguishable from broader the human values literature (e.g. valuing nature for nature's sake as a distinct value type) (e.g. Stern et al. 1995). Although there is a logical distinction between altruism centered on people and on nature, people do not necessarily make this distinction (Dietz et al. 2005). Furthermore, there is merit in addressing environmental values within a broader human values context because people have multiple competing interests and priorities (Mills et al 2011).

The structure of ecosystem service priorities was consistent with psychological theory on human values (Schwartz & Boehnke 2004) and in broad agreement with the categories determined in the MA (2003) framework; patterns that were common to both marginal and total value priorities. The structure of ecosystem service values meant that specific values appeared closer to one another, whereas others opposed one other. Furthermore, these structural relations were persistent across spatial scales, motivational goals, and priority estimates. All provisioning values (fishery and materials) fell within the same psychological value domain reflecting *self-enhancement* motivational goals. Regulating (coastal protection and sanitation) and supporting (habitat) values from the MA (2003) categories were all within the same psychological value domain reflecting *self-transcendence* motivational goals. *Self-transcendence* and *self-enhancement* values are structurally opposed to one another; and indeed, the ecosystem service literature acknowledges that the most common and pronounced trade-offs occur between provisioning and supporting or regulating services (Martin-Lopes 2012; Rodriguez et al. 2006; MA 2005).

The main distinction between the MA (2003) categories and the psychological value domains (Schwartz 1994) emerged when cultural (culture, education, bequest, and recreation) values (MA 2003) fell into two psychological value domains. Culture, education, and bequest fell within the *traditionalism* value domain, while recreation was associated with the *openness to change* value domain. Critically, these two value domains oppose one another suggesting an important distinction needs to be made between cultural ecosystem service values that are motivated by *traditionalism* goals and those that are motivated by *openness to change* goals.

Although ecosystem service categories group recreation with bequest, economic categorizations distinguish between recreation, which is considered a direct use value and bequest which is considered a non use value (Bateman et al. 2002). Indeed, there is a growing recognition that cultural ecosystem services have been inadequately represented, conceptualized and measured (Daniel et al. 2012; Chan et al. 2010). I contribute to this effort by demonstrating that services currently contained within the cultural services category are distinct, and opposed, based on their motivational goals. Different cultural services were contained within the *traditionalism* and *openness to change* value domains. This separation aligns with tradeoffs that have been documented between *traditionalism* (culture and bequest) and *openness to change* (recreation) values (Hicks et al. 2009). These values should be distinguished to help navigate conflicts and the potential unexpected erosion of values or support.

Ecosystem service trade-offs

The different domains of cognition that a consistent structure to ecosystem service values reflects has significant implications for the understanding of how and why trade-offs occur (Tetlock 2003). Tradeoffs are ubiquitous in ecosystem service projects, but they remain inadequately recognized (Vira et al. 2012). A better understanding of the processes that lead to trade-offs would therefore enable programs to be explicit about the losses, costs, and hard choices involved (Vira et al. 2012; McShane et al. 2010). I found provisioning services opposed to supporting and regulating services, suggesting a trade-off, consistent with the ecosystem services literature (Martin-Lopes et al. 2012; Rodriguez et al. 2006; MA 2005). However, it was not clear which direction this trade-off would take. Habitat, a supporting service, together with fishery, a provisioning service, were amongst the three most important services, suggesting it should be possible for the trade-off to favor supporting services over provisioning services and vice versa. The tendency for supporting services to be traded off in favor or provisioning services is therefore unlikely to be the result of people under valuing supporting services, but may be influenced by other factors that relate to behavior (e.g. beliefs, attitudes, and knowledge) (Rockeach 2008).

Fishery and habitat service values were structurally opposed to one another in both the MDS ordination (on priorities), and Schwartz values wheel (on motivations) (Figure 5.3), but both are considered amongst the most important ecosystem services (Figure 5.1), despite the fact that there is considerable variation in how important resource users consider a change in these ecosystem services to be (Figure 5.2). The combination of variable but important values being structurally opposed to one another creates the situation where it would be inadequate for policy to focus on either habitat or fishery. This is because individuals who would benefit from actions that realize fishery goals are different to those that would benefit from actions that realize habitat goals. Further, actions that realize habitat goals are likely to impact fishery goals, thus actively marginalizing a sector of society. Ecosystem service assessments therefore need to consider multiple ecosystem services and policy uptake needs to address a range of values.

5.6. Conclusions

People use broad goals to prioritize their decisions and develop behavioral norms; as a result, the state of natural resources is seldom the main priority, even in resource dependent societies (Mills et al. 2011). Dialogues that recognize the benefits that people gain from nature are an important part of any management and policy discussions. However, attempts to influence pro-environmental behavior need to understand people's psychological motivations. A better connection is needed between a psychological system of values and the ecosystem service values that management of nature is attempting to promote. This requires interdisciplinary research that engages the motivational aspects of complex moral and social psychology with ecological-economic and ecosystem services disciplines (Spash 2010; Nicholson et al 2009).

Chapter 6

An entitlements approach for the analysis of ecosystem service benefits

Chapter 6. An entitlements approach for the analysis of ecosystem service benefits

CC Hicks, JE Cinner

Adapted from: CC Hicks JE Cinner (in prep) An entitlements approach for the analysis of ecosystem service benefits ***PNAS***

6.1. Abstract

Ecosystem services are supplied by ecosystems or nature. However, ecosystem benefits, by definition, are felt by people. Ecosystem service assessments, intended to influence the decisions people make regarding their interactions with nature, therefore need to understand how people benefit from different ecosystem services. A critical question therefore is what determines the distribution of ecosystem service benefits between different sections of society? Here, I use an entitlements approach to determine whether key access mechanisms are related to people's perceptions of coral reef ecosystem service benefits. I find that access mechanisms are strongly related to how people perceive benefits from ecosystem services. There are broad similarities across countries studied in how people gain access to and are able to benefit from specific ecosystem services. Social access mechanisms in particular are associated with a large number and diversity of benefits. However, local context strongly determined how people perceived benefits from ecosystem services. Although a specific access mechanism may enable people to benefit from a certain ecosystem service in one context, it may hinder the ability of people to benefit in a different context. Ecosystem service assessments, and their resultant policies, need to take into consideration the mechanisms by which different people benefit from a supply of ecosystem services.

6.2. Introduction

Environmental degradation and ecosystem services

Increases in human population (Roberts 2011), rates of consumption (Berkes et al. 2006), and anthropogenic climate change stressors (Barnowsky et al. 2012), are currently the major drivers of environmental decline. As a result, a number of concepts have moved high on the international agenda including environmental "limits to growth" (Arrow 1995; Meadows 1972); "sustainable development" (Brundtland commission 1987); and global targets for people and the environment (COP 10 2011, MDG 2011). The concept of ecosystem services emerged amidst this growing realization of a need for practical solutions to environmental decline, and specifically, solutions that link people with nature. Ecosystem services refer to the many ways that nature benefits people (e.g. Carpenter et al 2009; Tallis et al 2008; Spash 1999; Daily 1997; Ehrlich & Mooney 1983). Scientists believed that reframing ecosystem function and biodiversity by highlighting its importance to humans, through the benefits they gain, would increase public consciousness of the importance of biodiversity (Ehrlich & Mooney 1983).

A number of frameworks, designed to illustrate the importance of nature to humans, have been applied to ecosystem services research (Chan et al 2012; Tallis 2008; Fisher et al in review). However, ecosystem services are generally conceptualized and measured spatially creating a focus on the supply of ecosystem services (e.g. Raudseppe Hearne 2010; Chan 2006). Ecosystem services are supplied by ecosystems or nature; however, ecosystem benefits, by definition, are felt by people. A supply side focus is therefore necessary, but not sufficient, since it assumes that all people in a given landscape benefit from ecosystem services in a similar manner. Ecosystem service supply statements therefore say something about ecosystem services, whereas benefit statements should be about the relationship between people *and* ecosystem services. The important question therefore, relating to a public consciousness of the importance of biodiversity, is what determines the distribution of ecosystem service benefits between different sections of society? There is existing scholarship on the relationship between people and the environments they interact with that ecosystem services can draw on

(e.g. Chambers & Conway 1992; Ostrom 1990; Johannes 1989; Blaikie 1989; Blaikie & Brookfield 1987). Here, I draw on an entitlements approach developed in welfare economics (Sen 1981).

Entitlements

It has been nearly 40 years since Amaytra Sen published his first paper on entitlements as a new way to approach the analysis of famines (Sen 1976). The crux of his idea is that starvation is about "people not *having* enough food…., it is not the characteristic of there *being* not enough food" (Sen 1981). Although the latter may cause the former, many famines occur where there is in fact sufficient food supply (Sen 1981). Entitlements in this context, does not apply to people's rights in a normative sense – what people *should* have – but describes the range of possibilities – what people *can* have (Leach et al. 1999; Gasper 1993; Sen 1981). The past 40 years has generated significant attention, both favorable (Osmani 1995) and critical (Nolan 1993) of Sen's entitlements approach. The critiques tend to focus on ambiguities in the terminologies used (e.g. entitlements has legal and lay interpretations) (Gasper 1993); whether Sen's approach amounts to a theory or was intended as a descriptive framework (Devereaux 2001; Sen 1981); and Sen's focus on economically mediated entitlements, ignoring social and political influences (Devereux 2001; Mearns 1996; Gore 1993; Gasper 1993). Nonetheless, an entitlements approach has had significant influence on poverty scholars and practitioners, who now question the paths of influence rather than simply the direct antecedents of poverty and starvation. Indeed Sen's entitlements approach, starting from the insight that availability does not necessarily mean access, has influenced research far beyond the analysis of famines (Gasper 1993). Entitlements have been used to examine: feminist issues (Nussbaum 2003; Kabeer 1991); the influence of economic or social reform (Fitzgerald 1991; Aslanbeigui & Summerfield 1989); and challenges facing environmental governance (Nunan 2006; Leach et al 1999; Adger & Kelly 1999). An entitlements approach therefore broadens analytical approaches; questions the validity of accepted causal relationships, and draws attention to the usually indirect nature of linkages between people and their environments (Mearns 1999).

Linking ecosystem services and entitlements

Leach et al. (1997), expanded Sen's (1981) entitlements approach to develop an environmental entitlements approach, which I adapt to examine how people benefit from different combinations of ecosystem services. Environmental entitlements differ from food entitlements by broadening the concept of access to include the 'ability to make use of' (environmental resources). In this way, environmental entitlements capture the social and institutional components that mediate the relationships between people and the environment (Leach et al. 1999; Mearns 1996). For a given supply of ecosystem services it is instructive to analyze two key components of an entitlements approach: first, *what* do people benefit from, and; second *how* are they able to benefit? Entitlements capture what people benefit from and are defined as the alternate commodity bundles that people have legitimate and effective command over (Leach et al 1999; Gasper 1993; Sen 1981). Ecosystem service entitlements therefore may include any combination of provisioning, cultural, regulating, and supporting services, or just a single ecosystem service. Endowments are the 'rights and resources that people have' that enable them to benefit (Leach 1999; Sen 1981). Ribot and Perusoe (2003) developed a theory of access that identified nine categories that shape processes and relations that enable people to benefit from things. Access gives people endowments which enable them to benefit from different combinations of ecosystem services (Figure 6.1).

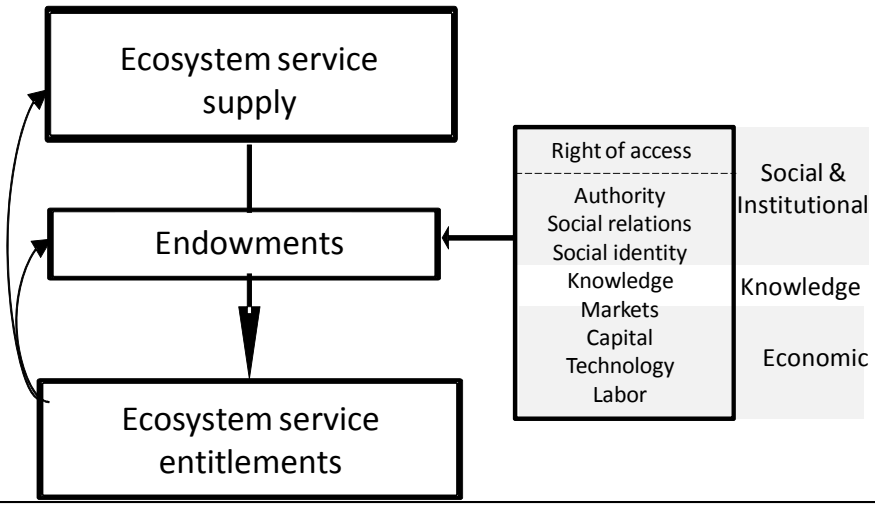

Figure 6.1 Ecosystem service entitlements framework
Data collection and analysis framework allowing me to investigate how, different social actors benefit from ecosystem services. Access mechanisms, or institutions, mediate the relationship between the supply of ecosystem services and the ability of actors to benefit from them (Modified from Leach et al 1999)

Access mechanisms

Access can be categorized into rights based and structural and relational access mechanisms (Fig 1) (Ribot & Peluso 2003). Rights based access refers to the legal rights actors have to access the environment (Figure 1). For example in Kenya, government regulations stipulate that fishers are not allowed to fish inside a national no-take marine park (e.g. see McClanahan et al. 2008). Similarly, local management arrangements may exist that forbid access to their fishing grounds from outside fishers (e.g., Gelcich et al. 2010). Structural and relational access mechanisms are established by the specific political, economic, and cultural frames within which access to resources is sought (Figure 6.1; also see Blaikie 1985 for a discussion of access qualifications). Ribot and Perusoe (2003) further identify eight distinct structural and relational access mechanisms (technology, capital, labor and labor opportunities, markets, knowledge, authority, social identity, and social relations). For example, a fisher will only be able to benefit from fishing if they have the gear (technology) to catch fish. Some gears need to be operated by a team of fishers (labor), and each fisher may need to purchase a license (capital) before they are able to catch any fish. Similarly, a fisher may only be able to gain an income from their fishing if there is a market nearby (access to markets) where they can sell their catch. These access mechanisms may be present or absent to varying degrees in different settings; thus influencing the types of benefits people are able to get from a supply of ecosystem services.

Knowledge and identity as access

Ecosystem service benefits are also likely to be constrained by more diffuse access mechanisms. Knowledge for example is important for shaping who can benefit, and how they are able to benefit, from resources (Ribot & Peruose 2003). Local ecological knowledge (LEK) is defined as scientific and practical knowledge held by a specific group of people about their local ecosystems (Crona 2006, Olsson & Folke 2001). For example, fishers who are aware of the ecological processes that sustain the productivity of their fishery (knowledge) are likely to perceive a benefit associated with being in, experiencing, and learning from the natural environment (representing the ecosystem service education). Social identity is similarly important in mediating who has access to resources, and how they use that access to benefit

from resources (Ribot & Peruose 2003). The identity and meanings people develop through their experiences with places influences who they are and what they do (Harvey, 2001). For example, someone who identifies themselves as an environmental steward (identity) is likely to interact with nature in particular ways and thus access certain benefits. The meanings and identities people develop may derive from the natural environment, but are more often made up of a mix of natural and cultural features in the landscape, including people. Finally, in addition to access mechanisms creating endowments and thus distinct entitlements, entitlements, in turn influence actors' endowments, and both would influence ecosystem service supply. For example, a fisher that benefits from the fishery will receive an income, increasing their capital, which would allow them to buy a new license the following year, or expand to a new fishery.

Benefit is defined in terms of people's preferences (Bateman et al. 2002). People's preferences are generally taken to be shaped by economic (e.g. created through: capital, labor and labor opportunities, and markets) and knowledge (e.g. created through: knowledge) based characteristics. However, I have also shown that they are associated with people's motivations (Chapter five). Ribot and Perloso's (2003) access mechanisms therefore make a significant contribution in allowing an examination of the role that broader social and institutional characteristics (e.g. created through: authority, social identity, and social relations) play in shaping people's preferences.

In a normative or legal sense, entitlements have been applied to the creation of markets for ecosystem services (e.g. Swallow et al. 2009; Salzman 2005). However, entitlements in an analytical sense have yet to be applied to an analysis of the distribution of multiple ecosystem services; and never to coral reefs. Coral reefs present a particularly pertinent system to explore how people benefit from nature because coral reef fishing communities are intimately connected to the environment, yet in many places a combination of anthropogenic impacts, and a lack of effective management threatens their long-term prospects. I therefore apply an extended entitlements approach (Leach et al. 1999) to examine how different people benefit from different coral reef ecosystem services. Specifically, I surveyed twenty eight coral reef

fishing communities, across four countries in the western Indian Ocean to ask the following research questions: 1) “what ecosystem service entitlements are evident in the western Indian Ocean?” 2) “What access mechanisms are responsible for the endowments associated with these entitlements?” And 3) “how are endowments and entitlements differentiated among countries?”

6.3. Methods

I used a qualitative and quantitative strategy, to examine people’s perceptions of coral reef ecosystem service benefits and their ability to benefit (fig 1).

Qualitative strategy

The qualitative strategy was conducted via focus group to conceptualized the coral reef ecosystem service benefits; and determine the local access mechanisms that give people the rights and resources necessary to benefit from different ecosystem services. I gathered this data through five “expert” focus groups with relevant managers and scientists, followed by 30 focus groups with fishers from 28 communities across Kenya, Tanzania, Madagascar, and Seychelles.

Ecosystem services

Ecosystem service benefits are classified into provisioning services (e.g. food), regulating services (e.g. coastal protection), cultural services (e.g. spiritual reflection) and supporting services (e.g. nutrient cycling) (MA 2003). First, five focus groups were conducted with managers and scientists working in all four countries to determine the relevant coral reef ecosystem service benefits, wording to describe them, and a picture to convey each benefit (as described in chapter four and five). Second, I conducted 30 focus groups (2 initial and 28 subsequent) with fishers from each community across the four countries to refine the chosen

list, descriptions, and photographs of ecosystem services (as described in chapter four[24] and five).

Access mechanisms

First, I conducted three focus groups with managers and scientists working in all four countries to explore factors that enabled, or constrained, the ability of fishers to benefit from ecosystem services. I categorized the identified factors into Ribot & Peluso's (2003) nine access mechanisms (Table 6.1). The outcome of the focus groups was a set of questions measuring indicators of access through: *technology, capital, labor and labor opportunities, markets, authority*, and *social relations* (Appendix 9.3) (Ribot & Perouse 2003).Second, because there are complex and multidimensional components of access through *knowledge* and *identity*, I conducted ten focus groups with fishers from all four countries to explore knowledge and identity in greater detail. The discussions sought to first determine knowledge that is common to both the scientific literature and the LEK of the communities I visited. Second, to describe some of the meanings and aspects of attachment associated with being a fisher. The outcome was. The outcome of the fisher focus groups was a set of questions eliciting suitable indicators access through *knowledge*, and access through *social identity* (Appendix 9.3) (Ribot & Perouse 2004).

[24] I conducted fewer focus groups in chapter four because I was unable to interview a sufficient number of scientists from Seychelles so I also excluded the Seychelles fishers data. Managers and scientists did not prioritize materials so materials were also excluded from chapter four.

Table 6.1. Access mechanisms determined in the focus groups guided by Riobot and Perosuo (2003). Access mechanisms fall into a broad Type, the description is given, measurement scale and subsequent analysis.

Type	Mechanism[25]	Description	Measurement	Analysis
Institutional	*Rights based access (n=28)*	The formal (de jure), or informal but adhered to (de facto), **restrictions** on fishing	Open access (0) or restricted access (1)	na
Social	*Access to authority (n=400)*	**Levels of trust** in, and **participation with,** local and national authorities. Respondents were asked to describe their level of trust in members of authority on a 5 point Likert scale and whether they engaged with members of authority in any groups or organizations.	5 point Likert scale	All combined into two factors explaining 31% (trust in authority), and 15% (participation with authorities) of the variation.
Social	*Access through social identity (n=400)*	**Meanings, heritage, attachment.** I measured 1) how strongly, on a 5 point Likert scale, respondents identified with seven statements conveying the meanings associated with being a fisher (determined in the focus groups); 2) whether the respondent grew up in a fisher family (marine heritage); and 3) how attached the respondent was to the marine environment (established as connection through marine related jobs; importance of marine related jobs; and number of dependents). Based on Marshall 2007, Steadman 2002	5 point Likert scale Fisher family (1) non fisher family (0) Number of connections (0-3) Importance of jobs in order of importance (1-3) Dependents (number (0-9)	Attachment factors combined into two explaining 31% (attachment to the fishery) and 28% (attachment to the marine environment) Meanings factors combined into two explaining 25% (place based meanings) and 20% (meanings) of the variation.
Social	*Access via the negotiation of social relations (n=400)*	**Levels of trust** in (on a 5 point Likert scale) and **participation with** community members (through community events, and resource management decisions on a scale of 0 to 2 ranging from no attendance, through passive to active participation (Cinner et al 2012)	5 point Likert scale Events yes (1) no (0) no attendance (0), through passive (1) to active participation (2)	All combined resulted in three factors, explaining 25% (trust in the community), 18% (trust in fishers) and 15% (participation)
Economic	*Access to markets (n=28)*	Average **price** of fish as sold in the nearest market	$/kg	na
Economic	*Access to*	**Capital** invested in the gears owned by the fisher, based on	Scale 1-4 lowest to highest	na

[25] Ribot & Perusoe (2003)

	technology (n=400)	Mangi et al (2007)	investment requirement. Spear guns had the na lowest investment requirements (US$ 4.6), followed by line (US$ 6.9), trap (US$ 33.9), and net the highest (US$ 200.6	
Economic	*Access to capital (n=400)*	**Income, expenditure**, and a **material style of life index** (MSL). MSL calculates a wealth score based on a person's material possessions (Pollnac Crawford 2000)**.** Our MSL index examined 15 items, including the types of walls, roof, and floor in a person's house, how they cooked (i.e. gas, charcoal, or firewood), the type of lighting they used (e.g. light bulbs, hurricane lamp, or kerosene lantern), whether they owned any form of transport (car, motorcycle, bicycle), and whether they had piped water, a generator, electricity, a fan, a refrigerator, a television, a DVD, a radio or cassette player, a mobile phone (Cinner et al 2012 PNAS)	$/fortnight Presence (1) absence (0) Combined in PCA	All combined into one factor explaining 59% of the variance
Economic	*Access to labour and labour opportunities (n=400)*	**Occupational diversity**, and **household occupation multiplicity** Determined from the activities (i.e. jobs) that people did that brought food or income into their homes (Allison and Ellis 2001; Cinner et al 2008 CB). I calculated the number of: 1) jobs respondents were engaged in; 2) jobs members from their house hold were engaged in, and; 3) different types of jobs that people in the household engaged in	Number of personal jobs (0-5) Number of household jobs (0-5) Number of different jobs in the household (0-5)	All combined into one factor explaining 74% of the variance
Knowledge	*Access to knowledge (n=400)*	**Years of education** a respondent had achieved, and **levels of local ecological knowledge** (LEK) LEK was determined from eight questions, based on the work of Crona (2006), that measured four components of LEK: 1) the importance of ecological knowledge; 2) how ecological knowledge was transferred; 3) the importance of particular practices (determined in the focus groups) all on a 5 point Likert scale and; 4) importance of ecological processes (5 point Likert scale) and knowledge of species.	Years education (0-14) 5 point Likert scale Knowledge aligned (1) Knowledge not aligned (0)	All combined into two factors explaining 35% (knowledge transfer, knowledge of species, and ecological processes) and 16% (formal education) of the variation.

Quantitative strategy

The quantitative section was intended to measure resource users perceived coral reef ecosystem service benefits and determine their levels of access. I gathered this data through 400 individual semi-structured questionnaires with fishers from all 28 communities. I obtained information from local fisher organizations, or the fisheries department, on the age, primary gear used, and place of residence for all registered fishers. I used this information to randomly select 20% - 40% of fishers from each community, across the age, gear, and geographic range of all involved in the coral reef fishery for the quantitative surveys. I piloted all surveys in each country. (see Appendix 9.2 methods for more details)

Ecosystem service prioritization

Benefits are defined in terms of people's preferences (Bateman et al. 2002). I therefore used the individual semi-structured interviews to elicit stakeholders' preferences for the identified ecosystem services (i.e. their ecosystem service benefits) (as described in chapter four and five). I designed the questions to establish how important the ecosystem services were to resource users (total value), and how important a change in the quality or quantity of ecosystem services was to the resource users (marginal[26] value). Respondents were provided with a photograph, a brief description of each ecosystem service (developed in the qualitative section), and 20 matches to be used as "counters" for the rating exercise (described below). The services were discussed with the respondents to establish a common understanding. I explained that I was interested in the respondents' preferences. I then asked the respondents to 1) rank the services in order of importance to them, and 2) rate the services by distributing counters according to "where they would most like to see an increase in the quantity or quality of the service they access". For the rating exercise, fishers were provided with 20 counters in four installments to distribute as they saw fit across the nine ecosystem services. For example, Fishers could place all counters on one particular service or distribute them among several services. Any additional information on how the services were conceptualized, challenges

[26] Marginal values are distinct from total value in that they capture a desired- or undesired- change (Pearce 1998, Bateman et al 2004) (See chapter five)

arising in assigning priorities, or rational behind the respondents' prioritizations were recorded. The rating responses were weighted as described in chapter five, and normalized to a common scale of 0-1.

Access mechanisms

I used the individual semi-structured interviews to determine respondents' levels of access to nine access mechanisms. *Rights based access* and a*ccess to markets* were determined at the site level (n=28) All other access mechanisms were calculated at the individual level (n=400) (Table 6.1). Ribot and Perluso's (2003) structural and relation access mechanisms were categorized according to the type of endowment they create. Economic endowments (technology, capital, markets, and labor), knowledge endowments (knowledge), and social or institutional endowments (authority, social identity, and social relations) Using this categorization, I examined the entitlements generated by each category of endowment.

Data Analysis

Where multiple indicators related to individual access categories (e.g. capital, labor and labor opportunities, knowledge, authority, social identity, and negotiation of social relations) I used a principal component analysis with a varimax rotation to reduce the number of explanatory variables (Cinner et al 2012).I normalized data to a common scale of 0-1 to allow comparisons across different types of variables to be made.

I used redundancy analyses (RDA) (ter Braak & Smilauer 2002, CANOCO v4.5; Legendre & Legendre 1999) to examine the distribution in ecosystem service benefit that is explained by access. An RDA thus allows me to simultaneously identify how ecosystem benefits cluster (into entitlements) and what access mechanisms are responsible for driving the clustering. I used a monte carlo permutation test (499 permutations) to forward select variables (i.e. variables were added to the model one by one, with variables explaining the largest amount of variation added first) until no further variation was explained. Inflation factors give an indication of how correlated a variable was with other variables. Where variables reported inflation factors

greater than 20[27], I removed variables by backward selection until all variables were within inflation index score of 20. To examine how access varied by context and scale I ran an RDA, on the whole data set (WIO) and on each country individually (Kenya, Tanzania, Madagascar, and Seychelles).

6.4. Results

Ecosystem services

I identified nine coral reef ecosystem services that were relevant across all four countries; two provisioning services (identified as fishery and materials), two regulating services (identified as coastal protection and sanitation), one supporting service (identified as habitat control), and four cultural services (identified as culture, education, recreation, and bequest). These services clustered in different ways dependent on the scale and context examined creating distinct ecosystem service entitlements (described below).

Ecosystem service access mechanisms

I corroborated the nine access mechanisms identified by Ribot and Peruso (2003) in the interviews and focus groups (Table 6.1). Principle components analysis reduction resulted in 17 final explanatory variables (Table 6.2) that in various combinations explained ecosystem service entitlements evident in the different scale and contexts.

[27] When a variable's inflation factor is large (>20) it is almost perfectly correlated with other variables, its ordination is therefore unstable and does not merit interpretation (ter Braak & Similauer 2002).

Table 6.2. Explanatory access mechanism variables. Factor loadings shown for the individual items contained within each category of access mechanism.

Type	Mechanism[28]	Explanatory variables	PCA Factor loadings
Social	Authority	Authority-trust PC1 42%	Village leaders 0.65 Religious leaders0.66; Police 0.77; Local government 0.78; NGO staff 0.70 Fisheries/park staff 0.60
		Authority-participation PC2 15%	Participation 0.95
Social	Access through social Identity[1]	Identity-attachment fishery PC1 31%	Connections to marine 0.68 Importance of fishing occupation 0.74
		Identity-attachment marine PCA 28%	Dependents 0.66 Proportion of catch for home consumption 0.82
		Identity-place PCA 1 26%	Attachment to sea 0.73 Attachment to job 0.69 Identity as a fisher 0.47 Attachment to people 0.53
		Identity-meanings PCA 2 20%	Identifying with freedom 0.75 Identifying with pride 0.69
		Identity-heritage	0, 1
Social	Access via the negotiation of Social relations	Relations- trust community PC1 25%	Family 0.56; Colleagues 0.72; Community villagers 0.73
		Relations- trust fisher PC2 18%	Outside fishers 0.58 Fishers using other gears 0.63
		Relations- participation PCA3 15%	Community celebrations 0.75 Meetings 0.44
Economic	Access to	Capital PC1 = 59%	House hold items 0.89

[28] Ribot & Perusoe (2003)

	Capital Redo pca just on MSL		Lighting 0.85 Cooking 0.90 Roofing 0.90 Floor 0.80 Wall 0.40 Expenditure 0.80 Income -0.30
Economic	Access to Labor and labor opportunities	Labor -Occupations PC1 = 72%	Individual occupations 0.81 Household occupations 0.82 Different HH occupations 0.92
Knowledge	Access to Knowledge	Knowledge-ecological PC1 35%	Knowledge transfer 0.61 Species & maturity S*iganus sutor* 0.69 Species & maturity *Leptoscarus vaigensis* 0.51 Species & maturity *Lutjanus bohar* 0.58 *Lutjanus gibbus*, 0.73)
		Knowledge-formal 16%	Ecological processes 0.73 Years of education 0.61

Ecosystem service entitlements explained by access: results of the RDA

Western Indian Ocean as a whole

Across the western Indian Ocean, four ecosystem service entitlements (representing distinct bundles of ecosystem services) were evident: 1) “sanitation” and “coastal protection”; 2) “habitat” and “recreation”; 3) “fisheries” and “materials”; and 4) “education”, “culture”, and “bequest”. These clusters were associated with the four countries and represent an above average tendency to prioritize the specific ecosystem services, rather than necessarily greater absolute values. A tendency to prioritize “education”, “culture”, and “bequest” was associated with *social identity* (place and heritage) (Figure 6.2). Access via the negotiation of *social relations* (participation) was associated with an above average tendency to prioritize “fishery” and “materials” benefits. Access to *knowledge* (ecological), access to *labor and labor opportunities*, access via the negotiation of *social relations* (trust in fishers), and access through *social identity* (the meanings people identified with) were associated with an above average tendency to prioritize “habitat” and “recreation” benefits. Finally, access to *markets* and access to *knowledge* (formal) were associated with an above average tendency to prioritize “sanitation” and “coastal protection” benefits (Figure 6.2). However, within each country, different access mechanisms were associated with distinct bundles of ecosystem service benefits.

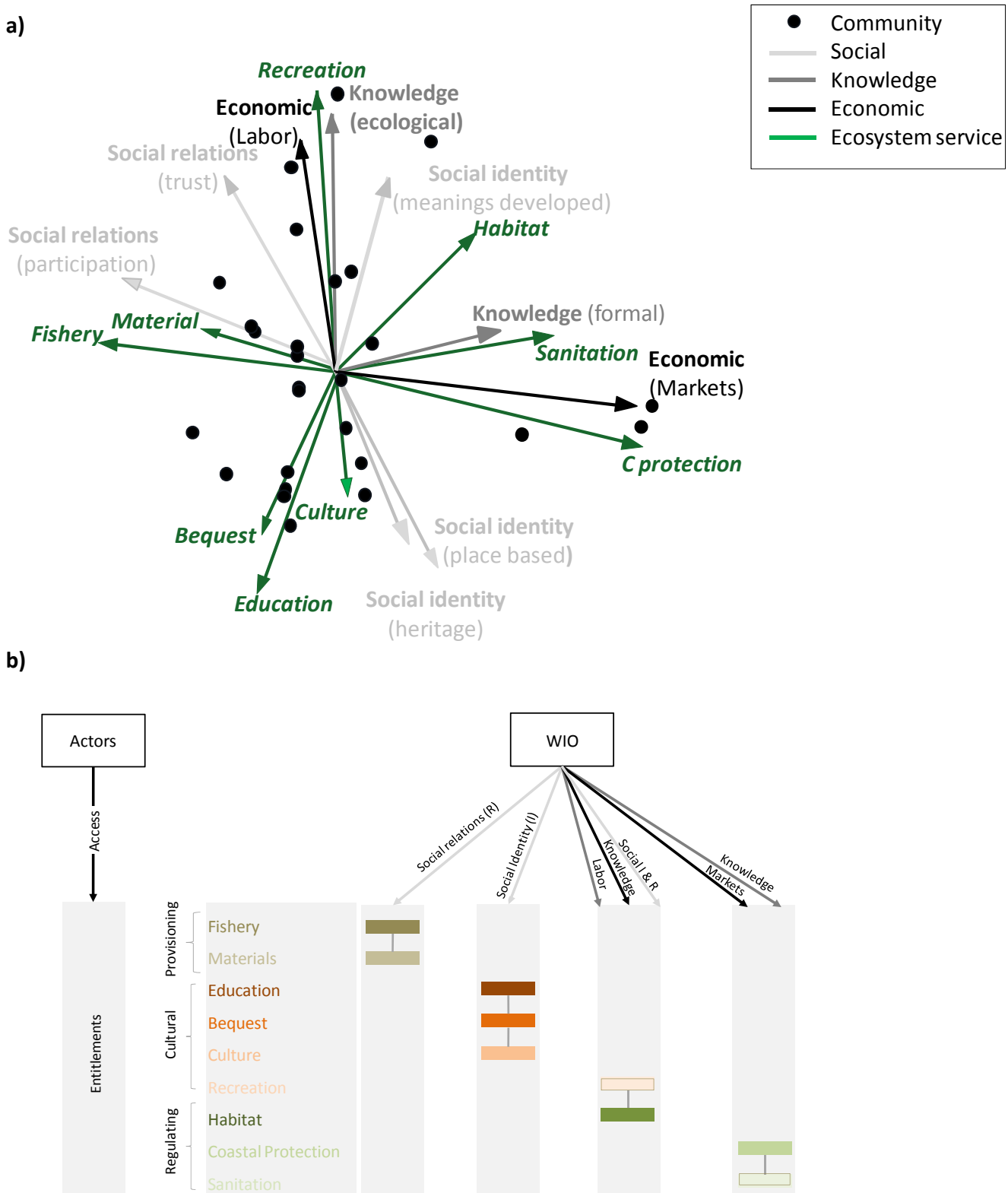

Figure 6.2 WIO Ecosystem service entitlements

a) Redundancy analysis showing variation in community priorities for ecosystem service benefits associated with distinct access mechanisms. **b)** Schematic entitlements frame work showing ecosystem service entitlements and their associated access mechanisms (in grey) derived from RDA

Tanzania

Four entitlements (clusters of ecosystem service benefits) were evident from the Tanzanian coastal communities studied: 1) "bequest", "culture", and "fishery"; 3) "sanitation", "recreation", and "materials"; 2) "habitat" and "coastal protection"; and 4) "education" (Figure 6.3, Appendix 9.6). Access through *social identity* (place) and access to *knowledge* (formal) was associated with a greater tendency to prioritize "bequest", "culture", and "fishery" benefits. Conversely, the lack of access through *social identity* (place) or access to *knowledge* (formal) was associated with a greater tendency to prioritize "sanitation", "recreation"; and "materials" benefits (Figure 6.2d).Access to *labor or labor opportunities* and access through *social identity* (meanings) was associated with a greater tendency to prioritize "habitat" and "coastal protection" benefits. Conversely, the lack of access to *labor or labor opportunities* and access through *social identity* (meanings) was associated with a greater tendency to prioritize "education" (Figure 6.3, Appendix 9.6).

Kenya

Four entitlements (clusters of ecosystem service benefits) were evident across the Kenyan coastal communities studied: 1) "fishery"; 2) "bequest" and "education"; 3) "sanitation", "materials", and "habitat"; and 4) "recreation" and "culture" (Figure 6.3, Appendix 9.6). Access via the negotiation of *social relations* (trust in fishers) and access through *social identity* (attachment to fishery and place) was associated with a greater tendency to prioritize "fishery" benefits. Access through *social identity* (heritage) was associated with a greater tendency to prioritize "education" and "bequest" benefits. Access through *knowledge* (ecological) was associated with a greater tendency to prioritize "sanitation", "materials", and "habitat" benefits. Access via the negotiation of *social relations* (trust in community), *rights based access*, and access through *capital* was associated with a greater tendency to prioritize "recreation" and "culture" benefits (Figure 6.3, Appendix 9.6).

Madagascar

Four entitlements (clusters of ecosystem service benefits) were evident from the Malagasy coastal communities studied: 1) "bequest" and "sanitation"; 2) "coastal protection", "recreation", and "fishery"; 3) "education" and "materials"; and 4) "habitat" and "culture" (Figure 6.3, Appendix 9.6). Access to *technology* and access to *knowledge* (ecological) was associated with a greater tendency to prioritize "bequest" and "sanitation" benefits. Access to *authority* (participation) and access via the negotiation of *social relations* (trust in community) was associated with a greater tendency to prioritize "coastal protection", "recreation", and "fishery" benefits. Access through *knowledge* (formal) was associated with a greater tendency to prioritize "education" and "materials" benefits. The lack of access to *technology* or *knowledge* (ecological) was associated with a greater tendency to prioritize "recreation" and "culture" benefits (Figure 6.3, Appendix 9.6).

Seychelles

Four entitlements (clusters of ecosystem service benefits) were evident from the Seychelles coastal communities studied: 1) "habitat"; 2) "sanitation" and "recreation"; 3) "coastal protection"; and 4) "bequest", "culture", "education", "fishery", and "materials" (Figure 6.3, Appendix 9.6). Access via the negotiation of *social relations* (trust in fishers) and access through *social identity* (meanings) was associated with a greater tendency to prioritize "habitat" benefits. *Rights based access* and access to *labor or labor opportunities* was associated with a greater tendency to prioritize "sanitation" and "recreation" benefits. Access to *authority* (participation and trust), to *capital*, and via the negotiation of *social relations* (participation) was associated with a greater tendency to prioritize "coastal protection" benefits (Figure 6.3, Appendix 9.6).

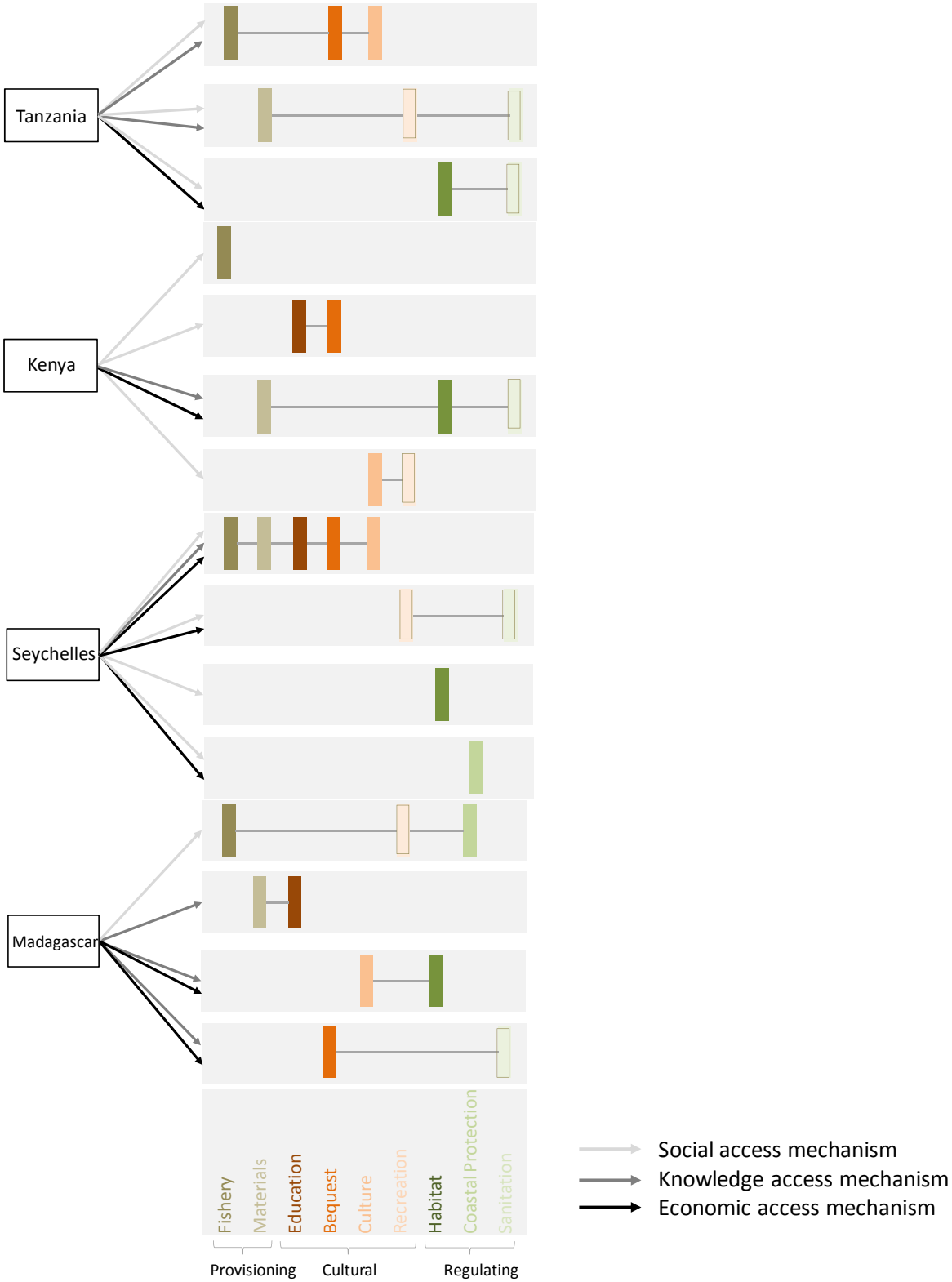

Figure 6.3 Ecosystem service entitlements at a country scale
Ecosystem service entitlements and their associated access mechanisms derived from the RDA's for each country (Appendix 9.6).

Type of endowment created

Access mechanisms associated with social or institutional characteristics (e.g. social relations and identity) were responsible for enabling fishers in all four countries, as well as the WIO in general, to benefit from the largest number and diversity on entitlements (Figure 6.2, Figure 6.3, Appendix 9.6).

6.5. Discussion

An entitlements approach has been applied to a diversity of fields to uncover the processes through which different people benefit from a supply of food, environmental, or economic resources (Leach et al 1997; Kabeer 1991; Sen 1981). I present an entitlements-based approach for assessing ecosystem services that explicitly acknowledges that different people access and benefit from ecosystems in diverse ways (Ringold et al 2013; Ribot & Perusoe 2003; Blaikie 1986). My comparative study of 28 communities across four countries revealed three key findings. First, I demonstrated that access mechanisms are strongly related to how people perceive benefits from ecosystem services. Second, I found broad similarities across countries studied in how people gain access to and are able to benefit from specific ecosystem services. In particular, social (rather than knowledge or economic) access mechanisms enable people to benefit from the greatest number and diversity of ecosystem service entitlements. Third, local context strongly determined how people perceived benefits from ecosystem services. Critically, a specific access mechanism may enable people to benefit from a certain ecosystem service in one context, but may hinder the ability of people to benefit in a different context. These results highlight the importance of distributional inequality issues (also see chapter three) that are regularly left out of ecosystem service assessments (MA 2005, Poverty Environment Initiative 2011).

The first key finding, using this bundling approach for the analysis of ecosystem services, was that access was strongly associated with the benefits people perceived from a supply of ecosystem services. Although most of the entitlements identified were unique, the distribution in entitlements was driven by a discrete set of access mechanisms (Ribot and Perusoe 2003). This suggests that the benefits people perceive from a supply of ecosystem services are

dependent on the access mechanisms they have available. Access therefore, gives people the rights and resources they need to benefit from a supply of ecosystem services. Ecosystem service assessments generally consider one or two ecosystem services at a time, with the inevitable outcome being that decisions are based on partial information and unexpected trade-offs occur (Hicks 2010; Foley, 2007; MA 2005). An entitlements approach differs in that it starts with the assumption that people benefit from bundles of things, rather than discrete individual commodities (Sen 1981; Leach et al. 1999). Entitlements are the different bundles of ecosystem services that people benefit from. Indeed, bundles are emerging as an important way of approaching ecosystem service assessments, useful for navigating potential trade-offs (Chapter four and five, Raudseppe-Hearn et al. 2010; Bennett et al. 2009,). Ecosystem service science would benefit from an inclusion of access mechanisms in their assessments of bundles. People are unlikely to respond to policy in the ways an ecosystem service approach intends until they perceive a benefit.

My second key finding highlights a number of similarities that emerged across context and scale in the social and institutional access mechanisms associated with ecosystem service benefit. Four of Ribot and Perluso's (2003) access mechanisms relate to wealth (technology, markets, labor and capital), a fifth to knowledge, and the remaining three structural and relation access mechanisms relate to social or institutional characteristics (i.e. access through authority, social relations, and social identity). Broad similarities emerged in the tendency for economic, knowledge, or social and institutional endowments to generate entitlements. Wealth and knowledge are standard considerations in the ability of individuals to benefit from goods and services and indeed Sen's original focus was on economically mediated entitlements (Devereaux 2001; Mearns 1996; Gore 1993; Gasper 1993). However, in line with critics of Sen's early work, I found that social or institutional access mechanisms enabled people to perceive a benefit from a supply of ecosystem services in more ways than knowledge and economic access mechanisms combined.

People that perceive a diversity of benefits from a supply of ecosystem services are likely to have a range of options available to them. For example, they may be able to take advantage of

benefit from, direct income generating options, such as through sales in a fish market or employment in the tourism industry. However, fishers who also perceive indirect benefits from the coral reef environment are likely to be sympathetic to a range of policy options. For example, fishers in the WIO articulated that their motivations for prioritizing "habitat" were to benefit the community and fishery as a whole, and their motivations for prioritizing "education" were to create responsible fishing practices (chapter five). Although a healthy ecosystem is in the interest of many resource users, fishers are unlikely to be sympathetic to policy approaches that limit their freedoms (e.g. by restricting fishing or the use of certain gears for biodiversity purposes), unless they first believe these approaches seek to preserve certain benefits – "habitat" and "education" - and second perceive a benefit from those services. People who perceive a diversity of benefits, are capable of improving their lot through a greater diversity of means, and have a greater freedom to adopt the desired environmentally friendly behaviors (Jentof 2010).

A number of additional, more specific, similarities were evident across countries connecting social endowments to specific ecosystem service benefits. For example, in all instances, social access mechanisms (e.g. authority, social identity, or social relations) were associated with entitlements containing fishery benefits. In Madagascar, fishery benefits were associated with access through authority. Access to authority reflects the existence of appropriate conflict resolution mechanisms. When conflict resolution mechanisms exist, people are more likely to cooperate for the successful management of common pool resources - such as fisheries (Cox et al. 2010; Ostrom 1990). In Kenya, fishery benefits were associated with stronger social relations which may have a positive effect on fish biomass (Cinner et al. 2012a). In Tanzania and Seychelles, fishery benefits were associated with social identity. In coastal Australia, people's sense of place, specifically having local heritage is strongly associated with the importance of fishing (Larson et al. 2013). A number of similarities exist between Tanzania and Seychelles. In both countries, people who identified strongly with the place they lived in were likely to perceive a benefit from bequest but unlikely to perceive a benefit from recreation. In the communities I visited, recreation tends to be associated with the modern and lucrative tourism industry which is likely to conflict with the more subsistence and traditional identity associated

with being a fisher. However, in Australia some recreational services (swimming) are negatively associated with the extent to which people identified with a place suggesting this relationship may, to a certain extent, transcend context (Larson et al 2013). Again, in both Tanzania and Seychelles, people who identified strongly with the meanings associated with being a fisher were likely to perceive a benefit from habitat, but unlikely to perceive a benefit from education.

My third key finding highlights significant differences across context that cannot be overlooked in determining how people perceive benefits from ecosystem services. Despite commonalities across countries, almost every ecosystem service entitlement was distinct (i.e. only a few bundles of ecosystem services occurred in more than one country). The exception was bequest and fishery which bundled in both Seychelles and Tanzania. Differences in ecosystem service entitlements across countries suggest the way people benefit from ecosystem services is dependent on local context. In one context, a specific access mechanism would enable people to benefit from a certain ecosystem services. However, the same access mechanism was found to hider the ability of people to benefit from the same ecosystem service in a different context. For example, entitlements containing fishery were associated with a higher levels of ecological knowledge in Seychelles, but lower levels of ecological knowledge in Kenya. Similarly, entitlements containing fishery were associated with a greater number of years in education in Tanzania, but a fewer number of years in education in Madagascar. The way people benefit is consequently complex and context dependent.

The tendency for benefits to co-occur has presented methodological challenges for approaches concerned with determining discrete quantities of individual ecosystem service values. However, individuals who benefit from ecosystem services do not conceptually distinguish between the different benefits associated with activities they engage in. For example, a fisher may primarily go fishing to catch fish to feed their family (a provisioning service), but they may at the same time go fishing because they love being out on the water; connecting with nature; the time for reflection that it gives them; and the knowledge they gain about the best spots to fish or times to go (a variety of cultural services). The benefits most fishers associate with their

occupations relate to income but also many non income related factors such as tradition and pleasure (Pollnac et al., 2001 OCM, Pollnac et al 2012). This growing body of knowledge points to the value of clustering associated benefits. For example, in the Torres Strait Islands, fishers hunt dugong for a number of reasons and cognitive mapping exercises show fishers to group cultural (e.g. pride in being a good fisher) and provisioning (providing for family and the community) benefits together (Delisle 2012). Similarly, recreational fishers in Australia primarily go fishing for recreational purposes (a cultural service) but they also land their catch and use it to feed their family (a provisioning service). It is therefore very difficult to disentangle and separate the different benefits people get from the same activities. By appreciating that benefits are felt in bundles, an entitlements approach is aligned with the way people perceive the benefits they gain from ecosystems

6.6. Conclusion

The concept of ecosystem services seeks to illustrate the importance of biodiversity to humans through the benefits they gain. In doing so it is hoped that people will become aware of the importance of biodiversity and therefore develop more environmentally responsible behaviors. However an ecosystem services approach does not at present consider how this increased awareness would lead to a change in the way people behave. Nor does it consider whether people are capable of changing their behavior. Understanding the processes by which people benefit from ecosystem services will enable a better understanding of who benefits and who is capable of changing their behavior. By integrating an entitlements approach with ecosystem services, this chapter developed an understanding of how different sectors of society are likely to be affected by changes in ecosystem service supply. In the western Indian Ocean, I found that access does mediate the ability of people to benefit from a supply of ecosystem services. I show that the greatest diversity of opportunities are created principally by a range of social access mechanisms. Options in resource dependent societies increase people's adaptive capacity, thus reducing their vulnerability to environmental and policy changes (Adger et al 1999). Natural resource governance, particularly of the commons, is therefore as much about creating opportunities as it is about solving problems (Jentoft et al 2010; Kooiman et al 2005).Although there are broad similarities, in how different people are able to benefit from

specific ecosystem services, context is a key determinant of how these mechanisms play out, and whether they ultimately increase or decrease the options people have available to them. Ecosystem service assessments, and their resultant policies, need to take into consideration the mechanisms by which different people benefit from a supply of ecosystem services. By doing so, an ecosystem services approach will be better equipped to mediate inherent issues of inequality (Poverty Environment Initiative 2011; MEA 2005).

Chapter 7

Discussion

Chapter 7. Discussion

7.1. Introduction

The Millennium ecosystem assessment (Perrings 2006; MA 2005) catalyzed the use of an ecosystem services approach that focuses on the relationship between people and nature (Martin et al. 2010; Perrings 2006). Ecosystem service science is a relatively new field[29], but it draws on established disciplinary tools and concepts to form a compelling model that is morally motivated. As a result, the field is developing rapidly and gaining considerable institutional support (e.g. UK NEA 2011; Sukhdev et al. 2010; Pagiola et al. 2004). The past few years have begun to see a shift in the way ecosystem service studies are approached; from an ecological and economic focus, towards a growing recognition of the need to embed social dynamics in the ways ecosystem services are understood (Daw 2012; Adams et al 2010). For example, there has been an increasing recognition of the importance of human preferences for ecosystem services (Martin-Lopez et al. 2012); the need to incorporate different dimensions of value (Chan et al. 2012; de Groot et al. 2010); and to develop concepts of cultural ecosystem services (Daniel et al. 2012; Tengberg et al. 2012). This thesis adds to this growing body of knowledge by integrating social, motivational, and institutional components of the way people interact with nature.

The aim of my thesis was to develop a better understanding of how people benefit from and value ecosystem services; and to determine how this knowledge can be integrated into the analysis and development of policy. To achieve this aim, I developed five objectives that established the state of the field and addressed four research gaps. Each objective was designed to build on the proceeding objectives, the conclusions of which are summarized in the

[29] References to natures services can be traced back to but the concept ecosystem services came to the fore in 1997 (Daily). These ideas reflect developments in economics. Concerns over how people interact with nature, and the need to maintain areas of nature have been echoed in various forms through the years (e.g. Wordsworth, Malthus, Marx, Leopold, Marsh). For a brief history on natural capital and environmental thinking on nature see Hicks et al (2010).

next sub-section. I then discuss the cross cutting themes that my thesis illuminates and the contributions my framework has made towards embedding social differentiation and a broader concept of ecosystem service values into a decision making processes.. I conclude this chapter with a discussion of the main theoretical contributions that this thesis has made, the practical implications, and some directions for future research.

7.2. Primary Objectives

1. **Establish what ecosystem services have been assigned monetary estimates of 'value' and to ascertain the implication of this work.**

I addressed this objective in chapter two using a meta-analysis of the valuation studies conducted in the western Indian Ocean. In this chapter I wanted to know, "if a non-economist from the western Indian Ocean (e.g. a manager or policy maker) was interested in the value of coral reef ecosystem services, what conclusions are they likely to draw from the existing literature?" I found a diversity of services had been measured, across all categories of services; however, there was a paucity of studies assessing supporting services. The methods used to assess different services calculated fundamentally different components of value which meant comparisons could not be made across services. Furthermore, studies tended to assess only one or two services at a time. The implications of this became apparent when I compared the scale to which services flowed and the estimates given. Studies measured services that flowed to beneficiaries at local (i.e. fishing communities), national (i.e. second home owners), or global (i.e. tourists) scales. Because global beneficiaries were capable of paying more than local beneficiaries this created the impression that global benefits are more important than local benefits. To navigate these challenges, assessments need to address multiple ecosystem services simultaneously, using the same methods, and explicitly identify whose values are being counted.

2. **Develop and apply a framework to evaluate the potential outcome of a set of rules taking resource users' ecosystem service values and their social characteristics into consideration?**

In chapter three, I addressed this objective by expanding a well tested and robust decision making framework that was developed to assess how a set of rules, address specific problems, and lead to desired outcomes (Imperial 1999). This framework has been applied extensively to the governance of common pool resources (Ostrom et al. 2010; 1999; 1990). My adaption of this framework, allowed an examination of how people and institutions interact to value the environment, and how under a given set of rules this is likely to lead to an outcome. I applied this framework to a case study in Seychelles. It was evident that different people have different values which are related to their social and institutional characteristics. Furthermore, I identified a need for policy to adopt multiple approaches to match the diversity of values and contexts represented. Common, centralized, approaches to fisheries management are likely to have distributional implications resulting in a tendency to fish harder by the poorest sectors of society. I therefore demonstrated that my adaption of the institutional analysis and development framework can inform a decision making processes as a robust framework that integrates information pertinent to how people are likely to behave.

3. **Examine ecosystem service priorities and interactions at different levels of decision making.**

The design of chapter four was guided by my framework where I examine the ecosystem service priorities and interactions between these priorities for actors at different levels of decision making (i.e. fishers, managers, and scientists). There were both similarities as well as differences in how the three groups of actors prioritized ecosystem services. Fishers had a far greater tendency to prioritize fishery benefits. Managers and scientists had a greater tendency to prioritize coastal protection and bequest benefits. There were no differences in the priorities that the three groups assigned to habitat and sanitation benefits. However, interactions representing bundles and trade-offs were an inherent part of ecosystem service priorities, and the three groups differed considerably in the interactions they perceived between the different ecosystem services. For example of eleven interactions, fishers overlap with scientists on only two interactions. Managers however, overlapped with both fishers and scientists on a total of seven interactions (five with scientists, four with fishers). Managers therefore have the

potential to play a brokering role between fishers and scientists in reaching decisions over resource management. Bundles and trade-offs should be a key consideration in ecosystem service assessments and policy development.

4. **Integrate socio-cultural and motivational components of value to determine why bundles and trade-offs emerge.**

In chapter five I drew on a human values theory from social psychology (Schwartz 1994) to understand why bundles and trade-offs, inherent in ecosystem service priorities, emerge. I found the motivational goals behind ecosystem services reflect human values. This finding suggests that ecosystem services are structurally related so that provisioning benefits are in opposition to regulating and supporting benefits, and that recreation benefits are in opposition to the other cultural benefits assessed (bequest, culture, and education). This structure was consistent between ecosystem services motivation and ecosystem services priority across all four countries studied. This suggests that the relationships between ecosystem services are dependent on motivation and manifest in priorities. Motivations therefore provides an understanding of why people prioritize certain ecosystem services and what trade-offs are likely to emerge

5. **Establish how different people benefit from a supply of ecosystem services**

In chapter 6 I used an entitlements approach to examine how different people benefit from ecosystem services. Access mechanisms were strongly related to how people perceived benefits from ecosystem services. I found broad similarities across countries studied in how people gain access to and were able to benefit from specific ecosystem services. In particular, social (rather than knowledge or economic) access mechanisms enabled people to benefit from the greatest number and diversity of ecosystem service entitlements, suggesting social characteristics were the primary determinants of how people perceive a benefit. However, these similarities should not overlook the influence of local context since the ecosystem service benefits that people perceived were fundamentally different in different contexts. Specifically,

a specific access mechanism that enabled people to benefit from a certain ecosystem service in one context hindered the ability of people to benefit in a different context.

7.3. Contributions and challenges

In this discussion below, I draw out the cross cutting themes that my thesis illuminates. I begin with four themes that contribute towards a broader understanding of the values and benefits people receive from nature: 1) a multiple services approach; 2) ecosystem services trade-offs; 3) ecosystem services bundles; and 4) heterogeneous values. I then illustrate how contextual characteristics determine how people benefit from and value ecosystem services.

The need to assess multiple services with consistent methods

This section highlights the contribution my thesis makes towards a multiple services approach. There has been a growing recognition of the need to assess multiple ecosystem services simultaneously (Carpenter et al. 2009; MA 2005; Foley et al. 2005). Ecosystem service concepts relate to social-ecological systems, which are systems linking people and nature. In fact these systems represent one system, whose components are inherently interlinked, with multiple and critical feedbacks existing between and within separate components (Nicholson et al. 2009; Berkes et al. 2000). Changes in one ecosystem service therefore, influence the magnitude or mix of other ecosystem services. Assessments that focus on single services fail to capture the system dynamics of ecosystem service benefits and if intended for policy, risk generating unexpected and unwanted consequences. In chapter two, I used a review of the coral reef valuation studies to highlight two additional issues associated with singles service assessments. A wide variety of services were measured in the western Indian Ocean (WIO); however, they tended to be measured in separate studies that employed incomparable methods, and measured the value of different stakeholders at different scales.

First, studies that focus on one or two services serve an important function because of the detail necessary to develop methodologically rigorous approaches (Nelson et al. 2009; Ricketts

et al. 2004). However, because methods developed to capture the value of an individual service are often specific to that service, comparisons cannot be made across services. I briefly illustrate this point with an example from my review in chapter two. I can assume the demand for ecosystem service "y" increases as the available quantity "y" decreases (Figure 7.1). A travel cost method, which is the most common method for measuring a recreation service, would determine the value of "y" as equal to consumer surplus. This approach takes into consideration that different people may be willing to pay different amounts above the market price. Simplistically, it is as if the travel cost method measures the triangular area below the demand curve but above the price paid (A on Figure 7.1). Alternatively, a market value method, which is commonly used to measure a fishery service, uses a different approach and determines value from the price set in a market and the quantity of fish sold. This is effectively the rectangular area representing the quantity sold at a certain price (B on Figure 7.1). I cannot therefore compare the recreation value determined from a travel cost method with the fishery value determined from a market value method.

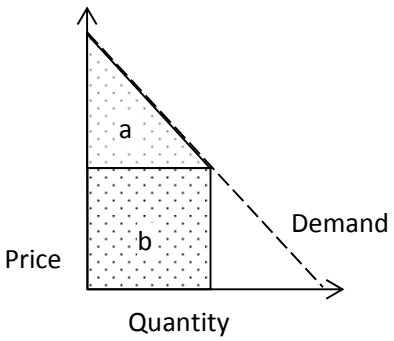

Figure 7.1 A demand curve for environmental goods.
This figure represents a simplified demand curve to illustrate the difference in value estimates made using different methods consumer surplus (A), and market value (B) Adapted from Pearce & Turner 1990.

Second, an explicit, or implicit, step in most valuation approaches is identifying the beneficiaries whose value is to be measured. However, monetary value estimates are strongly influenced by ability to pay (Kapp 1970; Stoeckl et al. in review). The review in chapter two highlighted this

inequality where national and global beneficiaries appeared to benefit and value ecosystem services more than their local counter parts.

For these reasons my thesis has addressed multiple ecosystem services throughout, using the same method to assess all ecosystem services (hence circumventing the triangle, rectangle problem discussed above), and explicitly identifying whose values are being counted. The next section highlights the contribution my thesis makes towards understanding ecosystem service trade-offs.

Recognition of ecosystem service trade-offs

Ecosystem service trade-offs occur when people's actions affect the type, magnitude, or relative mix of ecosystem services such that one ecosystem service is reduced as a consequence of an increase in another(Rodriguez et al. 2006). Trade-offs are inherent in many natural resource management decisions and are generally unavoidable. In some cases an explicit choice is made to maximize one thing at the cost of another, but often trade-offs are unexpected (Rodriguez et al. 2006) and particularly difficult to resolve (McShane et al. 2010). Identifying and addressing these hard choices, both within and across stakeholder groups, is a first step towards overcoming conflict (Hirsch et al. 2011). Chapter two highlighted how decisions are likely to lead to tradeoffs across scales. Ecosystem service studies in the western Indian Ocean tended to assign greater value estimates to services flowing to beneficiaries at a national or global scale (Hicks 2011). However, this greater value was likely to reflect a greater ability to pay by national and global beneficiaries, rather than (dollar free indicators of) the relative priorities of the different stakeholder groups (Kapp 1970), Stoeckl et al in review). Cultural services flowed to primary beneficiaries at all scales, provisioning services only flowed to primary beneficiaries at a local scale and regulating and supporting services flowed to primary beneficiaries at local and national scales. Although many other factors influence what trade-offs emerge. This study serves to illustrate that if decisions are to be based on the studies contained in chapter two we are likely to see trade-offs emerging between scales and resulting in the loss of local provisioning services (Fortin 2005).

Ecosystem services research has embraced the concept of trade-offs (Raudsepp-Hearne et al. 2010a; Bennett et al. 2009; Nelson et al. 2009). But ecosystem service trade-offs are generally determined spatially in biophysical units, with differences in stakeholders preferences rarely considered (Vira & Adams 2009) but see (Martin-Lopez et al. 2012; Hicks et al. 2009). Although chapter three was not designed to elicit trade-offs (instead focusing on how ecosystem service values and contextual characteristics are likely to lead to outcomes), differences in the salient values associated with the fishery revealed a potential trade-off in priorities. Individuals that prioritized cultural services (bequest and option) were different from individuals who prioritized provisioning services (fishery). This suggests that actions which protect the priorities of one group may create trade-offs for the other group, resulting in conflicts. For example, a management action could maximize the fishery by increasing gear efficiency; but, this is likely to impact the bequest values- that reflect the importance of passing the full range of benefits on to our kids.

In chapter four, I set out to explore the interactions between ecosystem services priorities at different levels of decision making (e.g. for fishers, managers, and scientists). In the coral reef fisheries of the western Indian Ocean, fishers are the main group of resource users expected to adhere to rules governing how they can interact with and extract coral reef resources. Although fishers may also be involved in the process of designing rules, managers and scientists are often the main group of actors informing this process. Chapter four illustrates how ubiquitous trade-offs are between ecosystem services across all three groups of actors. Although the production of trade-offs is an inherent characteristic of how I determined actors' priorities- the process reflects reality. Resources are finite (e.g. time, money, energy), and every day, people prioritize explicitly or implicitly certain things over others. In the fishers' network, trade-offs occurred between the three most important services (fishery, education and habitat) (Figure 4.4a). In the scientists' network trade-offs occurred between services that were of a high and a low priority (e.g. habitat and culture), but never between two services that were considered a high priority (Figure 4.4b). These differences are likely to reflect the different relationships the actor groups have with the coral reef environment. Prioritizing fishery conflicts with prioritizing habitat for the group of fishers, but managers and scientists see no such conflict. This reflects a common

belief amongst managers and scientists that conservation goals can also address fishery goals (Gaines et al. 2010), a belief that is not always shared by fishers (McClanahan et al. 2005).

Ecosystem service trade-offs are generally attributed to management decisions (Rodriguez et al. 2006). Clear patterns are beginning to emerge in how and what trade-offs occur, particularly between provisioning and supporting or regulating services (Raudsepp-Hearne et al. 2010a; Nelson et al. 2009; Kareiva et al. 2007; Rodriguez et al. 2006). The mechanisms behind these patterns are being explored conceptually in the ecological sciences (Bennett et al. 2009), but there has not been an equal effort to understand what creates these patterns in people's preferences for ecosystem services. In chapter five, I used insights from social psychology to examine people's motivations, and explore why specific trade-offs occur. The relationships between different types of motivations are such that certain motivations are more likely to be found together whereas others are likely to be opposed - thus creating a trade-off relationship (e.g. (Schwartz 1994). The motivations behind people's ecosystem service priorities aligned with those in psychology and were orientated to offer direct support for the trade-offs I found in chapters two, four, and five, as well as those reported in the literature (Rodriguez et al. 2006; MA 2005). Specifically, motivations behind provisioning services were in direct opposition to motivations behind regulating and supporting services. This chapter suggests ecosystem service trade-offs can be understood and anticipated from people's underlying motivations. Moreover, trade-offs are likely to emerge in a consistent manner which offers a potential for understanding and navigating the hard choices inherent in natural resource management decisions (McShane et al. 2010; Rittel & Webber 1973).

Existence of ecosystem service bundles

Although inherently linked to trade-offs, there has only recently been a move to address ecosystem services as bundles (occurring together). Consequently, empirical assessment into ecosystem service bundles is still in its infancy (Martin-Lopez et al. 2012; Raudsepp-Hearne et al. 2010a). However, a number of previous studies that spatially investigated ecosystems services have found them to occur together and used this as evidence for win-win situations (Nelson et al. 2009; Chan et al. 2006). I therefore explicitly addressed bundling in chapters 3

and 6; however, bundling also emerged as a key component of chapters 4 and 5. Certain commonalities emerged, that may relate to trade-offs. The evidence in this thesis suggests bundles are more variable across individuals and scales than trade-offs. This may be because bundling has not been investigated to the same extent as trade-offs, or it may be an artefact of how decisions are made, such that incidental bundling in more likely to emerge.

Ecosystem services bundled within individual service categories (e.g. cultural in chapters 3, 5, 6; provisioning in chapters 5, 6; and regulating in chapters 4, 5). Bundling was also evident across service categories (e.g. regulating and supporting in chapters 5, 6; and cultural with any other category in chapters 4 and 6). However, provisioning services only ever bundled with supporting or regulating services when the provisioning service was one of three service categories (i.e. provisioning with cultural *and* regulating, or provisioning with regulating *and* supporting, both in chapter 6). It is likely that the tendency for provisioning services to trade-off with regulating and supporting services reduces the likelihood of these services bundling together.

In, chapter six, I used an entitlements approach to examine bundles and found that almost every combination of bundling across and within service categories emerged. However, examination of the specific services shows only one of the bundles (bequest and fishery) occurred in more than one context. This suggests that bundling is less distinct than trade-offs in ecosystem service interactions. However, in the same way that trade-offs facilitate a better understanding of the interactions between multiple ecosystem services, addressing ecosystem services as bundles may also prove beneficial for ecosystem management (Bennett et al. 2009). Managers are likely to want to navigate trade-offs, which appear more absolute. But bundles may present a tool that managers can use to leverage negotiation around difficult trade-offs. Provisioning services often trade-off with supporting services (e.g. fishery and habitat). Rather than focus on the trade-off, managers may be able to use potential bundles to navigate conflicts. For example, because education or coastal protection benefits are more likely to bundle with both fishery and habitat benefits; aligning motivations and priorities in this way is thus more likely to resolve inherent tensions.

The heterogeneity of ecosystem service values

Chapter two highlighted the risk associated with assuming values are heterogeneous. This was particularly evident across scales which I attributed to differences in ability to pay. In all chapters, certain salient values appeared to be shared – that is specific ecosystem service priorities emerged as most important and there was *apparent* agreement across different stakeholder groups. In chapter 3 for example, option, bequest, and fishery services were prioritized above other ecosystem services suggesting these are the salient values in the coral reef fishery. However, when I looked into the social characteristics associated with these priorities it became apparent that individuals who prioritized option and bequest values were different to the individuals that prioritized the fishery values suggesting heterogeneity rather than similarity in salient values. Similarly, in chapter 4, I examined managers', scientists', and fishers' ecosystem services priorities. Although there were some similarities in actors' priorities there were just as many differences. Moreover, the interactions associated with ecosystem priorities differed considerably for the different actor groups, with managers' priorities showing the greatest potential for overlap with the priorities of other actor groups (Figure 4.4.).

Chapter 5 highlighted the degree to which apparent similarities can mask underlying variations. All of the 28 communities' studied prioritized ecosystem services in a similar order (Figure 5.2); however, within the communities there was considerable variation that is masked by a focus on mean values (Figure 5.3). This tendency to overlook community heterogeneity and social difference has been highlighted in the natural resource management literature (Leach et al. 1999). Leach et al. (1999) draws attention to a body of literature that emphasizes how diverse and often conflicting values, rather than shared beliefs and interests, pervade social life (Carney & Watts 1991; Moore 1993).

The importance of contextual characteristics

I explored how contextual characteristics determine how people benefit from and value ecosystem services, drawing on examples from a common property approach used in chapter three (Ostrom 2007; 1990), and an entitlements approach used in chapter six (Leach et al.

1999). A diversity of values were evident throughout this thesis. By exploring the differences between local, national, and global beneficiaries, chapter two illustrated that ecosystem service estimates are dependent on whose value is counted. In line with this, chapter four highlighted the differences that exist between managers, scientists, and fisher's in their ecosystem service priorities. I began to explore why values might differ in chapter five where I was able to accurately predict the distribution in people's ecosystem service priorities based on their underlying motivations (Figure 5.4a, b) (Schwartz 1994). The fact that people value things differently is hardly surprising, yet assessments routinely fail to make this distinction. Consequently, a number of scholars have highlighted that if ecosystem service science is to achieve its objectives then there is a need to recognize social differentiation (Daw et al 2012; Ringold et al. 2009).

In chapter three I used a common property approach to examine whether the way people value ecosystem services was related to a tendency to cooperate in the management of their resources (Cox et al. 2010; Ostrom 1990). Various social or institutional, economic, and knowledge characteristics are known to relate to a tendency of people to come together to successfully manage their resources (see Cinner et al. 2012b; Agrawal & Benson 2011; Ostrom 2007; 1990). Although knowledge and economic characteristics were included, social and institutional characteristics including levels of support, the existence of conflict resolution mechanisms, and a tendency to self monitor were the strongest predictors of the overall distribution on ecosystem service value in the Seychelles (Figure 3.4). In chapter six, I drew on an entitlements approach to complement this understanding and examined whether the way people value ecosystem services is related to the access they have to ecosystem services (Ribot & Perusoe 2003). Again, social or institutional mechanisms were the strongest predictors of the overall distribution in ecosystem service value (Figure 6.2, and Figure 6.3). These mechanisms are responsible for enabling access to the greatest diversity of ecosystems service entitlements.

An understanding of how people come to value things differently develops the skills necessary to manage nature's resources in an equitable and sustainable manner. Solutions tend to focus on economic or knowledge based interventions. For example, delivering training, building skills,

and providing technology. These are undoubtedly necessary; however, I have shown that an investment in social and institutional characteristics, for example developing conflict resolution mechanisms, holds great potential for mediating the ways people benefit from and value ecosystem services.

Informing policy

The principal aim of ecosystem service science is to inform policy; to achieve this, ecosystem services need to be explicitly integrated into decision making (Daily et al. 2009; Fisher et al. 2008). A large number of frameworks and classification systems have been developed for ecosystem services (e.g. Chan et al. 2012; Tallis et al. 2008; MA 2003). Many are conceptual and only a few guide the identification and inclusion of data (Ringold et al. 2013; Nahlik et al. 2012). The natural capital project's development of INVEST software (Daily et al. 2009) is to the best of my knowledge, the first attempt to explicitly include the multidimensional nature of ecosystem services into the analysis and development of policy. This framework links ecosystems, services, values, institutions, and decisions. INVEST spatially determines ecosystem services values in biophysical units, which are then converted into economic values using a variety of methods (www.naturalcapitalproject.org). Therefore, what this fails to do is account for differences attributable to method, allow for the integration of socio-cultural and motivational components of value, and address or incorporate social differentiation.

I therefore expanded a well tested and robust framework that evaluates the likely outcome of a given set of rules (Ostrom 2011) to also consider how individuals and institutions interact to value the environment. Chapter three demonstrated how this framework can be applied to the evaluation of two fisheries management approaches in the Seychelles, to illustrate where different approaches are likely to be most effective. The implications of focusing on economic solutions were highlighted where significant distributional implications were likely to be associated with a financial incentive approach to fisheries management (Figure 3.4). This chapter illustrated that management is most effective when it can adopt a variety of approaches in any given setting, thus maximize the chances of success across the greatest proportion of individuals (e.g. (Gutiterrez et al. 2011). Ecosystem service values and their

contextual characteristics proved pertinent in determining how people were likely to behave. This suggests the merit in my adaptation of the institutional analysis and development framework and its applicability to the assessment of ecosystem service and integration into decision making processes.

Here I would like to highlight three opportunities have emerged through this thesis that provide useful insights for management and policy.

Firstly, the role different actors' play in decision making, and their potential as agents of change, should not be over looked. Chapter four highlighted an overlap in the way managers perceived ecosystem service values with the way both scientists and fishers did; an overlap that did not exist between fishers and scientists (Figure 4.4). This suggests managers may be well placed to navigate inherent conflicts in the ways fishers and scientists see ecosystem service interactions in an effort to reach agreement.

Secondly, interactions between ecosystem services are inherent and complex. Management therefore needs to appreciate this complexity and seek opportunities where they arise. Common trade-offs emerged, particularly between regulating or supporting, and provisioning services. This trade-off persists, throughout this thesis and in the broader literature. However, bundles, which are more variable, may be amenable to management and offer an alternative approach to leveraging agreement. Management that addresses areas of agreement (bundles), rather that attempts to overcome areas of conflict (trade-offs) is more likely to align with the interests of all involved. Win-wins are likely to emerge where agreement exists. For instance provisioning services were only found to bundle with supporting or regulating services when bundles also contained a third category of service.

Thirdly, social and institutional characteristics emerged as instrumental in enabling resource users to come together to manage their resources (Chapter 3). These characteristics also reflected the dominant mechanisms that enabled individuals to benefit from a diversity of ecosystem services (Chapter 6). Policy would therefore be well placed to consider addressing

and investing in social characteristics to influence and broaden the potential benefits people perceive from nature.

7.4. Future directions and Limitations

Early papers advocating work in ecosystem services, or ecological economics more broadly, called for methodological pluralism (Norgaard et al 1999). Methodology is the principles and practices that underlie research, dictating how knowledge is formed in practice, and when methods are appropriate (Spash 2012; Burnham et al. 2004). Methodological pluralism therefore requires an appreciation of what knowledge means to the different disciplines informing an ecosystem services approach. However, it is unclear whether ecosystem service science is achieving this aim (Spash 2012). Few scientists study methodology or make their beliefs explicit (Norgaard 1989). Furthermore, because ecosystem service science seeks practical solutions to pressing issues, epistemology is seldom considered and the theoretical underpinnings of the divergent disciplines are often overlooked. The result is a tendency to brush over fundamental conflicts between different world views (Spash 2012), or to only draw on methods, tools, and analogies that support existing world views. However, interdisciplinary fields routinely face these challenges where the lack of a cohesive epistemology and methodology are cited as key barriers (Hicks et al. 2010; MacMynowski 2007; Max-Neef 2005; EPSNet 2003 p.2). This is therefore not a fault levied at ecosystem service science, but a point that needs to be made, since critical reflection is beneficial, and an issue that needs consideration and development. Furthermore, finding interdisciplinary solutions is challenging but a necessary part of conservation and natural resource management.

Throughout my thesis I have drawn on disciplinary traditions not routinely considered in ecosystem service science. In doing so I have challenged some common assumptions (highlighted in the introduction) and I have examined alternate theories of value and benefit to begin to develop new theories relevant to ecosystem services science (chapter 5, 6).

I believe these initial theoretical ideas can now be developed further and tested to ask, for example:

- How are ecosystem service motivations, and priorities, orientated and aligned in other contexts?
- What factors influence the motivational goals associated with ecosystem services? (i.e. connection, development, resource system)
- How do people gain access to ecosystem services? (i.e. drawing on political ecology)
- How common is the apparent trade-off between recreation benefits and other cultural service benefits, and should the MA (2003) categories capture this distinction?

There are a number of assumptions and limitations associated with this work. I have highlighted above, the challenges associated with interdisciplinary research, and many of these apply to this thesis. Because many of my findings (chapters 3, 5, and 6) focus on a single group of resource users -fishers- they cannot be extrapolated beyond this group. Indeed a number of other factors are likely to influence the ways in which people prioritize ecosystem services. In the same way, a number of factors are likely to influence the choices people made when responding to my interviews, which are beyond the scope of this thesis (Spash 1999). For reasons outlined in my introduction, I chose to focus on social aspects of ecosystem services. However, I acknowledge that integral to ecosystem services is the ecological system that produces them. I do not suggest that social perceptions of value are independent of the ecological components of the system. Integrating these two dimensions of value is a critical and I believe a fundamental next step.

7.5. Conclusions

The aim of my thesis was to develop a better understanding of how people benefit from and value ecosystem services; and to determine how this knowledge can be integrated into the analysis and development of policy. I set out to address this aim through five objectives, the conclusions of which are summarized below.

My thesis has thus conceptually and theoretically broadened the way ecosystem services values are understood. I have highlighted significant heterogeneity in the way different people perceive and value ecosystem service benefits. Identified why common trade-offs between

ecosystem services are likely to emerge, and established mechanisms that are likely to enable people to benefit from a supply of ecosystem services. Finally, I have developed and tested a framework for integrating this knowledge into the analysis and development of policy, suggesting options for leveraging agreement.

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9. Appendix

9.1. Economic Approach

Essentially willingness to pay can be shown to be a measure of preference satisfaction and hence a measure of wellbeing. The aim of my contingent valuation (CV) was to elicit individual preferencesh in monetary terms for changes in the quality or quantity of marketed and non marketed goods and services. Eg establishing maximum WTP or minimum WTA (see next page for a discussion of WTP versus WTA)

Our CV design was informed by standard economic valuation methods (e.g. Bateman et al., 2002), Theory of reasoned action (e.g. Fishbein and Ajzen 1975) and elements of a tailored design method (e.g. Dillman's 1978, 2000). For example we established trust by approaching participants with known and trusted members of the fisheries department and brought with us findings from previous research, we increased rewards by supporting group values and through a positive, polite and appreciative manner, and we reduced social costs by minimizing time taken and personal information asked.

Our survey consisted of three stages:

1. Formulating the valuation problem.
    a. Rating and ranking the goods and services in question (to contextualize the goods and services measured)
    b. Determining key ecosystem services for further consideration (we were interested in the key ecosystem services motivating resource use)
    c. Constructing the valuation scenario for each service to be measured (Stated preference survey formulation)
    d. Eliciting monetary value (Stated preference valuation)
2. Additional Questions
    a. Attitudes, opinions, knowledge, use
    b. Demographics
3. Pre-testing
    a. Discussing the range of goods and services in detail.
    b. One to one interviews
    c. Pilot surveys

Stated Preference Valuation Questions.

We have been talking about aspects of the environment that are important to you. I would like to ask you some more specific questions about some of the benefits that you have indicated are most important. These questions are hypothetical - they have not been discussed and are not intended to happen, but asking questions in this way helps us understand what is most important to different people. We have asked these questions in different countries and the answers have really helped us understand different people's priorities. I would like you to treat each question separately and imagine that they are really happening. If anything is not clear, or you need more information please feel free to ask.

Fishery (WTA * to forego fishery value)

Scenario: Your land has become available xxx and so your family decides to move xxx. Although they fish on xxx, the local fishers are trying to control the number of fishers so they can maintain their catches. Because you are a registered fisher, there is a scheme that offers you compensation whilst you look for alternative employment. You will have to report to the office on a weekly basis to report on your job search and collect your payment.

Question: Would you be willing to accept X a week to stop fishing?

Option (WTP to maintain option value, stop it from declining)

The local fishing leaders have identified two issues with the way things are happening at the moment and are deciding what to do with them.

Scenario: The local fishing leaders have gathered and they are concerned that in xxxx area fishing is at maximum capacity. They feel that it is important that other people should be able to start fishing, or use the coral reef environment, even if they are not currently using it now. They have suggested that we reduce the amount of fishing that happens in xxx so that others will be able to use the resources. A new area has been identified that is not being fished at the moment, the abundance and catchability is the same as in xxx, but it is a longer journey to get there. You will be compensated for the additional fuel costs but it will take you and extra 2 hours travel time to get there and back.

Question: Would you be travel the extra 2 hours X times a week to free up xxx for others?

Bequest (WTP to secure a gain)

Scenario: The local fishing leaders have gathered and they feel that are concerned that the amount of fishing happening in xxxx area is degrading the marine environment. If we continue like this our children and our children's children will not be able to fish or enjoy the environment in the same way that we do. They have suggested that we reduce the amount of fishing that happens in xxx so that others will be able to use the resources. A new area has been identified that is not being fished at the moment, the abundance and catchability is the same as in xxx, but it is a longer journey to get there. You will be compensated for the additional fuel costs but it will take you and extra 2 hours travel time to get there and back.

Question: Would you be travel the extra 2 hours X times a week to stop degrading the environment xxx for others?

Eliciting values

Although the intention was to use a payment card, because we could not be sure all respondents were able to read, we used a bidding game (or should we say payment ladder) to elicit values. This approach has been found to result in starting point biases (Bateman 2002). However, the biases we observed would be consistent across our sampled population. This should not pose a problem as we are interested in the relative importance of fisher preferences rather than establishing and absolute estimate of the value of goods and services measured.

*The difference between WTP and WTA is theoretically greatest when there is less substitutability between private consumption and public good and in most cases in which SP is used the divergence

between WTP and WTA is small (Bateman et al., 2002). Because we measure WTA for a marketed good, where substitutability exists, this difference should be small (Bateman et al, 2002).

Table A1.1 Ecosystem goods and services

The following table provides the categorization and definitions of the ecosystem goods and service values we identified through discussions with local experts and focus groups.

TEV categorization	Good or service identified	Definition as articulated in focus groups
Direct use values	Fishery	The benefit gained from the fishery catch as income or food.
	Medicine	The benefits gained when the marine environment is used to treat any ailments.
	Education	The benefits gained with the knowledge developed whilst fishing or interacting with the environment that is passed on from generation to generation.
	Recreation	The benefits gained at the end of the day or weekend, from relaxing and enjoying the marine environment.
	Culture	The benefits gained by having cultural connections to the marine environment.
	Option	The benefit gained from knowing the right to use the sea is maintained for everyone.
Indirect use values	Biodiversity control	The benefits gained from having a healthy, diverse coral reef.
	Habitat refuge	The benefits gained from having a structurally complex reef with refuge holes.
	Coastal protection	The benefit gained from having the reef buffer the force of the waves.
	Water quality maintenance	The benefit gained from using the water for sanitation, knowing the ecological processes will break down and remove the suspended particles and excess nutrients.
Non-use values	Bequest	The benefits gained from knowing your children and children's children will be able to benefit from the sea in the same way that we do.
	Existence	The benefits gained from maintaining the right of the sea to exist, aside from any uses we may have.

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9.2. Revised Approach

Sampling,

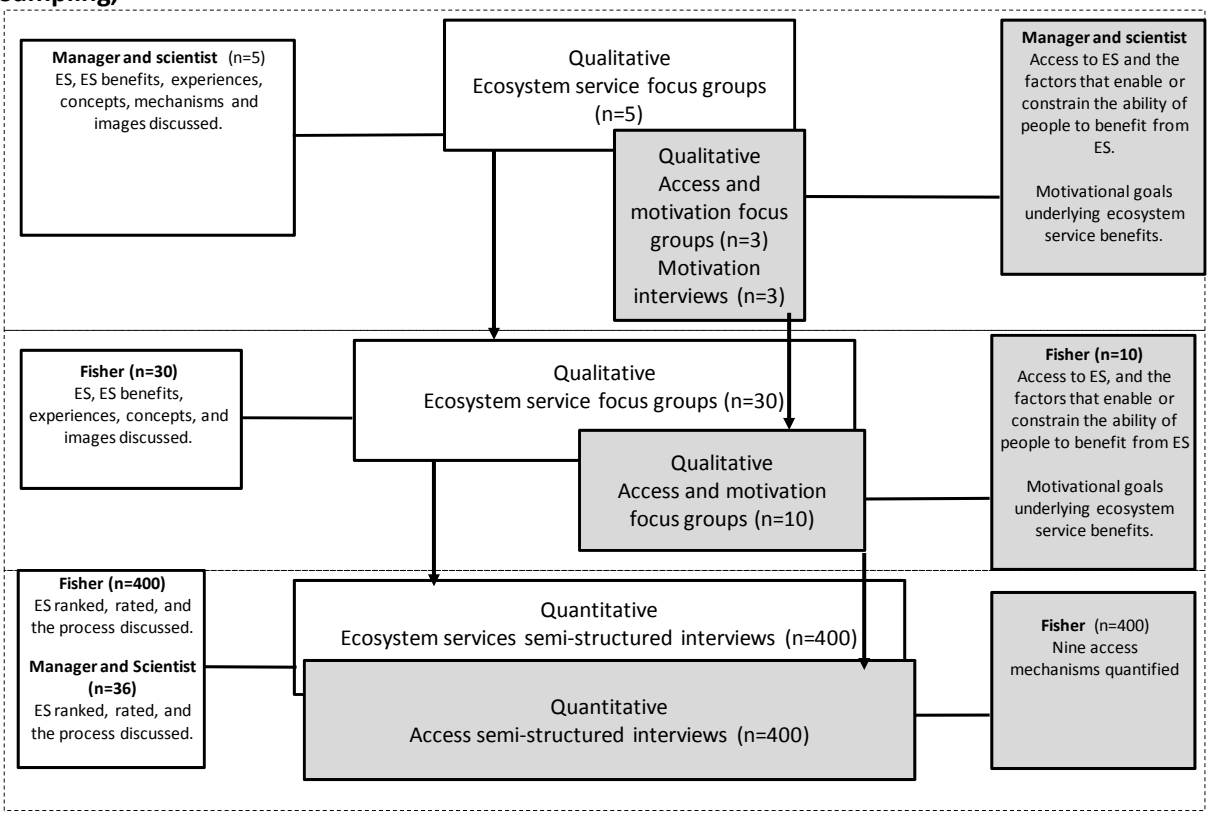

Figure 2. Sampling strategy. Sampling was conducted in three stages. First, a qualitative investigation within combined manager and scientist focus groups. Second, qualitative investigation within fisher focus groups. Finally semi-structured questionnaires with fishers and a smaller subset with managers and scientists

Our focus is on fishers however, we supplement this with household interviews. Ideally between 20-40% (or a minimum of 10) fishers from each area should be sampled. The respondents should be spread across the different gear types equally proportional to the gear composition of that site. A similar amount of households (20-40% or a minimum of 10) with fewer areas selected for the household surveys.

The list of participants from the introductory meeting, or from the fisheries department, was used to randomly draw (using a random number generator) the list of fishers to be interviewed.

I used excel to generate a random number between 1 and the number of fishers at that site, and select fisher, one by one using this random number until you have the number of fishers for each gear type needed. These are the fishers to be interviewed

Quality control

I conducted training and piloting prior to surveys in all countries. I conducted all surveys in Kenya and Seychelles. I worked through the coral reef conservation project in Kenya with two assistants in both of whom I have been working with since 2005 and 2006. These assistants were then responsible for data collection in Tanzania. . Seychelles Fishing Authority in Seychelles, with one assistant who I have worked with since 2008. I spent time training two research assistants in

Madagascar, who were responsible for all the data collection, one who has worked with my supervisor since 2006.

Questionnaires and interview questions are translated into the relevant languages and back again to ensure consistency in meaning.

Questionnaires were entered regularly and the data checked by a second person.

Focus groups;

Focus groups were recorded using a digital recorder and will need to be transcribed by either the interviewee or Notes should be entered into a word document, which continues with the transcription of the whole interview.

Development of the survey

Ranking-This method gets the respondent to rank the identified goods and services in order of importance to get at levels of total value. A two way process was decided on as a result of the cognitive difficulty in ranking a list of more than five. It was noted that this methodology would be difficult to follow, in particular, in Madagascar and if the method is to be modified then it should remain consistent across countries.

The first card is revealed and the respondent asked if the picture shown makes them think of any benefits that they receive from the coral reef environment. A standard description is then given and the picture placed on the ground. The same process is repeated with the next card, except the respondent is asked whether they feel the second card reflects a greater benefit, to the respondent, than the first card. If the benefit is greater, then it is placed above the first card and if less then below. The Third card is produced in a similar manner and the process repeated, working down the list till the card lies in its order of importance. This process is repeated for all 9 cards, however, the Questioner should judge based on how well the respondent recognizes benefits from the picture how important that service is likely to be and therefore which card they should start the pair wise comparison with. i.e. If the respondent does not seem to recognize much of a benefit from the picture then start the comparison lower down the list and work up, if the respondent clearly recognizes benefits then start towards the top of the list and work down. Once all the cards have been lain out, and the respondent is happy with the order this is recorded.

Why instalments-process

Rating- In order to get some more detail about the values assigned to the identified goods and services and get at some ideas of trading off values against each the respondent is asked to rate the identified goods and services. A finite number of matches is provided to the respondent who is asked to distribute them amongst all cards and so indicating their relative importance.

We trialled a number of options (10 matches, 20 matches, 3 matches). It was proving difficult for the respondent to think about distributing any more than 3-5 matched. So we developed an approach where the respondent was provided matches in instalments and given time to think about where to distribute each instalment. After 3-4 goes the respondent lost interest in distributing the matches so we decided this was a suitable umber. We compared responses with each approach.

In order to simplify the process of deciding which goods and services to give how many matches it was decided that the respondent is initially only supplied with 5 matches. The respondent is asked to distribute them according to how important each good or service is to them and it is up to them how many they give each service. For example if they feel fishery is much more important than everything else they may choose to give all 5 to fishery and none to any other good or service. They

may however feel that fishery is still the most important service but that culture and habitat are also important and so give fishery 3 and culture and habitat 1 each. Once the respondent does this the number of matches assigned to each good or service is recorded. The respondent is supplied with 5 more matches and the process repeated. This is repeated until the respondent has been given 20 matches.

In certain parts of Madagascar certain numbers are taboo, it should be checked at piloting what these numbers are to avoid offering these numbers of cards or matches.

Ecosystem service identification with managers and scientists

Identify and define ecosystem goods and services to be measured

An initial list of 14 ecosystem goods and services was developed and discussed and discussed; Fishery, Gleaning, Coastal protection, Bioremediation of waste, Habitat regulation, Resilience, Connectance, Scientific, Educational, Recreation, Cultural heritage, Aesthetic, Existence, Bequest, Other. Any missed services were identified and attempts were made to group services into fewer categories.

- Building and fuel materials, biodiversity and traditional medicine were suggested as services missed.
- Recreation was split into tourism as a potential income earner and local recreation activities. This distinction was made as the feeling was that they represent very different benefits which potentially accrue to different people and lumping could introduce a bias.
- It was decided that local recreation, which mainly consists of walking along the each can be suitably lumped with aesthetic
- Whilst it was recognized that cultural can and does cover a wide range of services it was decided that culture would also include aesthetic and the now local recreation included within that as well as spiritual. It was however, decided that qualitative surveys would be useful at the stage of piloting to categorize and discuss these cultural services further.
- Filtration was discussed and it was decided that other than mangrove system the filtration service was limited. However, it was identified that the sea is often used as a latrine or to wash and gut fish; therefore the service category sanitation was added.
- It was discussed whether education should be included in culture, particularly local knowledge however it was decided that education was an important service that may have the potential to add value t coastal areas and so generate income.
- It was decided that scientific and education should be lumped into the same category.

After a final list of services was developed I decided that in addition to a qualitative interview eliciting more information on cultural benefits and services, I should explore the services in more detail with all communities.

Justification for including supporting services

In addition to the methods, the review highlighted the lack of supporting services assessments. Economic studies tend not to measure supporting services as this would be considered double counting (de Groot scales paper). The direct contribution of supporting services to human well being is therefore expected to be small and difficult to distinguish (equation 7.1). Supporting services predominantly contribute to human well being by maintaining cultural, regulating, and provisioning services (Equation 7.1). Furthermore, as noted in the introduction, ecological assessments are likely to be best suited to assessing the supply of supporting services. However, because policy intends to influence people's decisions, which relate to the benefits they gain from supporting services, I

decided it was important to determine actors' relative priority for supporting services, independent of an ecological assessment.

Human well being = f(P, C, R) + f(s)

Where P=f(S), C=f(S), R=f(S), and f(s) is the direct benefit to human well being from supporting services

P= provisioning service, C = cultural service, R = regulating service,

.

9.3. Questionnaires

Guide for qualitative questions

1. **Sense of Place**

(Identity)

How long have you been a fisher?

Do you enjoy fishing?

How long have you lived by the sea?

What is it about being a fisherman that is important to you?

Is fishing a good life style or a good job?

When people ask what you do are you proud? Why?

How do you view yourself?

What do you think of other fishers?

Would you like to live elsewhere?

(Dependence)

Are there better areas to fish in Kenya?

Do you know the fishing grounds elsewhere?

Would you like to go fish elsewhere?

Do you think you would learn to fish in a new area quickly?

Would you be happy to work on land?

Would you be happy to take another job?

(Attachment)

Is the community important to you?

Do you feel like you belong in this community?

Do you feel safe in this community and that there are people that would support you here?

(Meaning)

Do you think it is your responsibility to look after the environment?

What do you think is important about the environment?

2. **<u>Ecological knowledge</u>**

(Local observational knowledge of species and environmental phenomena)

(Practice in the way people carry out their resource use)

(Belief in how people fit in or relate to ecosystems)

What are the species that you fish for?

What are the habitats that you fish in?

What are the common species here?

What elements of the marine environment are dangerous?

Are there specific ways that you are meant to fish or act around the marine environment?

Have practices changed? How?

What is our role in the marine environment?

Do you think man is meant to live in nature or control nature?

Is it important to know the species?

Is it important to know the ages, sex and about the life of species in the sea?

Is it important to know about other species in the sea that are not targeted?

What makes a good fisher?

What makes a responsible fisher?

What things should a new fisher know?

How can you tell a reef is healthy?

What makes a healthy reef?

How do you gain new knowledge about the sea and environments?

If I wanted to start fishing here what three things would you tell me?

3. **<u>Services and Cultural values</u>**<u>(Fishers, Managers, Scientists)</u>

I would like to talk to you about some of the benefits I believe we gain from living near the marine environment. However, I am more interested in what benefits you feel you gain from the marine environment.

Do you agree with the benefits I have here?

Have I missed any?

Do these pictures accurately reflect the benefits we have been talking about?

4. **Motivations** (Fishers, Managers, Scientists)

When you think about these benefits what are the reasons you find them important (one by one)

What are the reasons others may find these important

5. **Access**(Fishers, Managers, Scientists)

What factors do you feel help you benefits (each service and all)

What would you need to be able to take advantage of these benefits (each service and all)

What factors do you feel stop, or limit the benefits you gain (each service and all)

Services and Cultural values

I would like to talk to you about some of the benefits I believe we gain from living near the marine environment. However, I am more interested in what benefits you feel you gain from the marine environment.

Do you agree with the benefits I have here?

Have I missed any?

Do these pictures accurately reflect the benefits we have been talking about?

Quantitative Questionnaires

name_____
Village/landing site_____
date_____

1. Rank valuation (answer in table)
Use: picture cards, table for answers, service descriptions

I am interested in the coral reef environment and what things about it that you find important. I believe we need to consider this because how we behave, and the decisions we make, are dependent on how important things are to us. I have thought of 9 things that I consider important. I would like to show you some cards with pictures on them that I think represent them. I will then describe each one of them to you and would like you to let me know how important they are to you.

2. Rationality (answer in table)

Do you consider what these cards represent are important to you, the community or the Nation?

3. Rating (away from other respondents) (answer in table)
Use: matches, picture cards, table for answers

I would like you to imagine these matches relate to how important you feel things are. If you think something is very important then you can put more matches on it and if you think is less important you can put less or no matches on it. But you only have 5 matches. Can you place the matches according to how important you think what each card represents is?

If I now give you 5 more can you add them? (three times)

	1. Rank	**2.** Rationality	**3. rating**			
Ecosystem service	rank	Individual (I)/ community (C)/ nation (N)	1^{st} 5	2^{nd} 5	3^{rd} 5	4^{th} 5
Fishery						
Materials						
Coastal protection						
Sanitation						
Habitat						
Tourism						
Educational						

Bequest						
Access (landing site)						
Cultural						

4. Perceptions of action

I would like to talk a little about how you spend your time. For example if you think about your last week, what things did you do? I understand you are a fisher, what time do you normally go out to fish? How long do you spend fishing? So you come back at …? When you finish fishing what do you do? Do you do anything before fishing? When do you spend time with your family? When do you spend time with your friends? Do you have time that you spend just on your own, resting, walking, reading or thinking? Do you think you could tell me what you spend the most time doing?

Activity	**Mon**	**Tue**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**
Work							
Family							
Friends							
Self							
other							

Some answers that fishers from Kenya and elsewhere have given us in the past include 1) reducing effort; 2) reducing destructive gears; 3) protecting special areas, for example nursery habitats; 4) raising awareness and educating the youth; 5) reducing damaging activities such as walking on the reef crest; and 6) reducing the waste that enters the sea. Can you think about these suggestions and for each of these 4 benefits tell me, if the whole community and visiting fishers could agree them, whether you think this action will; 1) make my benefit a lot worse, 2) make my benefit a little worse, 3) not make a difference, 4) improve my benefit a little, 5) improve my benefit a lot.

Much worse	A little worse	No change	A little better	Much better

	ii. Likert effectiveness (1-5)	comments

Action	Fishery	Habitat	Education	Bequest	
1. Reduce destructive gears					
2. Reduce effort					
3. Protect grounds					
4. Raise awareness & educate					
5. Reduce damaging practices					
6. Reduce waste					

4. Contingent valuations with a time payment vehicle

We have been talking about the various aspects of the marine environment that you value. I would like to ask you a little more about this. I would like to think about fishery, habitat, education and future benefits. Have you thought of ways in which the condition of these benefits could be improved?

1. If the community was behind removing destructive gears how much time would you be willing to contribute to ensure people know which gears are destructive?

Half an hour a week one hour two hours etc

b. If you did not have the time would you be willing to contribute some money instead?

50 ksh/ week 100ksh 250ksh 500ksh

2. If the local school was interested in educating the kids and adults about traditional knowledge, fishing practices and ecology of the ocean how much time would you be willing to contribute to either help guiding, teaching or informing people when the clubs would be available.

Half an hour a week one hour two hours etc

b. If you did not have the time would you be willing to contribute some money instead?

50 ksh/ week 100ksh 250ksh 500ksh

3. If you were not to benefit financially in any way from these changes, would you still be willing to contribute the same time?

Continue_____
Increase _____
Reduce _____

1.saa_____ 1.pesa_____ 2.saa_____ 2.pesa_____

5. If I told you those changes would not produce an effect for at least 20 years, would you still be willing to contribute the same time?

   Continue_____
   Increase _____

   Reduce _____

1.time_____ 1. money_____ 2. time _____ 2. money _____

SOCIO-ECONOMIC SURVEY

Family characteristics

1. How many people normally live in your house? _____ and share meals and expenses with?
2. How many people do you provide for?

Adult male	Adult female	Male children	Female children

3. Age of respondent? _____
4. What is the highest level of education you have attained?

Sense of place

5. Where are you originally from?

This community	***this region***	***this country***	other country

6. How long have you lived in XXX?_____
7. Why did you move to XXX? ?_____
8. Was your father or grandfather a fisher

Fishing	***Other work***	***Family & friends***	Health/spiritual
Other			

Sense of place and Ecological knowledge

I am going to make some statements and I would like you to think about them one by one and tell me whether you; 1) strongly agree; 2) agree; 3) neither agree nor disagree; 4) disagree or 5) strongly disagree.

1) I could easily move away from the sea and make my living on land_____.
2) I would be happy to be employed by somebody._____

3) The best thing about being a fisher is the freedom it gives me_____.
4) Fishermen live long and healthy lives_____.
5) I feel very proud to tell people that I am a fisher from xxxx._____
6) I feel very much a part of this community and know that there are people here that I could always turn to when in trouble_____-.
7) So long as the fish we target are there, it does not matter whether the other species of fish are there or not._____
8) I think children should be taught about the sea, the processes and sustainable ways to fish from an early age in school and at home-_____.
9) Can you look at these three pictures of fish and tell me what they are? Can you also tell me for each one what is the smallest size that if you caught it you would know that this fish is now definitely an adult, no longer a child and could have had babies of its own already?
    a. Name:_____ weight_____
    b. Name:_____ weight_____
    c. Name:_____ weight_____

Connection to the reef (for each of the 9 ES or too much?)

9. Do you fish? Does anyone in your household fish?
10. Do you trade fish? Does anyone in your household trade fish?
11. Are you involved in the tourism industry? Is anyone in your household involved in the tourism industry.

Social capital

12. I want to ask you some questions about how much you trust different types of people. In general, how much do you trust:

	Not at all	Distrust more people than trust	About half-half	Trust more people than distrust	Trust all	DK/ NA	Decisions with	Group with
a. family								
b. People you work with								
c. People in your village								
d. Community leaders (e.g. elders)								

e. (religious leaders)								
f. Police/security								
g. Local government officials								
h. NGO staff								
if fisherman								
h. Fisheries/marine park enforcement officers (fisheries, marine park, etc.)								
i. Fishers from other landing sites								
j. People using different gear								

Leadership

1. Do you consider yourself a leader in this community or this landing site?
2. Who do you consider a leader in this community or this landing site?
3. Who do others consider a leader?
4. Who does the Fisheries Department or other authorities consider a leader**?**

Group Membership

1. If there is a decision to be made in your community, are you involved in that decision? (*yes or no)* _____ How? _____

2. Are you involved in decisions about marine resource use (fishing, shell collecting, etc.) or management? (*yes or no)* _____How? (active/passive) _____

3. Do you belong to any community groups or organisations? *Write in the table below* #of groups _____

4. Who from the above table are you involved in decision making with if any?

5. How many group meetings have there been in the last six month? *Write in the table below*

6. How many of these meetings have you attended? *Write in the table below*

7. Have you been involved in any community events outside of your family in the past 12 months (e.g. celebrations, feasts, etc.)? (*yes or no)* _____How many? _____

Name or group	Type	Nb meetings	Attended (none, few, most, all)

Income and employment

1. What jobs do you and other people in your house do that bring in food or money to your house? Which is the most important, which is the top earner and are they permanent or casual jobs?

ACTIVITY	Check if respondent	# of People	Rank importance	Top earner	Perm/ casual	comments
Fishing industry						
Farming industry						
Salaried Employment						
Tourism						
Other						

Total number of occupations_____ Number of different occupations_____

Financial status (and contribution to household expenses)

1. Last fortnightly expenditures

Item	Expense	Comment on frequency
Transport/fuel		
Food		
Clothes		
Health		
Material supplies		

If Fisherman

2. I realize that some days you catch a lot of fish, other days you may not catch many fish. What is your daily catch on a good day? How much is that worth? Same for poor day, average day. Ask whether this catch is for the crew or an individual!!

	Bad day	Average day	Good day	For crew or individual?	Units (kg, **hrs,** # traps)
Catch					
Gear					
Daily effort (hrs, traps etc)					
Value ($)					

3. From you catch, how much fish is consumed and how much is sold? %food_____ %market_____

Material Style of life

Household items & facilities.

Generator	Electricity	Car battery	
TV	VCR/DVD	Satellite dish	Refrigerator
Electric fan	Radio/cassette player	Piped water	Mobile phone

Lighting

Nothing	Kerosene wick	Candle	Hurricane lamp	Light bulb

Transport

Bicycle	Motorcycle	Vehicle	Other

Cooking

Firewood	Charcoal	Kerosene	Gas/electric

Roof material

Thatch	Metal	Tile	Other

Floor material

Dirt/soil	Bamboo/palm	Plank Wood	Cement	Finished (tiles, etc.)

Wall material

Bamboo/ thatch	Wood (plank)	Stone block	metal	Cement	Other

9.4. Validating rating weightings

Rating

Method

We got coral reef scientists to rate the importance of six aspects of their life (if they had extra time how would they distribute their extra time to improve the quality or quantity of that dimension). Respondents were offered three counters at a time, asked to distribute these and asked how satisfied they were with their distribution. If they were not 100% satisfied they were offered 3 more counters and the process repeated until they achieved 100% satisfaction or their satisfaction declined.

Analysis

The satisfaction for each round was calculated and regressed against rounds.

The weighting for each round was calculated based on the relationship, this was compared with the results obtained from the normalised mean of satisfaction scores.

Results

Non linear regression based on single exponential decay

f = a*exp(-b*x)

R = 0.94011180 Rsqr = 0.88381020 Adj Rsqr = 0.87980366

	Coefficient	**Std. Error**	**t**	**P**
a	4.7617	1.3826	3.4440	0.0018
b	1.7847	0.2803	6.3661	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	3.5340	3.5340	220.5916	<0.0001
Residual	29	0.4646	0.0160		
Total	30	3.9986	0.1333		

Durbin-Watson Statistic = 2.7114

Tests for normality and homogeneity of variances

Normality Test: K-S Statistic = 0.1151 Significance Level = 0.7816

Constant Variance Test: Failed (P = <0.0001)

O'Brien passed (P = <0.68)

Brown-Forsyth passed (P = <0.58)

Levene, passed (P = <0.17)

Equation

Rate weighting= $4.8^{-1.8x}$

	1	2	3	4	5	6
equation	0.793	0.131	0.022	0.004	0.001	0.000
Normalised average	0.745	0.117	0.069	0.047	0.023	

Weightings based on the logarithmic relationship and normalized average

We base ratings for each addition of matches on our rating exercise on the log equation established above.

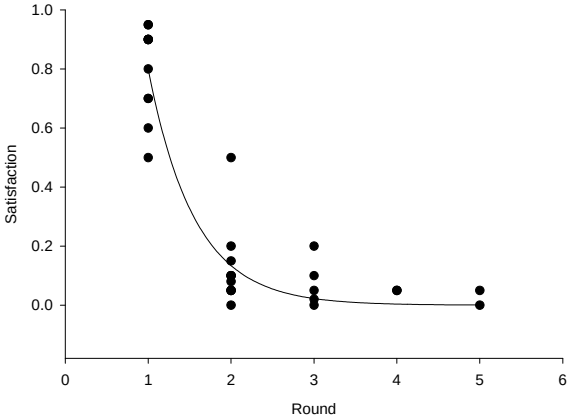

Fig 1b

Actual against predicted

Regressed Equation against normalized average

R2= 0.89, P<0.0001, F= 51.9

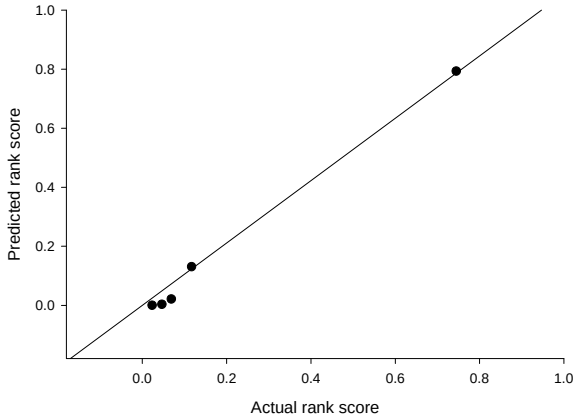

Fig 2b

Actual against predicted

Regressed Equation against normalized average

Rsqr = 0.93520393

Coefficient	**Std. Error**	**t**	**P**	
y0	4.0665	129.7732	0.0313	0.9758
a	0.9390	1.7694	0.5307	0.6100

Analysis of Variance	**DF**	**SS**	**MS**	**F**	**P**
Regression	1	0.2817	0.2817	115.4643	<0.0001
Residual	8	0.0195	0.0024		
Total	9	0.3012	0.0335		

9.5. WIO studies included in review

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9.6. Supporting data for chapters 5 and 6

The ordering of marginal ecosystem value estimates was largely consistent with those oftotal ecosystem services

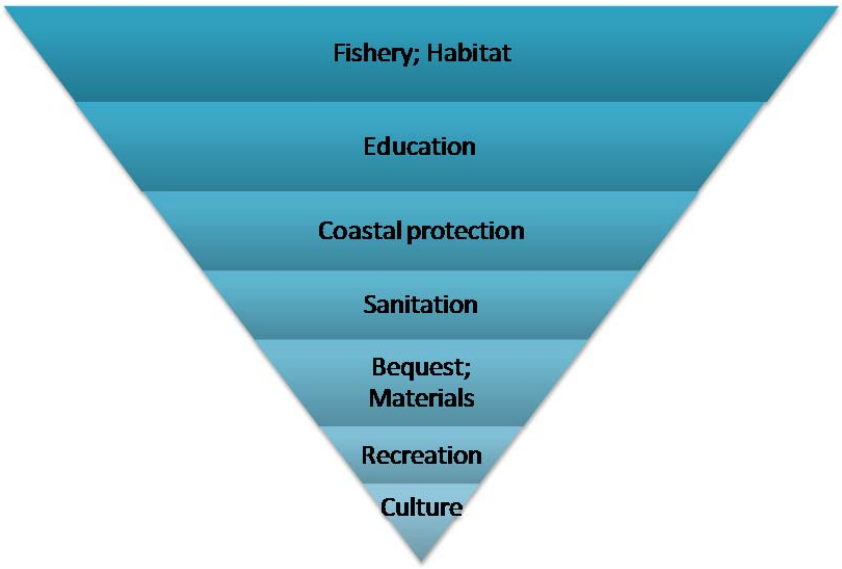

Figure A4.1. Coral reef ecosystem service hierarchy of the western Indian Ocean. Hierarchy of mean total ecosystem service values for the whole western Indian Ocean based on ecosystem service priorities.. Slices indicate levels of the hierarchy, where values are significantly different based on pairwise comparisons and least significant differences $\alpha = 0.05$. No effect of country of community as random effects

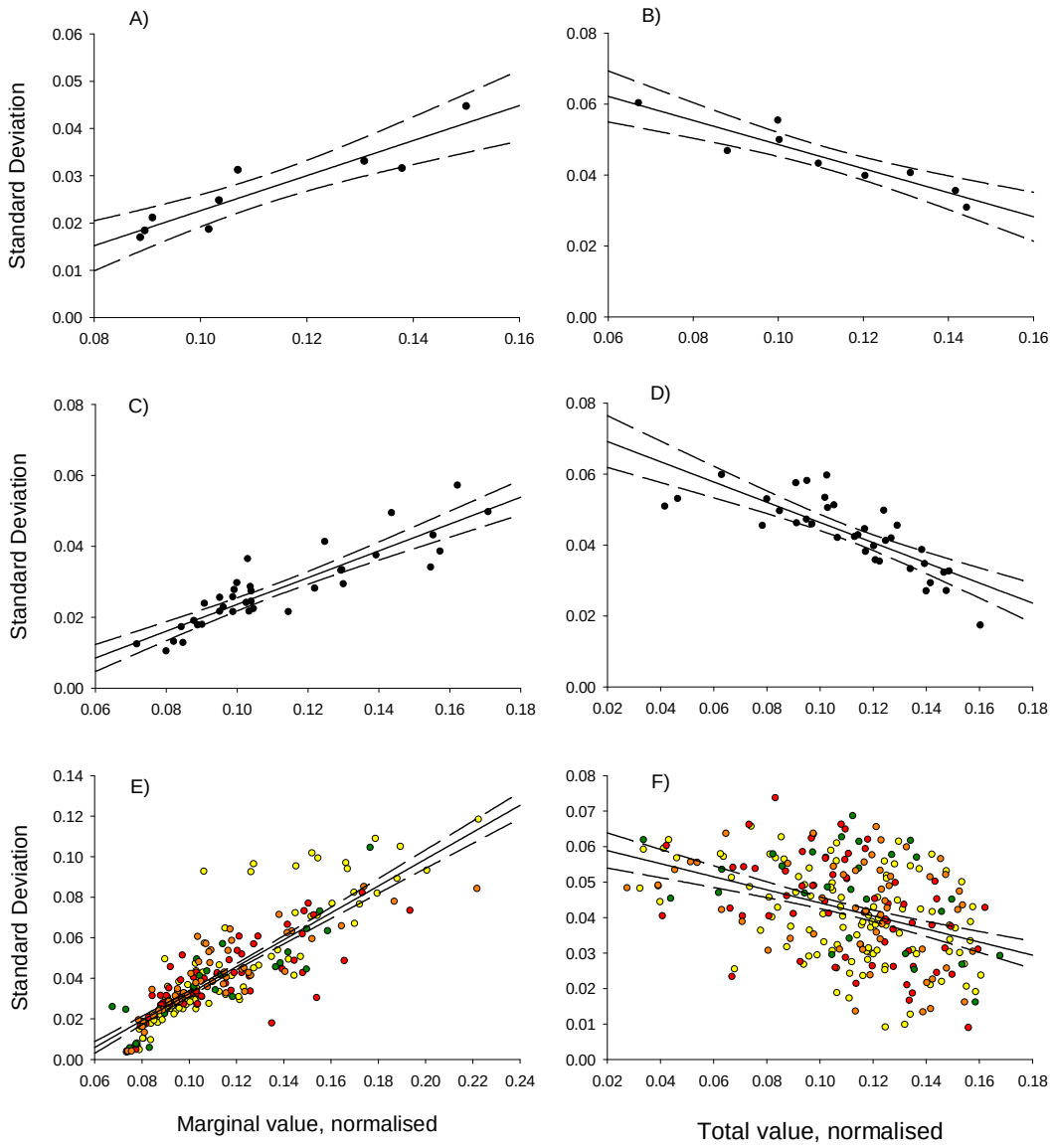

Figure A4.2 Variation in ecosystem service value as a function of value for a) marginal at a WIO scale; b) total at a WIO scale; c) marginal at a country scale and d) total at a country scale estimates; e) marginal at a community scale and b) total at a community scale.

These relationships between value and variability were consistent at the community, country and regional scale

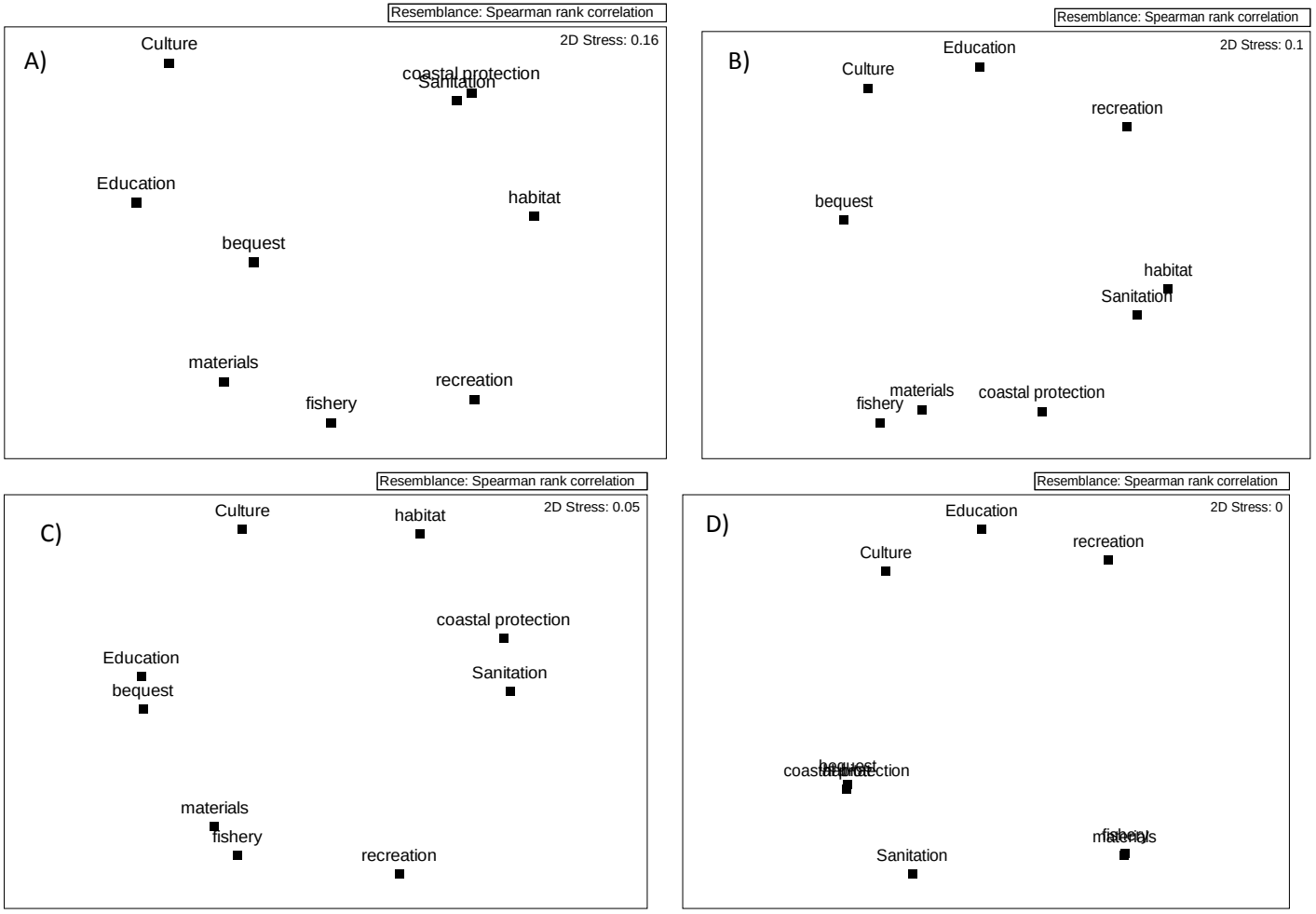

Figure A4.3 Ecosystem service value orientations A) MDS ordinations on quantitative marginal values at a community scale; B) quantitative total values at a community scale; C) quantitative marginal values at a country scale; D) quantitative total values at a country scale,

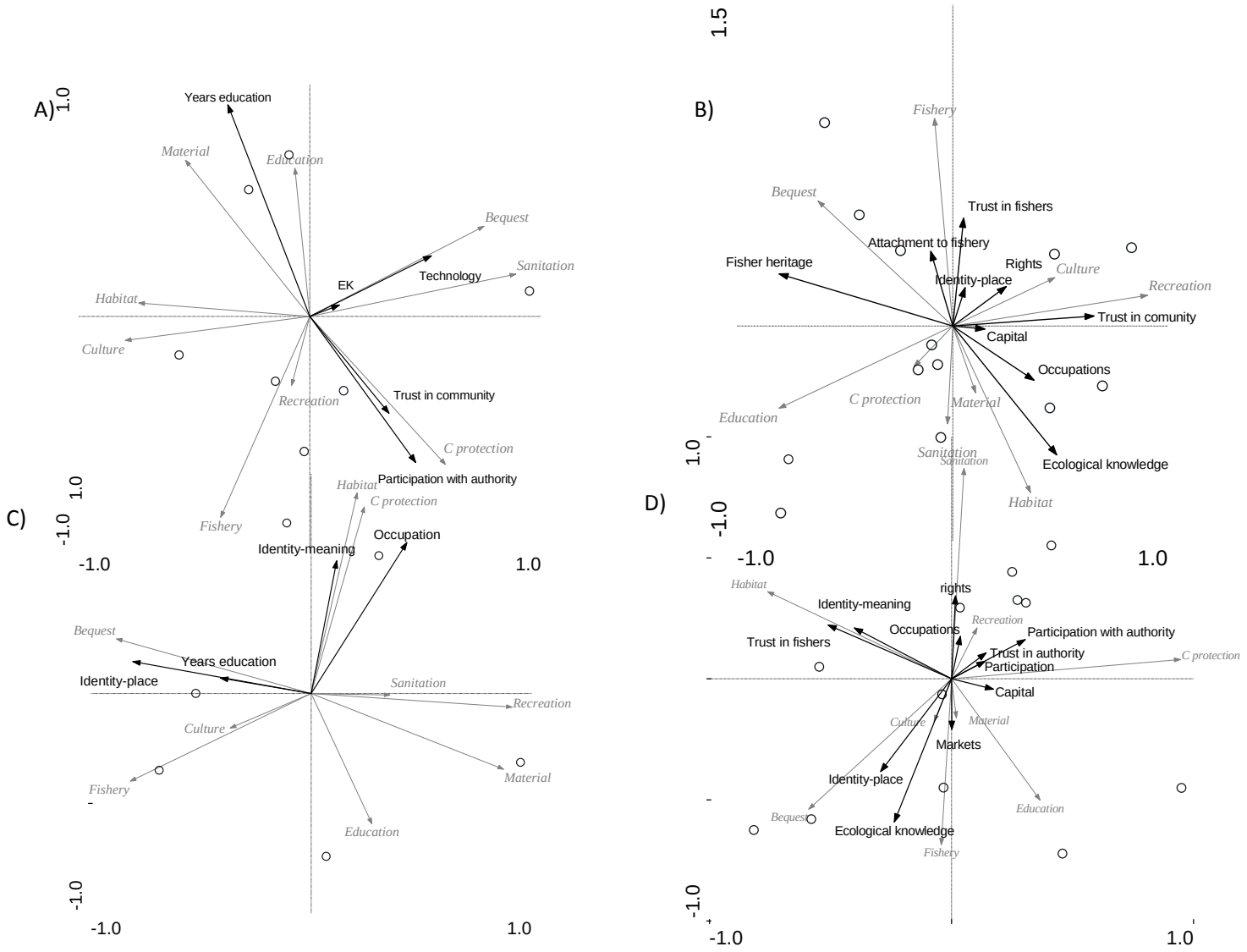

Figure A5.Entitlements redundancy analysis for each country showing variation in community priorities for ecosystem service benefits associated with distinct access mechanisms. A) Madagascar b) Kenya C) Tanzania D) Seychelles