Characteristics of traditional dugong and green turtle fisheries in Torres Strait: opportunities for management

Thesis submitted by
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Abstract

The management of dugongs (*Dugong dugon*) and green turtles (*Chelonia mydas*) is a complex social and ecological problem. Dugongs and green turtles are protected by Australian national and sub-national conservation legislation. Both species are important cultural, spiritual and economic (i.e., subsistence) resources for Indigenous Australians. In Australia, Aboriginal and Torres Strait Islander Traditional Owners may hunt these species to satisfy personal, domestic, or non-commercial communal needs. Torres Strait, not only has the largest population of dugongs in the world and one of the largest breeding populations of green turtles, but also has high rates of Indigenous hunting compared to other parts of Australia. Consequently, management of the traditional Torres Strait dugong and green turtle fisheries needs to include social–ecological considerations and involve Torres Strait Island communities.

The ecological scales at which dugongs and green turtle operate are large. Dugongs undertake large-scale movements and green turtles undertake breeding migrations, which means the populations that are hunted by Torres Strait Islanders are also hunted or impacted by threats in other countries and in waters off mainland Australia. Thus, management of these populations needs to occur at local, state, national and international scales.

To inform the development of management arrangements for the traditional dugong and green turtle fisheries in Torres Strait I aimed to provide an overall context for management at different spatial scales and investigate opportunities and challenges associated with co-management, particularly community-based monitoring.

The development of a participatory research process, particularly the research agreement, cultural reference group and employment of Indigenous research counterparts was integral to the study being resilient to external perceptions of

hunting reported in the media that threatened to cause hunters to withdraw their participation from the project. Without a process to establish trust, hunters were concerned that the information they provided would be used against them to stop them from hunting. Hence, the process I undertook confirms the importance of strong, resilient co-management partnerships.

The risk to dugongs from hunting was evaluated based on spatial data about hunting patterns and dugong distribution and relative abundance. More than 60% (10,690 km^2) of the areas supporting very high and high densities of dugongs are at low risk from hunting because hunting is largely restricted to areas close to inhabited islands (i.e., within 30 km). Nevertheless, the areas accessed by hunters also include a substantial amount (6,007 km^2) of the very high and high dugong density areas, most of which are the 'sea country' of individual communities. A spatial decision framework based on knowledge of jurisdictional arrangements suggested that different types of management will be appropriate in different parts of the Torres Strait region and that the relative importance of different co-management partners changes with spatial scale.

Hunters and elders from Hammond Island were interviewed regarding the need for local management, their perceptions of different management tools and multi-scale co-management from a community perspective. The Hammond Islanders considered some management tools, such as quotas and spatial management, appropriate to incorporate into co-management plans, but that other tools, such as seasonal closures and sex/size-based limits, were inappropriate because of social and cultural factors. Community-based management approaches were considered important especially the application of: (1) cultural norms to the development of tools to achieve compliance and enforcement within the community; and (2) consensus-based decision-making, with regard to the use of more formal rules. The need for cooperation with other communities and stakeholders across spatial scales was also recognised, particularly with regard to enforcement. Overall, the results suggested that co-management is likely to be a more appropriate approach for managing dugongs and green turtles in Torres Strait than either community-based management or government-driven management.

Re-analysis of data from two catch-monitoring projects previously conducted in Torres Strait to collect catch statistics and/or life-history parameters on dugongs: (1) occasional sampling and (2) census by an outsider showed that occasional sampling would not provide robust catch-estimates at the individual community level as required for community-based management. I investigated an alternative strategy that considered hunter as the sampling unit. Hunters in the Kaiwalagal communities of Hammond Island and Thursday Island recorded information on datasheets on the number of animals taken, demographic information about the animals taken and information on hunting patterns. Indigenous research counterparts recruited hunters to participate, distributed and collected datasheets, collected biological samples from harvested animals and helped provide feedback to hunters and their communities about the results and progress of the project. The results suggest that a community-based approach, such as hunter self-monitoring, will be a more reliable and cost-effective approach for determining catch-estimates for dugongs and green turtles to inform co-management at the community level than alternatives such as occasional sampling or census by scientists (e.g., professionally-based monitoring). Hunter self-monitoring has fewer limitations and more benefits than the alternatives with respect to: accuracy and precision of the catch estimates, financial costs, trust by communities and capacity to feedback results to communities in a timely manner.

Determining the sustainability of the catch requires demographic information about the animals taken as well as the number of animals taken. Hunters recorded information that was more straightforward (e.g., sex) more often than information that was more complex (e.g., reproductive status) and specimens were rarely collected. In addition, hunters did not record unsuccessful trips and therefore an understanding of catch-per-unit-effort could not be obtained. The amount and complexity of information to be collected should ideally be increased in stages as hunters become more proficient, with training in the provision of information at each stage.

Collection of information about hunting patterns, including social and cultural considerations, can provide important insight about hunting pressure, which can be useful for guiding decisions regarding the choice and application of management tools. Some of the management options included in the Community Dugong and Turtle Management Plans of other Torres Strait communities, such as stopping spotlighting of green turtles at night, could be effective in reducing catch, but could be difficult to implement. Dugongs and green turtles were caught mostly for general consumption. Therefore, management strategies that limit hunting to ceremonies may be difficult to implement due to the social pressure on hunters, particularly the few prolific hunters who are regularly asked by others to hunt for them. Thus, efforts to change beliefs and behaviours regarding hunting management needs to go beyond hunters to the broader community.

Although community-based catch-monitoring will be more appropriate than occasional sampling by professionals to inform co-management of the Torres Strait dugong and green turtle fisheries, there are significant challenges to its implementation. Obtaining insights into the population status and sustainability of the catch will require monitoring temporal trends in a series of indicators using a framework, such as developed in this thesis, to assist in accessing and coordinating the functions necessary to develop and implement a catch-monitoring project. Such a framework could be used by a coordinating organisation such as the Torres Strait Regional Authority to access the necessary technical skills and plan a monitoring project, including highlighting where capacity-building is needed.

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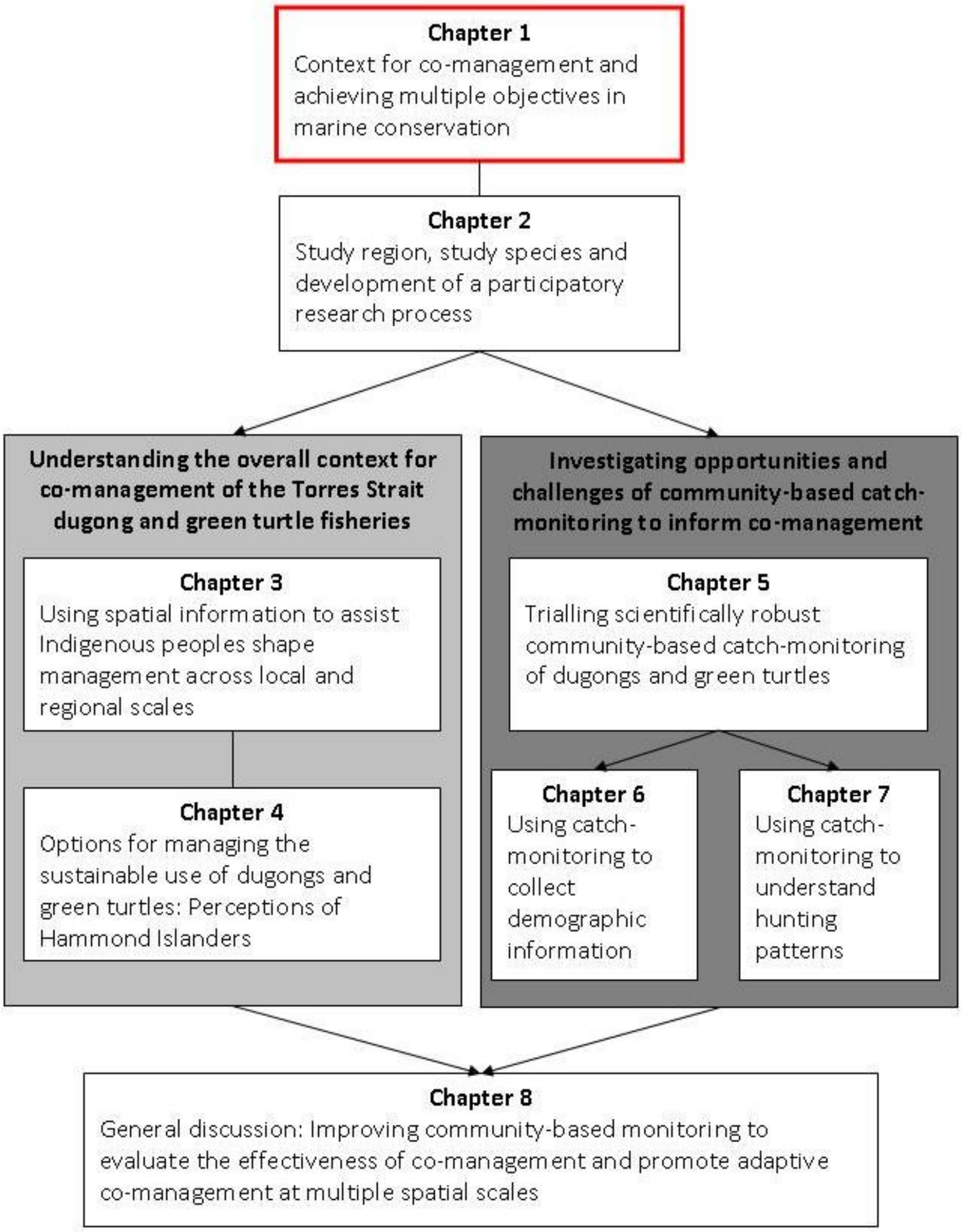
Chapter 1

The challenge of achieving multiple objectives in marine conservation projects: Review of current approaches



The management of species of conservation concern is a complex social–ecological problem. In this chapter, I review the development of co-management as a strategy to deal with this complex issue. I provide a rationale for my research by putting the current management arrangements for the Torres Strait dugong and green turtle fisheries in the context of Indigenous co-management for natural resource management in Australia. I also outline the aims of my thesis and its structure.

Chapter 1: The challenge of achieving multiple objectives in marine conservation projects: Review of current approaches

1. Introduction

The management of species of conservation concern that are hunted by Indigenous and local communities is a complex social and ecological problem. Over recent decades solutions have included a shift in laws and policies to require inclusion of Indigenous and local peoples in management decisions and implementation, and a shift from top-down command-and-control type management to bottom-up community-based management approaches. Nevertheless, the success of community-based projects has been varied (Kellert et al. 2000; Bradshaw 2003; Berkes 2004; Berkes 2005) and is often not measured (Kellert et al. 2000; Horwich and Lyon 2007).

Many species of conservation concern are often treated as common pool resources (Campbell 2007). Various approaches may be used to manage such species. The appropriate approach depends on factors such as the scale of the resource and the types of use, the degree to which stakeholders are willing to share decision-making power, the biology of the animal, and the capacity of various stakeholders to be involved (Berkes 2005; Campbell et al. 2009). Thus, management approaches may include community-based management, government-driven management and co-management.

The management of common pool resources faces problems including excludability (or controlling access) and subtractability (or rivalry) (Feeny et al. 1990; Ostrom et al. 1992; Ostrom 1999). Community-based management can overcome such problems for single resources that occur within a limited area and are used by relatively few groups because communities are able to exclude/manage other resource users and regulate their own use (Berkes 2005). However, as the spatial scale of the resource increases, the resource tends to be used by multiple groups, often in several jurisdictions (inter- and intra-nations). In these more complex situations, management approaches that bring together groups of resource users, stakeholders and governments tend to be needed to achieve effective management (Hilborn 2004; Berkes 2005).

Government-driven management is one option. Government-driven management may incorporate the views of multiple stakeholder groups that use and/or value various habitat and species resources (Karl et al. 2007; Sagarin and Crowder 2008; Miller et al. 2010). Although such an approach may utilise stakeholder participation, the government regulatory agency typically controls the implementation of management plans (Berkes 2005; Evans and Klinger 2008).

Alternatively, a co-management approach may be used. In contrast to top-down command-and-control approaches, co-management tends to focus on developing and maintaining a formal partnership between local resource users and government agencies (Berkes 2005; Pomeroy and Rivera-Guieb 2006; Campbell et al. 2009). The ultimate aim of co-management is the sharing, and eventually the transfer, of authority and responsibility to the community. Nevertheless, the co-management model includes a broad spectrum of arrangements where the decision-making power can vary widely among stakeholders (Berkes et al. 1991; Pomeroy and Rivera-Guieb 2006; Tyler 2006; McConney and Baldeo 2007).

Consequently, although many conservation projects involving communities are referred to as community-based management, many of these projects are probably co-managed because all conservation is guided by government legislation and necessarily involves multiple organisational levels, requiring partnerships and networks (Berkes

2007). Indeed, Berkes (2004) contends that community-based conservation should be rethought as "environmental governance and conservation action that starts from the ground up and deals with cross-scale relations".

Similar to government-driven management, co-management must be informed by reliable information and management planning and ideally requires monitoring in an adaptive management cycle to enable adjustments to management interventions to be made as necessary. In co-management, involvement of local peoples in monitoring is important for management success. This is because local peoples are more likely to believe the results if they are involved in the collection of the information, but also for reasons of logistics and cost (Agrawal 2003; Sheil and Lawrence 2004; Noss et al. 2005; Garcia and Lescuyer 2008; Rist et al. 2010). Nevertheless, similar to professional monitoring, community-based monitoring has many challenges (Sheil and Lawrence 2004; Noss et al. 2005; Garcia and Lescuyer 2008; Rist et al. 2010).

I aimed to develop and trial a community-based catch-monitoring program to inform dugong and green turtle hunting management. Dugongs and green turtles are both species of conservation concern in Australia and may be legally hunted by Aboriginal and Torres Strait Islander Traditional Owners for the purpose of satisfying their personal, domestic or non-commercial communal needs (see Chapter 2). I undertook this study in Torres Strait, Australia, where there are large numbers of dugongs and green turtles (Marsh et al. 2002; Limpus 2008) and high rates of Indigenous hunting. When I started my study in 2004, there was recognition from management agencies, communities and researchers that top-down monitoring would not provide reliable data to inform management of dugong and green turtle hunting because the sampling effort required was large (see Chapter 6; Skewes et al. 2004). In addition, management was moving towards co-management with the development of community-specific management plans (see Section 1.2.3 and Chapter 2). Consequently, it was considered that a community-based monitoring approach might provide reliable information, if the challenges of implementing such monitoring could be overcome (see Chapter 5).

Through the remainder of this introductory chapter, I review the development of co-management of natural resources, which has largely occurred in developing countries, and the need for adaptive co-management for managing complex social–ecological systems. Adaptive co-management combines adaptive management and co-management; it brings together the dynamic learning characteristics of adaptive management, often by combining different types of knowledge, and the linkage (i.e., of institutional arrangements) characteristics of co-management (Olsson et al. 2004; Armitage 2008). I also discuss the role of monitoring in adaptive co-management and discuss the generation, use and integration of different types of knowledge (e.g., Indigenous knowledge and western scientific knowledge) for informing adaptive co-management.

I then examine the Australian case with respect to co-managed conservation, focussing on the particular agreements and policies that enable co-management of dugongs and marine turtles in Australia. I also outline the management planning that has occurred for the Torres Strait dugong and green turtle fisheries and discuss how the community-based catch-monitoring program developed in my study could contribute to this planning. Finally, I present the aims of this research and explain the structure of the thesis.

1.1. The development of co-managed conservation

1.1.1. Biodiversity and bio-cultural diversity

Much of the world's remaining biodiversity occurs in tropical developing countries (Agrawal 1997; Kiss 2004). In particular, South-east Asia is the epicentre of marine biodiversity (Roberts et al. 2002), but coastal ecosystems in that region are becoming increasingly threatened by development-related activities, a situation which is likely to worsen with the expected increase in human populations living along the coast in that region.

Australia has a great responsibility for the conservation of biodiversity. Australia is one of 17 mega-diverse countries of the world and one of only two developed countries in the group (the other is the United States; Roberts et al. 2002). In developing countries the conservation of biodiversity is especially challenging because of competition between conservation and resource use for human survival. Northern Australia and New Guinea represent the largest areas of tropical coastline classed at low risk from coastal development near the global epicentre of marine biodiversity (Halpern et al. 2008). Thus, as other areas in South-east Asia with high biodiversity become increasingly degraded, northern Australia and New Guinea will become increasingly important for the conservation of marine biodiversity.

South-east Asia is also an epicentre of bio-cultural diversity, based on a global index (Loh and Harmon 2005). As the name suggests, bio-cultural diversity describes the interaction between biological diversity and cultural diversity (Maffi 2001). That is, it describes the interaction between humans, other species and the landscapes they inhabit (Loh and Harmon 2005). Thus, in highly bio-culturally diverse areas complex social–ecological systems affect biodiversity conservation.

1.1.2. Complex systems

Conservation of biodiversity involves consideration of natural ecosystems and human needs. Conservation practitioners must deal with ecological and social, factors that vary both spatially and temporally and interact with each other in unpredictable ways (Salafsky and Margoluis 2004). Both the ecological and social systems affecting biodiversity conservation are complex with respect to scale and uncertainty (Holling and Meffe 1996; Hughes et al. 2005; Silver 2008). Ecosystems are hierarchically organised with each subsystem nested in larger subsystems, with the levels linked in complex ways (Berkes 2007). In social systems, governance structures are linked across levels (e.g., local to international) and domains (e.g., resource use to management) and may have overlapping centres of authority (Berkes 2009).

Uncertainties in both natural ecosystems and social institutions present a major challenge for the conservation and sustainable use of natural resources (Milner-Gulland and Mace 1998), particularly in the measurement of management outcomes. For natural ecosystems, this uncertainty includes environmental stochasticity, problems associated with data collection (e.g., sampling error) and/or problems related to predictive science (e.g., climate-related modelling). For social systems, uncertainty may be related to changes in population sizes, migrations, changing livelihood needs, new economic opportunities, and multiple epistemologies and perspectives of different groups involved in resource use and management (Mackinnon 1998; Milner-Gulland and Mace 1998).

1.1.3. Co-managed conservation

As explained in the Introduction above, in recent decades co-managed conservation involving local communities has developed as an alternative to top-down command-and-control approaches to conservation. This change has occurred because of ethical, theoretical and practical considerations (Agrawal 2003; Horwich and Lyon 2007). It was not ethically justifiable to continually remove or restrict local people, who rely on natural resources for their livelihoods and way of life, from areas or use of resources to meet the needs of wildlife conservation (Milner-Gulland and Mace 1998; Wells et al. 2004; Lele et al. 2010). From a practical perspective, centralised forms of control over natural resources had failed to halt resource degradation (Holling and Meffe 1996; Milner-Gulland and Mace 1998; Agrawal 2003; McShane and Newby 2004). It was subsequently considered that local control over natural resources might be more effective than centralised control. That is, it was assumed that local communities would support conservation if they were involved in the management process (Freeman and Kreuter 1994; Agrawal and Gibson 1999; Berkes et al. 2001a; McShane and Newby 2004; Pomeroy and Rivera-Guieb 2006). Consequently, there have been significant international and local developments with regard to the involvement of Indigenous and local peoples in conservation (Milner-Gulland and Mace 1998).

Laws and Policies

International laws and policies have changed to recognize the rights and interests of Indigenous peoples and local communities. The *Convention on Biological Diversity*, signed in 1992, is a legally binding international agreement which, among other things, requires governments to respect the rights of Indigenous peoples to use and manage biological resources on traditional territories, in accordance with traditional cultural practices (e.g., Smyth 1997; Pandey 2003; Danielsen et al. 2005b; Green et al. 2005; Ban et al. 2008).

In addition, several international instruments also encourage governments to recognise the rights and interests of Indigenous peoples. For example, the United Nations Rio Declaration on Environment and Development, made in 1992, describes general principles on the rights of Indigenous peoples and how these rights relate to the environment. This international instrument declares that states should recognise and support the identity, culture and interests of Indigenous peoples and enable their effective participation in the achievement of sustainable development (Smyth 1997). The recent United Nations Declaration on the Rights of Indigenous People, adopted by the General Assembly on 13 September 2007, is a statement of support for the rights of Indigenous people[1]. Among other things, the declaration describes the rights of Indigenous peoples in relation to their traditional lands, territories and resources, as well as their rights to maintain and develop their political, economic and social systems or institutions, to be secure in the enjoyment of their own means of subsistence and development, and to engage freely in all their traditional and other activities.

Co-managed conservation projects

These international agreements and instruments compel or encourage governments to consider the needs of local and Indigenous peoples in conservation and management of natural resources and involve them in conservation projects. Consequently, co-managed conservation projects must deal with complex social–ecological systems and consider multiple objectives—ecological, social, cultural and economic (Kellert et al. 2000; Silver 2008).

Many co-managed conservation projects have tried to achieve biodiversity conservation through promoting socio-economic development (Kellert et al. 2000). These projects recognised that many local people rely on natural resources for their livelihoods and potential losses of income or access to resources could hamper the

[1] Australia was one of four countries to vote against the declaration, but has since supported it (on 3 April 2009).

acceptance and sustainability of conservation interventions (Berkes 2004; McShane and Wells 2004; Gjertsen and Niesten 2010). One example is the large-scale Integrated Conservation and Development Projects for protected areas, which were established extensively in developing countries (McShane and Wells 2004). These projects aimed to increase the benefits from alternative livelihood activities as a way to reduce the threat to biological conservation from local people (Robinson and Redford 2004; Berkes 2007; Horwich and Lyon 2007). However, the success of Integrated Conservation and Development Projects has been questioned because these projects provide little evidence that the benefits of alternative livelihoods alone have provided sufficient incentives for the protection of biodiversity, often because the incentives lack explicit links to conservation outcomes (Wainwright and Wehrmeyer 1998; Kellert et al. 2000; Berkes 2004; Kiss 2004; Wells et al. 2004).

One of the precepts of Integrated Conservation and Development Projects is that local people use natural resources to provide food for their household or to generate income (Wainwright and Wehrmeyer 1998). However, many cultures place great importance on the use of natural resources and not all community members respond to economic incentives (Gibson and Marks 1995). Therefore, failing to recognise the motivations of Indigenous and local people could limit the capacity of a project to reduce the use of natural resources by those people. The reasons that Indigenous and local peoples engage in a project may be varied and may include empowerment, capacity-building, re-enforcement of culture and tradition and protection of their biological resources (Campbell and Vainio-Mattila 2003; Tongson and Dino 2004). Thus, reconciling the multiple and often competing objectives of different partners is challenging for co-management projects like Integrated Conservation and Development Projects (Kellert et al. 2000).

The challenges for conservation projects of operating in complex social–ecological systems and reconciling multiple and often competing objectives have meant that the biodiversity conservation field has lagged behind other fields (e.g., public health) in evaluating management success (Saterson et al. 2004; Ferraro and Pattanayak 2006; Kapos et al. 2008; Margoluis et al. 2009; Pullin and Knight 2009). These challenges include the reluctance of some organisations and managers to redistribute staff and funds from implementation to evaluation activities, a lack of clearly articulated project goals and objectives, and absence of baseline and ongoing monitoring data (Saterson et al. 2004; Brooks et al. 2006).

However, evaluating the success of conservation projects is becoming increasingly important in biodiversity conservation because of the continued loss of biodiversity, limited resources available to achieve conservation outcomes and the associated social, economic, cultural and political trade-offs of conservation actions (Kleiman et al. 2000; Redford and Taber 2000; Salafsky and Margoluis 2004; Saterson et al. 2004; Sutherland et al. 2004; Ferraro and Pattanayak 2006; McBride et al. 2007; Kapos et al. 2008; Pullin and Knight 2009). In addition to evaluating a project for internal and public accountability (i.e., the money and time spent and activities completed), management agencies and donors are beginning to use frameworks such as adaptive management to determine: (1) whether to take conservation action and/or (2) whether particular management interventions are effective. This approach is taken to ensure that valuable resources are not wasted, unsuccessful or inappropriate interventions do not continue to be used and conservation outcomes can be achieved (Salafsky and Margoluis 2004; Saterson et al. 2004; Leslie 2005; Stem et al. 2005; Grantham et al. 2010).

1.1.4. Adaptive management

Adaptive management provides a way of dealing with complex systems and the inherent uncertainty associated with them (Milner-Gulland and Mace 1998; Salafsky and Margoluis 2004). It explicitly uses management and monitoring to gain reliable knowledge about the social–ecological system and reduce uncertainty (Yoccoz et al. 2001). ‘Passive’ adaptive management is more common than ‘active’ adaptive management in biological conservation because the experimental manipulation required by active adaptive management is often difficult to achieve in ecological systems (Holling 1978; Sutherland et al. 2004). Nevertheless, improved management through better-informed decisions can be achieved through reviewing the performance of previous and current actions and altering future actions in response (Holling 1978; Sutherland et al. 2004; Ferraro and Pattanayak 2006; Grantham et al. 2010). Adaptive co-management is simply adaptive management in a co-management framework and, as such, better integrates the needs of resource users than adaptive management and more effectively facilitates learning and adapting than co-management (Olsson et al. 2007; Berkes 2009). Folke et al. (2002) define adaptive co-management as “a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning-by-doing”.

The steps in the adaptive management process developed by Margoluis and Salafsky (1998) include: (1) developing a conceptual model based on local site conditions and the major threats to biodiversity; (2) developing a management plan including goals, objectives and activities; (3) developing a monitoring plan; (4) implementing the management and monitoring plans; (5) analysing the data and communicating the results; and iterating- using the results to adapt and learn (Figure 1.1).

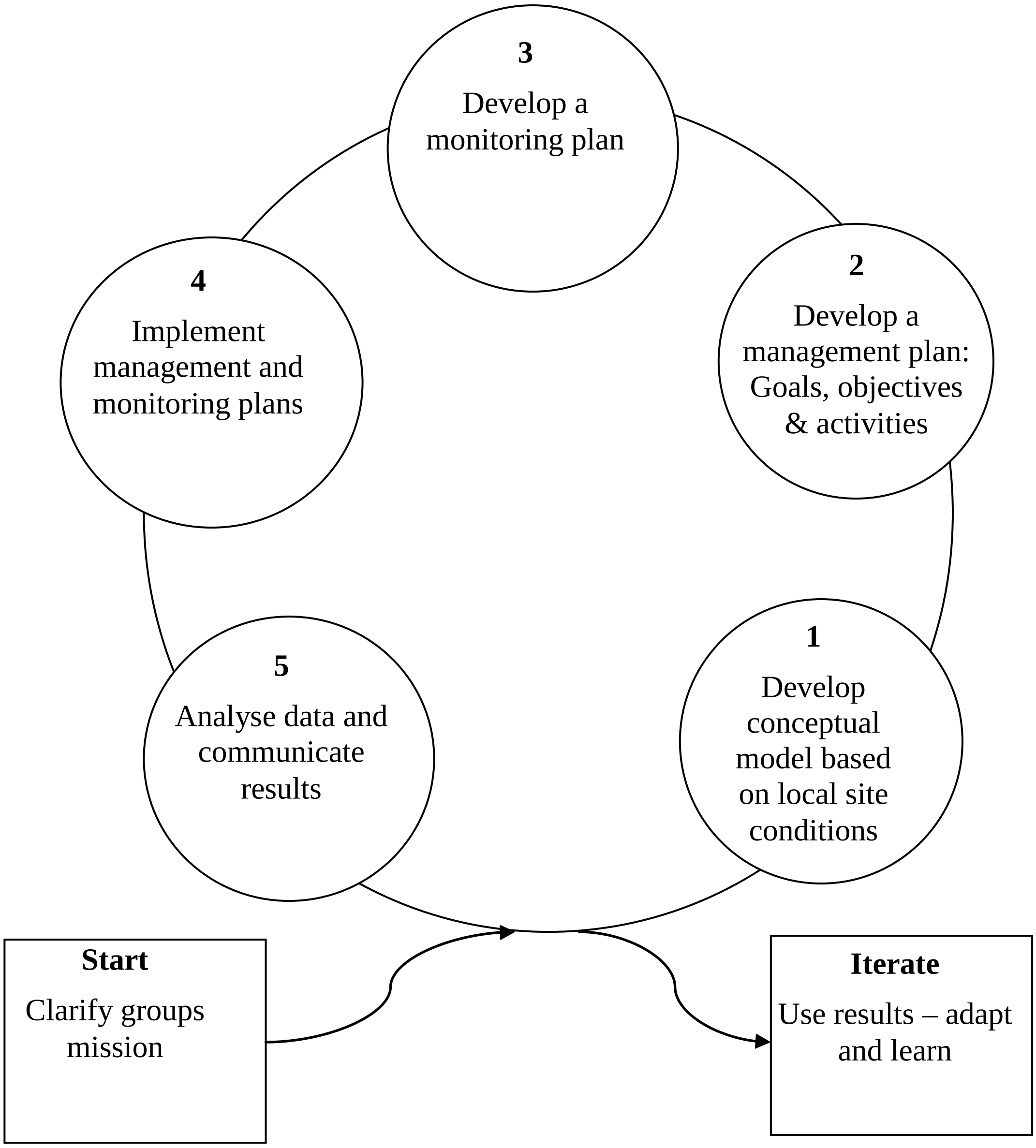


Figure 1.1. The adaptive management project cycle. (Redrawn from Margoluis and Salafsky 1998).

The role of monitoring in adaptive management

In adaptive management, monitoring is integrated into a constantly rotating planning and implementation cycle, rather than being one of the three sequential, linear and separate phases typical of many conservation projects (the other phases are planning and implementing; Wells et al. (2004)). Monitoring is essential for generating sound information on the state of the system on which management decisions are made and providing information on the response of the system to management actions (Yoccoz et al. 2001; Salafsky and Margoluis 2004; Sayer and Wells 2004; Sutherland et al.

2004; Danielsen et al. 2005a; Buckley et al. 2008). Therefore, monitoring is important for assessment and learning.

Assessing projects addressing problems of over-harvesting and misuse of ecological systems is not simple because these problems involve complex social–ecological systems (Ostrom 2007). The potential outcome(s) of such projects interact at multiple scales across multiple domains (i.e., ecological, social, policy/institutional). Thus, clarifying the desired outcome(s) of a project and the question(s) to be answered by monitoring is critical (Ostrom 2007; Armitage et al. 2009). In addition, indicators need to be monitored in each of the domains (i.e., social and ecological) that potentially interact to affect the expected outcome (Ostrom 2007; Armitage et al. 2009).

Project team partnerships

Conservation projects using adaptive management require a project team with a range of skills across the five functional areas of design, management, monitoring, analysis and communication (Salafsky et al. 2002; Table 1.1). For local projects, using adaptive co-management, partnerships are needed between experts in each of these areas and local stakeholders, who are most familiar with local conditions. These partnerships ensure that projects are designed effectively, indicators can be effectively monitored and data analysed appropriately. In adaptive co-management projects, different organisations may be involved in determining the outcomes to encourage, the questions to ask, and the choice of indicators used to assess outcomes (Armitage et al. 2009). In addition, adaptive co-management projects may use a participatory process for indicator development and monitoring (Armitage et al. 2009; Danielsen et al. 2009).

Table 1.1. The functional roles of co-management partners needed in an adaptive co-management project (adapted from Salafsky et al. 2002)**.**

			Functional role		
Skill type	***Design***	***Management***	***Monitoring***	***Analysis***	***Communication***
Knowledge and general aptitudes	*Conceptualisation* Systems thinking Model development Problem setting	*Strategic thinking* Visioning Weighing alternatives	*Assumption testing* Experimental design Cause-and-effect thinking	*Analytical thinking* Statistics Computer skills	*Strategic communications* Strategic thinking Writing and design Conflict resolution
Programming skills	*Situation analysis* Site assessment Capacity assessments	*Strategic planning* Setting targets, goals, objectives, activities	*Develop monitoring plan* Monitoring strategy Indicators and methods	*Information management* Data processing and storage Data cleaning	*Product planning* Audience and media identification Needs assessment
	Project design Planning Scenario evaluation	*Project implementation* Developing work plans Setting budgets	*Assess methods* Effectiveness Cost-effectiveness and practicality	*Data analysis* Qualitative data Quantitative data	*Product development* Pilot testing techniques Production skills
Administrative skills	*Coordination* Facilitation Partnership development Proposal development	*Organisational management* Personnel management Financial management Organisational development	*Evaluation* Performance evaluations Financial evaluations Process tracking	*Information systems* Develop and run systems Database management Cost-benefit analysis	*Routine communications* Internal systems, external reporting, public relations

Adaptive co-management requires monitoring data that are accessible and credible to the resource users (i.e., the local community partners) and are clearly linked to the management objectives jointly formed with their government partners (Andrianandrasana et al. 2005; Danielsen et al. 2005a; Green et al. 2005; Fernandez-Gimenez et al. 2006; Garcia and Lescuyer 2008). Otherwise, community members might not trust management decisions or see the need for investing in monitoring. Locally- based approaches to monitoring have begun to emerge, particularly in developing countries, or remote areas in developed countries. Such approaches have emerged where 'professional' monitoring (i.e., monitoring carried out by trained researchers working primarily for government agencies, universities or non-governmental organisations) has faced challenges of cost, logistical difficulties, insufficient relevance to managers or inadequate attention to the objectives of local stakeholders (Danielsen et al. 2005a; Hockley et al. 2005; Marsh 2006; Danielsen et al. 2009). Hence, locally- based approaches have made otherwise improbable monitoring happen (Danielsen et al. 2005).

Ideally, locally- based monitoring is a 'partnership' between scientists and local communities in which monitoring is carried out at a local scale, with local people (e.g., community members and/or local government staff) directly involved in data collection and (often) analysis (Danielsen et al. 2005a), and scientists involved in the monitoring design so that accurate and precise information is collected. Therefore, locally- based monitoring is a collective term for different types of collaborative monitoring approaches[2], 'community-based monitoring', 'hunter-self monitoring', 'participatory monitoring', or 'ranger-based monitoring', which may refer to the

[2] I draw a distinction between locally- based monitoring and citizen science. I consider that citizen science involves interested amateurs, while locally- based monitoring involves stakeholders and landholders.

specific monitoring objectives and/or the particular local people involved (Danielsen et al. 2005a).

The development of collaborative monitoring programs can increase trust between researchers and local communities and potentially enhance the rights and responsibilities of communities to manage their natural resources (Moller et al. 2004; Danielsen et al. 2005a; Garcia and Cochrane 2005; Marsh 2006). For example, involving local communities in various stages of the monitoring process, from determining the aims of the project, designing a monitoring protocol, collecting and analysing the data and disseminating the research results (refer steps C—E in Figure 1.1), can afford community members the opportunity to establish ownership. Establishing ownership in turn may strengthen the monitoring process by making it more valuable to local communities as a source of credible information (Danielsen et al. 2005a; Noss et al. 2005; Marsh 2006; Burger et al. 2007). This trust in the research outcomes may consequently improve the quality of the information collected.

Involvement in monitoring can also lead to community members gaining a better appreciation of the need to manage wildlife for sustainable use because they may obtain an improved understanding of their impact on the population dynamics of the wildlife they monitor (Noss et al. 2005; Townsend et al. 2005; Marsh 2006; Pomeroy and Rivera-Guieb 2006). In addition, partnerships between researchers and communities can be strengthened if, in addition to the reduced chance of stock collapse, participating in monitoring leads to socio-economic benefits to the community. Such benefits may include employment, education and training opportunities, which may balance the substantial investment by communities in monitoring (Danielsen et al. 2005a; Hockley et al. 2005; Nursey-Bray 2006).

Essentially, collaborative monitoring programs between researchers and local communities can increase the capacity of community members to make informed decisions (Pomeroy and Rivera-Guieb 2006).

Participatory monitoring can also assist in bringing together Indigenous knowledge and scientific knowledge in adaptive co-management because in adaptive co-management multiple sources and types of knowledge are relevant to problem solving (Armitage et al. 2009). However, combining different kinds of knowledge (e.g., scientific and Indigenous knowledge) is a difficult process. For example, many scientists and government managers do not trust tacit, unwritten knowledge, because it is often difficult to articulate, or at least difficult to make comprehensible to government managers and scientists (Reid et al. 2006). Furthermore, Indigenous knowledge may be based on a different worldview and have different starting points, assumptions and rules than western science and, therefore, can be particularly difficult to combine with scientific knowledge in co-management (Moller et al. 2004; Berkes 2009). Thus, using these two types of knowledge requires the development of mutual respect and trust rather than a synthesis of the two types of knowledge (Singleton 1998; Berkes 2009). Nevertheless, Indigenous peoples and researchers can work together in participatory processes to co-produce locally relevant knowledge and develop locally appropriate management strategies (Berkes 2009; Armitage et al. 2011).

Engaging different actors in monitoring, acknowledging and integrating different types of knowledge, and making sense of information to facilitate sharing are important roles that are being played by so called ‘bridging organisations’ (Olsson et al. 2007). These bridging organisations enable networking among institutions across scales (i.e., local communities with other scales of organisation) and, among other things, help to address conflicts, build trust, access needed resources and build a common vision and shared goals (Folke et al. 2005; Olsson et al. 2007; Berkes 2009). These functions, particularly building a common vision and shared goals, are important for implementing management for complex social–ecological systems, because of the tendency of projects operating in these systems to have multiple and often competing objectives from different co-management partners.

1.2. Co-managed Indigenous natural resource management in Australia

In Australia, co-management approaches for natural resource management have also developed as an alternative to top-down command-and-control type approaches, particularly for natural resources used by Indigenous peoples. Indigenous Australians include both Aboriginal and Torres Strait Islander peoples. Most Aboriginal and Torres Strait Islander Australians are disadvantaged compared with other Australians, as exemplified in the many ‘Closing the Gap’ policies of various governments since the 1970s (Altman 2009). Indeed, Indigenous Australians consistently have much higher rates of unemployment and much lower rates of employment participation (i.e., are not looking for work, possibly influenced by social and cultural factors), than other Australians (Jordan and Mavec 2010). Altman (2009) argues that natural resource management by Indigenous Australians on their ancestral lands is a viable option for improving disadvantage and also provides a valuable service to the broader Australian community.

As explained in Section 1.1, northern Australia, along with the island of New Guinea, is an area of high biodiversity and will become increasingly important for the conservation of marine biodiversity as areas in South-east Asian coastal seas become increasingly degraded. Indigenous people constitute the majority of the population in many remote areas across tropical northern Australia (Taylor 2011). For example, in parts of Arnhem Land Indigenous people form 91 per cent of the total population; in Torres Strait about 80 per cent. In addition, the size of the Indigenous population in Australia is rapidly increasing. The projected increase in the Indigenous share of the population between 2006 and 2031 is from 2.45 per cent to 3.5 per cent (Biddle and Taylor 2009; Taylor and Biddle 2010).

Many of the people in remote and rural areas are dependent on their lands and resources for their livelihoods, including the provision of subsistence food, as well as their cultural well-being. Participation in 'caring for country' or contemporary Indigenous natural resource management approaches, provides one of the few opportunities for employment in these areas. In the 1990s, several government inquiries and reviews, including the Royal Commission into Aboriginal Deaths in Custody, found that Indigenous involvement in the management of natural and cultural resources across Australia is an important social justice issue. They found that managing natural and cultural resources can have social, health and economic benefits, in addition to conservation benefits, and that such involvement has been insufficient, but could be improved. Recently, there has been increasing awareness of the social and health costs of limited employment options for Indigenous men (e.g., Nowra 2007). Indigenous people are well placed to manage Australia's biodiversity in tropical northern Australia. In addition, involvement in land management is one avenue for improving employment opportunities and thus improving the economic, social and cultural well-being of these Indigenous communities (Gilligan 2006; Altman 2009).

Indigenous peoples maintain strong cultural and social relationships with their ancestral lands, despite conflicts over ownership, use, and responsibilities for management of these traditional lands and their resources. Aboriginal and Torres Strait Islander peoples have been able to manage (or co-manage) their lands and natural resources based on property rights. A large proportion of the land in tropical Australia is now under some sort of Indigenous tenure (e.g., about 50 per cent of the Northern Territory is owned by Aboriginal people (Altman et al. 2007)). Indigenous Australians have acquired this land through successful land claims (e.g., *Aboriginal Land Rights (Northern Territory) Act 1976 Cth, Aboriginal Land Act 1991 Qld, Torres Strait Islander Land Act 1991 Qld*), recognition of native title (*Native Title Act 1993 Cth*) and purchases by the Indigenous Land Corporation. Nevertheless, other agreements also exist to enable co-management of natural resources by Indigenous Australians.

Partnerships between government agencies and Indigenous organisations have been established, such as: joint management of national parks, regional agreements, Indigenous Land Use Agreements, the development of the Indigenous Protected Area program and training programs that acknowledge and incorporate Indigenous knowledge and practices (May 2010). Some of the more recent arrangements, such as Indigenous Protected Areas, which are voluntarily entered into on Indigenous-owned land, have been negotiated under a more equal partnership approach, than some of the older agreements (i.e., joint management of national parks (e.g., Cobourg marine park, Kakadu national park); Smyth 2001; May 2010).

Aboriginal and Torres Strait Islander peoples have had particular difficulties gaining effective control of their sea country because of complex jurisdictional arrangements and government-led management of the seas as 'commons' (Sharp 1997; Muller 2008). In the Northern Territory almost 85 per cent of the coastline is Aboriginal land under the *Aboriginal Land Rights (Northern Territory) Act 1976 Cth*. However, under existing legislation, land rights do not extend below the low water mark. The *Native Title Act 1993 Cth* provides for native title in the sea.

The first successful sea claim was the Croker Island Sea Claim in the Northern Territory in 1998. The Federal Court found that native title existed over the entire area of sea and seabed (2000 km^2), but that it was not exclusive and therefore these rights must co-exist with the rights of licensed commercial fishers, recreational fishers, the general public, shipping, etc., and must yield to these other rights where there is a conflict.

Similarly, in 2007 the Full Court of the Federal Court found that non-exclusive native title existed over the tidal waters of Blue Mud Bay in Arnhem Land. However, it also found that the grant of freehold title, under the *Aboriginal Land Rights (Northern Territory) Act 1976 Cth*, to the low water mark gave the Aboriginal Land Trust rights to exclude people from waters overlying that land. This decision has broad implications for the commercial and recreational fishing industries in the Northern Territory since, as previously noted, about 85 per cent of the coastline is Aboriginal Land to the low water mark. However, the decision was made under Northern Territory legislation and therefore it does not have a legal basis in other places so cannot be applied outside the Northern Territory.

In August 2010, the Federal Court of Australia found that non-exclusive native title existed over some of the waters of the Torres Strait. The claim over a second claim area is yet to be determined. In particular, the decision included that the right to take resources includes the right to take marine resources for trading or commercial purposes. However, the court also found that native title holders, in enjoying their native title rights, must comply with the existing legislation (e.g., regulating commercial take).

In addition to property rights, conservation legislation and policies requiring or encouraging the involvement of Indigenous Australians in biodiversity conservation also provides a basis for co-management arrangements between Indigenous Australians and governments. Many of these arrangements encourage employment opportunities for Indigenous Australians as part of the co-management agreements. The involvement of Indigenous people in conservation is also being addressed at a national level through the actions of national strategies. For example, one of the objectives of Australia’s Biodiversity Conservation Strategy 2010–2030 is to increase Indigenous engagement. The expected outcomes of this objective are to increase the employment and participation of Indigenous peoples in biodiversity conservation activities, increase the use of Indigenous knowledge in biodiversity conservation decision-making and increase the extent of land managed by Indigenous peoples for biodiversity conservation.

The *Environment Protection and Biodiversity Conservation Act 1999 Cth* legislates a role for Indigenous peoples in the conservation and ecologically sustainable use of Australia’s biodiversity and promotes the use of Indigenous knowledge in cooperation with the owners of this knowledge. In particular, Indigenous Australian’s interests must be addressed when bilateral agreements, management plans, recovery plans, wildlife conservation plans or threat abatements plans are being developed, and when permits are issued to Indigenous Australians permitting them to take listed species.

The Act also provides for the Minister to enter into conservation agreements with Indigenous people or organisations that have ownership or usage rights over the land for the protection and conservation of biodiversity in Australia. The Act requires provisions of the Biodiversity Convention and Australia's National Strategy on the Conservation of Biological Diversity concerned with the rights and interests of Indigenous and local communities to be taken into account.

The Australian government has designed programs, such as Working on Country, to support the development of Indigenous land and sea management across northern Australia, and provide longer-term funding, and wage support to transition people off wages from the Community Development Employment Program (May 2010). Working on Country is an Indigenous-specific natural resource management program, which sits under the broader Caring for Our Country natural resource management initiative, as well as receiving additional funding from other government sources. May (2010) described the aims of the program as being to 'support Indigenous aspirations in caring for country, protect and manage Australia's environmental and heritage values by providing paid employment for Indigenous people to undertake environmental work on country and to provide training and career pathways for Indigenous people in land and sea management supported by local knowledge'. Therefore, the Working on Country program has the potential to support Indigenous land and sea management groups to achieve biodiversity conservation and Indigenous sustainable development. Many of these groups, including Torres Strait communities, are using this support to assist in co-management of dugongs and green turtles.

In the Northern Territory, the Aboriginal Benefits Account (http://www.facs.gov.au/sa/indigenous/progserv/land/Pages/aboriginals_benefit_acco unt.aspx) was established for the purposes of the *Financial Management and Accountabilities Act 1997*. It is administered by the Department of Families, Housing, Community Services and Indigenous Affairs, in accordance with the requirements of of the *Aboriginal Land Rights (Northern Territory) Act 1976.* The Aboriginal Benefits Account was established to receive and distribute royalty equivalent monies generated from mining on Aboriginal land in the Northern Territory. The money is used for the benefit of Aboriginal people living in the Northern Territory. Some communities and organisations have received support to assist them on managing sea country including dugongs and marine turtles.

1.2.1. The co-management of dugongs and green turtles

The sustainable harvest of dugongs and green turtles has been one of the key concerns of Indigenous land and sea managers, scientists and governments across northern Australia for many years. This concern is for the conservation of both biodiversity values and socio-cultural values associated with these species. Dugongs and green turtles are susceptible to over-harvesting because of their life-history strategies and diets (see Chapter 2). Although dugongs and green turtles have protected status under Australian legislation, they can be legally harvested by Aboriginal and Torres Strait Islander Traditional Owners throughout their Australian range (see Chapter 2).

The development of formalised co-management approaches to manage these species began in the 1980s in the Great Barrier Reef World Heritage Area (Marsh 2006) with the Hope Vale community and the Great Barrier Reef Marine Park Authority. The process of producing *A Guugu Yimithirr Bama Wii – Girrbithi and Ngawiya* – the Hope Vale Turtle and Dugong Management Plan, was a significant achievement by Hope Vale community. Hope Vale was the first major dugong and marine turtle hunting community in northern Australia to produce a comprehensive plan for managing marine hunting. Although the Hope Vale Plan has not been successfully implemented, some other remote Indigenous communities are now viewing this plan as a prototype for their own initiatives (Marsh 2006). In the early 1990s, Indigenous rangers from five communities (Injinoo, Hope Vale, Yarrabah, Lockhart River and Palm Island) were involved in a harvest-monitoring program sponsored by the Nature Conservation Agency and the Great Barrier Reef Marine Park Authority (Marsh 1996)[3]. Similarly, limited engagement by Torres Strait Islanders in the management of dugongs and marine turtles was achieved in the 1990s through their advisory role in the Protected Zone Joint Authority and the education and catch-monitoring program run by the Australian Fisheries Management Authority (Skewes et al. 2004).

More recently, the 2003 Great Barrier Reef Marine Park Zoning Plan specifically makes provisions for the development of Traditional Use of Marine Resource Agreements (TUMRAS; Havemann et al. 2005). These agreements are envisaged as the primary mechanism for reconciling traditional use of the marine environment, including hunting, with the conservation of biodiversity by encouraging Indigenous peoples to exercise their stewardship role in conservation in a culturally appropriate and scientifically robust manner (Marsh 2006). To date the Great Barrier Reef Marine Park Authority and Queensland Department of Environment and Resource Management have accredited five TUMRAs.

The first Traditional Use of Marine Resources Agreement to be accredited was the Girringun TUMRA in December 2005. This Traditional Use of Marine Resources Agreement applies to sea country between Rollingstone and Mission Beach. Since then and additional four Traditional Use of Marine Resources Agreements have been accredited with traditional owner groups. The second Dharumbal TUMRA-

[3] This project has lapsed and I can find no further information on it.

Woppaburra Section was accredited in September 2010 and applies to the sea country for the Keppel Islands region. The Mamu region TUMRA was accredited in June 2008 and applies to the Innisfail area in north Queensland. The Wuthathi people are the traditional owners for the Shelburne Bay area of Cape York and their TUMRA, accredited in June 2008, covers their traditional sea country area. The Port Curtis Coral Coast TUMRA was accredited in 2011. The Great Barrier Reef Marine Park Authority is assisting traditional owners implement their agreements. Some Traditional Use of Marine Resources agreements have been accredited several times (e.g., Girringun TUMRA and Dharmbal TUMRA-Woppaburra section), exemplifying the success of the process. Nonetheless, Traditional Use of Marine Resources Agreements have not yet been developed with major dugong and marine turtle hunting communities.

An Indigenous Land Use Agreement (ILUA) has also been signed with the Kuuku Ya'u people of north-eastern Cape York Peninsula, the Queensland Government and the Great Barrier Reef Marine Park Authority. While the legislative mechanism underpinning the document is different, the agreement is essentially similar to a Traditional Use of Marine Resources Agreement in that it provides a framework for engagement and outlines how the Kuuku Ya'u will use and manage resources within their sea country.

Investment in co-management has increased since 2005 under the Australian Governments' National Heritage Trust program, and has continued under the Caring for Our Country program, which incorporates the Indigenous-specific Working on Country program. This investment began with a cross-regional dugong and marine turtle project, which was funded by the Natural Heritage Trust and administered by the North Australian Indigenous Land and Sea Management Alliance (NAILSMA). This project supported the development of community-based dugong and marine turtle management in five regions across northern Australia: the Kimberley, Northern Territory, Gulf of Carpentaria, Torres Strait and Cape York. Other Indigenous land and sea management groups in Western Australia, the Northern Territory and Queensland also include management of dugongs and marine turtles in their sea management activities.

Sustainable Harvest of Marine Turtles and Dugongs in Australia – A National Partnership Approach 2005" (http://www.environment.gov.au/coasts/publications/pubs/turtle-harvest-national-approach.pdf) was developed by the Marine and Coastal Committee Taskforce on Turtle and Dugong Populations as a nationally coordinated response to the issue of sustainable harvest of dugong and turtle. It was endorsed by the Natural Resource Management Ministerial Council (NRMMC) in October 2005. The "National Partnership Approach" described how governments and Indigenous peoples could work together to ensure that harvests of dugongs and marine turtles were sustainable. A partnership group, consisting of Australian and State Government members and Indigenous members was formed to implement the "National Partnership Approach". This approach has been superseded because many of the activities are being addressed under other initiatives (e.g., Working on Country).

1.2.2. Torres Strait

A major effort to develop co-management of dugongs and green turtles is being made in Torres Strait. This focus on the Torres Strait is warranted not only because of the large populations of dugongs and green turtles occurring in the region (Marsh et al. 2002; Limpus 2008), but also the prevalence of Indigenous hunting. Torres Strait is one of the regions in the cross-regional project coordinated by the North Australian Indigenous Land and Sea Management Alliance mentioned above. However, the Torres Strait Regional Authority has since been successful in securing additional funding through the National Heritage Trust, Caring for Our Country and Working on Country programs to continue the development of co-management of land and sea country, including dugongs and green turtles, independently from the other regions.

The jurisdictional arrangements for dugongs and green turtles in Torres Strait are different from other parts of Australia because of the *Torres Strait Treaty 1985* between Australia and Papua New Guinea. A description of the governance arrangements for the management of dugongs and green turtles in Torres Strait is provided in Chapter 2. In summary, the management has previously been a top-down command-and-control approach, with dugongs and green turtles managed as fisheries under the *Torres Strait Fisheries Act 1984 Cth,* which currently includes input controls and a spatial closure (for dugongs; see Chapter 2). More recently, as described in the next section, community-specific co-management plans are also being developed and implemented throughout the region. However, the spatial scales at which the top-down and community-based management initiatives should operate and how they should interact has not yet been articulated. My thesis aimed to provide information to inform decision-making in this area in a co-management framework.

1.2.3. Community-specific co-management plans for dugongs and marine turtles

The Torres Strait Regional Authority has assisted Torres Strait communities in the development of 15 Community Dugong and Turtle Management Plans. These plans were developed in two stages, with eight plans being developed in the first round and seven plans in the second round. A ranger program facilitates the implementation of the first eight plans, which began in 2008. Implementation of the second round of seven plans commenced in 2011.

The Torres Strait Dugong and Turtle Project faces challenges similar to Integrated Conservation and Development Projects. It appears to have multiple objectives, including, sustainable use of dugongs and marine turtles, reinforcing cultural practices and protocols through the development and implementation of the Community Dugong and Turtle Management Plans, and capacity-building and employment through the implementation of a Ranger program. The Community Dugong and Turtle Management Plans include a range of overlapping tools: cultural practices and protocols, fisheries management tools, and spatial and temporal closures (Figure 1.2). These tools are supported by education and awareness-raising tools and feedback, which are designed to transfer knowledge of culture and conservation to younger generations and create a wider understanding and acceptance of the plans in the communities.

The Torres Strait Dugong and Turtle Project operates in a complex social–ecological system. Although the knowledge to implement management for this complex system is dispersed among local, regional, and national agencies and groups, this knowledge could be combined in a co-management framework. Nevertheless, because of their different epistemologies and perspectives, the co-management partners, which include Torres Strait communities, government agencies (e.g., Torres Strait Regional Authority, and Australian Fisheries Management Authority) and universities (e.g., James Cook University), may weight the objectives of a resource management project differently, although such differences are not yet explicit. For example, some partners may favour ecological outcomes and others may favour economic or social development outcomes (Wells et al. 2004; Berkes 2007; Olsson et al. 2007; Berkes 2009; Figure 1.3). Thus, it is important to set clear objectives as well as performance indicators to monitor management success in meeting the specific objectives of the different co-management partners (Saterson et al. 2004; Brooks et al. 2006; Helson et al. 2010; Lele et al. 2010). My thesis focuses particularly on community-based monitoring of indicators (i.e., parameters that provide information on the state of the environment; OECD 1997) to inform ecological objectives. As described below, my thesis focuses on monitoring indicators that may provide insights into the sustainability of the Torres Strait dugong and green turtle harvests or the population status of these species in Torres Strait.

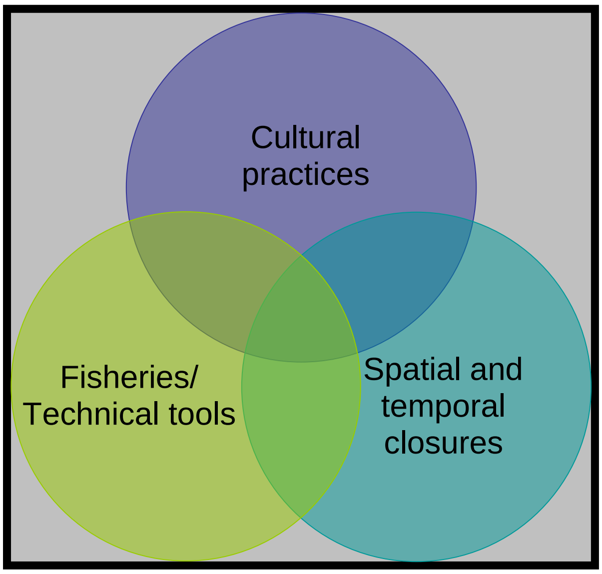


Figure 1.2. Conceptual diagram depicting how the Torres Strait Dugong and Marine Turtle Management Plans include overlapping categories of tools to manage the dugong and marine turtle fisheries in Torres Strait[4].

[4] Developed by Torres Strait Regional Authority officer and Traditional Owner, Frank Loban.

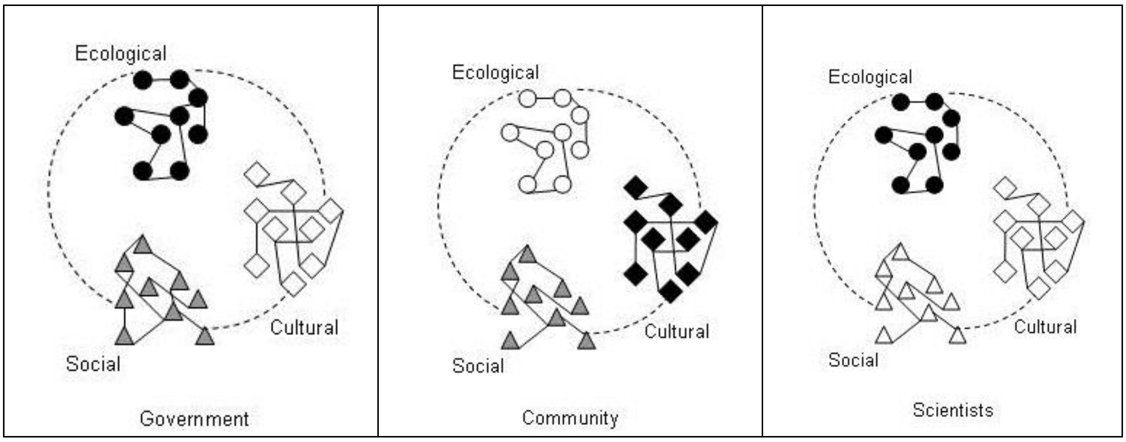


Figure 1.3. Complex social–cultural–ecological systems and some possible different weightings (Black = high; Grey = medium; White = Low) which could be given by different co-management partners to different management objectives.

It also appears that evaluation of the effectiveness of management through adaptive management is intended because the plans include catch-monitoring and monitoring of the status of habitat (e.g., sea grass) and dugong and green turtle populations, enabling communities to adjust their assumptions and interventions as necessary (Milne and Niesten 2009). Nonetheless, there has been no formal evaluation of the challenges of community-based monitoring in Torres Strait. These challenges are expected to include: 1) obtaining quantitative data on the level of take (at the individual community level) and the demography of animals taken to provide insights into the sustainability of the harvest and the population status of the species in Torres Strait; 2) estimating the bias and precision of the catch-estimates; and 3) understanding the patterns of hunting to provide insights about hunting pressure and contribute to informing management options. My research aimed to fill this gap.

The plans also include compliance monitoring, which is important to ensure the management strategies stated in the plans are adhered to by community members (Milne and Niesten 2009), but could be complicated by differences in rules among plans. At this stage, the plans do not explicitly include monitoring to assess the success of the socio-economic or cultural objectives. Nevertheless, social, cultural and economic factors are often linked to other management objectives and should also be monitored to evaluate management success (Helson et al. 2010; Lele et al. 2010). These aspects were beyond the scope of my thesis.

I conducted the research for my thesis prior to and during the development and implementation of the Torres Strait Community Dugong and Turtle Plans; however, the two communities that I worked with were not involved in the Torres Strait Dugong and Turtle Project under which the plans were developed. The Kaurareg are the Traditional Owners of the Kaiwalagal nation and they developed a plan in consultation with communities in the Kaiwalagal nation. However, this plan is yet to be finalised. I provide this overview of the features of the Torres Strait Community Dugong and Turtle Management plans and the co-management framework in which they operate because the findings of my thesis are relevant to the challenges and opportunities of implementing these plans. However, the findings of my thesis also provide broader insights not only into co-management of the Torres Strait dugong and green turtle fisheries, but also the management of species of conservation concern that are used by local or Indigenous peoples more generically.

1.3. Research aims and thesis structure

The overarching aim of my thesis is to inform the development of management arrangements for the Indigenous dugong and green turtle fisheries in Torres Strait. I aim to provide an overall context for management at different spatial scales, and investigate the opportunities and challenges associated with co-management, with particular emphasis on monitoring. My hypothesis is that different forms of management will be required at different spatial scales.

The thesis is divided into 8 chapters (Figure 1.4). A brief description of each chapter is provided below. In general, chapters 3 and 4 provide an understanding of the overall context for co-management of the Torres Strait dugong and green turtle fisheries. Chapters 5 through 7 investigate opportunities and challenges of community-based catch-monitoring to inform co-management. Chapters 3 and 4 have been written for publication in peer-reviewed journals. Chapter 3 will be submitted to *Conservation Biology*. A modified version of Chapter 4 was published in *Conservation and Society.* The version published in *Conservation and Society* is licensed under a Creative Commons Attribution 3 license. Chapters 6 and 7 include information (i.e., the total numbers of dugongs and green turtles caught) that is confidential under the terms of the Research Agreement (see Appendix A). This confidential information will be removed from versions of the thesis that will be made public. Figure 1.4 illustrates the overall structure of the thesis.

Chapter 1 provides an introduction to co-management and the challenge of achieving multiple objectives in marine conservation projects.

Chapter 2 describes the study region, study sites and study species. It also describes the process of developing a community-based catch-monitoring project and the effects of external perceptions on community-based monitoring and management.

Chapter 3 uses spatial information to assist Torres Strait communities shape Indigenous hunting co-management of dugongs across local and regional scales. Note: Only dugongs were considered in this chapter because the necessary spatial information for green turtles was not available. Models of distribution and relative density of green turtles, based on aerial survey data, have not yet been developed for Torres Strait.

Chapter 4 examines the perceptions of Hammond Islanders with respect to options for managing the sustainable use of dugongs and green turtles.

Chapter 5 presents a trial of community-based catch-monitoring of dugongs and green turtles to determine whether it can provide scientifically robust information and is practical to implement.

Chapter 6 evaluates an attempt to use community-based catch-monitoring to collect demographic information to determine what information can be reliably collected and what it reveals about the ecological and cultural sustainability of the catch.

Chapter 7 evaluates an attempt to use community-based catch-monitoring to collect information on hunting patterns to determine what information can be reliably collected and what it reveals about the drivers of hunting and possible options for management actions.

Chapter 8 discusses how community-based catch-monitoring of the Torres Strait dugong and green turtle fisheries could be improved to evaluate the effectiveness of co-management and inform adaptive co-management at multiple scales.

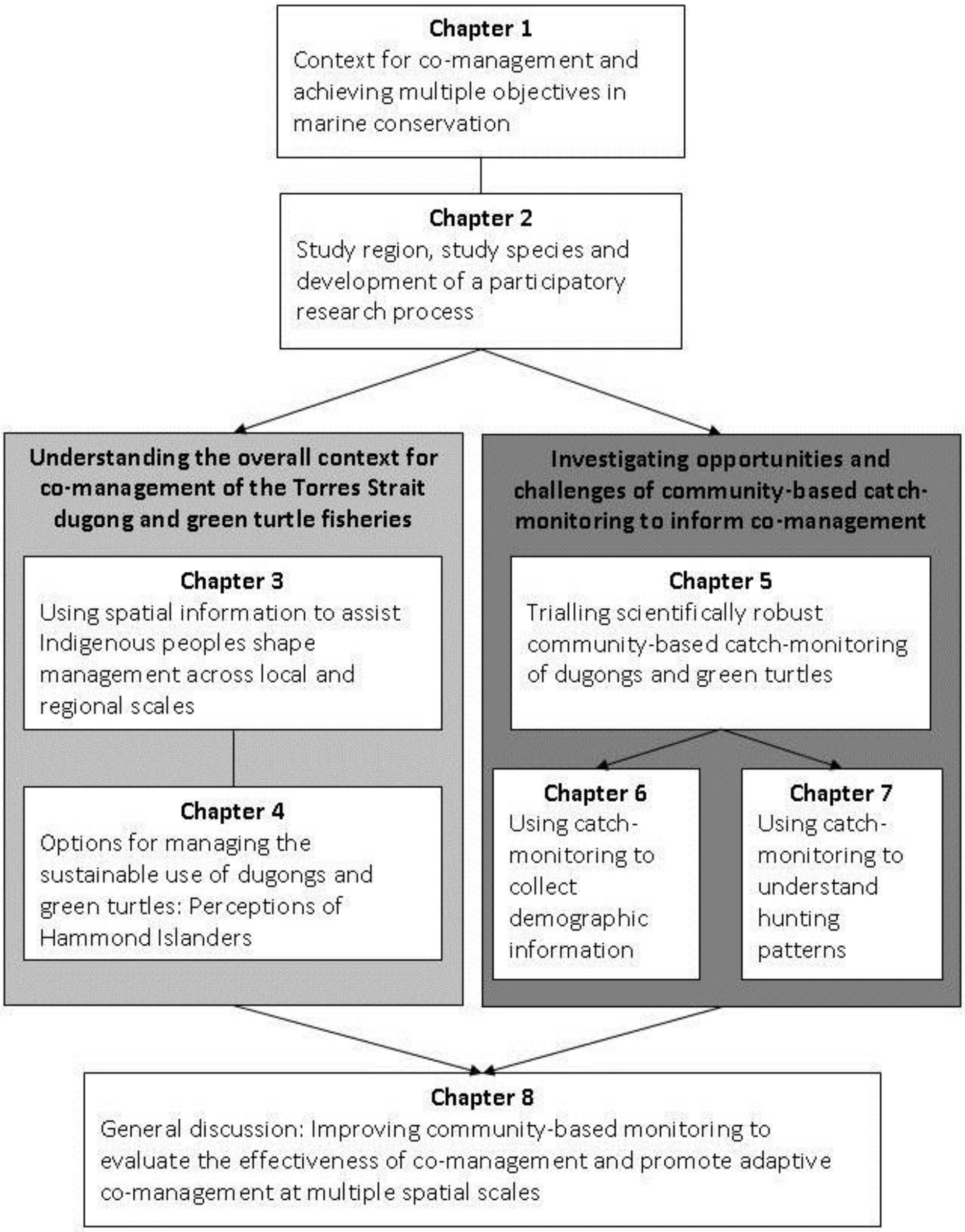
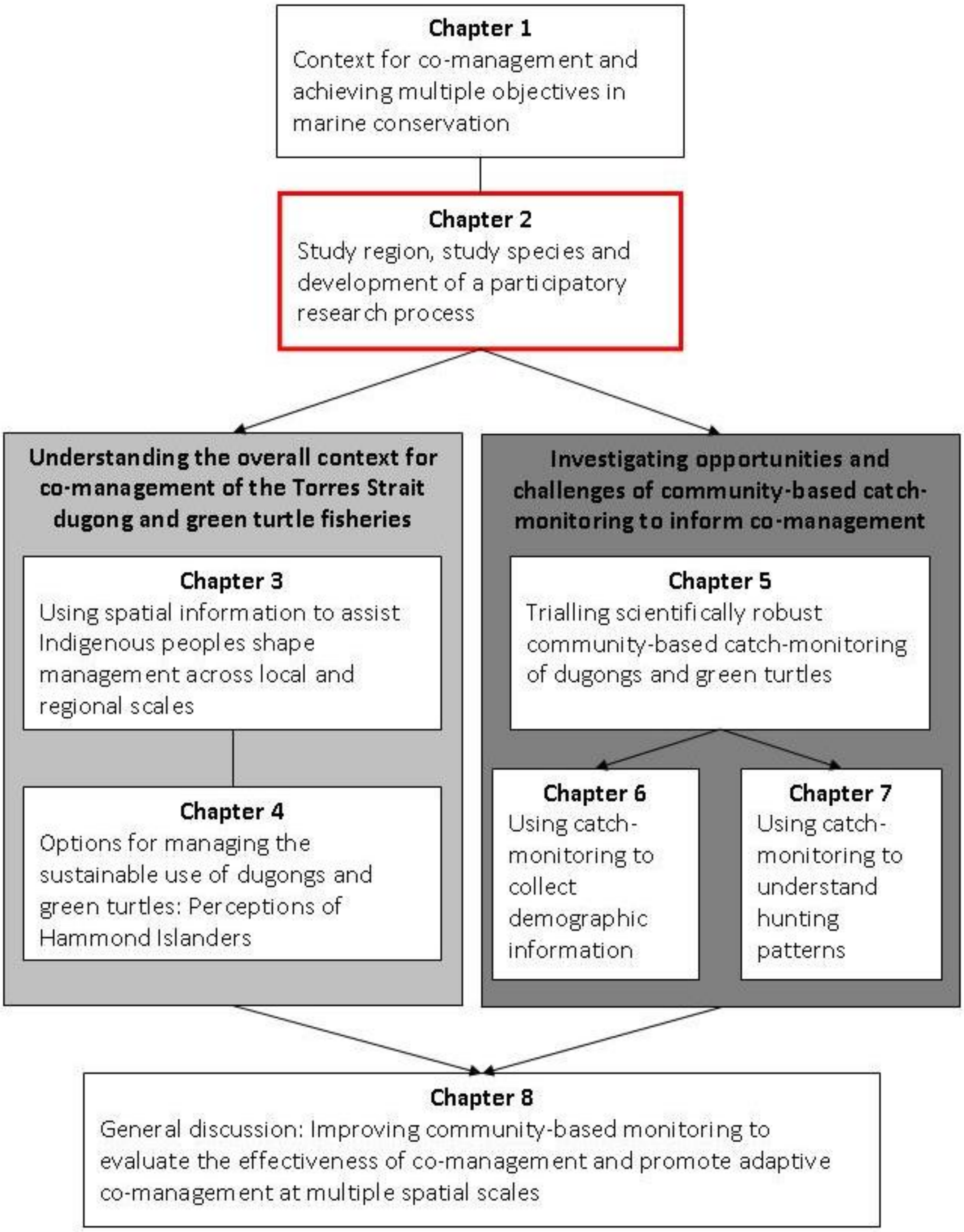


Figure 1.4. Illustrates the chapter structure of my thesis and it will be repeated on the front page of each chapter so that the reader can locate the relevant chapter (outlined in red) in the overall structure of the thesis.

Chapter 2

Study region, study species and development of a participatory research process



In this chapter, I describe the Torres Strait region, including my study communities Hammond Island and Thursday Island. I also describe the regional environmental management relevant to the Torres Strait dugong and green turtle fisheries and the biology, ecology and conservation status of dugongs and green turtles as background for this thesis. In addition, I describe the participatory research process that I undertook to develop trust between researchers and community members in developing a community-based ecological monitoring program for dugong and green turtle hunting.

Chapter 2: Study region, study species and development of a participatory research process

2.1. The Torres Strait Region

Zenadth Kes (Torres Strait) is the shallow body of water separating the Australian mainland and Papua New Guinea (150 km north-south; 250 km east-west; Figure 2.1). It formed some 8000 years ago when the land bridge between the Australian mainland and Papua New Guinea was inundated to create an island archipelago (Johannes and MacFarlane 1991; McNiven and Hitchcock 2004). The area of approximately 48,000 km^2 is mostly relatively shallow (< 20 m) open seas with more than 200 islands and a multitude of cays, sand banks and coral reefs scattered throughout (Harris et al. 2008) as well as some of the most extensive sea grass beds in the world (Coles et al. 2003). The earliest evidence of intensive human occupation and use of the Torres Strait is 2500 years ago (Barham et al. 2004) and Torres Strait communities have used marine resources for subsistence since that time (McNiven and Hitchcock 2004).

In the Australian jurisdiction, people from 18 island and two mainland communities inhabit this remote strait. There are five traditional island Nations[5] (i.e., clusters of Islands) in the Torres Strait, Guda Maluiligal (Top Western Islands), Maluiligal (Western Islands), Kemerkemer Meriam (Eastern Islands), Kulkalgal (Central Islands) and the Kaurareg Nation of Kaiwalagal (Inner Islands and the Northern Peninsula Area of the mainland). The regional population of Torres Strait is estimated at 8573 people (2006 Census of Population and Housing), of which approximately 80% are Indigenous. The main administrative centre of the Torres Strait region is Thursday Island, which is one of the inner islands. The inner islands have approximately 40% of the regional population. There are approximately 40,000 Torres Strait Islanders living on the mainland of Australia, in cities such as Townsville, Cairns and Brisbane (2006 Census of Population and Housing).

[5] Nation refers to a cluster or group of islands with similar cultural protocols or language.

2.2. Study sites

Hammond (Keriri) and Thursday (Waibene) Islands, which are the focus of this study are part of the Kaurareg Nation of Kaiwalagal (Figure 2.1). Traditional people of Aboriginal or Torres Strait Islander (Melenesian) descent live in Kaiwalagal. I conducted the present study in collaboration with the Hammond and Thursday Island communities. I obtained permission from the Kaurareg traditional owners to conduct my study on their traditional lands. On Hammond Island, I worked predominantly through the Hammond Island Council, which facilitated support from hunters and community members, including facilitating meetings with these groups for me to encourage participation by hunters or provide feedback about the project. On Thursday Island, I worked with the TRAWQ Community Council and the Waibene, Ngurapai, Muralug (WNM) and Prince of Wales (POW) Community Fisher Groups. The Community Fisher Groups were part of the Protected Zone Joint Authority consultative structure at the time of my study, but they are no longer included in this structure. They represented local dugong and turtle hunters through the Protected Zone Joint Authority process. A representative from each of the Kaurareg traditional owners, Hammond Island Council, TRAWQ Community Council, WNM Community Fisher Group and POW Community Fisher Group formed my cultural reference group.

Thursday Island is a large, diverse community of approximately 2550 people living in two main communities. Most of the hunters from the Community Fisher Groups live in the suburb of Port Kennedy and some live on nearby Horn Island or Prince of Wales Island. The Community Fisher Group representatives encouraged these hunters to participate in the project. Most of the other hunters live in the suburbs of Tamwoy, Rose Hill, Aplin, Waiben and Quarantine and many of them worked for the local community council. The TRAWQ Community Council encouraged these hunters to participate in the project. Thursday Island has many dispersed landing and butchering sites for hunted dugongs and green turtles, including peoples' back yards. In contrast, Hammond Island is a small close-knit community of about 230 people. It has one main landing and butchering site, which is on the main beach and in full view of most of the community. A Kaurareg Community Dugong and Turtle Management Plan (see section 2.3) is being developed for the Kaiwalagal region, which will include hunters from the Hammond and Thursday Island communities. However, this plan has not yet been finalised.

Comparisons with data on dugongs collected from Mabuaig Island in 1998 and 1999 by Kwan (2002) are made in several chapters (i.e., Chapters 3, 5 and 6). Mabuaig Island is in western Torres Strait and is one of the regions major dugong hunting communities (Haddon 1890; Nietschmann 1984; Nietschmann 1989; Johannes and MacFarlane 1991; Kwan 2002). It is a high continental island encircled by fringing reefs. The extensive Orman Reef complex extends to the north-east of the Island (Kwan 2002). The human population of Mabuaig Island was 209 people at the time of Kwan's study according to the 2001 census.

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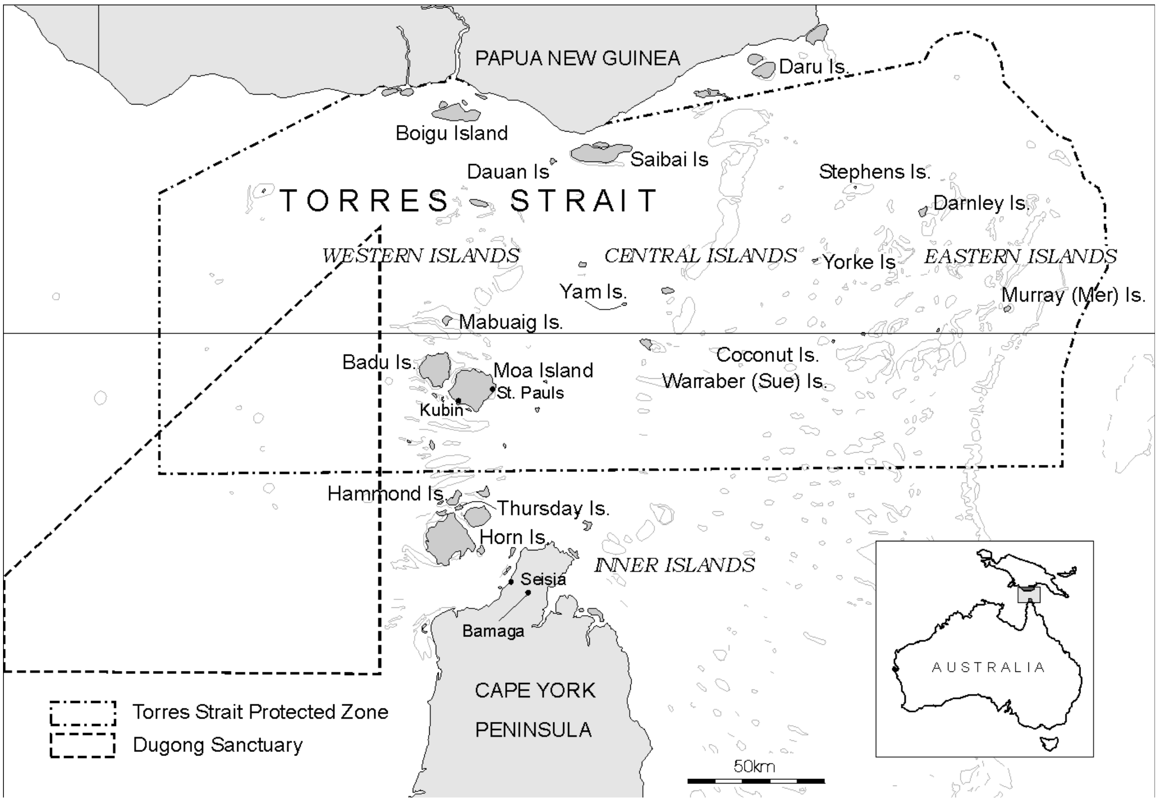

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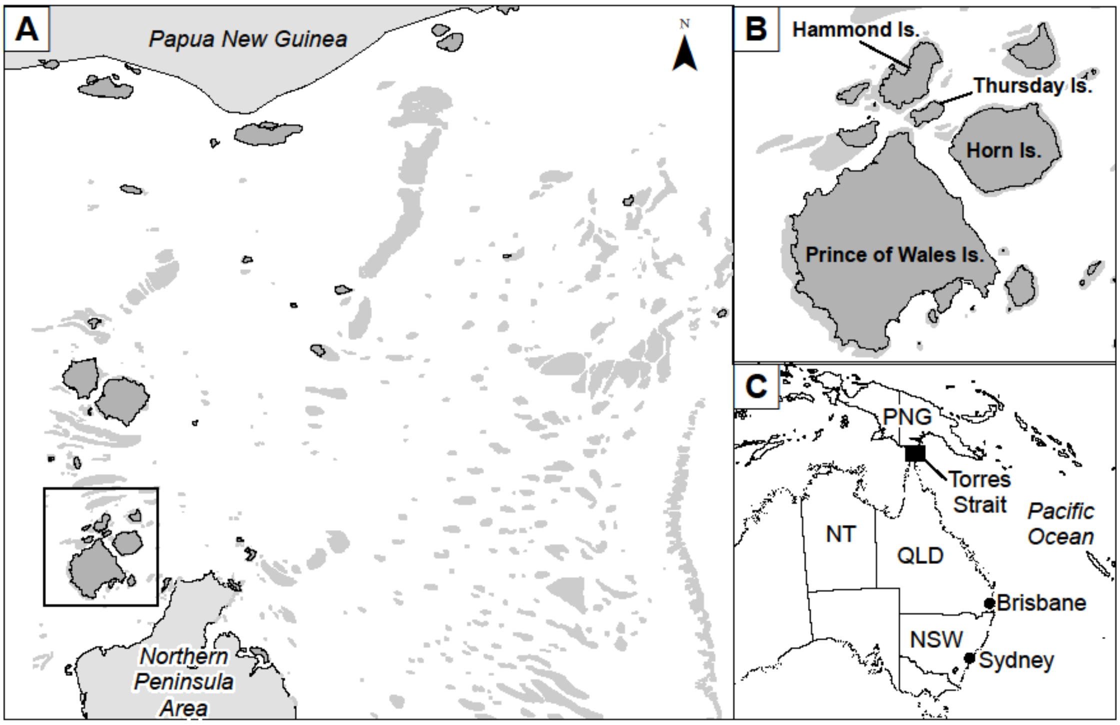

Figure 2.1. a) Torres Strait and b) Study site: A) Torres Strait, B) inner islands including the study communities Hammond Island (Keriri) and Thursday Island (Waibene) and neighbouring communities of Horn Island (Ngurapai) and Prince of Wales Island (Muralug), and C) Torres Strait relative to mainland Australia and Papua New Guinea (PNG).

2.3. Regional environmental management for dugongs and marine turtles

As noted in Chapter 1, the management arrangements for dugongs and marine turtles in Torres Strait are different from those in other parts of Australia. Australia and Papua New Guinea share many of the natural resources of the Torres Strait, including dugongs and green turtles, under the *Torres Strait Treaty 1985*. The Treaty concerns the sovereignty and maritime boundaries between the two countries, arrangements about which were necessary after Papua New Guinea became independent of Australia in 1973. This Treaty also protects the traditional way of life and livelihood of Traditional Inhabitants of the region. The governments of both countries set up a Protected Zone within which Traditional Inhabitants could move freely.

The Australian Government established the Torres Strait Protected Zone Joint Authority (PZJA) to manage the Protected Zone (Figure 2.2). Traditional fishing under the Treaty specifically includes dugongs and marine turtles. The *Torres Strait Fisheries Act 1984 Cth* implements the Australian Governments' obligations under the Treaty and therefore considers dugongs and marine turtles traditional fisheries in Torres Strait. As such, the Protected Zone Joint Authority manages these fisheries along with all other Commonwealth-managed fisheries (see Figure 2.2 for the areas of the Torres Strait dugong and marine turtle fisheries). Thus, the governance arrangements for formal dugong and marine turtle management in Torres Strait have traditionally been the top-down command-and-control type approach of the Protected Zone Joint Authority governance structure, despite some Indigenous involvement in the Protected Zone Joint Authority, as described below.

The Protected Zone Joint Authority has consisted of the Australian and Queensland Government ministers responsible for fisheries (Commonwealth Minister for Agriculture, Fisheries and Forestry (Chair), the Queensland Minister for Primary Industries, Fisheries and Rural and Regional Queensland) and the Chair of the Torres Strait Regional Authority since

2002. This Authority is responsible for the management of commercial and traditional fisheries within the Australian area of the Torres Strait Protected Zone and designated adjacent Torres Strait waters and for the formulation of policies and plans for their management (Cain 2004). Although the Protected Zone Joint Authority has established a consultative structure to assist with the management of the Torres Strait fisheries (Figure 2.3), it provides Islanders with an advisory role rather than a decision-making role, which Islanders find unsatisfactory (Loban 2007). In addition, there is currently no working group for dugong and marine turtle fisheries and no marine turtle or dugong researchers on the research advisory group.

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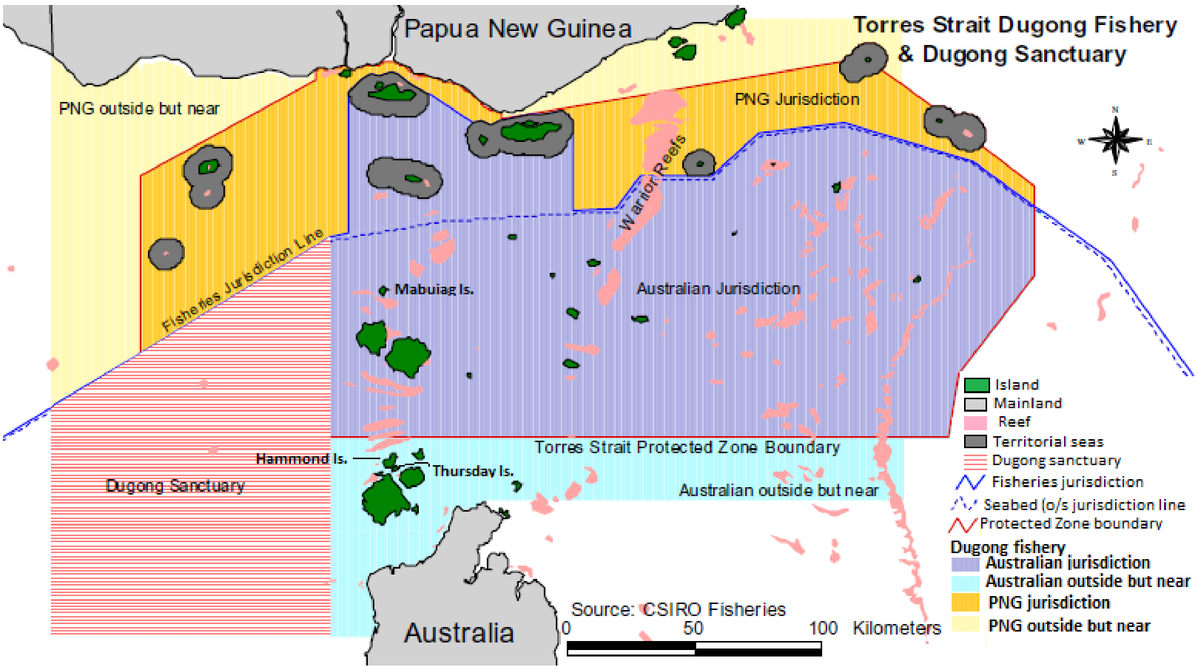

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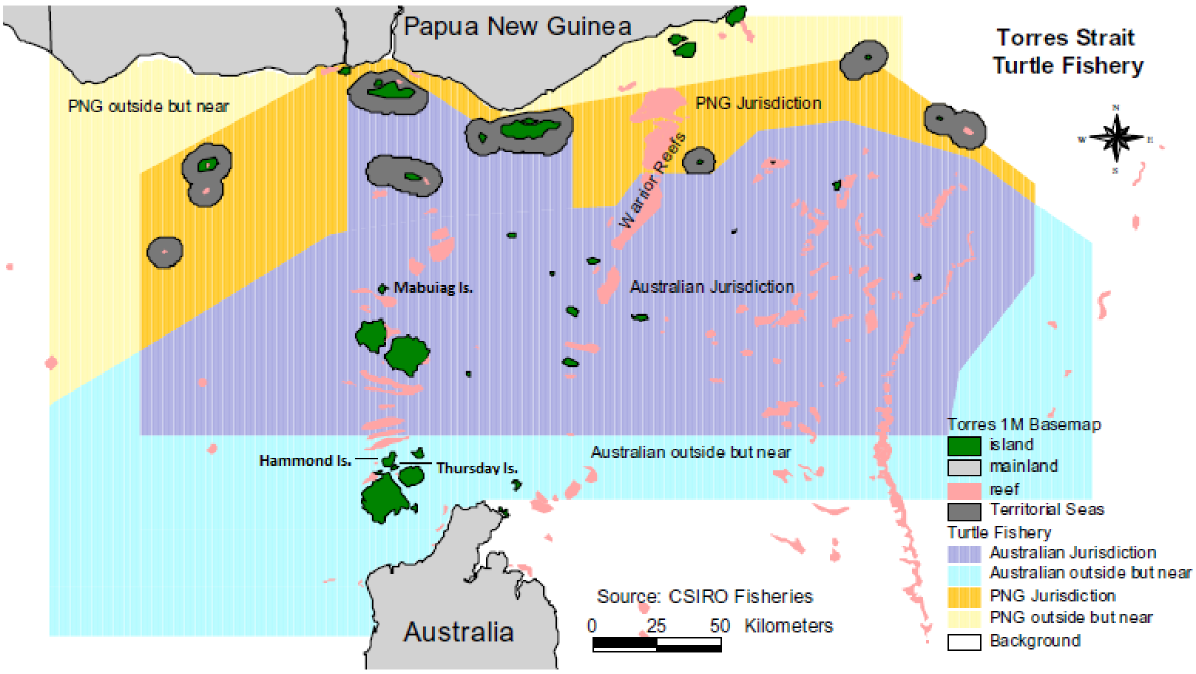


Figure 2.2. Maps of the area of a) the Torres Strait dugong fishery and b) the Torres Strait marine turtle fishery. The area of each fishery is shown in pink. Note the marine turtle fishery extends further to the east than the dugong fishery. The boundary of the Torres Strait Protected Zone is the dotted line. The dugong sanctuary is not shown on Figure 2.2a, but is shown on Figure 3.1a in Chapter 3.

The Australian Fisheries Management Authority along with the Queensland Department of Employment, Economic Development and Innovation, co-ordinates and delivers fisheries management and surveillance/enforcement programs in the Torres Strait on behalf of the Protected Zone Joint Authority (Cain 2004). The management arrangements for dugongs and marine turtles under the *Torres Strait Fisheries Act 1984* are:

- Dugongs and turtles may only be taken by Traditional Inhabitants.
- Dugongs may only be taken using the traditional spear (wap).
- Dugong hunting is banned in a large area of western Torres Strait which has been set aside as a dugong sanctuary (see Figure 3a).
- Dugongs and marine turtles cannot be taken or carried in a commercially licensed fishing boat greater than 6 m in length (boats < 6 m with a Traditional Inhabitant Boat licence are permitted to take and carry turtle and dugong).

In addition, as explained in Chapter 1, since 2008, 15 Torres Strait communities, assisted by the Torres Strait regional Authority, are developing and implementing (through a Ranger Program) community-specific co-management plans for dugongs and marine turtles. These plans are recognised as part of the management arrangements for the Torres Strait dugong and marine turtle fisheries by the Protected Zone Joint Authority (see http://pzja.gov.au/the-fisheries/dugong-and-turtle-fisheries/. Each community has a steering committee that oversees the development and implementation of the plans. The membership of the steering committee varies among communities, but may be made up of elders[6], prescribed body corporate members, community members, etc. The Torres Strait Regional Authority works through these steering committees to engage with community members, hunters, and others. When necessary, the Torres Strait Regional Authority may facilitate meetings among islands in a nation cluster to deal with issues such as shared reefs. Decision-making structures in

[6] An elder is determined by family lineage.

Torres Strait communities are dynamic. At the time of my study, the community councils were the main decision-making bodies. More recently, on some islands, native title representative bodies are exercising their right to make decisions.

The Papua New Guinean Government manages marine resources, including dugongs and marine turtles, in the Papua New Guinean jurisdiction of the Protected Zone (Harris et al. 2008). The Australian and Papua New Guinean Governments have a range of consultative mechanisms to facilitate subsidiary management of the shared marine resources under the Treaty. These mechanisms include Joint Advisory Council Meetings, Environmental Management Committee Meetings and Traditional Inhabitant Meetings. The two governments also hold fisheries bilateral meetings specifically regarding the management of fisheries in the Torres Strait.

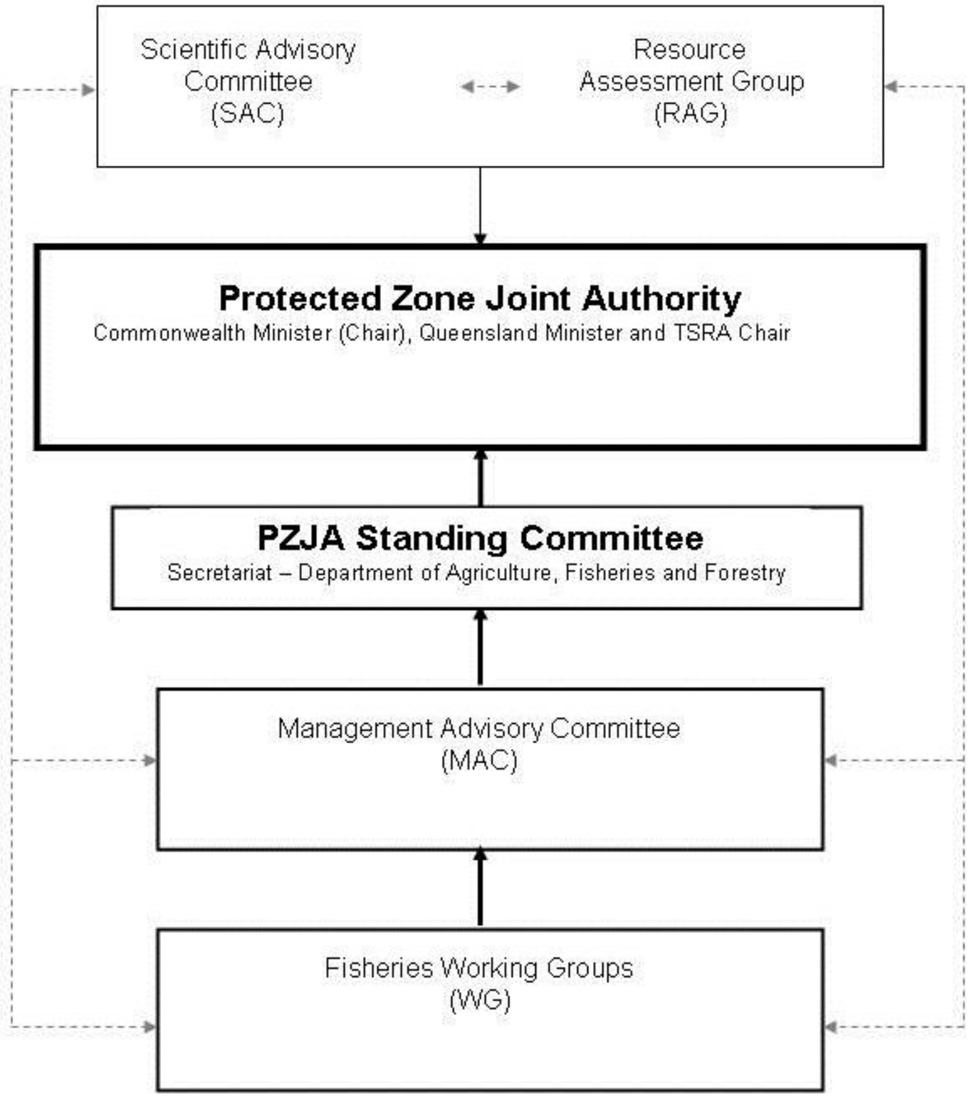


Figure 2.3. Protected Zone Joint Authority Consultative Structure. Adapted from 2010 Operational Plan for Torres Strait Fisheries, July 2010.

2.4. Dugongs and green turtles

The dugong has a large range that spans approximately 40 countries and territories and includes tropical and subtropical coastal and island waters from East Africa to Vanuatu. Throughout much of its range, dugong numbers have declined and its range has been fragmented (Marsh et al. 2002). Australia has the largest remaining population of dugongs, with the largest population in Australia occurring in the Torres Strait. As explained in Chapter 1, Australia is not only one of the few developed nations in the range of this species, but also has the most extensive coastline at low risk from coastal development (Marsh et al. 1999; Marsh et al. 2002). Most other countries in the dugong's range are unlikely to be able to protect high quality dugong habitat because of increasing pressures from high population growth and associated infrastructure and development (Marsh et al. 2011).

The genus *Chelonia* has a worldwide tropical and subtropical distribution (Limpus 2008). Australia supports one of the largest remaining breeding populations of green turtles in the world (Limpus 2008). Australia has seven widely separated breeding populations of green turtles identified. These separate breeding populations, which require independent management, are southern Great Barrier Reef, northern Great Barrier Reef, Coral Sea, Gulf of Carpentaria, Ashmore Reefs, Scott Reef and the Northwest Shelf (Limpus 2008; Jensen 2010). Although they have different breeding distributions, the green turtles from the different Australian breeding populations occupy sympatric feeding areas, which they also share with green turtles from other breeding populations that have nesting beaches in neighbouring countries (Limpus et al. 1992).

The Torres Strait dugong population is the largest in the world, but dugongs undertake large-scale movements (Sheppard et al. 2006) resulting in the population used by Torres Strait Islanders being shared with people in other parts of Australia and other countries, particularly Papua New Guinea. Similarly, the Torres Strait/northern Great Barrier Reef green turtle population is one of the largest in the world, but supports traditional harvests from geographically-dispersed sources within Australia from the Northern Territory to southern Queensland and from West Papua in Indonesia, to southern and eastern Papua New Guinea, and to Vanuatu and New Caledonia (Limpus 2008). Therefore, management needs to consider that Torres Strait Islanders share their dugongs and green turtles with other communities because these species operate at large ecological scales.

Both dugongs and green turtles have life-history strategies and diets that make them susceptible to anthropogenic impacts (Marsh et al. 2002; Limpus 2008). Dugongs are large long-lived (up to approximately 70 years) marine mammals (Marsh 1980; Marsh 1995a; Marsh et al. 1999), which are slow to reach sexual maturity (e.g., females have their first calf at between 6 and 17 years) and have long calving intervals of 2.4 to 7 years (Marsh 1995a; Kwan 2002). Population simulations indicate that a dugong population is unlikely to increase at more than 5 per cent per year (Marsh 1995a). Green turtles reach sexual maturity at approximately 30 to 40 years (Limpus 2008). The average remigration interval for female green turtles of the northern Great Barrier Reef stock is 5 years (range 1-8; Limpus 2008) and the average remigration interval showed an increasing trend from 1991-2001 (Limpus 2008). The protracted delay in maturity and the long intervals between breeding seasons put green turtle populations at risk from even modest increases in mortality that have an extended impact at any stage in their life history (Limpus 2008).

Dugongs are sea grass community-specialists (Heinsohn and Birch 1972; Marsh et al. 1982; Lanyon et al. 1989; Andre´ et al. 2005; Marsh et al. 2011), while green turtles feed on both algae and sea grasses in Torres Strait (Andre´ et al. 2005). Both dugongs and green turtles are sensitive to changes in the survival probability of adults and are therefore vulnerable to even small levels of anthropogenic mortality. Reduced habitat quality (i.e., available forage) compounds vulnerability to anthropogenic threats. Dugongs may respond by reducing fecundity (Marsh and Kwan 2008). A similar response has been speculated for green turtles in which El Nino Southern Oscillation climate impacts on foraging populations as they prepare for a breeding season, causing inter-annual variation in nesting, because in some seasons there is reduced forage and therefore fewer green turtles prepare to breed (Limpus 2008).

2.4.1. Conservation status

Dugong and green turtle populations face a range of threats in Australia and overseas. These threats include habitat loss (e.g., through coastal development), Indigenous hunting, illegal hunting (i.e., poaching), incidental capture in set mesh nets, marine debris, boat strike and poor water quality. Australia's status as one of the few developed countries in the range of both the dugong and green turtle highlights the importance of Australia fulfilling its obligations under the various international conventions that aim to protect these species. These include the *Convention on the Conservation on Migratory Species of Wild Animals* (the Bonn Convention, CMS), the *Convention on International Trade of Endangered Species of Wild Animals* (CITES), the *Convention on Biological Diversity*, and the *World Heritage Convention* (WHC).

Currently dugongs are classified as vulnerable to extinction under the 2010 World Conservation Union (IUCN) Red List of Threatened Species, which indicates that they face a high-risk of extinction in the wild in the medium-term future. The *Convention on Migratory Species* lists the dugong in its Appendix II, meaning that the conservation of the species would benefit from international cooperative activities organised across the dugong's migratory range. Thus, Australia, has also signed the *Memorandum of Understanding on the Conservation and Management of Dugongs (*Dugong dugon*) and their Habitats throughout their Range* under the auspices of the *Convention on Migratory Species* (http://www.cms.int/species/dugong/index.htm).

Green turtles are classified as endangered under the 2010 World Conservation Union (IUCN) Red List of Threatened Species, which indicates they face a very high risk of extinction in the wild. The *Convention on Migratory Species* lists the green turtle in its Appendices I and II, meaning they have been categorised as being in danger of extinction throughout all or a significant portion of their range, and the conservation of the species would benefit from international cooperative activities organised across their migratory range. To strive towards protecting green turtles, Australia has signed the *Memorandum of Understanding on the*

Conservation and Management of Marine Turtles and their Habitats in the Indian Ocean and South-east Asia under the auspices of the *Convention on Migratory Species* (http://www.cms.int/species/iosea/IOSEAturtle_bkgd.htm; htpp://www.ioseaturtles.org)

Both dugongs and green turtles are listed as species of conservation concern in Australia, where they are protected by biodiversity legislation at national and sub-national levels. Specifically, the national *Environment Protection and Biodiversity Conservation Act 1999* lists dugongs as migratory species and green turtles as vulnerable species and Queensland's *Nature Conservation Act 1992* lists both species as vulnerable.

2.4.2. Importance of dugongs and green turtles to Indigenous culture

Both dugongs and green turtles are culturally important to communities throughout their range. Dugongs are caught for meat, oil, medicaments, amulets and other products (Marsh et al. 2002). The eggs and meat of green turtles are eaten, while the skin is used for making leather, its oils for making cosmetics, its scutes for jewellery and its offal for fertiliser (Limpus 2008). In many countries, hunting of dugongs and/or green turtles is banned, but there is still a direct take of these species, either through exemption or illegally. As explained in Chapter 1, international agreements such as the *Convention on Biological Diversity* compel governments to respect the rights of Indigenous peoples to use and manage biological resources on traditional territories (e.g., Danielsen et al. 2005a; Green et al. 2005; Ban et al. 2008).

In contrast to most other countries in the ranges of green turtles and dugongs, the right of Aboriginal and Torres Strait Islander Traditional Owners to hunt them in Australia is protected by law and Indigenous Australians consider hunting these species to be an important expression of their identity (Marsh et al. 2002). In Torres Strait, dugongs and green turtles have considerable ecological, spiritual and cultural values and form the basis of an important subsistence economy (Marsh 1996; Kwan et al. 2006). Laws and treaties protect the cultural importance of dugongs and green turtles and their use by Indigenous Torres Strait Islanders and Aboriginal people. The *Native Title Act 1993* operates nationally, while the *Torres Strait Fisheries Act 1984* operates in Torres Strait. In addition, in Torres Strait, the *Torres Strait Treaty 1985* obliges both Australia and Papua New Guinea to protect hunting as part of the traditional way of life and livelihood of the traditional inhabitants (Kwan 2002).

2.5. The research process and implications of external perceptions

In this section, I describe the participatory research process (Wiber et al. 2009; Ballard and Belsky 2010) that I undertook to develop trust between researchers and community members in developing a community-based catch-monitoring project to inform co-management of dugong and green turtle fisheries in two Torres Strait communities. I also discuss the resilience of strong relationships to external forces such as media controversy.

2.5.1. Initial engagement of Indigenous communities

To achieve a participatory research process, I involved Torres Strait community members from the outset (Figure 2.4) and spent a substantial amount of time living on Thursday Island. In the initial stages of the project, I divided my time between Torres Strait and James Cook University in Townsville. I visited Torres Strait in February 2004 for two weeks, mid-May to mid-July 2004 and November to December 2004 and then I returned to Torres Strait in February 2005 and lived there until July 2006.

I initiated engagement with Torres Strait communities by obtaining the support of the Board of the Torres Strait Regional Authority by presenting my proposed research to them in February 2004. I chose to conduct the research with Kaiwalagal (inner island) communities based on interest from the Torres Strait Regional Authority Board members and advice from the Marine Research Liaison Officer employed by the Cooperative Research Centre for Torres Strait (CRC Torres Strait) research programme, which funded my research. I subsequently obtained support from the Kaurareg (Traditional Owners of the Kaiwalagal) to conduct the research in their traditional Sea Country[7] (mid-May to mid-July 2004), the Thursday Island Community Fisher Groups, which represented some traditional hunters living on Thursday, Horn and Prince of Wales Islands (mid-May to mid-July 2004), and the Hammond Island (mid-May-mid-July 2004) and Thursday Island Community Councils (April 2005). To obtain their support, I discussed my proposed research questions, the research process, proposed outputs and anticipated outcomes with each of these groups, including how the research could benefit their communities (Table 2.1). I also explained my intention to incorporate the agreed outcomes of these discussions into a Research Agreement (Appendix A) with them to ensure that I would conduct the research in a culturally appropriate manner.

[7] The term 'Sea Country' refers to the coastal, island and marine environments that together make up the traditional estates of coastal Indigenous groups in Australia. Rather than being additional to the groups' Country on land, an Indigenous group's Land and Sea Country are inseparable (Smyth 2001).

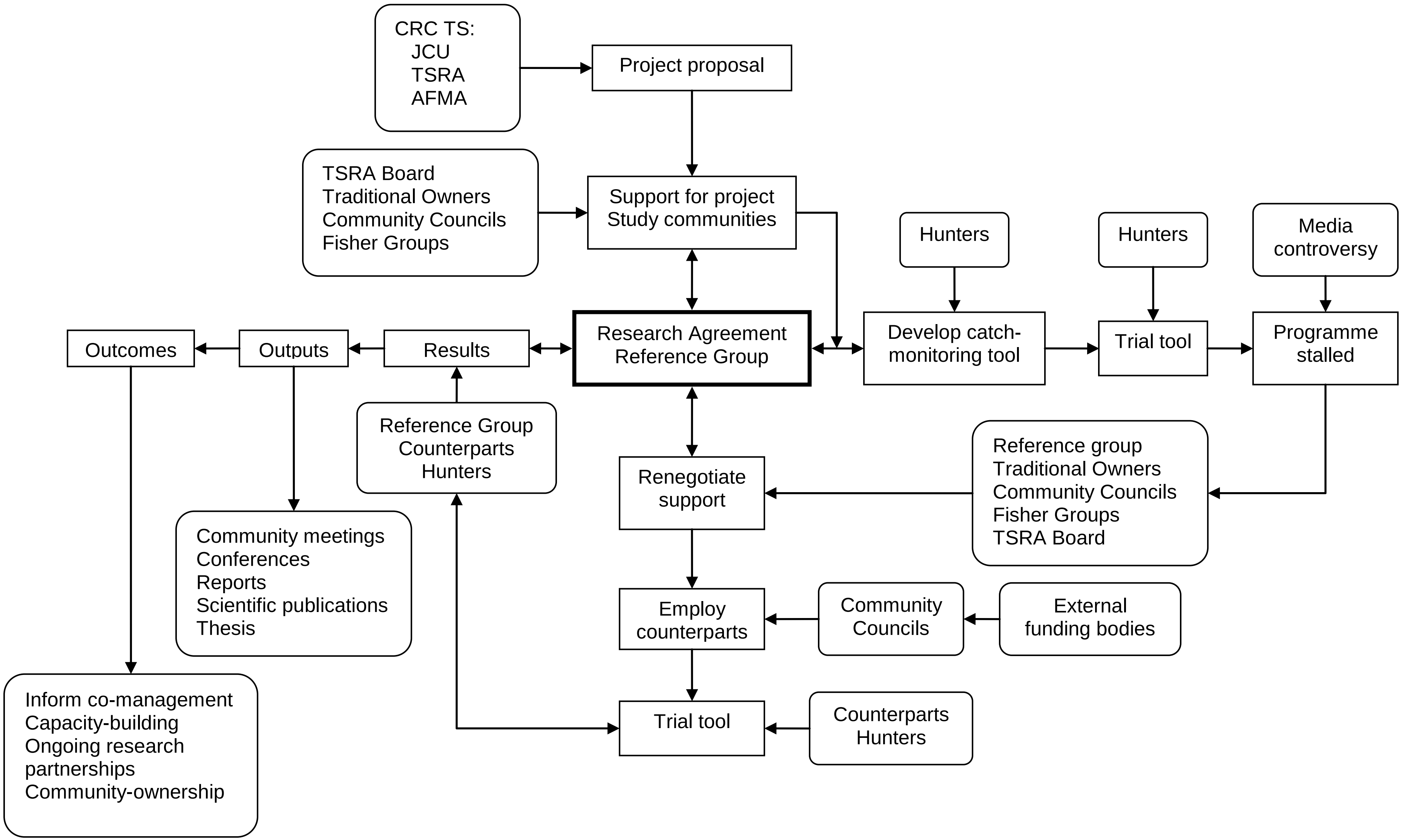


Figure 2.4. Schematic diagram of participatory research process to develop and implement a community-based catch-monitoring programme for dugongs and green turtles in the Kaiwalagal sea country of Torres Strait.

Table 2.1. Benefits matrix showing the benefits of the catch-monitoring program to each of the stakeholders.

Stakeholder	Benefits
Communities	Trial and test survey methods to find a method that your community can use to collect and organise information about your dugong and green turtle fisheries to: • better understand your dugong and green turtle fisheries; • Inform sustainable hunting so that you **know** there will be plenty of dugongs and green turtles for future generations. • Have greater capacity to negotiate hunting management arrangements with fisheries and environmental management agencies from the information you have collected; • Document the importance of dugongs and green turtles within your community. • Document the importance of dugongs and green turtles within the community to use in working out catch-sharing arrangements amongst communities and regions; • Identify problems or issues with the fishery; • Benefit from long-term planning; • Develop community designed and implemented work ethics and research management protocols; • Training and employment for community members who can advise future researchers or carry out research in some cases.
Jillian Grayson – research student	• PhD; • Publications to progress scientific career; • Valuable experience and lessons about community-based monitoring and management to use in future research projects; • Improved capacity to engage with Torres Strait communities in the design and conduct of research and transfer of research results. • Privilege of working with Torres Strait Islander and Aboriginal communities in the Kaiwalagal traditional sea country and living in their communities. • Information on the composition of the harvest relevant to understanding the health of dugong and green turtle populations.
James Cook University – Research Organisation	• Completion of a PhD project; • Publications to add to quantum for the University; • Ability to do further research in Torres Strait on the basis of a successful research project.

Stakeholder	Benefits

CRC Torres Strait[†] - primary funding agency

- Work with Islanders, managers and other stakeholders to provide collaborative research that is relevant to Torres Strait.
- Provide accurate information to Torres Strait communities and CRC Torres Strait partners to look after dugongs and green turtles in Torres Strait and make good choices for managing dugongs and green turtles.
- Support Torres Strait communities.
- Support the sustainable development of dugong and green turtle fisheries.
- Enhance the sustainability of dugongs and green turtles and conserve the social, cultural and economic well being of all stakeholders, in particular the Torres Strait peoples.
- Contribute to effective policy formulation and management decision making.
- Improve the capacity of Torres Strait communities to understand and utilise research results for enhanced social development.

Department of Environment and Heritage[‡] - supplementary funding agency

- Awareness-raised in Indigenous communities on the biology of and threats to green turtles and dugongs, the migratory nature of turtles and the need for Indigenous harvest to be sustainable.
- Indigenous communities involved in on-ground recovery actions (e.g., catch-monitoring program).
- Information on the composition of the harvest relevant to understanding the health of dugong and green turtle populations.

Ocean Parks Conservation Foundation - supplementary funding agency

- Facilitate the conservation of dugongs through research focussed on the sustainability of the dugong fishery in Torres Strait.
- Information on community-based dugong monitoring methods for education and awareness-raising.
- Information on the composition of the harvest relevant to understanding the health of dugong populations.

[†] CRC Torres Strait was a not-for-profit company established to implement the Torres Strait research program which was a supplementary research program of the Cooperative Research Centre for the Great Barrier Reef World Heritage Area (http://www.rrrc.org.au/crctorres/index.html).

[‡] Now the Department of Sustainability, Environment, Water, Population and Communities

2.5.2. Development and implementation of a research agreement with communities

The development of the Research Agreement with the Traditional Owners, Community Councils and Fisher Organisations enabled me to establish trust with the participating communities. To maintain this trust and develop productive working relationships with the communities, I also established a Cultural Reference Group comprised of representatives from each of the parties to the Research Agreement. This group was to provide advice to me about cultural protocols, and scrutinise my outputs to ensure that I would not inadvertently release culturally sensitive information or misrepresent the participating communities or Torres Strait Islanders in general.

2.5.3. Developing and implementing the catch-monitoring tool

Once I obtained support for the project, I started collaboratively developing the community-based catch-monitoring project with the hunters from the communities. I discussed options for catch-monitoring tools to trial and information to collect with hunters from the Community Fisher Groups, the Hammond Island community and the Thursday Island community separately in several meetings (see Chapter 5). Within this group we discussed the potential of using various catch-monitoring tools including: datasheets, dedicated repositories for dugong skulls and green turtle shells, dedicated processing sites, photographic records and verbal reports. We discussed the advantages and disadvantages of each tool and the hunters overwhelmingly chose to trial the datasheet (see Appendix B). A datasheet enabled them to collect more of the information (see Chapters 6 and 7) that they needed to inform management than the other tools and it gave them control over providing information. Many of the hunters assisted in designing the catch-monitoring datasheet and hunters from the Community Fisher Groups began recording information on the datasheets from mid-July 2004, while I returned to Townsville. These hunters wanted to start recording their catches immediately and did not feel that they needed to wait for me to return to Torres Strait later in the year. This group of hunters discontinued recording information in November 2004, just after my return to Torres Strait, in response to unforseen media scrutiny of Indigenous dugong and marine turtle hunting (see below), but re-engaged in the project by May 2005 after I renegotiated their support. The Hammond and Thursday Island communities began catch-monitoring in February and July 2005, respectively after I employed Indigenous research counterparts to do the catch-monitoring work in each community (see Section 2.5.5).

2.5.4. The effects of external perceptions

The media scrutiny of Indigenous dugong and marine turtle hunting was sparked by a joint media release on 8 November 2004 by the Australian Minister for the Environment and Heritage, Senator Ian Campbell and the Australian Minister for Fisheries, Forestry and Conservation, Senator Ian MacDonald (*The Daily Telegraph*, 9 November 2004). The media release announced that the traditional harvest of marine turtles and dugongs in the Torres Strait would be assessed under the *Environment Protection and Biodiversity Conservation Act 1999*, as required for Commonwealth fisheries managed under the *Torres Strait Fisheries Act 1984*. The Ministers said their decision came ahead of a report due to be released that day titled “Dugong distribution and abundance in Torres Strait” prepared by Professor Helene Marsh for the Australian Fisheries Management Authority (AFMA), which presented evidence that the harvest of dugongs in Torres Strait is unsustainable. The report was commissioned by the Minister for Fisheries, Forestry and Conservation in response to findings of the National Recreational and Indigenous Fishing Survey (2003). This fishing survey aimed to obtain fisheries statistics to inform the Australian and State Government’s management of non-commercial fisheries.

The media took up the story and two main issues were raised in subsequent media reports: restrictions on hunting and animal cruelty associated with the hunting practices of Indigenous people. The latter featured despite the fact that neither the report by Marsh et al. (2004a) nor the Minister's joint press release mentioned hunting practices or animal cruelty. At the time of the media controversy, hunters from only the Community Fisher Organisations had been fully engaged in the project and were collecting data, while the Traditional Owners and the Hammond Island Council had agreed to support the project. The Community Council on Thursday Island had not yet expressed interest in participating. The initial reaction of the participating traditional hunters from the Fisher Organisations to the media reports was to discontinue their participation in the catch-monitoring programme. In addition, they refused to provide me with any of the datasheets that they had filled in during my three-month absence from Torres Strait. To renegotiate support for the project, I examined the content of the media reports. With the assistance of the CRC Torres Strait Marine Research Liaison Officer, I discussed the potential implications for the community-based catch-monitoring project, in several meetings, with members of my Reference Group, representing the Traditional Owners, Hammond Island Council and the Community Fisher Organisations, and traditional hunters (Table 2.2).

Table 2.2. Summary of meetings that I held with traditional hunters to regain support for the project

Date	Location	Type	Attendees
29/11/2004	Thursday Island	Meeting	Thursday Island traditional hunters
26/02/2005	Thursday Island	Workshop	Thursday Island hunters
8/03/2005	Thursday Island	Meeting	Kaiwalagal Aboriginal Corporation; Community Fisher Organisation hunters, Community members
24/03/2005	Horn Island	Meeting	Kaiwalagal Aboriginal Corporation
7/04/2005	Thursday Island	Info & BBQ	Traditional hunters
28/04/2004	Thursday Island	Meeting	Community Council workers
5/05/2005	Thursday Island	Meeting	Community Council workers
6/05/2005	Thursday Island	Meeting	Community Fisher Organisation
hunters			

Animal welfare issues

During these meetings, my reference group and the traditional hunters explained that they felt that the media reports that focussed on animal cruelty were negative, emotive and portrayed Indigenous people as insensitive and uncaring in their traditional practices. The media reports focussing on animal cruelty, in particular, used emotive language such as ‘slaughter’ or ‘carnage’ to describe Indigenous hunting of dugongs (e.g., *Cairns Post*, 11 November 2004, 12 November 2004; *The Courier Mail*, 8 November 2004), ‘horror stories’ to describe some of their unsubstantiated reports of cruelty by Indigenous hunters to dugongs and marine turtles (e.g., *Cairns Post*, 13 November 2004) and described Indigenous hunters as ‘cruel and sadistic’ (e.g., *Cairns Post*, 13 November 2004). Senator Macdonald also referred to the ‘unsustainable slaughter’ of dugongs in his joint media release with Senator Campbell.

<u>Restriction of rights</u>

Other media reports focussed on proposed restrictions on traditional hunting rights of Torres Strait Islanders (e.g., quotas, *The Australian*, 8 November 2004) and reported that the government may change the legislation if a way of controlling the harvest could not be found ‘quickly enough’ (e.g., *Daily Telegraph,* 8 November 2004; *Courier Mail*, 13 November 2004). My reference group and the traditional hunters were therefore concerned that they would be forced to stop practising a very important part of their culture and that they would not be given the opportunity to manage their traditional natural resources, but instead would have management imposed on them. The Torres Strait Regional Authority Chairman, Toshie Kris pointed out in the media that hunters need to have ownership of the measures adopted to control hunting (4K1G 10 November 2004; *Torres News*, 17 November 2004; *Courier Mail*, 11 November 2004 ; *Cairns Post*, 12 November 2004).

Further concerns were raised that information collected by researchers would be given to the government and the media and used against Torres Strait Islanders. This sentiment seemed to be widespread. A letter to the editor of the local paper, the *Torres News*, stated, ‘Researchers shouldn’t be surprised if hunters think twice about helping them when their good will can be used to slap them in the face later.’ I alleviated the concerns of the hunters about the information being used in an inappropriate manner by outsiders by continuing to negotiate my

Research Agreement with the communities. Hunters felt most threatened about the total numbers of dugongs and green turtles caught being released to the government, because they thought the government would use this information to stop them from hunting dugongs and marine turtles. The main objective of this component of my project was to develop a process for community involvement in catch-monitoring to inform co-management. Therefore, although knowing the total numbers of dugongs and green turtles caught would be useful for the communities, this information was not essential to achieving the aims of my project and therefore I agreed to keep the catch data confidential. In addition, I agreed to pass draft outputs through the Cultural Reference Group to ensure that I had not inadvertently included culturally sensitive information or misrepresented the participating communities (see Appendix A).

<u>Hunters concerns about other impacts on dugongs and green turtles</u>

As explained in Section 2.4, both dugongs and green turtles undertake large-scale movements resulting in the stocks used by Torres Strait Islanders being shared with people in other countries (e.g., Papua New Guinea and Indonesia). The Islander hunters raised concerns that other impacts, particularly hunting by Papua New Guineans and impacts of illegal foreign fishers, on dugongs and green turtles should be addressed at the same time as traditional hunting. The hunters pointed out that, unless this was done, dugong and green turtle numbers would decline despite restrictions on their traditional practices. Hammond Island hunters interviewed about management options also raised this issue (see Chapter 4). The Torres Strait Regional Authority Chairman, Toshie Kris, also expressed these concerns about Papua New Guinean hunting in the media and he noted that Australia and Papua New Guinea would be meeting to discuss the issue (*Torres News* 17 November 2004; *Courier Mail* 11 November 2004; *Cairns Post* 12 November 2004). Other media reports from Indigenous spokespeople also highlighted impacts on dugongs and green turtles other than traditional hunting. For example, Francis Tapim from the National Torres Strait Islander Organisation and Peter Guivarra, Chairman of Mapoon Aboriginal Community, talked about the impacts of commercial fishing nets on dugongs (*Seven Local News Bundaberg*, 8 November 2004; *ABC Far North*, 9 November 2004). Similarly, Joe Morrison, coordinator of the North Australian Indigenous Land and Sea Management Alliance (NAILSMA) talked about other impacts including boat strikes, shark nets, marine debris, poaching for crab bait and polluted catchments damaging seagrass beds (*Cairns Post* 12 November 2004). Subsequently, the *Daily Telegraph* (9 November 2004) reported that the Fisheries Minister conceded that commercial fishing and the availability of food, particularly sea grass, were affecting the dugong.

These other impacts were outside the scope of my project, but I listened to the concerns of the hunters and acknowledged that I understood that these were substantial and legitimate concerns that needed to be dealt with. I also explained that dealing with such issues was outside the scope of my role to trial a community-based catch-monitoring programme, which I was happy to continue to work on with them if they wished. In addition, with the assistance of the CRC Torres Strait Marine Research Liaison Officer, I explained which agencies they should talk to about their concerns about these issues that were not directly relevant to the catch-monitoring project (e.g., harvesting by Papua New Guinean hunters and impacts of foreign fishing vessels).

<u>Discord between traditional knowledge and scientific information</u>

Some Torres Strait Islanders did not support the catch-monitoring project, in part because they did not support the findings of the report by Marsh et al. (2004b) with respect to dugong abundances and sustainable catch-rates. They argued that Islanders have strong traditional knowledge from spending a lot of time out on the water and the research results seem to conflict with what they see. They also noted that they perceived several problems with the dugong aerial survey technique, which made them think that Marsh et al. (2004b; 2004a) underestimate the number of dugongs. These problems included: (1) local people see more dugongs at night than during the day because dugongs hide in deep water during the day; (2) dugongs spend a lot of time diving underwater and therefore cannot be seen from the air; (3) dugongs might all dive at the same time, so there may not be any on the surface allowing the correction factor adjustments to be done; and (4) dugongs move large distances and therefore may have moved out of an area before they could be counted.

Marsh et al. (2004b; 2004a) controlled for each of these potential problems and I explained these controls to the hunters. The controls were: (1) doing aerial surveys on high spring tides during the day to maximise the likelihood that dugongs are in shallow water where they can be seen; (2) adjusting the count after calculating the proportion of dugongs that are diving and therefore are not available to be seen; (3) using time-depth recorders to determine that dugongs in a group dive independently of each other; (4) using aerial video footage obtained from a video mounted from a helium-filled aerostat (blimp) (A. Hodgson, James Cook University, personal communication) to examine the surfacing behaviour of dugongs in groups and determine that there is no synchronicity in surfacing amongst dugongs within a group (Pollock et al. 2006), and 5) using two aircraft at the same time so that dugongs do not have sufficient time to move into adjacent blocks during the survey. In addition, two observers are used on each side of the aircraft and a mark-recapture model applied to estimate the probability that dugongs that are available to be seen are counted (Pollock et al. 2006). I also explained that Marsh et al. (2004b; 2004a) recognise that aerial surveys are likely to underestimate the size of the population of dugongs in Torres Strait, but the estimated catch-rate is an order of magnitude larger than the estimated sustainable catch-rate and therefore the error associated with aerial surveys is unlikely to account for this difference.

In general, communities in Torres Strait seem to acknowledge a problem with the sustainability of dugong stocks. In addition, some Torres Strait Islander leaders and hunters have been calling for assistance with management arrangements for hunting for many years. However, it appeared from the reaction of hunters to the media controversy, that there was not a broad base of understanding of the aerial survey methods in the community and therefore there was not widespread support for the results of these surveys or the need to manage dugong and green turtle harvests. Consequently, small groups of people were able to question the results and convince others that the research was incorrect.

2.5.5. Re-engagement in the project

Employment and training

During our meetings to decide on and design a catch-monitoring tool, hunters had stated that they would prefer to deal directly with a local male Indigenous person because dugong and green turtle hunting was an important cultural activity done by males and I was a female researcher. In response to these concerns, I employed a local male Indigenous research counterpart from each of the Hammond Island (Stephen Ambar) and Thursday Island (Cyril Stephen) communities to conduct the catch-monitoring work on Hammond and Thursday Islands, respectively. I obtained additional funding from the Department of Environment and Heritage (now the Department of Sustainability, Environment, Water, Population and Communities) and Ocean Park Conservation foundation to employ the counterparts who also worked on a companion marine turtle research project conducted with their communities by Dr Mark Hamann with my assistance. We held several workshops with the counterparts and the hunters to train them in data collection, morphometric measurements and biological specimen collection and interpretation. I used practical hands-on exercises with hypothetical participation rates to demonstrate the importance of everyone participating (see Chapters 5, 8 and Appendix C). I also provided on-the-job training for my counterparts. The marine turtle research was less controversial, leading to the publication of several good news stories in the media.

A participatory process

The Torres Strait Regional Authority Board remained supportive of the project, even after the media controversy, because they recognised that, the project could help Torres Strait Islanders collect the information they needed to manage dugongs and green turtles. In addition, the Board had already acknowledged that management of these fisheries was needed, so, although they viewed many of the media reports as negative, they considered the best way forward was to use the heightened attention to further their case for assistance in managing their dugong and green turtle stocks. Similarly, although Hammond Island Council appreciated the concerns of the hunters from the Fisher Organisations, they perceived that the benefits to their community of participating in the project outweighed the risks of any external scrutiny. For example, they valued the employment and training that Dr Mark Hamann and I were providing. They also believed that the participatory research process would minimise the risks of external impacts and therefore reinstated their support for the project more quickly than the Community Fisher Groups. Hunters from Hammond Island commenced data collection in February 2005 at the same time as I employed Stephen Ambar. Hunters from the Community Fisher Groups recommenced participation in the project in May 2005. The Community Council on Thursday Island expressed interest in participating in the project shortly after the Torres Strait Regional Authority Board renewed their support for the project. Subsequently, hunters from the Thursday Island community, other than members of the Community Fisher Organisations, commenced participation in July 2005, after I employed Cyril Stephen to help engage them, and distribute and collect datasheets.

I communicated the progress and outcomes of the project to hunters and community members through community meetings. I also presented my research at a TAFE course on Thursday

Island and with Professor Helene Marsh did a radio interview to discuss the dugong aerial survey that was conducted in Torres Strait in 2006. My research counterpart, Stephen Ambar, was employed to assist with the aerial survey. I passed outputs from the project (e.g., conference presentations, scientific papers, reports and my thesis) through my cultural reference group to ensure they were culturally appropriate and did not misrepresent Torres Strait Island communities. The Torres Strait Regional Authority will receive a copy of my thesis with the confidential material removed.

Funding for the project was obtained from three sources: (1) the Cooperative Research Centre for Torres Strait, (2) the Australian Government's Department of Environment and Heritage (now Department of Sustainability, Environment, Water, Population and Communities) and (3) Ocean Park Conservation Foundation. In response to a progress report outlining the effects of the media scrutiny, the Australian Government attempted to intervene in the participatory process that I was developing with the communities. They were concerned that: (1) support for the project would not be re-established after the media controversy subsided and (2) they would not obtain a catch-estimate of dugongs and green turtles for the communities. Although disappointed that they would not be able to access data on the level of harvest in the inner islands, relevant government officers were eventually satisfied with a risk assessment of the likelihood of the communities re-engaging in the project and the milestones being achieved on time, which I included in the revised draft report, accompanied by a letter from my principal supervisor explaining why the project should continue given that the catch estimate would not be provided.

2.5.6. Discussion

The development of this community-based catch-monitoring project in Torres Strait shows that it is possible to build trust between scientists and local Indigenous communities through a participatory research process even in the face of challenging external circumstances. Trust was established by involving the communities in various stages of the monitoring process, from deciding on the research question to developing the monitoring protocols, collecting the data and disseminating the results, all of which gave community members a sense of ownership of the results (Danielsen et al. 2005a; Marsh 2006 Steps C–E in Figure 1.1, see Chapter 1). In particular, I demonstrated to the hunters, Traditional Owners, community leaders and Fisher Organisations that they would have control over the way the information collected in the project would be used. The most important features of the process to achieve this community control and the resultant trust were the Research Agreement, passing outputs through the Cultural Reference Group and my agreeing to keep the most sensitive information (i.e., the numbers of dugongs and green turtles caught) confidential (Figure 2.4). Ban et al. (2008) also found that a data sharing agreement was the most important aspect for developing a research partnership with First Nations in Canada. In addition, providing employment and training opportunities may have enhanced the communities' willingness to participate because of the benefits these opportunities provided to the communities in terms of money and increased capacity to undertake monitoring in the future. Thus, the communities and I were able to build a strong partnership through the monitoring process.

The re-engagement of the communities in this community-based catch-monitoring project after the media controversy also shows that strong partnerships can be resilient to external forces. It is inevitable that conflicting views will be polarised in the media and similar misrepresentation and sensationalism of research in the media caused trust to be eroded in other research projects concerning traditional dugong hunting in northern Australia (e.g., Hope Vale community on north-east Cape York (Smith 1989) and Boigu community in Torres Strait (Kwan 2002)). In both of these cases, the researchers spent considerable time re-establishing rapport with the participating communities and, although their efforts were largely successful, some discontent remained in parts of the communities, particularly amongst community members not directly involved in the projects (Smith 1989; Kwan 2002). Marsh (1999) also reported misrepresentation of research results and sensationalism in media reports over the decision of the Australian and Queensland governments to set up ‘Dugong Protection Areas’ in the Great Barrier Reef Marine Park, where gill nets would be limited or eliminated. In this case, the outraged fishers attacked the professional reputations of the researchers.

Islanders perceived the governments’ threats in the media, regarding the potential to change the legislation to enable the government to control hunting, to threaten their rights to hunt dugongs and green turtles and their responsibility to manage them, thereby threatening their cultural survival (see Smyth 2001; Nursey-Bray 2006). The hunters reacted to these perceived threats to their rights and responsibilities in a similar way to other resource users faced with the threat of the loss of their rights or the imposition of management (e.g., Table 2.3). Typical reactions include withdrawing support, blaming other impacts and criticising scientific results. In particular, Torres Strait hunters blamed Papua New Guinean hunters and illegal foreign fishers for the need for management of the Torres Strait dugong and green turtle stocks. Hunters also criticised the results of the dugong aerial surveys because they did not like the answers they gave.[8]

[8] Aerial survey estimates always far exceed estimates of Islanders that are asked how many dugongs they think there are in Torres Strait.

Table 2.3. Reactions of Indigenous and local resource user groups to perceived threats to the loss of rights or imposition of management with respect to use and access to natural resources.

Group	Reactions	Reason	Reference
Recreational fishers	Unwilling to participate in monitoring Blame commercial fishers, or to a lesser extent, other impacts such as coastal development and land-use practices for declines in their target fish stocks; Did not believe the scientific information that suggested Marine Protected Areas were needed to protect breeding aggregations of target species.	Concerned catch will be restricted if it is found to be too high.	(Kearney 1995; McPhee et al. 2002)
Nepabunna Community in South Australia	Initially sceptical about engaging in Indigenous Protected Areas	Suspicious that the governments' intention was to surreptitiously take their lands from them.	(Muller 2003)
First Nations People in Canada	Sceptical of no-take Marine Protected Areas	Concerned that no-take Marine Protected Areas would preclude them from exercising their rights to fish for food, social and ceremonial purposes.	(Ban et al. 2008)
Hunters in the Alaska Beluga Whale Commission	Initially reluctant to participate in monitoring[†] Did not agree with the survey timing and flight plan used by scientists in aerial surveys to survey beluga whale populations.	Feared that the harvest data would be used against them by outsiders	(Fernandez-Gimenez et al. 2006)

[†] In this case, scientist members of the Alaska Beluga Whale Commission pointed out that providing data gave hunters control over the information used to make decisions. The likely alternative was that decision-makers would use other data, if hunter data was not available. This other data may be of questionable quality or validity, but hunters would not be in a position to contest it (Fernandez-Gimenez et al. 2006).

The reaction of Islanders to the perceived threat of having their rights and responsibilities reduced demonstrates the importance of embedding community-based monitoring within co-management. Without decision-making responsibilities, monitoring will be irrelevant to communities (Garcia and Lescuyer 2008). Thus, co-management also needs a strong partnership between communities, governments and scientists. The monitoring project I established in Torres Strait shows that scientists are important in the community-based co-management partnership because developing the monitoring process can increase the capacity of the community to make informed decisions and thereby contribute to management (Fernandez-Gimenez et al. 2006). In addition, developing the monitoring process can establish the trust that enables strong partnerships (Kaplan and McCay 2004), but it takes a long time and a lot of effort on the part of scientists and communities. This type of process cannot be developed by simply giving technical advice. Living within communities increases the researcher's understanding of the potential impacts of their work and their appreciation of the knowledge and skills of Indigenous researchers (Fernandez-Gimenez et al. 2006). By developing ongoing long-term relationships with communities, scientists develop a deep understanding of the factors leading to the success or failure of various interventions. However, this type of experiential knowledge has not often been valued within advisory processes (Marsh 2008).

The success of co-management, including community-based monitoring depends on the capacity of both the community and the government (Garcia and Lescuyer 2008; Campbell et al. 2009). In Australia, the governments' capacity for co-management with respect to shared decision-making and providing resources for implementing and enforcing plans has changed since the start of this project from a limited to a large investment (see below). For example, in previous projects, rather than investing in developing a monitoring or management process to involve communities in management, government agencies were more interested in receiving information on which to base their own decisions (Nursey-Bray 2006). The predominant interest of external management agencies in knowing the catch-number compared with developing a process of community involvement in catch-monitoring, was apparent in concerns expressed by one of the funding agencies for this project. Nevertheless, the agencies later accepted that developing such a process was an important and necessary step in achieving sustainable management of dugongs and green turtles in northern Australian. Similarly, in the development of the Hope Vale Dugong and Green Turtle Plan, the management agency staff expected to receive detailed information about where, what species and how many individuals were being caught, while the community was focussed on who would manage and how the hunting season would be conducted (Nursey-Bray 2006; Nursey-Bray and Rist 2009; Nursey-Bray et al. 2010). The development of the National Partnership Approach 2005 (see Chapter 2) was an important initiative in managing public perception around the issue of Indigenous hunting of dugongs and marine turtles around the time of my study.

Lack of resources to implement management plans has been a major impediment to many co-management initiatives with Indigenous people in Australia (Davies et al. 1999). Indeed, the lack of resources to implement the Hope Vale Dugong and Green Turtle Management Plan contributed to its failure (Marsh 2006). Investment by the Australian Government in community-based management of dugongs and marine turtles across northern Australia has increased since 2008. In Torres Strait the investment is more than $20 million over 5 years to 2013 and includes the development and implementation of 15 Community Dugong and Turtle Management Plans and a Ranger program to assist in the implementation of the plans. These projects are funded through the Australian Governments Caring for Our Country and Working on Country programs.

2.6. Chapter summary

- My study sites, both in the inner islands, are different with respect to population size. Hammond Island is a small community of approximately 230 people, while Thursday Island is the main administrative centre of Torres Strait and has a residential population of approximately 2500 people.

- The *Torres Strait Treaty 1985* provides a framework for the management of the common border area between Australia and Papua New Guinea in the Torres Strait. It also protects the traditional way of life of Traditional Inhabitants in the Torres Strait Protected Zone, including the movement of Traditional Inhabitants across borders.

- Dugongs and green turtles are considered fisheries under the Treaty and consultative mechanisms between the Australian and Papua New Guinean Governments are in place to facilitate subsidiary management arrangements under the Treaty.

- In Australia, the governance of the Torres Strait dugong and green turtle fisheries management has traditionally been the top-down command-and-control approach of the Protected Zone Joint Authority, including management arrangements under the *Torres Strait Fisheries Act 1984.*

- Support for a community-based approach to the management of these fisheries was increased in 2008 in response to concerns about the sustainability of the fisheries, the adequacy of the management arrangements and dissatisfaction by Islanders with the top-down management approach.

- Australia has significant populations of dugongs and green turtles and has international and national obligations to protect them. Dugongs and green turtles also have high cultural value to Indigenous Australians and the right of Traditional Owners to hunt these species is protected by law. Dugongs and green turtles both have life history characteristics that make them susceptible to over-harvesting and other anthropogenic impacts.

- The development of the participatory research process that I undertook to develop a community-based catch-monitoring program for dugong and green turtle hunting was based on a research partnership with the Hammond and Thursday Island communities after obtaining support from the Board of the Torres Strait Regional Authority. The research agreement with the communities, involved establishing a cultural reference group, and the development and implementation a catch-monitoring tool with hunters. Two Indigenous research counterparts assisted with the collection of information and dissemination of results.

- Hunters chose to trial a datasheet as the catch-monitoring tool and they started using the datasheets to record their dugong and green turtle catches in mid-July 2004, but discontinued in early November 2004 in response to media scrutiny surrounding Indigenous hunting of dugongs.

- External perceptions reported in the media in response to research suggesting that the Torres Strait dugong harvest was unsustainable stalled the project because Islanders were concerned that information collected by researchers, including me, would be given to the government and used against them to stop them from hunting and thus take away their rights and responsibilities.

- I found that Islanders were also concerned about reports in the media of restrictions on hunting and the focus on the issue of animal cruelty associated with the hunting practices of Indigenous people, which they felt were negative, emotive and portrayed Indigenous people as insensitive and uncaring in their traditional practices.

- In re-negotiating Islander involvement in the catch-monitoring project, I also discussed their concerns about threats to dugongs other than Indigenous hunting (e.g., hunting by Papua New Guinean traditional inhabitants) and the discord between traditional knowledge and scientific knowledge regarding the aerial survey data that was used in the research that found unsustainable harvest levels.

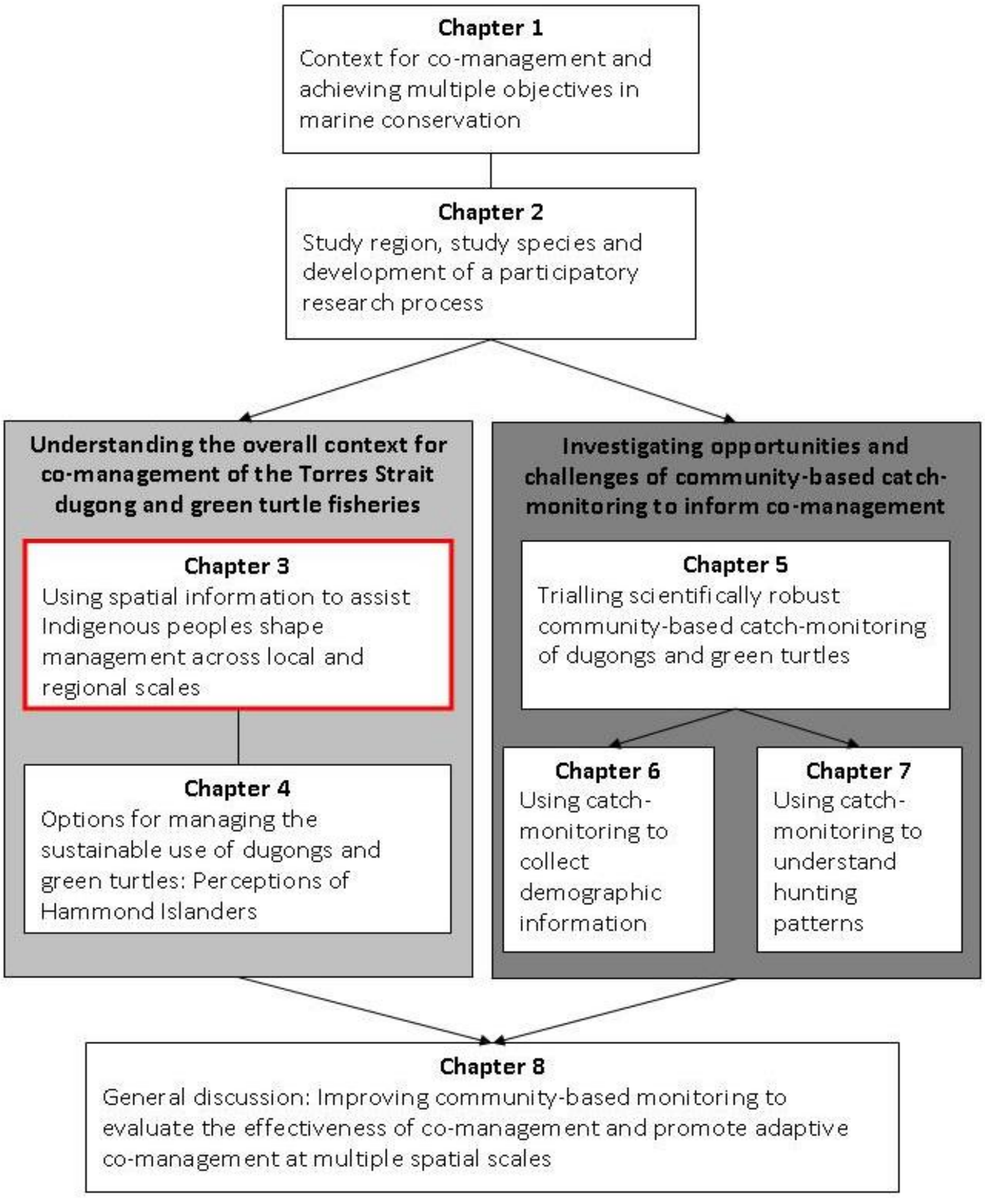
- The development of the research agreement, the cultural reference group and the employment and training of Indigenous research counterparts were major factors in the decision of the communities to re-engage in the project.

- My research indicates that it is inevitable that conflicting views will be polarised in the media so it is extremely important to build strong, resilient co-management partnerships.

- In order to make the relationship between researchers and ‘stakeholders’ resilient to outside forces such as adverse media attention, effort needs to be expended on increasing the strength of such relationships by investing in activities that are valued by the stakeholders, such as employment and capacity building, as well as respecting their values.

Chapter 3

Using spatial information to assist Indigenous peoples shape management across local and regional scales



In this chapter, I combine historical spatial datasets for hunting and dugong distribution and relative abundance using a spatial risk assessment approach to inform the spatial design of management arrangements for dugongs in Torres Strait. I also combine the quantitative assessment of risk with knowledge of the jurisdictional arrangements to develop a decision framework to inform the delineation of management responsibilities at local and regional scales. A modified version of this chapter has been prepared for submission to *Conservation Biology* as "Using spatial information to assist Indigenous peoples shape management across local and regional scales." Only dugongs were considered in this chapter because the necessary spatial information for green turtles was not available. Models of distribution and relative density of green turtles, based on aerial survey data, have not yet been developed for Torres Strait.

Chapter 3. Using spatial information to assist Indigenous peoples shape management across local and regional scales

3.1. Introduction

As explained in Chapters 1 and 2, in recent decades, international and national agreements and instruments have recognised the rights and interests of Indigenous peoples and local communities in relation to the conservation of biodiversity. The resultant enabling national legislation (e.g., Australia's *Environment Protection and Biodiversity Conservation Act 1999*) to protect biodiversity values, including marine mammals, typically has several objectives: (1) to prevent further decline in the harvested stocks; (2) to protect the culture of Indigenous peoples by allowing them to use marine resources for particular purposes (which differ slightly in each jurisdiction); and (3) to encourage co-management (Berkes et al. 2001b; Havemann et al. 2005; Mooers et al. 2007; Findlay et al. 2009; Robards and Lovecraft 2010). For example, some communities in the Arctic and Australia have developed co-management arrangements with governments, including community-based management plans to regulate their harvests of marine mammals (Cain 2004; Havemann et al. 2005; GBRMPA 2007; Havemann and Smith 2007; Hovelsrud et al. 2008; Huntington 2009; Nursey-Bray and Rist 2009; Robards et al. 2009).

Co-management arrangements for marine mammals harvested by Indigenous peoples typically include obligations by all parties to collect the data required to improve options for sustainable management. These obligations have generally resulted in considerable government investment in western scientific approaches aimed at strengthening the knowledge base. However, a key challenge is that both ecological and logistical factors make it difficult to collect the information required to determine sustainable catch levels. In particular, natural variability in the populations of the target species, including population size and demographic parameters, coupled with variation in harvest patterns, often leads to uncertainties in estimates of sustainable harvest or indicators of population status. Additionally, the effects of environmental stochasticity on life-history parameters may be confounded with the density dependent effects of resource extraction (e.g., Marsh and Kwan 2008). The collection of demographic information on the target stock is also challenging, especially in remote communities because of the demanding logistics, high expense and variable local capacity (Harwood et al. 2002; Robards et al. 2009). These challenges can create uncertainty in decision-making despite considerable investment in research.

The links between co-management and research outputs are often tenuous. There may be a mismatch in spatial scale between the research outputs (large scale) and the area used and managed by individual communities (local scale; Berkes 2006; Cumming et al. 2006; Campbell et al. 2009). In addition, as explained in Chapter 1, Indigenous communities are understandably reluctant to use the results of research as a basis for management when the results do not support their expectations based on experience or Traditional Knowledge. Sometimes these concerns have proved correct and incorporating Indigenous Knowledge or other forms of local knowledge has improved the management process (e.g., Huntington 2000).

Dugong populations in northern Australia illustrate these management challenges. Although dugongs have protected status under Australian legislation, Aboriginal and Torres Strait Islander Traditional Owners can legally harvest them throughout their Australian range (see Chapter 2). As explained in Chapter 2, the Torres Strait region has the largest dugong population in the world (Marsh et al. 2002). In this region, dugongs are of high cultural value to Torres Strait Islanders and the people from the coastal villages of the Western Province of Papua New Guinea, who have hunted them for thousands of years (McNiven and Bedingfield 2008).

Driven by concerns about sustainability (Heinsohn et al. 2004; Marsh et al. 2004b), Islanders, scientists and government agencies agree that the Torres Strait dugong population needs improved management to ensure maintenance of both tradition and sustainability. Despite the mutual acknowledgment of these concerns, management is challenging for several reasons. First, the Torres Strait region is remote and thus the capacity at government or community levels to implement management or enforce legislation has been limited. Second, quantifying key parameters such as dugong population size, natural and anthropogenic mortality is difficult. Finally, because telemetry and genetic studies have revealed that dugong populations operate at large ecological scales (McDonald 2006; Sheppard et al. 2006), there is a mismatch between the dugong's ecological scale and the scale of community-based management.

The implementation of both research and community-based initiatives assist the management of the Torres Strait dugong population. The need for management combined with the importance of involving local communities have led to considerable investment in both co-management at the local scale (see Chapter 1) and in recording the spatial patterns of hunting (Hudson 1986; Kwan 2002; this study; see Chapter 8). From a western science perspective, a central component of management is the aerial survey data, collected regularly since 1987 (Marsh et al. 2007). These surveys have not detected long-term trends in the populations possibly because the power of such surveys to detect trends is usually weak unless the change is very large (Taylor et al. 2007). Nonetheless, the surveys have provided significant information on the distribution and relative abundance of dugongs in the Torres Strait region and thus aerial surveys remain a central component of dugong management in this region.

I aimed to assist governments and communities design effective management arrangements that overcome the mismatch between ecological and management scales, by combining the historical spatial datasets for hunting and dugong distribution and relative abundance using a spatial risk assessment approach. I then developed a decision framework that can be used to clarify appropriate areas for both local and regional scales of management and thus better inform the potential relative roles of government and community in co-management arrangements. I discuss this decision framework in the context of dugong management in northern Australia, marine conservation planning more generally and as a tool that can add value to the investments in large-scale surveys of marine and migratory species (see Grech et al. 2011).

3.2. Methods

I assumed that the likelihood of dugongs being killed by hunting is a function of hunting effort and dugong density and that the spatial pattern of hunting effort has been stable since the 1980s when the use of outboard-powered vessels became common. Hunting effort and dugong density are not independent; Indigenous inhabitants of the Torres Strait region are more likely to hunt in areas where dugong density is high relative to other areas because that is where they are more likely to encounter dugongs. Hunters are also more likely to hunt in areas where the likelihood of dugongs escaping is lower (e.g., shallow water and reefs). In areas where there is high hunting effort, dugongs may exhibit elusive behaviour, occupy deeper water or feed in shallow water only at night. However, the evidence of such changes is anecdotal and could not be quantified. I used a spatial risk assessment approach to quantify the exposure of dugongs to hunting, as described below.

3.2.1. The spatial pattern of hunting effort in the Torres Strait

Hunters living in 10 of the 16 inhabited islands in the Australian jurisdiction of the Torres Strait (Figure 3.1) catch most of the dugongs in Australian waters from dinghies powered by outboard motors. Hunters from the six most easterly islands with significant human communities were not included in this analysis because they catch dugongs only occasionally (Johannes and MacFarlane 1991). Dugongs are also caught by Kiwai hunters from villages along the southern coast of Papua New Guinea (Hudson 1986; Figure 3.1). These hunters mostly use outboard powered banana boats and canoes and nets to catch dugongs (Hudson 1986; Marsh et al. 2002). The Northern Peninsula Area communities on the adjacent Australian mainland were outside the scope of this study because, unlike the situation on the Torres Strait islands and in the coastal villages of Papua New Guinea, the Northern Peninsula Area communities used land transport in hunting and I did not have the opportunity to interview them. Therefore, it was inappropriate to extrapolate the information I had on hunting patterns to these communities.

I categorised the Torres Strait region into major or minor hunting areas on the basis of empirical information on the hunting patterns of Australian and Papua New Guinea Western Province (Kiwai) hunters. For the Australian hunters, data were collected on the hunting patterns of Inner Island (Kaiwalagal) hunters of Hammond and Thursday Islands between 2005-2006 (see Chapter 8; Figure 3.1) and Mabuaig Island (Goemulgal) hunters between 1997-1999 (Kwan 2002; Marsh and Kwan 2008; Figure 3.1). The hunting patterns of Papua New Guinea Western Province (Kiwai) hunters were inferred from the records of hunters selling their catch at markets in Daru between 1978-1982 (Hudson 1986; Marsh 1995a). As explained in Chapter 7, Inner Island (Kaiwalagal) hunters recorded the distance from their home island where they caught dugongs (i.e., not the location dugongs were caught). Kwan (2002) and Hudson recorded the name of the reef where each dugong was caught for the Mabuaig Island (Goemulgal) and Papua New Guinea Western Province (Kiwai) hunters, respectively. The spatial data on hunting effort favor successful hunting trips as information was recorded only when dugongs were caught.

The information on hunting patterns described above, and the path-distance analysis tool in ArcGIS® 9.3 (Environmental Systems Research Institute 2004), were used to estimate the spatial extent of hunting areas in Torres Strait. I assumed that hunters in the 10 hunting communities of Torres Strait (Figure 3.1) traveled the same distance to hunting areas as the Inner Island (Kaiwalagal) and Mabuaig Island (Goemulgal) hunters. The ArcGIS® path-distance analysis tool was used to estimate the distance that hunters traveled during a hunting trip from boat ramps in the 10 communities. The ArcGIS® path-distance analysis tool allowed me to account for the area that is actually traversed by a dinghy (i.e., the dinghy must travel around an island). I assumed that dugongs were hunted on all the reefs identified by the Mabuaig Island (Goemulgal) and Papua New Guinea Western Province (Kiwai) hunters, and I estimated the total area of reef tops using ArcGIS® 9.3. In both analyses, I used information on the recorded frequency of dugong catches to designate major and minor hunting effort (data from Chapter 7; Hudson 1986; Kwan 2002).

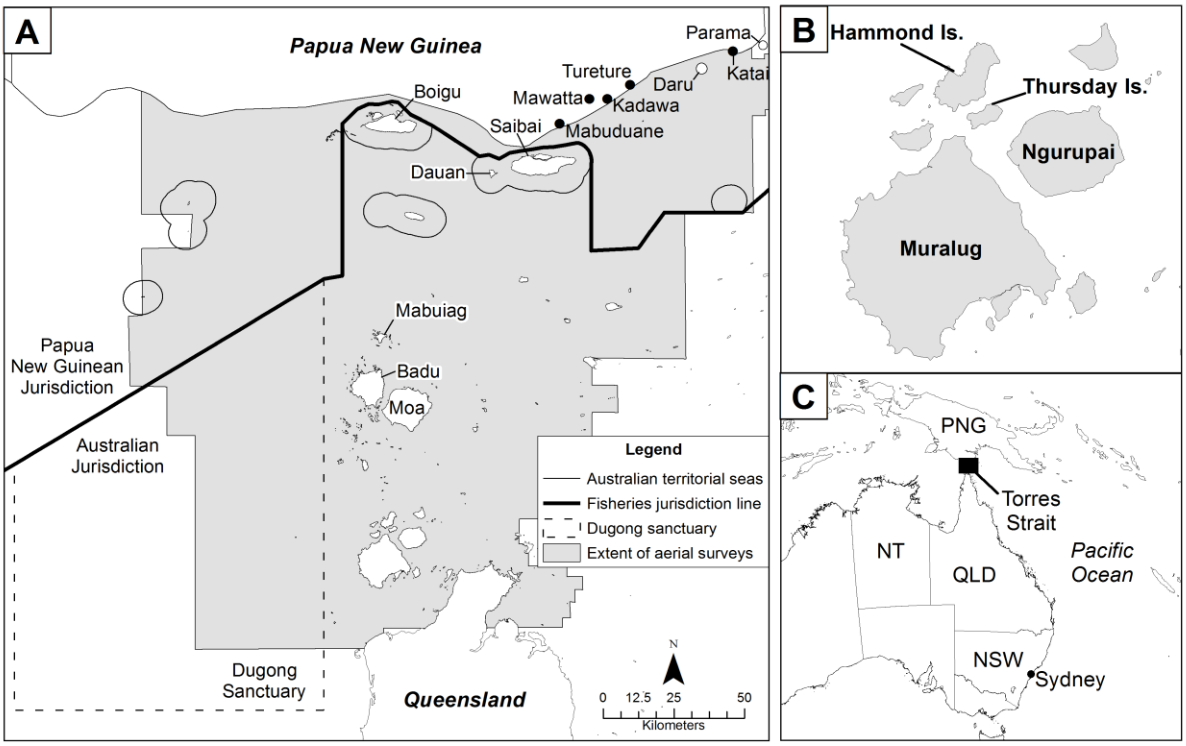


Figure 3.1. (a) Torres Strait showing the extent of dugong aerial surveys, location of hunting communities, Australian territorial seas, fisheries jurisdiction line and the dugong sanctuary; (b) the hunting communities of the Inner Islands of Torres Strait; and (c) Torres Strait relative to Australia and Papua New Guinea. The fisheries jurisdiction line delineates Australian and Papua New Guinean waters. The Northern Peninsula Area hunting communities on the adjacent Australian mainland are beyond the scope of this analysis because they use land transport in association with catch vessels to catch dugongs.

3.2.2. Dugong density

Standardised aerial surveys for dugongs were undertaken over ~30,000 km^2 of Torres Strait (the aerial survey region; Figure 3.1) approximately every five years from 1987 to 2006 (Marsh et al. 1997; 2004b; 2007). I used the data on dugong distribution and abundance from this time series and the method of Grech and Marsh (2007) and Grech et al. (2011) to develop a spatially explicit dugong population model for the aerial survey region. The model accounts for temporal changes in the use of local areas by dugongs, including movements resulting from events such as sea grass dieback (Marsh and Kwan 2008). I estimated dugong distribution and relative abundance at a cell size of 2 km x 2 km. Based on the relative density of dugongs estimated from the model and a frequency analysis, I classified the dugong density in each cell in the aerial survey region as very high (relative density > 0.5 dugongs/km^2), high (0.5 – 0.25 dugongs/km^2), medium (0 – 0.25 dugongs/km^2) and low (0 dugongs/km^2) (Grech and Marsh 2007; Grech et al. 2011).

3.2.3. Risk estimation

I overlaid the spatial models of hunting effort and relative dugong density to estimate the proportion of the area of dugong habitats that are within major and minor hunting areas. I assumed that the risk to dugongs from hunting increased with increased hunting effort and dugong density (see Table 3.2). I classified areas as 'low risk' when: (1) hunting effort was minor or (2) hunting effort was major and dugong density was low. I classified areas as 'medium risk' when hunting effort was major and dugong density was medium. Areas that had a very high or high density of dugongs and major hunting were classified as 'high risk'. Risk estimation should not be affected by small scale movements of dugongs (e.g., any changes in dugong behaviour from increased hunting effort) because dugong density is based on the density of dugongs from surveys over 20 years.

3.2.4 Spatial decision framework

I developed a decision framework (see Table 3.3) to inform the spatial arrangements for the management of dugong hunting in the Torres Strait by combining this quantitative assessment of risk with knowledge of the jurisdictional arrangements, to inform the delineation of management responsibilities at local and regional scales (see Table 3.3; Figure 3.2d).

3.3. Results

3.3.1. Hunting effort

As shown in Chapter 7, Inner Island (Kaiwalagal) hunters reported catching dugongs up to 30 km from their home islands; however, most dugongs (83%) were caught in shallow water relatively close (within 10 km) to the hunters' home communities

(Table 3.1). 87% of the dugong hunting trips by Mabuaig Island (Goemulgal) hunters were to reef tops within 30 km of Mabuaig Island, and 39% of trips were within 10 km of this island (Kwan 2002; Marsh and Kwan 2008; Table 3.1). Papua New Guinea Western Province (Kiwai) hunters mainly caught dugongs on reefs close to (<30 km) their communities or on the Auwamaza or Warrior Reefs (Hudson 1986; Table 3.1). Most of the hunting on the Warrior Reefs was north of Moon Passage (around 9°35.0'S, 142° 47.0'E) (Hudson 1986). Anecdotal evidence suggests that this situation still applies.

Table 3.1. Number of successful hunting trips to various distances from Hammond, Thursday and Mabuaig Islands and Papua New Guinea. The percentage of hunting trips in the various categories for which the precise hunting location was recorded is in brackets along with the percentage of trips from each area for which the hunting location was not recorded.

Communities	*Distance between community and hunting location*			*% trips for which hunting location not recorded*
	< 10 km	*10 – 30 km*	*> 30 km*	
Kaiwalagal (Hammond and Thursday Islands) †	63 (83)	13 (17)	0	50
Goemulgal (Mabuaig Island) ‡	56 (39)	70 (49)	18 (12)	29
Kiwai (Papua New Guinea)‡	127 (30)	201 (48)	95 (22)	45

† habitat of catch unknown

‡caught on reefs/sandbanks

Within the aerial survey region, I designated major hunting areas as: (1) cells within 30 km of the 10 inhabited islands in western Torres Strait; (2) the reefs adjacent to the Papua New Guinean hunting communities; and, (3) the reef tops in the Warrior Reef complex (9,556 km^2; 33% of the aerial survey region; Figure 3.2). Minor hunting areas within the aerial survey region were classified as the regions outside the major hunting areas (19,745 km^2; 67%; Figure 3.2). Minor hunting areas include large areas where there is likely to be no hunting. However, hunters traverse these areas during other activities (e.g., crayfishing) so hunting could occasionally occur opportunistically in these areas. Illegal Unreported and Unregulated (IUU) fishers may also catch dugongs and marine turtles.

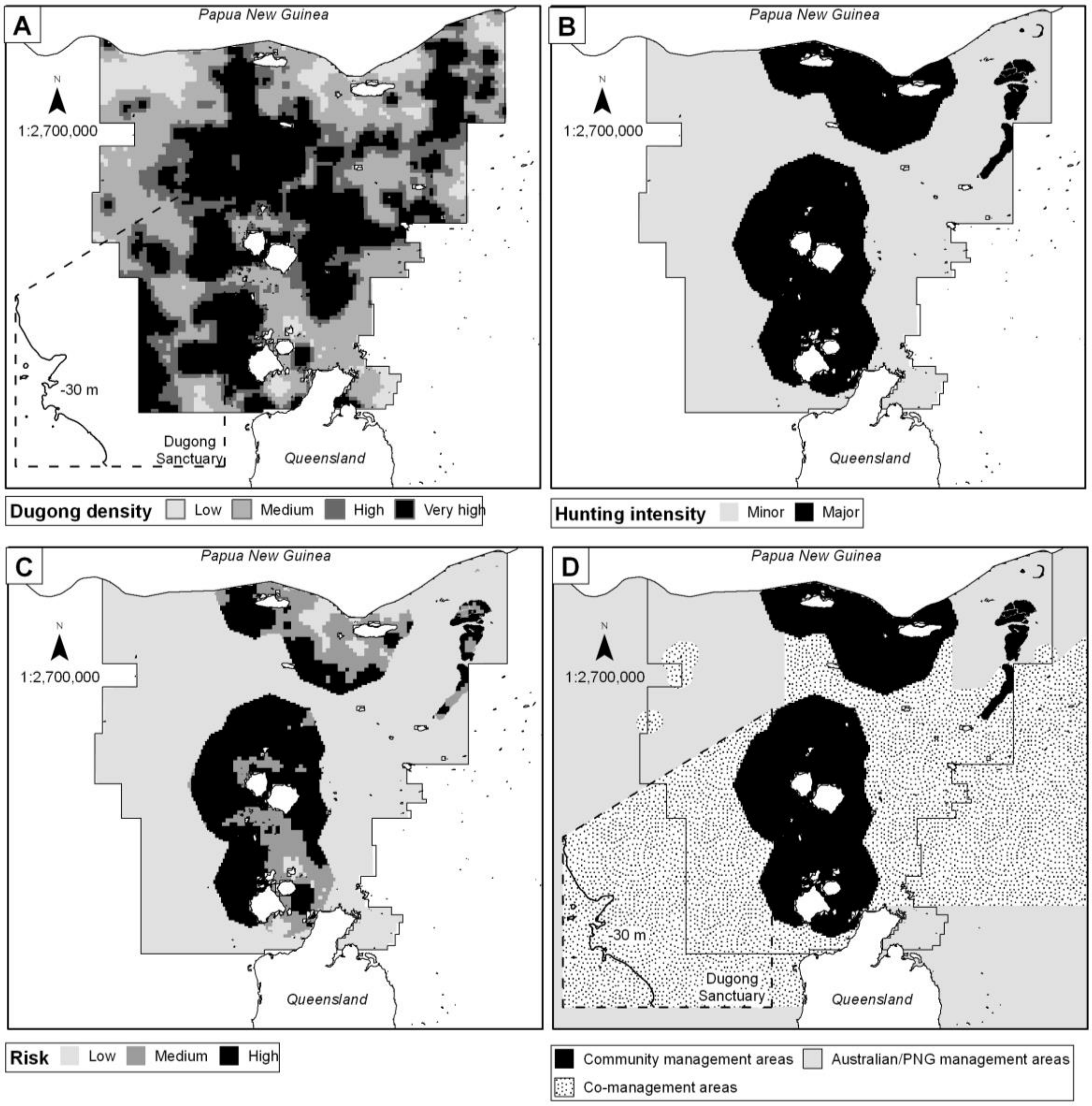


Figure 3.2. Torres Strait showing (a) dugong relative density (very high, high, medium and low) in the aerial survey region, determined from the dugong density model; (b) major, and minor hunting areas around inhabited western islands and PNG coastal villages; (c) areas of low, medium and high risk to dugongs; and (d) the combined community management areas, co-management areas and government management areas where spatial closures to hunting could be negotiated and the existing Dugong Sanctuary where enforcement is required. The high relative density of dugongs at the western edge of the aerial survey region in (a) indicates that dugong habitat in Torres Strait extends west of the aerial survey region in the Dugong Sanctuary.

3.3.2. Dugong density

The model indicated that more than half (57%) of the ~30,000 km^2 Torres Strait survey area supported a very high or high density of dugongs (Figure 3.2). The areas of highest relative density were between Buru and Mabuaig Islands and along the Warrior Reefs (Figures 3.1 and 3.2). The spatially-explicit population model showed areas of very high and high dugong density at the western limits of the survey region including parts of the Torres Strait Dugong Sanctuary (Figure 3.2), which clearly shows that the aerial surveys did not cover the entire habitat for dugongs.

The data demonstrate that 38% of very high dugong density areas and 32% of high dugong density areas were at 'high risk' from hunting (Table 3.2); 28% of medium dugong density areas were at 'medium risk' from hunting; and 62% of very high dugong density areas, 68% of high dugong density areas, 72% of medium dugong density areas and all low dugong density areas were at 'low risk' from hunting.

Table 3.2. (A) The assumed risk to dugongs from major and minor hunting in areas of low, medium, high and very high dugong density; and (B) area (km^2) and proportion of the four dugong density levels (percentage) classified as low, medium and high risk from hunting.

Hunting intensity		*Dugong density*			
		Low	*Medium*	*High*	*Very high*
A	*Minor*	Low risk	Low risk	Low risk	Low risk
	Major	Low risk	Medium risk	High risk	High risk
B	*Minor*	1683 (73)	7372 (72)	3965 (68)	6725 (62)
	Major	634 (27)	2915 (28)	1890 (32)	4117 (38)

3.3.3. Spatial decision framework

The spatial decision framework suggests that different types of management would be appropriate in different parts of the Torres Strait region and that the relative importance of different co-management partners changes with spatial scale (Table 3.3). Hunting generally occurs <30 km from communities (Table 3.1), making it appropriate for individual communities to manage dugong hunting within their Community Management Areas (Table 3.3). Groups of communities should be encouraged to coordinate management of areas at high risk from hunting if their Community Management Areas are contiguous or overlap (Table 3.3). Government assistance is needed for matters that cannot easily be dealt with by communities or at local scales. For example, government assistance may be needed in dealing with hunters in the wrong areas (i.e., not their sea country). In addition, because they are further from communities, some areas at low risk from hunting (i.e., minor hunting areas) in the Community Management Areas of communities are more difficult for communities to police than high risk areas, without a substantial increase in overall capacity of the community, particularly enforcement capability. Thus, co-management will be important in these areas. Such management may be needed to ensure that hunting effort does not increase into those areas. Governments should also have a greater role in the management of areas at low risk from hunting outside of the control of individual or combined communities, where the management of threats other than hunting is a major consideration. The Australian and Papua New Guinean Governments also need to negotiate complimentary management arrangements to manage the shared dugong stock (Table 3.3).

Table 3.3. The steps in the generic spatial decision framework to clarify the relative roles of different co-management partners at different spatial scales in the management of resources of conservation concern and as applied in the specific case of dugongs in the Torres Strait.

Step	Generic Spatial Decision Framework	Torres Strait Example
1	Develop spatial model of distribution and relative abundance of resource of conservation concern at a regional scale e.g., from species distribution modelling (Guisan and Thuiller 2005); habitat mapping; wildlife surveys; traditional ecological mapping; remotely sensed imagery; etc.	Spatial model of dugong distribution and relative abundance from time series of aerial surveys
2	Develop spatial model of distribution and relative intensity of anthropogenic impact at regional scale e.g., from data held by relevant management agencies; local knowledge (e.g., Aswani and Lauer 2006); traditional knowledge mapping (Calamia 1996); occupancy and use mapping (Tobias 2000); etc.	Spatial model of hunting effort in Torres Strait from records/surveys of hunters
3	Spatially assess risks to resource and identify areas of conservation concern	Assessment of risk to dugongs from hunting leading to identification of areas of conservation concern
4	Overlay map of jurisdictional and community boundaries from relevant agencies and community mapping	Overlaid information on individual Community Management Areas (not depicted in Figure 2d), Torres Strait Protected Zone (TSPZ) boundaries and Torres Strait Dugong Fishery Management Area.
5	Identify areas for management by: (1) Individual communities, (2) Groups of communities in cross-community co-management agreements, (3) Communities and government in co-management agreements, (4) Individual governments; (5) Intergovernmental agreements.	Identification of areas for predominant management by: (1) Individual Torres Strait Islander communities, (2) Groups of communities within Australia or PNG, (3) Communities and Australian and/or PNG governments (e.g., through the Protected Zone Joint Authority (PZJA)), within the Torres Strait Protected Zone (TSPZ); (4) Australian and/or PNG governments unilaterally or bilaterally in complimentary arrangements outside the TSPZ.

3.4. Discussion

As explained in Chapter 1, the management of vagile marine wildlife subject to traditional use is challenging because mismatches occur not only between the spatial scales of ecology and management but also between management approaches (e.g., top-down and community-based approaches). Thus, managing such species requires a combination of approaches at both local and regional scales. Approaches based on a spatial decision framework such as the one developed here can assist in shaping an appropriate management regime for such species. In particular, such a framework could help in identifying areas of conservation concern appropriate for management by different co-management partners and their relative importance: individual communities, groups of communities, and government(s) in unilateral or bilateral arrangements.

As in many other situations (Cumming et al. 2006; Campbell et al. 2009; McCook et al. 2010), in northern Australia there is a mismatch between the ecological scale at which dugongs operate, the local scale of community-based management and the complex state, national and international statutory management arrangements. This research has generated a comprehensive picture of the risk to dugongs from hunting at spatial scales that range from the entire Torres Strait aerial survey region to the local scales of individual cells (2 km x 2 km) relevant to communities. I have demonstrated that the risk is spatially variable and that large areas of highly significant dugong habitat are at only low risk from hunting. Also of importance was the finding that some of the very high and high dugong density areas where hunting effort is low or zero extend further west than the aerial survey region and are thus outside the influence of hunting (Figure 3.2). The spatial variability of the risk to dugongs in Torres Strait from hunting has resulted in numerous areas that operate as *de facto* dugong sanctuaries. These areas may be one reason that a large population of dugongs has persisted in Torres Strait despite the dugong being hunted there for thousands of years (McNiven and Bedingfield 2008).

The results indicate that different types of dugong management would be appropriate in different parts of the region. At a local scale (i.e., close to communities) community-based management is appropriate. Hunting generally occurs <30 km from communities and can thus be managed within the Community Management Areas of individual communities or a combination of communities with contiguous or overlapping management areas. Local scale management initiatives such as these may achieve some local conservation objectives, but they do not generally achieve regional conservation objectives without broader regional conservation planning (Mills et al. 2010). For example, such local initiatives may enable hunters to regulate their own use and to exclude others from the local area, but they do not enable local communities to exclude the use by others more broadly or to regulate other types of risks (Berkes et al. 2006). Consequently, efforts to conserve dugongs at the community level may be counteracted by the actions of groups at larger scales (see Chapter 4; Grayson et al. 2010). Each of the community-based marine turtle and dugong management plans recently developed by 15 Torres Strait communities recognises this need by mentioning the intent to develop collaborative arrangements with surrounding Islander communities and government agencies in the implementation of their plan. In addition, although not in place at present, each community-based plan envisions that it will eventually form part of an overarching regional management framework. The spatial decision framework potentially informs this approach by identifying areas where cooperation among communities will be required to reduce the risk of hunting to dugongs and where governments will need to facilitate such coordination as well as managing external threats (Table 3.3). Indeed, the results show that in some areas, cooperative management through partnerships among communities, and between communities and government agencies, may be more effective than individual community-based management. An overarching framework could also include spatial closures to pre-empt future expansion of hunting and assist in improving public perception of Indigenous hunting by demonstrating that hunting is not occurring everywhere.

Importantly, I also demonstrate that there are areas of high dugong density in Torres Strait that are at low risk from hunting and outside of individual Community Management Areas and thus outside the aegis of individual, or combined community-based management. The management of such areas is likely to require significant commitment from government management agencies and top-down management may need to be involved to overcome broader scale risks. Therefore, at the scale of the Torres Strait region an integrated approach to planning is needed to ensure that: (1) local scale initiatives are coordinated at an appropriate scale, and (2) complementary co-operative measures are applied in areas outside the Community Management Areas. This approach should include the enforcement of the Dugong Sanctuary in western Torres Strait, which although gazetted in 1986, has not been actively enforced (Kwan et al. 2006). This approach may also need to be re-evaluated in light of climate change.

Cooperative management is essential because the management of Indigenous hunting has typically been separated from the management of other risks to the sea country of Indigenous peoples. Hunters have tended to defend their hunting rights while advocating the need to mitigate or prevent impacts from activities other than hunting

(Huntington 2009). Although Indigenous people control their own use of marine mammals, governments have typically retained responsibility for the management of other risks that occur at broader scales or originate from other stakeholders e.g., in Australia's Great Barrier Reef Marine Park, which is adjacent to Torres Strait to the south-east (Dobbs et al. 2008). Migratory marine species, such as dugongs, typically have home ranges that span larger geographic areas than most local management initiatives and consequently they are exposed to broad-scale risks in much of their range. The need to protect large areas of the marine environment is increasingly recognised (Halpern 2003; Lubchenco et al. 2003; Norse et al. 2005; Hilborn et al. 2006; Wood et al. 2008) and is progressively being used to: (1) protect the habitats of marine mammals (Hooker and Gerber 2004; Dobbs et al. 2008; Grech and Marsh 2008; Notarbartolo-di-Sciara et al. 2008; Bailey and Thompson 2009; McCook et al. 2010), and (2) mitigate the impacts of various broad-scale risks to marine mammals and their habitats (e.g., climate change, coastal development, oil and gas development, vessel strike, pollution, fishing impacts etc; Hooker and Gerber 2004; Grech et al. 2008).

My approach highlights the need for conservation planning that enables community-based management to be part of the broader management framework necessary for species that operate at large ecological scales. Regional-scale planning is needed to ensure that broader-scale risks, which are not regulated under local-scale initiatives or cooperative management arrangements, will be addressed. Management of broad-scale risks (e.g., hunting by outsiders (legal and illegal), climate change, oil and gas development, increased shipping, fisheries bycatch, Illegal Unreported and Unregulated fishing) require regional planning and support from one or more government agencies (Sejersen 2001; Huntington 2009). Consequently, although management of broad-scale risks may need to rely on a top-down approach, the design of this approach could be enhanced by conservation planning conducted within a co-management framework such as the one developed here (Table 3.3). Use of a spatial decision framework such as the one developed here can structure information in a manner that provides a starting point for discussions and negotiations about where community-based management or top-down management is most suitable, what partnerships might be needed, and what management tools might be used. For example, the increasing use of economic instruments associated with spatial management could see negotiations focussing on what incentives might be offered/accepted in exchange for spatial closures (Milne and Niesten 2009; Gjertsen and Niesten 2010).

This approach may also be applicable to managing the hunting of other species of marine mammals (including beluga, bowhead, gray and humpback whales, harbour, northern-fur, ribbon, ringed and spotted seals and stellar sea lions in Alaska) using data collected for stock assessments under the *US Marine Mammal Protection Act 1972* (Allen and Angliss 2010). It may also be used to assist with spatial planning in the Arctic to manage the changing uses of the area due to receding sea ice (e.g., changes in Indigenous hunting, increased shipping, and oil and gas exploration; Hovelsrud et al. 2008; Huntington 2009). Such use of spatial models, which integrate data from different sources, adds value to the investment in large-scale surveys of marine and migratory species because it assists in identifying the relative contributions that could be made by different co-management partners at different spatial scales. Thus, my hypothesis that different forms of management will be required at different spatial scales could also be tested for other species of marine mammals (see Chapter 1, Section 1.4).

3.5. Chapter summary

- In this chapter, to inform the spatial design of management arrangements in Torres Strait, I evaluated the risk to dugongs from hunting based on spatial data about hunting patterns and dugong distribution and relative abundance.

- Data on dugong hunting patterns were obtained from Australian and Papua New Guinean hunters. For the Australian hunters, data were collected from the Inner Island (Kaiwalagal) hunters of Hammond and Thursday Islands between 2005-2006 and Mabuaig Island (Goemulgal) hunters between 1997-1999. The hunting patterns of Papua New Guinea Western Province (Kiwai) hunters were inferred from the records of hunters selling their catch at markets in Daru between 1978-1982.

- Data on dugong distribution and abundance obtained from the time series of standardized aerial surveys for dugongs undertaken over ~30,000 km^2 of Torres Strait approximately every five years from 1987 to 2006. A spatially explicit dugong population model for the aerial survey region was developed using the method of Grech and Marsh (2007).

- The risk to dugongs from hunting was spatially variable. More than 60% (10,690 km^2) of the areas supporting very high and high densities of dugongs are at only low risk from hunting because hunting is largely restricted to areas less than 30 km from inhabited islands.

- The areas accessed by hunters also included a substantial amount (6,007 km^2) of the very high and high dugong density areas, most of which were the 'sea country' of individual communities.

- The spatial decision framework I developed suggests that different types of management would be appropriate in different parts of the Torres Strait region and that the relative importance of different co-management partners changes with spatial scale.

- The interaction between important dugong areas and hunting areas indicates that community-based management of dugong hunting will be important at local scales.

- Formal protection of areas that are not currently hunted should provide long-term regional benefits by safeguarding against local pressures on the dugong stock, including data uncertainties and difficulties in implementing community-based management.

- At the Torres Strait regional scale, cooperation among communities will be important and governments (Queensland, Australian and Papua New Guinea) will be necessary partners in co-management arrangements, particularly beyond Community Management Areas.

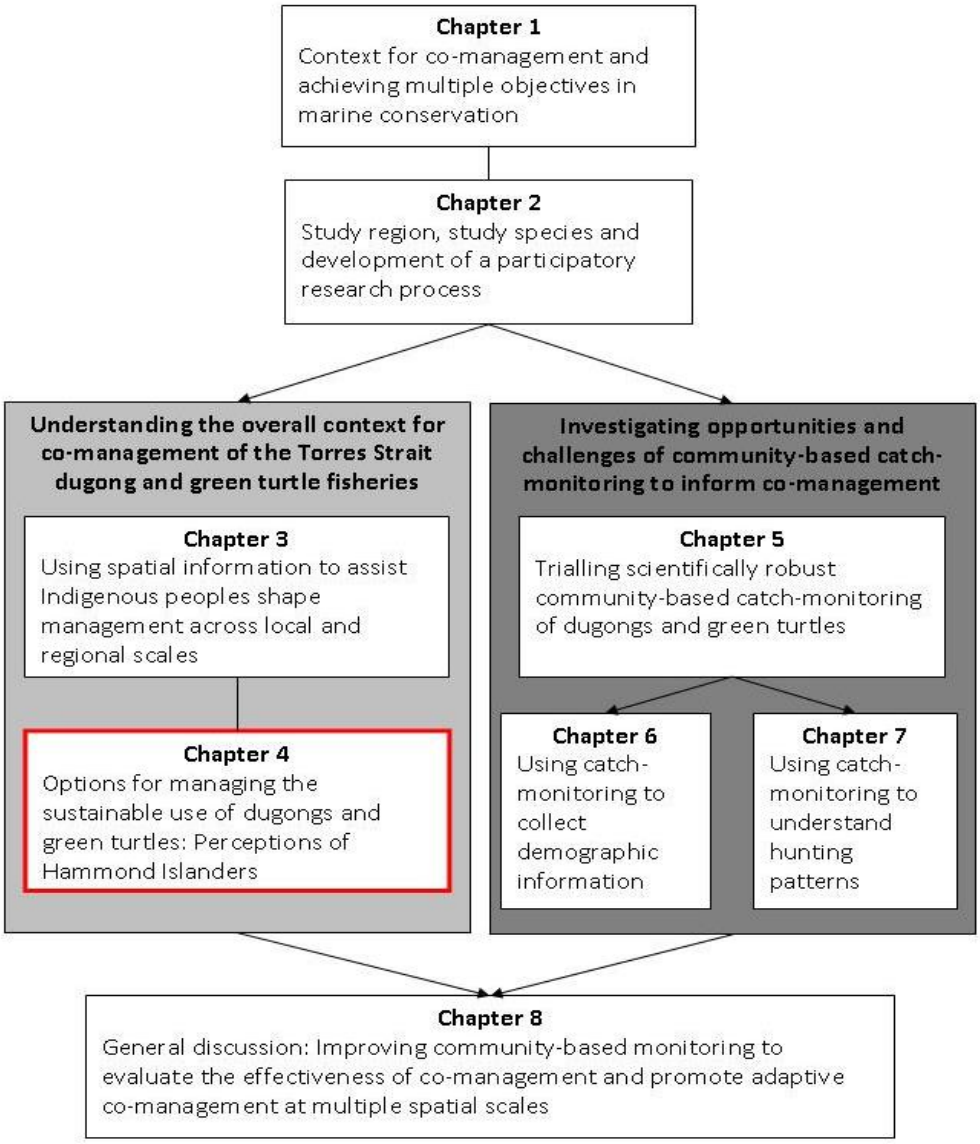
- Governments should have a greater role in the management of areas at low risk from hunting which are outside of the control of individual or combined communities, and where the management of threats other than hunting is a major consideration.

- Use of a spatial decision framework such as the one developed in this chapter can structure information in a manner that provides a starting point for discussions and negotiations about where community-based management or top-down management is most suitable, what partnerships might be needed, and what management tools might be used.

- The use of spatial models, which integrate data from different sources, adds value to the investment in large-scale surveys of marine and migratory species because this approach can assist in identifying the relative contributions that could be made by different co-management partners at different spatial scales.

Chapter 4

Options for managing the sustainable use of dugongs and green turtles: perceptions of Hammond Islanders in Torres Strait



In this chapter, I investigated Islanders' thoughts and aspirations regarding dugong and green turtle management by interviewing hunters and Islander elders from Hammond Island community in the Kaurareg nation of Kaiwalagal (inner islands). With the assistance of my Indigenous research counterpart, Stephen Ambar, I conducted 15 open-ended semi-structured interviews regarding the need for local management, their perceptions of different management tools and multi-scale co-management from a community perspective. I then evaluated the opportunities and challenges of different approaches for managing dugong and green turtle hunting in Torres Strait. A modified version of this chapter is published in *Conservation and Society* as "Options for managing the sustainable use of green turtles: Perceptions of Hammond Islanders". This paper in *Conservation and Society* is licensed under a Creative Commons Attribution 3 license.

Chapter 4. Options for managing the sustainable use of dugongs and green turtles: perceptions of Hammond Islanders in Torres Strait.

4.1. Introduction

As explained in Chapter 1, the appropriate management approach for common pool resources; community-based management, co-management or government-driven management, depends on factors such as the scale of the resource and the types of use, the degree to which stakeholders are willing to share decision-making power, and the capacity of various stakeholders to be involved (Berkes 2005; Campbell et al. 2009). Co-management is likely to be a more appropriate approach than either community-based management or top-down government-driven management for managing the use of migratory marine resources such as dugongs and green turtles. Co-management will be more appropriate, especially when people: (1) have rights to use the resources and exclude or limit the activity of non-community members; and (2) require access to the resources for livelihood and cultural survival; and when (3) resource management needs to occur in remote communities or regions.

Compliance and enforcement, both at the community scale and especially at larger scales are major challenges for community-based management (Berkes 2005). People with enforcement powers in communities generally find it difficult to impose local rules on outsiders who also use the resource in other parts of its range (Feeny et al. 1990). Intra community enforcement can also be challenging, especially in small communities, because community rangers find it difficult to impose rules on their family or neighbours, unless there are strong cultural rules (Gibson and Marks 1995). In addition, governments with broad responsibilities for natural resource management are often unwilling (or unable) to delegate management responsibilities to only one interested party (Berkes 1995; Berkes 2005; Campbell et al. 2009). Thus, local communities may not have the capacity to control use across the range of the resource or to prevent exploitation outside the community, leading to the reduction of resources for their community, rendering community-based management ineffective (e.g., as discussed in Chapter 3). Conversely, as discussed below, the government will find enforcement challenging in remote communities also rendering government-driven management ineffective.

Government-driven management may attempt to address the issue of scale by allowing for the participation of multiple stakeholders (Berkes 2005). However, this top-down approach may not adequately ensure compliance of people that have legal rights to use a resource, because it does not always include mechanisms for communities to self-regulate their resource use (Pomeroy and Rivera-Guieb 2006). Indeed, while not always the case, top-down management has been criticised for displacing local knowledge, experience and priorities, which enable communities to self-regulate their resource use (Hilborn 2004; Sagarin and Crowder 2008). Furthermore, when resource users live in remote locations, issues of implementation, enforcement and compliance within communities are challenging for management agencies that are based in distant urban centres (Agrawal 2003; Campbell et al. 2009). In contrast, the partnership approach of co-management systems uses the capacities and interests of local resource users and communities and complements them with the provision of government services such as enabling legislation, conflict resolution, and other assistance (Pomeroy and Berkes 1997; Campbell et al. 2009). Hence, the development of co-management arrangements between government and other stakeholders in management of resource use by Indigenous and local communities has increasingly led to the development of management plans to guide use (Fernandez-Gimenez et al. 2008). These plans may be drafted together, through an iterative process started by the government or the community, or drafted by communities, but usually require the approval of government before they are implemented.

Many tools and/or control measures used in contemporary fisheries management were developed out of traditional management systems used by communities (e.g., closed areas, closed seasons, catch quotas, and size limits; Berkes et al. 2001a). However, traditional and more contemporary approaches tend to differ in the way decisions on when and how to apply the tools are reached (Berkes et al. 2001a). Approaches of traditional societies use the community's observations to decide when to apply management tools and these tools are applied through community norms or rules that are disseminated by the community (Wilson et al. 1994). In contrast, contemporary approaches tend to use broad-scale scientific information to decide when to apply management tools and these tools are applied through formal rules implemented by centralised management agencies (Wilson et al. 1994). Co-management uses aspects of each of these approaches. In particular, a community's observation of a crisis in the stock has been cited as one of the many pre-conditions for successful co-management (Pinkerton 1989), because such a crisis increases the acceptability of using scientific information to implement formal intervention. In addition, community cohesion and multi-scale cooperation among resource users and stakeholders may also influence co-management outcomes (Campbell et al. 2009).

It is my hypothesis that a co-management approach is likely to be most appropriate for managing the Indigenous fishery for dugongs and green turtles in the Torres Strait region of northern Australia for many of the reasons outlined above. As explained in Chapter 2, the Torres Strait/northern Great Barrier Reef green turtle population is one of the largest in the world, but supports traditional harvests from geographically-dispersed sources within Australia from the Northern Territory to southern Queensland and from West Papua in Indonesia, to southern and eastern Papua New Guinea, and to Vanuatu and New Caledonia (Limpus 2008). Similarly, the Torres Strait dugong population is the largest dugong population in the world, and supports traditional harvests from geographically dispersed sources including the northern and eastern coasts of Australia, eastern Indonesia and Papua New Guinea. Both dugongs and green turtles have protected status under Australian national and sub-national legislation, but Aboriginal and Torres Strait Islander Traditional Owners can legally harvest them throughout their Australian range (see Chapter 2). These statutory rights to use dugongs and green turtles, together with their cultural and economic importance to Torres Strait Islanders (see Chapter 2), mean that successful management will be strongly related to the level of involvement of Torres Strait Islander communities in the management of these species.

In this chapter, I present a case study investigating the perceptions of one Torres Strait community, Hammond Island, with regard to managing dugongs and green turtles. I investigate the opportunities and challenges of management from a community perspective. The migratory nature of dugongs and green turtles requires management at a large-scale, which makes community-based management less suitable than co-management. Government-driven management is also less suitable than co-management because Indigenous Australians' right to hunt for non-commercial cultural purposes is protected by law. I provide a potential model for the management of dugongs and green turtles based on community-based management plans, but with broader regional coordination by the Torres Strait Regional Authority. This model is consistent with the spatial decision framework developed in Chapter 3 for dugongs, which suggested that different types of management would be appropriate in different parts of the Torres Strait region and that the relative importance of different co-management partners changes with spatial scale. I also investigated various management tools, and how decisions about when and how to apply these tools are made within communities. The outcomes of this case study have potential implications for other Torres Strait communities, other northern Australian communities and Indigenous coordinating bodies and Papua New Guinean communities. Indeed, the development of dugong and marine turtle co-management plans by 15 other Torres Strait communities has taken several years partly because of the dual need to incorporate both cultural norms and more formal management rules.

4.2. Methods

4.2.1. Study site

Hammond Island is the focus of this study. As described in Chapter 2, Hammond Island is part of the Kaurareg Nation of Kaiwalagal (Figure 2.1) and is a small cohesive community of about 230 people, which is across a narrow (<1 km) channel from Thursday Island, the main administrative centre of Australian Torres Strait.

Like the other Nations in the western part of the Torres Strait, hunters in the Kaiwalagal region mostly harvest green turtles that are caught while feeding or mating. Although most hunting of both dugongs and green turtles is carried out within 10 km of the hunter's community, some hunters were recorded travelling up to 30 km (see Chapters 3 and 7). In addition, both green turtles and dugongs are hunted from a motor powered dinghy using a wap (see Chapter 7). Given the relatively small area of the Torres Strait and these hunting patterns, it is clear that Hammond Island hunters share the local resident dugongs and green turtles with hunters from other Torres Strait communities especially the neighbouring communities in the Kaurareg Nation: Thursday Island, Horn Island and Prince of Wales Island. At a larger spatial scale the dugongs and green turtles are shared by other Torres Strait communities, Northern Peninsula Area communities, and green turtles are shared even further afield into the Northern Territory as well as communities from other countries (e.g., Papua New Guinea (for both species) and Indonesia, Vanuatu and New Caledonia (for green turtles)).

Chapter 2 describes the management arrangements of the Torres Strait dugong and green turtle fisheries. These arrangements include regulations under the *Torres Strait Fisheries Act 1984* and a recent shift towards community-based approaches. As explained in Chapter 1, since 2008, the Australian Government has supported 15 communities to develop and implement community-specific co-management plans for dugongs and marine turtles. In addition to hunting, other sources of mortality of dugongs and green turtles in Torres Strait include seagrass dieback, illegal foreign fishing, and ghost nets.

4.2.2. Data collection and analysis

Data collected and analysed in this chapter compliment data collected for the community-based catch-monitoring project (see Chapters 5-7) to assist two neighbouring Torres Strait communities, Hammond Island and Thursday Island, collect information relevant to the management of their traditional dugong and green turtle harvests. The first stage of the project was to meet with the Chair of the Hammond Island Community Council to discuss the project's scope and direction. Following advice from the Hammond Island Council, my Indigenous counterpart, Stephen Ambar and I interviewed two groups of people: active hunters and elders that had been hunters in the past. These two groups were interviewed because they are closest to the issue and would be most affected by any changes resulting from management. In Torres Strait, dugong and green turtle hunting is exclusively a male activity and therefore all of the interviewees were male.

With the help of Stephen Ambar (the Community Ranger employed on the project), I conducted 15 open-ended semi-structured interviews with 13 hunters and three elders (two hunters were interviewed together, and are analysed as one interview). The total number of hunters on Hammond Island was 26, and 21 of these were participating in the catch-monitoring project (those who were not participating were not convinced that Hammond Islanders would be given the responsibility of managing their own use of dugongs and marine turtles and this was the same reason they did not participate in the interviews). Of the 13 hunters interviewed, 12 were participating in the catch-monitoring project and one was not. The nine hunters who were participating in the catch-monitoring project but who were not interviewed were either away from the island or were busy working at the time of the interviews. Only one elder approached did not wish to be interviewed.

Ambar organised the interviews and conducted two interviews alone; Ambar and I conducted the other interviews. Interviews were digitally recorded except in one case in which I scribed the responses. I transcribed the digitally recorded interviews and the transcriptions were given to the participants to ensure that there had been no misunderstandings. The digital recordings and transcribed interviews are stored in password protected computer files at James Cook University according to James Cook University Ethics requirements under Human Ethics Approval Number H1805.

I chose to use open-ended semi-structured interviews because I was interested in gaining rich information from experts rather than more superficial information from a larger selection of participants that could be obtained using a questionnaire (Kvale

1996). I also considered that people would feel more comfortable engaging in informal face-to-face conversations than filling out a questionnaire. The interviews were analysed using the software QSR NVivo (version 7) to facilitate coding of the information into themes (Table 4.1).

Ambar and I asked each question (Table 4.1) with regard to both dugongs and green turtles, though sometimes the flow of questions did not follow the plan of the interview, and depending on the interviewee, the answer was sometimes more specific for one species than the other. Attempts were made to clarify whether the statement referred to dugongs, green turtles, or both. In this chapter, I was interested in a sub-set of themes related to the original research questions and I used the responses to several questions to address these themes. Not all of the questions asked were relevant to these themes so are not discussed (those not discussed are indicated in Table 4.1). For example, I do not present the discussions about the community-based catch-monitoring project. Some additional themes emerged during the discussions (Table 4.2). Rather than sticking to the schedule, Ambar and I allowed the discussion to flow, and therefore, responses to some questions were often given as part of responses to other questions. I present a range of responses to questions being examined because of the small number of participants, but I indicate where there was a strong prevalence for particular responses. I have also provided some examples of responses that illustrate the perceptions presented.

Table 4.1. Questions asked in semi-structured interviews with hunters and elders organised into themes that emerged during analysis. (Supplementary questions were asked after some questions).

	Questions (framed to include both green turtles and dugongs)	Supplementary questions
Perceived need for local management		
Local status of dugongs/green turtles		
1	What is your opinion about dugong/green turtle numbers around the inner islands?	Do you perceive a decline or have the populations remained stable?
Causes of declines		
2	What do you think has contributed to these declines in numbers?	Do you think Indigenous hunting has contributed?
3	Do you think more people are hunting now than there used to be?	Do you think this has affected the numbers of dugongs/green turtles around?
4	Do you think people are catching more dugongs/green turtles now than they used to?	Do you think this has affected the numbers of dugongs/green turtles?
5	Have the methods used to catch dugongs/green turtles changed? How?	What do you think about this?
6	Do you think any of these changes are a problem for future dugong/green turtle hunting?	
Perception of controlling take		
7	What is your opinion about controlling the take of dugongs/green turtles? Why?	How would you feel about going along as you are without any controls?
Management options		
8	What types of controls and rules, if any, should the community implement to look after dugongs/green turtles?	
9	How do you feel about implementing a zoning plan for dugong/green turtle hunting, leaving some areas as sanctuaries and designating other areas as hunting grounds?	
10	What are your thoughts about having a permit/quota system administered by the community for dugong/green turtle hunting?	
11	What are your thoughts about closing the dugong/green turtle fishery for some parts of the year?	
12	What are your thoughts about applying sex limits - banning/restricting the catch of female dugongs/green turtles?	
13	What are your thoughts about applying size limits – banning/restricting the catch of dugongs/green turtles above a particular size?	
14	What are your thoughts about restricting the types of gear or methods that could be used to catch dugongs/green turtles?	
Community based catch-monitoring project		
15*	In what ways has the information collected during the dugong and green turtle catch-monitoring project contributed to your ideas about the types of management controls that	

	you think might work in your community?
16*	How long do you think you need to collect catch-monitoring information before you can use it to inform management plans?
Perception of the future situation	
17*	Thinking about the future, what do you think is going to happen to dugong/green turtle numbers and what do we need to do?

*These questions are not discussed here.

I provide an analysis of two main issues relating to community-based management; community cohesion and cooperation at various scales. I investigate community cohesion by evaluating the consensus of hunters and elders surrounding the need for management and perceptions of various management tools. With regard to cooperation, the dugong and green turtle populations hunted locally by Hammond Islanders are shared with other northern Australian communities and other countries as explained above (see Chapters 1, 2 and 3). Thus, the actions of local, regional and international communities are likely to affect the effectiveness of management by individual communities. I did not set out to investigate cooperation at these different scales. However, the issue of collaboration between communities was raised during the discussions with hunters and elders and therefore I provide an analysis of their perceptions of this issue with respect to co-management. Thus, I started out investigating community-based management in one community and ended up also investigating multi-scale co-management from a community perspective.

Table 4.2. The number of Hammond Islanders interviewed that answered questions about particular themes and topics.

Theme (based on interview questions)	Answered			Not answered[†]
	Both species	Dugongs only	Green turtles only	
Perceived need for local management				
Local status of dugongs/green turtles	12	1	1	1
Causes of declines	4	3	2	6[‡]
Need for controls	13	0	0	2
Management Options				
Type(s) of controls that should be used	6	4	2	3
Spatial closures	5	7	0	3
Quotas	13	0	0	2
Breeding season closure	10	0	2	3
Sex limits	10	0	2	4
Size limits	7	1	4	1
Gear restrictions[§]	N/A	11	N/A	4
Theme (based on free-flowing component of interviews)	**Discussed**			**Not discussed**
Cultural considerations				
Flexibility for ceremonies	5			10
Cooperation at various scales				
Cooperation within the community	10			5
Cooperation amongst communities	5			10
International cooperation	2			13
Compliance with local level management	4			11

[†] The question was not answered for one or both species.
[‡] These participants did not think the local population of green turtles and/or dugongs was declining and therefore were not asked about possible causes of declines
[§] Responses for this question are reported only for dugongs.

4.3. Results

Not all of the Hammond Islanders interviewed answered all of the questions (see Table 4.2). Hammond Islanders did not answer particular questions because they did not wish to, they were not asked or they answered for one species, but not the other.

4.3.1. Perceived need for local management

There was no widespread perception of a crisis in the local stocks of dugongs or green turtles. Although there was strong consensus that dugongs are abundant in the local area, there was also strong consensus that the local population was declining. In contrast, although almost all of the respondents thought that green turtles are abundant in the local area, there was approximately equal agreement that the local population was either stable or declining. One hunter commented that it was impossible to gauge the population status without more information on population size. The interviewees that thought the numbers of dugongs or green turtles locally were declining suggested reasons such as boat traffic scaring the animals away and making them more dispersed, hunting and green turtle egg predation, and effects on feeding grounds from pollution, but there was no consensus as to the relative importance of these reasons.

The perceived need for management mirrored the perception of the status of the dugong and green turtle populations. There was strong consensus that management was needed for dugongs. In contrast, about half of the respondents thought that management was needed for green turtles. The remainder had a range of alternative views implying that management was not needed or would not be accepted. Nonetheless, many respondents thought it would be good to have controls so that future generations could access dugongs and green turtles.

'It's good to have the taking of how much you take controlled so that in time to come there will be plenty for our future generations;'

‘If we just went along as we are I reckon there will be none left in the future.’

‘I think for our kids there probably won’t be much around at all, especially dugong because dugong take a long time to grow.’

Another view was that management was not needed at all.

‘We don’t need a control for turtles because there are heaps up here;’

‘No we don’t need to, there’s all this piece going around to stop this thing, we don’t need to.’

Other participants thought that management would not be needed if hunters only took what they needed.

‘They really need to start to think about how to hunt, just like I said, take what they need not over-fish them.’

‘They should just drift and just spear enough for whatever’s going on.’

Finally, concern was expressed about the impact of management on culture.

‘I wouldn’t like a control because it’s our culture.’

4.3.2. Management options

Although some hunters did not perceive a need for management, Ambar and I asked them to tell us their views on different controls, in the event that management was needed in the future. When asked to suggest controls that could be implemented by the community to look after dugongs or green turtles, quotas/permits were suggested by more participants than other controls, including spatial closures, seasonal closures, size limits, gear restrictions for dugongs and turtle farming for green turtles.

However, when participants were asked specifically about quotas/permits, almost all participants who suggested them as a management tool admitted that some people would not want a quota/permit system or would not be willing to abide by a quota/permit system.

'Some people might not want to have a permit system, but I think it's a good idea.'

'It's good, but people have different ideas. Maybe just keep going. It would be hard to stop people.'

Although seven participants answered only for dugongs, about half of participants suggested that spatial management was an appropriate strategy and/or noted that it was already being used in the form of the Dugong Sanctuary, established by the Australian Government in 1986 in western Torres Strait, external to most community hunting areas (see Chapter 3). The remaining respondents identified problems with spatial management including: (1) difficulties with enforcement, illustrated by the occurrence of hunting in the existing dugong sanctuary, (2) the challenge of incorporating cultural needs, and (3) the need to discuss the approach with the Council and elders.

'That would be good if we had sanctuaries…and if you don't hunt in the sanctuary then it gives them a lot more chance to survive and they'll breed up more and you'll have a lot more for future generations.'

'I suppose you could do that (have closed areas), but you'd have to put a marker and have people there all the time.'

Opinions about seasonal closures for dugongs were provided by two-thirds of participants and there was approximately equal agreement for and against them. It was suggested that part of the breeding season or part of the rough season (i.e., rough weather), when dugongs are most abundant locally, could be closed. Alternatively, it was suggested that dugongs are needed all year round and would be needed for feastings.

'…yeah certain time off, probably mainly when they're starting to breed, like, especially the woman dugong, and they start breeding up. It's probably good to have that bit of space because they actually spot a lot quicker and, you know, they're a lot more easy to get too, in a way, because they've always got to come up a lot more for the small one for air.'

'Well a lot of people go dugong hunting when it's rough…yeah, limit it. If you can put bans in, but the main time is the north-west (season) when it's blowing and that's usually when most of the dugong are taken and if you can put in a strategy to probably one month on one month off.'

A large number of green turtles migrate through the Torres Strait at breeding time, between August and November each year (see Chapter 2). This time, when the green turtles are in courtship, is known locally as 'turtlefast'. Ambar and I asked participants specifically whether they thought there should be a temporal closure on marine turtle hunting during turtlefast. There was approximately equal agreement that there should not be a closure during turtlefast or that at least part of the turtlefast season could be closed to hunting.

'…I reckon maybe when they've got eggs in there they should limit it to half that breeding season.'

Reasons for not wanting to restrict hunting during turtlefast included the perceived very large impact on the community because hunting during turtlefast gave many "non regular" hunters the opportunity to practise hunting, an important part of their culture, that they did not do at other times of the year.

'That's part of our culture, if you're going to close that then that's going to have a big impact.'

Similar to dugongs, another reason that people did not want to have a closure during turtlefast was that green turtles were needed all year round because they are an important source of fresh meat, which is expensive to buy in Torres Strait. Marine turtle and dugong meat cannot be sold in Torres Strait and is shared around the family or community when marine turtles and dugongs are caught.

'Dugong and turtle are fresh meat for us here so we need them all year round.'

There was strong consensus that, although sex based limits on dugong hunting may be acceptable, they would not work because hunters could not tell the difference between male and female dugongs, unless the female had a calf.

'Well that's going to be very hard to control now because in the old days the hunter knows a female dugong from a male, but we don't practice today. We just see a dugong and we go out to get it, not knowing if it's a male or female. But I think the elderly hunters should teach the younger hunters to determine the difference between a male and female.'

'You probably could (have sex based limits) but you can't really tell if it's male or female when they're coming up because all you see is a big black shadow and you just go oh here it comes. But probably another one is if it's got a calf if somebody sees a calf then they could say well you’re not allowed to take that, but that’s another thing how are you going to control that when you spear a female you don’t take the calf so it’s pretty hard to say if they have or haven’t got a calf when it’s back on the beach.’

In contrast, most respondents considered that sex based limits on green turtle hunting would not be an acceptable management option because people tend to catch female green turtles and they did not think that there would be interest in catching male green turtles.

‘…that won’t work because everyone catches females.’

The main reason given for preferring females was the taste, consistency and amount of fat. For example:

‘…we just catch female turtles…because of the meat, the taste is different, the female is more fat.’

Respondents did not say whether or not they thought size based limits could be acceptable for dugongs, but they mentioned a range of different preferences for size classes of dugongs from any size, young females with calves, bigger dugongs to medium-sized dugongs. Other respondents suggested they should not take young females with calves and that people did not catch old male dugongs.

In contrast, most respondents considered that people prefer large green turtles and are unlikely to agree to take smaller green turtles, although some Hammond Islanders do take ‘murai’ size green turtles (i.e., large immature green turtles). One of the main concerns was that small turtles were too small to share and sharing the catch is an important part of turtle hunting. Some of the responses include:

‘…people want the adults. Murai, it will only be for say myself and the next door neighbour. People do catch them.’

‘…the big ones are better, there’s more fat, murai’s not much for sharing.’

There was strong consensus that people still practise the traditional way of hunting dugongs by drifting without the outboard motor, but that some people were chasing dugongs using the outboard motor, particularly at night and using a spotlight to keep track of the dugong. There was strong consensus that stopping the use of this latter method could be an appropriate management tool for the community to use for dugongs.

‘Some methods are still practised, like some of the hunters still drift, without the motor and that and…they don’t always catch, some of them get away. Some of the methods that they have been using or have been practicing which hasn’t been done before is nightlighting, catching them by spotty and running by motor and we should outlaw doing that and (start) drifting without the power motor.’

‘…some are still there like the drifting style of it from the traditional way of the past you hunt and drift. That still happens. There’s one island I think that at night time they chase it you know – especially the dugong…if you chase the dugong and scare them away next time you go they won’t be there. That night time hunting has to stop. It’s making it hard for people who hunt the proper way who go there and drift and don’t chase them, hunt the way they’re supposed to be hunted.’

There was a strong consensus that using a boat and spotlight to see, chase and catch green turtles at night has been used for a long time, but it was inappropriate to do continue using these methods.

4.3.3. Free-flowing component of the interviews

During the discussions, issues about the process of developing and implementing community-based management plans emerged. About a third of participants suggested that management options would need to be flexible so that dugongs and green turtles would be available for cultural ceremonies and it would be impossible to predict annual numbers of certain ceremonies such as weddings and funerals.

The issue of intra-community cooperation was raised by two-thirds of participants. Three main perspectives were raised. First, it was noted that people within a particular community will have different ideas and they may not wish to participate in certain types of management, or even overall management, so it may be difficult to get them to follow the rules without enforcement.

'…it depends what the community wants, some will agree, some will disagree, that's the problem.'

Second, it was suggested that the Council and/or a group of elders should guide the management process.

'…sit down and talk to the old people, seek advice and gain advice from them so that way they can manage dugong and turtle for future generations…I think it needs to go through the Council and also have an elected body of elderly people sitting outside the Council to make decisions…'

Third, it was suggested that all of the hunters within a community should be brought together to discuss managing dugongs and green turtles.

‘…you need everyone’s involvement, you need everyone to participate, I reckon that’s the answer, you need everyone on the island to participate…it comes down to everyone together, talking.’

The issue of cooperation among Torres Strait communities was raised by approximately one-third of participants. Similar to intra-community cooperation, there was uncertainty that neighbouring communities would abide by rules and it was suggested that everyone would need to be brought together to discuss and agree on management.

‘For something like that to happen, it’s got to come from the hunters themselves, get their input so in the end we have their decision.’

‘I reckon hunters should come together and have a meeting about this and have a talk because we’re all from Torres Strait…’

The issue of international cooperation was raised by only two participants who were concerned that any efforts by Torres Strait Islanders to manage dugongs and green turtles may be counteracted by over-harvesting in countries with which the dugong and green turtle stocks are shared (e.g., Papua New Guinea (for both species) and Indonesia and Solomon Islands (for green turtles)). For example, one participant said:

‘If they’re taking them there and we’ve been trying to protect them it’s not going to do any good because they’re taking them all the time.’

The issue of enforcement was associated with cooperation and a third of participants raised perceptions including that controls would be difficult to enforce, both within the community and among communities and that involvement from the government might be needed.

‘…well I suppose the only way you can do it is by law, but all of the Islands, all Islanders, would have to agree and importantly it would need to be in black and white with the government and not only the government, but the tribal people.’

‘Well the government should be able to fund it or do something if they want to push it and they want to patrol on limits and size and all that and patrolling areas there shouldn’t be any problem about it because it’s part of protecting species really.’

4.4. Discussion

Consistent with the findings of Chapter 3 for dugongs, the attitudes expressed by Hammond Islanders in regard to management suggest that co-management will be a more appropriate approach for managing dugongs and green turtles in the Torres Strait than either community-based management or government-driven management. Community-based processes, such as applying cultural norms to tools to achieve compliance and enforcement within the community and consensus-based decision-making within the community in regard to applying more formal rules, were considered to be important. However, the need for cooperation with other communities and stakeholders across scales was also recognised, particularly in regard to achieving enforcement. Thus, it appears appropriate to accept my hypothesis that different forms of management will be required at different spatial scales (see Chapter 1; Section 1.4).

4.4.1. Community cohesion

There was strong consensus surrounding the need for management for dugongs but weak consensus surrounding both: (1) the need for management for green turtles and (2) attitudes towards the appropriateness of various management tools for the community to incorporate into any co-management plans for both dugongs and green turtles. However, there was strong consensus that there is no perceived crisis in either the local dugong or green turtle stocks. A conservation crisis is often cited as a precondition for successful co-management (Fernandez-Gimenez et al. 2008; Campbell et al. 2009). However, Campbell et al.(2009) also suggest that engagement in co-management may be based on perceived threats that are independent of stock status, such as the threat of fisheries closures. Indeed, during the development of the community catch-monitoring project in 2004, Hammond Islanders were concerned that management may be imposed on them because of statements by Australian Government ministers in the media that the green turtle and dugong fisheries may need to be managed by the government (see Chapter 2). At this time, Hammond Islanders I spoke to perceived that if their fisheries were well regulated by them, they would be better able to withstand outside scrutiny and it would be less likely that management would be imposed. Therefore, an incentive for Hammond Islanders to engage in co-management may be to avoid having management imposed. Further, given the strong cultural connection of Hammond Islanders to dugongs and green turtles, those Hammond Islanders that did perceive a need for management may be concerned about the resultant cultural loss if dugongs or green turtles were to become locally extinct.

In contrast, tensions between communities that use the same resources may make them reluctant to engage in co-management (Fernandez-Gimenez et al. 2008). Although the plans were not completed at the time of this study, the Kaurareg Traditional Owners, along with seven other communities, were being supported by the Australian Government through the Torres Strait Regional Authority to develop community management plans for dugongs and marine turtles (see Chapters 1 and 2). The Kaurareg plan was to be developed for the Kaiwalagal region and therefore included the area in which Hammond Islanders hunt. There may have been some reluctance amongst Hammond Islanders to cooperate with the Kaurareg plan, perhaps because, as with other local communities (e.g., Berkes et al. 2001a), there are inter-nation differences in traditional practices and Hammond Islanders may not have felt adequately included in the development of the plan. Fernandez-Gimenez et al. (2008) suggested that strained relationships or a reluctance to communicate or cooperate amongst neighbouring communities that shared the same resource posed barriers to formalising resource management plans for Beluga whales in Alaska and livestock in Arizona. It may be important to investigate the relationships between the Kaurareg Traditional Owners and other Kaiwalagal communities to determine if barriers to developing a co-management relationship exist.

Wilson et al. (1994) pointed out that traditional local communities usually used fisheries management systems that control the how, when and why of fishing, rather than the number of fish caught. The results of this study are consistent with the suggestion of Wilson et al. (1994); however, some social and cultural issues may preclude some of the management strategies commonly used by other traditional local communities. The analysis suggests that while the Hammond Island community may consider some management tools, such as quotas and spatial management, and gear restrictions for dugongs appropriate to incorporate into co-management plans, there was strong consensus that others, such as seasonal closures, and sex/size-based limits, were inappropriate or impractical.

Quotas are the predominant management tool used in Australian and indeed most western centralised fisheries management systems (Wilson et al. 1994; Berkes et al. 2001a). However, to manage small scale/local traditional resources, communities typically have not used quota-based management (Wilson et al. 1994). The perception, of at least some Hammond Islanders, that a quota system could be a good tool to manage their dugong and green turtle fisheries may reflect a familiarity with commercial fisheries in the Torres Strait, all of which are now managed using log books and a quota system. However, their assertion that it would be difficult to get hunters to comply with a quota system, suggests that such a system would be challenging to implement, particularly with respect to fulfilling cultural obligations such as ensuring that dugongs and green turtles are provided for ceremonies. One way around this dilemma could be to set quotas for dugongs and green turtles for everyday food, or *'Kai Kai'*, while making less predictable cultural events such as funerals quota exempt. The permit system introduced by the Great Barrier Reef Marine Park Authority in the northern Great Barrier Reef in the 1980s was not well received by hunters and has subsequently been discontinued (Baldwin 1985; Smith and Marsh 1990; Nursey-Bray 2006; Marsh 2007).

Spatial management is increasingly used in centralised western management systems as the primary tool to achieve ecosystem-based management (Lubchenco et al. 2003). This approach aims to protect the ecological characteristics of the system that are linked to growth, reproduction, migration, hierarchy, and predation of species rather than individual species protection or maintenance of the size of the populations (Wilson et al. 1994). Spatial management is also the predominant strategy used traditionally by local communities for fisheries management (Wilson et al. 1994). Although green turtles and dugongs are migratory species, spatial management may be an appropriate tool, particularly if used in combination with other tools. For marine turtles, this is because: (1) green turtles are resident in foraging areas for decades (recruitment at about five years and maturity at about 35 years); (2) large adult female green turtles are the most sensitive life-history stage. They do not breed each year, instead having a mean breeding interval of around six years, hence most of their lives are spent resident at the foraging areas; and (3) green turtles in Australia show strong fidelity to particular foraging areas and individual home ranges are typically in the tens to hundreds of kilometres squared. Therefore, if adequately planned, spatial closures minimise the risks to marine turtle populations because they can protect marine turtles for a large proportion of their life.

In Chapter 3, I combined historical spatial datasets for hunting and dugong distribution and relative abundance using a spatial risk assessment approach to inform the spatial design of management arrangements for dugongs in Torres Strait. I found that there are large areas of Torres Strait that consistently have very high or high densities of dugongs. As described in Chapter 3, the spatial variability of the risk to dugongs in Torres Strait from hunting has resulted in numerous areas that operate as *de facto* dugong sanctuaries. These areas may be one reason that a large population of dugongs has persisted in Torres Strait despite the dugong being hunted there for thousands of years (McNiven and Bedingfield 2008). In addition, spatial management could be used to mitigate the effects of broad-scale risks to dugongs and their habitats (e.g., Hooker and Gerber 2004; Grech et al. 2008).

I found that some Hammond Islanders thought that spatial closures would be an appropriate management tool for their community, but considered the difficulties associated with enforcement to be a barrier. The management agency has not enforced the existing dugong sanctuary (Kwan et al. 2006) and perceived difficulties associated with enforcement expressed during the interviews may be derived from this lack of enforcement of the dugong sanctuary. In addition, Wilson et al. (1994) found that in many traditional societies, territorial areas belonging to communities have often been used to retain resources for community use and to exclude outsiders. Hence, some Hammond Islanders may perceive spatial management to be an appropriate management tool because they do not wish to forego access to any of the resources in their sea country. However, this may be difficult because much of their hunting area is shared with other communities.

Seasonal closures, particularly during the breeding season, are another tool commonly used by traditional societies to manage fisheries (Wilson et al. 1994). Although some Hammond Islanders could see the benefits of enabling dugongs and green turtles to breed, social and cultural factors (e.g., practising hunting and sharing) appeared to preclude the widespread agreement of stopping or limiting the green turtle harvest during the breeding season. In contrast, some of the marine turtle and dugong co-management plans developed by other communities include limits on harvesting during the marine turtle breeding season (Marsh et al. 2009). This difference may relate to differences in preferences for adult female green turtles by communities in the Kaiwalagal (see below) that are not as strong in some other communities.

As mentioned above, Hammond Islanders appear to have a strong preference for adult female green turtles because they are big enough to share and they are considered to have a superior taste to smaller green turtles or male green turtles. The sex ratio of both the southern and northern Great Barrier Reef foraging populations of green turtles in Queensland is around 2:1 in favour of females (Limpus 2008). Thus, we might expect Indigenous hunters to catch more female green turtles than males. However, the prevalence of females in the catch far exceeds the sex-ratio in the population. All but one of the green turtles reported in the catch-monitoring project for which sex was recorded was female (97%; see Chapter 6), which suggests a strong preference for female green turtles. Population models demonstrate that larger green turtles are the most important part of the population to protect for the population to grow and that more animals overall could be taken if males and younger green turtles are taken in addition to, or even in replacement of, large females (Chaloupka and Limpus 2005). However, social and cultural factors are likely to preclude the use of sex-based or size limits for managing green turtles in the Hammond Island community at present.

Gear restrictions limit how people hunt and Hammond Islanders considered that dugong hunting could be limited to drift hunting. Such limits would make it more difficult for inexperienced hunters who chase dugongs in shallow water after startling them with a spotlight (Kwan 2002) to practice dugong hunting. Consequently, hunters would need to be more skilled and more patient to participate in dugong hunting. The results of the catch-monitoring project presented in Chapter 7 suggest that gear restrictions may not be a major issue for Hammond Island. Spotlighting does not appear to be widely practised (or reported), and most of the hunters that reported information about the vessel they hunted from used a clinker dinghy (67%; i.e., a wooden or fibreglass non-motorised boat that is towed to the catch site) rather than a motorised dinghy, which suggested that they were drift hunting. However, some chasing in motorised boats likely occurs. Other communities also seem to perceive that gear restrictions could help to limit hunting. Some of the marine turtle and dugong co-management plans developed by other communities include rules banning the use of spotlights and limiting the dugong hunting method to drift hunting (Marsh et al. 2009). Limiting dugong hunting to drift hunting appears to be a way to ensure culturally appropriate dugong hunting. Many of the Islanders Ambar and I spoke to referred to it as the ‘proper way’ or ‘traditional way’ of hunting.

4.4.2. Cooperation at various scales

The data suggested that cultural norms at the community level form the basis of hunting of dugongs and green turtles by Hammond Islanders. For example, the suggestion that, hunters should take only what they need, is a type of norm or guideline motivating people to voluntarily-limit their harvest (Wilson et al. 1994; Fernandez-Gimenez et al. 2008). This type of recommendation is different from a community or government specifying the amount of a species that can be taken by imposing a quota (Wilson et al. 1994). However, in discussing the use of more formal controls, Hammond Islanders indicated that consensus within the community would be needed. Consensus decision-making is a common feature of many local communities, but often requires a large investment of time (Berkes 1994; Fernandez-Gimenez et al. 2008) and therefore may prolong the development of formal management plans. Indeed, the development of marine turtle and dugong co-management plans by 15 other Torres Strait communities has taken several years partly because of the dual need to incorporate both cultural norms and more formal management rules.

Silver and Campbell (2005) suggested that participation by fishers in research may have implications for changes in government policies or community actions. My survey was undertaken in the context of informing co-management. The Hammond Island community was participating in a broader dugong and green turtle monitoring project (i.e., my PhD project) because they considered that having information and their views recorded would put them in a good position when negotiating management arrangements for dugongs and green turtles in the future and for gaining opportunities to be involved in monitoring and management activities. Thus, the outcomes of this study should assist the Hammond Island community in articulating their views with respect to co-management of dugongs and green turtles to coordinating bodies such as the Torres Strait Regional Authority. The rights of Indigenous Australians to hunt dugongs and marine turtles for non-commercial purposes and the progress made towards co-management in recent years suggest that it is unlikely that the participation of Hammond Islanders in this study would lead to changes in government policy that would have a negative impact on the Hammond Island community. However, the outcomes of this study could encourage the development of community-based management plans in the Hammond Island community, or participation of Hammond Islanders in the development of broader plans, such as the Kaurareg Plan[9], which may negatively affect those hunters that do not think that management is necessary. It will be important, therefore, that hunters continue to be involved in any development of co-management affecting their community.

As discussed above, Hammond Islanders share their local dugong and green turtle stocks with neighbouring Kaiwalagal communities, other Torres Strait communities, and communities from the Northern Territory to southern Queensland within Australia and from southern and eastern Papua New Guinea (both species), and Indonesia, Vanuatu and New Caledonia (green turtles). In addition to community-level considerations, some Hammond Islanders recognised that efforts to conserve dugongs and green turtles at the community level might be counteracted by the actions of other groups at larger scales (Berkes 2005). Concern about the impact of the Papua New Guinean and other overseas harvests on the management efforts of Torres Strait communities, and the need for effective collaboration, is common among

[9] The Kaurareg Traditional Owners are developing a Community Dugong and Turtle Management Plan for the Kaiwalagal nation under the Torres Strait Regional Authority's Dugong and Marine Turtle Project. However, the Kaurareg plan has not yet been finalised.

communities in Torres Strait. This concern has been expressed repeatedly in the workshops that other James Cook University researchers and I have conducted with Torres Strait Islanders (e.g., Hamann et al. 2006; Marsh et al. 2009). The development of co-management partnerships across these various local, regional, national and international scales is likely to be a suitable mechanism to obtain agreement from other communities to manage their harvest, as well as to enforce rules across scales. In addition, the cross-jurisdictional complexities entail that government, in addition to communities, will need to be included in these partnerships. Thus, a hierarchical approach to co-management is likely to be needed for managing dugongs and green turtles in the Torres Strait, because this social–ecological system crosses multiple scales and therefore requires governance at multiple levels (see also Chapter 3; Olsson et al. 2004; Folke et al. 2005; Berkes 2006). Co-management at the level of individual communities will need to be co-ordinated among communities at various levels including regional Torres Strait (see Chapter 3), the whole of northern Australia, and international management arrangements with neighbouring countries such as Papua New Guinea, Indonesia, Vanuatu and New Caledonia.

Bodies to provide such coordination already exist. The National Partnership Approach for the Sustainable Harvest of Dugongs and Marine Turtles 2005 (see chapters 1 and 2) also provides a framework for coordinating actions for the sustainable management of dugongs and marine turtles between governments and Indigenous groups across northern Australia. Similarly, the Australian Government Recovery Plan for Marine Turtles in Australian 2003 sets out research and management actions for marine turtle conservation and management. Both of these frameworks originally had groups associated with them to guide their implementation, but these groups have not met for several years.

In Torres Strait, the Torres Strait Regional Authority is a strong regionally-based Indigenous organisation that has coordinated the development of 15 community-based management plans for dugongs and marine turtles and is now coordinating their implementation, as well as broader sea country management. This coordinating role of the Torres Strait Regional Authority, which is an Australian Government Statutory Authority, has been the strength of the situation (i.e., engagement and management arrangements) in Torres Strait. Although similar statutory authorities do not exist in other regions in Australia, some Land Councils have also played an effective coordinating role in land and sea management (e.g., Kimberley Land Council). In Torres Strait, coordination with Papua New Guinea could occur through the Protected Zone Joint Authority, which includes representation from the Australian Government, Queensland State Government and the Torres Strait Regional Authority. The Protected Zone Joint Authority (see Chapter 2) is responsible for managing commercial and traditional fisheries in the Australian area of the Torres Strait Protected Zone and designated adjacent Torres Strait waters. Consultative mechanisms under the *Torres Strait Treaty1985* could facilitate coordination between Australia and Papua New Guinea (see Chapter 2). Coordination with other neighbouring countries such as Indonesia and Pacific Island nations could occur through agreements and organisations such as: the Secretariat for the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (ISOEA); Secretariat for the Memorandum of Understanding on the Conservation and Management of Dugongs

(*Dugong dugon*) throughout their range; and the Secretariat for the Pacific Regional Environment Program (SPREP).

4.5. Chapter Summary

- In this chapter, I used open-ended semi-structured interviews to investigate the thoughts and aspirations of Hammond Islanders regarding the management of dugong and green turtle hunting. The interviews were conducted with 15 Hammond Islander hunters (13) and elders (2) regarding the need for local management, their perceptions of different management tools and multi-scale co-management from a community perspective;

- There was strong consensus surrounding the need for management of dugongs, but weak consensus surrounding both: (1) the need for management of green turtles; and (2) the attitudes towards the appropriateness of various management tools to incorporate into any co-management plans for both dugongs and green turtles. There was strong consensus that there is no perceived crisis in either the local dugong or green turtle stocks;

- The analysis suggests that while the Hammond Island community may consider some management tools, such as quotas and spatial management, appropriate to incorporate into co-management plans, there was strong consensus that other tools, such as seasonal closures and sex/size-based limits, were inappropriate because of social and cultural factors;

- Hammond Islander hunters and elders considered community-based processes to be important, especially the application of: (1) cultural norms to the development of tools to achieve compliance and enforcement within the community; and (2) consensus-based decision-making among hunters and elders within the community, with regard to the use of more formal rules.

- My data indicate that communities and stakeholders need to cooperate across scales, particularly with regard to enforcement.

- The right of Torres Strait Islanders to hunt dugongs and green turtles is protected. The geographic extent of the dugong and green turtle stocks means that, in addition to community-based management within their communities, co-management is likely to be more appropriate at larger scales (see also Chapter 3). Thus, the results of this chapter (and Chapter 3) support my hypothesis that different forms of management will be required at different spatial scales (see Chapter 1, Section 1.4)

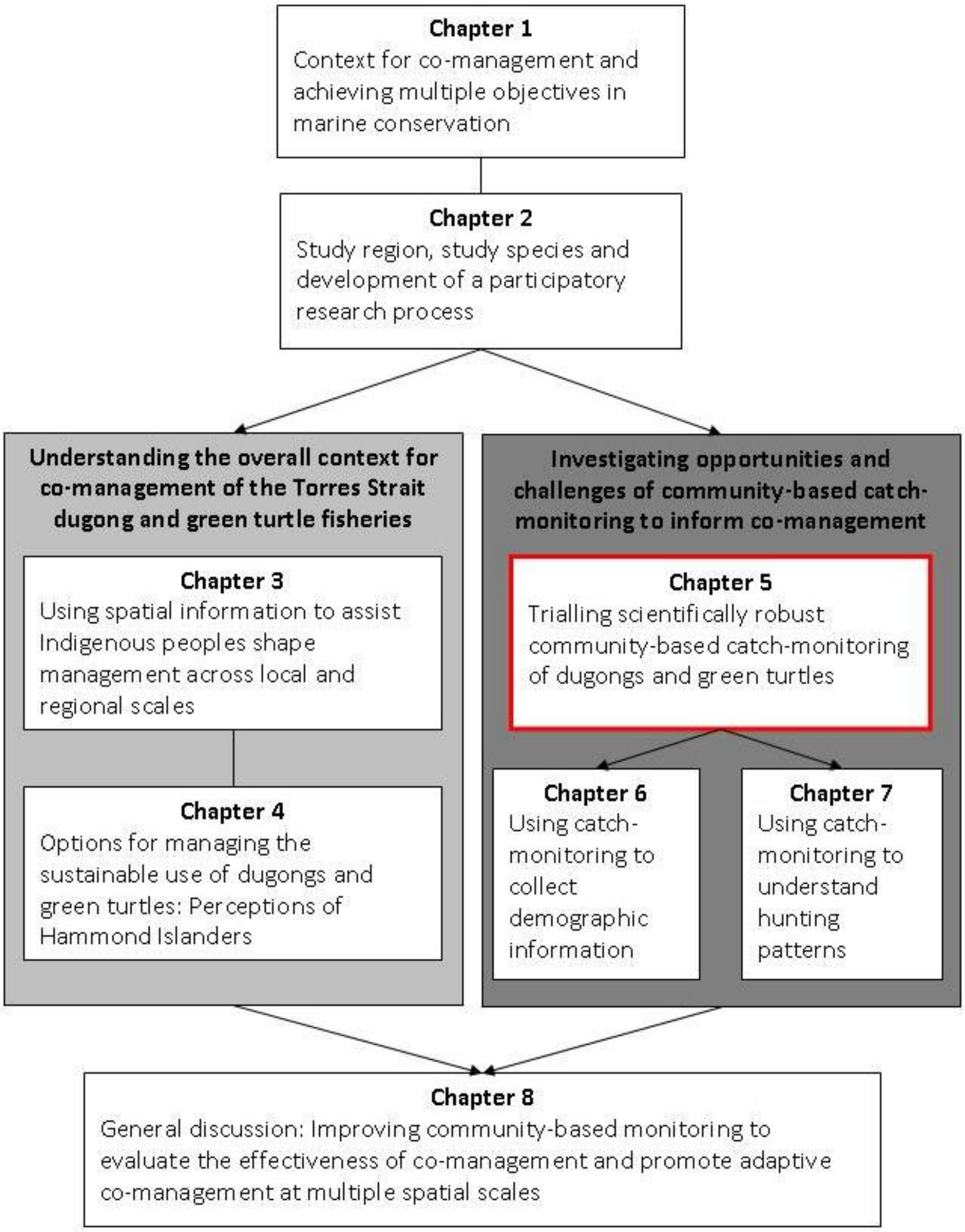
- The Australian Government, through agencies such as the Torres Strait Regional Authority, could provide assistance in coordinating co-management among communities at a hierarchy of scales;

- Native Title rights mean that both the Australian national and sub-national governments have limited capacity to act unilaterally unless there is a severe crisis in the stock and therefore governments are likely to benefit from the outcomes of the partnership in which community access and responsibility result in the protection of the resource because communities have a vested interest in such protection;

- Establishing co-management arrangements across local, regional, national and international scales for dugongs and green turtles should also have implications for the management of other traditional shared resources in the Torres Strait.

Chapter 5

Trialling scientifically robust community-based catch-monitoring of dugongs and green turtles.



In this chapter, I investigated cost-effective and culturally appropriate monitoring strategies that would provide accurate, unbiased and precise catch-estimates for Torres Strait dugong and green turtle harvests at the individual community level. I investigated differences in the precision and biases of dugong catch-estimates obtained using occasional sampling and daily census. I also trialled a hunter self-monitoring project with the Torres Strait communities of Hammond and Thursday Islands, to determine whether a community-based approach such as hunter self-monitoring could provide reliable catch-estimates and would be practical to implement.

Chapter 5. Trialling scientifically robust community-based catch-monitoring of dugongs and green turtles.

5.1. Introduction

Monitoring trends in the abundance of an animal population is not generally the most reliable way to determine the status of a population, particularly for small or highly variable populations because the change has to be very large, or occur quickly to be detected (Taylor and Gerrodette 1993; Marsh 1995b; Nichols and Williams 2006; Taylor et al. 2007). Further, for long-lived animals, by the time significant changes in abundance are detected it is often hard to re-build population levels (e.g., marine turtles (Bjorndal et al. 1993; Bjorndal et al. 1999). Therefore, models are often used to determine the level of anthropogenic mortality a population can sustain, and this value is compared with the estimated level of anthropogenic mortality for the population (Robinson and Redford 1991; Wade 1998; Marsh et al. 2004b; Lonergan 2011). Both of these methods require datasets on life-history parameters, mortality, survivorship, growth and behaviour (Bjorndal et al. 2011).

Hunting is a major source of anthropogenic mortality for many wildlife species that are used for subsistence purposes by Indigenous and local peoples. Harvest estimates have been obtained using a variety of monitoring methods (Noss et al. 2003; Danielsen et al. 2009). As described in Chapter 1, the right of Indigenous groups to harvest wildlife for subsistence purposes is often protected by laws and treaties, rather than being provided by a license. Therefore, subsistence harvests by Indigenous communities have not generally been tracked in the same way as commercial harvests (i.e., reporting requirements attached to a license or permit that authorises the hunter to hunt; Usher and Wenzel 1987). Instead, subsistence harvests of wildlife by Indigenous (and local) communities have generally been monitored by external researchers and/or agency staff, sometimes with the assistance of local community members, using a range of methodologies (Table 5.1). In addition, local people have carried out locally- based monitoring, sometimes with the assistance of external researchers and/or agency staff (Table 5.1).

Table 5.1. Methodologies used by external researchers/agency staff or local people to monitor subsistence harvests of wildlife by Indigenous (and local) communities.

Methodology	References
Monitoring by external researchers and/or agency staff	
Participant observation of hunting activities	(Usher and Wenzel 1987; Robinson and Redford 1991; Vickers 1991)
Interviews and questionnaires	(Usher and Wenzel 1987; Vickers 1991; Burn 1998; Kennett et al. 1998; Henry and Lyle 2003; Hill et al. 2003; Godley et al. 2004; Gavin 2007; Jones et al. 2008)
Daily household visits	(Vickers 1991; Robinson and Bennett 2004)
Direct observations while collecting biological data	(Burn 1998; Kwan 2002)
Monitoring by local people	
Ranger monitoring	(Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005)
Stockpiling of bones or shells	(Mittermeier 1991; Kennett et al. 1998)
Hunter self-monitoring (usually assisted by harvest monitors)	(Marks 1996; Burn 1998; Kennett et al. 1998; Noss et al. 2003; Fernandez-Gimenez et al. 2006)

The choice and success of monitoring method depends on a variety of factors. These factors include: the specific objectives and scale of monitoring (Danielsen et al. 2005a; Green et al. 2005); local and external expertise and capacity (Danielsen et al. 2005a; Hockley et al. 2005; Danielsen et al. 2009); the structure of the community(s) using the wildlife resource (e.g., population size, social cohesion and geographic dispersion; Pinkerton 1989; Vickers 1991; Danielsen et al. 2005a; Topp-Jørgensen et al. 2005; Campbell et al. 2009); the transparency of harvests (Kwan 2002); and available resources (Hockley et al. 2005; Danielsen et al. 2009).

Both agency-based and locally- based monitoring need to be grounded in distinct objectives (Yoccoz et al. 2001; Ostrom 2007; Armitage et al. 2009) because clearly defining the objectives enables decisions to be made about what variables to measure and how to measure them (Yoccoz et al. 2001). Making these decisions ensures that the relevant management decisions are informed and the information collected is reliable. Therefore, as with 'professional monitoring,' locally- based monitoring must balance program endurability with scientific rigour (Danielsen et al. 2003; Rodriguez 2003; Yoccoz et al. 2003; Brashares and Sam 2005). Monitoring of catches will waste time and resources if the harvest estimates lack precision and accuracy or are biased or if monitoring cannot be sustained long enough to answer the questions needed for effective management (Brashares and Sam 2005).

The management of dugongs and green turtles in Torres Strait will rely on multiple lines of evidence (see Chapter 8). At the community level, determining trends in the total catch through time will require precise catch-estimates (see Box 5.1), otherwise the changes will not be detected unless they are very large (e.g., Taylor et al. 2007). At the regional level, a catch-estimate, scaled-up from individual community catch-estimates, can be compared with an estimate of a sustainable catch. This comparison requires accurate estimates (see Box 5.1) and must be made at the regional scale because it is not possible to obtain an estimate of a sustainable catch for dugongs and green turtles at the individual community level because of the ecological scale at which these species operate. Nevertheless, accurate estimates are needed for comparisons at the regional scale.

Both precision and accuracy of catch-estimates can be improved by increasing the sample size. Biases (see Box 5.1) are systematic errors that arise from methodological problems with the collection of data (Usher and Wenzel 1987) and are a measure of inaccuracy. For example, the accuracy of an estimate may be improved by ensuring that the sample is representative and minimising any biases introduced through mis-reporting. If a catch-estimate is inaccurate because of a consistent bias, it may not affect the interpretation of trends in catches through time. However, if the bias fluctuates, then the perceived changes in the catch through time may be due to the changes in the bias, rather than the catch. Therefore, it is important to account for biases when estimating catches.

Box 5.1. Definitions of terms used in Chapter 5.

Term	Definition
Precision	Precision is the closeness of repeated measures to the same quantity and is a function of the sample estimate (Cochran 1977).
Accuracy	Accuracy is the closeness of the sample mean to the true population mean.
Bias	Bias is the magnitude and direction of the difference between the sample mean and the true population mean (Cochran 1977).
Representative sample	The hunters who reported their catch (i.e., the sample) are typical of the population of hunters with respect to their harvesting and reporting characteristics.
Proportional projection	Extrapolation of total harvests from reported harvests
Transparency of the catch	How obvious it is that a dugong or green turtle has been caught. For example, if the community is small and there is only one butchering beach, it is usually obvious that a dugong or green turtle has been caught (i.e., the catch is transparent). Alternatively, if the community is large and there are many butchering sites, it may not be obvious that a dugong or green turtle has been caught (i.e., the catch is not transparent) and may be missed by the catch-monitor.

A sample of hunters providing data may not be representative if these hunters are not typical of members of the population of hunters with respect to their harvesting and reporting characteristics (refer Box 5.1; Usher and Wenzel 1987; Danielsen et al. 2005a; Viteri and Chávez 2007). Most harvest monitoring programmes rely on voluntary participation by hunters and it is rare to obtain a complete census. The problem of non-response bias (i.e., some hunters do not report their catch) may not be severe if the sample of hunters providing data is large and the population of hunters is homogeneous (Usher and Wenzel 1987). However, a large, but incomplete, sample will not be a random sample and populations of hunters are often not homogeneous. For example, two hunters out of 29 individuals accounted of 56% and 59% of the total harvest of dugongs at Mabuaig Island in 1998 and 1999 (Kwan 2002). Similarly, Izoceno hunters in Bolivian forests averaged less than one hunt per month, but the most active hunters hunted two or more times per week (Noss et al. 2003). In one village in the Brazillian Amazon, four hunters accounted for 47% of the total weight of game killed in 1978 and two hunters killed over 58% of the total game taken in 1980 (Ayres et al. 1991). Therefore, using proportional projection (see Box 5.1) to obtain the total harvest, even from a large sample of hunters, may result in a biased estimate if the sample of hunters is not representative of the population of hunters in the community (Usher and Wenzel 1987).

Other biases may arise if hunters intentionally or unintentionally under- or over-report their catches (e.g., response bias, Usher and Wenzel 1987) or if catches are double counted or missed (Hone 2008). Hunters may strategically under-report their catches if they think that their harvests will be regulated if they are too large (Usher and Wenzel 1987) or over-report their catches to generate a catch-history for permit entitlements if they think management will be imposed. This type of strategic response bias can be minimised by building trust with the hunters and addressing their concerns about harvest regulation as well as conducting anonymous surveys (Usher and Wenzel 1987; Fernandez-Gimenez et al. 2006). Catches may be missed if they are not directly observed by a catch-monitor, but follow-up surveys of hunters can minimise the chance that unobserved catches are not reported (Pollock et al. 1994). Having clear objectives, careful consideration of likely biases in the sampling strategy and survey methods, and thorough training of data gatherers to achieve rigorous standardisation of procedures can improve the precision and accuracy of estimates and reduce biases for a catch-monitoring program (Yoccoz et al. 2001; 2003; Danielsen et al. 2005a; Hone 2008).

As described in Chapter 1, Torres Strait Islanders hunt dugongs and green turtles for cultural, spiritual and subsistence purposes. The availability of data required for a robust assessment of the sustainability of dugong and green turtle harvests in Torres Strait is limited. Data limitations include catch-rates, geographic ranges of the stocks, and population sizes of dugongs and green turtles in Torres Strait and estimates of life-history parameters of these species in Torres Strait. Two of these pieces of required information, catch-statistics and life-history parameters (see Chapter 6), as well as information on hunting patterns (see Chapter 7) can be collected by monitoring harvested dugongs and green turtles. However, obtaining estimates of life-history parameters is difficult, especially for green turtles, for which age estimation is difficult (Heppell et al. 2003; Hamann et al. 2010).

The Australian Government has funded two “professionally-based” projects to monitor harvested dugongs (both projects) and green turtles (one project) to collect information on catch statistics and/or life-history parameters in Torres Strait. One project was a catch-monitoring project, using occasional sampling, which aimed to obtain an annual total catch-estimate for the Australian part of the Torres Strait

Protected Zone (i.e., 14 communities, including Mabuaig Island; Skewes et al. 2004). Therefore, this project aimed to obtain a precise catch-estimate at the level of the Torres Strait Protected Zone rather than at the level of individual communities, as required for community-based management. The second project aimed to collect life-history information from harvested dugongs. This project, on Mabuaig Island, obtained a daily census by a scientist outsider for a period of nine months in each of 1998 and 1999 (Kwan 2002). Mabuaig Island is a major dugong hunting community in the Torres Strait Protected Zone (see Chapter 2).

As described in Chapter 1, co-management of dugongs and green turtles in Torres Strait requires information to be collected at a range of spatial scales. Catch-monitoring is needed at the scale of individual communities because it will inform management at the community level as well as at larger scales (see Chapters 3 and 4). My objective was to investigate cost-effective and culturally appropriate monitoring strategies that would provide accurate, unbiased and precise catch-estimates for Torres Strait dugong and green turtle harvests at the individual community level. Both of the methods previously used for monitoring harvests of dugongs and green turtles in Torres Strait: 1) occasional sampling and 2) daily census by outsiders, considered day as the sampling unit. Therefore, I investigated how practical it was for a monitoring strategy that considered day as the sampling unit to provide accurate, unbiased and precise catch-estimates at the individual community level. The results of my investigation also led me to investigate how practical it was for an alternative monitoring strategy that considered hunters as the sampling unit, to provide accurate, unbiased and precise catch-estimates.

By comparing the precision and accuracy of catch-estimates and the biases associated with different catch-monitoring strategies, I demonstrate both the limitations and benefits of these different strategies for monitoring catches of dugongs and green turtles at the individual community level in Torres Strait.

5.2. Methods

5.2.1. Study sites

Investigating the practicality of considering day as the sampling unit

I re-analysed data from the two catch-monitoring projects previously conducted in Torres Strait to collect catch statistics and/or life-history parameters on dugongs: 1) occasional sampling and 2) census by an outsider. These two projects were conducted simultaneously at Mabuaig Island in 1998 and 1999. Mabuiag Island is one of the Torres Strait's major dugong hunting communities as described in Chapter 2 (Haddon 1890; Nietschmann 1984; 1989; Johannes and MacFarlane 1991; Kwan 2002).

Investigating the practicality of considering hunter as the sampling unit

I trialled a hunter-self monitoring tool in the Kaiwalagal communities of Thursday Island and Hammond Island. These communities are described in Chapter 2 (Figure 2.1). On Thursday Island, Community Fisher Organisations and the local Community Council participated in the trial of a hunter-self monitoring tool. Some of the hunters in the Community Fisher Organisations live on Horn Island or Prince of Wales Island. Other hunters, not in these Fisher Organisations, living on Horn Island and Prince of Wales Islands did not participate in the project.

5.2.2. Investigating the practicality of considering day as the sampling unit

Sampling regimes

As described in Section 5.1, in 1998 and 1999, both the Australian Fisheries Management Authority (Skewes et al. 2004) and Kwan (2002) monitored dugong catches on Mabuiag Island. The Australian Fisheries Management Authority used a randomised frame survey method in which roving local Indigenous observers, based on Thursday Island, systematically monitored the catches of dugongs and marine turtles in the 14 different island communities in the Torres Strait Protected Zone, including Mabuiag Island, for periods of three to seven days throughout the year (Dews and Harris 1995). Sampling was stratified according to the contribution of the community to the total catch landed each year (Skewes et al. 2004). The observers collected information on fishing activities (method, catch, composition, effort, location, boats, fishers, weather and tide), which was used to estimate the catch, effort and participation for the year (Harris et al. 1997; Skewes et al. 2004). Sampling on Mabuiag Island was done on 26 days in 1998 and 18 days in 1999 (Table 5.2). On Mabuiag Island, the Australian Fisheries Management Authority sampled six blocks, each of between one and six days in 1998 and four blocks, each of between three and seven days in 1999 (referred to as the AFMA sample; Table 5.3). The sampling strategy used by the Australian Fisheries Management Authority in each year was different. Therefore, to facilitate comparisons with Kwan's (2002) data, I set a typical yearly sampling regime for the Australian Fisheries Management Authority for Mabuaig Island of five blocks, each of four days (referred to as AFMA's sampling regime; Table 5.3).

Kwan was based on Mabuiag Island in 1998 and 1999 and recorded catches of dugongs from 1 January 1998 – 31 October 1999 (except for the month of February in each year; Table 5.2). Thus, she obtained a census (i.e., all days were sampled) of the dugong catch between March and October in each year (i.e., 245 days per year; referred to as Kwan's census; Tables 5.2 and 5.3). Kwan (2002) interviewed hunters and collected biological samples from dugongs caught by Mabuaig hunters. For each dugong caught, hunters provided information on: the duration of their hunting trips; the location of hunting; the number of hunters in the hunting party; the number and sex of dugongs caught; and how the catch was used or distributed.

Table 5.2. Sampling efforts (days) of the Australian Fisheries Management Authority (Skewes et al. 2004) and Kwan (2002) for each of 1998 and 1999. Note: Kwan obtained a census of catches between March and October in each year (i.e., 245 days in each year, highlighted in grey; Kwan's census).

	Australian Fisheries Management Authority		**Kwan (2002)**	
	1998	**1999**	**1998**	**1999**
Jan	0	0	31	30
Feb	3	0	0	0
Mar	1	7	31	30
Apr	0	3	30	30
May	0	4	31	31
Jun	3	4	30	30
Jul	5	0	31	31
Aug	6	0	31	31
Sep	4	0	30	30
Oct	1	0	31	31
Nov	3	0	30	0
Dec	0	0	31	0
Total	**26**	**18**	**337**	**274**

Precision and bias of catch-estimates from occasional sampling

First, I investigated the precision of catch estimates of dugongs obtained by occasional sampling. I calculated the precision (i.e., coefficient of variation) of estimates of the mean number of dugongs caught per day from the Australian Fisheries Management Authority's data from Mabuiag Island (i.e., AFMA's sample) for each of 1998 and 1999. The population of days in a year from which the catch-estimates were determined is a finite population because there was a maximum of 365 days from which the sample could be taken. Therefore, the standard error was calculated using the finite population correction (i.e., 1-n/N) such that:

$$S.E. = (s^2)^{\wedge 0.5}/n(1-n/N)^{\wedge 0.5} \quad \text{(Equation 5.1)}$$

Where, s^2 is the variance, n is the number of days sampled in the year, and N is the total number of days in the year (i.e., 365).

Second, I investigated the likely bias associated with estimates of the mean number of dugongs caught per day obtained from occasional sampling (e.g., AFMA's sampling regime (i.e., the typical sampling regime of five blocks, each of four days)) by comparing the sample mean with a standard (e.g., the true mean calculated from Kwan's census (i.e., March to October)) for each year, separately (Table 5.3). For each year separately, I randomly sampled from Kwan's census, setting a random start date and doing 100 simulations. I set a minimum interval of 20 days between start dates because the Australian Fisheries Management Authority aimed to spread their sampling blocks throughout the year (Skewes et al. 2004). I calculated the mean (±S.E.) number of dugongs caught per day and associated 95% confidence intervals for each of the 100 samples to investigate what proportion of times the true mean (i.e., the standard) obtained from Kwan's census was included in the 95% confidence intervals of the sample means.

I also investigated the precision of catch-estimates that could be obtained using AFMA's sampling regime (i.e., the typical sampling regime of five blocks, each of four days). I calculated the coefficient of variation for each of the 100 samples taken from Kwan's census. I constructed a frequency distribution of the coefficients of variation to determine the frequency with which precise estimates were obtained. The population of days in the period March to October in each year is a finite population because there is a maximum of 245 days per year from which the sample can be taken. Therefore, the standard error was calculated using the finite population correction using Equation 5.1

Using census data to investigate improvements in precision of catch-estimates

Third, I investigated the improvement in precision of estimates of the mean number of dugongs caught per day with increased sample size by randomly sampling the 245 days per year in Kwan's census, choosing samples sizes of n=10, n=20 and so on to n=245. I calculated the mean, standard error and coefficient of variation for each sample size (Table 5.3).

Table 5.3. Datasets and comparisons made to 1) investigate the precision of catch estimates obtained from occasional sampling (AFMA's sample) 2) investigate the bias associated with catch-estimates obtained from occasional sampling (i.e., AFMA's sampling regime) by comparing the estimated mean to a standard (based on Kwan's census from March to October), 3) investigate the precision of catch-estimates obtained from occasional sampling by examining the frequency with which the 100 random samples of Kwan's census using AFMA's sampling regime produced different CVs, and 4) compare the precision (i.e., CV) of samples of different sizes based on Kwan's census data, $\bar{x}_D$ = mean number of dugongs per day, S.E. = standard error, CV = coefficient of variation and 95% C.I. = 95% confidence interval.

Dataset	#sampling days/total days		Parameters calculated	Comparisons
	1998	1999		
AFMA's sample	26/365	18/365	$\bar{x}_D \pm$ S.E.; CV	1) Calculate CV
AFMA sampling regime	20/245	20/245	$\bar{x}_D \pm$ S.E.; CV and 95% C.I. for 100 random samples of Kwan's census using AFMA's sampling regime, for each year	2) Proportion of times 95% C.I. of sample means includes $\bar{x}_{D(census)}$ from Kwan's census; 3) Frequency distribution of CVs
Kwan's census	245/245	245/245	$\bar{x}_D \pm$ S.E.; CV for samples of size n = 10, 20…n = 245, for each year;	4) Compared CVs obtained from different sample sizes

5.2.3. Investigating the practicality of considering hunters as the sampling unit

As described in Chapter 2, hunters decided to self-monitor their harvests of dugongs and green turtles using datasheets (Appendix B). They were supplied with data collection kits consisting of a clipboard, datasheets, pencils and a tape measure. Hunters filled in datasheets, providing information about their catches, including morphometric and reproductive information about the animals caught (see Chapter 6) and information relating to hunting patterns (see Chapter 7). The Indigenous research counterparts (i.e., local catch-monitors) employed on the project (see Chapter 2) in their respective communities recruited hunters to participate, distributed and collected datasheets, collected biological samples from harvested animals and helped provide feedback to hunters and their communities about the results and progress of the project. The catch-monitors contacted hunters when they brought in their catch or periodically (at least monthly) as they saw them in the community. At Hammond Island, the Chairman and Councillors helped collect datasheets when they could and at Thursday Island, some hunters delivered datasheets directly to me. I held workshops to train hunters and the local catch-monitors in taking morphometric measurements and collecting and interpreting biological specimens from hunted animals. The hunters used code names to ensure their confidentiality.

Precision, accuracy and bias of catch-estimates from hunter self-monitoring

Hunters were the sampling unit in the hunter-self monitoring approach because they provided information on the dugongs and green turtles they caught. To obtain robust catch-estimates it was, therefore, important that as many hunters as possible participated in the catch-monitoring project. The recruitment of hunters was an ongoing and adaptive process. This approach ensured that as many hunters as possible participated and the method of engaging them evolved and improved over time. Initially hunters were recruited during information meetings and training workshops and later by the local catch-monitors employed on the project (see Results for details).

In each community, to assist in determining the precision, accuracy and bias of the catch-estimates, the catch-monitors, assisted by the CRC Torres Strait Marine

Research Liaison Officer[10] on Thursday Island, generated a list of all potential hunters in the community and assigned each potential hunter to categories based on whether or not they registered to participate in the project, their level of participation in the project and whether or not they actively hunted during the project (Table 5.4). The lists of potential hunters were generated from the hunters that registered to participate in the project by completing an informed consent form (James Cook University Animal Ethics No. A932; see also Chapter 6) and additional hunters (i.e., those that did not register to participate in the project) were identified by the local catch-monitors, community councils and CRC Torres Strait Marine Research Liaison Officer. Hunters were assigned to the registration, participation and activity categories after the catch-monitors had recruited as many hunters to the project as they could, in July 2006 on Hammond Island and in March 2006 on Thursday Island.

Table 5.4. To assist in determining the precision and bias of catch-estimates, hunters were categorised based on whether or not they had registered to participate in the project, their level of participation in the project and how actively they hunted during the project.

Hunter registered in catch-monitoring project	Yes	No
Participation in catch-monitoring project	Always, Sometimes, Never	Never
Hunting activity	Active (Top, Regular, Occasional),	Inactive

As described above, the precision and accuracy of the catch-estimate will increase with the number of participating hunters. The importance of all hunters in the community participating all of the time was demonstrated to hunters using a practical hands-on exercise with hypothetical participation rates during several workshops and meetings as opportunities arose (Appendix C). I evaluated the precision of the catch-monitoring tool by assessing the participation rates of hunters (i.e., the completeness of the sample of hunters) in each community separately.

[10] The CRC Torres Strait Marine Research Liaison Officer provided a link between the Torres Strait communities and me. He assisted with two-way communication about the project (see Chapter 8).

Potential biases associated with hunter self-monitoring

Hunters that were voluntarily reporting their catches to local catch-monitors may have been unintentionally or strategically over- or under-report their catches. The catch-estimate might also have been biased if the sample of hunters used to estimate the catch was not representative of the population of hunters in the community. I examined mis-reporting of catches and the representativeness of the sample of hunters as described below.

Avoiding mis-reporting: design of the catch-monitoring tool

The catch-monitoring strategy was designed to obtain as many reports of caught dugongs and green turtles from as many hunters as possible. Some hunters completed datasheets upon return from their hunting trip. Catch-monitors worked part-time and, on Thursday Island, landing sites were dispersed, therefore it was unlikely that catch-monitors would observe all of the catches of dugongs and green turtles. Nevertheless, the catch-monitors obtained information about unobserved catches by maintaining regular contact with hunters and obtaining verbal reports of catches that they recorded on datasheets. They contacted hunters at least weekly. As noted in the results, they were not able to maintain regular contact with all of the hunters.

Double counting of caught dugongs and green turtles was avoided by having only the main hunter on each hunting trip fill in the datasheet to report their catch. The main hunter was defined as the hunter that harpooned, hooked (for green turtles) or hand caught the animal. In addition, most of the datasheets were collected by one catch-monitor in each community and I queried any potential duplicate records with the catch-monitor.

I minimised the chance of strategic under-reporting of catches by hunters by building trust with them through the research agreement (see Chapter 2) and agreeing to keep the total catch numbers confidential. Therefore, hunters had little reason to be concerned about the information they provided being used by outsiders to regulate their harvest.

Investigating mis- reporting: supplementary surveys and monthly activity reports

I investigated whether hunters mis-reported their catches by comparing the information recorded on datasheets from the hunters with that reported during surveys by catch-monitors. At Hammond Island, in October 2005, the Hammond Island catch monitor surveyed 11 of the 21 registered hunters in the community at the time about their hunting activity from the beginning of the project. In addition, the local catch-monitor was absent from the community for some of the time between December 2005 and March 2006. Therefore, at the beginning of March 2006 he surveyed 15 of the registered hunters about their hunting activities to supplement the information reported using datasheets. At Thursday Island, in each of May and June 2006, the Thursday Island catch-monitor surveyed a subset of registered hunters about their hunting activity in the preceding month. These surveys of Thursday Island hunters were designed to obtain monthly activity reports of a subset of 43 registered hunters with whom the catch-monitor thought he could maintain regular contact. Monthly activity records were trialled because the catch-monitor had difficulty maintaining regular contact with all of the registered Thursday Island hunters, particularly those that he did not recruit to the project. At the end of each of May and June 2006, the catch-monitor contacted 38 and 39 of the 43 hunters, respectively, asked them about their hunting activity in the preceding month, and collected any datasheets they had filled in.

Investigating whether the sample of hunters is a representative sample

To obtain a robust estimate of the total catch using proportional projection, it is necessary that the sample of participating hunters is representative of the population of hunters in the community; otherwise, the catch may be over- or under-estimated. Similar to the population of potential hunters at Mabuiag Island (e.g., Kwan 2002), in which there were a few top hunters, regular hunters, occasional hunters and hunters that did not hunt, it is unlikely that the population of potential hunters in each of the study communities is homogeneous. In addition, the sample of registered hunters is not random, because hunters voluntarily register to participate. The catch-monitors assigned each of the registered hunters who went hunting and provided datasheets to one of three categories: top hunter, regular hunter or occasional hunter. They also assigned each of the hunters that were not registered, but who went hunting to one of these categories. I assessed whether the sample of registered hunters who went hunting and provided datasheets was representative of the population of active hunters in the community. I did this by comparing the relative proportions of active hunters in the categories top, regular or occasional hunter between registered hunters and hunters that did not register to participate in the project using a χ^2 test for Thursday Island. I made a qualitative comparison at Hammond Island because the samples size was too small to obtain expected values of greater than five as required for χ^2 tests.

5.3. Results

5.3.1. Investigating the practicality of considering day as the sampling unit

There was high temporal variability in the dugong catches per day at Mabuiag Island in 1998 and 1999 (Figure 5.1). The distribution of the catch of dugongs was skewed towards days with no hunting or zero catches and there were relatively few days when large numbers of dugongs were caught.

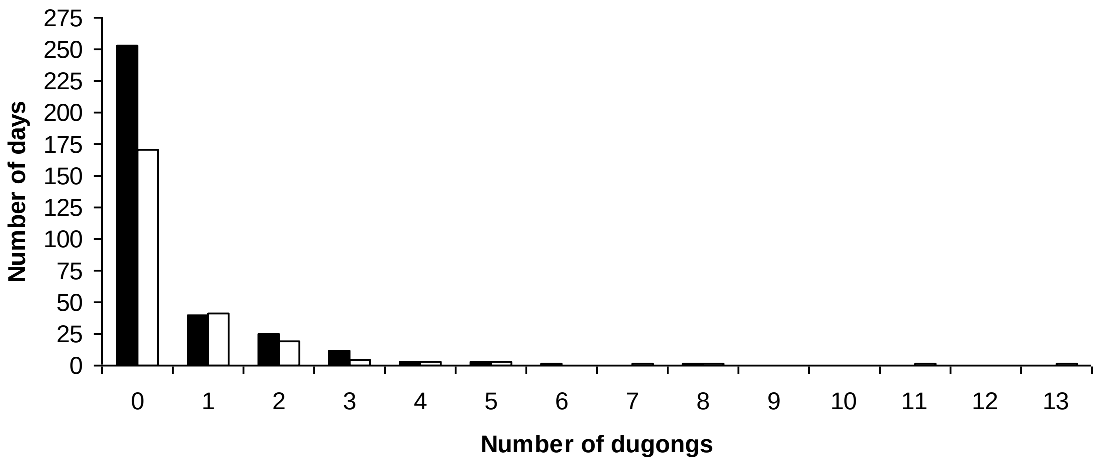


Figure 5.1. Frequency distribution of dugong catches per day for Kwan's (2002) study on Mabuiag Island in 1998 (filled) and 1999 (empty).

Precision of catch-estimates from occasional sampling

The precision of the estimated mean number of dugongs caught per day obtained from occasional sampling (i.e., AFMA's sample) was low in both 1998 and 1999 as evidenced by the large coefficient of variation (standard error as a proportion of the mean) values for AFMA's sample (Table 5.5).

Table 5.5. The mean (S.E.) number of dugongs caught per day at Mabuiag Island in 1998 and 1999 estimated from each of AFMA's sample and calculated from Kwan's census and the precision of the Australian Fisheries Management Authority's estimates calculated as the coefficient of variation (CV; standard error as a proportion of the mean).

	1998			1999		
	n	**Mean (S.E.)**	**CV (%)**	**n**	**Mean (S.E.)**	**CV (%)**
AFMA's sample	26	0.15 (0.07)	45.20	18	0.50 (0.21)	42.45
Kwan's census	245	0.62	n.a.*	245	0.64	n.a.*

*Kwan's census is a total count so there is no CV.

Bias of catch-estimates from occasional sampling

The mean number of dugongs caught per day at Mabuiag Island between March and October in each of 1998 and 1999 was 0.62 and 0.64 dugongs, respectively, calculated from Kwan's census (Table 5.5). The estimated means obtained from 100 random samples of Kwan's census data using AFMA's sampling regime were not significantly different from the true mean (P = 0.05) in 84% and 79% of samples in

1998 and 1999, respectively. This result indicates that occasional sampling using AFMA's sampling regime should provide an unbiased estimate of the mean number of dugongs caught per day on most occasions.

However, in each year most of the 95% confidence intervals of the 100 estimates of the mean number of dugongs caught per day obtained using AFMA's sampling regime (i.e., five blocks, each of four days) were wide (Figure 5.2). Thus, the imprecision of the estimates of the mean number of dugongs caught per day is likely to be the reason why most of the estimated means were not significantly different (P = 0.05) from the true mean (i.e., the true mean was included in the 95% confidence intervals of the estimated mean; Figure 5.2).

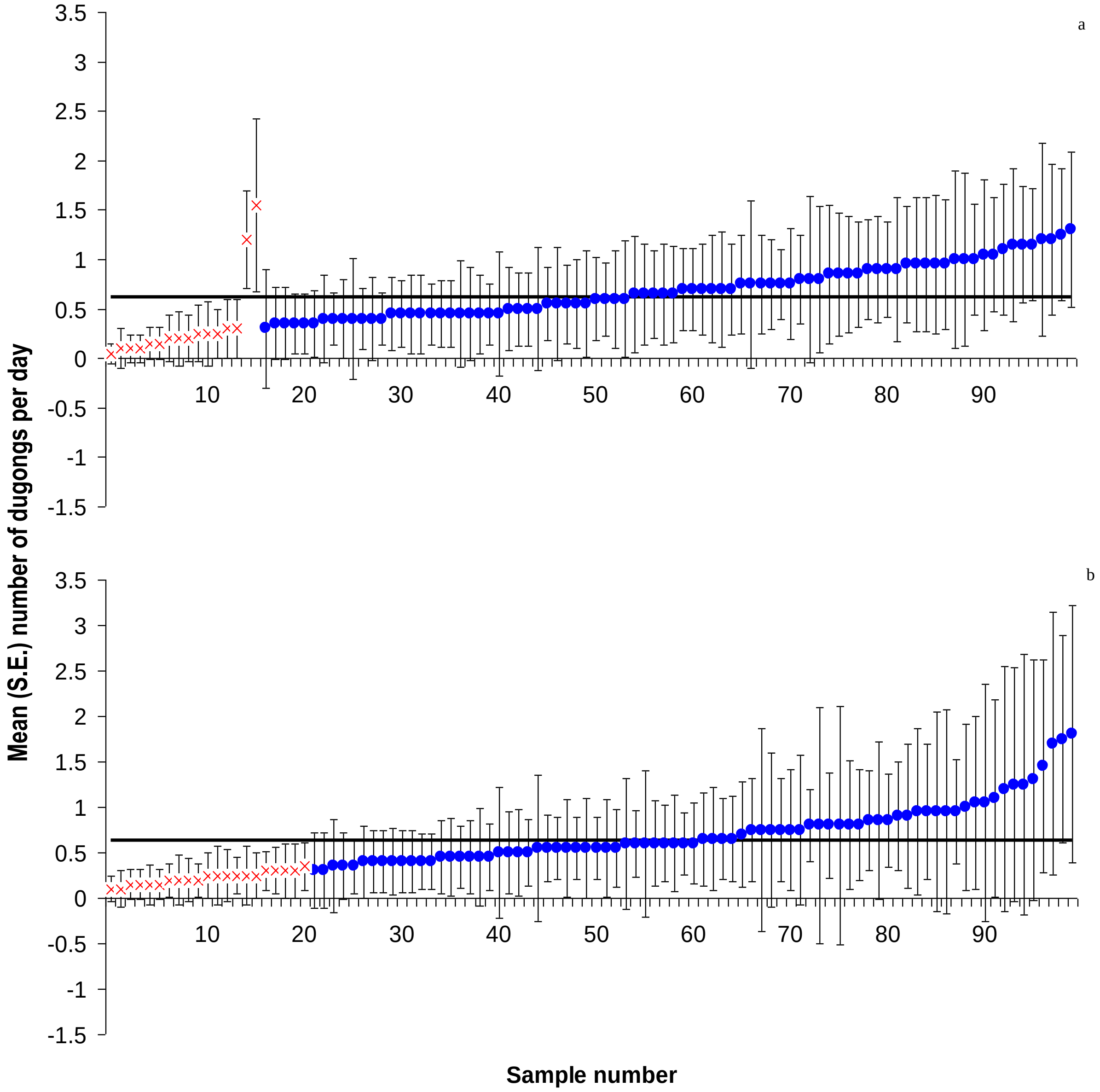
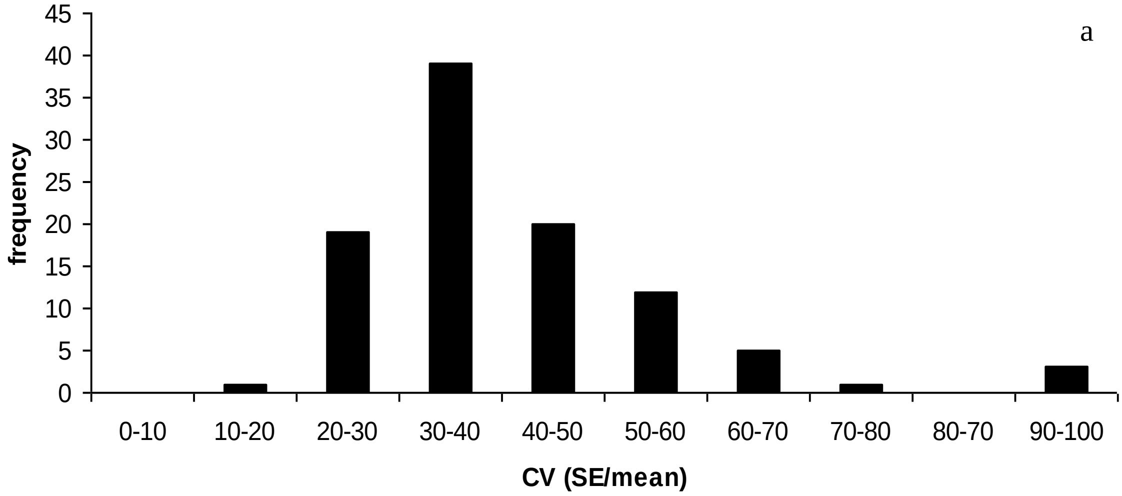


Figure 5.2. Estimated mean and 95% confidence intervals for 100 samples obtained using AFMA's sampling regime of five blocks, each of four days from Kwan's census for a) 1998 and b) 1999. X's are estimates that are significantly different from the true mean (solid line) calculated from Kwan's census (see text) and circles are estimates that are not significantly different from the true mean.

Further, all and 99% of the coefficients of variation of the estimated means from AFMA's sampling regime were greater than 20% in 1998 and 1999, respectively (Figure 5.3). The imprecision of the estimates of the mean number of dugongs caught per day obtained using AFMA's sampling regime (i.e., five blocks of four days) is due to the small number of sampling days (i.e., 20) and variation in number of dugongs caught per day.



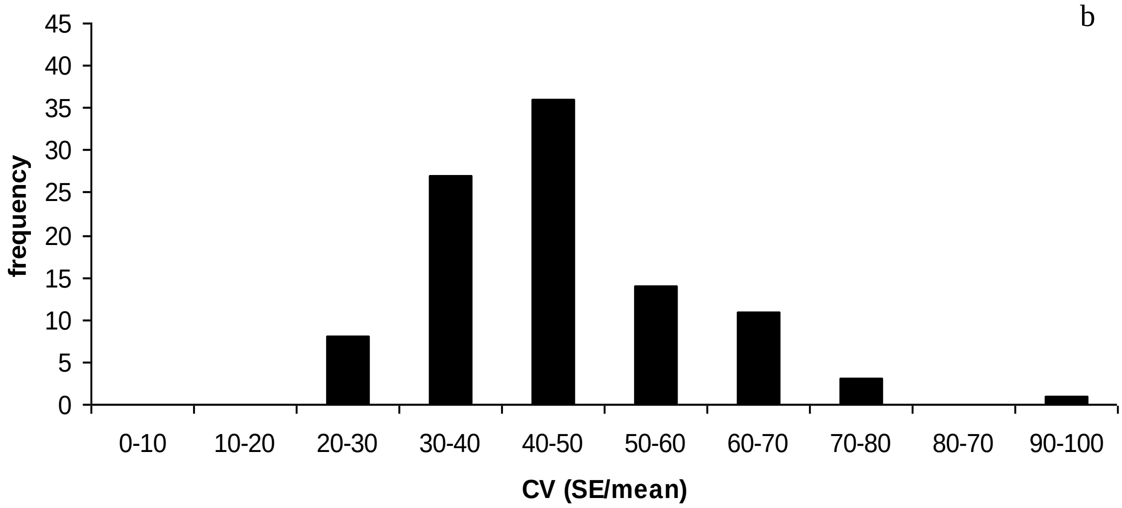


Figure 5.3. The frequency of the coefficients of variation (ratio of S.E. to mean) of the 100 estimated mean number of dugongs caught per day obtained using AFMA's sampling regime (five blocks, each of four days) on Kwan's census in a) 1998 and b) 1999.

Using census data to investigate improvements in precision of catch-estimates

In both years, the mean number of dugongs caught per day in samples obtained from Kwan's census got closer to the true mean as the sample size increased and the amount of fluctuation from the true mean became smaller at a sample size of about 90 days (Figure 5.4). In addition, the coefficient of variation of a sample from Kwan's census improved as sample size was increased. In both years, at least 150 days of sampling from Kwan's census was required to obtain a coefficient of variation of <10% and 70 days of sampling was required to obtain a coefficient of variation of <20% (Figure 5.4).

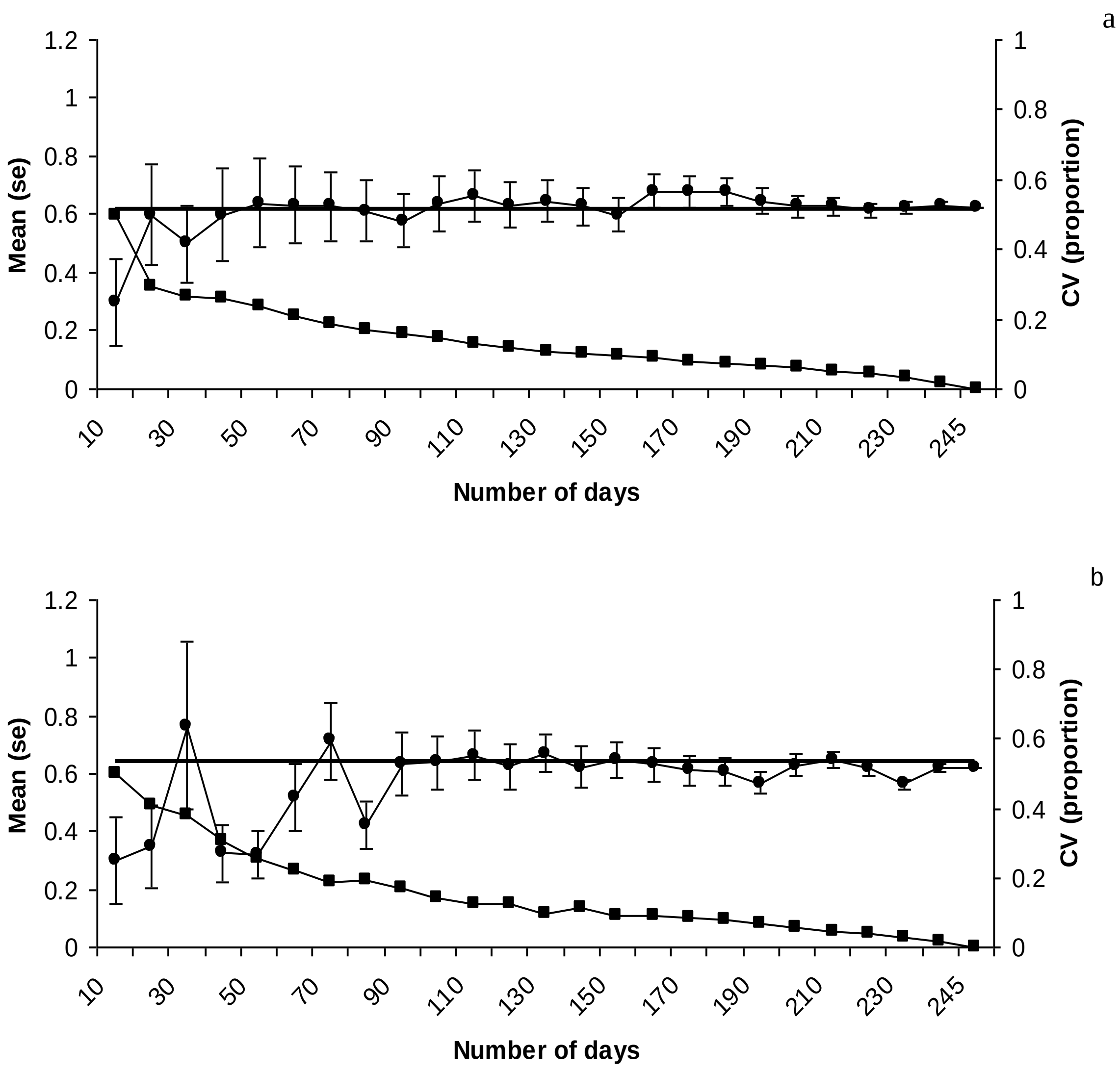


Figure 5.4. Mean (S.E.) number of dugongs per day (circles) and CV (squares) for different sample sizes (n=10, n=20…n=245) obtained by randomly sampling the 245 possible days of Kwan's census in a) 1998 and b) 1999. The solid line is the true mean calculated from Kwan's census.

5.3.2. Investigating the practicality of considering hunters as the sampling unit

Recruitment of hunters

The catch-monitoring project was well supported by hunters in both communities. Eighty-one percent of the 26 potential hunters in the Hammond Island community and 83% of the 75 potential hunters in the Thursday Island community registered to participate in the project (Figure 5.5). The recruitment of hunters was an ongoing and adaptive process, taking about eight months to recruit the maximum number of hunters to the project in each community (Figure 5.5). Nevertheless, most of the

Hammond Island hunters that registered to participate in the project were recruited during two training workshops in February and April 2005. Additional hunters, who had returned to the community after being absent, registered to participate during the year. In addition, three hunters left the community during the project so that at the end of data collection in November 2006 there were 18 (78%) hunters registered to participate out of 23 potential hunters in the community (Figure 5.5).

The recruitment process was less straightforward at Thursday Island than Hammond Island because the local catch-monitor was not employed on the project until mid-July 2005. Thursday Island hunters from the Community Fisher Organisations began collecting data from mid-July 2004, but discontinued recording information in November 2004 in response to the unforseen media scrutiny of Indigenous dugong and marine turtle hunting (see Chapter 2). Many of these hunters re-engaged in the project after I renegotiated their support during meetings in February, March and May 2005 (Table 2.2, Figure 5.5). The CRC Torres Strait Marine Research Liaison Officer and Community Fisher Organisation representatives recruited a few other hunters in April and June 2005 (Figure 5.5). Thus, 25 hunters from the Port Kennedy side of Thursday Island, Prince of Wales Island and Horn Island had registered to participate by June 2005 (Figure 5.5).

Hunters from the suburbs of Tamwoy, Rosehill, Aplin, Waiben and Quarantine on Thursday Island, many of whom worked for the Community Council, were informed of the project in two meetings at the Community Council on Thursday Island in April and May 2005. Subsequently, I employed a local catch-monitor through the Community Council in mid-July 2005 to engage hunters from these suburbs in the project and distribute and collect datasheets from them and the hunters from the

Community Fisher Organisations that had already registered to participate. The local catch-monitor recruited 26 hunters to the project in July 2005 and both he and the CRC Torres Strait Marine Research Liaison Officer recruited additional hunters throughout the year. Thus, by November 2005 there were 62 hunters (83%) from Thursday Island registered to participate in the project out of 75 potential hunters in the community (Figure 5.5). By the end of the project in July 2006, seven hunters had left the community, leaving 55 registered hunters (81%) out of 68 hunters in the community (Figure 5.5).

Participation rates

In both communities, only hunters that registered to participate in the catch-monitoring project reported their catches. All of the identified hunters that did not register to participate in the catch-monitoring project were active hunters. Approximately 20% of the registered hunters from Hammond Island and 40% of the registered hunters from Thursday Island did not go hunting during the project. Participation[11] rates of active hunters were higher at Hammond Island (100%) than Thursday Island (81%; Table 5.6) as of July 2006 and March 2006, respectively. In addition, some participating active hunters from both communities participated by reporting their catches only some of the time (Table 5.6).

[11] Participation refers to participation in the catch-monitoring project such that the hunter reported their catch on a datasheet and submitted it to the local catch-monitor.

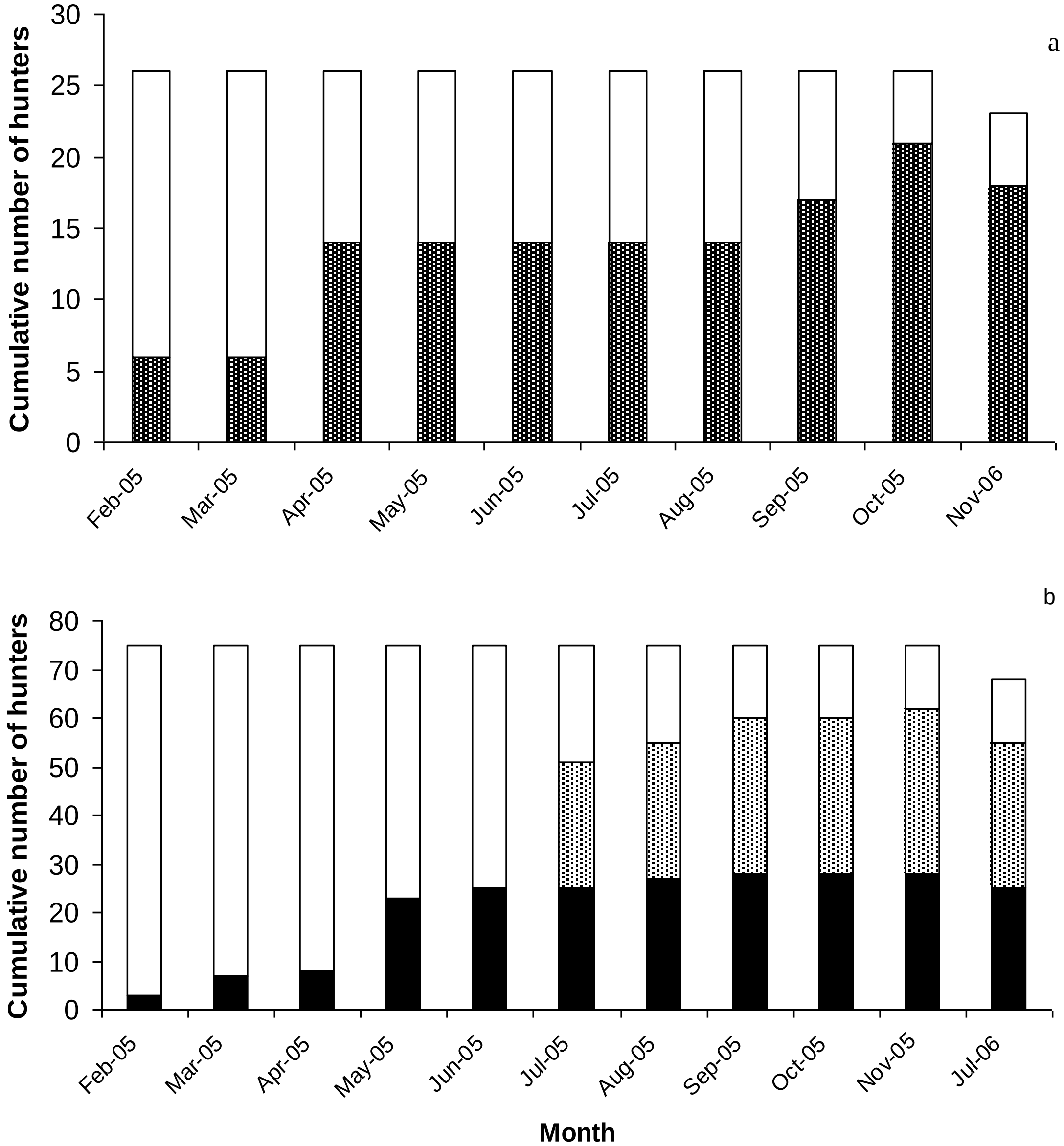


Figure 5.5. Cumulative number of hunters by month that registered to participate in the catch-monitoring project in 2005 and at then end of the project on a) Hammond Island in November 2006 and b) Thursday Island in July 2006 out of the total number of hunters identified in the community. The CRC Torres Strait Marine Research Liaison Officer, Community Fisher Organisation representatives and I (closed bars) and the local catch monitors (stippled bars) recruited hunters.

Table 5.6. The per cent of hunters at each of Hammond Island, as of July 2006, and Thursday Island, as of March 2006 that a) registered to participated in the catch-monitoring project and the per cent of these registered hunters that actively hunted during the project and b) the per cent of these active registered hunters that participated in the catch monitoring project.

a

	Total # of hunters in the community	**# of registered hunters (% of total)**	**% of registered hunters that were active**
Hammond Island	n = 23	18 (78%)	83%
Thursday Island	n = 68	55 (81%)	58%

b

Active registered hunters that participated	**Hammond Island n = 15**	**Thursday Island n = 32**
Always	87%	47%
Sometimes	13%	34%
Never	0	19%
Total that participated (%)	**100%**	**81%**

Potential biases

Investigating mis-reporting: supplementary surveys and monthly activity reports

Some of the participating active hunters in each community (23% at Hammond Island and 35% at Thursday Island) under-reported their catches because they participated only some of the time (Table 5.6). These hunters provided datasheets when they were asked by the catch-monitors and their under-reporting was likely the result of the catch-monitors not observing the catches and not contacting the hunters. In a survey of 11 registered Hammond Island hunters in October 2005, all seven of the hunters who said they went hunting handed in datasheets. However, three of these active hunters had not provided datasheets for some of the catches they reported in the survey and one hunter had provided a datasheet for a catch that he did not report in the survey (Table 5.7). Unsuccessful hunting trips were also under-reported using datasheets (Table 5.7). Only three unsuccessful trips were reported using datasheets, while 55 unsuccessful trips were reported in the survey.

Table 5.7. The differences in data reported since the beginning of the project obtained in a survey in October 2005 of seven registered hunters from Hammond Island who said they went hunting and data recorded on datasheets. The data are the difference in catches reported between datasheets and surveys and the differences in unsuccessful trips reported between datasheets and surveys.

Hunter	Differences in catches between datasheets and surveys	Difference in unsuccessful trips between datasheets and surveys
1	0	-5
2	0	-13
3	-3	-4
4	-4	-4
5	0	-7
6	+1	-4
7	-4	-15

The loss of information when the catch-monitor was unable to contact hunters (e.g., when he was absent from the community) was able to be minimised by surveying hunters. Fifteen registered hunters from Hammond Island provided supplementary information regarding their hunting activity from December 2005 to the beginning of March 2006 in a survey conducted by the local catch-monitor in March 2006 (Table 5.8). Six of these hunters had been hunting during that period. Information about the capture of 10 additional dugongs and 10 additional green turtles was obtained from the survey that was not recorded on the datasheets.

Table 5.8. Supplementary (survey) data from six Hammond Island hunters that went hunting between October 2005 and the beginning of March 2006 reported in a survey of 15 registered hunters in March 2006. The values are the differences from data recorded on datasheets during that time. na = The hunter did not record a dugong or an unsuccessful trip on the datasheet or in the survey and therefore I did not calculate a difference between the datasheet and the survey.

Hunter	Difference in number of dugongs reported between datasheets and survey	Difference in number of green turtles reported between datasheets and survey	Unsuccessful trip
1	+10	+6	na
2	0	-2	na
3	na	+1	na
4	na	+1	+4
5	-1	0	na
6	na	+2	na

Surveys to obtain monthly activity records of a subset of registered hunters at Thursday Island showed that some active hunters did not provide datasheets in May 2006. Four hunters out of the nine hunters (44%) that said they went hunting did not provide any datasheets (Table 5.9). In addition, these hunters did not provide information about the numbers of animals they caught to the catch-monitor during the survey. Reporting improved in June 2006 with only one of the seven hunters (14%) that said he went hunting not providing any datasheets (Table 5.9). In addition, this hunter may not have reported the hunting trip because it was unsuccessful. The information recorded on the datasheets was also consistent with that provided in the survey with respect to the numbers of animals reported as caught. Consistent with the hunting activities recorded up to March 2006, a large proportion of registered hunters did not go hunting in May (71%) or June (82%) 2006.

Table 5.9. Activity of Thursday Island hunters based on monthly surveys of hunters that the local catch-monitor could maintain regular contact with in each of May and June 2006.

	# hunters surveyed	# of hunters that went hunting (i.e., active hunters)	# hunters who provided datasheets (i.e., participated)	% active hunters participating	# inactive hunters (i.e., not hunting)
May 2006	38	9	5	56%	27
June 2006	39	7	6	86%	32

Investigating whether the sample of hunters is a representative sample

In both communities, the populations of registered hunters were heterogeneous with respect to whether they reported catching dugongs, green turtles or both species and the numbers of animals they reported catching.

Of the 32 active registered hunters at Thursday Island, four hunters reported catching both dugongs and green turtles, six hunters reported catching only dugongs, 16 hunters reported catching only green turtles, and six hunters did not participate (i.e., did not submit datasheets). In addition, nine hunters reported some unsuccessful hunting trips (Figure 5.6b). Two hunters caught 64% of the dugongs and 33% of the green turtles. One of these hunters always participated in the data collection, but the other only participated sometimes. These two hunters and an additional two hunters, who always participated, caught 89% of the dugongs. In addition, these two hunters and an additional four hunters, who always participated, caught 74% of the green turtles.

Of the 15 active registered hunters at Hammond Island, five hunters reported catching both dugongs and green turtles, two hunters reported catching only dugongs, and eight hunters reported catching only green turtles (Figure 5.6a). Two hunters caught 79% of the dugongs and 42% of the green turtles. These two hunters and another hunter caught 91% of the dugongs. In addition, these two hunters and an additional four hunters caught 74% of the green turtles.

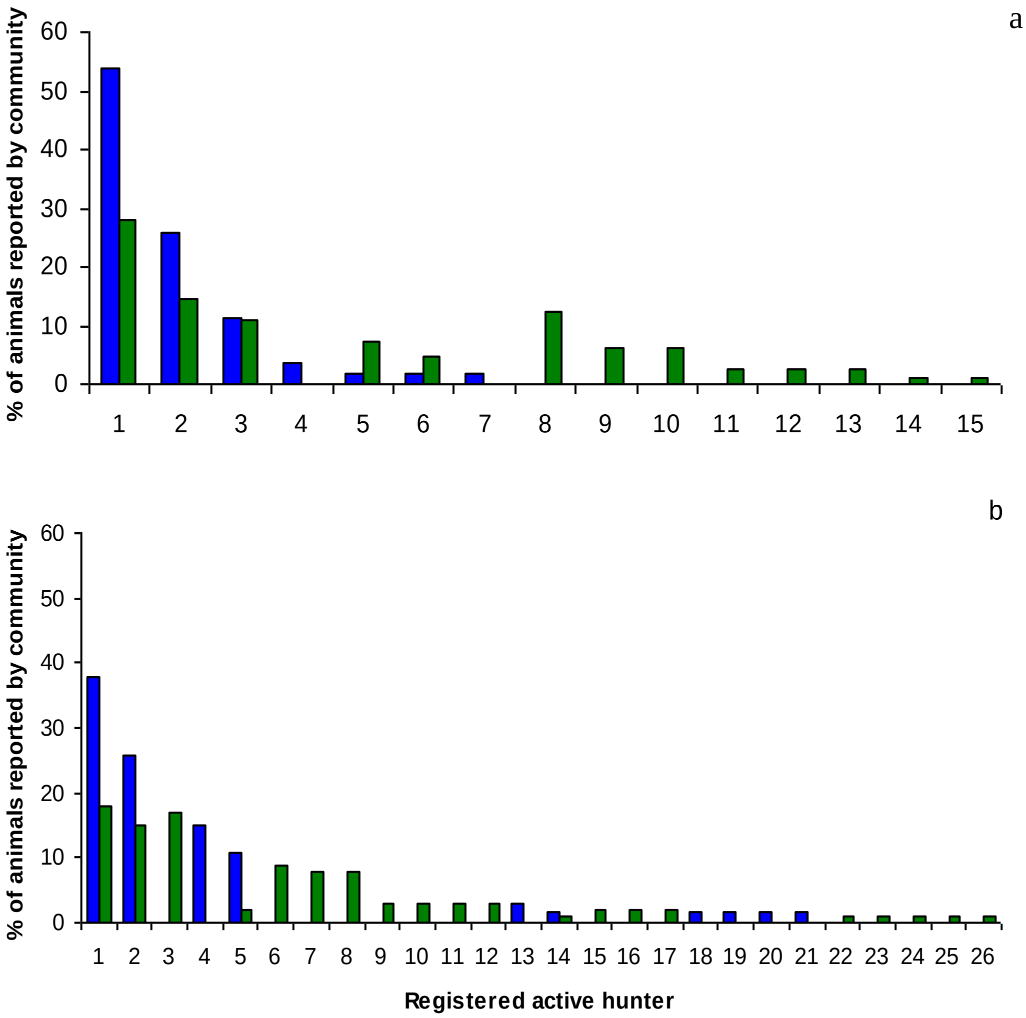


Figure 5.6. The proportion of dugongs (■) and green turtles (■) reported as caught by registered active hunters at a) Hammond Island as of November 2006 and b) Thursday Island as of July 2006.

All of the identified hunters that did not register to participate in the catch-monitoring project were active hunters. However, the local catch-monitor could not assign three of the 13 hunters from Thursday Island to an activity category (top, regular or occasional hunter). The sample of active hunters at Thursday Island as of July 2006 was representative of the population of active hunters in the community. The proportion of top, regular and occasional hunters (as categorised by the catch-monitor) was not significantly different between registered hunters and hunters that did not register to participate in the catch-monitoring project ($\chi^2 = 3.26$, $p = 0.17$, 2 d.f, Table 5.10a). In addition, there was no significant difference in the proportion of top, regular and occasional hunters between registered hunters and hunters that did not register to participate in the catch-monitoring project, when I pooled the top and regular hunters to obtain expected values of greater than five (χ^2 = 1.79, p = 0.18, 1 d.f, Yates' correction, Table 5.10b)

Table 5.10. Observed and expected numbers (per cent) of active registered or not registered hunters that are top, regular or occasional hunters on Thursday Island in July 2006 for a) chi-squared test and b) chi-squared test pooling top and regular hunters to obtain expected values greater than five. See text for results of χ^2 tests.

a)

	Observed				**Expected**		
	Top	**Regular**	**Occasional**	**Total**	**Top**	**Regular**	**Occasional**
Registered	4 (15%)	9 (35%)	13 (50%)	26	3.10	9.29	9.90
Not registered	1 (6%)	6 (60%)	3 (30%)	10	1.90	5.71	6.10
total	5	15	16	36			

b)

	Observed			**Expected**	
	Regular	**Occasional**	**Total**	**Regular**	**Occasional**
Registered	13	13	26	12.38	9.90
Not Registered	7	3	10	7.62	6.10
Total	10	16	26		

The sample of registered active Hammond Island hunters remaining in the community in November 2006 was probably representative of the population of active hunters (i.e., 20 hunters in total; 15 registered and five not registered) in the community. The proportions of top, regular and occasional hunters were similar for registered hunters and hunters that had not registered to participate in the catch-monitoring project. However, I could not test this hypothesis statistically because of the small number of active hunters (i.e., small sample size). The two top hunters in the community were participating and one of the non-participating hunters was also a top hunter. One of the participating hunters was a regular hunter and the rest of the active hunters were occasional hunters.

5.4. Discussion

Occasional sampling did not provide precise catch-estimates at the scale of individual communities. In both years, coefficients of variation of the Australian Fisheries Management Authority's estimates of the mean numbers of dugongs caught per day at Mabuaig Island were large. Consequently, trends in the mean number of dugongs caught per day at the community level could not be detected using occasional sampling.

In addition, when 100 simulations of sampling Kwan's census data using AFMA's sampling regime (i.e., five blocks of four days) were run, most of the 95% confidence intervals were very wide and almost all of the coefficients of variation of the 100 estimated means in each year were greater than 20%. The imprecision of the estimates of the mean number of dugongs caught per day obtained using AFMA's sampling regime (i.e., five blocks of four days) on Kwan's census is due to the small number of sampling days (i.e., 20) and the heterogeneity of the catch per day (see below). The precision of the estimates increased as sample size increased when I randomly took samples of 10 to 245 days from Kwan's census. In addition, it is likely that at least 150 days of sampling would be needed to obtain precise estimates (i.e., CV < 10%) and at least 70 days of sampling would be needed to consistently obtain estimates with coefficients of variation of less than 20 % for dugong hunting at Mabuaig Island.

The imprecision and bias of catch-estimates of dugongs obtained from occasional sampling, using day as the sampling unit, at the scale of an individual community is due to the small number of sampling days and the fact that dugong catches are highly variable through time (Kwan et al. 2006). This variability is caused by the interaction of environmental, cultural, social and economic factors, which influence hunting effort and success (Kwan et al. 2006). For example, Kwan et al. (2006) found that the probability of dugong hunting at Mabuiag Island was influenced by local environmental factors, including the abundance of dugongs in the traditional hunting grounds, which was in turn affected by wind speed, year, season and lunar day. Therefore, hunting effort is not normally distributed through time and not easy to predict and these factors make it very difficult to obtain reliable estimates of total catch from sampling.

The approach of the Australian Fisheries Management Authority's projects to send independent observers to islands on sampling days was both financially expensive and limited the time and effort spent collecting data. By staging specific sampling days the Australian Fisheries Management Authority studies had no mechanism to ensure that the data they collected were representative and free from the bias associated with hunters changing their behaviour on sampling days. For example, because the project used outside observers, monitoring days had to be scheduled in advance, and hunters knew that the sampling period would be short. Therefore, hunters could strategically change their hunting behaviour whenever the observer was on the island, resulting in a higher (or lower) catch. The Australian Fisheries Management Authority's projects aimed to obtain catch estimates of dugongs and marine turtles for the whole of Torres Strait. However, co-management at the community level requires catch-estimates at the level of the community. In fact, the project was discontinued after 2000/01 because of the expense and difficulty in running the observer program and problems of precision, bias and coverage of the catch estimates it produced for the Torres Strait Protected Zone as a whole. Focus was shifted to establishing effective community-based monitoring programmes (Skewes et al. 2004). The Australian Fisheries Management Authority held a technical catch-monitoring workshop in May 2003 to work out one or more appropriate community-based monitoring methods as discussed in Chapter 2 (Turtle and Dugong Catch Monitoring Workshop, 2003).

It is important that hunters have confidence in the scientific advice they receive. For example, hunters are unlikely to accept management strategies reducing their catch if they are not convinced that the catch-estimate and the calculation of a sustainable catch rate are correct (Hønneland 2000; Rist et al. 2010). Further, failure to accept the accuracy of scientific estimates is likely to lead to fewer hunters participating in catch-monitoring and/or future under-reporting of catches; consequently, the accuracy of the data will decline resulting in further degradation of confidence in the scientific advice about the dugong and green turtle resources (Hønneland 2000).

Involving stakeholders in all stages of the research process, including the study design and collection of data makes the research more valuable as a source of credible information (Burger et al. 2007). Experience elsewhere shows that the results of western scientific research are more likely to be accepted if Indigenous people are involved in actual collection of the data (e.g., Kennett et al. 2004). With adequate support and funding, community-based catch-monitoring can provide employment, training and capacity-building enabling community members to be more actively involved in the monitoring and management of their dugong and green turtle resources.

I consider that it would be possible to obtain reliable catch-estimates from a hunter self-monitoring programme at small and large Torres Strait communities. A large proportion of hunters from each of the communities in the present study registered to participate in the project (78% at Hammond Island and 81% at Thursday Island) and although the participation rate of registered active hunters was higher at Hammond

Island (100%) than Thursday Island (81%), it was high in both communities. In addition, the sample of registered hunters that went hunting and participated in the project by providing datasheets in each community was representative of the population of active hunters in that community. Thus, in both communities, it would be appropriate to estimate total catches of dugongs and green turtles using proportional projection based on the hunting activity of the registered active hunters. It would also be possible to track the community's catch level through time.

An alternative approach to involving all of the potential hunters in the community would be to involve only the few top hunters who accounted for most of the harvest in each community. Similar to hunters at Mabuaig Island in 1998 and 1999 (see Kwan 2002), two hunters from each of Thursday and Hammond Island caught 64% and 79% of the dugongs, respectively and 33% and 42% of the green turtles, respectively. At Hammond Island, the harvest of the participating top hunters could be used as a minimum harvest for the community because there was only one non-participating hunter that was a top hunter. However, at Thursday Island, several non-participating hunters were considered top hunters and therefore their unknown harvest could be substantial. Thus, extrapolating based on the sample of top hunters participating from the population of top hunters in the community would be more appropriate. This approach of involving only the top hunters could greatly reduce the effort required to determine the harvest of dugongs and green turtles compared with a programme involving all of the potential hunters in the community. However, involving all of the potential hunters in the community encourages broad participation and broad interest in wildlife management in the communities (Noss et al. 2003). This latter outcome was an objective of my study and the choice of monitoring scheme for future studies would need to be based on the specific objectives (and resources) of the monitoring programme, which need to be negotiated with the community.

Local catch-monitors, maintaining regular contact with hunters, are essential for obtaining complete catch-records from hunters. High rates of participation by walrus hunters in one of the communities in an Alaskan walrus harvest tagging monitoring programme was thought to have resulted in part from the diligence of taggers who regularly "made the rounds" throughout the village to tag walrus tusks (Burn 1998). In my study, local catch-monitors were diligent about contacting hunters and utilised their social networks to contact hunters when they were not working.

Despite the efforts of the catch-monitors, some mis-reporting by registered active hunters occurred (i.e., datasheets were not provided). This mis-reporting was likely the result of the local catch-monitors not being able to observe every catch or not always being able to maintain regular contact with every hunter. However, most registered active hunters provided datasheets when they were asked for them, and catches missed by the catch-monitors in their usual work programs were obtained by surveying hunters at the end of a one or three month period. However, there was a small amount of recall bias associated with such surveys. At Thursday Island, these surveys resulted in an improvement in the provision of datasheets. One of the two hunters that had successful hunting trips in both May and June 2006 and did not provide datasheets in May, provided datasheets in June after reporting his catch for May in the survey, probably because he knew he would be asked about his hunting activity at the end of the month. The other hunter may not have filled in a datasheet in June because his hunting trip was unsuccessful.

At Hammond Island, the surveys enabled the recording of the number of unsuccessful trips. Hunters did not record unsuccessful trips on datasheets. Under reporting of unsuccessful trips will affect estimates of hunting effort and thereby complicate the evaluation of whether hunting is sustainable. Changes in catch-per-unit-effort can indicate whether a population is over-hunted (Noss et al. 2005). Wildlife densities are probably not decreasing in the hunted areas if long-term harvest rates are not declining (Noss et al. 2005). The results of the present study suggest that it will be easier to obtain accurate estimates of total counts of dugongs and green turtles caught than catch-per-unit effort using community-based monitoring because of the difficulties of recording unsuccessful trips. An alternative to estimating catch-per-unit-effort could be to record where animals were caught (which is likely to be sensitive information) or how far hunters travelled to catch the animals. This information was collected in the present study (see Chapters 3 and 7). The insights for management provided by different indicators are discussed in Chapter 8.

Surveying hunters in Torres Strait at the end of each month regarding their hunting activity in the preceding month could make it easier to derive total catches from a sample of participating hunters. These monthly activity records enable: (1) an assessment of whether the sample of participating hunters is representative; (2) proportional projection based on active hunters rather than all potential hunters (this will be important if non-participating hunters are mostly active hunters); and (3) ensures catch-monitors contact each hunter at least monthly (this will be important for those hunters whose catches the catch-monitors do not observe or who the catch-monitors to do not regularly see in the community). Such surveys may also provide an alternative way to collect effort information, particularly regarding unsuccessful trips, which are often not recorded on datasheets (Pollock et al. 1994).

When assigning hunters to an activity category, an additional category "absent from the community" would be useful because hunters periodically leave the community (e.g., Noss et al. 2003). Vickers (1991) kept a log of the activities and comings and goings of people in an Amazonian Indian community in Ecuador to deal with the complexity of the population and to be able to define "mean annual population" with a fair degree of precision. This method gave a more accurate index of human presence than a static list of "residents" (who may or may not be present at any given time).

The difference in participation rates between the Hammond Island and Thursday Island communities is not large compared with other hunter self-monitoring programs. For example, participation of Izoceno hunters in Bolivia in a hunter self-monitoring programme ranged between 30% and 100% of active hunters in 14 communities, with all but one over 70% (Noss et al. 2003). In addition, compliance with regulations to tag the tusks of harvested walruses by hunters in three communities in Alaska ranged from 41% to 99% (Burn 1998).

The differences between the two communities, Hammond Island and Thursday Island, in recruitment and participation rates of hunters may have resulted from differences in leadership, community size and cohesion and the transparency of the catch (see Box 5.1). As discussed in Chapter 2, leadership may have influenced the acceptance of the project by hunters. The Community Council was the only leadership group on Hammond Island and it strongly encouraged hunters to participate in the project. In contrast, the Community Fisher Organisations and the local Community Council on Thursday Island assisted in informing hunters of the project, but left their participation up to the individual hunters. In addition, at the beginning of the project the Hammond

Island Council was less concerned about the potential impacts of adverse media controversy surrounding Indigenous hunting of dugongs and marine turtles (see Chapter 2) than the Community Fisher Organisations and Community Council on Thursday Island. The Hammond Island Council was therefore able to convince its community's hunters to participate more quickly than the Thursday Island leaders.

It is likely that the ability of local catch-monitors to recruit hunters and ascertain catches was influenced by the size and cohesion of the community and the transparency of catches. Hammond Island is a small, cohesive community within which most people are willing to share information. In addition, everyone in the community knows when dugongs and green turtles are caught because the main landing site is on the main beach and word about a harvest spreads quickly through the community.

In contrast, Thursday Island is a large, diverse population centre with hunters living in two main communities on Thursday Island (i.e., Port Kennedy and the suburbs of Tamwoy, Rose Hill, Aplin, Waiben and Quarantine); some hunters live on nearby Prince of Wales Island or Horn Island. It was difficult for one catch-monitor to maintain regular contact with such a large number of hunters, particularly those from the part of the community that he did not belong to and therefore did not know very well. This situation could be improved by having a local catch-monitor responsible for each part of the community, ideally one that knows the hunters in that part of the community well. In addition, Thursday Island has many landing and butchering sites, including peoples back yards, which made it very difficult to observe catches directly and relatively few of the people in the community knew about each catch. Catches could be made more transparent on Thursday Island by designating a common butchering site that is compulsory to use. However, designating a common butchering site that is compulsory to use may not be feasible because of concerns raised by community members about attracting crocodiles to these areas. In addition, it may be politically challenging (perhaps impossible) to endorse or underwrite building such sites given the opposition to hunting expressed by some sections of the wider Australian community. Such opposition has been prevalent over a long period of time (see Ponte 1996).

Confirmation that the hunter self-monitoring method trialled here will provide reliable catch-estimates can only be obtained by quantitatively comparing the results to those obtained using another independent method to estimate the catch. Catches of wildlife species in forests in Bolivia were shown to be under-reported by hunter self-monitoring compared with small scale focussed studies of several species in which catches were monitored by direct observation and/or daily household visits by monitors (Noss et al. 2004). Conversely, trends in game population abundances determined from the Ghana Wildlife Division's vertebrate monitoring programme in African game reserves were corroborated by independent, shorter term monitoring efforts of externally funded scientists in the same reserves (Brashares and Sam 2005).

It was not possible to conduct such a validation of the hunter self-monitoring programme in the current study because hunters considered that simultaneously using another method to monitor the catch would be confusing because they were already providing the information on the datasheets. It would also waste their time and implied that they were not trusted to provide accurate information. Similarly, Danielsen et al. (2005a) suggested that calibrating every locally- based monitoring scheme against a professional method would imply widespread distrust of local communities, in addition to being logistically impractical and unaffordable.

In addition, walrus hunters in Alaska were confused about the independence of two walrus harvest-monitoring programmes (Burn 1998). A year round tagging programme required hunters to have the tusks from the walruses they caught be tagged by official local taggers. During the spring hunting season only, monitors from a second programme met hunters at landing sites and collected more detailed information about the harvest than the tagging programme, as well as biological samples for life-history and contaminant analysis. This second programme was also used to evaluate compliance with the year round tagging programme. However, some hunters thought that once the tusk had been tagged (using a different tag than the tagging programme) by the monitors at the landing site, it did not need to be tagged by the official local taggers (Burn 1998).

Many scientists remain concerned about the ability of locally- based monitoring schemes to provide reliable information and therefore calibrating the results against a professional method can increase the confidence in the information by managers responsible for species conservation (Noss et al. 2003; Rodriguez 2003; Yoccoz et al. 2003; Danielsen et al. 2005a). Nevertheless, my results suggest that a community-based catch-monitoring approach such as hunter self-monitoring will be a better approach for determining catch-estimates for dugongs and green turtles to inform co-management at the scale of individual communities than alternatives such as occasional sampling or a census by scientists. Hunter self-monitoring has fewer limitations and more benefits than the other alternatives with respect to: accuracy and precision of the catch estimates; financial cost; trust by communities and capacity to feedback results to communities in a timely manner (Table 5.11).

Table 5.11. Comparison of the limitations and benefits of different monitoring approaches to obtain catch-estimates for dugongs and green turtles at the scale of individual communities in Torres Strait.

	Hunter self-monitoring	**Occasional sampling**	**Census by scientist**
Accuracy and precision of estimates	high	low	high
Financial costs	medium	high	high
Trust by community	high	low	low
Capacity to feedback results to the community in a timely manner	high	low	low

5.5. Chapter summary

- In this chapter, I investigated cost-effective and culturally appropriate catch-monitoring strategies that would provide accurate, unbiased and precise catch-estimates for the Torres Strait dugong and green turtle harvests at the individual community levels.

- I investigated how practical it was for a monitoring strategy that considered day as the sampling unit (e.g., occasional sampling) to provide accurate, precise and unbiased catch-estimates at the individual community level.

- I re-analysed data from two catch-monitoring projects previously conducted in Torres Strait to collect catch statistics and/or life-history parameters on dugongs: (1) occasional sampling and (2) census by an outsider. The Australian Fisheries Management Authority (Skewes et al. 2004) and Kwan (2002) conducted these two projects simultaneously at Mabuaig Island in 1998 and 1999.

- The results of my investigation led me to investigate how practical it was for an alternative monitoring strategy that considered hunters as the sampling unit to provide accurate, precise and unbiased catch-estimates at the individual community level.

- Hunters in the Kaiwalagal communities of Hammond Island and Thursday Island recorded information on datasheets on the number of animals taken, demographic information about the animals taken and information on hunting patterns. The Indigenous research counterparts employed on the project recruited hunters to participate, distributed and collected datasheets, collected biological samples from harvested animals and helped provide feedback to hunters and their communities about the results and progress of the project.

- Co-management of dugongs and green turtles in Torres Strait requires information to be collected at a range of spatial scales. Catch-monitoring is needed at the scale of individual communities because it will inform management at the community level as well as large scales. Occasional sampling, using day as the sampling unit, did not provide precise catch-estimates at the scale of individual communities and therefore trends cannot be detected.

- I consider it would be possible to obtain accurate and precise catch-estimates from a hunter self-monitoring program at small and large Torres Strait communities. A large proportion of hunters from both Hammond Island and Thursday Island participated in the project and the sample of participating active hunters in each community was representative of the population of active hunters in that community.

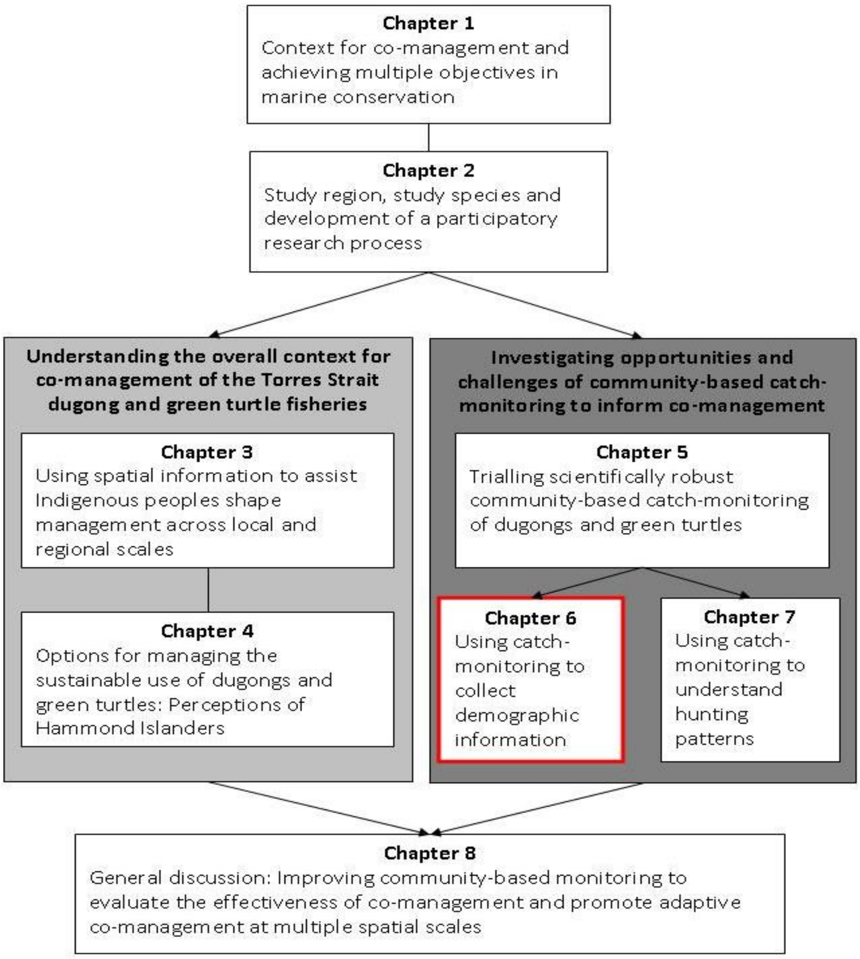
- It will be easier to obtain accurate total counts of dugongs and green turtles than catch-per-unit-effort in a hunter self-monitoring program because of problems with obtaining reports of unsuccessful trips.

- The high participation rates achieved here required a great deal of effort from the local Indigenous research monitors who kept in regular contact with hunters. The required effort was greater at Thursday Island than Hammond Island because it is a larger, more diverse community. Other factors affecting differences in recruitment and participation rates between the two communities included differences in leadership, community size and cohesion and the transparency of the catch.

- My results suggest that a community-based approach, such as hunter self-monitoring, will be a better approach for determining catch-estimates for dugongs and green turtles to inform co-management at the community level than alternatives such as occasional sampling or census by scientists. Hunter self-monitoring has fewer limitations and more benefits than the alternatives with respect to: accuracy and precision of the catch estimates; financial costs; trust by communities and capacity to feedback results to communities in a timely manner.

Chapter 6

Community-based monitoring as a method of determining the nature of the dugong and green turtle catch in two Torres Strait communities to inform Indigenous hunting management



Achieving sustainable harvests depends on understanding population trends, the demographic processes that drive those trends and the harvest rate. In this chapter, I investigate how well hunters could collect demographic information from harvested dugongs and green turtles to inform Indigenous hunting management. In particular, I examine what information hunters could practically collect and assess whether the information collected could provide insights into the ecological and cultural sustainability of the catch or the population status of dugongs and green turtles in Torres Strait. I discuss the results of this trial with respect to informing the development of community-based monitoring programs for the management of marine turtles and dugongs by Torres Strait communities as well as other Indigenous communities. Chapter 6 (and Chapter 7) includes information (i.e., the total numbers of dugongs and green turtles caught) that is confidential under the terms of the Research Agreement (see Appendix A). This confidential information will be removed from versions of the thesis that will be made public.

Chapter 6. Community-based monitoring as a method of determining the nature of the dugong and green turtle catch in two Torres Strait communities to inform Indigenous hunting management.

6.1. Introduction

As I described in Chapters 3 and 5, determining whether subsistence harvesting is sustainable requires quantitative data on the size of the population of the target species, the demography of the animals taken and the level of take (Hamann et al. 2010; Bjorndal et al. 2011). In Chapter 5, I suggested that two of these pieces of required information, level of take and demography of the animals taken, could be collected for the Torres Strait dugong and green turtle fisheries by monitoring harvested dugongs and green turtles. I also examined the feasibility of using locally-based monitoring for estimating catch-numbers and showed that it can provide more reliable information than occasional professionally-based monitoring (see Chapter 5). Locally- based monitoring may also assist local people to monitor the demography of the animals taken in their catch by incorporating monitoring of biological parameters such as the sex, size, maturity and reproductive status of caught animals into their catch-monitoring programs. Monitoring these parameters can provide insights of the ecological and cultural sustainability of the catch as well as trends in the population status of the species being harvested.

As explained in Chapter 2, dugongs and green turtles are both long-lived species that are slow to reach sexual maturity (Marsh 1995a; Kwan 2002; Limpus 2008). The population growth rates of marine turtles are most sensitive to juvenile and adult survival (Heppell et al. 2000), while population growth rates of mammals, like dugongs are most sensitive to adult survival (Eberhardt 2002). Therefore, a bias in the catch towards a particular size/age class (e.g., adults) may indicate that the harvest is not ecologically sustainable, or will not be sustainable in the long-term.

The nature of the catch can also indicate whether the harvest is culturally sustainable, based on known preferences for animals of a particular sex, sizes or reproductive stages. In the past, Torres Strait Islanders showed a strong preference for adult female green turtles (Nietschmann and Nietschmann 1981; Johannes and MacFarlane 1991; Kowarsky 1995), with larger numbers of females than males reported in the catches. Reports of other catches in northern Australia show a similar preference (e.g., Smith 1989; Kennett et al. 1998). Adult female green turtles are preferred to male green turtles or immature green turtles because they are larger, generally fatter and during their vitellogenic or breeding phase, they contain large numbers of ova (known locally as yellow eggs or *webud*) and the latter two features improve the taste (Nietschmann and Nietschmann 1981; Johannes and MacFarlane 1991; Kowarsky 1995; Kennett et al. 1998).

Torres Strait Islander hunters also reportedly preferred the meat of female dugongs in the past (Haddon 1912; Nietschmann and Nietschmann 1981; Raven 1990; Johannes and MacFarlane 1991; Kwan 2002; Marsh and Kwan 2008) because females are fatter than males. In addition, hunters in Torres Strait also allegedly prefer breeding female dugongs to resting females because they are fatter (Nietschmann and Nietschmann 1981; Raven 1990; Johannes and MacFarlane 1991).

A change from a biased catch that matches cultural preferences to an unbiased catch may indicate that the population has been over-harvested because preferred animals are no longer available (provided hunters can realise their preference by distinguishing amongst animals of different life history stages and reproductive status and the catch is not regulated in some way to change its' biological composition). Other biases associated with hunting, in addition to hunter preferences, that may lead to biases in the catch should also be considered when determining whether the catch is ecologically or culturally sustainable. Thus, it would be informative to understand the demographic and reproductive parameters of the foraging population occupying the area from which the catch is obtained to assist in determining whether there are biases in the catch due to selectivity of hunters.

Biological parameters collected from the catch to inform sustainable catch and population status may be confounded by stochastic environmental conditions, which makes any patterns in these parameters difficult to interpret. In addition to being regulated by population density, population dynamics, especially age at first reproduction and reproductive rates, may be regulated by environmental conditions, but it can be difficult to distinguish the influences of each of these factors (Sæther 1997; Gaillard et al. 2000). Both major climatic events, such as El Nino Southern Oscillation events, and local weather conditions (e.g., flooding), can affect the quality and quantity of food resources available to a population (Limpus 2008). In some large vertebrates, fecundity is closely linked to nutrition and body condition and therefore changes in food availability can affect life history traits relating to reproduction (Eberhardt 2002). As described in Chapter 2, stochastic environmental conditions may change the quality of feeding habitat and thereby affect the fecundity, survival or movement patterns of dugongs and green turtles.

Having local people on-the-ground monitoring biological parameters can enable rapid identification of changes and enable early intervention (Robards et al. 2009). For example, during a period of seagrass dieback in Torres Strait in the 1970s a large proportion of dugongs caught were reportedly lethargic and had poor tasting fat. Islanders attributed their poor condition to either inadequate food availability, the loss of sea grass because of the Oceanic Grandeur oil spill or too many dugongs grazing on the sea grass (Nietschmann and Nietschmann 1981; Nietschmann 1984; Johannes and MacFarlane 1991; Kwan 2002; Marsh and Kwan 2008). As was the case in the 1970s, hunters are likely to notice the poor condition of the dugongs they catch before external researchers notice sea grass dieback (Kwan 2002). Therefore, local people monitoring the life history characteristics of caught dugongs could record this information and subsequently would be able to attribute changes in age at first reproduction and reproductive rates to inadequate food availability. In addition, the hunters could quickly limit the catch to avoid further stressing the reproductive capacity of the population during the period of inadequate food availability.

In this Chapter, I report my trial of locally- based monitoring of biological parameters of dugongs and green turtles caught by hunters in two Torres Strait communities to examine how feasible it was to use such monitoring to collect life-history information to inform Indigenous hunting management in these fisheries. In particular, I examined what information hunters could practically collect and assessed whether the information collected could provide insights into the ecological and cultural sustainability of the catch or the population status of dugongs and green turtles in Torres Strait. The results of this trial will be useful for informing the development of community-based monitoring programs for the management of marine turtles and dugongs by Torres Strait communities as well as other Indigenous communities.

6.2. Methods

6.2.1. Data collection

I assessed whether the biological nature of the catch of green turtles and dugongs could be determined through locally- based monitoring as part of the trial of community-based catch-monitoring at Hammond and Thursday Islands in the

Kaiwalagal region in Torres Strait in 2005-2006. As described in Chapter 5, Hammond and Thursday Island hunters recorded their catches of green turtles and dugongs on catch-monitoring datasheets (see Appendix B), with the assistance of local catch-monitors employed on the project. One datasheet was completed for each animal caught and the datasheets enabled hunters to record demographic information about the catch as well as information relating to hunting patterns (see Chapter 7). The datasheets requested information on the sex, size, reproductive status and maturity of the green turtle and dugong catch.

I designed the datasheet together with some of the hunters (see Chapters 2 and 5). Dr Mark Hamann and I trained the hunters and local catch-monitors in taking morphometric measurements and biological sample collection, storage and assessment from green turtles and dugongs captured during hunting through two workshops (in February 2005) and demonstrations as opportunities arose throughout the project. The local catch-monitors were able to assist hunters that had not attended the workshops. As I was based on Thursday Island for most of the project, I was available to assist whenever necessary. Hunters were provided with catch-monitoring kits that included the datasheets, pencils, a flexible tape measure and a straight tape measure (see Chapters 2 and 5). The work was carried out under Scientific Purposes Permit No. WSP02582304, *Queensland Nature Conservation Act 1992* and James Cook University Animal Ethics No. A932 and A957.

Monitoring occurred over different periods with Hammond and Thursday Island hunters (Figure 6.1). Monitoring commenced when I engaged local catch-monitors in each community, which was the end of February 2005 and the end of July 2005, at Hammond and Thursday Islands, respectively. Although I left Torres Strait at the beginning of July 2006, the local catch-monitor from Hammond Island continued to collect information from hunters until the beginning of November 2006.

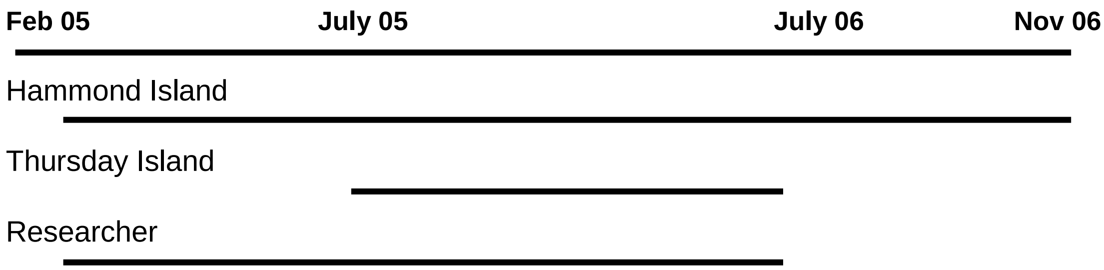


Figure 6.1. The monitoring period at each of Hammond and Thursday Islands relative to the period of time I (i.e., researcher) was available to assist with monitoring.

Hunters determined the sex of green turtles and dugongs they caught by examining the reproductive organs and gonads when butchering the animal. This approach was considered more reliable than using external indices. Green turtles exhibit some external sexual dimorphism, with adult males having longer tails than females, but large immature males cannot be reliably distinguished from adult females based on tail length. Dugongs exhibit little external sexual dimorphism and the distance between the genital opening and the anus is the most reliable external index of sex. Tusks (second incisors) can be regarded as a secondary sexual characteristic (Boyd et al. 1999). Tusks erupt in male dugongs at puberty, but not all dugongs with erupted tusks are male. Tusks also erupt in some old females (Boyd et al. 1999).

Hunters measured the curved carapace length (CCL) of the green turtles they caught using flexible tape measures following standard practices for marine turtle research in Australia (Limpus and Reed 1985b). Cultural protocols precluded the measurement of the sizes of dugongs. Instead, hunters estimated the length of caught dugongs visually. One of the Cultural Reference Group members for the Project, Willie Wigness explained this cultural protocol:

"The dugong is totem, a spiritual God for certain clans. The myth of Gelam speaks of the journey of life to its resting place and establishment of its permanent house in the eastern Torres Strait, what is now known as Mer Island. It is the Kaurareg's and Mualalgal's belief that measuring the animal gives you a precise measurement of a house (coffin), in the spiritual sense, marking yourself and family members for a short life"

The maturity and reproductive status of female green turtles was assessed in two ways: (1) hunters recorded the presence or absence of yellow eggs (i.e., mature follicles >2.5 cm), known locally as *webud*, in the ovaries; and (2) Dr Mark Hamann and I assessed 9% of the ovaries using the criteria described by Limpus and Reed (1985b). These ovaries were assessed for ovarian scars (*corpora albicantia*), indicating that the green turtle had bred in a previous season, or recent scars (*corpora lutea*), indicating that the green turtle had bred in the most recent season.

The maturity and reproductive status of female dugongs were determined based on whether or not they were pregnant. I also invited hunters to provide the uteri and ovaries of the dugongs they caught to the local catch-monitor or me to enable interpretation of the reproductive status of the dugongs to be more refined or enable me to train hunters to undertake such interpretations. However, only one hunter provided dugong reproductive organs for interpretation on one occasion. Similarly, I invited hunters to provide the tusks of dugongs they caught for age-determination. Again, only one hunter provided dugong tusks for interpretation. I made a crude estimate of the pregnancy rate in the dugong catch based on the proportion of pregnancies reported by hunters. Early pregnancies were unlikely to be detected by hunters and therefore the pregnancy rate was likely to be an under-estimate.

For those green turtles and dugongs for which reproductive status was not determined, maturity was assessed indirectly based on: (1) the size of the animal or (2) the perception of the hunter. Hunters classified green turtles as adult (*Waru*), sub-adult (*Murai*) or juvenile (*Waru kaz*) and dugongs as adults, sub-adults or calves[12]. The appropriateness of using hunter perception as an index of maturity was evaluated by examining the results for those animals for which maturity could be confirmed based on reproductive status.

6.2.2. Data analysis

The green turtle catch in Torres Strait is comprised of green turtles from the resident foraging population as well as green turtles migrating to breed and it is therefore impossible to determine the appropriate reference population for comparisons. The catch comprises green turtles from breeding populations from northern and eastern Australia, Indonesia and the south-western Pacific (Jensen 2010). In addition, there have been no published catch-independent studies of the Torres Strait green turtle foraging population for comparison. Similarly, there have been no published catch-independent studies on the population dynamics of dugongs in Torres Strait. Comparisons with catch-independent studies on the population dynamics of green turtles or dugongs in other areas were not made because the results could be spatially and/or temporally confounded.

Therefore, I compared the green turtle and dugong catches in the present study to those in previous studies in the Torres Strait region to examine changes in the population dynamics of these species through time and thereby investigate whether catches in the present study were typical of Torres Strait catches.

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[12] Although there are traditional names to describe some types of dugongs (e.g., young pregnant dugongs, young female dugongs, old male dugongs), hunters did not use traditional names to classify dugongs into the classes required on the datasheets.

Biological parameters were examined from green turtle catches at Daru in 1985-1987 (Kwan 1991) and Boigu Island in 1985-1987 (Johannes and MacFarlane 1991) for comparison with the data recorded in my study. Comparisons for all of the biological parameters could not be made with all of the previous catches because only some of the biological parameters were recorded in some of the previous studies or there were limitations in the data, which precluded comparisons (Table 6.1).

Similarly, biological parameters were compared with those from dugong catches at Daru in 1978-1983 (Hudson 1986), Boigu Island in 1985-1987 (Johannes and MacFarlane 1991), and Mabuiag Island in 1998-1999 (Kwan 2002), but not all comparisons could be made (Table 6.1).

The raw data from the Torres Strait Protected Zone studies (1991-1993 (Harris et al. 1995), 1993-1996 (Harris et al. 1997), and 1996-2001 (Skewes et al. 2004)) were made available to me. However, upon scrutinising these data, I found anomalies that lead me to question their validity and therefore I did not use these data in my comparisons. I consider that too much time has now elapsed since the data were collected to interpret them from the raw datasheets because the people who filled in the datasheets are no longer available for consultation.

Table 6.1. Biological parameters of green turtles and dugongs collected in the present study and comparisons with other green turtle and dugong catches in the Torres Strait region.

	Location	Date	Study
	Green turtles		
Sex ratio[†]	Daru	1985-1987	Kwan (1991)
Size class distribution[‡]	Daru	1985-1987	Kwan (1991)
Adult/immature ratio[§]	Daru	1985-1987	Kwan (1991)
Proportion of adults breeding[|]	Daru	1985-1987	Kwan (1991)
	Dugongs		
Sex ratio	Mabuiag Island Boigu Island Daru	1998-1999 1985-1987 1978-1983	Kwan (2002) Johannes and MacFarlane (1991) Hudson (1986)
Size class distribution[¶]	Mabuiag Island	1998-1999	Kwan (2002)
Adult/immature ratio[#]	Mabuiag Island	1998-1999	Kwan (2002)
Reproductive rate (i.e., pregnancy rate)[+]	Mabuiag Island	1998-1999	Kwan (2002)

[†] Boigu Island 1985-1987 (Johannes and MacFarlane, 1991) – uncertainty in the determination of sex; short-tailed immature males may sometimes have been mistaken for females;
[‡] Boigu Island 1985-1987 (Johannes and MacFarlane, 1991) – Size was not recorded;
[§] Boigu Island 1985-1987 (Johannes and MacFarlane, 1991) – Maturity was not recorded;
[|] Boigu Island 1985-1987 (Johannes and MacFarlane, 1991) – Reproductive status was not recorded
[¶] Daru 1978-1983 (Hudson 1986) – only the size range was reported, Boigu Island 1985-1987 (Johannes and MacFarlane 1991) – Size was not recorded;
[#] Daru 1978-1983 (Hudson 1986) – Maturity not reported, Boigu Island 1985-1987 (Johannes and MacFarlane 1991) – Maturity not recorded;
[+] Boigu Island 1985-1987 (Johannes and MacFarlane, 1991) – Reproductive status was not recorded; Daru 1978-1983 (Hudson 1986) – Reproductive status was not reported.

<u>Sex ratio</u>

I compared the sex ratios of each of green turtles and dugongs in the catches in the Torres Strait region. I examined whether there was a difference in the sex ratios among catches in the Torres Strait region using Chi-squared contingency tests. Where there was a difference amongst catches, to determine which catches differed from each other, I conducted post-hoc Chi-squared tests between each possible pair of catches. I used the Bonferroni procedure (α/c, where $\alpha = 0.05$, is the nominated significance level and c is the number of comparisons in the collection of tests) to minimise the probability of making at least one type I error among the collection of tests (Quinn and Keough 2002).

6.3. Results

6.3.1. Completeness of the information recorded by hunters

The datasheets included a wide range of questions to prompt the collection of information on hunting patterns (see Chapter 7) as well as biological information. Hunters rarely filled in the datasheets completely. Indeed, only seven hunters, two from Hammond Island and five from Thursday Island, filled in the datasheets completely. In addition, these hunters only filled in the datasheets completely for a small proportion (i.e., only one or two animals) of the dugongs or green turtles that they caught (Table 6.2). Some questions were completed more often than others (Table 6.3). At Hammond Island, the capture of a small number of animals ([redacted] green turtles and [redacted] dugongs) was not recorded on datasheets by hunters, but noted by the local catch monitor during surveys of hunters. Thus, there was no biological information recorded for these animals.

Table 6.2. The percentage of the green turtle and dugong catches of Hammond and Thursday Islands for which the hunters filled in the datasheets completely. n is the total number of green turtles or dugongs caught by the relevant hunter.

	Hunter	n	Green turtles (%)	Dugongs (%)
Hammond Island	1	[redacted]	16	
	2	[redacted]		7
Thursday Island	1	[redacted]	22	
	2	[redacted]	6	
	3	[redacted]		6
	4	[redacted]		20
	5	[redacted]		4

Table 6.3. The percentage of datasheets filled in by hunters for which questions were completed on the species, sex, size, maturity and reproductive status of green turtles and sex, size, maturity and pregnancy of dugongs.

Entry	**Hammond Island**		**Thursday Island**	
	Total (%)	Female (%)	Total (%)	Female (%)
	Green Turtles			
	n=[redacted]†	n=[redacted]	n=[redacted]	n=[redacted]
Species	44		52	
Sex	81		93	
Size (measurement)	60	73	78	80
Maturity	61	76	81	84
Reproductive status (*webud*)	-	46	-	49
Reproductive status (ovaries)	-	3	-	11
	Dugongs			
	n=[redacted]	n=[redacted]	n=[redacted]	n=[redacted]
Sex	79		95	
Size (estimate)	67	98	23	23
Maturity	60	92	74	95
Pregnancy		10		77

† The total number of turtles and dugongs includes only those recorded on datasheets and does not include those animals for which the local catch-monitor noted their capture during surveys of hunters. The latter animals were not included in the total because biological information was not recorded.

The extent to which different questions were filled in also varied among hunters (Figure 6.2). In particular, one hunter from Hammond Island (HI-B) filled in the questions on the datasheet for only a small proportion of the dugongs and green turtles that he caught. The local catch-monitor usually filled in the datasheet for this hunter and three of the dugongs and five of the green turtles for which no information was recorded on a datasheet were caught on the same hunting trip when the local catch-monitor was not available.

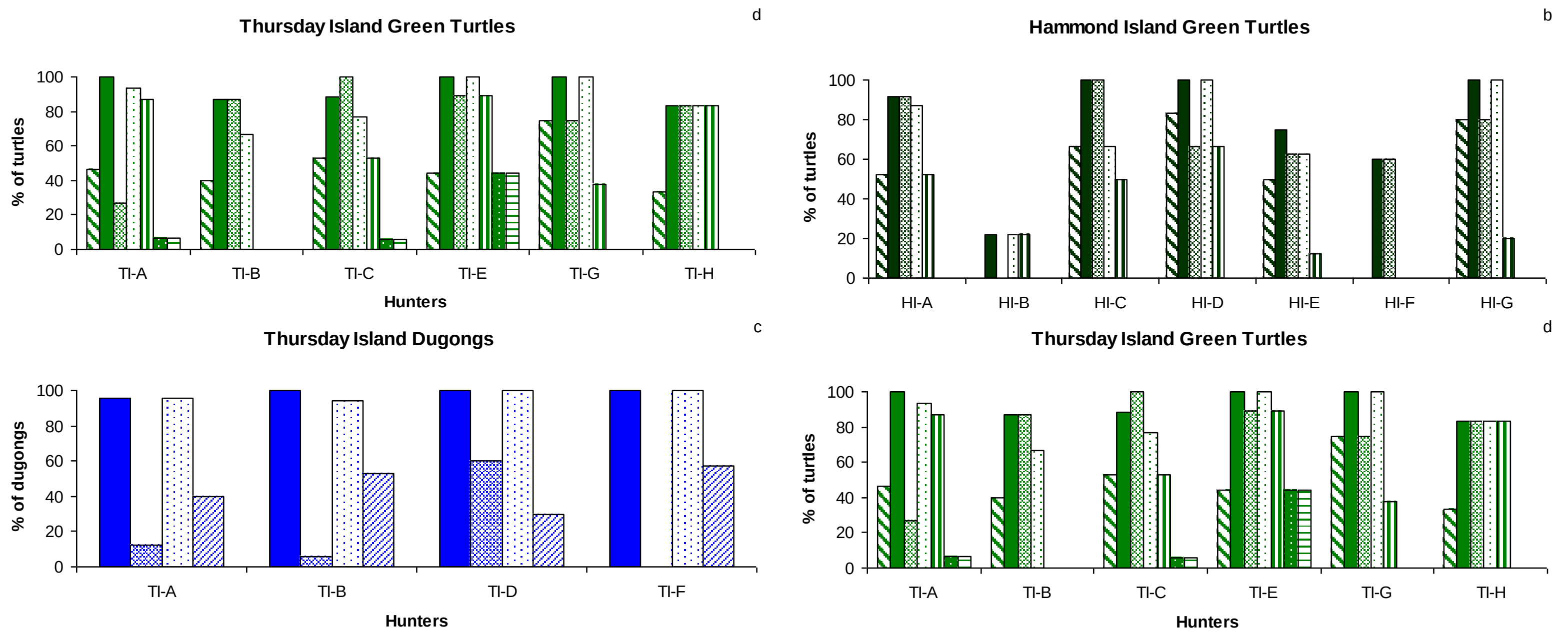


Figure 6.2a-d. The extent to which biological information was recorded on datasheets by hunters. a) The per cent of dugongs for which biological information (sex, size, maturity, and pregnancy) was recorded by the four most prolific dugong hunters from Hammond Island (hunters HI-A, HI-B, HI-C and HI-D); b) The per cent of green turtles for which biological information (species, sex, size, maturity, the presence of mature follicles in the ovary (i.e., *webud*), , whether the ovary was examined, and the reproductive status (based on the presence of corpora lutea or corpora albicantia on the ovary) was recorded by the seven most prolific green turtle hunters from Hammond Island (hunters HI-A, HI-B, HI-C, HI-D, HI-E, HI-F and HI-G); c) The per cent of dugongs for which biological information (sex, size, maturity, and pregnancy) was recorded by the four most prolific dugong hunters from Thursday Island (TI-A, TI-B, TI-D and TI-F); and d) ; The per cent of green turtles for which biological information (species, sex, size, maturity, the presence of mature follicles in the ovary (i.e., *webud*), , whether the ovary was examined, and the reproductive status (based on the presence of corpora lutea or corpora albicantia on the ovary) was recorded by the six most prolific green turtle hunters from Thursday Island (TI-A, TI-B. TI-C, TI-E, TI-F, TI-G and TI-H). Some hunters were prolific hunters of both dugongs and green turtles and therefore are included in the figures for both species. Other hunters were only prolific hunters of one species and therefore are only included in the relevant figure. For example, HI-A caught both dugongs and green turtles, but HI-E caught only green turtles.

6.3.2. Biological information on the green turtle and dugong catch

<u>Species</u>

Species was recorded for only approximately half of the marine turtles in the catch (Table 6.3). All of the marine turtles for which species was recorded were green turtles. All but two of the most prolific turtle hunters recorded the species of marine turtle for some of the marine turtles they caught (Figure 6.2). Like the other nations in the western part of the Torres Strait, hunters in the Kaiwalagal mostly harvest green turtles that are caught while feeding or mating (Johannes and MacFarlane 1991). It is therefore likely that hunters did not complete information about the species of marine turtle caught because they considered the species was obvious.

<u>Sex</u>

<u>*This study*</u>

The sex of both green turtles and dugongs was recorded more often than any other data (Table 6.3), probably because hunters can easily determine it during butchering. In most cases where other questions were completed on the datasheets, sex was also recorded.

<u>*Comparison with other studies*</u>

Green turtles

Kwan (1991) determined the sex of a large proportion (73%, n= 1788) of the green turtles sampled from the Daru fishery in 1985-1987. In Kwan's (1991) study green turtles for which sex was unable to be determined were immature green turtles that had not been butchered and green turtles with partially developed gonads, from which fishermen could not determine the sex. In the present study, sex may not have been recorded for some green turtles because: (1) similar to Kwan's (1991) study, hunters were unable to determine the sex; or (2) hunters may not wish to record the capture of male green turtles because female green turtles are preferred because they are fatter and better tasting than male green turtles and it is not considered as prestigious to catch males as females. The latter explanation could result in a biased sex ratio due to a bias in reporting if sex was not recorded for a large proportion of the caught green turtles. In the present study only a small proportion of green turtles did not have sex recorded (Table 6.3).

Size

This study

Hunters did not record size as completely as sex for either dugongs or green turtles (Table 6.3; Figure 6.2), despite being provided with the necessary equipment (i.e., tape measures). However, hunters in the present study recorded the size of a greater proportion of the green turtle catch than did technicians and observers in other studies in the Torres Strait region.

Comparison with other studies

Green turtles

Only trained technicians (not fishermen) measured the size (CCL) of green turtles caught from the Daru fishery in 1985-1987 (Kwan 1991). In addition, a smaller proportion (48%, n=1788) of the green turtle catch had size recorded than sex in that study. Similarly, observers measured and recorded the sizes of only approximately half (48%, n=244) of the green turtles observed in the Torres Strait Protected Zone project from 1996-2001 (Skewes et al. 2004). In these two studies, technicians and observers were not always able to measure the size of the green turtle because they needed to minimise the disturbance to the fishermen during the butchering and selling (Kwan's 1991 study only) process or the green turtle had already been butchered by the time the technician or observer arrived to measure it. These results suggest that training hunters to measure sizes of animals can result in the collection of a greater amount of data than relying on trained technicians only.

However, measurement or recording errors in the sizes (curved carapace length; CCL) of some green turtles were evident in the present study, but also in the Torres Strait Protected Zone (TSPZ) project in both 1993-1996 and 1996-2001 (Skewes et al. 2004). For example, the CCL recorded for four green turtles in the present study, several green turtles in the TSPZ 1993-1996 study (Harris et al. 1997) and one green turtle in TSPZ 1996-2001 study (Skewes et al. 2004) were greater than the largest size of breeding green turtles recorded from Raine Island over 25 years, 130.1cm (n = 20, 947). In addition, small green turtles about 25cm and 27cm CCL were recorded from the TSPZ 1993-1996 study (Harris et al. 1997) and the present study, respectively, but green turtles recruit to the continental shelf at approximately 40-50cm (Limpus 2008), which suggests that the sizes of these green turtles were measured or recorded incorrectly.

Dugongs

The very small proportion of dugongs for which size was recorded by Thursday Island hunters (Table 6.3) reflects the cultural protocols that preclude the exact measurements of dugongs (see methods). In addition, because sizes were estimated rather than measured at Thursday Island, sizes are likely to have been rounded off. Measurement or recording errors were also evident for dugongs in the studies from the TSPZ during the 1990s. For example, the sizes recorded for some of the dugongs would mean that they must be foetuses. The mean recorded size of dugongs at birth is 115cm and the range is 100-130cm (Boyd et al. 1999). The 1993-1996 TSPZ study included dugongs as small as 90cm (Harris et al. 1997) and the 1996-2001 study included a 79cm long dugong (Skewes et al. 2004). Thus, training of hunters in precise measurement and recording is very important for obtaining reliable information.

Maturity and reproductive status

Maturity and reproductive status were determined directly only for female dugongs and green turtles in the present study because there were no questions on the datasheet relating to the reproductive status of male green turtles or dugongs.

Comparison with other studies

Green turtles

Although Kwan (1991) set out to determine the maturity and reproductive status of both male and female green turtles, ninety percent of the green turtles for which gonad examinations were conducted (n= 462) were female. Kwan (1991) considered it was likely this bias in the sample was due to conspicuous gonads (e.g., ovaries with developing follicles) being offered for sale because of the higher return to the fisherman and the bias in the catch towards females.

This study

Dugongs

The reproductive status of female dugongs was determined based on whether or not they were considered pregnant. Thursday Island hunters filled in this information more consistently than the Hammond Island hunters did (Table 6.3).

Green turtles

Maturity and reproductive status were recorded for only approximately half of the female green turtles in the catch of both Hammond and Thursday Island hunters (Table 6.3). In addition, Dr Mark Hamann and I examined the ovaries from only 4% of the green turtles caught by Hammond Island hunters and 11% of the green turtles caught by Thursday Island hunters to assess the maturity and reproductive status of the green turtles. Hunters may not have recorded the presence or absence of yellow eggs, known locally as *webud*, because they were not present and therefore the hunter decided to record nothing, or the hunter did not have time or preparedness to record the information. Hunters did not provide ovaries for refined interpretation by trained staff because: (1) I was not able to be present at the butchering because of cultural protocols; and (2) hunters found it inconvenient to cut out the ovary and keep it in a bag for the local catch-monitor or me to collect later.

<u>Comparison with other studies</u>

Green turtles

Kwan (1991) was also able to examine only a small proportion (16%, n=1788) of all of the green turtles butchered in the Daru fishery during the sampling period of her study. Gonad examinations could be conducted for only a small proportion of the green turtles because of the need to minimise disturbance and hindrance to the fishermen during butchering and selling of meat in the market and the inadequate number of trained technical staff available during periods of high green turtle catches.

<u>Hunters' perceptions of maturity</u>

Although the indirect assessment of maturity, based on the hunters' perceptions, simply required the hunter to record the maturity category he thought the animal belonged to, this information was not recorded as completely as sex, but was recorded more completely than size, which required some measurement (Table 6.3).

<u>This study</u>

Green turtles

Hunters generally classified green turtles into maturity classes consistent with the size class and reproductive status recorded for the green turtle. However, there were a few discrepancies: one green turtle classified as immature was recorded as having *webud* and therefore must have been mature; five green turtles classified as adults were smaller than the smallest size recorded for breeding green turtles at Raine Island (i.e., 86cm). One of these green turtles, for which the size was recorded as 80cm, was also recorded as having *webud*, but the reproductive status of the other four green turtles (which were 67, 68, 80 and 84cm) was not recorded. Based on the Raine Island data[13], the two smaller ones, at least, should be classified as immature.

Dugongs

Only five Hammond Island hunters recorded the maturity class of the dugongs they caught. These hunters also recorded the sizes of most of the animals for which they recorded the maturity class. The size range recorded for sub-adults and calves overlapped (Table 6.4). In addition, individual hunters sometimes classified dugongs in the same size range as either a sub-adult or a calf (Table 6.4). This overlap in size range between dugongs classified as sub-adults or calves suggests that it is difficult for hunters to make a distinction between these two maturity classes and therefore probably only one category should be used. Thursday Island hunters recorded the sizes of too few of the dugongs they classified into maturity categories to determine whether the size ranges of dugongs they classified as sub-adults or calves also overlapped. The dugongs considered adults by both Hammond and Thursday Island hunters were all larger than 200 cm (Table 6.4).

[13] Most of the green turtles hunted in Torres Strait belong to the Northern Great Barrier Reef population. A long-term nesting beach tagging study has been done at Raine Island, which is the major rookery for this green turtle stock.

Table 6.4. The number (and %) and sizes (cm) of dugongs that hunters classified in each maturity class, adult, sub-adult or calf. Note: the sizes of most dugongs were estimated visually by hunters, rather than being measured.

	Hammond Island		**Thursday Island**	
	Number (%) n=[redacted]	**Size range (cm) n=[redacted]**	**Number (%) n=[redacted]**	**Size range (cm) n=[redacted]**
Adult	[redacted] (45%)	200-250	[redacted] (63%)	200-300
Sub-adult	[redacted] (14%)	176-200	[redacted] (31%)	200[†]
Calf	[redacted] (41%)	155-200	[redacted] (6%)	166[‡]

[†] All dugongs classified as sub-adults for which size was recorded were 200cm
[‡] Size was recorded for only one dugong classified as a calf and it was 166cm.

6.3.3. Patterns in life-history traits to inform decision-making

<u>Sex ratio</u>

<u>This study</u>

Green turtles

Both Hammond and Thursday Island hunters targeted female green turtles (Table 6.5). Ninety-seven percent of the green turtles caught for which sex was recorded were female.

<u>Comparison with other studies</u>

Green turtles

The Daru catch in 1985-1987 had only a small bias towards female green turtles (Table 6.5; Kwan 1991). There was a significant difference in sex ratios amongst catches in the Torres Strait region (Table 6.6; $\chi^2 = 28.8$, 2df, $P = 0$). The sex ratios of the Hammond Island and Thursday Island green turtle catches were not significantly different from each other, but were both significantly different from the 1:5 sex ratio in favour of females of the Daru catch in 1985-1987 (Table 6.6). It appears that there has been a change through time and/or among locations towards a female biased catch. This bias may reflect hunter preferences, because unpublished data from Dr Mark Hamann shows that the sex ratio of green turtles in foraging grounds around Hammond and Thursday Islands is 1:5 in favour of females. However, the green turtles in this sample are mostly juvenile green turtles and therefore the difference in sex ratio between these green turtles and those in the catch of Hammond and Thursday Island hunters may reflect the different age classes of green turtles being caught.

Table 6.5. Sex ratios (male : female) of green turtle catches in the Torres Strait region.

Location	Year	Sex ratio M:F	Reference
Hammond Is.	2005-6	1:31 (n=[redacted])	Present study
Thursday Is.	2005-6	1:36 (n= [redacted])	Present study
Daru	1985-7	1:5 (n=1299)	Kwan (1991)

Table 6.6. Post-hoc chi-squared comparisons† of the sex ratios of the green turtle catch between different pairs of fisheries. * represents a significant difference in the sex ratios of the green turtle catch between a pair of fisheries at P <0.017, 1 df.

	Thursday Is.	P	Daru	P
Hammond Is.	0.21	0.885	10.6*	0.001
Thursday Is.			18.8*	0

† The Bonferroni procedure (i.e., $\alpha/c = 0.05/3$) was applied to this collection of tests to minimise the probability of making at least one Type I error among the collection of tests. This procedure reduced the significance level from $\alpha = 0.05$ to $\alpha = 0.017$.

This study

Dugongs

Hunters did not appear to target dugongs based on sex. Both Hammond and Thursday Island hunters caught almost equal proportions of male and female dugongs (Table 6.7) and the sex ratios of the dugong catches were not significantly different from a 1:1 sex ratio ($\chi^2 = 0.01$, Yate's correction, n= [redacted], 1 df, $P < 0.01$ and $\chi^2 = 0.46$, Yate's correction, n= [redacted], 1 df, $P < 0.01$ for Hammond Island and Thursday Island, respectively). Most other recent catches from the Torres Strait region have also shown a small bias towards females (Table 6.7).

Comparison with other studies

Dugongs

The sex ratios of some of the dugong catches from the Torres Strait region were significantly different from the others ($\chi^2 = 16.5$, 4 df, $P = 0.002$). The Boigu Island catch of 1985-1987 showed the greatest bias towards female dugongs and the sex ratio of the Boigu Island catch was significantly different from that of the Daru catch (Table 6.8). Thus, there appears to be some variability in the sex ratio of dugongs in catches through time and among locations.

Table 6.7. Sex ratios (male : female) of dugong catches in the Torres Strait region.

Location	Sex ratio M:F	Date	Study
Hammond Is.	1:1.0 (n=[redacted])	2005-2006	Present study
Thursday Is.	1:1.3 (n=[redacted])	2005-2006	Present study
Mabuiag Is.	1:1.7 (n=256)	1998-1999	Kwan (2002)
Boigu Is.	1:2.4 (n=72)	1985-1987	Johannes and MacFarlane (1991)
Daru	1.1.08 (n=453)	1978-1983	Hudson (1986)

Table 6.8. Post-hoc chi-squared comparisons[†] of the sex ratios of the dugong catch between different pairs of fisheries. * represents a significant difference at $P < 0.005$.

	Thursday Is.	*P*	Mabuiag Is.	*P*	Boigu Is.	*P*	Daru	*P*
Hammond Is.	0.42	0.517	2.17	0.141	5.16	0.023	0.05	0.842
Thursday Is.			0.818	0.366	3.58	0.059	0.52	0.472
Mabuiag Is.					2.09	0.148	7.48	0.006
Boigu Is.							11.8*	0.001

[†] The Bonferroni procedure (i.e., $\alpha/c = 0.05/10$) was applied to this collection of tests to minimise the probability of making at least one Type I error among the collection of tests. This procedure reduced the significance level from $\alpha = 0.05$ to $\alpha = 0.005$.

<u>Size class distribution –adult/immature ratio</u>

<u>This study</u>

Green turtles

Hammond and Thursday Island hunters recorded catching green turtles of a range of sizes, from 67-130cm (CCL) and 60-130cm (CCL), respectively (Figure 6.3). The size frequency distributions of these catches were not significantly different (Kolmogorov-Smirnov comparison of two datasets, D = 0.2125, $P = 0.126$, n= [redacted] for Hammond Island and n= [redacted] for Thursday Island).

The greatest proportion of green turtles caught by Hammond and Thursday Island hunters was in the 100-110cm (CCL) size class. Most of the green turtles caught were large immature or adult-sized green turtles (Limpus 2008; Figure 6.4).

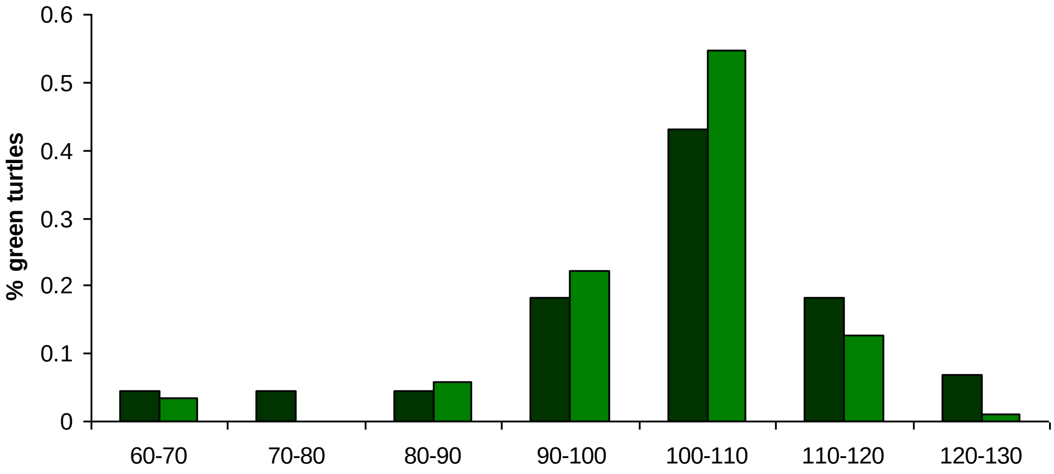


Figure 6.3. The size frequency distribution of green turtles in catches from the Hammond Island 2005-2006 ■ and Thursday Island 2005-2006 ■.

Comparison with other studies

Green turtles

The result of the present study is consistent with the Daru catch in 1987-1972, in which large green turtles of both sexes accounted for most of the annual catch ((Kwan 1991; Figure 6.4). Green turtles of 90cm CCL or greater were considered large green turtles because at the time of Kwan's (1991) study, the minimum size of mature green turtles from Heron Island was 90cm (Limpus and Reed 1985b) and she used this information as the basis for categorising green turtles into large and small size classes. Kwan's (1991) raw data set was not available for me to re-categorise the sizes of green turtles based on more recent information from Raine Island that suggests that the minimum size that green turtles from the northern Great Barrier Reef green turtle stock mature is 86cm CCL (Limpus 2008). Furthermore, based on the perception of maturity by hunters, most of the green turtles in the Hammond and Thursday Island catches were adults (i.e., *Waru*; 88%, n=[redacted] and 94%, n=[redacted], respectively). Thus, Torres Strait Islanders appear to prefer adult and sub-adult green turtles to juveniles.

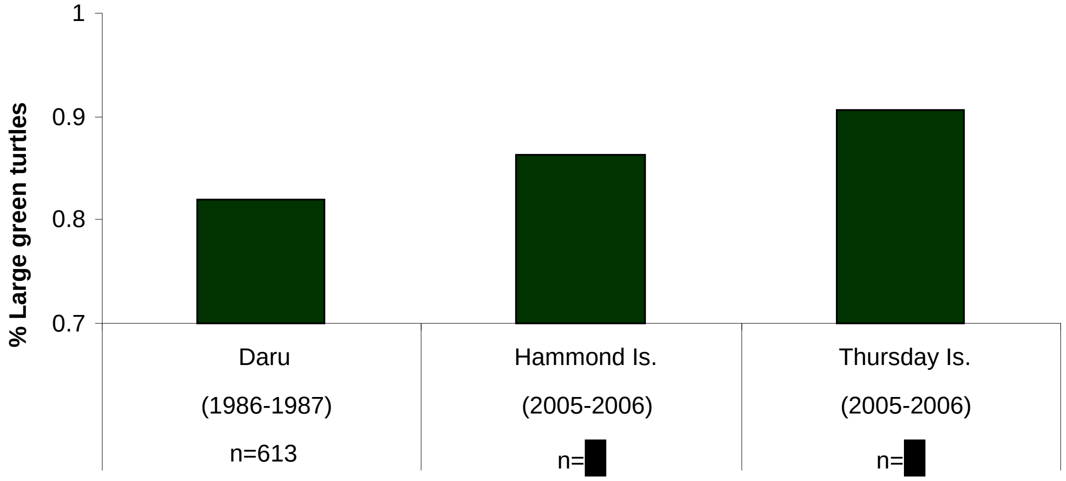


Figure 6.4. The proportion of large green turtles (>90cm CCL) in catches in the Torres Strait region.

This study

Dugongs

The sizes of dugongs in the Hammond and Thursday Island catches ranged from 155-250cm and 166-300cm, respectively. A dugong as small as 104cm was caught in previous studies in the Torres Strait region (Figure 6.5) and the largest dugong in the Daru catch of 1978-1984 was 331cm long (Hudson 1986). Hammond and Thursday Island hunters may prefer or target dugongs in different size classes, but the small sample sizes mean that it is impossible to make robust comparisons.

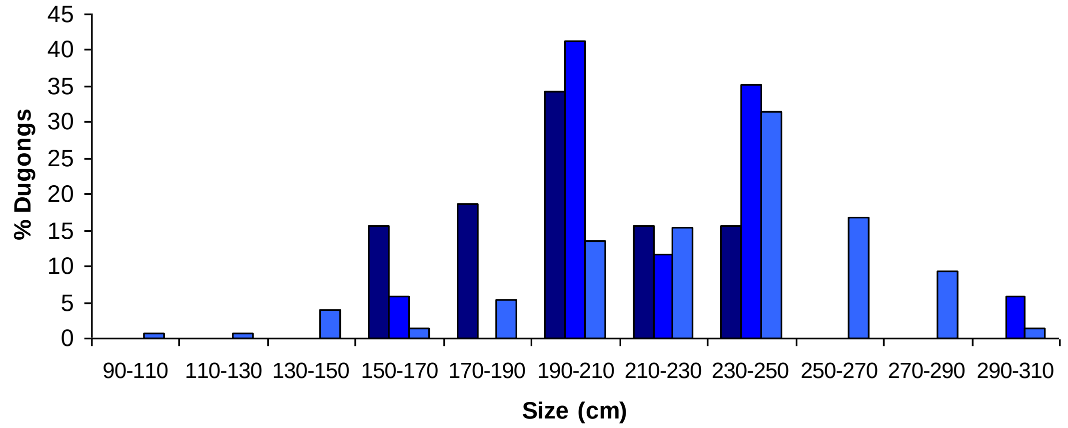


Figure 6.5. The size frequency distribution of dugongs in catches from Hammond Island 2005-2006 ■, n=[redacted], Thursday Island 2005-2006 ■, n=[redacted] and Mabuiag Island 1998-1999 ■, n=148. Note: dugongs that were likely to have been measured or recorded incorrectly have not been included in the figure.

Comparison with other studies

Dugongs

Previous studies have suggested that dugongs greater than 250cm are likely to be adults and those smaller than 205cm are likely to be calves (Boyd et al. 1999; Kwan 2002). Between 205cm and 250cm, it is difficult to discern the maturity of dugongs based on size. The lower limit of maturity is based on the report by Kwan (2002) of a small pregnant dugong (205cm) at Mabuiag Island (Figure 6.6) in 1998-1999. Two of the pregnant females in the present study were estimated to be only 200cm long. However, the fact that sizes were estimated, rather than measured in the present study suggests that this result may not be valid.

There was a significant difference in the number of dugongs that hunters from Hammond Island, Thursday Island and Mabuaig Island caught from the different maturity categories; calves, undetermined and adults (Figure 6.6; $\chi^2 = 28.6$, 4df, $P < 0.01$).

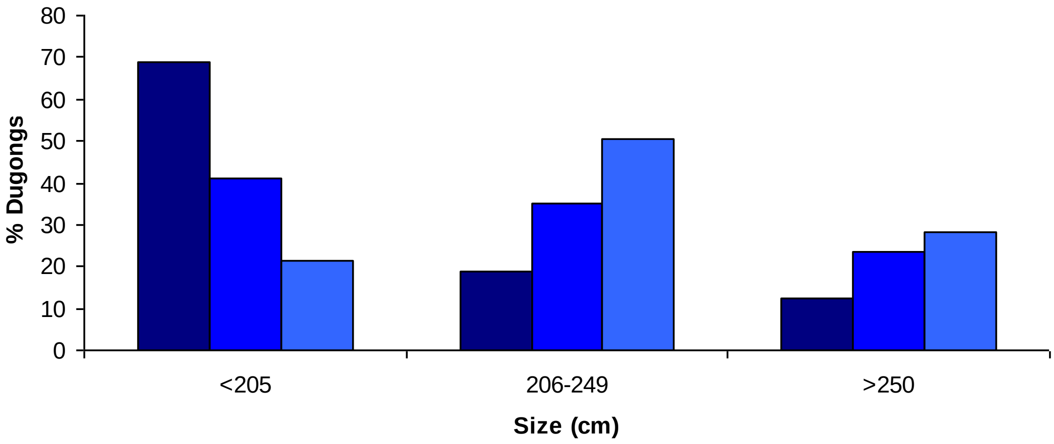


Figure 6.6. The proportion of dugongs of different maturity status based on size: calves (<205cm), undetermined (206-249cm) or adults (>250cm) caught by hunters from Hammond Island ■, n=[redacted] Thursday Island ■, n=[redacted] and Mabuiag Island ■ (n=149).

The sizes of dugongs caught by Hammond Island hunters and Thursday Island hunters in 2005-2006 were smaller on average than those caught by Mabuaig Island hunters in 1998-1999 (Kwan 2002; Figure 6.7; Tables 6.9, 6.10). The analysis of variance indicates a significant difference in the mean size of dugongs caught by hunters among the three communities ($P < 0.05$; Table 6.9). The mean size of dugongs caught by Mabuiag Island hunters was significantly different from those caught by both Hammond Island hunters ($P < 0.01$, Table 6.10) and Thursday Island hunters ($P < 0.05$; Table 6.10; post hoc Tukey's HSD test; Quinn and Keough 2002). However, the mean size of dugongs caught by Hammond Island hunters and Thursday Island hunters were not significantly different from each other (Table 6.10; post hoc Tukey's HSD test; Quinn and Keough 2002).

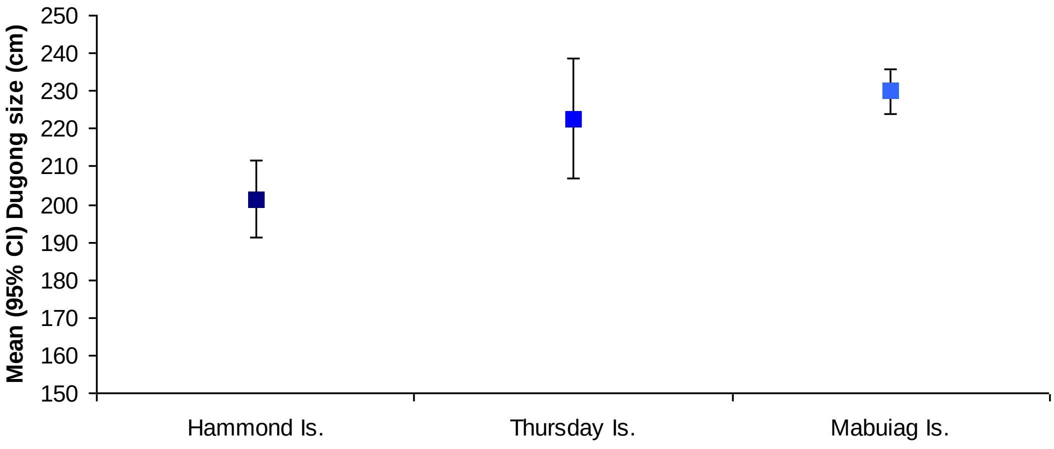


Figure 6.7. Mean (95 % CI) dugong size (cm) caught at Hammond, Thursday and Mabuiag Islands.

Table 6.9. Analysis of variance table for comparison of sizes of dugongs caught by hunters from Hammond Island and Thursday Island in 2005-2006 and Mabuaig Island in 1998-1999.

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	21693.87	2	10846.94	8.864775	0.000207	3.04223
Within Groups	238602	195	1223.6			
Total	260295.8	197				

Table 6.10. Observed differences in the mean sizes of dugongs caught by hunters between pairs of communities, used in the post-hoc Tukey's HSD analysis to determine whether there was a significant difference in the mean size of dugongs caught by hunters at Hammond Island and Thursday Island in 2005-06 and Mabuaig Island in 1998-99. Tukey's $HSD_{0.05}$ = 20.86 and Tukey's $HSD_{0.01}$ = 26.20.

Comparisons	Difference between means in size of dugongs (cm)
Mabuaig Island - Hammond Island	28.64**
Mabuaig Island – Thursday Island	21.33*
Thursday Island - Hammond Island	7.31

** difference between means is greater than HSD at $P < 0.01$ significance level

* difference between means is greater than HSD at $P < 0.05$ significance level

The data from the other studies in the Torres Strait region are not available in an appropriate format to make comparisons. The proportion of dugongs for which size was recorded was small, particularly at Thursday Island.

Furthermore, based on the perception of maturity of dugongs by hunters, Hammond Island hunters recorded catching approximately equal numbers of adults and calves, while Thursday Island hunters recorded catching more adults than sub-adults or calves (Table 6.4). These results reflect those obtained from examining the size classes of dugongs in the catches, which suggests that the patterns found for size classes are robust.

<u>Reproductive rate</u>

<u>This study</u>

Green turtles

As mentioned above, reproductive status was recorded for only approximately half of the female green turtles in both the Hammond and Thursday Island catches. Most of these female green turtles were classified as mature because they had mature follicles >2.5cm (72% and 54% in the Hammond and Thursday Island catches, respectively; Figure 6.8, Table 6.9). A further 10% of females in the Thursday Island catch were classified as mature based on ovarian scars (Table 6.11) and one green turtle was confirmed as immature because it had no mature or developing follicles and no ovarian scars. The females in the late stages of vitellogenesis would have bred in the upcoming breeding season and most of them (95% and 54% for Hammond and Thursday Islands, respectively) were caught in the main breeding season between September and November (Figure 6.9a). In contrast, green turtles without mature follicles (i.e., no *webud*) were caught throughout the year. These green turtles may have been mature green turtles that were not breeding in that particular year or immature green turtles, but it is impossible to know without further examination of the ovary. Thus, a large proportion of adult females were caught during the breeding season, particularly at Hammond Island.

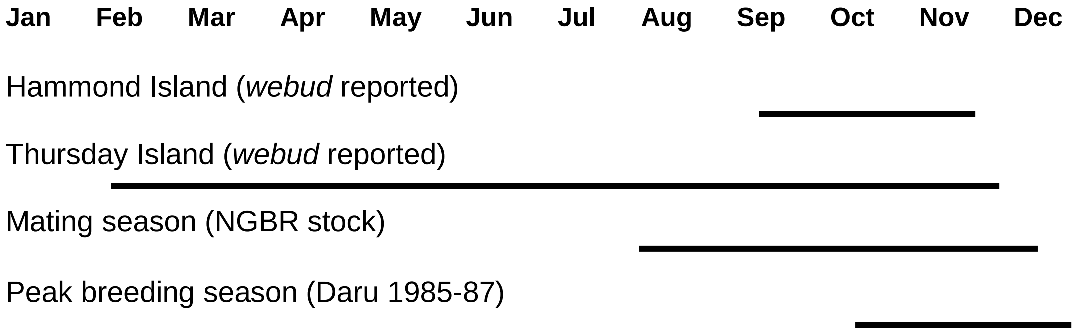


Figure 6.8. The time period over which Hammond and Thursday Island hunters reported the presence of *webud* in the ovaries of green turtles compared with the mating season of the northern Great Barrier Reef stock of green turtles (Limpus 2008) and the peak breeding season of green turtles reported from Daru in 1985-1987 (Kwan 1991).

Almost half of the green turtles with mature follicles (i.e., *webud* present) in the Thursday Island catch were caught outside the main breeding season (Figures 6.8, 6.9a). This result may have been a result of Thursday Island hunters reporting developing follicles as well as mature follicles. Follicles start to be detectable about eight to nine months before the breeding season (Limpus and Reed 1985b; Limpus and Nicholls 1988).

<u>Comparison with other studies</u>

Green turtles

Kwan (1991) found that green turtles caught at Daru followed the pattern of vitellogenesis developing throughout the year with mature follicles being present towards the end of the year (i.e., October to December). Kwan (1991) also found that almost all green turtles in the late stage of vitellogenesis in the Daru catch were caught in the main breeding season, which was between October and December. Although some green turtles, preparing to breed in the Gulf of Carpentaria may be in the late stages of vitellogenesis mid-year, it is unlikely that so many green turtles would be at this stage of reproduction over so many months.

Table 6.11. The number and (percentage) of female green turtles recorded in the catch by Hammond and Thursday Island hunters for which reproductive status was recorded.

Ovary examination	**Reproductive status**	**Hammond Is.**		**Thursday Is.**	
		Breeding season (Aug-Nov)[†]	**Non-breeding season (Dec-Jul)**	**Breeding season (Aug-Nov)**	**Non-breeding season (Dec-Jul)**
Webud, ovary not examined	Mature – breeding in upcoming season	[redacted] (62)	[redacted] (3)	[redacted] (25)	[redacted] (23)
Webud, ovary examined and corpora albicantia present	Mature – breeding in upcoming season; bred in previous season	[redacted] (6)		[redacted] (6)	
No *webud*, ovary examined and corpora albicantia present	Mature – not breeding in upcoming season, bred in previous season			[redacted] (5)	[redacted] (6)
No *webud*, ovary examined and corpora albicantia not present	Immature or adult yet to breed			[redacted] (2)	
No *webud*, ovary not examined	Undetermined	[redacted] (9)	[redacted] (21)	[redacted] (15)	[redacted] (18)
	Total mature	**[redacted] (72)**		**[redacted] (64)**	
	Total immature			**[redacted] (2)**	

[†] Mating activity of the northern Great Barrier Reef stock of green turtles begins in Torres Strait in August and increases in occurrence until late October/early November. Little mating activity is seen after mid December (Limpus 2008).

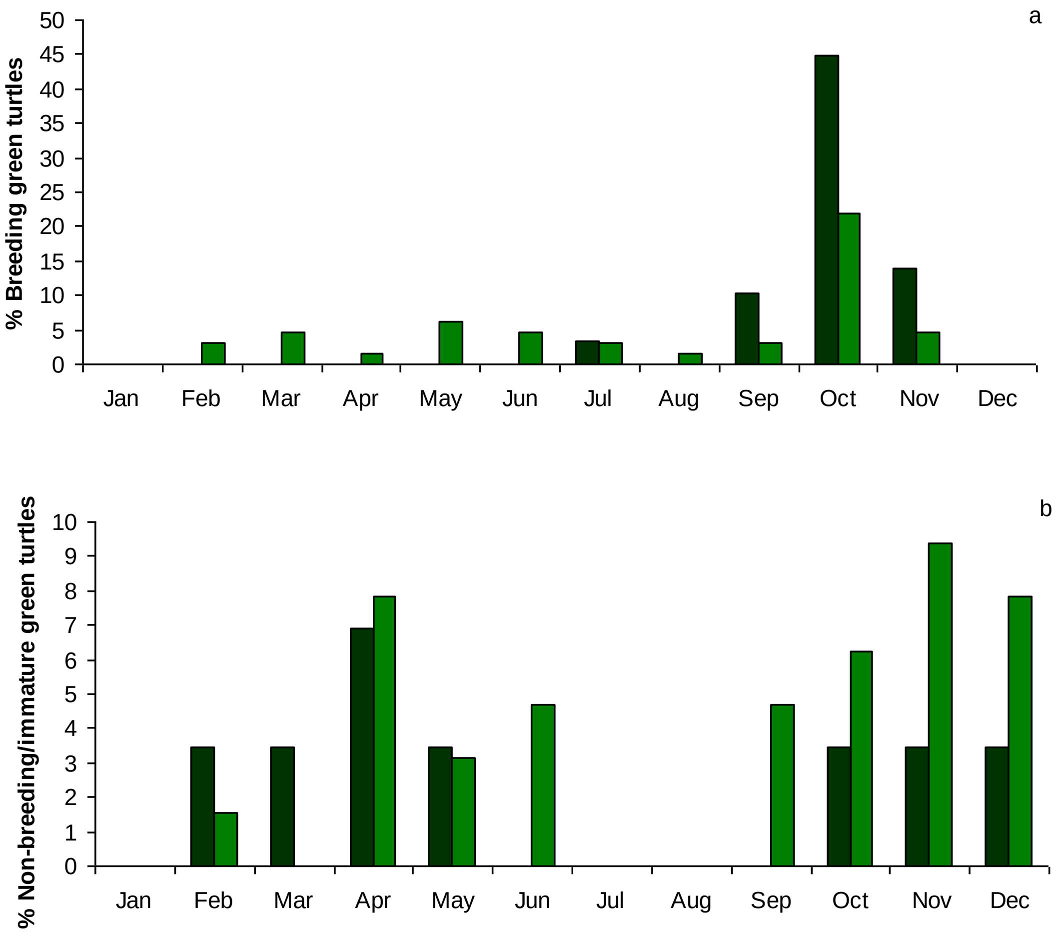


Figure 6.9. The proportion of: a) breeding and b) non-breeding or immature female green turtles in the Hammond ■ and Thursday ■ Island catches in each month in 2005-2006. Data from 2005-2006 are combined.

<u>This study</u>

Dugongs

The pregnancy rate of dugongs could not be determined for the Hammond Island dugong catch because Hammond Island hunters recorded only two dugongs as pregnant and did not record any dugongs as not pregnant. In contrast, Thursday Island hunters recorded whether dugongs were pregnant for 77% (n=[redacted]) of the female dugongs in the catch. Of these dugongs, 40% were pregnant.

<u>Comparison with other studies</u>

Dugongs

Kwan (2002), a scientist, examined the carcasses of dugongs at Mabuiag Island in 1998-1999 and found a similar proportion of pregnant dugongs (38%). In addition, Kwan (2002) found that 87% of the dugongs at Mabuiag Island were either pregnant or lactating or both. Lactation was not recorded in the present study. Hudson (1986) reported that of 74 dugongs informally reported in the Daru catch in 1976-1977 none was thought to be pregnant, while in 1978-1982, 12% (n=235) of the female dugongs caught were pregnant (Hudson 1986). Thus, there appears to have been a shift from low to high pregnancy rates of Torres Strait dugongs through time. The temporal difference implies a monotonic increase in pregnancy rates coincident with sea grass recovery (Marsh and Kwan 2008).

Some of the pregnant dugongs reported in the present study and at Mabuiag Island in 1998-1999 were among the smallest ever recorded (Table 6.12). Although there may be some errors associated with the values obtained in the present study because size was estimated visually by hunters rather than being measured, Kwan, who is a trained scientist, measured the sizes of dugongs in her study at Mabuiag Island (Kwan 2002) and therefore the results from that study are much less likely to contain errors.

Table 6.12. Minimum sizes of sexually mature female dugongs caught from Townsville (Marsh et al. 1984), Daru (Hudson 1986), Mabuiag Island (Kwan 2002), Hammond Island (present study) and Thursday Island (present study). n is the number of mature females examined.

Location	n	Size (cm)	Date	Study
Hammond Is.	[redacted]	200*	2005-2006	Present
Thursday Is.	[redacted]	200*	2005-2006	Present
Mabuiag Is.	81	205	1998-1999	Kwan (2002)
Daru	28	240	1978-1983	Hudson (1986)
Townsville	22	234	1969-1981	Marsh et al. (1984)

*estimated

6.4. Discussion

In this Section, I discuss the results from the present study in relation to: (1) how completely biological information was recorded by hunters; (2) how useful the biological information collected by hunters was in providing insights into the population status of dugongs and green turtles and the sustainability of the catch; and (3) how the collection of biological information by hunters could be improved.

6.4.1. How well was the biological information collected by hunters?

In this study, the more straightforward information (e.g., sex) was more likely to be recorded by hunters on datasheets than the more complex information (e.g., reproductive status). Specimens were rarely provided. Information categories, which were easy to determine and could simply be recorded on the datasheet (e.g., sex) were recorded more often than information categories that were more time-consuming or complicated to collect (e.g., measuring the size of the animal). In addition, information categories that required the assistance of the local catch monitor were recorded least comprehensively (e.g., collecting biological specimens of ovaries for detailed interpretation and collecting dugong tusks for age determination).

A similar pattern in the reporting of information by hunters has been found in other studies. For example, Noss et al. (2004) found that Isoseno hunters in the Bolivian Chaco recorded information on sex for a much greater proportion of mammals than they recorded information on size or weight, even though the necessary equipment (i.e., scales and tape measures) was provided to the hunters. However, the Isoseno hunters did not always report the sex of mammals that they caught even though this information was easily determined. Noss et al. (2004) also found that there was variability in the provision of specimens such as skulls and stomach contents. Skulls from ungulates with strong bones, or those collected as trophies, such as from peccaries, were collected more frequently than skulls from animals with fragile bones such as grey brocket deer. Stomach contents were most often provided from small animals brought whole into the community, such as armadillos but not from large ungulates that hunters preferred to butcher at the hunting site rather than transport whole. Therefore, specimens were most likely to be provided from species for which it was most easy for hunters to collect and keep the specimens.

The results of all of these studies suggest that the collection of biological information by hunters needs to be introduced over the long-term in a step-wise manner. That is, the more straightforward information is collected in the initial phase, with the collection of more complex information being introduced as hunters become proficient, perhaps after some training, in the provision of information at each step. The intention is that once the most straightforward information is being collected well, the collection of more complex information can be introduced, along with training if necessary, to ensure data reliability.

6.4.2. How useful was the information collected by hunters?

The biological information collected by hunters in this study could contribute in the longer-term to the assessment of population trends and sustainable (or ecologically optimal) harvests. No attempt was made to do such assessments here, but biases in the catch (e.g., hunter selectivity) or reporting, confounding influences of environmental factors and changes in biological parameters through time would make it difficult to interpret the effects of changes in the biological parameters on the populations. In addition, the limited baseline data for both dugongs and green turtles with which to make comparisons and the difficulty in determining the appropriate reference population with which to compare the green turtle catch (i.e., mixture of foraging and breeding green turtles) would also make interpretation difficult.

Catch-per-unit-effort monitoring, including the collection of demographic/biological information on the nature of the catch provided some indication of the ecological and cultural sustainability of the catch. That is, indications of potential over-harvesting included ecologically biased harvests, culturally sub-optimal harvests and changes in biological parameters through time.

Ecological Sustainability

Green turtles

The strong bias in the Hammond and Thursday Island green turtle catches towards adult and near adult females suggests an ecologically sub-optimal harvest. Unfortunately, effort information is not available to determine whether large females continue to be caught because they are abundant or because they are preferred and therefore increased effort is expended to catch them. During the development of the first eight Torres Strait Community Dugong and Turtle Management Plans (see Chapter 1), a marine turtle expert, Dr Col Limpus, suggested to Torres Strait communities that if during the mating season, they caught one male in every three green turtles they would be harvesting in line with the natural sex ratio of the Northern Great Barrier Reef green turtle stock and therefore their harvest would be more sustainable than one that focussed on taking only females. Hammond and Thursday Island hunters clearly do not harvest in line with the natural sex ratio of the Northern Great Barrier Reef green turtle stock and could therefore consider catching more males and fewer females as a management approach.

The information on sex ratio provided some insights into the sustainability of the green turtle and dugong catches of the Hammond and Thursday Island communities. There was a strong bias in the green turtle catch towards adult and sub-adult females. However, the catch consists of foraging and breeding turtles so the sex ratio cannot be compared with a reference population to determine whether this catch could be unsustainable. Nevertheless, it is unlikely that a harvest strongly biased towards females could be sustained as long as one with sex ratio more reflective of the population. In addition, sub-adult and adult survivorship is the most influential life-history parameter for population growth in marine turtles and therefore a harvest consisting of mostly adults is unlikely to be as sustainable as one consisting of a range of ages of marine turtles (Heppell et al. 2003). Therefore, information on the sex ratio of the catch of green turtles provides the communities with options to consider for management other than reducing the total number of animals caught (e.g., they could consider taking a greater proportion of males).

Dugongs

The even sex ratio reported for dugongs differed from the previously reported strong preference for female dugongs. This change could reflect an over-harvested dugong population or a change in the ability of hunters to distinguish the sex of dugongs in the water. As mentioned in the Introduction, Eberhardt (2002) predicted that changes in biological parameters through time could indicate a density-dependent response, or indeed over-harvesting. Information on reproductive parameters of dugongs (size at first reproduction and pregnancy rate) recorded in the present study was consistent with those collected by Kwan (2002) from the Mabuiag Island fishery in 1998-1999 and different from those collected by Hudson (1986) from the Daru fishery in the late 1970s – early 1980s. Therefore, the information on reproductive parameters of dugongs collected by hunters can be useful as part of long-term datasets to inform adaptive management of dugong populations. The pattern observed by Kwan (2002) and in the present study (i.e., small size at first reproduction and high pregnancy rates) is early in the sequence predicted by Eberhardt (2002) as a density dependent response to over-harvesting. However, Kwan (2002) was not able to distinguish between the effects of over-harvesting or improved environmental conditions (see Introduction) and Marsh and Kwan (2008) suggested that both processes might be operating. Marsh and Kwan (2008) suggest that management strategies need to consider the possible effects of sea grass dieback on dugongs (and green turtles), including reduced fecundity and the potential redistribution of animals. In addition, they suggest that management strategies should be able to be adjusted for sea grass dieback events.

Green turtles

It is much more complicated to examine changes in the biological parameters of green turtles than dugongs because baseline foraging ground data for Torres Strait is not available and the mixed nature of the catch, consisting of foraging and breeding green turtles, makes it difficult to determine the appropriate reference population. In addition, phenomena such as climate change may affect the mixed nature of the population and the population structure and thereby influence the selectivity in the catch by changing the availability of green turtles. Nevertheless, more extensive information on the biological parameters of green turtles could be obtained than in the present study through more detailed examination of the ovaries. For example, Kwan (1991) was able to examine the proportion of the Daru green turtle catch that were residents or migrants by examining the terminal reproductive status of green turtles throughout the year through detailed examination of their ovaries. Genetic studies could also provide more detailed information.

For both species, the sustainability of the harvests based on information on sex ratios remains inconclusive because 1) the baseline sex ratio is not known and 2) explanations for the recorded sex ratio of the catch, other than over-harvest, are plausible.

Cultural sustainability

Dugongs

Other biological information collected by hunters suggested that the dugong harvest may be culturally sub-optimal, which as mentioned in the introduction, could indicate an over-harvested population. The even sex ratio of dugongs caught in this study may be of concern because previous studies have reported a preference by Torres Strait Islander hunters for the meat of female dugongs (Haddon 1912; Nietschmann and Nietschmann 1981; Raven 1990; Johannes and MacFarlane 1991; Ponte 1996). In addition, hunters in the present study indicated during interviews (see Chapter 4) that they prefer young dugongs, particularly pregnant females (known locally as *Kazi laig*. Therefore, the sex ratio of caught dugongs recorded in the present study may reflect the availability of dugongs whereby female dugongs have been removed from the population through selective hunting and have not been replaced fast enough to meet demand so that hunters are forced to take males as well. However, Kwan (2002) also found that there was no bias towards females in the sex ratio of dugongs caught from Mabuiag Island in 1998-1999 and suggested that there was little evidence that Mabuiag Island hunters could differentiate between or target dugongs on the basis of sex, age or body condition. In addition, other recent studies showed either no bias or only a small bias in the harvest towards female dugongs (see Results, Section 6.3.3). Hammond Island hunters that I interviewed suggested that hunters from that community could not distinguish between male and female dugongs (see Chapter 4).

6.4.3. Trade-offs in collecting biological information

It is clear that biological information about dugong and green turtle catches will be valuable in informing management decisions. Nevertheless, there are advantages and problems associated with the collection of different types of biological information that may affect what can be learned. The outcomes that can be achieved from the collection of different types of biological information and the effort required to collect it may influence whether or not communities consider it worthwhile to expend additional effort in collecting a broad suite of biological information. Table 6.13 outlines the advantages and problems associated with the collection of different categories of biological information. Adding the collection of a new, more complex, category of biological information provides a more comprehensive understanding of the population, but also requires more effort and poses more potential problems than the collection of more straightforward categories of biological information.

The results of my study suggest that a suitable approach would be to focus on collecting information on the catch-numbers, catch-per-unit-effort and training hunters in the collection of straightforward information such as sex and size. Training hunters in the collection of genetic samples is also likely to be important because of the importance in understanding the shared nature of the stocks of green turtles and dugongs throughout the region. Methods other than catch-monitoring may also be used to collect information relevant to understanding the biological characteristics of green turtles and dugongs. For example, focus groups (e.g., discussions amongst hunters) may be conducted to discuss what people are seeing, but are not required to record on the datasheets, such as ‘wati dhangal’ (i.e., thin, lethargic dugongs with watery fat; Kwan 2002). It will be important to ensure that methods are standardised across communities and through time. Long-term comparisons throughout the Torres Strait region were not possible for many of the biological parameters considered in the present study because of problems with standardisation.

Table 6.13. The advantages, problems and potential outcomes of collecting different levels of biological information.

Information	Advantages	Problems	Outcomes
1. Only numbers (no biological information).	Concentrate on collecting the numbers.	The number of animals that can be caught sustainably depends on the nature of the catch as well as the numbers caught.	Good estimates of catch-number, but difficult to interpret because the nature of the catch will determine/influence whether the number of animals caught is sustainable.
2. Numbers and sex.	May obtain some indication of cultural preferences if the sex-ratio is heavily biased (e.g., as it was for green turtles in the present study).	For green turtles, have a mixed stock so cannot determine which is the baseline population with which to compare the sex ratio; For both green turtles and dugongs, do not have sex ratio data from unhunted population in Torres Strait.	Difficult to determine whether the sex ratio is biased due to hunter preferences/mis-reporting because do not know the natural sex-ratio; May provide some indication of possible management options (e.g., if the sex ratio is heavily biased can try to make it more even).
3. Numbers, sex and size.	May indicate whether vulnerable life-history stages are being targeted (e.g., adults).	If size is estimated rather than measured (i.e., as was done for dugongs in the present study), the size classes may not be robust; Size is not a precise indicator of maturity for either dugongs or green turtles. However, below a certain size, animals can be considered juveniles and above a certain size, they can be considered adults.	May provide some indication of possible management options; May indicate a shift in the size range of animals (e.g., loss of large animals from the population), but difficult to disaggregate such changes from hunter preferences.
4. Numbers, sex, size and reproductive status (qualitative).	Examination of the ovaries of green turtles can indicate whether or not the turtle is mature (e.g., presence of yellow ova); The presence of a foetus indicates that a female	False negatives are likely; Very difficult to determine the reproductive status of male green turtles or dugongs	May under-estimate the level of reproductive activity; May under-estimate the proportion of mature animals in the catch; Only able to collect information for female green turtles and dugongs.

Information	Advantages	Problems	Outcomes
	dugong is mature.		
5. Numbers, sex, size, reproductive status (qualitative) and specimens (straightforward and convenient to collect).	e.g., genetics.	Requires extra equipment to be carried, labelling and storage of samples and substantial education in the collection and labelling of samples.	Improved understanding of the connections of Torres Strait populations of green turtles and dugongs with other regions.
6. Numbers, sex, size, reproductive status (qualitative), specimens (straightforward and convenient to collect) and specimens (logistically difficult to collect).	The collection of tusks of dugongs enables age-determination; The collection of reproductive organs enables detailed interpretation of maturity and reproductive status; The collection of stomach contents enables analysis of the diet.	Requires a large investment of effort by hunters/catch-monitors to extract the specimens from the animals, label, and store them; Requires substantial education in collection and labelling of samples because there is a great potential for mis-labelling, particularly when multiple samples are collected from multiple animals at the same time (e.g., skulls and reproductive organs from different animals); Requires funds to process samples; Patterns in reproductive parameters may be confounded by stochastic environmental conditions.	Provides information that can inform population/sustainability models, e.g.,: Age distribution; Age at first reproduction; Reproductive rate; Recruitment rate (i.e., new breeders); It may be difficult to disaggregate the influence of environmental conditions and density dependence on changes in some reproductive parameters through time, particularly in the absence of complimentary information on environmental conditions and seagrass distribution and abundance.

In addition, because patterns in reproductive parameters may be confounded by external natural and anthropogenic events as well as biases in the demographics due to hunter preferences, other datasets are needed to assist in evaluating trends in the population status and the sustainability of the catch of green turtles and dugongs in Torres Strait. Broader studies should be undertaken on the population dynamics and distribution and abundance of green turtles and dugongs through turtle rodeos in foraging areas (Limpus and Reed 1985a), boat-based surveys of dugongs and aerial surveys of dugongs (to provide data on the proportion of calves in the population). Furthermore, as explained in Chapter 2, dugongs rely on sea grass for food (Heinsohn and Birch 1972; Marsh et al. 1982; Lanyon et al. 1989; Andre´ et al. 2005), while green turtles feed on both algae and sea grass in Torres Strait (Andre´ et al. 2005) and their biological parameters and reproductive capacity are likely to be affected by the availability and quality of sea grass resources (Nietschmann and Nietschmann 1981; Kwan 2002; Marsh et al. 2011). Therefore, understanding changes in seagrass distribution, abundance and quality will also assist in understanding changes in the biological parameters of dugongs and green turtles and changes in the population status of these species. A conceptual framework for determining who might be appropriate to do what with respect to the various stages of the scientific process (e.g., study design, data collection, data analysis, interpretation, data management, and management) for various studies is presented in the General Discussion (see Chapter 8).

6.4.4. Improvements in catch-monitoring

The datasheet used in the present study included a wide range of questions. The quality of information recorded by hunters could be improved by focussing the datasheet more narrowly (at least in the first instance). Noss et al. (2004) found that focussed studies on particular species (e.g., parrots) or particular aspects led to greater reporting of that species or aspect because particular hunters were engaged directly in that aspect of reporting through meetings and discussions. In addition, the participation by hunters could be improved by emphasising, through discussions and demonstrations, the specific information required to respond to particular research questions (Noss et al. 2005; Ban et al. 2009).

Hunters may be more likely to record biological information relating to the green turtles and dugongs that they catch if the results of their catch-monitoring are reported back promptly and are clearly linked to management actions for their community. Volunteers tend to be motivated through prompt delivery of results, particularly if these results are clearly linked to management actions (Noss et al. 2005; Uychiaoco et al. 2005; Mellors et al. 2008). For example, Seagrass-Watch in Torres Strait maintained volunteers through a comprehensive communication strategy including a website, radio interviews, presentation of monitoring trip results and rewarding long-tem participants with awards (Mellors et al. 2008).

6.4.5 Goals of locally- based monitoring

It is important not to lose sight of the goals of locally- based monitoring. In addition to quantifying catch-numbers and producing biological data as a basis for managing exploited species, the goal of locally- based monitoring is to involve local hunters in research and community-based management (Noss et al. 2004; Berkes 2009). Therefore, even if all of the information that would be necessary to manage an exploited population sustainably cannot be collected by hunters in the first instance, involving hunters in the collection of some information to contribute to long-term datasets will have benefits for adaptive management of dugong and green turtle populations. This is because, by generating data, people become conscious of underlying problems. As community members generate data, the data bear greater weight and value in community discussions. The reflection process can lead to preliminary management action that can be consolidated in the adaptive management process (Noss et al. 2005; Berkes 2009).

6.5. Chapter Summary

- In this chapter, I examined what demographic information hunters could practically collect and investigated whether the information collected could provide insights into the ecological and cultural sustainability of the catch or the population status of dugongs and green turtles in Torres Strait.

- Hunters from Hammond and Thursday Islands recorded their catches of green turtles and dugongs on catch-monitoring datasheets in 2005-2006 with the assistance of Indigenous research counterparts employed on the project (see Chapter 5).

- The datasheets requested demographic information including the sex, size, reproductive status and maturity of green turtles and dugongs caught by hunters.

- I investigated what proportion of datasheets had demographic information recorded completely. Only seven hunters filled in demographic information completely on some of the datasheets they submitted for the dugongs and green turtles they caught. At Hammond Island, hunters filled in demographic information completely on 16% of the datasheets one hunter submitted for the green turtles he caught and 7% of the datasheets another hunter submitted for the dugongs he caught. At Thursday Island, hunters filled in demographic information completely on 6% and 22% of the datasheets, respectively two hunters submitted for the green turtles they caught and on 4%, 6% and 20% of the datasheets, respectively three hunters submitted for the dugongs they caught.

- I also compared the demographic information collected from green turtles and dugongs in the present study with that collected from dugongs and green turtles in previous studies in the region to examine changes in the population dynamics of these species through time and thereby investigate whether catches in the present study were typical of Torres Strait catches.
- Hunters recorded more-straightforward information (e.g., sex) more often than more-complex information (e.g., reproductive status) and specimens were rarely provided.
- There was a strong bias in the green turtle catch towards adult females; the sex ratio of caught dugongs was even.
- Consistent with Kwan's (2002) study in 1998-1999 at Mabuiag Island, the size at first reproduction of dugongs in this study was small compared with that found by Hudson (1986) for dugongs in the Daru fishery in the late 1970s-early 1980s in the Torres Strait region and other studies in other regions.
- There was some indication that collection of demographic information could inform the ecological or cultural sustainability of the catch, but the results remain inconclusive because: (1) baseline information is not available for comparison and (2) explanations for the recorded sex ratios, size frequencies, size at first reproduction and reproductive rates, other than over-harvesting, are plausible.

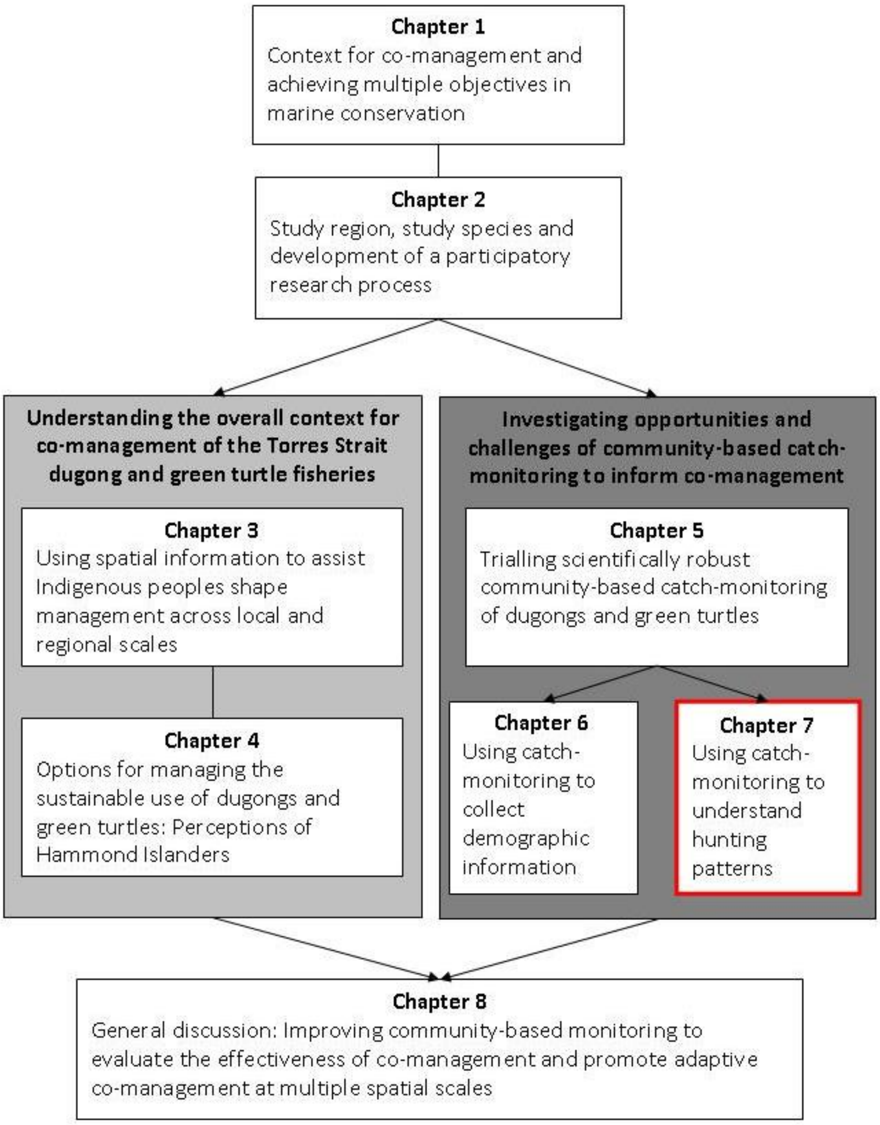
- Patterns in demographic parameters may be confounded by external natural and anthropogenic events as well as biases in the demographics due to hunter preferences and therefore other datasets (e.g., demographics of unhunted populations; sea grass condition) are needed to assist in evaluating trends in the population status and sustainability of the catch of green turtles and dugongs in Torres Strait.

- The collection of demographic information needs to be introduced over the long-term in a step-wise manner such that the more straightforward information is collected in the initial phase, with the collection of more complex information being introduced as hunters become more proficient, including training in the provision of information at each step.

- Monitoring could be improved by limiting the number of questions on the datasheet and ensuring prompt feedback of results to hunters and the broader community.

Chapter 7

Community-based monitoring as a method for determining patterns of hunting for dugongs and green turtles to inform Indigenous hunting management



In this chapter, I investigate how well hunters could collect information on hunting patterns to inform Indigenous hunting management. In particular, I examine what information hunters could practically collect and assess whether the information collected could provide insights into appropriate management interventions for dugong and green turtle hunting in Torres Strait. I discuss the results of this trial with respect to informing the development of community-based monitoring programs for the management of marine turtles and dugongs by Torres Strait communities as well as other Indigenous communities. Chapter 7 (and Chapter 6) includes information (i.e., the total numbers of dugongs and green turtles caught) that is confidential under the terms of the Research Agreement (see Appendix A). This confidential information will be removed from versions of the thesis that will be made public.

Chapter 7. Community-based monitoring for determining patterns of hunting for dugongs and green turtles to inform Indigenous hunting management

7.1. Introduction

As described in Chapter 5, locally- based monitoring can be more effective than professionally-based monitoring for informing Indigenous hunting management, particularly in remote areas and for culturally important species. In Chapter 5, I examined the feasibility of using locally- based monitoring for estimating catch-numbers of dugongs and green turtles and showed that it can provide more reliable information than professionally-based monitoring. In Chapter 6, I showed that locally- based monitoring can also be used to collect demographic information about animals taken. These parameters can provide insights into the ecological and cultural sustainability of the catch and trends in the population of the harvested species. However, the collection of demographic information should be introduced in a staged-approach, with more-straightforward information collected in the initial phase and more-complex information introduced as hunters become more proficient. Information about hunting patterns, including social and cultural considerations, can provide important insight about hunting pressure (Kwan 2002) which can be useful for guiding decisions regarding the choice and application of management tools.

Traditional Owners developed the Torres Strait Community Dugong and Turtle Management Plans described in Chapter 1 with input from government agencies. As described in Chapter 1, the plans incorporate the existing statutory regulations under the *Torres Strait Fisheries Act 1984* as well as traditional management arrangements aimed to reinforce traditional values, cultural protocols and ethics. The plans incorporate a variety of management tools including permits, total allowable catch quotas, temporal and spatial closures, restrictions on hunting methods and consideration of ceremonies for which dugongs and marine turtles may be taken. The implementation of the plans also includes catch-monitoring.

In this Chapter, I aimed to investigate what information on hunting patterns it was realistic for hunters to collect using catch-monitoring datasheets; and potential management options based on information collected by Hammond Island and Thursday Island hunters. The insights gained from this study may be applicable to the plans developed by other Torres Strait communities.

7.2. Methods

7.2.1. Data collection

As described in Chapters 5 and 6, Hammond and Thursday Island hunters recorded their catches of green turtles and dugongs on catch-monitoring datasheets (see Appendix B), with the assistance of local catch-monitors employed on the project. One datasheet was completed for each animal caught and the datasheets enabled hunters to record demographic information (see Chapter 6) about the catch as well as information relating to hunting patterns.

The datasheet requested information about activity patterns (i.e., date and time of hunting), the duration of hunting trips, the distance from the hunters' island that the dugong or green turtle was caught, hunting methods, what was being targeted on the trip when the dugong or green turtle was caught, the reason for hunting, whether the hunter was asked to hunt by others, whether they shared their catch and the number of hunters in the hunting party (Table 7.1). These categories of information were requested from hunters because they could contribute to their understanding of hunting patterns, including social and cultural considerations, and thereby possible management options for dugongs and green turtles. The rationale for the collection of different categories of information sought from hunters is provided in Table 7.1.

The period that data were collected was the same as for the demographic information because both types of information were collected together (see Section 6.2.2; Figure 6.1). Thus, monitoring was conducted from 25 February 2005 to 11 November 2006 (623 days) at Hammond Island and from 19 May 2005 to 3 July 2006 (410 days) at Thursday Island.

7.2.2. What information is realistic for hunters to record?

One of the aims of the trial of the datasheet for monitoring was to investigate what information was realistic for hunters to collect. I examined how consistently each piece of information was recorded by calculating, for each item of information, the proportion of datasheets for which that item of information was recorded (as I did for demographic information in Chapter 6). I also examined whether the number of dugongs and green turtles a hunter caught affected how completely he recorded information on the datasheets.

Table 7.1. Rationale for the collection of categories of information sought from hunters.

Category of information sought	Insight(s)	Rationale
Date	• Seasonality • Temporal variability	• Hunting effort;
Time	A greater proportion of hunting at night than during the day may indicate: • dugongs and green turtles may be easier to catch at night. • green turtles and dugongs are not abundant close to communities during the day or have been displaced from areas close to communities during the day. • conditions are suitable for hunting at night (Kwan 2002)	• Whether hunting is done during the day or at night. • Hunters in the present study and Kwan's (2002) study at Mabuiag Island suggest that green turtles and dugongs are displaced from reefs during the day because they are disturbed by boat traffic, but they return to the reefs at night to feed.
Duration of the hunting trip	• Indication of whether animals are becoming more or less abundant; • Indication of whether animals are moving closer or further away from the hunters' communities.	• Hunting effort
Distance from the hunters Island	• Indication of whether animals are becoming more or less abundant; • Indication of whether animals are moving closer or further away from the hunters' communities; • Spatial distribution of hunting. • Geographic analysis of species and hunting pressure as a basis for spatial planning (see Chapter 3; Noss et al. 2004)	• Hunting effort
Hunting methods	• Indication of the level of use of different hunting methods	• Hunters who helped design the datasheet

Category of information sought	Insight(s)	Rationale
	and their efficacy in catching dugongs and green turtles.	expressed concern about some hunting methods and wished to gain an understanding of the level of use of these methods
Target of the hunting trip	• Indication of the level of incidental take of dugongs and green turtles; • May indicate changes in the availability of the target species (if hunters need to settle for a non-target species); but could also reflect the skill of the hunter.	• Understanding of hunting patterns to inform management options.
Reason for hunting	• Indication of the relative importance (based on numbers of animals used) of different uses to the community. • Assist in directing management decisions.	• Hunting pressure; • Understanding of hunting patterns to inform management options.
Whether the hunter was asked by others to hunt	• Indication of the pressure put on hunters by the community to go hunting. • Assist in determining whether the community will need to manage the behaviour and attitudes of only hunters or also the broader community.	• Hunting pressure
Whether the hunter shared his catch with others	• Indication of how many people in the community are benefiting from the capture of dugongs or green turtles.	• Hunting pressure
Number of hunters in the hunting party.	• Indication of hunting effort. • The minimum number of people that will benefit from the hunt and that will contribute to the cost of hunting.	• Hunting pressure

7.3. Results

7.3.1. Completeness of the information recorded by hunters

The datasheets included a wide range of questions to stimulate the collection of information on biological information (see Chapter 6) as well has hunting patterns. Hunters rarely filled in the datasheets completely (Table 7.2) and some questions relating to hunting patterns were completed more often than others (Table 7.3). As noted in Chapter 6, at Hammond Island, the capture of a small number of animals ([redacted] green turtles and [redacted] dugongs) was not recorded on datasheets by hunters, but noted by the local catch-monitor during surveys of hunters. Thus, there was no information on hunting patterns recorded for these animals.

The most prolific hunters (i.e., those that filled in >10 datasheets) filled in information on hunting patterns completely for between 24% and 70% of datasheets (Table 7.2). At Hammond Island, the hunter who filled in between 5-9 datasheets for dugongs, did not fill in any datasheets completely for hunting patterns for either dugongs or green turtles. If he is ignored, then hunters from Hammond Island, who filled in between 5-9 datasheets for green turtles, filled in information on hunting patterns completely for between 33% and 80% of datasheets for the green turtles they caught. This result is similar for hunters from Thursday Island, who filled in between 5-9 datasheets (Table 7.2). Hunters, who filled in 1-4 datasheets, filled in information on hunting patterns completely for between 0% and 100% of datasheets (Table 7.2). Thus, all but one hunter who filled in five datasheets or more filled in datasheets completely for hunting patterns some of the time. In contrast, some hunters who filled in between one and four datasheets never filled in datasheets completely for hunting patterns, some hunters sometimes filled in datasheets completely and other hunters always filled in datasheets completely.

Table 7.2. The range of the percentage of datasheets filled in completely by an individual hunter for hunting patterns for hunters from Hammond Island and Thursday Island that filled in 1-4 datasheets, 5-9 datasheets and >10 datasheets to record caught green turtles and dugongs. n is the number of individual hunters.

Species		**Green turtles**		**Dugongs**	
Datasheets filled in by individual hunters	**Number of datasheets**	**n**	**Range of the % of datasheets filled in completely**	**n**	**Range of % of datasheets filled in completely**
Hammond Island	1-4	52%	0-100	73%[†]	0-100
	5-9	33%	0-80	12.5%[‡]	0
	>10	5%	52	12.5%[§]	41
Thursday Island	1-4	52%	0-100	60%[|]	0-100
	5-9	14%	33-50	10%	43
	>10	14%	27-35	30%[¶]	24-70

[†] Includes four of the hunters that caught 1-4 green turtles at Hammond Island
[‡] Includes one of the hunters that caught 5-9 green turtles at Hammond Island
[§] This includes a hunter that caught >10 green turtles at Hammond Island
[|] Includes one of the hunters that caught 1-4 green turtles at Thursday Island
[¶] Includes two of the hunters that caught >10 green turtles at Thursday Island

The reason for hunting both dugongs and green turtles was recorded for the greatest proportion of datasheets by both Hammond and Thursday Island hunters. The distance from the hunters' home Island that the dugong was caught was least recorded on datasheets by Hammond Island hunters and the distance from the hunters' home island that both dugongs and green turtles were caught was least recorded on datasheets by Thursday Island hunters (Table 7.3). Whether the green turtle was shared was least recorded on datasheets by Hammond Island hunters (Table 7.3).

Table 7.3. The percentage of datasheets filled in by hunters from Hammond Island and Thursday Island for which different questions on hunting patterns were completed. n is the total number of dugongs and green turtles caught for which datasheets were filled in by hunters.

	% of datasheets with question competed:			
	Hammond Island		Thursday Island	
Question	Dugongs n = [redacted]†	Green turtles n=[redacted]	Dugongs n=[redacted]	Green turtles n=[redacted]
Hunting details (code number of hunter; number in hunting party)	76	75	88	89
Time caught	73	66	85	78
Distance from Island where the hunter lives that the animal was caught	65	70	63	64
Method of capture (gear/platform)	73	66	81	89
Duration (start time/finish time/number of hours)	73	78	86	92
Target (what species the hunter set out to catch)	67	73	81	89
Reason	92	83	92	96
Was the hunter asked by others to hunt?	73	76	78	78
Share (how many people will the hunter share with?)	67	65	85	85

† The total number of turtles and dugongs only includes those recorded on datasheets and does not include those animals for which the local catch-monitor noted their capture during surveys of hunters. The latter animals were not included in the total because hunting pattern information was not recorded for these animals.

The extent to which different questions were completed also varied among hunters (Figure 7.1). In particular, one hunter from Hammond Island (HI-B) filled in the questions on the datasheet for only a small proportion of the dugongs and green turtles that he caught. The local catch-monitor usually filled in the datasheet for this hunter and three of the dugongs and five of the green turtles for which no information was recorded on a datasheet were caught on the same hunting trip when the local catch-monitor was not available.

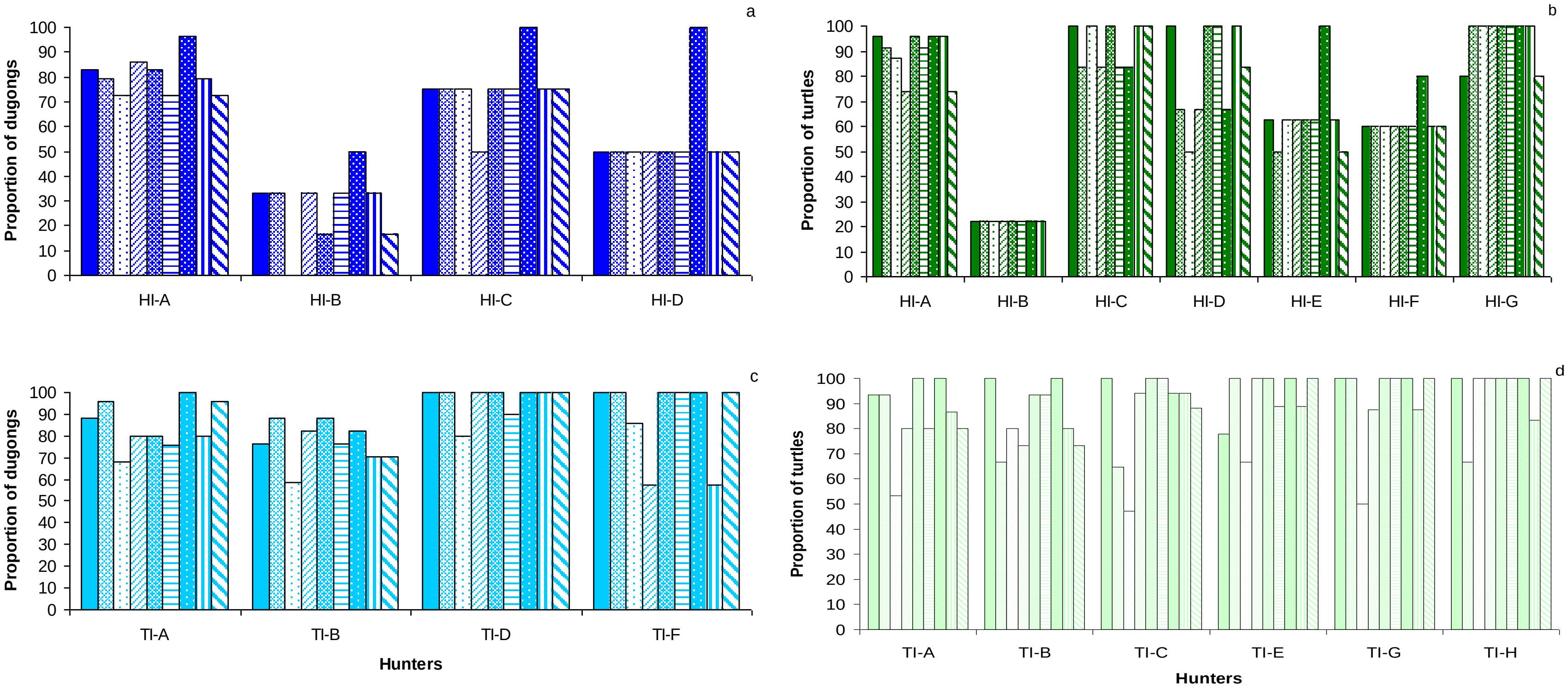


Figure 7.1a-d. a) The proportion of dugongs for which information on hunting patterns (■ crew, ▩ time, ⁙ location, ▨ method, ▩ duration, ☰ target, ■ reason, ▥ asked to hunt, ▧ sharing) was recorded by the four most prolific dugong hunters from Hammond Island (hunters HI-A, HI-B, HI-C and HI-D); b) The proportion of green turtles for which information on hunting patterns (■ crew, ▩ time, ⁙ location, ▨ method, ▩ duration, ☰ target, ■ reason, ▥ asked to hunt, ▧ sharing) was recorded by the seven most prolific green turtle hunters from Hammond Island (HI-A, HI-B, HI-C, HI-D, HI-E, HI-F, HI-G); c) The proportion of dugongs for which information on hunting patterns (■ crew, ▩ time, ⁙ location, ▨ method, ▩ duration, ☰ target, ■ reason, ▥ asked to hunt, ▧ sharing) was recorded by the four most prolific dugong hunters from Thursday Island (hunters TI-A, TI-B, TI-D and TI-F); d) The proportion of green turtles for which information on hunting patterns (■ crew, ▩ time, ⁙ location, ▨ method, ▩ duration, ☰ target, ■ reason, ▥ asked to hunt, ▧ sharing) was recorded by the six most prolific green turtle hunters from Thursday Island (hunters TI-A, TI-B, TI-C, TI-E, TI-G and TI-H); n is the number of dugongs or green turtles caught by each hunter. Some hunters were prolific hunters of both dugongs and green turtles and are therefore included in the figures for both species. Other hunters were prolific hunters of only one species and are therefore only included in the relevant figure.

7.3.2. Hunting patterns

Hunters

A description of the species caught by hunters and the distribution of the catch among hunters in each community is provided in Chapter 5 (Section 5.3.2).

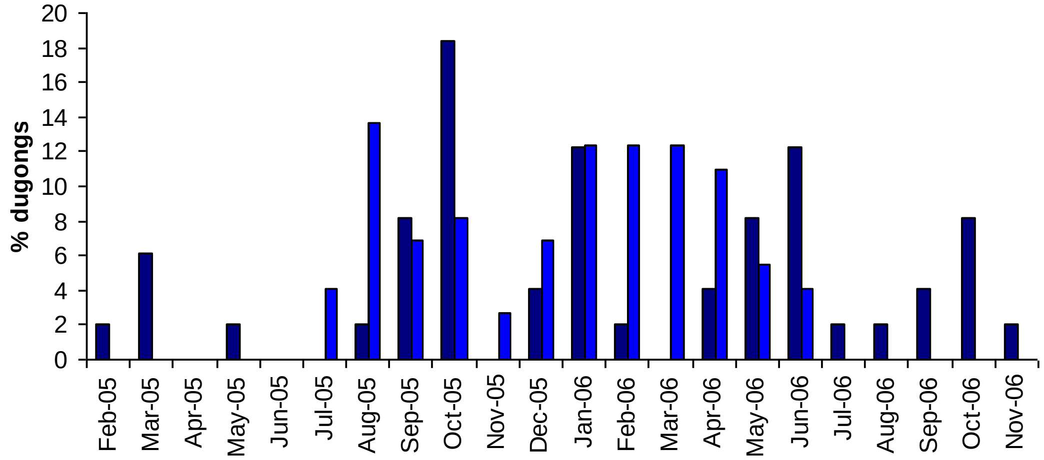
Temporal variability of hunting

Information on the date that animals are caught can be used to establish whether there is any temporal variability in catches. Information on catches needs to be collected across multiple months and multiple years to establish any temporal patterns. Temporal patterns in the total catch per month shown in my study may be confounded by hunter participation because participation rates were changing through time as the catch-monitoring project became established.

There appeared to be a temporal peak in the catches of green turtles during the Northern Great Barrier Reef breeding season (September to October 2005) and the Gulf of Carpentaria breeding season (May-June 2006) in both communities (but not Hammond Island in May 2006). Nevertheless, information on reproductive status of green turtles would be needed to confirm any temporal trends in catches.

Kwan (2002) found that the dugong catch at Mabuiag Island in 1998-1998 was temporally variable both within and between years. In 1998, most of the catch was taken in the latter part of the year and in 1999 most of the catch was taken in the first part of the year (noting that Kwan (2002) obtained a census of the dugong catch between October and March each year).

a



b

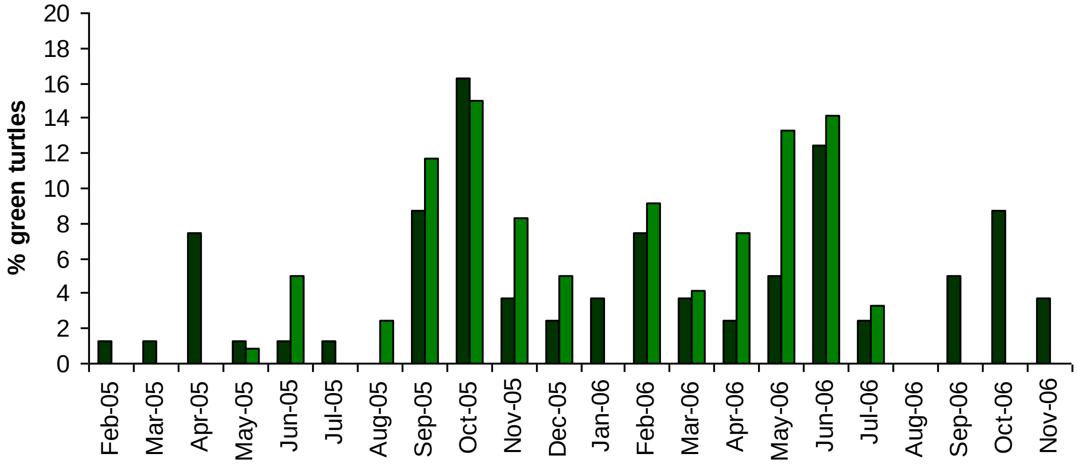


Figure 7.2. The proportion of a) dugongs and b) green turtles reported on datasheets by Hammond Island hunters (dark bars) and Thursday Island hunters (light bars) each month. Note: the catch-monitoring programme was conducted from May 2005 to early July 2006 at Thursday Island.

Time of hunting

Dugongs

The times at which dugongs were caught differed between Hammond Island hunters and Thursday Island hunters (χ^2=8.65, 3df, P = 0.034). Both Hammond and Thursday Island hunters caught most of their dugongs during the day, but Thursday Island hunters caught a greater proportion of their dugongs in the morning than in the afternoon (Figure 7.3a).

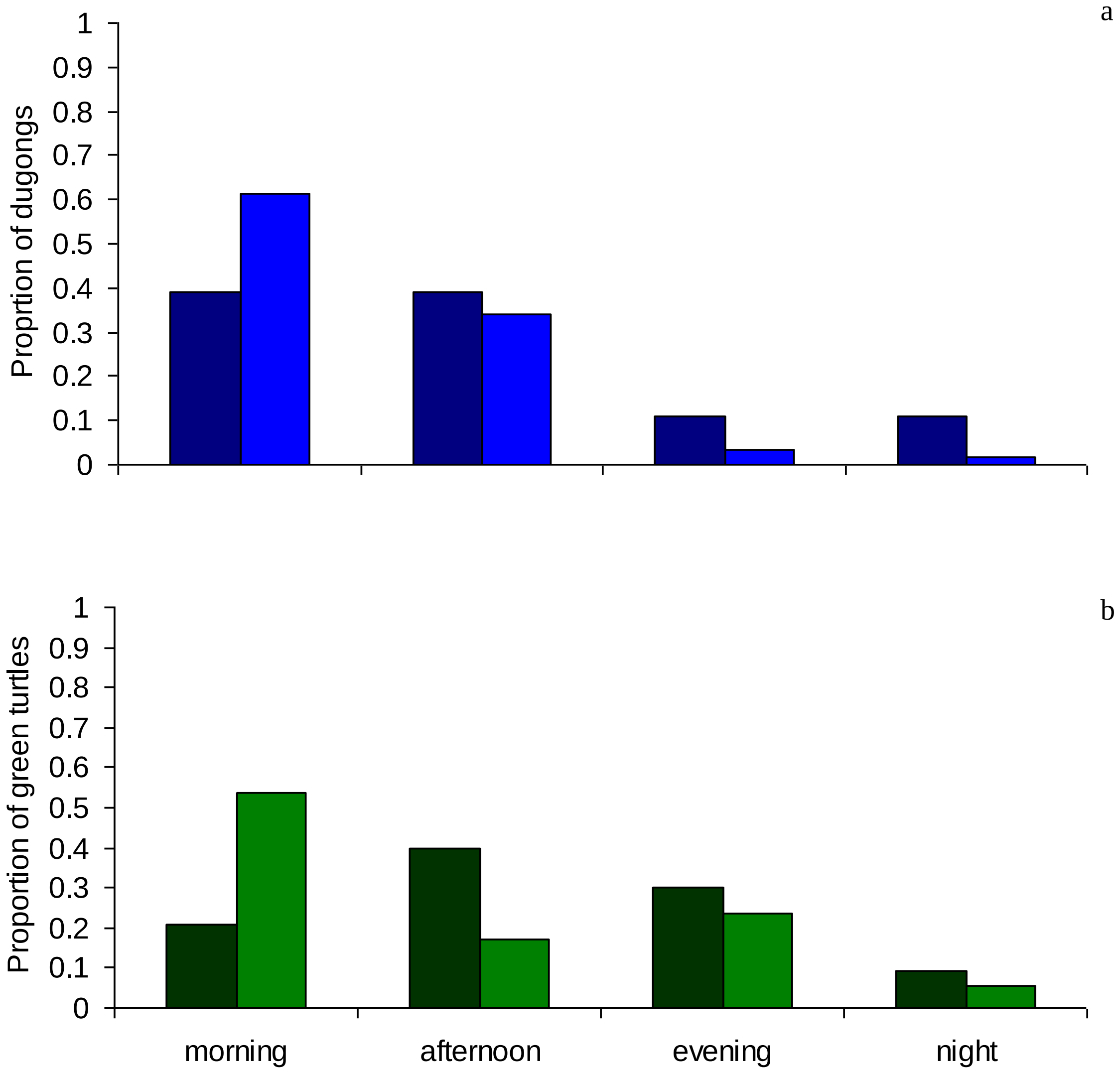


Figure 7.3. The proportion of a) dugongs caught by Hammond Island hunters (dark bars; n=[redacted]) and Thursday Island hunters (light bars; n=[redacted] and b) green turtles caught by Hammond Island hunters (dark bars; n=[redacted]) and Thursday Island hunters (light bars; n=[redacted]) reported as caught at different times of day. Morning = 6am-midday; Afternoon = midday-6pm; Evening = 6pm-midnight; Night = midnight-6am.

Green turtles

The times at which green turtles were caught also differed between Hammond Island hunters and Thursday Island hunters (χ^2=16.9, 3df, P = 0.001). Both Hammond Island hunters and Thursday Island hunters caught most of their green turtles during the day and evenings, but Thursday Island hunters caught a greater proportion of green turtles in the morning than at any other time (Figure 7.3b).

Hunting methods

Dugongs

Hammond and Thursday Island hunters used the same methods to catch dugongs. There was no significant difference between the two groups of hunters in the type of vessel used (χ^2=2.92, 1df, P = 0.008) or the hunting instrument used (χ^2=1.49, 1df, P = 0.223). Dugongs were mostly caught using clinker dinghies and a wap (Figure 7.4). It does not appear that the fast pursuit method was used at night/evening to chase dugongs on the reef. Dinghies do not appear to have been used to chase dugongs at night because only one hunter from each of Hammond and Thursday Islands reported one dugong as having been caught from a dinghy at night/evening. In addition, hunters did not report using spotlights to catch dugongs and these would be needed to chase dugongs at night. Furthermore, there were an additional 22% and 5% of dugongs caught by Hammond Island hunters and Thursday Island hunters, respectively, for which it is not known whether they were chased at night/evening because information on the time of hunting and the hunting platform was not recorded on the datasheets.

Green turtles

The methods used to catch green turtles differed between Hammond and Thursday Island hunters. There was a significant difference between the two groups of hunters in the type of vessel used (χ^2=16.9, 2df, P = 0.000) and the hunting instrument used (χ^2=82.5, 3df, P = 0.000). Green turtles were mostly caught from a dinghy. In some cases, but not all, when they were caught from a clinker dinghy it was because the hunter was targeting dugongs. Hunters reported using spotlights at night to catch green turtles, but not dugongs. Thursday Island hunters appeared to use this practice more than Hammond Island hunters did. They reported using spotlights to catch a greater proportion of the green turtles they recorded as caught at night/evening than did Hammond Island hunters (82% compared with 56%).

Although both Hammond and Thursday Island hunters used a wap to catch green turtles, Thursday Island hunters also reported catching most of their green turtles using a hook, which Hammond Island hunters did not use (Figure 7.4).

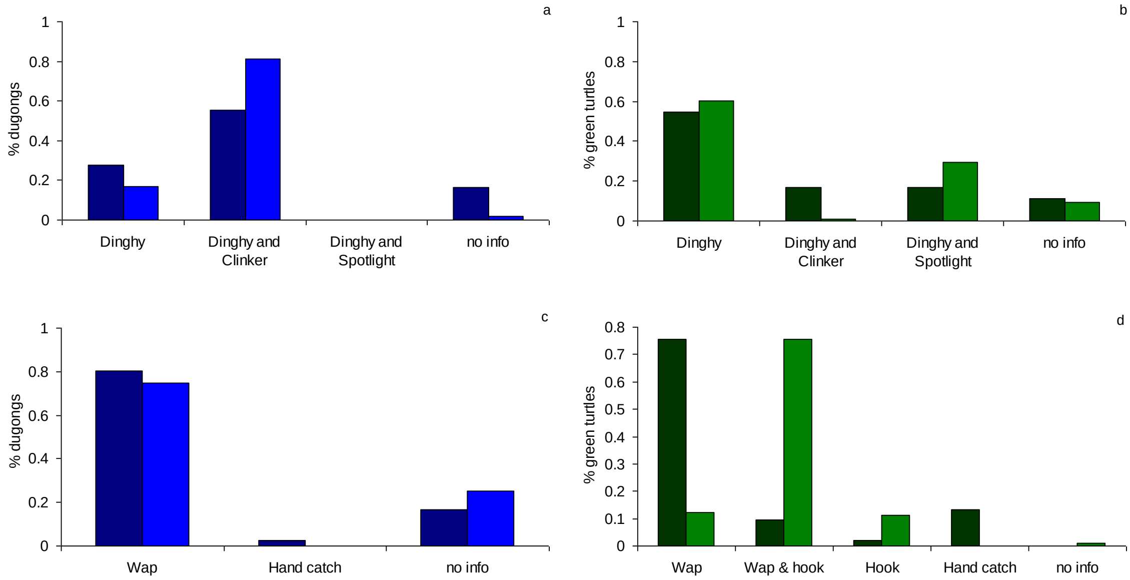
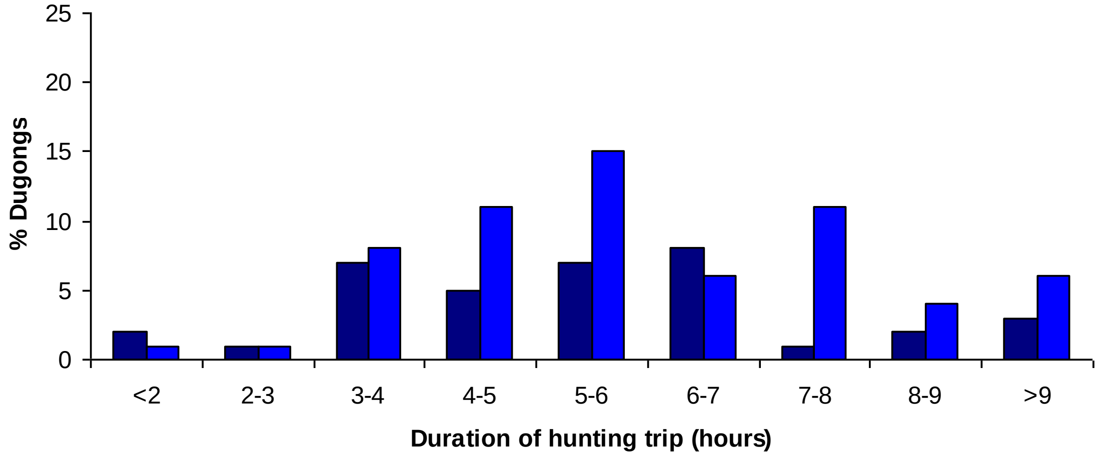


Figure 7.4. Vessels used to catch a) dugongs and b) green turtles by Hammond Island hunters (dark bars) and Thursday Island hunters (light bars) and hunting instrument used to catch c) dugongs and d) green turtles by Hammond Island hunters (dark bars) and Thursday Island hunters (light bars). Hammond Island hunters recorded information on vessels and hunting instrument for n = [redacted] dugongs and n = [redacted] green turtles; Thursday Island hunters recorded information on vessels and hunting instrument for n = [redacted] dugongs and n = [redacted] green turtles.

Duration of hunting trips

The duration of successful hunting trips was variable, ranging between a quarter of an hour and twelve hours (Table 7.4; Figure 7.5). The duration of unsuccessful hunting trips was recorded for only four trips by Hammond Island hunters and six trips by Thursday Island hunters, and these trips were within the ranges of successful trips (Table 7.4). There was no significant difference in the duration of trips made by hunters from Hammond and Thursday Islands to catch either dugongs (χ^2=9.16, 8df, P = 0.329) or green turtles (χ^2=10.7, 8df, P = 0.221). Hammond Island hunters most frequently took six hours to catch dugongs and four hours to catch green turtles, while

Thursday Island hunters most frequently took five hours to catch dugongs and two and a half hours to catch green turtles (Table 7.4).



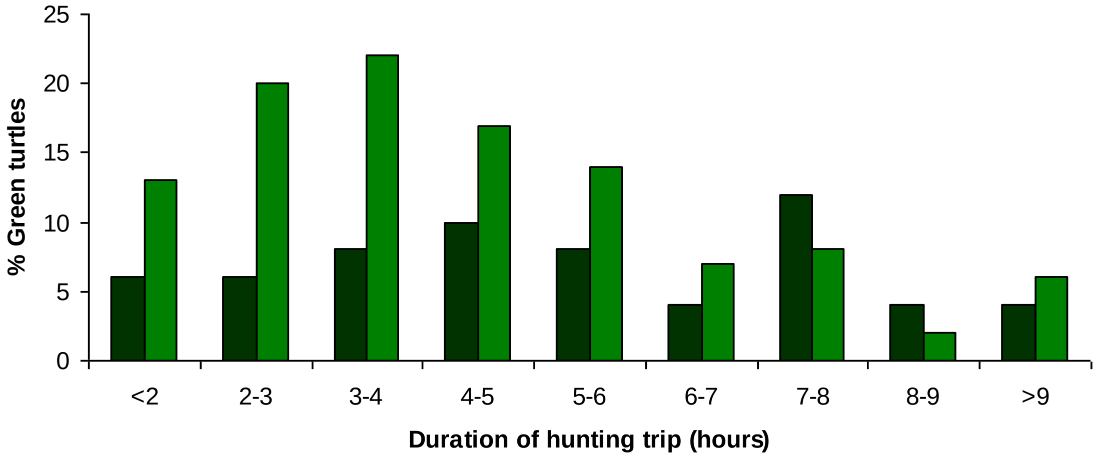


Figure 7.5. The percentage of a) dugongs and b) green turtles caught on hunting trips of different durations in hours by Hammond (dark bars) and Thursday (light bars) Island hunters.

Table 7.4. Duration of hunting trips by Hammond and Thursday Island hunters.

	Hammond Island			**Thursday Island**		
	Dugongs	Green turtles	No catch	Dugongs	Green turtles	No catch
n (trips)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
# dugongs or green turtles	[redacted]	[redacted]	na	[redacted]	[redacted]	na
Range duration (hrs)	0.5-11	0.5-10	3.75-7	1.5-11	0.25-12	3-9.5
Mode duration (hrs)	6	4	7	5	2.5	5.5

Hunting areas

Distance was either measured in, or converted to, kilometers. Dugongs and green turtles were generally caught within 30 km from the hunters starting point (Figure 7.6; Table 7.5; see Chapter 3). Both Hammond and Thursday Island hunters recorded information on the distances travelled on unsuccessful trips for only three trips. These trips were within the range of distances that dugongs and green turtles were caught (Table 7.5).

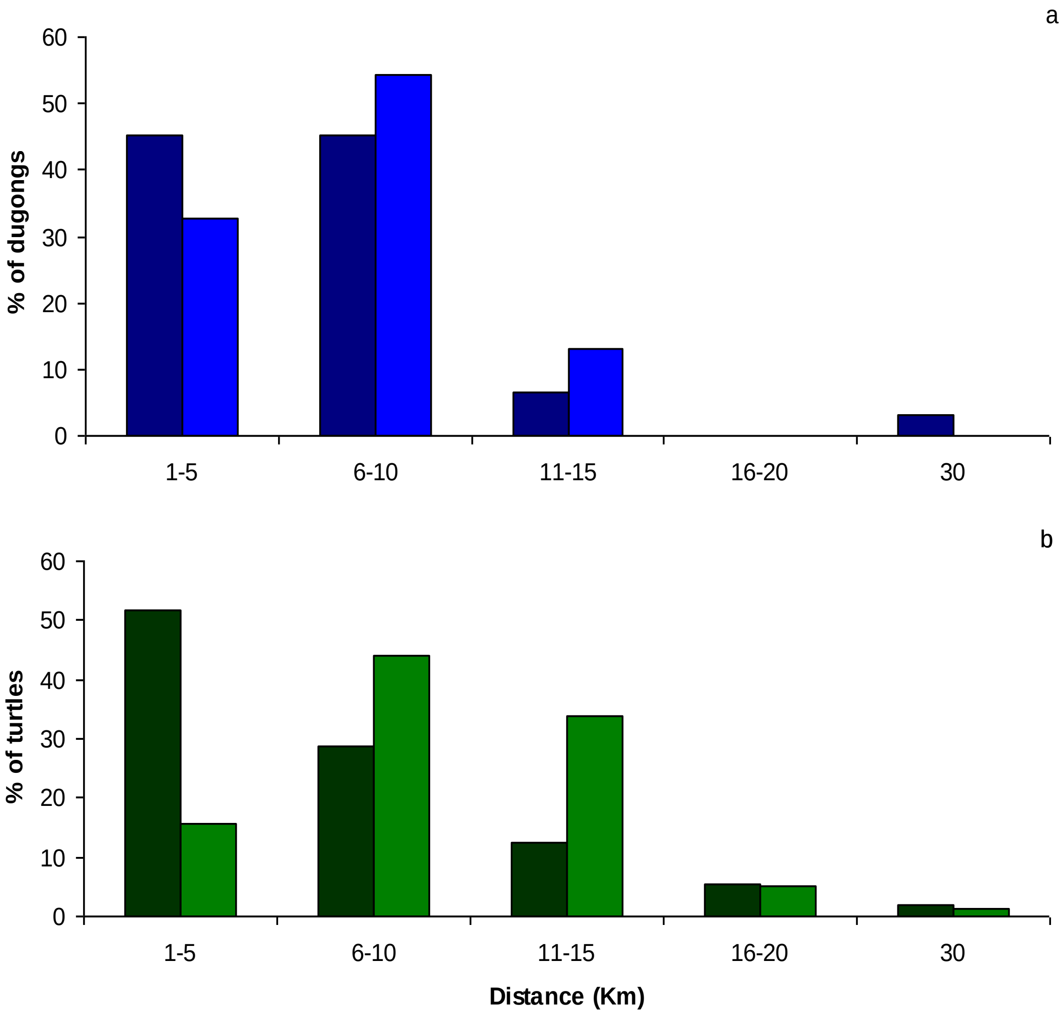


Figure 7.6. The frequency distribution of distances (km) from the island from which hunting was initiated that a) dugongs and b) green turtles were caught by Hammond Island (dark bars) and Thursday Island (light bars) hunters.

Table 7.5. Distance of hunting trips by Hammond and Thursday Island hunters.

	Hammond Island			Thursday Island		
	Dugongs	Green turtles	No catch	Dugongs	Green turtles	No catch
n (dugongs or green turtles)	[redacted]	[redacted]	na	[redacted]	[redacted]	na
# trips	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Range distance (km)	1-30	0.2-30	3-20	2-15	2-30	15
Mean distance per animal (km)	6.8	6.6	14.3	7.5	10.6	11.7
Mode distance per animal (km)	9	9	na	5	15	na
Mode distance per trip (km)	9	2	20	5	15	-[†]

[†] there was no mode because three different distances were travelled, 3, 12 and 15 km.

Target of the hunting trip

Hunters usually set out to catch a particular species, they caught the species they were targeting for almost all of the dugong and green turtle catching trips that they reported (Table 7.6). Only occasionally were green turtles or dugongs caught incidentally while travelling between Islands or undertaking other activities such as crayfishing or fishing (Table 7.6).

Table 7.6. The percentages (%) of datasheets on which dugongs and green turtles were reported as caught by Hammond and Thursday Island hunters for trips with different target species.

	Species caught			
	Hammond Island		**Thursday Island**	
	Dugongs	Green turtles	Dugongs	Green turtles
Target	n=[redacted]	n=[redacted]	n=[redacted]	n=[redacted]
Dugong	79	2	98	0
Green turtle	12	91	2	91
Dugong and green turtle	6	5	0	4
Green turtle and crayfish	0	0	0	2
Green turtle and fish	0	0	0	2
Crayfish	3	0	0	0
Fish	0	2	0	<1
Incidental	0	0	0	<1

Reasons for hunting

The main reason for hunting both dugongs and green turtles recorded on datasheets was for subsistence purposes (i.e., *kai kai*; Figure 7.7). Other reasons for hunting dugongs and green turtles included ceremonies (tombstone unveiling ceremonies, funerals and shaving ceremonies) and other significant events such as birthday parties, community functions, church functions, weddings and wedding anniversaries. Although Hammond Island hunters appeared to hunt dugongs for different reasons than they hunted green turtles, there was no significant difference (Table 7.7). However, there was a significant difference in the reasons for hunting dugongs between Hammond Island hunters and Thursday Island hunters (Table 7.7). This difference is likely to be due to the very few dugongs caught for significant events by Hammond Island hunters compared with Thursday Island hunters. Hammond Island hunters caught a greater number of green turtles than dugongs for significant events, but caught a smaller proportion of both species for significant events than Thursday Island hunters did (Figure 7.7).

Table 7.7. Differences in the reasons (*Kai Kai*, ceremonies and significant events) for hunting dugongs compared with green turtles by hunters within each of the Hammond and Thursday Island communities and differences between communities in their reasons for hunting each of dugongs and green turtles. df = 2; *significant difference.

		Hammond Island Green turtle		Thursday Island Dugong	
		χ^2	*P*	χ^2	*P*
Hammond Island	Dugong	5.11	0.078	8.48	0.014*
Thursday Island	Green turtle	3.24	0.198	2.08	0.354

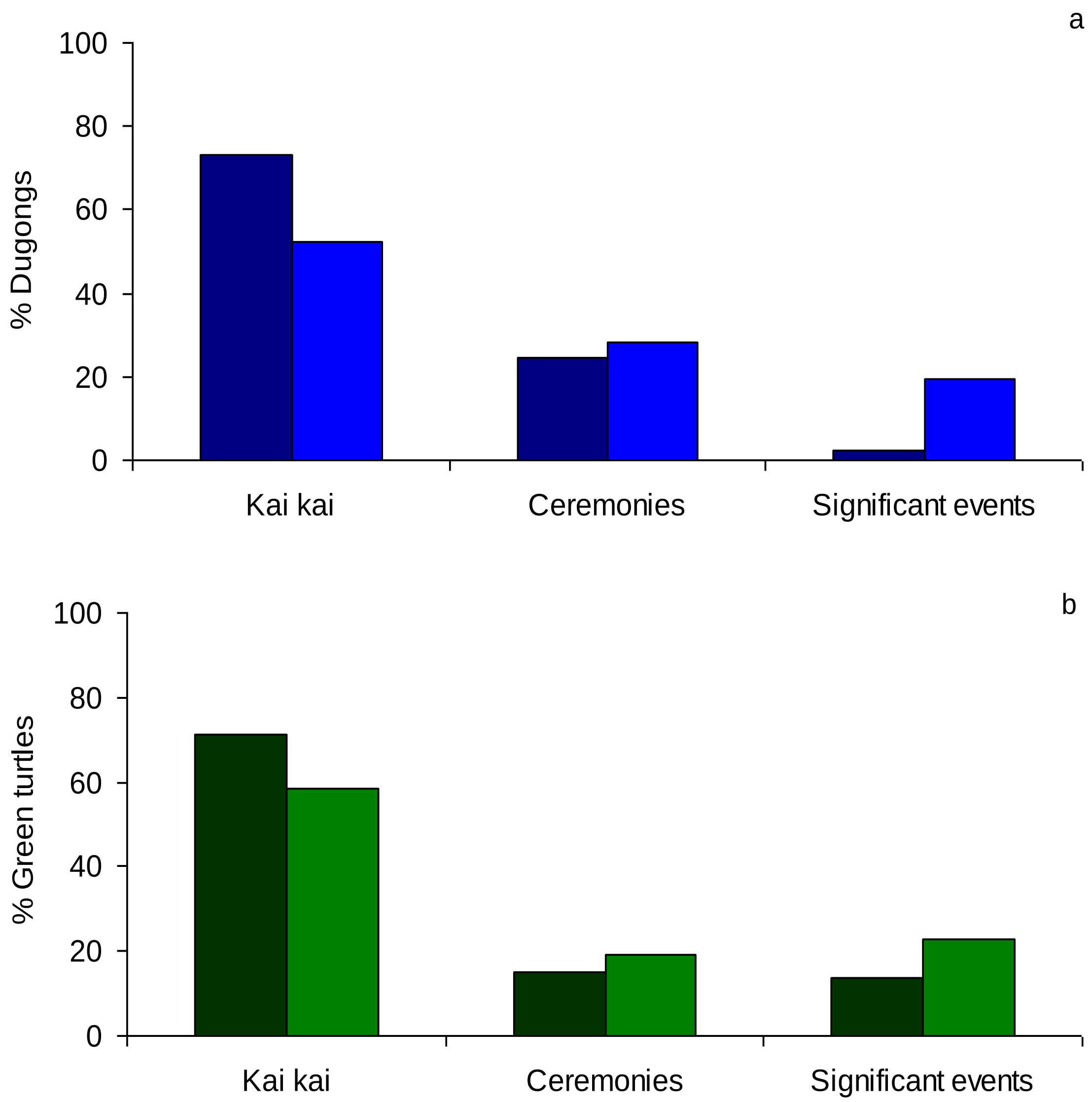


Figure 7.7. Reasons for hunting a) dugongs and b) green turtles reported as caught by Hammond Island hunters (dark bars) and Thursday Island hunters (light bars). Hammond Island hunters reported the reason for hunting for n = [redacted] dugongs and n = [redacted] green turtles and Thursday Island hunters reported the reason for hunting for n = [redacted] dugongs and n = [redacted] green turtles.

Social obligations - sharing of dugongs and green turtles

The datasheet asked, "How many people did you share your personal dugong or green turtle with?" However, hunters did not always fill in the number of people. In many cases, they filled in the number of shares that were distributed or the number of families that they shared with or, if the dugong or green turtle was to be used for a community event, they recorded that it was to be shared with the community.

Hunters from both communities reported sharing their dugongs and green turtles extensively. Most of these animals were shared with the hunters' families or other community members (Figure 7.8), but some were shared with their entire communities for community ceremonies and events.

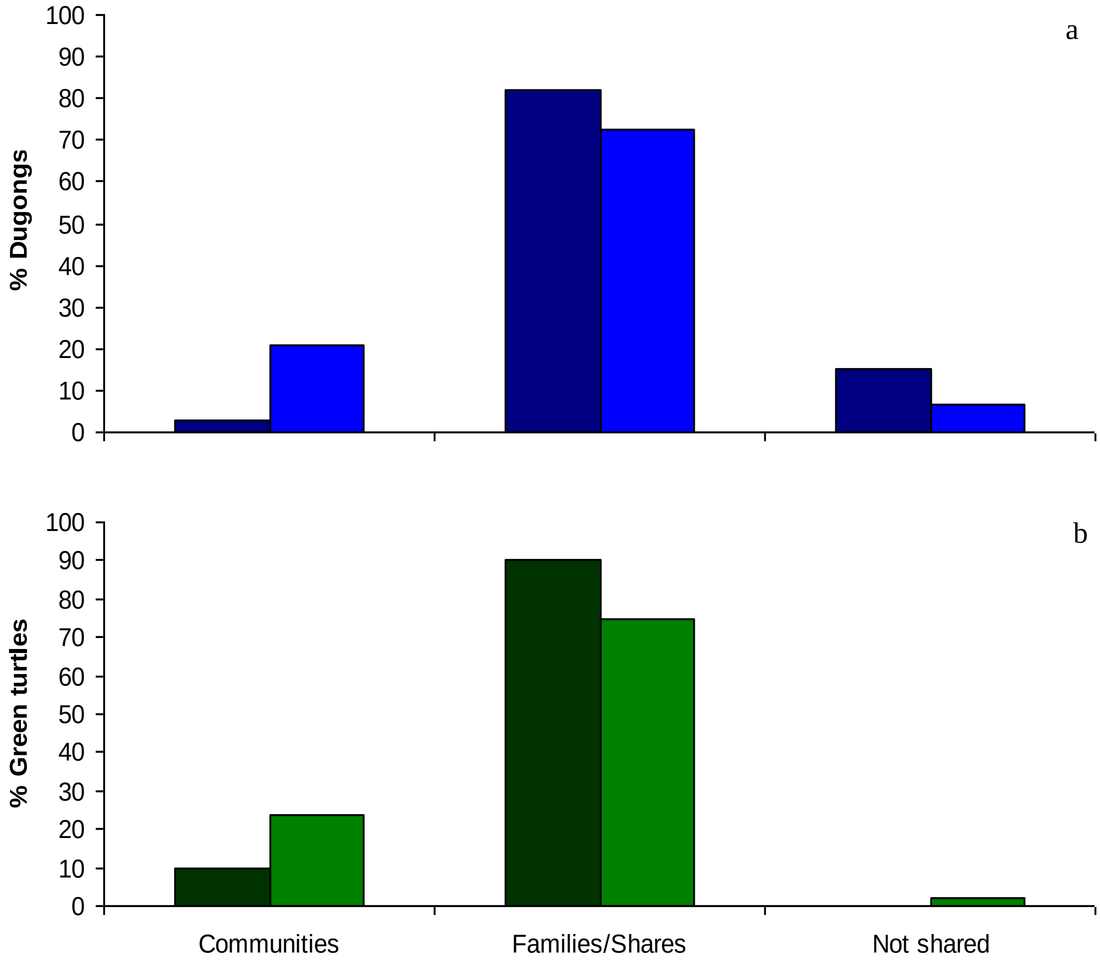


Figure 7.8. The percentage of a) dugongs and b) green turtles for which sharing was recorded on datasheets by Hammond Island (dark bars) and Thursday Island (light bars) hunters. Hammond Island hunters reported sharing for n = [redacted] dugongs and n = [redacted] green turtles and Thursday Island hunters reported sharing for n = [redacted] dugongs and n = [redacted] green turtles.

<u>Social obligations – hunting for others</u>

Hunters reported being asked to hunt by others for at least a third of the dugongs and green turtles for which they provided the relevant information (Figure 7.9). Only the two most prolific Hammond Island hunters were asked by others to hunt for dugongs and the six hunters (amongst the seven most prolific Hammond Island hunters) who caught the most green turtles were asked by others to catch green turtles. Similarly, the four most prolific dugong hunters from Thursday Island were also the only hunters asked by others to catch dugongs. In contrast, while the five most prolific green turtle hunters from Thursday Island were asked by others to catch green turtles, such requests extended to other hunters, including two hunters that each recorded catching only one green turtle. The Thursday Island hunter who caught the most green turtles (TI-C) caught three-quarters of them for other people. Hunting for others was not included as a reason for hunting because such behaviour can be induced for any of the reasons listed under the reasons for hunting. The reason for hunting would be from the perspective of the person who asked the hunter to go hunting.

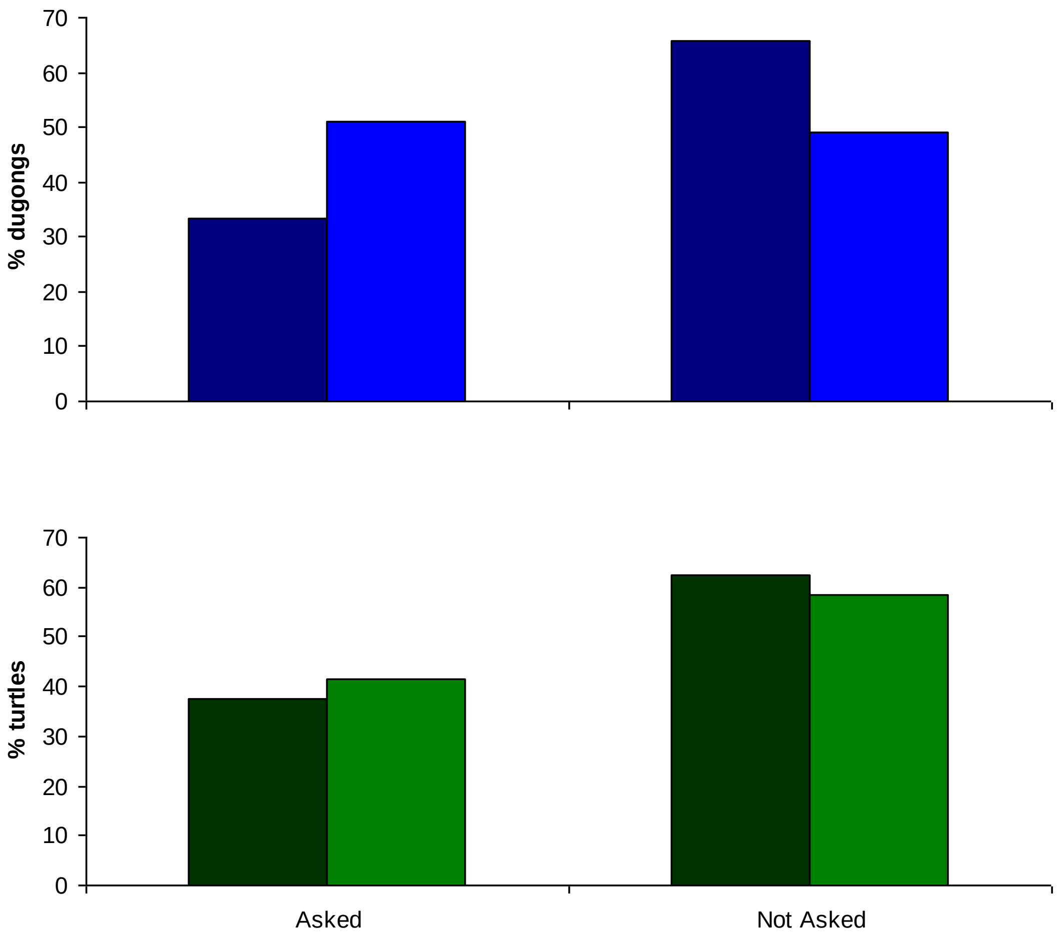


Figure 7.9. The percentage of a) dugongs and b) green turtles for which Hammond Island (dark bars) and Thursday Island (light bars) hunters reported whether or not they had been asked to hunt by someone else.

7.4. Discussion

Locally- based monitoring was successful in providing information relevant to management of green turtles and dugongs, but required the support of community catch-monitors. Hunters did not always complete all questions relating to hunting patterns on each datasheet for each dugong and green turtle they caught. Each question about hunting patterns was completed on at least 65 % of datasheets for both dugongs and green turtles reported as caught by Hammond Island hunters and on at least 63% of datasheets and 64% of datasheets for dugongs and green turtles, respectively reported as caught by Thursday Island hunters. Noss et al. (2004) also found that hunters experienced difficulties providing coherent or completed information and required assistance. Hunters cannot be expected to complete all of the information on the datasheets all of the time and it is thus necessary to be patient and build a sustainable monitoring system rather than trying to collect all the data at all costs (Stuart-Hill et al. 2005).

Some information will be realistic for hunters to collect and some information will be much more difficult to obtain. For example, as discussed in Chapter 5, one item of information that it may not be realistic for hunters to report is the number of unsuccessful trips. This item of information was virtually non-reported in the present study (see Chapter 5) and other studies have found that unsuccessful trips are greatly under-reported (Noss et al. 2004). As discussed in Chapter 5, alternative ways of recording unsuccessful trips, such as monthly activity surveys, may enable the collection of effort information and thereby enable the calculation of catch-per-unit effort (Pollock et al. 1994).

Hunters might not report some items of information because they want to avoid to be seen to be doing the wrong thing, they are embarrassed about their catch for some reason, they do not wish to divulge particular information (i.e., they strategically under-report or mis-report), or they do not understand the importance or implications of the information. These practices could lead to erroneous patterns and incorrect management decisions so it is important to understand why hunters are not completing some items of information.

7.4.1. What empirical information can monitoring provide to inform Indigenous hunting management?

My trial of a community-based catch-monitoring approach was implemented in an iterative manner as local catch-monitors gained greater participation from hunters through time. Temporal patterns in the catch of dugongs and green turtles are therefore likely to be confounded by participation rates of hunters. In addition, monitoring needs to be conducted over the long-term to determine temporal patterns in the catch.

There appeared to be some temporal peaks in the catch of green turtles that could be associated with the breeding seasons of green turtles, but reproductive information from the caught green turtles would also be needed to confirm these patterns. Management planning for green turtles may include closures during the breeding season or limiting the numbers and/or sizes of female green turtles that can be taken during the breeding season. As discussed in Chapter 4, strategies to limit green turtle hunting during the breeding season were unacceptable to some Hammond Island hunters. The breeding season was important in providing some hunters with their only opportunity throughout the year to practice their culture through hunting, green turtle meat was needed all year round and there was a preference for adult female green turtles.

Location information is useful for geographic analysis of species distribution and hunting pressure distribution, which can be used for the basis of spatial management (Noss et al. 2004; see Chapter 3). In the present study hunters caught the dugongs and green turtles they reported as caught within 30 km of their home island and most of these animals were caught within 10 km of their home islands. Similarly, Mabuiag Island hunters caught most of the dugongs recorded as caught in 1998-1999 within 35 km from Mabuiag Island (Kwan 2002). In Chapter 3, I combined historical spatial datasets for hunting and dugong distribution and relative abundance using a spatial risk assessment approach to inform the spatial design of management arrangements for dugongs in Torres Strait. Furthermore, changes in the hunting areas through time can also indicate changes in the abundances of animals. However, if hunting areas and areas where hunting is unsuccessful are not recorded and therefore shifts in hunting areas are not known, over-harvesting could be masked (Green et al. 2005).

Johannes and MacFarlane (1991) describe the two main hunting methods used by Islanders to catch dugongs. The fast pursuit method involves chasing the dugong in a motorised dinghy on the reef until it tires and then harpooning it with a wap. Spotlights enable hunters to see dugongs at night. The drift hunting method for dugongs involves the use of a small wooden or fibreglass dinghy ("clinker" dinghy) with a sail. Hunters transport this "clinker" dinghy out to the hunting area using a motorised dinghy. The drift hunting method may be practised during the day or at night, but a spotlight is not generally used at night. Hunters may also use the aluminium dinghy with outboard motor to drift hunt, by switching off the outboard motor and rowing the boat into position (Nietschmann 1984). Hunters catch green turtles using the fast pursuit method, including using a spotlight at night.

Restrictions on hunting methods can limit the catch by limiting the efficiency or effort with which hunters can operate. As discussed in Chapter 4, Hammond Islanders that I interviewed considered drift hunting to be the traditional way of catching dugongs and that stopping chasing dugongs at night with the use of an outboard motor and a spotlight could be an appropriate management measure for dugongs. Hunters from Thursday Island and Hammond Island who assisted in developing the datasheet were also concerned about the fast-pursuit method being used to catch dugongs, especially at night, and wanted to monitor the use of such methods. The fast-pursuit method was not widely practised to catch dugongs in the present study and both Hammond and Thursday Island hunters used drift hunting to catch most of the dugongs. Therefore, banning the fast-pursuit method and spotlighting at night may not limit the number of dugongs caught by Hammond Island hunters and Thursday Island hunters. Limiting dugong hunting to drift hunting seems to be a way to ensure that dugong hunting is done in a culturally appropriate way and is a way to reinvigorate cultural practices, which appears be an objective of management planning for dugongs (and green turtles) in Torres Strait (see Chapter 1). This method may also keep dugongs close to the community because it does not scare them away with motors.

Kwan (2002) found that hunters from Mabuiag Island used the fast pursuit method to catch dugongs mostly at night and the drift hunting method during the day and at night during the south-east season, but not the north-west season when the weather was too rough. Thus, other Torres Strait communities may find that banning the fast-pursuit method or requiring drift hunting be used could limit the numbers of dugongs that are caught and these strategies have been included in some Torres Strait Community Dugong and Turtle Management Plans.

Similar to the situation for dugongs, hunters who helped design the datasheet in the present study were concerned about the fast-pursuit method being used to catch green turtles at night using a spotlight and wished to monitor the use of such methods. In addition, Hammond Island hunters that I interviewed considered that it was appropriate to continue chasing green turtles and using a spotlight at night to keep track of them because these methods had been used to catch green turtles for a long time (see Chapter 4). In the present study, fast-pursuit hunting at night was practiced more widely for green turtles than for dugongs, particularly by Thursday Island hunters. Banning spotlight hunting might represent a useful management strategy for marine turtles, particularly given the concern about the method expressed by hunters who helped develop the datasheet and Hammond Island hunters, as discussed in Chapter 4. However, it will be necessary to understand why so many hunters are using this method and what would be the implications of banning it. For example, Hammond Island hunters suggested that green turtles are not on the reefs near their community during the day and only move up onto the reefs to feed at night (see Chapter 4). Therefore, it appears that the only opportunity to catch green turtles close to the community is on the reefs at night.

Most of the dugongs and green turtles reported as caught in the present study were caught for general consumption (i.e., *kai kai*), which suggests that limiting the catch to ceremonies would significantly reduce the overall catch. However, before implementing such a strategy, Hammond and Thursday Island communities might consider what is driving such a high demand for subsistence food.

In Torres Strait, the social obligation to share dugongs and green turtles caught with family and community members is strong and is part of *Ailan kastom*[14] (Raven 1990). In addition, many people, including the Torres Strait diaspora living on the mainland, who are unable to hunt, ask experienced hunters to hunt for them. Therefore, monitoring the social obligations associated with the catch of dugongs and green turtles, such as the number of shares and whether the hunter was asked to hunt, helps provide an understanding of the pressure that is put on individual hunters to hunt, as well as the number of people whose behaviour would need to be influenced to achieve effective management. That is, it is not only the hunters who are putting pressure on the stock, but a wide range of people that are putting pressure on the hunters to go hunting. It is therefore also important to understand their needs and reasons for asking the hunter to catch the dugongs and green turtles and what changes they would be willing to make to conserve dugongs and green turtles.

7.5. Chapter Summary

- In this chapter, I examined what information on hunting patterns hunters could practically collect and discussed whether the information collected could provide insights into appropriate management interventions for dugong and green turtle hunting in Torres Strait.

- Hunters from Hammond and Thursday Islands recorded their catches of green turtles and dugongs on catch-monitoring datasheets in 2005-2006 with the assistance of Indigenous research counterparts employed on the project (see Chapters 5 and 6).

[14] Island custom

- The datasheets requested information on hunting patterns including the activity patterns (i.e., date and time of hunting), the duration of hunting trips, the distance from the hunters Island that the dugong or green turtle was caught, hunting methods, what was being targeted on the trip when the dugong or green turtle was caught, the reason for hunting, whether the hunter was asked to hunt by others, whether they shared their catch and the number of hunters in the hunting party.

- I investigated for what proportion of datasheets the information on hunting patterns was recorded for dugongs and green turtles.

- The reason for hunting was the most-recorded data item on datasheets. Hammond Island hunters recorded it on 92% and 83% of the datasheets they submitted for the dugongs and green turtles they caught, respectively. At Thursday Island the percentages were 92% and 96% for dugongs and green turtles, respectively.

- The distance from the hunters' home island that the animal was caught was the least-recorded data item on datasheets submitted by Hammond Island hunters for the dugongs (63%) they caught and Thursday Island hunters for both the dugongs (63%) and green turtles (64%) they caught. Whether or not the green turtle was shared was the least-recorded data item recorded on datasheets submitted by Hammond Island hunters for the green turtles (65%) they caught.

- Dugongs were mostly caught using the drift hunting method, while green turtles were mostly caught using the fast pursuit method, including spotlighting at night.

- More dugongs and green turtles were caught during the day than at night.

- Dugongs and green turtles were mostly caught for general consumption (i.e., *kai kai*). Both dugongs and green turtles were also caught for ceremonies and other significant events, but the reasons different between Hammond and Thursday Island hunters and between dugongs and green turtles for Hammond Island hunters.

- All of the dugongs and green turtles were caught within 30 km of Hammond and Thursday Islands.

- The duration of successful hunting trips was variable ranging from 15 minutes to 12 hours.

- Hunters usually caught the species they claimed they set out to catch.

- Only a small proportion of animals for which information on sharing was recorded were not shared. Most animals were shared with family.

- Hunters were asked by others to catch the dugongs or green turtles for at least a third of the caught dugongs and green turtles recorded. In most cases, it was the few most prolific hunters that were asked by others to go hunting.

- Information on the spatial distribution of hunting collected in this study has been used in a spatial decision framework to inform hunting management (see Chapter 3).

- It is likely to be difficult to limit hunting to ceremonies because of the great reliance on dugongs and green turtles for general consumption.

- There is a great deal of social pressure on hunters, thus efforts to change beliefs and behaviours need to go beyond hunters to the broader community.

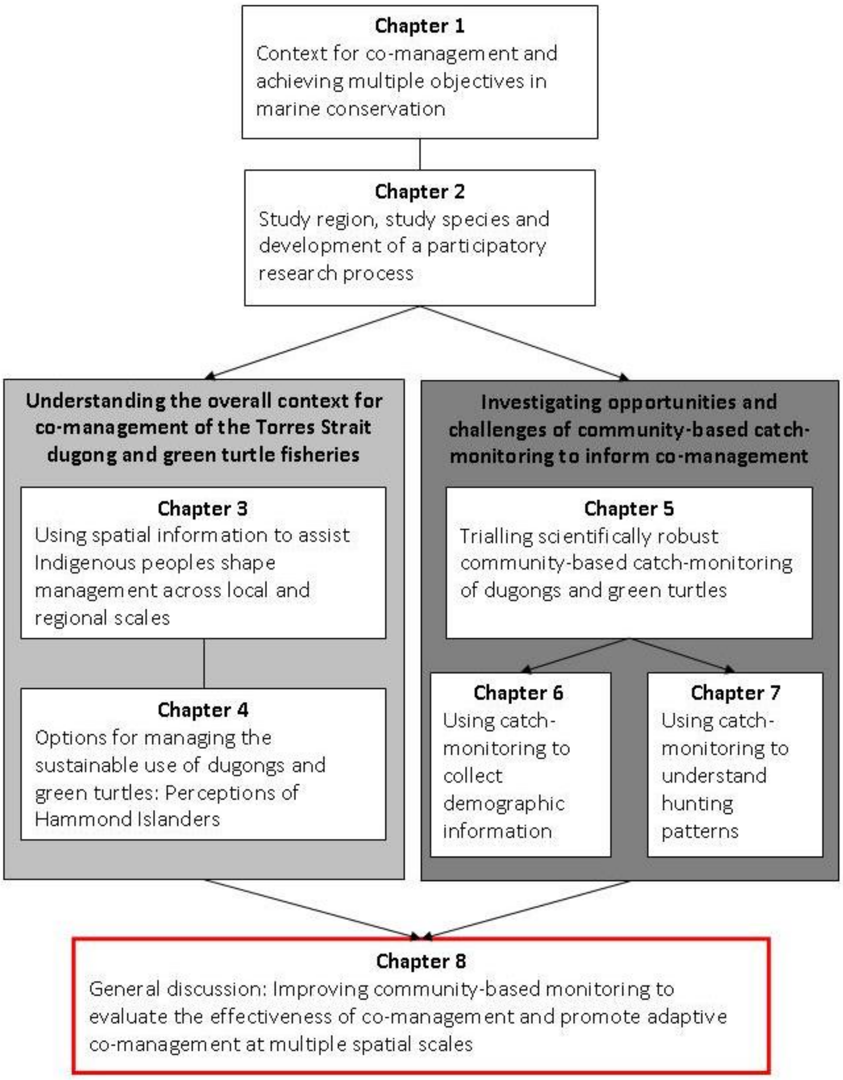
- Locally- based monitoring can provide useful information to inform Indigenous hunting management, but it needs to be kept as simple and locally appropriate as possible (Danielsen et al. 2005a; Stuart-Hill et al. 2005).

- It will be important for communities to determine what information they consider most important for making the decisions they need to make about managing dugongs and green turtles in their sea country and they may obtain advice from co-management partners.

- I have discussed a range of management strategies based on the information obtained from the hunting patterns of Hammond Island hunters and Thursday Island hunters. The appropriateness of any of these strategies for use by the Hammond Island community and Thursday Island community would need to be discussed at length within each of these communities.

Chapter 8

General discussion: Improving community-based monitoring to evaluate the effectiveness of community-based management and promote adaptive co-management at multiple spatial scales



In this Chapter, I provide a summary of the major results of this study and discuss these results in relation to their contribution to informing management arrangements for the Indigenous dugong and green turtle fisheries in Torres Strait. I describe a conceptual framework for the development of an ecological monitoring program to inform the management of the Torres Strait dugong and green turtle fisheries that could also be relevant to other Indigenous natural resource management programs. I discuss insights from my study at various spatial scales about what could be done to improve management and monitoring of the Torres Strait dugong and green turtle fisheries.

8. General Discussion

8.1. Introduction

Dugongs and green turtles are both species of conservation concern and important cultural resources for Indigenous peoples. Australia has international and national obligations to conserve these species and to protect the Indigenous culture and way of life associated with the traditional use of these species by Aboriginal and Torres Strait Islander peoples.

The management of the Torres Strait dugong and green turtle fisheries has moved from largely government-based management to an increased emphasis on community-based management along a co-management continuum over the past decade. Consequently, my thesis aimed to inform the development of co-management arrangements for these Indigenous dugong and green turtle[15] fisheries in Torres Strait by providing an overall context for co-management at different spatial scales. In particular, my thesis investigated the opportunities and challenges associated with co-management with a particular emphasis on monitoring.

My contribution to the co-management and community-based monitoring of the Torres Strait dugong and green turtle fisheries is synthesised below. The major findings of this study are presented at the end of each chapter of this thesis. Thus, instead of repeating this information, this general discussion will focus on describing the insights, at various spatial scales, gained from this research about what could be done to improve the management and monitoring of the Torres Strait dugong and green turtle fisheries.

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[15] My thesis considered the hunting of green turtles for their meat and not the collection of turtle eggs. The collection of turtle eggs is part of the Torres Strait green turtle fishery, but limited turtle nesting occurred in my study area and therefore turtle egg collection was not prevalent.

8.2. Insights

In Australia, Aboriginal and Torres Strait Islander communities are increasingly being supported, in various co-management arrangements to manage their sea countries, including their dugong and green turtle harvests. In Torres Strait the investment in dugong and marine turtle management is more than AUD$20million over five years to 2013. This investment is in response to the large populations of dugongs and green turtles in Torres Strait, which it is important to conserve, concern about the sustainability of the harvest (Marsh et al. 2004b), and the increasing recognition, including from the international conservation community, that Indigenous people are often best placed to manage culturally important resources in remote areas (Garcia and Lescuyer 2008). In Torres Strait, the investment includes the development and implementation of 15 Community Dugong and Turtle Management Plans and a Ranger Program to assist in the implementation of the Plans.

8.2.1. Management

An overall context for management of the Torres Strait dugong and green turtle fisheries at different spatial scales is provided in this thesis. The results of Chapters 3 and 4 show that management arrangements for these fisheries should be developed in a co-management framework and that the relative importance of different co-management partners differs with spatial scale. For example, the results of Chapters 3 and 4 highlight that community-based management is appropriate at the local level and communities require assistance from governments to ensure compliance and enforcement with community-agreed rules, coordinate management among communities, and assist to manage threats other than hunting at larger scales. The ecological scales at which dugongs and green turtles operate are large (Sheppard et al. 2006; Limpus 2008). Dugongs undertake large-scale movements and green turtles undertake breeding migrations, which means that the populations that are hunted by Torres Strait Islanders are also hunted or impacted by threats in other countries (e.g., Papua New Guinea) and in the waters off mainland Australia. For example, the Gulf of Carpentaria and Papua New Guinea green turtle stocks were among four major stocks that each contributed more than 10 % of the harvest of the Bali fishery (Dethmers and Broderick 2002). Thus, management of these stocks needs to occur at local, state, national and international levels.

8.2.2. Monitoring

I trialled an ecological community-based catch-monitoring project which aimed to provide information to assist Torres Strait communities sustainably manage their dugong and green turtle harvests. I examined whether a hunter self-monitoring approach could be used to collect quantitative data on the level of take, the demography of the animals taken and hunting patterns. The first two pieces of information assist in determining the sustainability of the catch and trends in population status, while information on hunting patterns, including social and cultural factors that influence hunting pressure, assists in determining appropriate management options.

As discussed in Chapters 1 and 5, the stages in a monitoring project are not straightforward and there are many challenges associated with developing and implementing a monitoring plan, particularly if it is to be implemented largely by non-scientists (Salafsky and Margoluis 2004; Stem et al. 2005; Nichols and Williams 2006; Grantham et al. 2010). Thus, meeting the objectives of a monitoring plan can be challenging. However, the consequences of not meeting the objectives of a monitoring plan may be serious. For example, in the case of the Torres Strait dugong and green turtle fisheries, the consequences of not meeting the objective of sustainable use of dugongs and green turtles could include local extinction of these species, loss of the ability of Torres Strait Islanders to practise their culture, and wasted money, time and other resources that could have been spent on other activities. It is therefore important to minimise the risk that monitoring will fail to meet the stated objectives.

To assist in this process in Torres Strait, with the assistance of my James Cook University research group, I have developed a generic checklist for framing discussions between managers, the community, scientists and/or other experts about the development and implementation of monitoring plans (Table 8.1). I have identified five main characteristics for discussion, but my list is not exhaustive: foundation setting; capacity and investment; ownership and acceptance; logistics; and design and methodology (including data-collection and analysis and validation). I use examples from my study to demonstrate some of the long-term needs of the community for developing and implementing a community-based catch-monitoring project for dugongs and turtles (Table 8.1).

Table 8.1. Checklist for framing the discussion between managers, community, scientists and other experts in the development and implementation of a monitoring program to be conducted in collaboration with non-scientists. The relevance of this table to dugong and turtle monitoring is discussed in the text.

		Stages in a monitoring project:						
		decision to monitor	design	data collection	data storage	analysis and interpretation	communication	adaptive management
Foundation setting	Cultural context	✓	✓	✓	✓	✓	✓	
	Evidence of biological and ecological need	✓						
Capacity and investment	Literacy and numeracy of personnel		✓	✓		✓	✓	
	Required capacity – financial	✓	✓	✓	✓	✓	✓	✓
	Required capacity – personnel, training, expertise, etc.	✓	✓	✓	✓	✓	✓	✓
	Required long-term investment (matching effort to rewards; incremental investment and rewards).	✓	✓	✓	✓	✓	✓	✓
Ownership/ acceptance	Ease of ownership by the community;	✓	✓					✓
	Acceptability of consistent methodology among communities and through time;		✓	✓	✓	✓		✓
	Level of use of personal knowledge;		✓	✓		✓		
	Perception that the monitoring is threatening or not threatening;	✓		✓	✓		✓	✓
	Generic advantages from training (e.g., GPS)		✓	✓	✓	✓	✓	✓
	Immediacy of benefits to the community	✓		✓			✓	✓
	Relevance	✓		✓			✓	✓
	Intellectual Property issues (e.g., related to releasing results/data)	✓					✓	✓
Logistics	Ease with which monitoring can be achieved	✓	✓	✓	✓	✓	✓	✓
	Level of dependence on infrastructure/equipment (e.g., boats and CybertTacker†)		✓	✓	✓			
	Does capacity match design	✓	✓					
	Level of additional investment (e.g., time/money); e.g., could monitoring be incorporated into existing work plans?	✓	✓	✓		✓		
	Scale - spatial/temporal		✓	✓				✓
	Safety of participants		✓	✓				✓
	Ethics and permits	✓	✓	✓	✓	✓	✓	✓
Design and methodology	The question(s) to answer;		✓					
	Type of survey (opportunistic or dedicated);		✓					
Data collection / analysis	Technical complexity of the tasks;		✓	✓		✓		
	Amount of complex data to be collected		✓	✓		✓		
	Training required – does design match capacity		✓					
	Level of need for professional processing (analysis) of the data.		✓			✓		
Validation	Importance of errors		✓	✓		✓		

† GPS based field data collection software that can be used on a hand-held computer. See http://www.nailsma.org.au/projects/i-tracker.html.

	Importance of repetitive sampling		✓	✓		✓		
	Potential for biases (e.g., in recording);		✓	✓		✓		
	Level of benefit of under or over reporting		✓	✓		✓		

Foundation setting

Dugongs and green turtles are an important cultural resource in Torres Strait and therefore it was important to consider the cultural context of the monitoring project. I established a cultural reference group to ensure the project was being conducted in a culturally appropriate manner (see chapter 2). One of the reasons hunters agreed to trial the monitoring project was to collect information to inform management to ensure that Torres Strait Islanders could continue to practice their hunting culture. It was important to demonstrate a biological and ecological need for monitoring dugong and green turtle catches. Most hunters agreed that there was a need to monitor their harvest of dugongs and green turtles (see chapters 2 and 4). Discussions with hunters regarding the development of a monitoring tool suggested that most hunters were literate and numerate and therefore a datasheet would be appropriate to use.

Capacity and investment

Capacity and investment are likely to affect all stages of the monitoring process. Consideration is needed of whether: (1) sufficient funding is available for personnel and equipment and (2) personnel have appropriate training and expertise to carry out the work. A monitoring project is unlikely to be sustained if it is too elaborate and costly to be continued in the long-term (Danielsen et al. 2009). The level of external and local expertise that is required at different stages of the monitoring project should also be considered (see Section 8.2.3; Danielsen et al. 2009). As I demonstrated in Chapter 5, employing local people as rangers (or catch-monitors) can provide expertise with respect to local knowledge and community connections, which may not be possible without the incentive of employment. In addition, scientific expertise was required to design the catch-monitoring project and training of catch-monitors was required in data collection (see Chapters 6 and 7). Nevertheless, not all data were collected as well as I would have liked and I suggest a stepwise approach for future catch-monitoring in Torres Strait (see Chapters 6 and 7). Therefore, future community-based catch-monitoring in Torres Strait might consider long-term incremental investment to account for the need for additional training and equipment because of adaptations in the monitoring program (e.g., Bennun et al. 2005).

Ownership and acceptance

As described in Chapter 2, the perception that monitoring was threatening reduced the Islanders acceptance of the catch-monitoring project I was trialling with them. Nevertheless, reinforcing their sense of ownership of the project by reiterating the partnership approach I had taken (i.e., research agreement; cultural reference group; development of the catch-monitoring tool with hunters; and employment of Indigenous counterparts) led them to re-engage in the project. External perceptions reported in the media in response to research suggesting that the Torres Strait dugong harvest was unsustainable stalled my project and raised concerns of Islanders about participating in the management and monitoring of dugong and green turtle hunting (see Chapter 2). Islanders were concerned that information collected by researchers, including me, would be given to the government and used against them to stop them from hunting and thus take away their rights and responsibilities. Thus, a community's sense of ownership and acceptance can be affected by both threats and incentives.

Logistics

Logistics is an important factor to consider in developing and implementing a monitoring plan because it determines the likelihood of any monitoring actually being undertaken. Although they may have high initial start-up costs, community-based monitoring projects tend to be more cost-effective than professionally-based monitoring projects because they use approaches that are simple, cheap and require few resources (Bennun et al. 2005; Garcia and Lescuyer 2008; Danielsen et al. 2009). I chose my study sites acknowledging logistics of time and funding. It was relatively easier to find accommodation on Thursday Island than the outer Islands to live for long periods as required by my project (see Chapter 2). Conducting the study on the outer and more remote islands would have required periodic travel by light aircraft and would not have been optimal for the study design. I also considered logistics in choosing a monitoring tool. The hunters and I considered a number of tools, including those that required the use of technology (e.g., cameras) or were deemed culturally inappropriate (e.g., stockpiling green turtle shells), but chose a simple datasheet[16].

Design and methodology– question(s), data collection/analysis, validation

The aim of my project was to develop an ecological monitoring project that could provide information to contribute to determining whether the subsistence harvest of dugongs and green turtles by Torres Strait communities was sustainable and guide decisions regarding the choice and application of management tools. Determining whether a subsistence harvest is sustainable requires quantitative data on the demography of the animals taken and the level of take (in addition to information on the size of the population). Information about hunting patterns, including social and cultural considerations, can provide important insight about hunting pressure, which

[16] The CyperTracker was starting to be used by Indigenous ranger groups (e.g., through the North Australian Indigenous Land and Sea Management Alliance Dugong and Marine Turtle Project) in other parts of northern Australia shortly after my study began. My study focussed on hunters completing their own datasheets, where possible. CyperTrackers cost more than $1000 each and therefore it would not have been feasible to provide every hunter with one on which to record their catch. Thus, the CyberTracker was not considered as a monitoring tool.

can be useful for guiding decisions regarding the choice and application of management tools.

I discussed these aims with the participating communities (Hammond Island and Thursday Island) and considered catch-monitoring methods tried previously in Torres Strait. Occasional sampling proved to be too logistically difficult and expensive to sample on enough days to provide robust catch-estimates at the scale of individual communities, as required for co-management at the community level. Therefore, a different approach was needed. Rather than sample on every day, I trialled a survey design that considered hunters as the sampling unit. Hunters submitted datasheets to local catch-monitors whenever they went hunting. The datasheets included a range of questions.

This hunter self-monitoring approach required consideration of the accuracy, precision and bias associated with the sampling design. The accuracy and precision of the catch-estimate will increase with the number of participating hunters. Therefore, before starting the monitoring program with hunters, I demonstrated the importance of all hunters in the community participating all of the time using a practical hands-on exercise with hypothetical participation rates (see Chapters 5 and Appendix C). Hunter self-monitoring required considerable effort from local catch-monitors to maintain contact with hunters and collect datasheets. The original survey design had to be modified to include monthly activity surveys conducted by the local catch-monitor. These surveys of hunters at the end of each month, regarding their hunting activity in the preceding month, made it easier to derive the total catch and catch-per-unit-effort from a sample of participating hunters because the activity surveys improved the accuracy and precision of the estimates and the reporting of unsuccessful hunting trips.

I also aimed to determine what information on the demographics of animals taken and hunting patterns hunters could practically collect. The technical complexity of the tasks and the amount and type of complex data to be collected affected the amount of information that was collected. I found that hunters collected information that was more-straightforward (e.g., sex) more often than information that was more-complex (e.g., reproductive status) and that requested specimens were rarely provided (see Chapter 6). I speculated on the reasons that some datasets might not be reported in Chapter 6.

I suggest that the collection of biological information by hunters should be introduced over the long-term in a step-wise manner such that more-straightforward information is collected in the initial phase, with the collection of more-complex information introduced as hunters become more proficient, perhaps after some training, in the provision of information at each step (see Chapter 6). I also concluded that monitoring could be improved by limiting the number of questions on the datasheet.

Some of the data collected requires interpretation by scientists (e.g., reproductive status of animals from examination of reproductive organs). In addition, local catch-monitors could enter the data from the catch-monitoring datasheets into a database[17], but I (i.e., the scientist) did the analysis, interpretation and presentation of the results. Additional training could be provided to catch-monitors (or rangers) to enable them to conduct some of these tasks.

[17] I designed a Microsoft Access database for each community, which enabled presentation of some summary results.

The results of community-based catch-monitoring need to be integrated into management at multiple spatial scales. As described in Chapter 5, because of the variability in catch levels, catch-monitoring needs to be done at the scale of individual communities to obtain reliable estimates to inform co-management at the community level. However, dugong and green turtle management is required at local, regional and national spatial scales and therefore local monitoring would benefit if it were designed (e.g., consistent methods among communities) so that the results could be scaled-up to be compiled into regional and national indices and thereby demonstrate trends at larger scales (e.g., Bennun et al. 2005). Local communities require quick regular feedback of detailed information to maintain morale and enthusiasm in monitoring and to make management decisions. Regional agencies, such as the Torres Strait Regional Authority and Protected Zone Joint Authority, may require collated catch information (e.g., across all communities) at longer time intervals (e.g., half-yearly to yearly) to gauge management at the regional scale. They may also feed this information back to communities to provide a context for local management. Finally, national agencies (e.g., Department of Sustainability, Environment, Water, Population and Communities), with broader management responsibilities may need to know trends in catch rates over longer time intervals (e.g., annually to bi-annually) because they are interested in the status of the Torres Strait population in the context of the species at a national level.

Community-based catch-monitoring will not provide all of the answers for adaptive co-management of dugongs and green turtles at multiple spatial scales in Torres Strait. Therefore, the results of catch-monitoring need to be integrated with the results of other research and monitoring projects (e.g., Sea grass-Watch (Mellors et al. 2008), large-scale aerial surveys (Marsh et al. 1997; Marsh et al. 2004b; Marsh et al. 2007), and others) to inform management (see Section 8.3.1).

Finally, the design of the monitoring project needs to be checked against the capacity of the community to undertake the monitoring. This is not only the financial and logistical capacity, but also capacity with respect to personnel with the relevant skills to undertake the necessary tasks described below.

8.2.3. Monitoring partnerships and the importance of bridging individuals

As discussed above, development of monitoring plans to support the adaptive co-management of the Torres Strait dugong and green turtle fisheries would benefit from the transfer of knowledge, skills and capabilities among different co-management partners (e.g., Torres Strait communities, the Torres Strait Regional Authority, the Australian Fisheries Management Authority, the Department of Sustainability, Environment, Water, Population and Communities, other management agencies, and scientists). As described in Chapter 1, Salafsky et al. (2002) identified the critical functional roles for conservation practitioners in an adaptive management project to achieve successful conservation. Acknowledging that the Torres Strait Regional Authority (or any Indigenous organisation) is unlikely to have all of the skills to fulfil all of the monitoring functions, I have developed a conceptual framework to represent the different functions of partners in an ecological monitoring program for Torres Strait (Figure 8.1). My framework uses the development and implementation of a catch-monitoring project for the adaptive co-management of the Torres Strait dugong and green turtle fisheries as a specific example (Figure 8.1). However, the framework could be used in general to assist Indigenous organisations consider what functions they need to achieve successful ecological monitoring programs and what partnerships they might need to develop to access those functions.

The functions that are needed to develop and implement a community-based catch-monitoring project in Torres Strait include planning, design, data collection, data analysis and interpretation, data sharing and storage, assessment of the effectiveness of monitoring and integration of the results of catch-monitoring into management (Salafsky et al. 2002; Figure 8.1). In addition, the results of different monitoring projects need to be integrated to inform management. Fulfilling these functions requires assistance from experts such as scientists, database experts, communication experts, trainers and educators, rangers and hunters and other community members (Figure 8.1). For example, in a participatory monitoring project, concern about the scientific validity of the data is likely to be minimised if the sampling strategy is designed by scientists, the methods are simple and robust and rangers receive appropriate training in data collection and interpretation (Sheil and Lawrence 2004; Bennun et al. 2005).

The Torres Strait Regional Authority plays a significant coordinating role in the co-management of the Torres Strait dugong and green turtle fisheries and already has several co-management partners with which it exchanges knowledge, skills and expertise. Thus, the Torres Strait Regional Authority could be considered a bridging organisation as described by Olsson et al. (2007) and Berkes (2009). That is, such organisations help combine the complimentary knowledge, skills and capabilities of different actors at different levels of organisation in co-management arrangements. Individuals are also required to play bridging functions by serving a range of social mechanisms (e.g., leaders, knowledge generators, sense-makers, facilitators; Folke et al. 2005; Olsson et al. 2007). For example, such individuals enable access to and control of knowledge to be shifted from experts and scientists to the people whose lives are affected by it (i.e., “situating” knowledge; Campbell and Vainio-Mattila 2003) and vice versa.

In the development of my project the CRC Torres Strait Liaison Officer, who was employed as a fisheries policy officer in the Torres Strait Regional Authority, provided a significant bridging function. He was able to assist in the gaining of mutual trust so that hunters could communicate their cultural and practical needs and I could communicate my scientific needs for the catch-monitoring project. This transfer of knowledge resulted in a monitoring project that was practical for hunters to use, culturally appropriate and was able to provide reliable information because hunters understood the consequences to the reliability of the results of not reporting their catches (see Chapters 5 and 6).

My framework suggests that the different functions required for an ecological monitoring project can be brought together through a bridging organisation (*sensu* Olsson et al. 2007), which will ultimately run the monitoring project. It also suggests that in considering staffing, a bridging organisation might benefit from employing one or more individuals to provide bridging functions. These individuals would ideally have a collective skill set that could combine the complimentary knowledge, skills and capabilities of different co-management partners.

Recruiting such individuals may require investment in the development of skills (e.g., leadership; training in western science methods; understanding local Indigenous knowledge). Strong leadership was important in the present study because it influenced the recruitment and participation rates of hunters (see Chapter 5). Training models that promote “both-ways” learning (e.g., Batchelor Institute of Indigenous Tertiary Education in the Northern Territory) encourage Indigenous rangers and other

Indigenous community members to participate in higher education because they can learn about western science and Indigenous knowledge at the same time (Gardener 2005; Ober and Bat 2007).

In addition, increasing community capacity to take on more of the functional roles in monitoring could be achieved through on-the-job experiential based learning and the more formal vocational and educational training (Gardener 2005). Training models in which University lecturers are positioned in communities and work alongside rangers and ranger supervisors have shown some success in improving the capacity of rangers in monitoring (e.g., Younger 2008).

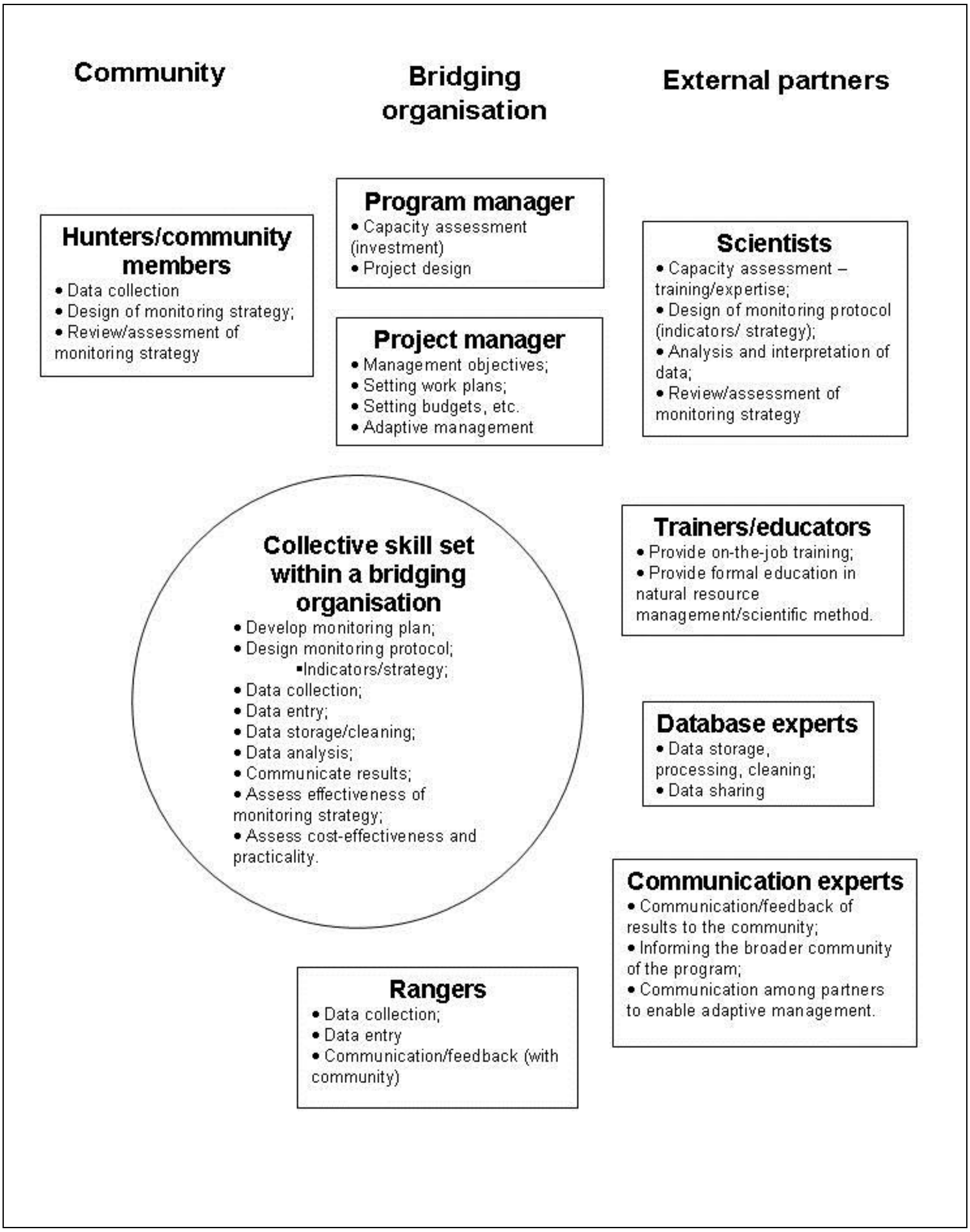

Figure 8.1. The suggested functions of co-management partners in the Torres Strait dugong and green turtle fishery monitoring program. A bridging organisation (e.g., Torres Strait Regional Authority) needs to develop a collective skill set to combine the complimentary knowledge, skills and capabilities of different co-management partners.

8.3. Areas for further research

8.3.1. Implementing community-based catch-monitoring

Catch-monitoring is one monitoring tool that can assist Islanders manage their harvests and evaluate their management plans. The research presented in this thesis demonstrated that community-based catch-monitoring is likely to be more appropriate than occasional sampling by professionals (see Chapter 5) to inform co-management of the Torres Strait dugong and green turtle fisheries. However, management of dugongs and green turtles will rely on multiple lines of evidence (Table 8.2). A series of indicators need to be monitored to provide insights for managing the dugong and green turtle harvest. Indicators monitored by community-based monitoring (and combined with other datasets) may provide insights into the sustainability of the harvest or the population status of the species at the community scale, regional scale, or both (Table 8.2). However, there are limitations associated with monitoring many of the indicators and the insights they can provide (Table 8.2).

I found that catch-monitoring required considerable effort by community catch-monitors and did not provide as much information as I hoped. For example, hunters did not record unsuccessful trips and therefore an understanding of catch-per-unit-effort could not be obtained. In addition, demographic information was not collected as completely as it could have been because of factors such as logistics, training, understanding of the benefits/relevance to management, the technical complexity of the task, and the level of need for professional processing of the data. Furthermore, demographic information on caught dugongs and green turtles was confounded by factors such as the movement of dugongs and green turtles, environmental stochasticity and potential biases in data derived from hunters (e.g., selectivity towards female green turtles; see Chapter 6) and this made it difficult to interpret the result with respect to management.

Catch-monitoring is included in the Torres Strait Community Dugong and Turtle Management Plans. Although catch-monitoring is being implemented in the outer islands, the Kaurareg Plan for the inner islands had not yet been finalised. Despite the difficulties and challenges described above, investment in catch-monitoring should provide useful information to evaluate management effectiveness. However, as discussed in Chapters 6 and 7, the amount and complexity of information to be collected should be increased in stages. For example, stage 1 might be the number of dugongs and green turtles caught; stage 2 might add the number of trips (including unsuccessful trips) to obtain an estimate of catch-per-unit-effort; and stage 3 might add the collection of demographic information about the animals taken.

There is a range of management frameworks in which the development, monitoring and evaluation of indicators can sit (Reed et al. 2006). In Australia, national and state/territory level governments capture and present key information on the state of the 'environment' in terms of: its current condition; the pressures on it and the drivers of those pressures; and management initiatives in place to address environmental concerns, and the impacts of those initiatives. The Organisation for Economic Cooperation and Development (OECD) suggest this approach (Reed et al. 2006). At local and regional scales, more bottom-up approaches may be preferred, or a combination of bottom-up and top-town approaches may be appropriate (Rice and Rochet 2005; Reed et al. 2006). Thus, data like those collected in this study and being collected by the Torres Strait regional Authority could feed into pressure, state, response management frameworks, which tend to be considered by policy makers at a much higher level than individual species at a regional scale.

Table 8.2. The insights provided by and limitations of monitoring temporal trends in a range of indicators for dugong and green turtle management that might be monitored using community-based catch-monitoring.

Indicator Temporal trends in:	**Data required**	**Logistical difficulty**	**Capacity required**	**Data required external to Community Based Monitoring**	**Insights and limitations**	
					Local scale	Regional Scale
Total catch.	Catch.	Catch data needs to be collected at the local scale to provide accurate and precise estimates to inform management at the community level.	Catch-monitors collect datasheets/survey hunters in each community.		Trends in total catch through time; Total catch does not provide insights into the sustainability of the catch without accompanying information on population size and catch-effort.	Trends in total catch through time; Total catch does not provide insights into the sustainability of the catch without accompanying information on population size and catch-effort.
Catch per unit effort.	Catch; Effort.	Effort data difficult to obtain (i.e., unsuccessful trips)	Catch-monitors collect datasheets/survey hunters in each community; Education on the importance of collecting effort data (i.e., unsuccessful trips)		Confounded by: movements of animals; abilities of hunters; changes in technology	Population growth or decline.
Modal distance covered to catch.	Catch; Distance to where animal was caught.		Catch-monitors collect datasheets/survey hunters.	Models of relative densities of species.	Local population growth or decline confounded by movement of animals.	Geographic analysis of the species and hunting pressure provides a basis for spatial planning; May provide insights into population status if patterns are consistent at the regional scale.

Indicator Temporal trends in:	Data required	Logistical difficulty	Capacity required	Data required external to Community Based Monitoring	Insights and limitations	
					Local scale	Regional Scale
# days on which animals caught p.a.	Catch; Date.		Catch-monitors collect datasheets/survey hunters.		Temporal variability of the catch – informs design of monitoring strategy at the scale of individual communities.	May provide insights into population status if patterns are consistent at the regional scale.
Sustainability of catch.	Catch; Age-determination; Reproductive status.	Catch data need to be collected at the local scale and scaled up to the regional scale for comparison; Obtaining estimates of life-history parameters of marine turtles is difficult, particularly age-estimation.	Catch-monitors collect datasheets/survey hunters; Requires substantial education in collection and labelling of samples because there is a great potential for mis-labelling, particularly when multiple samples are collected from multiple animals at the same time (e.g., skulls and reproductive organs from different animals); Requires funds to process samples.	Estimate of population size.	Sustainability of the catch cannot be determined at the local scale because the population size cannot be estimated at this scale.	The sustainability of the catch; May provide insights into population status if patterns are consistent at the regional scale.
Species composition of catch.	Catch; Species.		Catch-monitors collect datasheets/survey hunters; Training in identification of species.		The species that require management.	

Indicator Temporal trends in:	Data required	Logistical difficulty	Capacity required	Data required external to Community Based Monitoring	Insights and limitations	
					Local scale	Regional Scale
Sex ratio of catch.	Catch; Sex.	For green turtles, have a mixed stock in Torres Strait so cannot determine which is the baseline population with which to compare the sex ratio.	Catch-monitors collect datasheets/survey hunters.	Sex ratio from unhunted population.	May provide some indication of possible management options (e.g., if the sex ratio is heavily biased can try to make it more even); Selectivity of females is not optimal for a sustainable harvest.	
Size composition of catch.	Catch; Size.	Measuring the size requires the use of equipment (tape measure) and therefore size may not be recoded as often as other data items; If size is estimated rather than measured (i.e., as was done for dugongs in the present study), the size classes may not be robust. It was not culturally appropriate to measure size for dugongs; Size is not a precise indicator of maturity for either dugongs or green turtles. However, below a certain size, animals can be considered juveniles and above a certain size, they can be considered adults.	Catch-monitors collect datasheets/survey hunters; Requires training in measurement technique.	Historical size composition from unhunted population or previous harvests; Size composition from unhunted population.	May indicate whether vulnerable life-history stages are being targeted (e.g., adults, sub-adults). (Harvesting vulnerable life-history stages is not optimal for a sustainable harvest).	May indicate a shift in the size range of animals (e.g., loss of large animals from the population), but difficult to disaggregate such changes from hunter preferences; May provide insights into population status if patterns are consistent at the regional scale.
Reproductive status of catch (dugongs).	Catch; Size;	If size is estimated rather than measured (i.e., as was done for dugongs in the present	Catch-monitors collect datasheets/survey hunters.	Sea grass condition.		Small size at first reproduction and high pregnancy rates can indicate over-harvesting or

Indicator Temporal trends in:	Data required	Logistical difficulty	Capacity required	Data required external to Community Based Monitoring	Insights and limitations	
					Local scale	Regional Scale
	Pregnancy status	study), the size classes may not be robust; False negatives are likely when using the presence of a foetus as an indicator of pregnancy.				good environmental conditions; It may be difficult to disaggregate the influence of environmental conditions and density dependence on changes in some reproductive parameters through time, particularly in the absence of complimentary information on environmental conditions and seagrass distribution and abundance.
Maturity and Reproductive status of the catch.	Catch; Reproductive organs (e.g., ovaries); Age determination (e.g., dugong tusks).	Requires a large investment of effort by hunters/catch-monitors to extract the specimens from the animals, label, and store them; It is very difficult to determine the reproductive status of male dugongs and green turtles.	Catch-monitors collect datasheets/survey hunters; Requires substantial education in collection and labelling of samples because there is a great potential for mis-labelling, particularly when multiple samples are collected from multiple animals at the same time (e.g., skulls and reproductive organs from different animals);			Provides information that can inform population/sustainability models, e.g.,: Age distribution; Age at first reproduction; Reproductive rate; Recruitment rate (i.e., new breeders); It may be difficult to disaggregate the influence of environmental conditions and density dependence on changes in some reproductive parameters through time,

Indicator Temporal trends in:	Data required	Logistical difficulty	Capacity required	Data required external to Community Based Monitoring	Insights and limitations	
					Local scale	Regional Scale
			Requires funds to process samples			particularly in the absence of complimentary information on environmental conditions and seagrass distribution and abundance.
# active hunters.	Catch.	Need to contact each hunter regularly (e.g., monthly).	Catch-monitors collect datasheets/survey hunters.		Estimate of total catch based on active hunters rather than all potential hunters; determine whether have a representative sample.	
Proportion of catch caught by top (e.g., 5) hunters.	Catch; Proportion of top hunters participating in catch-monitoring.	Only need to contact a small number (e.g., 5) of top hunters; Need to determine the proportion of top hunters participating in catch-monitoring.	Catch-monitors collect datasheets/survey hunters.		The total catch of the top hunters could be used as the minimum catch. Such a strategy would reduce monitoring effort, but limit the involvement of all the community's hunters in catch-monitoring. The proportion of top hunters participating in catch-monitoring may change through time.	Consistent method needed across communities if scaling-up to the regional scale.
% catch caught for ceremonies /subsistence.	Catch. Reason for hunting.		Catch-monitors collect datasheets/survey hunters.		May provide an indication of possible management options (e.g., the	

Indicator Temporal trends in:	Data required	Logistical difficulty	Capacity required	Data required external to Community Based Monitoring	Insights and limitations	
					Local scale	Regional Scale
					community could decide to: limit harvesting to ceremonies; undertake further research to understand the drivers of the subsistence harvest, etc)	

8.3.2. Integration of monitoring outcomes

The design of the catch-monitoring program in Torres Strait needs to consider local and regional scales of management. Thus, data collected at the local scale, needs to be able to be scaled-up to be integrated into management at the regional scale. Therefore, monitoring methods should be consistent across communities. In addition, participation in catch-monitoring should put the issue of harvesting in context for hunters, especially if feedback about catch-numbers is provided at local and regional scales.

Integration of the outcomes of different types of monitoring contributing to adaptive co-management is also important. For ecological parameters, some type of report card (e.g., Stem et al. 2005) might be used to report on the condition of dugongs, green turtles and their habitats in Torres Strait to help gauge progress towards management goals. Report cards may present site-specific information, regional level information and national level information and thus provide a context for local managers (Stem et al. 2005).

8.3.3. Understanding socio-economic drivers of hunting

Cultural or socio-economic values can influence hunting patterns and determining these drivers requires social science research techniques rather than biological science techniques (Sheil and Lawrence 2004). For example, the research presented in this thesis showed that approximately half of the dugongs and green turtles caught were used for general consumption (or *kai kai*). It is not clear from my research why so much of the catch is needed for general food, but it suggests that there are food security issues in Torres Strait and dugongs and green turtles are a preferred food (i.e., with respect to taste). Understanding the drivers of the harvest and how behaviours might be changed to limit the harvest, or whether alternative food sources could and should be provided, will be important for determining sustainable management options. These data are being collected by Aurelie Delisle in a parallel study.

The Torres Strait Dugong and Turtle Management Plans support the movement of dugong and green turtle meat to the mainland of Australia to support traditional purposes. Approximately 86% of Torres Strait Islanders live on the mainland of Australia (2006 census) and ongoing research by Delisle (pers. comm.) suggests that a 'substantial' proportion of the dugongs and green turtles caught in Torres Strait could be moved to the diaspora of Torres Strait Islanders living on the mainland. However, relatively little is known about this potentially important contributor to the harvest or how to manage it sustainably.

The diaspora of Torres Strait Islanders living on the mainland of Australia do not appear to have been involved in the development of the current Community Dugong and Turtle Management Plans. Further research is needed to include them in the management process because they are potentially affected stakeholders and the plans may be less likely to succeed if all affected stakeholders are not included in their development and do not contribute to and accept the management actions (Ewing et al. 2000; Webler et al. 2001).

8.4. Final remarks

There has been a very large investment in community-based management of the Torres Strait dugong and green turtle fisheries of more than AUD$20 million over five years to 2013. It will be important to evaluate whether this management is effective. This study has provided an overall context for co-management at different spatial scales and trialled community-based catch-monitoring as a tool to assist Torres Strait Islanders inform their co-management. The Torres Strait Regional Authority modified the catch-monitoring tool developed in this study for their catch-monitoring program, which they have begun implementing on the outer islands. However, catch-monitoring has not continued in the inner islands because the Kaurareg Plan has not yet been finalised. As described in chapter 2, the governance arrangements in the Kaiwalagal region (i.e., the inner island communities) are more complicated than on the outer islands because the majority of people living there are not the traditional owners, but were historically relocated from other islands. Thus, establishing management arrangements in the inner islands is more challenging than on the outer islands.

Community-based catch-monitoring is an important option for Torres Strait Islanders to assist with managing their dugong and green turtle fisheries at local and regional scales. However, it requires considerable effort to obtain reliable information. As the Torres Strait Regional Authority assists communities to conduct an effective catch-monitoring program as part of adaptive co-management, they will require capacity-building in terms of financial resources for personnel as well as in obtaining the necessary mix of technical skills. Therefore, it will be important that the investment in implementation of the Community Dugong and Turtle Management Plans continues and that it includes resources for evaluating management effectiveness through monitoring (i.e., adaptive co-management).

Management of the Torres Strait dugong and green turtle fisheries will continue to rely on multiple lines of evidence. That is, a series of indicators must be monitored to determine whether the harvest is sustainable and management is effective. In addition, the information needed for some indicators is more difficult to collect than for others. Therefore, community-based monitoring needs to be implemented in a staged-approach. It will, therefore, take time for the results of catch-monitoring to inform adaptive co-management. Thus, community-based catch-monitoring should be considered part of a long-term adaptive process.

While Islanders can manage hunting at local scales through their Community Dugong and Turtle Management Plans, they will still require assistance from governments at larger spatial scales because of the ecological scales at which dugongs and green turtles operate. Thus, the significant coordinating role of the Torres Strait Regional Authority should be further supported to combine the complimentary knowledge, skills and capabilities of the different co-management partners and facilitate learning through monitoring.

References

Agrawal A. 1997. The Politics of development and conservation: Legacies of colonialism. *Peace & Change*, 22:463-482.

Agrawal A. and C.C. Gibson. 1999. Enchantment and disenchantment: The role of community in natural resource conservation. *World Development*, 27:629-649.

Agrawal A. 2003. Sustainable governance of common-pool resources: Context, methods, and politics. *Annual Review of Anthropology*, 32:243-262.

Allen B.M. and R.P. Angliss. 2010. Alaska Marine Mammal Stock Assessments, 2009. *NOAA Technical Memorandum NMFSAFSC-206*. 276pp. United States Department of Commerce.

Altman J., G. Buchanan and L. Larsen. 2007. The environmental significance of the Indigenous estate: Natural resource management as economic development in remote Australia. *CAEPR Discussion Paper No. 286*. Centre for Aboriginal Economic Policy Research, Australian National University, Canberra.

Altman J. 2009. Beyond closing the gap: Valuing diversity in Indigenous Australia. *CAEPR Working Paper No. 54*. Centre for Aboriginal Economic Policy Research, Australian National University, Canberra.

Andre´ J., E. Gyuris and I.R. Lawler. 2005. Comparisons of the diets of sympatric dugongs and green turtles on the Orman Reefs, Torres Strait, Australia. *Wildlife Research*, 32:53–62.

Andrianandrasana H.T., J. Randriamahefasoa, J. Durbin, R.E. Lewis and J.H. Ratsimbazafy. 2005. Participatory ecological monitoring of the Alaotra wetlands in Madagascar. *Biodiversity and Conservation*, 14:2757-2774.

Armitage D. 2008. Governance and the commons in a multi-level world. *International Journal of the Commons*, 2:7-32.

Armitage D., F. Berkes, A. Dale, E. Kocho-Schellenberg and E. Patton. 2011. Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change*, 21:995-1004.

Armitage D.R., R. Plummer, F. Berkes, R.I. Arthur, A.T. Charles, I.J. Davidson-Hunt, A.P. Diduck, N.C. Doubleday, D.S. Johnson, M. Marschke, P. McConney, E.W. Pinkerton and E.K. Wollenberg. 2009. Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment*, 7:95-102.

Aswani S. and M. Lauer. 2006. Incorporating Fishermen's Local Knowledge and Behavior into Geographical Information Systems (GIS) for Designing Marine Protected Areas in Oceania. *Human Organization*, 65:81.

Ayres J.M., D.M. Lima, E.S. Martins and J.L. Barreiros. 1991. On the track of the road: Changes in subsistence hunting in a Brazilian Amazonian village. In: *Neotropical wildlife use and conservation*. (eds. J.G. Robinson and K.H. Redford), pp 82-92. University of Chicago Press, Chicago.

Bailey H. and P.M. Thompson. 2009. Using marine mammal habitat modelling to identify priority conservation zones within a marine protected area. *Marine Ecology Progress Series*, 378:279-287.

Baldwin C. 1985. Management fo Dugong: an endangered marine species of traditional significance. 26pp. Great Barrier Reef marine Park Authority, Townsville, Queensland.

Ballard H.L. and J.M. Belsky. 2010. Participatory action research and environmental learning: Implications for resilient forests and communities. *Environmental Education Research*, 16:611-627.

Ban N.C., C. Picard and A.C.J. Vincent. 2008. Moving toward spatial solutions in marine conservation with Indigenous communities. *Ecology and Society*, 13:32.

Ban N.C., C.R. Picard and A.C.J. Vincent. 2009. Comparing and Integrating Community-Based and Science-Based Approaches to Prioritizing Marine Areas for Protection

Comparación e Integración de Métodos Basados en Evaluaciones Comunitarias y Cientificas para la Priorización de Áreas Marinas Protegidas. *Conservation Biology*, 23:899-910.

Barham A.J., M.J. Rowland and G. Hitchcock. 2004. Torres Strait Bepotaim: An overview of archaeological and ethnoarchaeological investigations and research. In: *Torres Strait Archaeology and Material Culture*. (eds. I.J. McNiven and M. Quinell) vol 3, pp 1-72. Memoirs of the Queensland Museum, Cultural Heritage Series.

Bennun L., P. Matiku, R. Mulwa, S. Mwangi and P. Buckley. 2005. Monitoring important bird areas in Africa: Towards a sustainable and scaleable system. *Biodiversity and Conservation*, 14:2575-2590.

Berkes F., P. George and R.J. Preston. 1991. Co-management: The evolution in theory and practice of the joint administration of living resources. *Alternatives*, 18:12.

Berkes F. 1994. Co-management: bridging the two solitudes. *Northern Perspectives*, 22:18-20.

Berkes F. 1995. Community-based management of common property resources. *Encyclopedia of Environmental Biology*, 1:371-373.

Berkes F., R. Mahon, P. McConney, R. Pollnac and R. Pomeroy. 2001a. *Managing small-scale fisheries: Alternative directions and methods*. IDRC

Berkes F., J. Mathias, M. Kislalioglu and H. Fast. 2001b. The Canadian Arctic and the Oceans Act: The development of participatory environmental research and management. *Ocean & Coastal Management*, 44:451-469.

Berkes F. 2004. Rethinking community-based conservation. *Conservation Biology*, 18:621-630.

Berkes F. 2005. Commons theory for marine resource management in a complex world. *SENRI Ethnological Studies: Indigenous use and management of marine resources*, 67:13-31.

Berkes F. 2006. From community-based resource management to complex systems: The scale issue and marine commons. *Ecology and Society*, 11:45.

Berkes F., T.P. Hughes, R.S. Steneck, J.A. Wilson, D.R. Bellwood, B. Crona, C. Folke, L.H. Gunderson, H.M. Leslie, J. Norberg, M. Nystrom, P. Olsson, H.

Osterblom, M. Scheffer and B. Worm. 2006. Globalization, roving bandits, and marine resources. *Science*, 311 1557-1558.

Berkes F. 2007. Community-based conservation in a globalized world. *Proceedings of the National Academy of Sciences*, 104:15188-15193.

Berkes F. 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management*, 90:1692-1702.

Biddle N. and J. Taylor. 2009. Indigenous population projections, 2006–2031: planning for growth. *CAEPR Working Group Paper No. 56*. Centre for Aboriginal Economic Policy Research, The Australian National University, Canberra.

Bjorndal K.A., A.B. Bolten and C.J. Lagueux. 1993. Decline of the Nesting Population of Hawksbill Turtles at Tortuguero, Costa Rica. *Conservation Biology*, 7:925-927.

Bjorndal K.A., J.A. Wetherall, A.B. Bolten and J.A. Mortimer. 1999. Twenty-Six Years of Green Turtle Nesting at Tortuguero, Costa Rica: An Encouraging Trend. *Conservation Biology*, 13:126-134.

Bjorndal K.A., B.W. Bowen, M. Chaloupka, L.B. Crowder, S.S. Heppell, C.M. Jones, M.E. Lutcavage, D. Policansky, A.R. Solow and B.E. Witherington. 2011. Better science needed for restoration in the Gulf of Mexico. *Science*, 331:537-538.

Boyd I.L., C. Lockyear and H.D. Marsh. 1999. Reproduction in marine mammals. In: *Biology of marine mammals*. (eds. J.E. Reynolds III and S.A. Rommel), pp 218-286. Smithsonian Institution Press, Washington, D.C., USA.

Bradshaw B. 2003. Questioning the credibility and capacity of community-based resource management. *The Canadian Geographer*, 47:137-151.

Brashares J.S. and M.K. Sam. 2005. How much is enough? Estimating the minimum sampling required for effective monitoring of African reserves. *Biodiversity and Conservation*, 14:2709-2722.

Brooks J.S., M.A. Franzen, C.M. Holmes, M.N. Grote and M.B. Mulder. 2006. Testing hypotheses for the success of different conservation strategies. *Conservation Biology*, 20:1528-1538.

Buckley R., J. Robinson, J. Carmody and N. King. 2008. Monitoring for management of conservation and recreation in Australian protected areas. *Biodiversity and Conservation*, 17:3589-3606.

Burger J., M. Gochfeld, C.W. Powers, D.S. Kosson, J. Halverson, G. Siekaniec, A. Morkill, R. Patrick, L.K. Duffy and D. Barnes. 2007. Scientific research, stakeholders, and policy: Continuing dialogue during research on radionuclides on Amchitka Island, Alaska. *Journal of Environmental Management*, 85:232-244.

Burn D.M. 1998. Estimation of hunter compliance with the marine mammal marking, tagging, and reporting program for walrus. *Wildlife Society Bulletin*, 26:68-74.

Cain P. 2004. A practical guide to government management and regulation regimes over marine areas in Queensland. *National Native Title Tribunal, Occasional paper series 1/2004*. National Native Title Tribunal.

Calamia M.A. 1996. Traditional ecological knowledge and geographic information systems in the use and management of Hawaii's coral reefs and fishponds. *High Plains Applied Anthropologist*, 16:144-164.

Campbell L. and A. Vainio-Mattila. 2003. Participatory development and community-based conservation: Opportunities missed for lessons learned? *Human Ecology,* 31:417-437.

Campbell L.M. 2007. Local conservation practice and global discourse: A political ecology of sea turtle conservation. *Annals of the Association of American Geographers*, 97:313-334.

Campbell L.M., J.J. Silver, N.J. Gray, S. Ranger, A. Broderick, T. Fisher, M.H. Godfrey, S. Gore, J. Jeffers, C. Martin, A. McGowan, P. Richardson, C. Sasso, L. Slade and B. Godley. 2009. Co-management of sea turtle fisheries: Biogeography versus geopolitics. *Marine Policy*, 33:137-145.

Chaloupka M. and C. Limpus. 2005. Estimates of sex- and age-class-specific survival probabilities for a southern Great Barrier Reef green sea turtle population. *Marine Biology*, 146:1251-1261.

Cochran W.G. 1977. *Sampling Techniques*. John Wiley and Sons, New York.

Coles R.G., L.J. McKenzie and S.J. Campbell. 2003. The seagrasses of Eastern Australia. In: *The world atlas of seagrasses*. (eds. E.P. Green, F.T. Short and M.D. Spalding)

Cumming G.S., D.H.M. Cumming and C.L. Redman. 2006. Scale Mismatches in social-ecological systems: Causes, consequences, and solutions. *Ecology and Society*, 11:14

Danielsen F., M.M. Mendoza, P. Alviola, D.S. Balete, M. Enghoff, M.K. Poulsen and A.E. Jensen. 2003. Biodiversity monitoring in developing countries: What are we trying to achieve? *Oryx*, 37:407-409.

Danielsen F., N. Burgess and A. Balmford. 2005a. Monitoring matters: Examining the potential of locally-based approaches. *Biodiversity and Conservation*, 14:2507-2542.

Danielsen F., A.E. Jensen, P.A. Alviola, D.S. Balete, M. Mendoza, A. Tagtag, C. Custodio and M. Enghoff. 2005b. Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. *Biodiversity and Conservation*, 14:2633-2652.

Danielsen F., N.D. Burgess, A. Balmford, P.F. Donald, M. Funder, J.P.G. Jones, P. Alviola, D.S. Balete, T. Blomley, J. Brashares, B. Child, M. Enghoff, J. FjeldsÅ, S. Holt, H. HÜbertz, A.E. Jensen, P.M. Jensen, J. Massao, M. Mendoza, Y. Ngaga, M.K. Poulsen, R. Rueda, M. Sam, T. Skielboe, G. Stuart-Hill, E. Topp-JØrgensen and D. Yonten. 2009. Local participation in natural resource monitoring: A characterization of approaches. *Conservation Biology*, 23:31-42.

Davies J., K. Higginbottom, D. Noack, D. Ross and E. Young. 1999. *Sustaining Eden: Indigenous Community Wildlife Management in Australia*. Evaluating Eden Series no. 1. International Institute for Environment and Development London, UK.

Dethmers K.E.M. and D. Broderick. 2002. Green turtle fisheries in Australasia: assessing the extent of their impact using mtDNA markers. In: Proceedings of the twenty second annual symposium on sea turtle biology and conservation, Miami, USA

Dews G., J. and A. Harris. 1995. Monitoring Islander seafood catch in the Torres Strait. In: *Conservation through the sustainable use of wildlife*. (eds. G. Grigg, P. Hale and D. Lunney), pp 145-150. Centre for Conservation Biology, University of Queensland, Brisbane.

Dobbs K., L. Fernandes, S. Slegers, B. Jago, L. Thompson, J. Hall, J. Day, D. Cameron, J. Tanzer, F. Macdonald, H. Marsh and R. Coles. 2008. Incorporating dugong habitats into the marine protected area design for the Great Barrier Reef Marine Park, Queensland, Australia. *Ocean & Coastal Management*, 51:368-375.

Eberhardt L.L. 2002. A paradigm for population analysis of long-lived vertebrates. *Ecology*, 83:2841-2854.

Evans K.E. and T. Klinger. 2008. Obstacles to bottom-up implementation of marine ecosystem management. *Conservation Biology*, 22:1135-1143.

Ewing S.A., R.B. Grayson and R.M. Argent. 2000. Science, citizens, and catchments: Decision support for catchment planning in Australia. *Society & Natural Resources: An International Journal*, 13:443 - 459.

Feeny D., F. Berkes, B.J. McCay and J.M. Acheson. 1990. The tragedy of the commons: Twenty-two years later. *Human Ecology*, 18:1-19.

Fernandez-Gimenez M.E., H.P. Huntington and K.J. Frost. 2006. Integration or co-optation? Traditional knowledge and science in the Alaska Beluga Whale Committee. *Environmental Conservation*, 33:306-315.

Fernandez-Gimenez M.E., J.U. Hays (Jr), H.P. Huntington, R. Andrew and W. Goodwin. 2008. Ambivalence toward formalizing customary resource management norms among Alaska Native beluga whale hunters and Tohono O'odham livestock owners. *Human Organization*, 67:137.

Ferraro P.J. and S.K. Pattanayak. 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biol*, 4:e105.

Findlay C.S., S. Elgie, B. Giles and L. Burr. 2009. Species listing under Canada's Species at Risk Act. *Conservation Biology*, 23:1609-1617.

Folke C., S. Carpenter, T. Elmqvist, L. Gunderson, C.S. Holling, B. Walker, J. Bengtsson, F. Berkes, J. Colding, K. Danell, M. Falkenmark, L. Gordon, R.E. Kasperson, N. Kautsky, A. Kinzig, S.A. Levin, K.-G. Mäler, F. Moberg, L. Ohlsson, P. Olsson, E. Ostrom, W. Reid, J. Rockström, S. Hubert and U. Svedin. 2002. Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. In: ICSU Series on Science for Sustainable Development No.3. International Council for Science, 74pp.

Folke C., T. Hahn, P. Olsson and J. Norberg. 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, 30:441-473.

Freeman M. and U. Kreuter. 1994. *Elephants and whales. Resources for whom?* Gordon and Breach Science Publishers, Switzerland.

Gaillard J.M., M. Festa-Bianchet, N.G. Yoccoz, A. Loison and C. Toigo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. *Annual Review of Ecology and Systematics*, 31:367-393.

Garcia C. and G. Lescuyer. 2008. Monitoring, indicators and community based forest management in the tropics: Pretexts or red herrings? *Biodiversity and Conservation*, 17:1303-1317.

Garcia S.M. and K.L. Cochrane. 2005. Ecosystem approach to fisheries: A review of implementation guidelines. *ICES Journal of Marine Science,* 62:311-318.

Gardener M. 2005. Towards more strategic weed management on top end Aboriginal lands. Tropical Savannas CRC, James Cook University, Townsville.

Gavin M.C. 2007. Foraging in the fallows: Hunting patterns across a successional continuum in the Peruvian Amazon. *Biological Conservation*, 134:64-72.

GBRMPA. 2007. A Reef-wide framework for managing traditional use of marine resources in the Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Gibson C.C. and S.A. Marks. 1995. Transforming rural hunters into conservationists: An assessment of community-based wildlife management programs in Africa. *World Development*, 23:941-957.

Gilligan B. 2006. The National Reserve System programme 2006 evaluation. Department of the Environment and Heritage, Canberra.

Gjertsen H. and E. Niesten. 2010. Incentive-based approaches in marine conservation: Applications for sea turtles. *Conservation and Society*, 8:5-14.

Godley B.J., A.C. Broderick, L.M. Campbell, S. Ranger and P.B. Richardson. 2004. An assessment of the status and exploitation of marine turtles in the UK Overseas Territories in the wider Caribbean. 253pp. Final Project Report for the Department of Environment, Food and Rural Affairs and the Foreign and Commonwealth Office.

Grantham H.S., M. Bode, E. McDonald-Madden, E.T. Game, A.T. Knight and H.P. Possingham. 2010. Effective conservation planning requires learning and adaptation. *Frontiers in Ecology and the Environment*, 8:431-437.

Grayson J.E., M. Hamann, H. Marsh and S. Ambar. 2010. Options for managing the sustainable use of green turtles: Perceptions of Hammond Islanders in Torres Strait. *Conservation and Society*, 8:73-83.

Grech A. and H. Marsh. 2007. Prioritising areas for dugong conservation in a marine protected area using a spatially explicit population model. *Applied GIS*, 3:1-14.

Grech A. and H. Marsh. 2008. Rapid assessment of risks to a mobile marine mammal in an ecosystem-scale marine protected area. *Conservation Biology*, 22:711-720.

Grech A., H. Marsh and R. Coles. 2008. A spatial assessment of the risk to a mobile marine mammal from bycatch. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18:1127–1139.

Grech A., J. Sheppard and H. Marsh. 2011. Informing species conservation at multiple scales using data collected for marine mammal stock assessments. *PLoS ONE*, 6:e17993.

Green R.E., A. Balmford, P.R. Crane, G.M. Mace, J.D. Reynolds and R.K. Turner. 2005. A Framework for improved monitoring of biodiversity: Responses to the World Summit on Sustainable Development. *Conservation Biology*, 19:56-65.

Guisan A. and W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology Letters*, 8:993-1009.

Haddon A.C. 1890. The ethnography of the western tribe of Torres Strait. *Journal of the Royal Anthropological Institute,* 19:297-440.

Haddon A.C. 1912. *Reports of the Cambridge Anthropological Expedition to Torres Straits.* Cambridge University Press, Cambridge.

Halpern B.S. 2003. The impact of marine reserves: Do reserves work and does reserve size matter? *Ecological Applications*, 13:117-137.

Halpern B.S., S. Walbridge, K.A. Selkoe, C.V. Kappel, F. Micheli, C. D'Agrosa, J.F. Bruno, K.S. Casey, C. Ebert, H.E. Fox, R. Fujita, D. Heinemann, H.S. Lenihan, E.M.P. Madin, M.T. Perry, E.R. Selig, M. Spalding, R. Steneck and R. Watson. 2008. A global map of human impact on marine ecosystems. *Science,* 319:948-952.

Hamann M., C.S. Schauble, T. Simon and S. Evans. 2006. Demographic and health parameters of green sea turtles *Chelonia mydas* foraging in the Gulf of Carpentaria, Australia. *Endangered Species Research*, 2:81-88.

Hamann M., M.H. Godfrey, J.A. Seminoff, K. Arthur, P.C.R. Barata, K.A. Bjorndal, A.B. Bolten, A.C. Broderick, L.M. Campbell, C. Carreras, P. Casale, M. Chaloupka, S.K.F. Chan, M.S. Coyne, L.B. Crowder, C.E. Diez, P.H. Dutton, S.P. Epperly, N.N. FitzSimmons, A. Formia, M. Girondot, G.C. Hays, I.J. Cheng, Y. Kaska, R. Lewison, J.A. Mortimer, W.J. Nichols, R.D. Reina, K. Shanker, J.R. Spotila, J. Tomás, B.P. Wallace, T.M. Work, J. Zbinden and B.J. Godley. 2010. Global research priorities for sea turtles: informing management and conservation in the 21st century. *Endangered Species Research,* 11:245–269.

Harris A.N.M., G.J. Dews, J. Kerr and I. Poiner. 1995. Monitoring the traditional and island-based catch of the Torres Strait Protected Zone: Report on CSIRO Research 1991-1993. *Report to the Torres Strait Fisheries and Scientific Committee June 1995*. CSIRO Division of Fisheries

Harris A.N.M., M. Bishop, T.D. Skewes, G.J. Dews and C.R. Pitcher. 1997. Transfer of traditional fisheries monitoring in Torres Strait, with AFMA training - Report on CSIRO research 1993-1996. *Report to the Torres Strait Fisheries and Scientific Committee August 1997*. CSIRO.

Harris P.T., A.J. Butler and R.G. Coles. 2008. Marine resources, biophysical processes, and environmental management of a tropical shelf seaway: Torres

Strait, Australia - Introduction to the special issue. *Continental Shelf Research*, 28:2113-2116.

Harwood L.A., P. Norton, B. Day and P.A. Hall. 2002. The harvest of Beluga whales in Canada's western Arctic: Hunter-based monitoring of the size and composition of the catch. *Arctic*, 55:10-21.

Havemann P., D. Thiriet, H. Marsh and C. Jones. 2005. Traditional use of marine resources agreements and dugong hunting in the Great Barrier Reef World Heritage Area. *Environmental and Planning Law Journal*, 22:258-280.

Havemann P. and R. Smith. 2007. TSRA Torres Strait Dugong and Marine Turtle Project governance and policy review. Torres Strait Regional Authority, unpublished report

Heinsohn G.E. and W.R. Birch. 1972. Foods and feeding habits of the dugong in north Queensland, Australia. *Mammalia*, 36:414–422.

Heinsohn R., R.C. Lacy, D.B. Lindenmayer, H. Marsh, D. Kwan and I.R. Lawler. 2004. Unsustainable harvest of dugongs in Torres Strait and Cape York (Australia) waters: two case studies using population viability analysis. *Animal Conservation*, 7:417-425.

Helson J., S. Leslie, G. Clement, R. Wells and R. Wood. 2010. Private rights, public benefits: Industry-driven seabed protection. *Marine Policy*, 34:557-566.

Henry G.W. and J.M. Lyle (eds). 2003. *The National Recreational and Indigenous Fishing Survey July 2003*. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australia.

Heppell S.S., H. Caswell and L.B. Crowder. 2000. Life histories and elasticity patterns: Perturbation analysis for species with minimal demographic data. *Ecology*, 81:654.

Heppell S.S., M.L. Snover and L.B. Crowder. 2003. Sea turtle population ecology. In: *The biology of sea turtles*. (eds. P.L. Lutz, J.A. Musick and J. Wyneken) vol 2, pp 275-306. CRC PRess, Boca Ranton, Florida.

Hilborn R. 2004. Ecosystem-based fisheries management: the carrot or the stick? *Marine Ecology Progress Series*, 274:275-278.

Hilborn R., F. Micheli and G.A. De Leo. 2006. Integrating marine protected areas with catch regulation. *Canadian Journal of Fisheries and Aquatic Sciences*, 63:642-649.

Hill K., G. McMillan and R. Fariña. 2003. Hunting-related changes in game encounter rates from 1994 to 2001 in the Mbaracayu Reserve, Paraguay. *Conservation Biology*, 17:1312-1323.

Hockley N.J., J.P.G. Jones, F.B. Andriahajaina, A. Manica, E.H. Ranambitsoa and J.A. Randriamboahary. 2005. When should communities and conservationists monitor exploited resources? *Biodiversity and Conservation*, 14:2795-2806.

Holling C.S. 1978. *Adaptive Environmental Assessment and Management*. Wiley, New York.

Holling C.S. and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology*, 10:328-337.

Hone J. 2008. On bias, precision and accuracy in wildlife aerial surveys. *Wildlife Research*, 35:253-257.

Hønneland G. 2000. Compliance in the Barents Sea fisheries. How fishermen account for conformity with rules. *Marine Policy*, 24:11-19.

Hooker S., K. and L.R. Gerber. 2004. Marine reserves as a tool for ecosystem-based management: The potential importance of megafauna. *Bioscience*, 54:27.

Horwich R.H. and J. Lyon. 2007. Community conservation: Practitioners' answer to critics. *Oryx*, 41:376-385.

Hovelsrud G.K., M. McKenna and H.P. Huntington. 2008. Marine mammal harvests and other interactions with humans. *Ecological Applications*, 18 S135-S147.

Hudson B.E.T. 1986. The hunting of dugong in Daru, Papua New Guinea, during 1978–82: Community management and education initiatives. In: A.K. Haines, G.C. Williams and C. Coates (eds) Torres Strait Fisheries Seminar. Australian Government Printing Service, Canberra., Port Moresby, 77-94pp.

Hughes T.P., D.R. Bellwood, C. Folke, R.S. Steneck and J. Wilson. 2005. New paradigms for supporting the resilience of marine ecosystems. *Trends in Ecology & Evolution*, 20:380-386.

Huntington H.P. 2000. Using Traditional Ecological Knowledge in science: Methods and applications. *Ecological Applications*, 10:1270-1274.

Huntington H.P. 2009. A preliminary assessment of threats to arctic marine mammals and their conservation in the coming decades. *Marine Policy*, 33:77-82.

Jensen M.P. 2010. *Assessing the composition of green turtle (Chelonia mydas) foraging grounds in Australasia using mixed stock analyses*. Unpublished PhD thesis. University of Canberra, Canberra.

Johannes R.E. and W. MacFarlane. 1991. *Traditional Fishing in the Torres Strait Islands*. CSIRO Division of Fisheries, Hobart, Australia.

Jones J.P.G., M.M. Andriamarovololona, N.J. Hockley, J.M. Gibbons and E.J. Milner-Gulland. 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. *Journal of Applied Ecology*, 45:1205-1212.

Jordan K. and D. Mavec. 2010. Corporate initiatives in Indigenous employment: The Australian employment covenant two years on. *CAEPR Working Paper No. 74*. Centre for Aboriginal Economic Policy Research, Australian National University, Canberra.

Kaplan I.M. and B.J. McCay. 2004. Cooperative research, co-management and the social dimension of fisheries science and management. *Marine Policy*, 28:257-258.

Kapos V., A. Balmford, R. Aveling, P. Bubb, P. Carey, A. Entwistle, J. Hopkins, T. Mulliken, R. Safford, A. Stattersfield, M. Walpole and A. Manica. 2008. Calibrating conservation: New tools for measuring success. *Conservation Letters*, 1:155-164.

Karl H.A., L.E. Susskind and K.H. Wallace. 2007. A Dialogue, Not a Diatribe: Effective Integration of Science and Policy through Joint Fact Finding. *Environment: Science and Policy for Sustainable Development*, 49:20-34.

Kearney R.E. 1995. Recreational fishing: What's the catch? In: Australian Society for Fish Biology Workshop Proceedings No. 12. Australian Society for Fish Biology, Canberra, 10-23pp.

Kellert S.R., J.N. Mehta, S.A. Ebbin and L.L. Lichtenfeld. 2000. Community natural resource management: Promise, rhetoric, and reality. *Society and Natural Resources*, 13:705-715.

Kennett R., N. Munungurritj and D. Yunupingu. 1998. The Dhimurru Miyapunu Project. In: R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill (eds) Marine Turtle Conservation and Management in Northern Australia, Proceedings of a Workshop held at the Northern Territory University, Darwin, 3–4 June 1997, Centre for Indigenous Natural and Cultural Resource Management and Centre for Tropical Wetlands Management, Northern Territory University, Darwin, 69-75pp.

Kennett R., N. Munungurritj and D. Yunupingu. 2004. Migration patterns of marine turtles in the Gulf of Carpentaria, northern Australia: Implications for Aboriginal management. *Wildlife Research*, 31:241-248.

Kiss A. 2004. Making biodiversity conservation a land-use priority. In: *Getting biodiversity projects to work. Towards more effective conservation and development*. (eds. T. McShane and M.P. Wells), pp 98-123. Columbia University Press, New York.

Kleiman D.G., R.P. Reading, B.J. Miller, T.W. Clark, J.M. Scott, J. Robinson, R.L. Wallace, R.J. Cabin and F. Felleman. 2000. Improving the evaluation of conservation programs. *Conservation Biology*, 14:356-365.

Kowarsky J. 1995. Subsistence hunting of sea turtles in Australia. In: *Biology and Conservation of Sea Turtles*. (ed K.A. Bjorndal), Revised edn, pp 305-313. Smithsonian Institution Press, Washingtion, D.C.

Kvale S. 1996. *Interviews: An introduction to qualitative research interviewing*. SAGE publishing, Thousand Oaks, California.

Kwan D. 1991. *The turtle fishery of Daru, Western Province, Papua New Guinea: Insights into the biology of the green turtle (Chelonia mydas) and implications for management*. Unpublished MSc thesis. James Cook University, Townsville.

Kwan D. 2002. *Towards a sustainable Indigenous fishery for dugongs in Torres Strait: a contribution of empirical data and process*. Unpublished PhD thesis. James Cook University, Townsville, Queensland.

Kwan D., H. Marsh and S. Delean. 2006. Factors influencing the sustainability of customary dugong hunting by a remote indigenous community. *Environmental Conservation*, 33:164-171.

Lanyon J.M., C. Limpus and H. Marsh. 1989. Dugongs and turtles: grazers in the seagrass system. In: *Biology of Australian Sea Grasses: A Treatise on the Biology of Sea Grasses with Special Reference to the Australian Region*. (eds. A.W.D. Larkum, A.J. McComb and S.A. Shepherd), pp 610–634. Elsevier, Amsterdam, The Netherlands.

Lele S., P. Wilshusen, D. Brockington, R. Seidler and K. Bawa. 2010. Beyond exclusion: alternative approaches to biodiversity conservation in the developing tropics. *Current Opinion in Environmental Sustainability*, 2:94-100.

Leslie H.M. 2005. A synthesis of marine conservation planning approaches. *Conservation Biology*, 19:1701-1713.

Limpus C. and P.C. Reed. 1985a. The green turtle, Chelonia mydas, in Queensland: a preliminary description of the population structure in a coral reef feeding ground. In: *Biology of Australasian frogs and reptiles*. (eds. Grigg G, Shine R and E. H), pp 47–52. Royal Zoological Society of New South Wales, Sydney.

Limpus C.J. and P.C. Reed. 1985b. The green sea turtle, *Chelonia mydas*, in Queensland: a preliminary description of the population structure of a coral reef feeding ground. In: *Biology of Australian Frogs and Reptiles* (eds. G. Grigg, R. Shine and H. Ehmann), pp 47–52. Royal Zoological Society of New South Wales, Sydney.

Limpus C.J. and N. Nicholls. 1988. The Southern Oscillation regulates the annual numbers of green turtles (*Chelonia mydas*) breeding around northern Australia. *Wildlife Research*, 15:157-161.

Limpus C.J., J.D. Miller, C.J. Parmenter, D. Reimer, N. McLachlan and R. Webb. 1992. Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries. *Wildlife Research*, 19:347–358.

Limpus C.J. 2008. A biological review of Australian marine turtle species. 2. Green turtle, *Chelonia mydas* (Linnaeus). 95pp. Queensland Environmental Protection Agency, Brisbane.

Loban F. 2007. *Ngalpun adhabat a goeygayil bangal (our sea our future): an examination of Torres Strait Protected Zone Joint Authority principles and Torres Strait Islander needs and aspirations for Torres Strait fisheries, from a Torres Strait Islander perspective.* Unpublished Masters of Indignenous Studies Thesis. James Cook University, Townsville.

Loh J. and D. Harmon. 2005. A global index of biocultural diversity. *Ecological Indicators*, 5:231-241.

Lonergan M. 2011. Potential biological removal and other currently used management rules for marine mammal populations: A comparison. *Marine Policy*, 35:584-589.

Lubchenco J., S.R. Palumbi, S.D. Gaines and S. Andelman. 2003. Plugging a hole in the ocean: The emerging science of marine reserves. *Ecological Applications*, 13:3-7.

Mackinnon K. 1998. Sustainability as a conservation tool in the forests of south-east Asia. In: *Conservation of Biological esources*. (eds. E.J. Milner-Gulland and G.M. Mace), pp 174-192. Blackwell Science Ltd, Oxford.

Maffi L. 2001. *On biocultural diversity: Linking language, knowledge, and the environment*. Smithsonian Institution Press, Washington, D.C.

Margoluis R. and N. Salafsky. 1998. *Measures of success: Designing, managing, and monitoring conservation and development projects*. Island Press, Washington, D.C.

Margoluis R., C. Stem, N. Salafsky and M. Brown. 2009. Using conceptual models as a planning and evaluation tool in conservation. *Evaluation and Program Planning*, 32:138-147.

Marks S.A. 1996. Local hunters and wildlife surveys: An assessment and comparison of counts for 1989, 1990 and 1993. *African Journal of Ecology*, 34:237-257.

Marsh H. 1980. Age determination of the dugong (*Dugong dugon* (Muller)) in northern Australia and it's biological implications. *Reports of the International Whaling Commission*:181-201.

Marsh H., P.W. Channells, G.E. Heinsohn and J. Morrissey. 1982. Analysis of stomach contents of dugongs from Queensland. *Wildlife Research*, 9:55-67.

Marsh H., G.E. Heinsohn and P.W. Channells. 1984. Changes in the ovaries and uterus of the dugong, *Dugong dugon* (Sirenia: Dugongidae), with age and reproductive activity. *Australian Journal of Zoology*, 32:743-766.

Marsh H. 1995a. The life history, pattern of breeding and population dynamics of the dugong. *Population Biology of the Florida Manatee*. (eds. T.J. O'Shea, B.B. Ackerman and H.R. Percival), US Department of the Interior, National Biological Service, Information and Technology Report 1.

Marsh H. 1995b. The limits of detectable change. In: *Conservation through sustainable use of wildlife*. (eds. G. Grigg, P. Hale and D. Lunney), pp 122-130. Centre for Conservation Biology, The University of Queensland, Brisbane.

Marsh H. 1996. Progress towards the sustainable use of dugongs by Indigenous peoples in Queensland. In: *Sustainable use of wildlife by Aboriginal and Torres Strait Islander peoples*. (eds. M. Bomford and J. Caughley) Australian Government Printing Service, Canberra.

Marsh H., A.N.M. Harris and I.R. Lawler. 1997. The Sustainability of the Indigenous Dugong Fishery in Torres Strait, Australia/Papua New Guinea. *Conservation Biology*, 11:1375-1386.

Marsh H. 1999. Beware flying mud! (How researchers can safeguard their reputation). *New Scientist*, 2182:65.

Marsh H., C. Eros, P. Corkeron and B. Breen. 1999. A conservation strategy for dugongs: Implications of Australian research. *Marine and Freshwater Research*, 50:979-990.

Marsh H., H. Penrose, C. Eros and J. Hugues. 2002. The dugong (*Dugong dugon*) status reports and action plans for countries and territories in its range. *Early Warning and Assessment Reports*. 163pp. United Nations Environment Programme, Nairobi.

Marsh H., I.R. Lawler, D. Kwan, S. Delean, K. Pollock and M. Alldredge. 2004a. Dugong distribution and abundance in Torres Strait. Torres Strait Research Program Report to Australian Fisheries Management Authority.

Marsh H., I.R. Lawler, D. Kwan, S. Delean, K. Pollock and M. Alldredge. 2004b. Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. *Animal Conservation*, 7:435-443.

Marsh H. 2006. Progress towards the cooperative management of marine hunting in the Great Barrier Reef. In: *Fisheries Management: Progress Towards Sustainability*. (eds. T.R. McClanahan and J.C. Castilla), pp 186-203. Blackwells.

Marsh H. 2007. Progress towards the cooperative management of marine hunting in the Great Barrier Reef. In: *Fisheries Management: Progress Towards Sustainability*. (eds. T.R. McClanahan and J.C. Castilla), pp 186-203. Blackwells.

Marsh H., A. Hodgson, I.R. Lawler, A. Grech and S. Delean. 2007. Condition, status and trends and projected futures of the dugong in the Northern Great Barrier Reef and Torres Strait; including identification and evaluation of the key threats and evaluation of available management options to improve its status. Final report to the Marine and Tropical Science Research Facility.

Marsh H. 2008. Bridging the gap between conservation science and real world outcomes: lessons from working with Indigenous communities. *Society for Conservation Biology Newsletter*, 15:1.

Marsh H. and D. Kwan. 2008. Temporal variability in the life history and reproductive biology of female dugongs in Torres Strait: The likely role of sea grass dieback. *Continental Shelf Research*, 28 2152– 2159.

Marsh H., M. Hamann, A. Grech and J. Grayson. 2009. Report on Workshop on spatial closures as one of the possible management tools for community-based management of dugongs and turtles in Torres Strait. Report to the Marine and Tropical Sciences Research Facility. 26pp. Reef and Rainforest Research Centre Limited, Cairns.

Marsh H., T.J. O'Shea and J.E. Reynolds (III). 2011. *The ecology and conservation of Sirenia: dugongs and manatees* Cambridge University Press, Cambridge, UK.

May K. 2010. Indigenous cultural and natural resource management and the emerging role of the Working on Country program. *CAEPR working paper No. 65*. Centre for Aboriginal Economic Policy Research, Australian National University, Canbarra.

McBride M.F., K.A. Wilson, M. Bode and H.P. Possingham. 2007. Incorporating the effects of socioeconomic uncertainty into priority setting for conservation investment. *Conservation Biology*, 21:1463-1474.

McConney P. and R. Baldeo. 2007. Lessons in co-management from beach seine and lobster fisheries in Grenada. *Fisheries Research*, 87:77-85.

McCook L.J., T. Ayling, M. Cappo, J.H. Choat, R.D. Evans, D.M. De Freitas, M. Heupel, T.P. Hughes, G.P. Jones, B. Mapstone, H. Marsh, M. Mills, F.J. Molloy, C.R. Pitcher, R.L. Pressey, G.R. Russ, S. Sutton, H. Sweatman, R. Tobin, D.R. Wachenfeld and D.H. Williamson. 2010. Adaptive management of the Great Barrier Reef: A globally significant demonstration of the benefits of networks of marine reserves. *Proceedings of the National Academy of Sciences*, 107:18278–18285.

McDonald B. 2006. *Population genetics of dugongs around Australia: implications of gene flow and migration*. Unpublished PhD thesis. James Cook University, Townsville, Queensland.

McNiven I.J. and G. Hitchcock. 2004. Torres Strait Islander marine subsistence specialisation and terrestrial animal translocation. In: *Torres Strait Archaeology and Material Culture*. (eds. I.J. McNiven and M. Quinell) vol 3, pp 105-162. Memoirs of the Queensland Museum, Cultural Heritage Series, Brisbane.

McNiven I.J. and A.C. Bedingfield. 2008. Past and present marine mammal hunting rates and abundances: dugong (*Dugong dugon*) evidence from Dabangai Bone Mound, Torres Strait. *Journal of Archaeological Science*, 35:505-515.

McPhee D.P., D. Leadbitter and G.A. Skilleter. 2002. Swallowing the bait: Is recreational fishing in Australia ecologically sustainable? *Pacific Conservation Biology*, 8:40-51.

McShane T. and S.A. Newby. 2004. Expecting the unattainable: The assumptions behind ICDPs. In: *Getting biodiversity projects to work. Towards more effective conservation and development*. (eds. T. McShane and M.P. Wells), pp 49-76. Columbia University Press, New York.

McShane T. and M.P. Wells. 2004. *Getting biodiversity projects to work: Towards more effective conservation and development*. Columbia University Press

Mellors J.E., L.J. McKenzie and R.G. Coles. 2008. Seagrass-Watch: Engaging Torres Strait Islanders in marine habitat monitoring. *Continental Shelf Research*, 28:2339-2349.

Miller T.J., J.A. Blair, T.F. Ihde, R.M. Jones, D.H. Secor and M.J. Wilberg. 2010. FishSmart: An Innovative Role for Science in Stakeholder-Centered Approaches to Fisheries Management. *Fisheries*, 35:424-433.

Mills M., R.L. Pressey, R. Weeks, S. Foale and N.C. Ban. 2010. A mismatch of scales: challenges in planning for implementation of marine protected areas in the Coral Triangle. *Conservation Letters*, 3:291-303.

Milne S. and E. Niesten. 2009. Direct payments for biodiversity conservation in developing countries: practical insights for design and implementation. *Oryx*, 43:530-541.

Milner-Gulland E.J. and R. Mace. 1998. *Conservation of biological resources*. Blackwell Sciences Ltd, Oxford.

Mittermeier R.A. 1991. Hunting and its effect on wild primate populations in Suriname. In: *Neotropical wildlife use and conservation*. (eds. J.G. Robinson and K.H. Redford), pp 28–143. University of Chicago Press, Chicago, IL.

Moller H., F. Berkes, P.O. Lyver and M. Kislalioglu. 2004. Combining science and traditional ecological knowledge: Monitoring populations for co-management. *Ecology and Society*, 9:2.

Mooers A.Ø., L.R. Prugh, M. Festa-Bianchet and J.A. Hutchings. 2007. Biases in legal listing under Canadian endangered species legislation. *Conservation Biology*, 21:572-575.

Muller S. 2003. Towards decolonisation of Australia's protected area management: The Nantawarrina Indigenous Protected Area experience. *Australian Geographical Studies*, 41:29-43.

Muller S. 2008. Community-based management of Saltwater Country, Northern Australia. *Development*, 51:139.

Nichols J.D. and B.K. Williams. 2006. Monitoring for conservation. *Trends in Ecology & Evolution*, 21:668-673.

Nietschmann B. and J. Nietschmann. 1981. Good dugong, bad dugong; bad turtle, good turtle. *Natural History*, 90:54-63, 86-87.

Nietschmann B. 1984. Hunting and ecology of dugongs and green turtles in Torres Strait. *National Geographic Society Research Reports* 17:625–651.

Nietschmann B. 1989. Traditional sea territories, resources, and rights in Torres Strait. In: *A Sea of Small Boats. Cultural Survival*. (ed J. Cordell), pp 60-94. Cambridge, Massachusetts.

Norse E.A., L.B. Crowder, K. Gjerde, D. Hyrenbach, C. Roberts, C. Safina and M.E. Soulé. 2005. Place-based ecosystem management in the open ocean. In: *Marine conservation biology: The science of maintaining the sea's biodiversity* (eds. E.A. Norse and L.B. Crowder), pp 302-327. Island Press, Washington, DC.

Noss A.J., E. Cuéllar and R.L. Cuéllar. 2003. Hunter self-monitoring as a basis for biological research: Data from the Bolivian Chaco. *Mastozoología Neotropical*, 10:49-67.

Noss A.J., E. Cuéllar and R.L. Cuéllar. 2004. An evaluation of hunter self-monitoring in the Bolivian Chaco. *Human Ecology*, 32:685-702.

Noss A.J., I. Oetting and R. Cuéllar. 2005. Hunter self-monitoring by the Isoseño-Guaraní in the Bolivian Chaco. *Biodiversity and Conservation*, 14:2679-2693.

Notarbartolo-di-Sciara G., T. Agardy, D. Hyrenbach, T. Scovazzi and P. Van Klaveren. 2008. The Pelagos Sanctuary for Mediterranean marine mammals. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18:367-391.

Nowra L. 2007. *Bad dreaming: Aboriginal men's violence against women and children*. Pluto Press, Australia.

Nursey-Bray M. 2006. *Conflict to co-Management: Eating our words: Towards socially just conservation of green turtles and dugongs in the Great Barrier Reef, Australia*. unpublished PhD thesis. James Cook University, Townsville, Australia.

Nursey-Bray M. and P. Rist. 2009. Co-management and protected area management: Achieving effective management of a contested site, lessons from the Great Barrier Reef World Heritage Area (GBRWHA). *Marine Policy*, 33:118-127.

Nursey-Bray M., H. Marsh and H. Ross. 2010. Exploring Discourses in Environmental Decision Making: An Indigenous Hunting Case Study. *Society & Natural Resources*, 23:366-382.

Ober R. and M. Bat. 2007. Both-ways: The philosophy: The both-ways research project: Defining both-ways and translating it into Batchelor Institute practice. *Ngoonjook*, 31:64-86.

OECD. 1997. *Glossary of environmental statistics, studies in methods*. United Nations, New York.

Olsson P., C. Folke and F. Berkes. 2004. Adaptive comanagement for building resilience in social–ecological systems. *Environmental Management*, 34:75-90.

Olsson P., C. Folke, V. Galaz, T. Hahn and L. Schultz. 2007. Enhancing the fit through adaptive co-management: Creating and maintaining bridging functions for matching scales in the Kristianstads Vattenrike Biosphere Reserve, Sweden. *Ecology and Society*, 12:28.

Ostrom E., J. Walker and R. Gardner. 1992. Covenants with and without a sword: Self-governance is possible. *The American Political Science Review*, 86:404-417.

Ostrom E. 1999. Coping with tragedies of the commons. *Annual Review of Political Science,* 2:493-535.

Ostrom E. 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences*, 104:15181-15187.

Pandey D.N. 2003. Cultural resources for conservation science. *Conservation Biology,* 17:633-635.

Pinkerton E. (ed) 1989. *Co-operative management of local fisheries: New directions for improved management and community development*. University of British Columbia Press, Vancouver.

Pollock K., H., H. Marsh, D., I. Lawler, R. and M. Alldredge, W. 2006. Estimating animal abundance in heterogeneous environments: An application to aerial surveys for dugongs. *Journal of Wildlife Management*, 70:255-262.

Pollock K.H., K. Tsai and J.M. Hoenig. 1994. Band return models: Use of solicited bands and separation of hunting and natural mortality. *The Journal of Wildlife Management*, 58:193-198.

Pomeroy R.S. and F. Berkes. 1997. Two to tango: The role of government in fisheries co-management. *Marine Policy* 21:465-480.

Pomeroy R.S. and R. Rivera-Guieb. 2006. *Fishery co-management: A practical handbook*. CABI Publishing and International Development Research Centre, Wallingford, UK.

Ponte F. 1996. *It has nothing to do with hunting: An examination of the attitudes and values associated with recognition of indigenous hunting rights*. Unpublished PhD thesis. James Cook University, Townsville, Australia.

Pullin A.S. and T.M. Knight. 2009. Doing more good than harm - Building an evidence-base for conservation and environmental management. *Biological Conservation*, 142:931-934.

Quinn G.P. and M.J. Keough. 2002. *Experimental design and data analysis for biologists*. Campbridge University Press, Cambridge.

Raven M. 1990. *The point of no diminishing returns: Hunting and resource decline on Boigu Island, Torres Strait*. Unpublished PhD Thesis. University of California, Davis, USA.

Redford K. and A. Taber. 2000. Writing the wrongs: Developing a safe-fail culture in conservation. *Conservation Biology*, 14:1567-1568.

Reed M.S., E.D.G. Fraser and A.J. Dougill. 2006. An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological Economics*, 59:406-418.

Reid W.V., F. Berkes, T. Wilbanks and D. Capistrano (eds). 2006. *Bridging scales and knowledge systems: Linking global science and local knowledge in assessments*. Millennium Ecosystem Assessment and Island Press, Washington D.C.

Rice J.C. and M. Rochet. 2005. A framework for selecting a suite of indicators for fisheries management. *ICES Journal of Marine Science*, 62:516-527.

Rist J., E.J. Milner-Gulland, G. Cowlishaw and M. Rowcliffe. 2010. Hunter reporting of catch per unit effort as a monitoring tool in a bushmeat-harvesting system. *Conservation Biology*, 24:489-499.

Robards M.D., J.J. Burns, C.L. Meek and A. Watson. 2009. Limitations of an optimum sustainable population or potential biological removal approach for conserving marine mammals: Pacific walrus case study. *Journal of Environmental Management*, 91:57-66.

Robards M.D. and A.L. Lovecraft. 2010. Evaluating comanagement for social-ecological fit: Indigenous priorities and agency mandates for Pacific Walrus. *Policy Studies Journal*, 38:257-279.

Roberts C.M., C.J. McClean, J.E.N. Veron, J.P. Hawkins, G.R. Allen, D.E. McAllister, C.G. Mittermeier, F.W. Schueler, M. Spalding, F. Wells, C. Vynne and T.B. Werner. 2002. Marine biodiversity hotspots and conservation priorities for tropical reefs. *Science,* 295:1280-1284.

Robinson G. and K.H. Redford. 1991. Sustainable harvest of neotropical forest animals. In: *Neotropical wildlife use and conservation*. (eds. G. Robinson and K.H. Redford), pp 415-429. University of Chicago Press, Chicago.

Robinson J.G. and E.L. Bennett. 2004. Having your wildlife and eating it too: an analysis of hunting sustainability across tropical ecosystems. *Animal Conservation*, 7:397-408.

Robinson J.G. and K.H. Redford. 2004. Jack of all trades, master of none: Inherent contradictions. In: *Getting biodiversity projects to work: Towards more effective conservation and development*. (eds. T. McShane and M.P. Wells), pp 10-34. Columbia University Press, New York.

Rodriguez J.P. 2003. Challenges and opportunities for surveying and monitoring tropical biodiversity: A response to Danielsen et al. *Oryx*, 37:411-411.

Sæther B.E. 1997. Environmental stochasticity and population dynamics of large herbivores: a search for mechanisms. *Trends in Ecology & Evolution*, 12:143-149.

Sagarin R.D. and L.B. Crowder. 2008. Breaking through the crisis in marine conservation and management: Insights from the philosophies of Ed Ricketts. *Conservation Biology*, 23:24-30.

Salafsky N., R. Margoluis, K.H. Redford and J.G. Robinson. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conservation Biology*, 16:1469-1479.

Salafsky N. and R. Margoluis. 2004. Using adaptive management to improve ICDPs. In: *Getting biodiversity projects to work. Towards more effective conservation and development*. (eds. T. McShane and M.P. Wells), pp 372-396. Columbia University Press, New York.

Saterson K.A., N.L. Christensen, R.B. Jackson, R.A. Kramer, S.L. Pimm, M.D. Smith and J.B. Wiener. 2004. Disconnects in evaluating the relative effectiveness of conservation strategies. *Conservation Biology*, 18:597-599.

Sayer J. and M.P. Wells. 2004. The pathology of projects. In: *Getting biodiversity projects to work: Towards more effective conservation and development*. (eds. T. McShane and M.P. Wells), pp 35-48. Columbia University Press, New York.

Sejersen F. 2001. Hunting and management of beluga whales (*Delphinapterus leucas*) in Greenland: Changing strategies to cope with new national and local interests. *Arctic*, 54:431-444.

Sharp N. 1997. Why Indigenous sea rights are not recognised in Australia ...: 'the facts' of Mabo and their cultural roots. *Australian Aboriginal Studies*, 1:28-37.

Sheil D. and A. Lawrence. 2004. Tropical biologists, local people and conservation: New opportunities for collaboration. *Trends in Ecology & Evolution*, 19:634-638.

Sheppard J.K., A.R. Preen, H. Marsh, I.R. Lawler, S.D. Whiting and R.E. Jones. 2006. Movement heterogeneity of dugongs, *Dugong dugon* (Muller), over large spatial scales. *Journal of Experimental Marine Biology and Ecology*, 334:64-83.

Silver J. 2008. Weighing in on scale: Synthesizing disciplinary approaches to scale in the context of building interdisciplinary resource management. *Society and Natural Resources*, 21:921-929.

Silver J.J. and L.M. Campbell. 2005. Fisher participation in research: Dilemmas with the use of fisher knowledge. *Ocean & Coastal Management*, 48:721-741.

Singleton S. 1998. *Constructing cooperation: the evolution of institutions of comanagement*. University of Michigan Press, Ann Arbor.

Skewes T.D., A.G. Kingston, D.R. Jacobs, C.R. Pitcher, M. Bishop, C.M. Burridge and S. Lilly. 2004. The traditional fisheries catch of Torres Strait Islanders. Project Final Report, 1996-2001. *Australian Fisheries Management Authority Torres Strait Research Program Final Report*. Australian Fisheries Management Authority, Canberra Australia.

Smith A. 1989. Usage of marine resources by Aboriginal communities on the east coast of Cape York Peninsula. *GBRMPA Research Publication Series*. 137pp. Great Barrier Reef Marine Park Authority, Townsville.

Smith A. and H. Marsh. 1990. Management of Traditional Hunting of Dugongs (Dugong dugon (Muller, 1776) in the Northern Great Barrier Reef, Australia. *Environmental Management*, 14:47-55.

Smyth D. 1997. Saltwater Country Aboriginal and Torres Strait Islander interest in Ocean Policy development and implementation. *Australia's Oceans Policy* *socio-cultural considerations - Issues Paper 6*. Commonwealth of Australia, Canberra.

Smyth D. 2001. Joint management of national parks in Australia. In: *Working on Country: Contemporary Indigenous management of Australia's lands and coastal regions*. (eds. R. Baker, J. Davies and E. Young) Oxford University Press, Oxford.

Stem C., R. Margoluis, N. Salafsky and M. Brown. 2005. Monitoring and evaluation in conservation: A review of trends and approaches. *Conservation Biology*, 19:295-309.

Stuart-Hill G., R. Diggle, B. Munali, J. Tagg and D. Ward. 2005. The event book system: A community-based natural resource monitoring system from Namibia. *Biodiversity and Conservation*, 14:2611-2631.

Sutherland W.J., A.S. Pullin, P.M. Dolman and T.M. Knight. 2004. The need for evidence-based conservation. *Trends in Ecology & Evolution*, 19:305-308.

Taylor B.L. and T. Gerrodette. 1993. The uses of statistical power in conservation biology: The vaquita and northern spotted owl. *Conservation Biology,* 7:489-500.

Taylor B.L., M. Martinez, T. Gerrodette, J. Barlow and Y.N. Hrovat. 2007. Lessons from monitoring trends in abundance of marine mammals. *Marine Mammal Science,* 23:157-175.

Taylor J. and N. Biddle. 2010. Estimating the accuracy of geographic variation in Indigenous population counts. *Australian Geographer*, 41:469-484.

Taylor J. 2011. Postcolonial transformation of the Australian Indigenous population. *Geographical Research*, 49:286–300.

Tobias T. 2000. *Chief Kerry's moose: a guidebook to land use and occupancy mapping, research design, and data collection*. Union of British Columbia Indian Chiefs and Ecotrust Canada, Vancouver, Canada.

Tongson E. and M. Dino. 2004. Indigenous peoples and protected areas: The case of the Sibuyan Mangyan Tagabukid, Philippines. In: *Getting biodiversity projects to work: Towards more effective conservation and development*. (eds. T. Mcshane and M.P. Wells), pp 181-207. Columbia University Press, New York.

Topp-Jørgensen E., M.K. Poulsen, J.F. Lund and J.F. Massao. 2005. Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania. *Biodiversity and Conservation*, 14:2653-2677.

Townsend W.R., A.R. Borman, E. Yiyoguaje and L. Mendua. 2005. Cofán Indians' monitoring of freshwater turtles in Zábalo, Ecuador. *Biodiversity and Conservation*, 14:2743-2755.

Tyler S.R. (ed) 2006. *Communities, livelihoods, and natural resources action research and policy change in Asia*. Intermediate Technology Publications Ltd and International Development Research Centre

Usher P.J. and G.W. Wenzel. 1987. Native harvest surveys and statistics: a critique of their construction and use. *Arctic,* 40:145-160.

Uychiaoco A.J., H.O. Arceo, S.J. Green, M.T. Cruz, P.A. Gaite and P.M. Aliño. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: Tightening the adaptive management cycle. *Biodiversity and Conservation*, 14:2775-2794.

Vickers W.T. 1991. Hunting yields and game composition over ten years in an Amazonian village. In: *Neotropical Wildife Use and Conservation*. (eds. G. Robinson and K.H. Redford), pp 53-81. University of Chicago Press, Chicago.

Viteri C. and C. Chávez. 2007. Legitimacy, local participation, and compliance in the Galápagos Marine Reserve. *Ocean & Coastal Management*, 50:253-274.

Wade P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. *Marine Mammal Science*, 14:1-37.

Wainwright C. and W. Wehrmeyer. 1998. Success in integrating conservation and development? A study from Zambia. *World Development*, 26:933-944.

Webler T., S. Tuler and R. Krueger. 2001. What is a good public participation process? Five perspectives from the public. *Environmental Management*, 27:435-450.

Wells M.P., T. McShane, H. Dublin, S. O'Connor and K.H. Redford. 2004. The future of Integrated Conservation and Development Projects: Building on what works. In: *Getting biodiversity projects to work. Towards more effective conservation and development*. (eds. T. McShane and M.P. Wells), pp 397-422. Columbia University Press, New York.

Wiber M., A. Charles, J. Kearney and F. Berkes. 2009. Enhancing community empowerment through participatory fisheries research. *Marine Policy*, 33:172-179.

Wilson J.A., J.M. Acheson, M. Metcalfe and P. Kleban. 1994. Chaos, complexity and community management of fisheries. *Marine Policy*, 18:291-305.

Wood L.J., L. Fish, J. Laughren and D. Pauly. 2008. Assessing progress towards global marine protection targets: shortfalls in information and action. *Oryx*, 42:340-351.

Yoccoz N.G., J.D. Nichols and T. Boulinier. 2001. Monitoring of biological diversity in space and time. *Trends in Ecology & Evolution*, 16:446-453.

Yoccoz N.G., J.D. Nichols and T. Boulinier. 2003. Monitoring of biological diversity - a response to Danielsen et al. *Oryx*, 37:410-410.

Younger P. 2008. Integrated training: Delivering better results for Indigenous rangers. In: Kantri Laif, 24pp.

Appendix A: Research Agreement

MEMORANDUM OF UNDERSTANDING

RESEARCH COMMUNICATION AGREEMENT

This administrative form has been removed

Dugong and turtle catch monitoring program: Community monitoring datasheet

Appendix B: Catch-monitoring datasheet

Fill in 1 datasheet per animal (**if no dugongs or turtles were caught, fill in the other details for the trip**).
To be filled in my one member of the hunting party only.

HUNTING DETAILS: **Date:** ____/____/_____ (Day / Month / Year)

Code number of hunter: _______________

Number in hunting party: ______________

CATCH DETAILS: (Use a separate sheet for each animal)

What type of DUGONG, if any, did you catch:

Type	**Sex**	**Pregnant female?**	
Adult ☐	Female ☐	Yes ☐	**Time caught:** ___________________________
Youth ☐	Male ☐	No ☐	**How far from the island where you live:** ____ _____________________________________**km**
Calf ☐			**Guess size:** _________ cm

What type of GREEN TURTLE, if any, did you catch (Use a separate sheet if you also caught a dugong and have filled in the information for dugongs on this sheet)**:**

Type	**Sex**	**webud?**	
Waru ☐	Female ☐	Yes ☐	**Time caught:** ___________________________
Murai ☐	Male ☐	No ☐	**How far from the island where you live:** ____ _____________________________________**km**
Waru kas ☐			**Measure size:** ________ cm **Tag number:** _________

What equipment did you use for the hunt?
Dinghy & clinker ☐ Dinghy only ☐ Dinghy and spotlight ☐ Wap ☐ Hand catch ☐
Hook (turtle) ☐

Catch rate:
Today, what time did you: Start your trip? ____________ Finish your trip? ___________

How many hours did you spend hunting? ____________ (including looking for dugongs and turtles)

What did you set out to catch today?
Dugong ☐ Turtle ☐ Crayfish ☐ Fish ☐ Other __________________________

What was the purpose for hunting today?

Tombstone unveiling	☐	Funeral	☐
Wedding	☐	Initiation ceremony	☐
Shaving ceremony	☐	Coming of age ceremony	☐
Kai Kai	☐	Other (please say what) _______________________	

Did someone else ask you to hunt for them today? Yes ☐ No ☐
How many people? ________

How many people did you share your personal Turtle or dugong with? ________________

Comments:____

____

If you have any questions, please contact one of the research team:
Insert names and phone numbers.

Appendix C: Sampling Exercise

There are 30 hunters in the community. The community caught 36 dugongs.

1	0	a	b	16	0	c	d
2	8			17	0		
3	0			18	0		
4	0			19	1		
5	0			20	7		
6	0			21	13		
7	0			22	0		
8	0			23	2		
9	0			24	0		
10	0			25	0		
11	2			26	0		
12	0			27	0		
13	0			28	1		
14	0			29	1		
15	0			30	1		

a. Only 2 hunters reported their catch.
One hunter caught 0 dugongs and the other hunter caught 8 dugongs.

Use proportional projection to calculate the total number of dugongs caught by the community:

1. Calculate the average number of dugongs caught per hunter:
   - Add up the number of dugongs reported:

     0 + 8 = 8 dugongs
   - Divide the number of dugongs reported by the number of hunters that reported them:

     8 dugongs/2 hunters = 4 dugongs per hunter
2. Multiply the average number of dugongs per hunter by the total number of hunters in the community:

   4 dugongs per hunter x 30 hunters in the community= <u>120 dugongs</u>

In this case the catch was over-estimated.

b. Half (i.e., 15) of the hunters reported their catch
One hunter caught 8 dugongs, one hunter caught 2 dugongs and the rest caught 0 dugongs.

Use proportional projection to calculate the total number of dugongs caught by the community:

1. Calculate the average number of dugongs caught per hunter:

- Add up the number of dugongs reported:

0+8+0+0+0+0+0+0+0+0+2+0+0+0+0 = 10 dugongs

- Divide the number of dugongs reported by the number of hunters that reported them:

10 dugongs/15 hunters = 0.67 dugongs per hunter

2. Multiply the average number of dugongs per hunter by the total number of hunters in the community:

0.67 dugongs per hunter x 30 hunters in the community= <u>20 dugongs</u>

In this case the catch was under-estimated, but it was closer to the real catch than when only two hunters reported their catches.

c. Half (i.e., 15) of the hunters reported their catch (but they are different hunters from b).

One hunter caught 13 dugongs, one hunter caught 7 dugongs, one hunter caught 2 dugongs, four hunters caught 1 dugong and the rest caught 0 dugongs.

Use proportional projection to calculate the total number of dugongs caught by the community:

1. Calculate the average number of dugongs caught per hunter:
   - Add up the number of dugongs reported:

     0+0+1+7+13+0+2+0+0+0+0+0+1+1+1 = 26 dugongs

   - Divide the number of dugongs reported by the number of hunters that reported them:

     26 dugongs/15 hunters = 1.7 dugongs per hunter

2. Multiply the average number of dugongs per hunter by the total number of hunters in the community:

1.7 dugongs per hunter x 30 hunters in the community= <u>52 dugongs</u>

In this case the catch was over-estimated. It makes a difference which hunters are participating. This sample of 15 hunters included more top hunters than the sample of hunters at b so the estimate was larger.

d. All (i.e., 30) of the hunters reported their catches

One hunter caught 13 dugongs, one hunter caught 8 dugongs, one hunter caught 7 dugongs, two hunters caught 2 dugongs, four hunters caught 1 dugong and the rest caught 0 dugongs.

Count the number of dugongs caught:

0+8+0+0+0+0+0+0+0+0+2+0+0+0+0 0+0+1+7+13+0+2+0+0+0+0+0+1+1+1 = 36 dugongs

If everyone reports their catch we get the true catch