Marine protected area management costs: an analysis of options for the Coral Sea

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Executive Summary

This study reviews the existing costs of marine park management in Australia and overseas. We define management costs as the costs associated with maintenance of established protection zones for marine waters and offshore islands. After providing background information on the scientific knowledge about management costs, existing reserves and current management of the Coral Sea, and cost of managing the Great Barrier Reef, the report then examines three scenarios for the Coral Sea Conservation Zone regarding management requirements and costs: a network of no-take reserves (30%) in a multiple-use zoned park; three smaller no-take areas, together comprising 30% of the area, and managed as separate parks; and a single large no-take reserve. The intent of this report is to explore the magnitude of management costs associated with these different zoning configurations for the Coral Sea. The report is not meant to advocate for any particular scenario nor does it present the establishment costs and benefits associated with different scenarios.

We investigated two methods of estimating management costs for a Coral Sea MPA. The first is to examine the current operational budgets for Commonwealth MPAs and, through statistical modeling, identify key predictors for management costs within these reserves. The second method was to identify management requirements for the Coral Sea and estimate costs for these activities based on expert interviews and informed by existing operating costs for GBRMPA and QPWS.

Using multiple-regression we estimated an equation to predict the management cost per hectare. We found that the management cost per hectare decreases with the area of the MPA but then increases again; is lower for MPAs that have been gazetted longer; lower for areas that have special purpose zones; and higher for MPAs with larger areas in IUCN Categories III to VI. Yearly management costs estimates range from $2.7 million for the no-take scenario, to $17.6 million for the multiple MPA scenario. Over the course of 20 years, the difference between the most expensive and least expensive management option would be about $430 million. While our model is notably limited by the number of available data points, 100% of funded Commonwealth MPAs with suitable data have been included. Therefore, although the number of points is small, it is representative of current funding levels and management arrangements in Australia.

In line with the results of the statistical model, the expert-based estimate indicates that a complete no-take area in the Coral Sea would be less expensive to manage than several smaller (30% total) no-take areas. These estimates are the same order of magnitude as the top-down estimate, although the 100% scenario is more costly and the 30% scenario less costly in the bottom-up approach. Compliance-related activities comprise the biggest proportion of the bottom-up management cost estimates.

Our results are indicative of the relative differences in management costs between full no-take and smaller no-take scenarios: 100% no-take is the least expensive management option. We have less confidence, however, in the specific management cost estimates. Because the Coral Sea is so much larger than other Commonwealth marine reserves and the GBRMP, the data points used to estimate the management cost of the Coral Sea may not be indicative of the management costs of such a large area. A detailed assessment of the management needs, together with a full risk assessment, would have to be undertaken for the Coral Sea to obtain more accurate management cost estimates.

1. Background

In May 2009, the Federal Environment Minister announced the declaration of a Coral Sea Conservation Zone over 972,000 km^2 of the Coral Sea, between the Great Barrier Reef Marine Park and Australia's maritime boundary with Papua New Guinea, the Solomon Islands and New Caledonia.

A collaboration of groups and individuals is proposing that this entire area be placed in a permanent marine reserve under the *Environment Protection and Biodiversity Conservation Act 1999*, after an assessment of the biodiversity values of the area has been carried out. The collaboration is proposing that the entire reserve be zoned as 'no-take'. As the EPBC Act refers to the IUCN reserve categories, this could mean a mixture of IUCN 1a, 1b and possibly II, provided that II is interpreted as a ban on recreational fishing. The single large no-take approach is in contrast to the multiple-use zoning approach used in the Great Barrier Reef Marine Park, which is a more intensively used area.

This study reviews the existing costs of marine park management in Australia and overseas. It then examines three scenarios for the Coral Sea Conservation Zone regarding management requirements and costs: a network of no-take reserves in a multiple-use zoned park; three smaller no-take areas, together comprising 30% of the area, and managed as separate parks; and a single large no-take reserve. The intent of this report is to explore the magnitude of management costs associated with these different zoning configurations for the Coral Sea. The report is not meant to advocate for any particular scenario nor does it present the establishment costs and benefits associated with different scenarios.

2. Scientific knowledge about MPA management costs

In this report, we focus on management costs of MPAs. We define management costs as the costs associated with maintenance of established protection zones for marine waters and offshore islands. These include the costs associated with control of invasive species, enforcement, monitoring, outreach and education.

However, other potential costs are associated with establishing MPAs: acquisition costs, transaction costs, and opportunity costs (see Naidoo *et al.* 2006). The framework that outlines these costs was developed for terrestrial systems (Naidoo *et al.* 2006), but is generally applicable to marine environments (Ban & Klein In press). *Acquisition costs* – akin to purchasing land – are atypical in the marine environment because waters are not usually privately owned. *Transaction costs* are those associated with negotiating protection, such as the time and staff involved in stakeholder negotiations. *Opportunity costs* are forgone revenues, such as the extractive value to fisheries and other marine uses (Naidoo *et al.* 2006). Another category of costs from the terrestrial realm are *damage costs*, associated with damages to economic activities due to conservation activities (e.g., elephants trampling fields) (Naidoo *et al.* 2006); there are no reports of such costs in the marine environment (Ban & Klein In press).

The benefits of MPAs – through improved ecosystem services – may be greater than the establishment and management costs, but such benefits are not usually considered (Balmford et al. 2004; Bhat 2003; Gravestock et al. 2008). For example, Bhat et al. (2003), using non-market valuation methods, found that visitors would undertake 43-80% more trips as a result of habitat improvements due to a marine reserve. Therefore the annual management costs would constitute an insignificant portion – about 2% – of the annual recreational benefits the marine reserve would generate (Bhat 2003). Visitor fees can also offset the cost of management (Reid-Grant & Bhat 2009; Teh et al. 2008). While the benefits – economic and other – are important, this report focuses only on management costs because of the uncertainty in benefits and the highly variable nature of estimates based on methods applied (e.g., Jason et al. 1994),

2.1. Data and literature on management costs of MPAs

Several different kinds of information can elucidate management costs of MPAs. First, management costs of existing MPAs within and outside Australian waters can provide an indication of financial needs of management of MPAs. In particular, the management cost per unit area can be used to extrapolate indicative costs for new MPAs. Second, existing statistical models of factors associated with MPA costs can be applied to obtain an estimate of

management costs (e.g., see discussion of Balmford et al. 2004 below). Third, data on management costs and potential drivers of those costs can be used to build new models that are more relevant to the local context than application of global management cost models would be. We applied this approach (section 8.1) because it allows us to base our management cost estimate on relevant drivers and costs from Australian MPAs (Commonwealth and the Great Barrier Reef Marine Park). Finally, specific management needs and projects can be outlined and budgeted for. We also applied this approach (section 8.2).

The scientific literature provides some guidance on the management costs of MPAs. A systematic literature review using the ISI Web of Knowledge database (search terms: ("marine protected area*" or "marine reserve*) and ("cost of management" or "management cost*" or "running cost*")) revealed only five publications, four of which provide estimates of management-related costs (Balmford et al. 2004; Bhat 2003; Gravestock et al. 2008; Teh et al. 2008). Bhat (2003) used non-market valuation to evaluate alternative management proposals for funding the Florida Keys marine reserve program, and found that the management cost would constitute an insignificant portion (~2%) of annual recreational benefits that the marine reserve would generate; but the paper does not provide guidance for estimating management costs. Teh et al. (2008) review a private management approach of an MPA in Malaysia, and conclude that conservation fees allowed private management to be effective at conserving biodiversity. Again, their study does not provide guidance on estimating management costs of MPAs. Other studies have identified drivers of management costs such as compliance, influence of poaching, fishers' perceptions of management and institutional arrangements (Byers & Noonburg 2007; Christie & White 2007; Dimech et al. 2009). While these studies have not explicitly estimated management costs of MPAs, they identify important considerations for identifying the types of management actions that may be required and the costs associated with them.

Global estimates of MPA management costs link back to one study (Balmford et al. 2004). Their global analysis of annual MPA running costs revealed that, per unit area, bigger MPAs cost substantially less to run per unit area than smaller ones (Balmford et al. 2004). In addition, MPAs close to inhabited land and where cost structures are high (e.g., where property, infrastructure costs, and salaries are high) cost more to manage (Balmford et al.

2004). Economies of scale mean that larger MPAs achieve considerable management cost savings (Balmford et al. 2004). For example, a minimum level of staffing and infrastructure may be required for any MPA, but the same minimum personnel may be sufficient to manage a large area, perhaps with additional fuel expenses. Therefore the management cost per unit area is much less for larger MPAs. The higher cost of managing MPAs closer to inhabited land was independent of the number of people living within 50 km (Balmford et al. 2004). Balmford et al. do not provide an explanation of this relationship. We speculate that proximity to inhabited land serves as a surrogate for accessibility, and hence visitor numbers to MPAs and fishing in surrounding areas is likely higher. Higher usage numbers of MPAs and surrounding waters likely results in increased permitting and enforcement costs. Gravestock et al. (2008), using data from the survey by Balmford et al. (2004), attempted to build an explanatory model of the income requirements of MPAs, and also found that area and visitor numbers were the most important drivers of minimum income requirements (Gravestock et al. 2008).

A global approach to estimating MPA management costs has several limitations. The resolution is coarse (global), and therefore regional or local drivers of costs may be missed. Information limitations also meant that the Balmford et al. (Balmford et al. 2004) study did not account for the level of protection and zoning arrangements within MPAs. In addition, using current management budgets to extrapolate costs assumes that these MPA budgets are sufficient. Globally most MPA managers (~85%) indicated that their current funding was inadequate for effective conservation (Balmford et al. 2004).

The Conservation and Community Investment Forum (http://www.cciforum.org/) created a tool to assist in financial management of MPAs (http://ccif-test.digitalclouds.net/costmodel/authentication/login). The tool is intended to assist in designing comprehensive, bottom-up budgeting and cost forecasting models for individual MPAs. The user has to provide estimates of personnel, contractors, fuel needs, etc. (Conservation and Community Investment Forum (CCIF) 2008). The model does not provide an estimate of costs based on modeled relationships. Unfortunately this model does not help in situations where knowledge about specific MPA management needs (e.g., staffing levels, equipment requirements) is lacking. The tool could complement current risk analysis and budget allocation strategies currently employed by Australian agencies such as QPWS and

GBRMPA. However, for our analysis, a comprehensive risk analysis of the Coral Sea is not feasible and therefore we have not utilized such tools.

2.2. Management of islands and islets

Islands and islets warrant particular attention in discussions about management costs because management of islands and islets is typically much more active than in the surrounding waters. Small islands and islets are often included within marine protected areas, yet management activities required for islands and islets are different from marine systems. Islands and islets frequently harbor sensitive species (e.g., seabirds, sea turtles) (Congdon et al. 2007; Turner & Batianoff 2007). Invasive species on islands (e.g., cats, rats) can be particularly destructive for sensitive species such as seabirds and sea turtles. Eradication of such invasive species involves (often expensive) eradication programs (Simberloff 2001). Invasive invertebrate species are also problematic. Examples include the African big-headed ant, which is affecting Pisonia forests on Great Barrier Reef and Coral Sea islands (Hoffmann & Kay 2009; Hoffmann & Parr 2008). Other potential management actions necessary for islands and islets include enhanced visitor management to protect the sensitive nature of island ecosystems, and fire management. Due to the sensitivity of island ecosystems and the required land management actions, MPAs with active island management are expected to have higher costs than those MPAs with no islands.

3. Existing marine reserves in the Coral Sea

In this section, we describe the existing marine reserves in the Coral Sea Conservation Zone and the Commonwealth and Queensland management arrangements for those reserves; and we identify the current costs of managing the existing reserves, including monitoring and enforcement, based on available information. Where possible, we estimate quantitatively or discuss qualitatively the shortfall of current management budgets to adequately manage marine reserves in the Coral Sea Conservation Zone.

3.1 Description

Two marine reserves currently exist in the Coral Sea, the Coringa-Herald National Nature Reserve (www.environment.gov.au/coasts/mpa/coringa) and the Lihou Reef National Nature

Reserve (www.environment.gov.au/coasts/mpa/lihou). Collectively they are known as the Coral Sea National Nature Reserves. Both reserves are no-take areas that have the highest level of protection, Category Ia. They were designated in 1982, and are of similar sizes (885,249 hectares and 843,670 hectares respectively) (Director of National Parks 2008).

The Coral Sea National Nature Reserves are both considered important and relatively pristine ecological areas. The Coringa-Herald National Nature Reserve has the only forested cays in the Coral Sea Islands Territory, and contains other vegetated islets and cays. The forested islets are particularly important for species of resident birds and migratory seabirds. The terrestrial habitat provides important breeding areas for the green sea turtle, while the reef habitats support benthic flora and fauna distinct from the Great Barrier Reef (www.environment.gov.au/coasts/mpa/coringa). The Lihou Reef National Nature Reserve does not have forested islets, instead containing the largest reef structure in the Coral Sea, also distinct in species composition from the Great Barrier Reef (www.environment.gov.au/coasts/mpa/lihou).

3.2 Management arrangements

Management arrangements are the same for both reserves. They are managed by the Marine Division of the Department of the Environment, Heritage and the Arts (now the Department of the Environment, Water, Heritage and the Arts, or DEHWA). Formal arrangements with other government agencies exist to carry out on-site management and surveillance. The Bureau of Meteorology (http://www.bom.gov.au/) collects weather information and stores an emergency cache at islands on both reserves. Coastwatch (http://www.customs.gov.au/site/page.cfm?u=4472) provides aerial surveillance of the reserves. Customs also provides compliance and enforcement of the Coringa-Herald National Nature Reserve; this service is not mentioned for Lihou Reef National Nature Reserve (Director of National Parks 2008). The management plans for the reserves do not provide an indication of the cost arrangements for these activities.

Monitoring efforts vary by reserve. Coringa-Herald National Nature Reserve has more active monitoring. Seabird monitoring began in 1991 and has run continuously with the help of volunteers. Research programs are underway to gain an understanding of the *Pisonia* forest ecosystem, terrestrial invertebrates, sea turtle ecology, and marine biodiversity. Subsurface

sea temperature loggers provide information for an ongoing temperature monitoring program. In contrast, the most recent marine survey carried out at the Lihou Reef National Nature Reserve was in 2004 by the Australian Institute of Marine Science (AIMS). Seawater temperature is also monitored by AIMS at Lihou. In both reserves, satellite imagery has been used to improve habitat information and bathymetric maps (Director of National Parks 2008).

3.3 Current cost of management

Only one of the two reserves has an operating budget. The operating budget of the Coringa-Herald National Nature Reserve was $202,756 in 2007-2008. The Lihou Reef National Nature Reserve had no operating budget in 2007-2008. It is unclear whether any management activities are taking place on Lihou Reef National Nature Reserve. The Marine Division of DEHWA spent $729,524 across the 26 Australian Commonwealth marine reserves in 2007-2008 to pay for professional services, permits and performance assessment systems, training, communications, workshops and conference attendance, surveillance and enforcement activities (Director of National Parks 2008).

4. Current management of the Coral Sea outside marine reserves

In this section, we identify the activities and, where possible their costs, of Australian and Queensland government authorities related to management of those parts of the Coral Sea Conservation Zone outside marine reserves (e.g. for regulation of commercial fishing, recreational fishing, tourism and shipping), focusing particularly on those activities likely to be reduced by complete no-take zoning in the Coral Sea.

4.1 Activities

Commercial fisheries

According to the East Marine Bioregional Plan (Australian Government 2009),

> "Data on the costs and net returns of the Region's fisheries is patchy and incomplete and is subject to a number of external influences such as world seafood market prices and fluctuations in the value of the Australian dollar against major currencies. However, available data, the high level of latency and low Gross Value of Production (GVP), suggest that fisheries in the Region generally appear to have either a low or

negative return on investment (ABARE 2007b, Moore et al. 2007, Newton et al. 2007)."

The East Marine Region extends beyond the Coral Sea, and includes the waters off New South Wales (see Figure 1 and 2 for annual total catches and GVP, respectively).

The tonnage and value of commercial catches in the East Marine Region have declined over the past decade, and some allocated catch is not being used (Australian Government 2009). Recent policies were aimed at increasing the profitability of the fishery through license buy-back and adjustments to reduce fishing effort (Australian Government 2009).

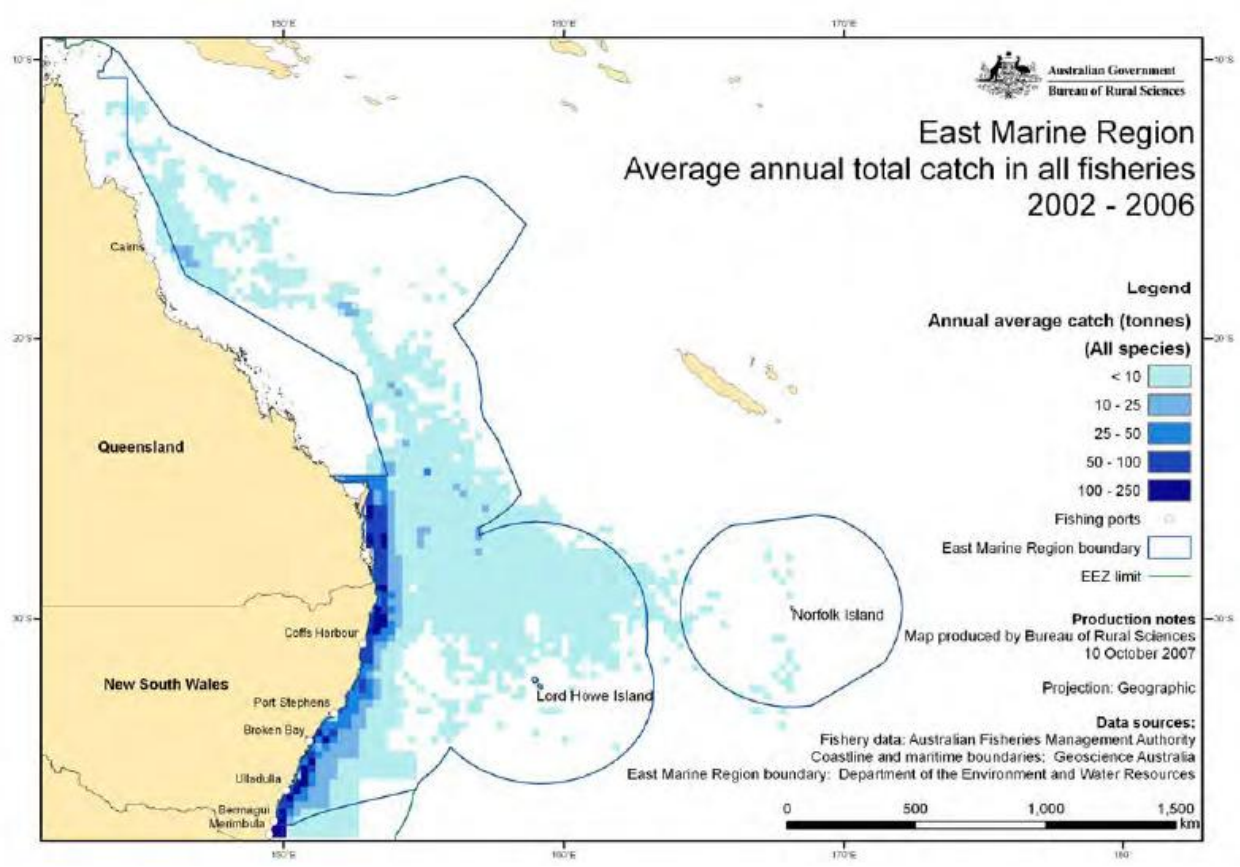

Figure 1. East Marine Region average annual total catch in all fisheries. Map taken from (*Moore et al.* 2007), p.v

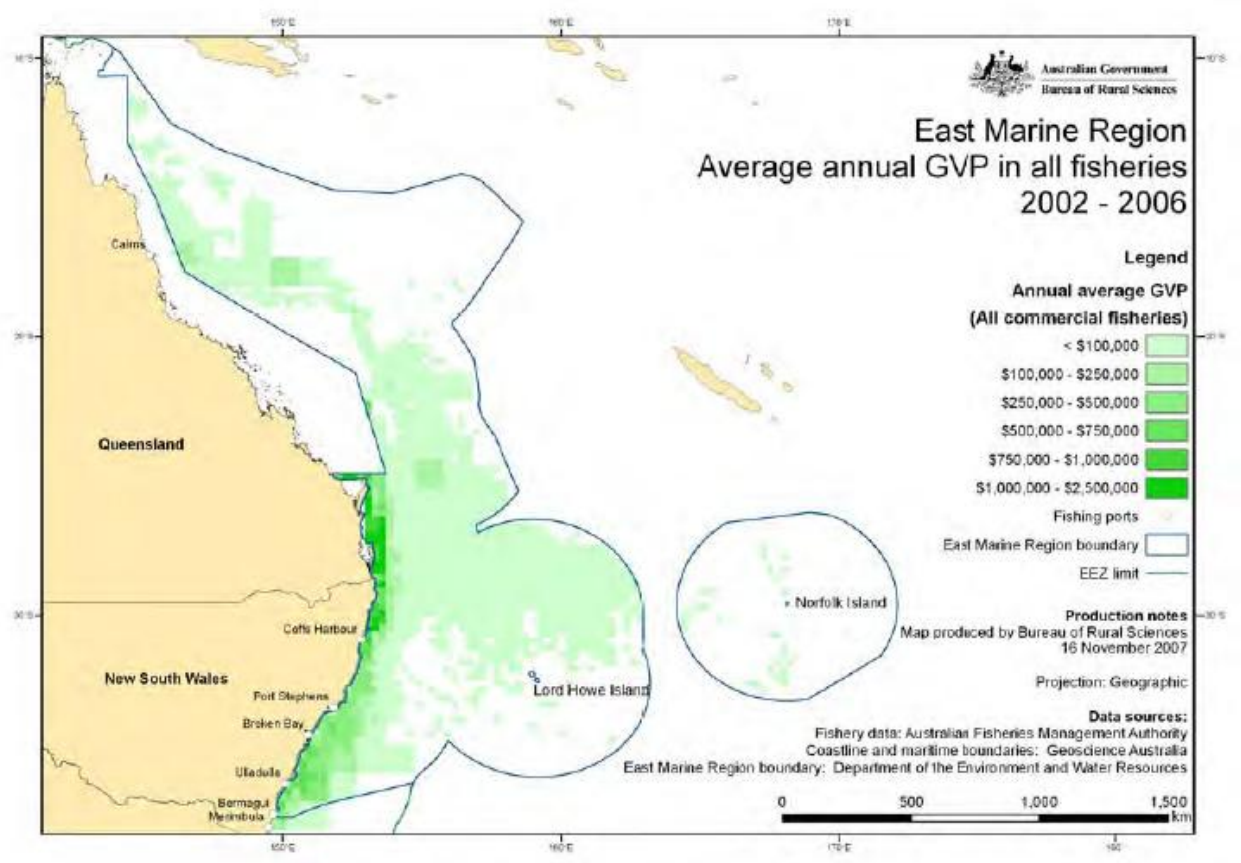

Figure 2. Average annual gross value of production in the East Marine Region. Map taken from (*Moore et al.* 2007), p.vi.

Commercial fishing in Commonwealth waters – Australian Government

A management brief by the Australian Fisheries Management Authority (AFMA) indicated that the annual gross value of production (GVP) of fishing from Commonwealth fisheries in the East Marine Bioregion, north of 24° 29' 54" S, ranged between AU$6.5 million and AU$14.4 million over the period 2002 to 2006 (AFMA 2008). With the exception of the Eastern Tuna and Billfish Fishery and the Coral Sea Fishery, fishing effort, catch and GVP has been very low over the period 2002 to 2006 (Table 1).

Table 1. Gross value of production estimates for the East Marine Bioregion, north of 24° 29' 54" S (Source: AFMA 2008)

Fishery name*	**2002 GVP ($'000)**	**2003 GVP ($'000)**	**2004 GVP ($'000)**	**2005 GVP ($'000)**	**2006 GVP ($'000)**	**average GVP ($'000)**
Coral Sea	574.5	825.3	875.9	1,551.1	503.0	866.0
Eastern tuna and billfish (includes small amounts of southern bluefin tuna)	13,800.0	7,900.0	5,600.0	6,000.0	9,600.0	8,580.0
Total	**14,374.5**	**8,725.3**	**6,475.9**	**7,551.1**	**10,103.0**	

* No fishing occurred in the Eastern Skipjack Fishery over these years.

The Coral Sea Fishery (CSF) targets a wide range of finfish species, with rosy jobfish, alfonsino and red emperor the three most common species by weight. The fishery consists of 18 fishing permits. The fishery landed about 192 tonnes of fish in 2006-7, the latest year for which data are available (http://www.afma.gov.au/fisheries/ext_territories/coral_sea/at_a_glance.htm). The estimated value was approximately $1.38 million. This fishery is managed by the Australian Fisheries Management Authority. Management arrangements are developed in consultation with stakeholders. The Coral Sea Fishery is a limited entry fishery, where harvest strategies include input and output controls. The overall status of the fishery is uncertain, and most stocks are not assessed.

The area of the Eastern Tuna and Billfish Fishery includes the Coral Sea. The principal species are yellowfin tuna, bigeye tuna, albacore tuna, broadbill swordfish, and striped marlin. There are 141 permits, and 53 vessels, with an estimated catch and value in 2007-8 of 6,452 tonnes and $31.960 million (data are for all of the fishing grounds, not just the Coral Sea) (http://www.afma.gov.au/fisheries/tuna/etbf/at_a_glance.htm). Management restrictions include input controls (restrictions on the number of hooks). The management method is being changed to output controls in the form of individually tranferable quotas (ITQs) and the allocation of statutory fishing rights. The status of the stocks varies: yellowfin and bigeye have overfishing occurring but are not overfished; the status of striped marlin and broadbill swordfish is uncertain; and albacore is considered underfished (http://www.afma.gov.au/fisheries/tuna/etbf/at_a_glance.htm). According to the East Marine Bioregional plan, the majority of effort occurs outside of the Coral Sea (i.e., in the southern portion of the East Bioregion, south of the Coral Sea Conservation Area Zone boundary) (Australian Government 2009).

The area of the Eastern Skipjack Tuna Fishery includes the Coral Sea. The Fishery targets skipjack tuna, and consists of 19 permits. The value of the fishery is considered low and variable. The fishery is not considered overfished or subject to overfishing (http://www.afma.gov.au/fisheries/tuna/skipjack/at_a_glance.htm). According to the East Marine Bioregional plan, the majority of effort occurs outside of the Coral Sea (Australian

Government 2009) (see also Table 1, which shows that there has been no effort in the Coral Sea from 2002 to 2006, the last year for which data were available).

The area of the Southern Bluefin Tuna Fishery includes the Coral Sea. There are 118 statutory fishing right owners. Almost all (~98%) of the quota is taken by 5-8 purse seine vessels fishing in the Great Australian Bight for juvenile bluefin tuna, which are then fattened in grow-out cages. The species is overfished globally. The fishery is managed through output controls comprising ITQs. Australia received a national quota allocation of 5,265 tonnes for the 2008-9 season. The estimated value for 2006-7 was ~$41 million (http://www.afma.gov.au/fisheries/tuna/sbt/at_a_glance.htm). According to the East Marine Bioregional plan, very little of this fishery occurs within the Coral Sea (Australian Government 2009) (see Table 1).

Commercial fisheries – Queensland government

Commercial fisheries in Queensland are managed by the Department of Primary Industries and Fisheries (http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/28_ENA_HTML.htm). The majority of Queensland fisheries operate in coastal waters. The East Coast Otter Trawl extends into the Coral Sea beyond the boundaries of the Great Barrier Reef Marine Park (Australian Government 2009), although it occurs in only a very small portion (southwestern corner) of the Coral Sea Conservation Zone. The Queensland deepwater finfish fishery is also permitted to operate in the Coral Sea east of GBRMP; its GVP in 2006 was $90,000. Several other Queensland fisheries are permitted to operate in the Coral Sea, but no effort has been observed there in recent years.

Recreational fisheries

Recreational and charter fishing is very popular in Queensland. Although few people fish in the offshore environment (i.e., the Coral Sea) relative to coastal waters, the contribution per fisher is higher because of the equipment requirements and charter costs associated with fishing in the open ocean (Australian Government 2009) (Figure 3). Charter fishing operations are regulated by the Department of Primary Industries and Fisheries (http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/28_ENA_HTML.htm).

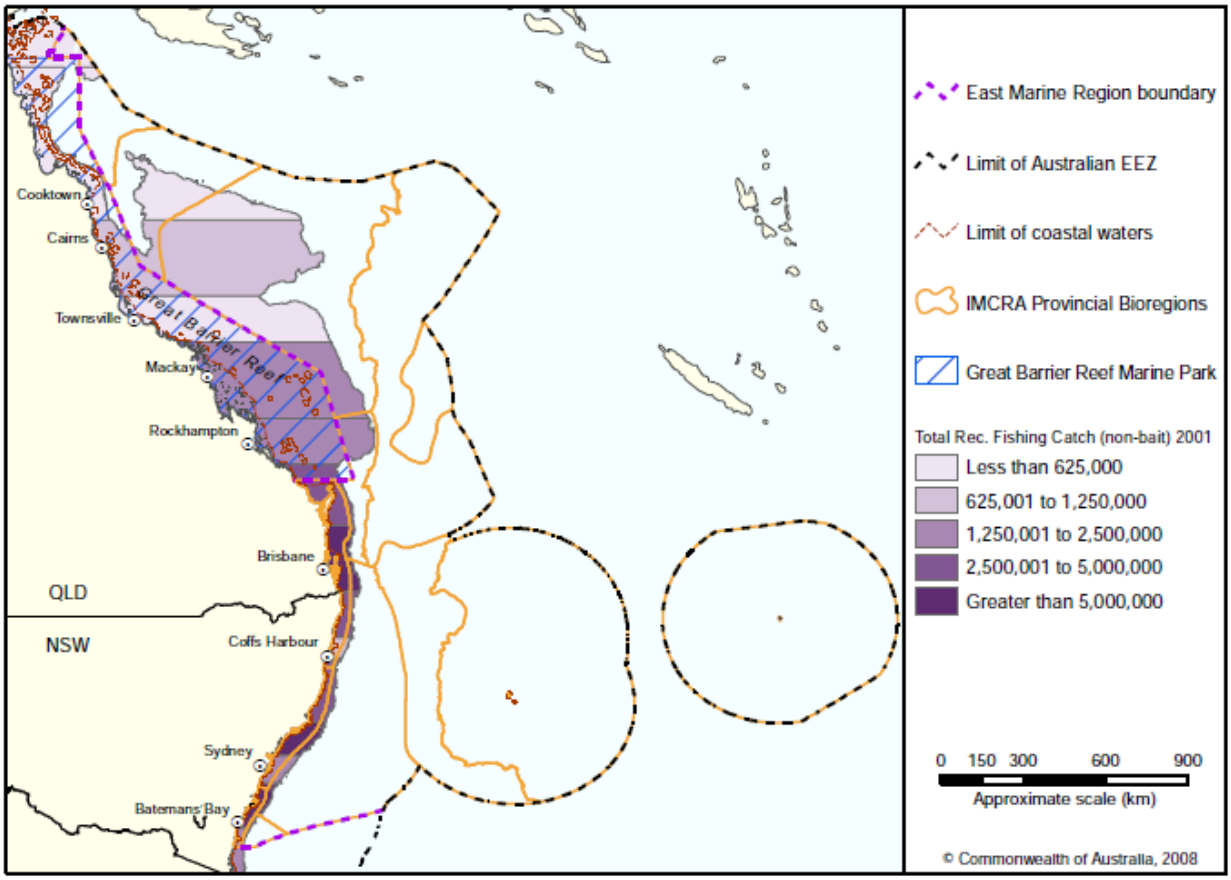

Figure 3. Number of fish caught by recreational fishermen in the East Marine region and adjacent waters. Figure copied from p.121 of the East Marine Bioregional Plan (Australian Government 2009).

Marine-based tourism

The Coral Sea is remote, and therefore few tourists visit it. There are, however, two scuba diving hotspots in the Coral Sea: Osprey and Shark reefs. Some diving also occurs at the Coral Sea National Nature Reserves, but the remoteness of these reserves results in few visitors (Australian Government 2009). Charter boats also visit the area for recreational fishing. Marine-based tourism may also take place in other shallow water features in the Coral Sea.

Cruise ships visit Willis Island, an island in the middle of the Coral Sea. This island is of interest to the cruise industry because under Australian Customs law it is legally outside of Australia; it is an external territory of Australia, about 420 km east of Cairns. This means that a cruise trip to Willis Island is considered an international voyage, and is therefore duty-free and GST free concessions apply (Australian Government 2009).

Shipping

The Coral Sea contains shipping routes that link Australia to Europe and Asia (Figure 4).

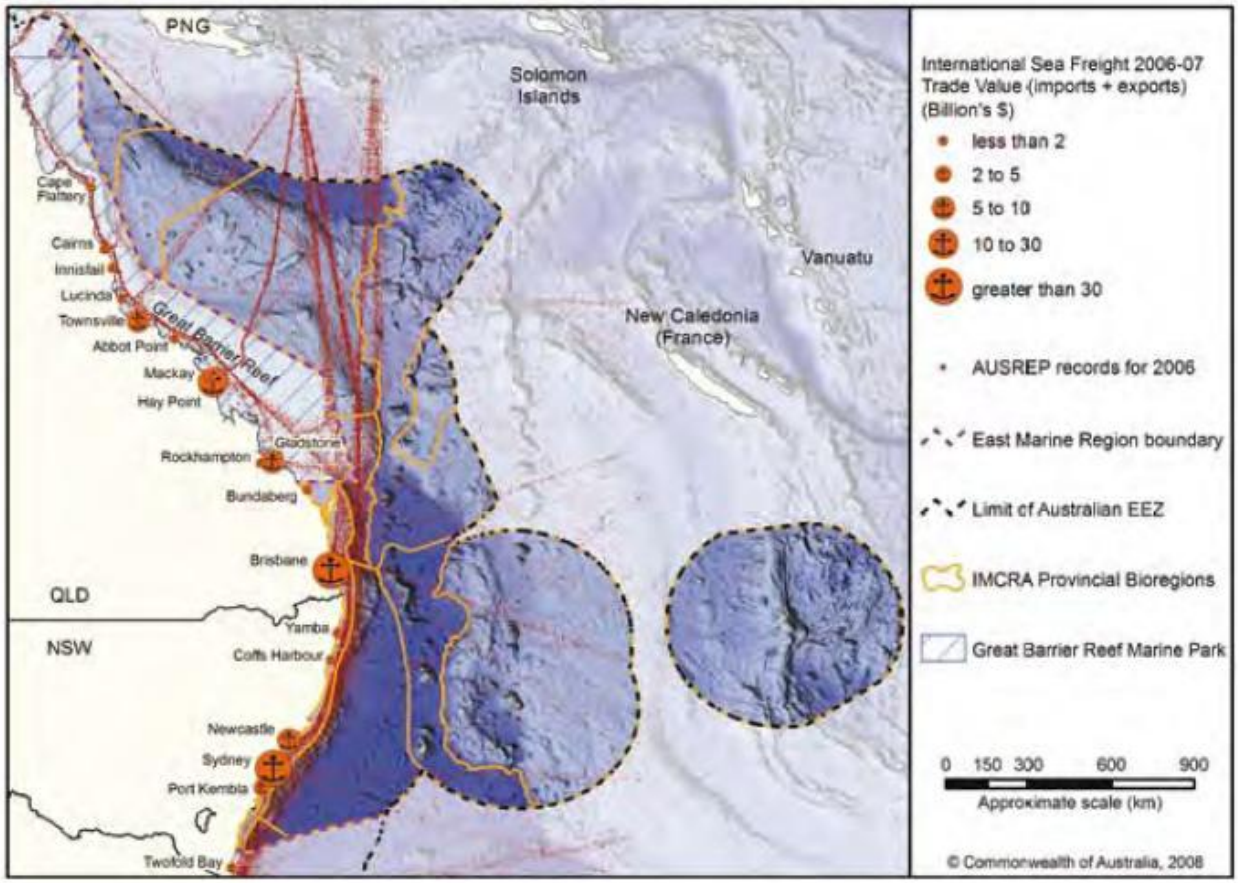

Figure 4. Shipping lanes in the East Marine Region and the International Sea Freight Trade Value of ports in state waters adjacent to the region. Map copied from The East Marine Bioregional Plan, p. 126 (Australian Government 2009).

4.2 Management costs

The management costs of activities taking place in the Coral Sea outside of the Coral Sea National Nature Reserves are difficult to determine. Budgets for agencies with management responsibilities are not categorized by region, making it impossible to gauge this information from annual reports or other existing documents.

5. Cost of managing the Great Barrier Reef

The purpose of this section is to obtain information on management costs of islands, marine no-take areas and other marine zonings in the Great Barrier Reef Marine Park (GBRMP) that

are directly relevant to the Coral Sea, i.e., that can, through extrapolation, inform estimates of management costs in the Coral Sea.

The Great Barrier Reef Marine Park Authority and the Queensland Parks and Wildlife Service (QPWS) are jointly responsible for the field management of the Great Barrier Reef Marine Park and World Heritage Area (http://www.gbrmpa.gov.au/corp_site/management/ddm). We reviewed annual reports of these agencies, and interviewed key individuals involved in management in these agencies. Additionally, individuals from AFMA were interviewed about fisheries compliance practices and issues. Managers at DEWHA declined our request for their participation in our study. To ensure confidentiality, identities of interviewed persons are not revealed. Interviews were conducted to gain additional insights into financial figures contained in annual reports, determine how resources are allocated, obtain opinions on the adequacy of those resources, and request suggestions for determining management costs of the Coral Sea scenarios.

The budget for GBR field operations (GBRMPA and QPWS) is about $17 million for 2009-2010, of which about $10 million are labour costs, the rest operating costs. The overall GBRMPA budget was about $45 million in 2008-9, the latest year for which an annual report was available at the time of writing. Expenses in 2008-9 fell into the following categories: employees (42%), suppliers (28%), field management (27%), other (3%) (http://www.gbrmpa.gov.au/__data/assets/pdf_file/0009/41778/AR2008-2009.pdf). The focus in our discussions with managers was on the field operations component of management. Field management will be a particularly important aspect of management to consider for a proposed remote park such as the Coral Sea.

There are 12 field offices that carry out field management in the Great Barrier Reef region (previously called day-to-day management). As the GBRMPA website outlines, "the day-to-day Management Program guides the field operations and routine day-to-day activities required for the management of the Great Barrier Reef Marine Park and World Heritage Area. The Day-to-day Management Program is primarily delivered through the QPWS by Marine Parks Officers— professional rangers and conservation staff working with industries and coastal communities" (http://www.gbrmpa.gov.au/corp_site/management/ddm).

Budgets are allocated based on priorities and risk assessments for each year. This means that budgets are not allocated geographically, or by zone type, or by specific projects. Extrapolating the details of the GBR field operations budget to the Coral Sea through spatially explicit modeling is therefore not feasible. (The bottom-up approach, however, uses GBR expenditures to estimate management costs of the Coral Sea.) Generally, though, no-take (green) zones are classified as higher risk areas, and therefore would be allocated more resources (e.g., enforcement personnel) than other types of zones.

We consistently heard that current resources are not adequate to ensure full compliance in the GBRMP. Evidence of inadequate resources comes from the much higher biomass in no-go (pink) zones than no-take (green) zones, of sharks for example (Robbins et al. 2006). Pink zones are easier to enforce, as no boat is allowed inside that zone's boundaries. Green zones, on the other hand, are more difficult to enforce, as boats are allowed inside these areas but, in principle, not to take fish or other organisms. In addition, increasing management challenges related to climate change require more resources than at present. For example, monitoring of bleaching events requires personnel on the water, and increasing temperatures are known to enhance problems of invasive species on islands, therefore necessitating additional management actions. Estimates by participants in interviews indicate that 2.5 to 3 times the current resources would enable sufficient field management presence to ensure compliance and allow for other management activities (e.g., visitor services).

Participants in interviews independently agreed on two suggestions for estimating management costs for the Coral Sea. First, they suggested that a bottom-up estimate of management costs would be more informative than a top-down (modeled) estimate based on management costs of other marine reserves. By bottom-up estimate, we mean an approach that takes into account the management actions and line items that might be necessary for managing the Coral Sea. The top-down approach refers to a modeling exercise of extrapolating management budgets of existing marine reserves and cost drivers to estimate management costs of the Coral Sea. We have followed this recommendation, and have added a section on bottom-up estimates of management costs. However, a comprehensive bottom-up approach using a risk assessment approach for management planning (i.e., identify threats, treatment for those threats, priorities) is beyond the scope of this report.

Second, participants indicated that cost savings would likely be substantial if management of the Coral Sea (should a reserve be implemented) were carried out by existing management agencies with experience in the region, i.e., as per the current arrangement between GBRMPA and QPWS for field management. In particular, duplicating expertise, such as pest management in Pisonia forests on the islands in the Coral Sea, would be expensive and inefficient. It would be much preferable to add staff to the existing management arrangement, and assign tasks to current and new staff based on expertise (i.e., experts in Pisonia management would manage islands within the GBRMP and the Coral Sea). Participants indicated that extending the current arrangement of field management of the GBR to the Coral Sea, with addition of sufficient resources, might be viewed favorably by those agencies.

Participants also agreed on a couple of themes regarding the management options of one large no-take zone versus several smaller no-take areas. First, participants indicated that several smaller marine reserves (even if these were still very large, given the large area of the Coral Sea) would be more difficult and more costly to enforce. While all commercial fishing can be mandated to carry vessel monitoring systems (VMS), if some fishing is allowed in the area, ensuring that no-fishing areas are not illegally fished will require active monitoring. Also, most of the commercial vessels that fish in the Coral Sea are longline vessels. The longline gear, which can extend many kilometers, drifts in the water. Therefore remotely monitoring the location of fishing vessels does not necessarily indicate the location of that vessel's fishing gear, resulting in enforcement challenges. Similarly, participants suggested that designating the Coral Sea as a no-go zone for fishing vessels would be much easier to enforce than allowing access similar to green zones in the Great Barrier Reef Marine Park. If the Coral Sea is closed to fishing, fishing vessels should not need to be within the area. If such a need arose, a permitting system could be set up to allow for transiting permits, which should require a minimum vessel speed to be maintained (so that fishing while transiting is not feasible).

6. Analysis of costs outside GBR

6.1 Commonwealth marine reserves

The purpose of this section is to analyse the current costs per km^2 for management of a representative set of Commonwealth marine reserves outside the Great Barrier Reef Marine Park. Based on available information, we identify the factors that influence the costs of managing these reserves, such as complexity of management issues and intensity of use by recreational and commercial fishers.

The Australian government manages marine protected areas as Commonwealth reserves under the *Environmental Protection and Biodiversity Conservation Act 1999*. At present, 26 MPAs covering almost 50,000,000 hectares comprise the Commonwealth MPA system (http://www.environment.gov.au/coasts/mpa/commonwealth/manage/index.html), including the two marine reserves in the Coral Sea. Management measures within these MPAs range from general use zones (IUCN Category VI) to strict protection zones (IUCN Category I) (Director of National Parks 2008). The largest single Commonwealth marine reserve is the Macquarie Island Marine Park with 16 million hectares (5.7 million hectares as IUCN Category I, and 10.5 million hectares as IUCN Category IV). The largest Commonwealth marine reserves network is the South-east Commonwealth Marine Reserve Network with 22.6 million hectares contained within 13 new reserves, plus the Macquarie Island Marine Park. The network provides a range of protection measures (IUCN Category I to VI). This area within this network is smaller than the area of the Coral Sea (97.2 million hectares) (http://www.environment.gov.au/coasts/mpa/southeast/index.html). The South-east Marine Reserve Network was established in 2007. A management plan for these MPAs has not yet been developed, and management budgets are not yet assigned by MPA (http://www.environment.gov.au/coasts/mpa/southeast/arrangements.html).

Of the 12 Commonwealth marine reserves outside of the South-east Commonwealth Marine Reserve Network, 10 have operating budgets and two do not. We were unable to ascertain whether management actions are not considered necessary for these two reserves, or whether they were a lower priority and hence received no budget. The 14 MPAs comprising the South-east Commonwealth Marine Reserve Network do not yet have a management plan, and only one combined budget is given. Therefore, they were excluded from our analysis due to

difficulty in assigning predictors for the aggregated reserve network. Therefore we had 10 operating budgets for marine reserves available for our analysis (Table 2).

Table 2. Commonwealth marine reserves and their operating costs.

Marine protected area	Year declared	IUCN category	Area per zone (hectares)	Total area (km^2)	Operating costs 2007-2008*	Operating costs per km^2
Ashmore Reef National Nature Reserve	1983	Ia - Sanctuary Zone;	54,991	583	$ 49,730	$ 85.25
		II - Recreational Use Zone	3,346			
Cartier Island Marine Reserve	2000	Ia - Sanctuary Zone	17,238	172		NO BUDGET
Cod Grounds Commonwealth Marine Reserve	2007	Ia - Sanctuary Zone	314	3	$ 103,233	$ 32,876.75
Coringa-Herald National Nature Reserve	1982	Ia - Sanctuary Zone	885,249	8,852	$ 202,756	$ 22.90
Elizabeth and Middleton Reefs Marine National Nature Reserve	1987	Ia - Sanctuary Zone	143,146	1,880	$ 9,703	$ 5.16
		II - Habitat Protection Zone	44,850			
Great Australian Bight Marine Park (Commonwealth Waters)	1998	VI - Multiple Use Zone	1,940,000	19,372	$ 172,500	$ 8.90
Heard Island and McDonald Islands Marine Reserve	2002	Ia - Sanctuary Zone	6,465,845	64,658	$ 63,000	$ 0.97
Lihou Reef National Nature Reserve	1982	Ia - Sanctuary Zone	843,000	8,437		NO BUDGET
Lord Howe Island Marine Park (Commonwealth Waters)	2000	IV - Habitat Protection Zone	204,121	3,003	$ 52,233	$ 17.39
		Ia - Sanctuary Zone	96,166			
Mermaid Reef Marine National Nature Reserve	1991	Ia - Sanctuary Zone	53,987	540	$ 132,200	$ 244.87
Ningaloo Marine Park (Commonwealth Waters)	1987	II - Recreational Use Zone	243,513	2,435	$ 169,750	$ 69.71
Solitary Islands Marine Reserve (Commonwealth Waters)	1993	Ia - Sanctuary Zone	79	152	$ 93,300	$ 612.49

		IV - Habitat Protection Zone	3,746			
		VI - Multiple Use Zone	11,408			
South-east Commonwealth Marine Reserve Network**	2007	VI	38,851,700	388,517	$ 449,344	$ 1.16

* Separate line items were not provided for different zones in the marine reserve budgets. The first line item for each reserve includes management costs of all zones for that reserve.

** The aggregated budget for the South-east Commonwealth Marine Reserve Network is excluded in our regression analysis due to difficulty in assigning predictors for the aggregated reserve network. The individual MPAs that comprise this network are listed below.

South-east Commonwealth Reserve Network MPAs:	**Year declared**	**IUCN category**	**Area per zone (hectares)**	**Total area (km2)**
Apollo Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	118,360	1,184
Beagle Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	292,758	2,928
Boags Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	53,748	537
East Gippsland Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	413,664	4,137
Flinders Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	123,111	27,043
		Ia - Sanctuary Zone	2,581,195	
Franklin Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	67,077	671
Freycinet Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	82,649	57,942
		Ia - Sanctuary zone	5,679,269	
		II - Recreational use zone	32,330	
Huon Commonwealth Marine Reserve	2007	1a - Benthic Sanctuary	960,177	9,991
		VI - Multiple Use Zone	38,897	
Macquarie Island Marine Park	1999	Ia - Sanctuary Zone	5,713,710	161,895
		IV - Habitat Protection Zone	10,475,756	

Murray Commonwealth Marine Reserve	2007	VI - Multiple Use Zone	590,687	25,803
		VI - Special Purpose Zone	714,709	
		1a - Sanctuary Zone	1,274,916	
Nelson Commonwealth Marine Reserve	2007	IUCN VI - Special Purpose Zone	612,311	6,123
South Tasman Rise Commonwealth Marine Reserve	2007	IUCN VI - Special Purpose Zone	2,770,437	27,704
Tasman Fracture Commonwealth Marine Reserve	2007	IUCN VI - Multiple Use Zone	2,049,572	42,501
		IUCN VI - Special Purpose Zone	2,131,272	
		IUCN 1a - Sanctuary Zone	69,212	
Zeehan Commonwealth Marine Reserve	2007	IUCN VI - Multiple Use Zone	93,298	19,897
		IUCN VI - Special Purpose Zone	1,896,399	

It costs more per unit area to manage small reserves than it does to manage large reserves (Figure 5), and much more is spent managing terrestrial than marine reserves (Figure 5, Table 3). The disparity between land and marine management costs within the same agency is particularly striking (Director of National Parks 2008). The average cost per square kilometer of terrestrial reserve management is more than 700 times higher than that of marine reserve management (Table 3).

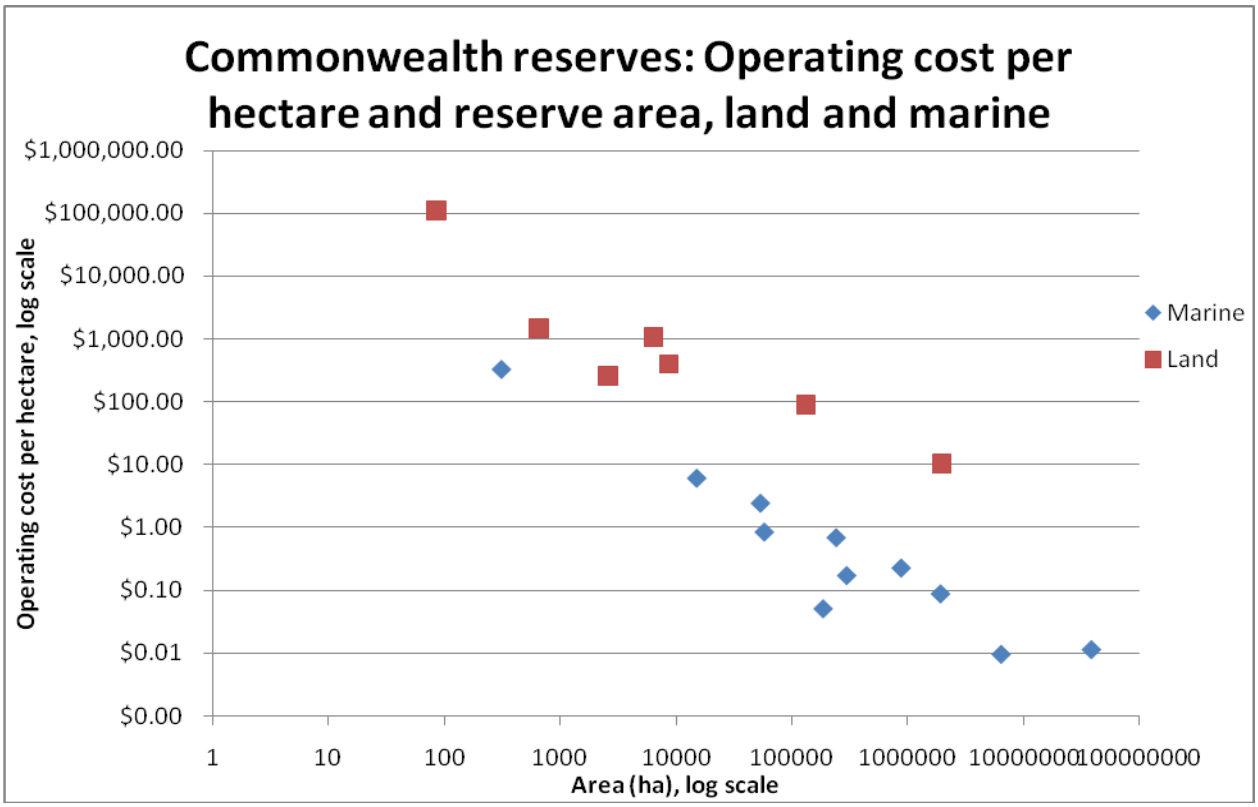

Figure 5. Operating cost per hectare and reserve area for terrestrial and marine Commonwealth reserves. Both axes are graphed on a log scale. Data from (Director of National Parks 2008).

Table 3. Mean cost per km2, 2007-8.	
Commonwealth marine reserves (incl. Coral Sea National Nature Reserves)	$ 4.47
GBRMPA	$ 134.40
Commonwealth land reserves	$ 2,868.49

We used the available characteristics for the existing 10 Commonwealth MPAs (the aggregated Southeast marine budget was excluded due to restrictions in determining

predictors apart from area) with annual management budgets to determine the driving factors for management costs. The predictors identified from the data are summarized in the table below (Table 4). These predictors are based on all readily available data for the MPAs. Additional predictors, such as distance from land and presence of islands, were considered as potential predictors for this analysis but not used. Distance from land has been used in previous regression analysis (Balmford et al. 2004). The current Commonwealth MPAs are all much closer to the coast than the Coral Sea Conservation Zone. Distance from coast may capture a reduced management cost for MPAs that are closer to shore for visitor management and monitoring costs, or an increased cost for inshore MPAs because of higher usage and related requirements for information and compliance. However, offshore MPAs may experience increased management costs for compliance and surveillance because of the larger distances that need to be travelled. Therefore, we felt that distance as a predictor may be confounding and chose to exclude it from our analysis. The presence of islands within MPAs is also likely to be a driver of management costs. Islands have additional management requirements such as management of invasive species, monitoring and protection of threatened species such as seabird and turtle nesting sites. However, due to data limitations we were unable to accurately assess the percent area of islands within the Commonwealth MPAs and therefore this predictor was also excluded from our analysis.

Table 4. Predictors of Commonwealth marine reserve operating costs

Predictor	Justification
Area of MPA on a log scale (log(ha))	Studies have indicated that management costs decrease as area increases due to scales of economy
Number of years since established (yrs_{est})	Initial management costs may be larger in order to provide outreach and education to ensure compliance and community support
Years since last gazettal ($yrs_{gazette}$)	Changes in designations and management may have similar effects as the initial establishment of the MPA requiring education and outreach to inform users of new zoning requirements etc
Percent area designated a recreational zone (pct_{rec})	Recreational zones may require additional operational budgets for maintenance, placement of facilities such as moorings and signs as well as additional park staff

Percent area designated a special purpose zone (pct_{sp}) (the management of special purpose zones varies; could be recreational zones, or fishing zones with gear restrictions)	Special purpose zones may require additional surveillance and compliance measures
Number of zones (num)	Multiple zones may indicate multiple management schemes to manage areas for different uses and therefore require more monitoring to ensure compliance
IUCN classification (IUCN)	IUCN classifications I and II may require more surveillance and enforcement to ensure compliance
Percent area not in IUCN Category I or II (pct_{other})	IUCN classifications other than I and II may require more surveillance and enforcement to ensure compliance

Using multiple-regression we estimated an equation to predict the management cost per ha on a log scale. The equation is:

$$\log(costperha) = 6.27 - 1.02\log(ha) - 0.0425\,yrs_{gazette} + 0.0195\,yrs_{est} + 0.552\,pct_{rec} + 2.07\,pct_{sp} - 0.632\,num - 0.529\,IUCN + 0.836\,pct_{other}$$

All predictors contribute to explaining the operating costs of Commonwealth marine reserves (i.e., all coefficients were significant with $p<.05$ and the R^2 value was 100%). The operating cost per hectare on a log scale is explained by the equations as follows: it decreases with the area of the MPA on a log scale; is lower for MPAs that have been gazetted longer; is slightly higher for MPAs that have been established longer; higher for areas with big recreational zones; higher for areas that have special purpose zones; slightly lower for MPAs with fewer zones; slightly lower for MPAs with strict protection (IUCN Category I and II); and slightly higher for MPAs with larger areas in IUCN Categories III to VI. Analysis of correlations between predictors showed that there are no confounding issues with correlations.

Although the explanatory power of equation above is extremely high (R^2 value was 100%), none of the MPAs included in the prediction approach the size of the Coral Sea. In the equation and Figure 5, the size of the Coral Sea would make it an outlier. Extrapolating the relationship between the operating cost on a log scale, and the size of MPAs on a log scale, would result in an operating cost approaching zero dollars per hectare for the Coral Sea,

which is clearly unrealistic. Because of this issue, our extrapolation of potential operating costs for the Coral Sea includes the Great Barrier Reef Marine Park (see section 8).

6.2 State marine parks

State and territory governments in Australia manage coastal marine parks. An inquiry into management of parks and reserves found that it is difficult to obtain information on resources allocated by states and territories to the management of parks and reserves (Government of Australia 2007). Although the inquiry recommended improving the tracking of expenditures on parks, the most recent annual reports do not reflect that recommendation, and obtaining funding levels remains a challenge. Most of the States and Territories do not report individual park budgets because state agencies are part of wider portfolios and expenditures are not tracked by park (Government of Australia 2007). We were therefore unable to include State or Territory park management costs in our analysis.

7. Management costs of large international offshore marine reserves

Large offshore international marine reserves may provide an indication of management costs for the Coral Sea Conservation Zone. Here we searched for large international offshore marine reserves managed by developed countries. We assumed that marine reserves managed by developing countries would have limited financial resources, and hence would not provide for a useful comparison (Balmford et al. 2004).

In early 2009, former President George W. Bush declared several large Marine National Monuments encompassing 505,000 square kilometers (Marianas Trench, Pacific Remote Islands, and Rose Atoll). While the sizes and remoteness of these National Monuments would provide for an ideal comparison for the Coral Sea, unfortunately none of these areas have management budgets yet.

In late 2009, the UK government launched a public consultation to establish a marine protected area in the British Indian Ocean Territory (http://www.fco.gov.uk/en/news/latest-news/?view=PressS&id=21156642). If successful, this could be a potentially very large no-take area. The consultation document outlines costs and benefits of establishing such a reserve, indicating that additional costs would be around 1 million pounds (~AUD $1,800,000) per annum for surveillance

(http://www.fco.gov.uk/resources/en/pdf/21153320/mpa-consultation-101109). This announcement, coupled with the large no-take areas established by the Bush administration, indicate a world-wide trend towards protecting large tracts of the ocean. Details about this cost estimate or not provided, and therefore it does not contribute to our cost estimation.

The Papahānaumokuākea Marine National Monument in Hawaii, USA, is one of the world's largest conservation areas, encompassing 105,564 square nautical miles (~360,000 square kilometers). It was designated in 2006. The management plan provides estimates of costs to achieve desired outcomes. These estimates are substantially above their current budget allocations (unfortunately their current budget is not listed in their public documentations). Their cost estimates include the following priorities: understanding and interpreting the area (22%), conserving wildlife and habitats (21%), reducing threats to Monument resources (12%), managing human uses (7%), coordinating conservation and management activities (8%), and achieving effective monument operations (30%). Over their 15-year time horizon, estimated annual costs start at US$38 million, and increase to US$78 million (years 6-10), with a subsequent drop to US$66 million (http://papahanaumokuakea.gov/management/mp/vol1_mmp08.pdf; table 3.1).

8. Analysis of management cost scenarios for the Coral Sea Conservation Zone

The purpose of this section is to draw on information from previous sections, list and analyze the management, monitoring and enforcement requirements and costs in the Coral Sea Conservation Zone over and above the existing arrangements and costs (as described in sections 1 and 2) for the following three scenarios:

a. A representative network of no-take zones that protect the reefs and seamounts within the Coral Sea Conservation Zone, and allow existing uses to continue within a multiple-used zone park, and is managed as one park with multiple zones;
b. Same as (a), but the no-take zones are managed as three separate parks; and
c. A single large no-take reserve that continues to allow non-extractive uses (e.g. dive tourism, shipping, defense activities).

We then analyze the differential cost of long-term management (i.e. 20 years) under each of these options.

We investigated two methods of estimating management costs for a Coral Sea MPA. The first is to examine the current operational budgets for Commonwealth MPAs and identify key predictors for management costs within these reserves. This methodology is similar to other studies estimating management costs (Balmford et al. 2004; Frazee et al. 2003), and we call it the "top down" approach. The second method was to identify management requirements for the Coral Sea and estimate costs for these activities based on existing operating costs for GBRMPA and QPWS. This method was recommended by participants in interviews, and we call it the "bottom up" approach.

8.1 Top down estimates for managing a Coral Sea MPA

We investigated the relationship between size and management cost per hectare for the existing Commonwealth MPAs with allocated budgets. The Coral Sea Conservation Zone is an order of magnitude larger than the largest Commonwealth MPA. Therefore, we assume that using models based only on the DEWHA managed Commonwealth MPAs would not be effective in predicting costs for a potential Coral Sea MPA because the Coral Sea would be an outlier in the data set. To correct for this we included the management costs per hectare of the Great Barrier Reef Marine Park (GBRMP). GBRMP is also an order of magnitude larger than any other Commonwealth MPAs and was therefore an outlier in the set of 11 MPAs. However, we feel that models derived using GBRMP in the dataset are more indicative and potentially able to predict costs for a Coral Sea MPA. (Note, though, that our interviews indicated that current funds for GBRMP are inadequate, and a global analysis (Balmford et al. 2004) showed this to be true globally. Our model is based on management budgets, why may be inadequate.) By including the GBRMP, we assume (1) that its cost structure is relevant to the Coral Sea; and (2) that there is a basis for assuming that economies of scale only stretch to a point, beyond which per unit area costs rise again. We performed an initial exploration of the relationship between cost per ha and the size of MPAs and identified that the shape of the relationship is best described by a polynomial regression (Figure 6).

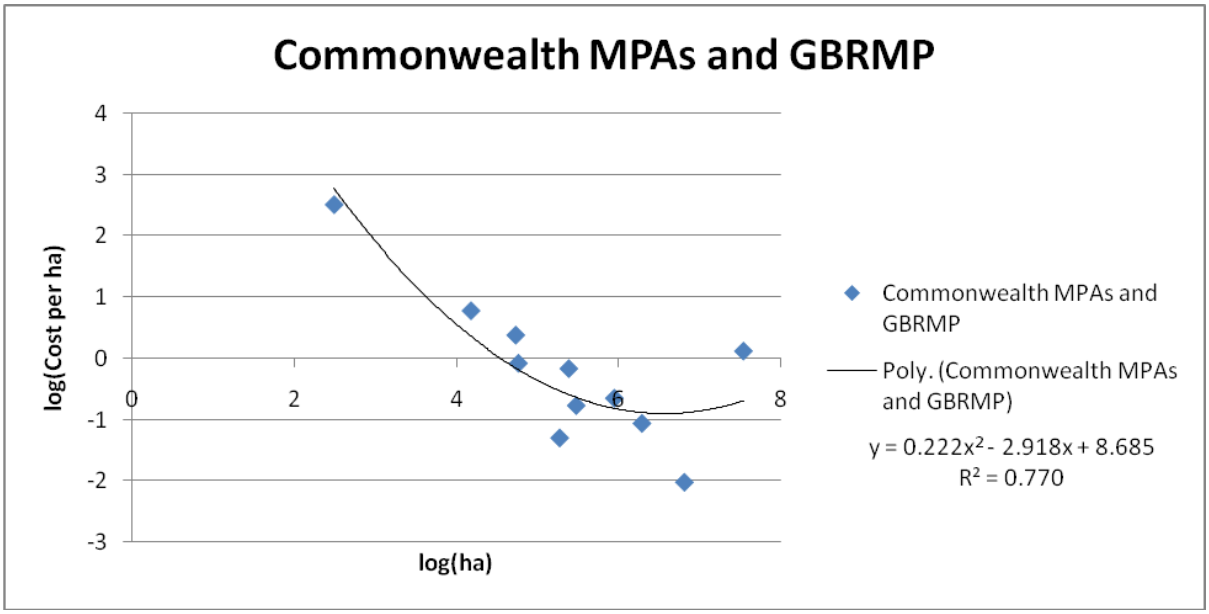

Figure 6. Polynomial relationship between log of cost per hectare and log of the size of MPAs. This figure includes Commonwealth MPAs and GBRMP annual budgets.

We used the available characteristics for the existing 10 Commonwealth MPAs with annual management budgets as well as GBRMP to determine the driving factors for management costs.

The predictors identified from the data are summarized in Table 4.

Using multiple-regression we estimated an equation to predict the management cost per ha on a log scale. We examined all best subsets of predictors. The equation with the best fit is:

$$\log(costperha) = 8.74 - 3.03\log(ha) + 0.218\log(ha)^2 + 0.0515\,yrs_{est} - 0.0590\,yrs_{gazette} - 0.739\,pct_{sp} + 1.02\,pct_{other}$$

All coefficients were significant with $p<.10$ except for pct_{sp} ($p=.256$) and the R^2 value was 96.4%.

This equation tells us that the log of the management cost per hectare: decreases with the area of the MPA but then increases again; is lower for MPAs that have been gazetted longer; lower for areas that have special purpose zones; and higher for MPAs with larger areas in IUCN Categories III to VI.

The fitted values versus the actual values are shown below (Figure 7).

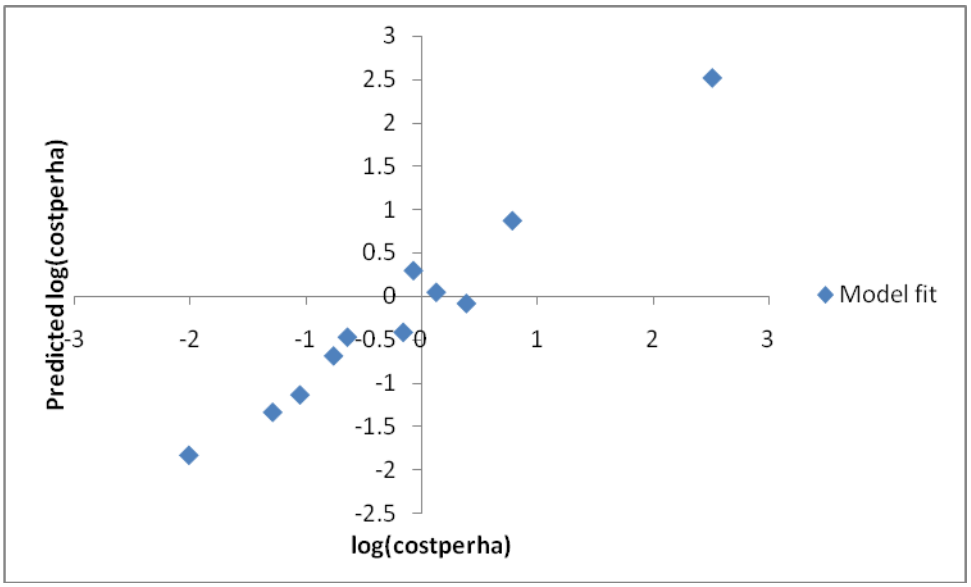

Figure 7. Fitted values versus the actual values

The model is notably limited by the number of available data points. However, 100% of funded Commonwealth MPAs with suitable data have been included. Therefore, although the number of points is small, it is representative of current funding levels and management arrangements in Australia. It is reasonable to expect that MPAs established in the near future will be similar to the existing MPAs in both management arrangements and funding levels. As more MPAs are established models will need to be refined to reflect changing management arrangements and budgets.

The addition of the GBRMP data point changes the regression equation from linear (see section 6.1) to polynomial. We assume that the addition of GBRMP in the analysis makes the cost estimates more realistic. It is possible, though, that GBRMP is an anomaly, and that the relationship may be a different one (e.g., exponential). Without additional data points of large MPAs, we do not have sufficient information on which to base other relationships. If only size were used as the cost estimate, and we assume that the lowest cost per unit area ($0.1 per km2) applies to the Coral Sea, then the annual budget for the Coral Sea would be about $950,000. However, our models indicate that area is not the only predictor. Our extrapolations therefore assume multiple predictors, and that the polynomial regression result based on Commonwealth MPAs and GBRMP is the best available data on which to model cost estimates.

We developed 3 management scenarios for the Coral Sea to predict potential management costs. The first scenario was that the entire area would be one IUCN Category I MPA. The second scenario assumed that all of the Coral Sea would be managed as a single MPA but 30% would be Category I and the remaining 70% would be multiple-use (Category VI). The final scenario assumed that there would be 3 MPAs each 10% of the area (Category I) and the remaining 70% would outside the marine reserve network. We assume that the Coral Sea would not have any special management or recreational zones, and calculated the annual costs assuming no such zones.

For each of the three scenarios, we calculated the cost based on four different methods for a twenty year time horizon. The basic differences between the three scenarios and 4 methods are summarized below (Table 5).

Table 5. Differences between the three scenarios and 4 methods

Scenario	No-take component	Management of areas outside of no-take areas	Method	Discount Rate Used	Constant Operational Budget over 20 year time horizon
1	100%	-	1	No	No
	100%	-	2	Yes	No
	100%	-	3	No	Yes
	100%	-	4	Yes	Yes
2	30%	Category VI	1	No	No
	30%	Category VI	2	Yes	No
	30%	Category VI	3	No	Yes
	30%	Category VI	4	Yes	Yes
3	30%	Not managed	1	No	No
	30%	Not managed	2	Yes	No
	30%	Not managed	3	No	Yes
	30%	Not managed	4	Yes	Yes

Because our model identified that operational budgets are lower for reserves that have been gazetted for longer, the first two methods acknowledge that our model will predict different operational budgets for each year that a Coral Sea MPA network has been in place. The first method used the regression equation to calculate the cost for each year for a twenty year time horizon (i.e., the equation is recalculated every year). The second method used the annual costs from the first method but included a discount factor of 3%. The discount rate is an interest rate a central bank charges for loans and may be included in the calculation of the net

present value of a payment stream to indicate that money valued at future dates has a different value than money valued at the current date. Net present value calculations are sensitive to the selection of the discount rate. We selected a rate of 3% as this reflects the current Australian reserve bank policy interest rate (currently 3.5%, http://www.rba.gov.au/). For the final two methods we used a constant annual operational budget rather than allowing for a slightly declining budget for future years. The third method assumed a constant annual budget equal to the amount calculated from the initial time step in the regression equation over twenty years. The fourth method used the annual costs from the third method but included a discount factor of 3%. The initial annual budget and total budget over a twenty year time horizon is given in the following table (Table 6).

Table 6. Scenarios to estimate potential operating costs for the Coral Sea

Scenario 1: entire area would be one IUCN Category I MPA

Method	Initial Annual Budget	Total budget for twenty years	Discount Factor
1 (used regression equation to calculate the cost for each year for a twenty year time horizon)	2,716,756	46,342,740	N/A
2 (used the annual costs from the first method but included a discount factor of 3%)	2,716,756	61,217,292	3%
3 (assumed a constant annual budget equal to the amount calculated from the initial time step in the regression equation over twenty years)	2,716,756	54,335,113	N/A
4 (used the annual costs from the third method but included a discount factor of 3%)	2,716,756	73,000,241	3%

Scenario 2: all of the Coral Sea would be managed as a single MPA but 30% would be

Category I and the remaining 70% would be multiple-use (Category VI)

Method	Initial Annual Budget	Total budget for twenty years	Discount Factor
1	14,062,000	239,873,000	N/A
2	14,062,000	316,865,000	3%
3	14,062,000	281,242,000	N/A
4	14,062,000	377,854,000	3%

Scenario 3: 3 Category I MPAs each 10% of the area and the remaining 70% would be outside the reserve network

Method	Initial Annual Budget	Total budget for twenty years	Discount Factor
1	17,625,000	300,649,000	N/A
2	17,625,000	397,148,000	3%
3	17,625,000	352,499,000	N/A
4	17,625,000	473,590,000	3%

Our results from extrapolating the regression equation to estimate management costs of several Coral Sea marine reserve scenarios indicate that management of the entire Coral Sea as a no-take area is the least expensive management option. In contrast, the most expensive option for management would be to designate three separate MPAs of 10% of the area each, with the other 70% as outside the reserve network.

Yearly management costs estimates range from $2.7 million for the no-take scenario, to $17.6 million for the multiple MPA scenario. Over the course of 20 years, the difference between the most expensive and least expensive management option would be about $430 million. These results arose because our model indicated that management cost per hectare decreases with the area of the MPA initially, but then increases again once the MPA gets very large (i.e., the relationship is polynomial). Therefore the scenarios that have a smaller no-take component (30% (Scenarios 2 and 3) versus 100% (Scenario 1)) are more costly to manage. The model also indicated that the management cost is lower for MPAs that have been

gazetted longer. Therefore the methods that recalculate the management cost each year into the future are less costly than those that assumed a constant annual budget equal to the amount calculated from the initial time step. Finally, the management cost is higher for MPAs with larger areas in IUCN Categories III to VI. Therefore one big no-take area (Scenario 1) is extrapolated to be less expensive to manage than the same area with a large multiple use component (Scenario 2). We did not include any special management areas in our scenarios, and hence that part of the regression equation did not influence the results.

Our results are indicative of the relative differences in management costs between full no-take and smaller no-take scenarios: 100% no-take is the least expensive management option.

We have less confidence, however, in the specific management cost estimates. Because the Coral Sea is so much larger than other Commonwealth marine reserves and the GBRMP, the data points used to estimate the management cost of the Coral Sea may not be indicative of the management costs of such a large area. A detailed assessment of the management needs would have to be undertaken for the Coral Sea to obtain more accurate management cost estimates.

8.2 Bottom up estimates for managing a Coral Sea MPA

The management cost estimates in this section are indicative of the kinds of costs and actions that would be required to manage the Coral Sea under two management scenarios: full no-take, and 30% no-take. Here we do not distinguish between the 30% no-take managed separately, and the whole area with 30% no-take managed as one multiple use area. To properly account for all management costs, a full risk assessment would have to be undertaken to identify priority areas and actions. We note that particularly for the 30% no-take scenario the spatial arrangement of no-take areas will affect the risk assessment. Such a risk assessment was beyond the scope of this report; the management costs shown here are meant to be indicative of the relative magnitude of potential costs, rather than precise estimates.

As outlined in Section 5, participants indicated that cost savings would likely be substantial if management of the Coral Sea (should a reserve be implemented) were carried out by existing management agencies with experience in the region, i.e., as per the current arrangement between GBRMPA and QPWS for field management. In our bottom-up estimate, we assumed such a management arrangement. For example, monitoring of island ecosystems and vulnerable species was estimated to require 12 people to visit the islands at least twice per year. If the Coral Sea were managed in isolation, those 12 people would have to be on staff year-round. If managed based on the GBRMPA and QPWS arrangement, those staff could be shared between the parks, and hence only ~4 FTEs would be required for the Coral Sea.

With input from knowledgeable managers from GBRMPA, QPWS and AFMA, we determined management activities and potential costs that relate to the eight key outputs of the Field Management Program. These align with the objectives of the GBRMP Act, the Queensland Marine Parks Act and the Queensland Nature Conservation Act and the outcomes specified in Schedule C of the GBR Intergovernmental Agreement (Table 7).

Table 7. Key outputs of the Great Barrier Reef field management program used to estimate management costs in the Coral Sea

Long-term protection and conservation

1. Protected marine ecosystems (intact trophic structures in no-take zones etc)
2. Protected island ecosystems (high levels of natural integrity, minimal pests)
3. Protected vulnerable species and habitats

Ecologically sustainable use

4. Sustainable tourism and recreation opportunities (permits and planning)
5. Sustainable tourism and recreation facilities (marine, island NP and islands)
6. Sustainable shipping (ship groundings, pollution incident response, introduced marine pests)
7. Sustainable traditional use

Understanding and enjoyment

8. Education and understanding about GBRWHA natural and cultural resources and values (interpretation, communication)

In addition to the above outputs, a further section is presented reviewing program performance and capability needs:

Performance and capability

9. Vessels and bases
10. Workforce skills, abilities and knowledge

Several assumptions were necessary to estimate compliance and enforcement costs.

- We assumed that several no-take areas (30% scenario) would be at higher risk of infringement than a complete no-take area (100% scenario). If fishing vessels, for example, are allowed to fish in parts of the Coral Sea, then the risk would be greater that vessels may mistakenly or deliberately enter no-take zones. If the whole area is no-take, then there is little reason for fishing vessels to be present, and if they need to transit the region, a minimum speed that prevents fishing could be legislated. Detection of potential illegal activity should therefore be easier in the 100% no-take scenario. Hence more aerial and on-water surveillance would be necessary for the 30% than 100% scenario.
- We assumed that legislation could facilitate effective compliance and enforcement. For example, permits should be required for tourism operators and vessel monitoring

systems (VMS) should be mandatory for all tourism and fishing vessels that operate in the region.

- Based on experience in the GBR, we assumed that aerial surveillance would be more effective than on-water surveillance, because approaching surveillance vessels can easily be seen, allowing time for evidence of infringement to be disposed of (e.g., illegal catches discarded or removing gear from the water).
- We assumed that potential infringements detected by aerial surveillance would have to be followed up through a rapid on-water response. Such on-water response would be necessary to collect evidence to enable prosecution. As stated above, we assumed such infringements would be more common in the 30% than 100% scenario.
- We assumed that a regular surface patrol would discourage illegal activity. One effective strategy would be to deploy a multi-agency team on a surveillance vessel several times each year. All vessels encountered could then be boarded to check legal requirements such as boat safety, food storage safety, customs and quarantine, etc.
- We assumed that it would be more economical to charter vessels and crew for surveillance and natural resource management than to own such vessels and employ crew.
- Additionally, while participants indicated that international fishing is not currently thought to be threat to the Coral Sea, they felt that an increase in illegal activity could be expected if there were perceived benefits of a Coral Sea MPA, such as increased biomass. Therefore, heavier monitoring of the MPA boundaries both aerially and on-water would be needed.

Additional assumptions are necessary for protection and conservation, and sustainable use outputs. We assumed that basic monitoring requirements would be the same for the scenarios, but that additional effort would be required for marine monitoring in the 30% scenarios to detect the ecological effectiveness of different zones. We assumed that the permitting and planning requirements would be the same for the scenarios. We also included estimate for sufficient staff and research budgets to enable stronger monitoring and research to address climate change issues and support adaptive management.

The bottom-up estimates for staff (Table 8) and management activities (Table 9) were based on interviews with experts who had extensive experience in management and compliance

activities of the Great Barrier Reef. Where possible, cost estimates are taken from financial information of GBRMP and QPWS.

Table 8. Bottom-up approach to estimating potential management costs for the Coral Sea: Staff and on-costs

Category	Estimated staff for 100% no-take	Estimated cost for 100% no-take	Estimated staff for 30% no-take	Estimated cost for 30% no-take
General administration and management	Management: 1FTE		Management: 1FTE	
	Administration 2FTEs		Administration 3FTEs	
Long-term protection and conservation	Compliance: 4FTEs		Compliance: 8FTEs	
	NRM experts: 4FTEs		NRM experts: 6-8 FTEs	
Ecologically sustainable use	Permits: 2FTEs		Permits: 2FTEs	
	Planning: 2FTEs		Planning: 2FTEs	
	Incidence response: 1FTE		Incidence response: 1FTE	
Understanding and enjoyment	1 FTE		1 FTE	
Operating expenses (computers, training, field equipment, etc)		$20,000 per staff		$20,000 per staff
Facility leasing		$10,000 per staff		$10,000 per staff
Total staff and on-costs	**17 FTEs**	**~ $2.2 million**	**24-26 FTEs**	**~ $3.1 million**

Table 9. Bottom-up approach to estimating potential management costs for the Coral Sea: management actions (rough estimates not based on a risk assessment)

Outputs	Activity	Estimated effort for 100% no-take	Estimated cost for 100% no-take	Estimated effort for 30% no-take	Estimated cost for 30% no-take
Long-term protection and conservation					
Protected marine ecosystems (intact trophic structures in no-take zones etc)	Compliance monitoring* (fishing, tourism)				
	Aerial surveillance (Coastwatch); Frequency of flights should be determined by risk profile (e.g., timing and effort of fishing in regions adjacent to no-take areas)	One Coastwatch aircraft dedicated to Coral Sea about half of the time	2 million	One Coastwatch aircraft mostly dedicated to Coral Sea	4 million
	On-water compliance monitoring; on-call vessel to ensure incident response capacity	3 times regular rate = $60k/day, 14 days	840,000	3 times regular rate = $60k/day, 28 days	1.68 million
	Multi-agency surface patrol	~3 times per year, for 2-3 week trips (estimate based on 20 days per trip)	1.2 million	~6 times per year, for 2-3 week trips (estimate based on 20 days per trip)	2.4 million
	VMS and AIS operating costs		25,000	Assumes increased need to request data from VMS systems	50,000
	Compliance investigations support (legal fees, international travel for investigations)		100,000	Assumes double the investigations	200,000

Protected island ecosystems (high levels of natural integrity, minimal pests)	Research and monitoring of islands: invasive species management, surveys of seabirds and turtles	2 visits per year, 1 in summer, 1 in winter, 3 weeks on-site per visit, 12 people plus vessel crew (vessel and crew ~$20,000 per day)	$920,000	Additional on-site monitoring required for marine areas for complex zoning to determine effectiveness. 3 visits per year, 3 weeks on-site per visit, 12 people plus vessel crew	$1,380,000
Protected vulnerable species and habitats	Research funds (e.g., for collaboration with universities)		500,000		500,000
<u>Ecologically sustainable use, understanding and enjoyment</u>					
Sustainable tourism and recreation facilities	Outreach, including development and distribution of educational materials and maps, signage, website		50,000		100,000
Total management actions			~$ 5.6 million		~ $10.3 million

* Compliance scenario: We assume that legislation would enable effective compliance and enforcement. For example, permits should be required for tourism operators, vessel monitoring systems (VMS) should be mandatory for all tourism and fishing vessels that operate in the region, minimum vessel speeds should be imposed for no-take areas so that vessels transiting such an area could not fish. A relatively new system, the Automatic Identification System (AIS) may soon be mandatory, and would further facilitate compliance and enforcement.

As with the top-down estimate, the bottom-up estimate indicates that a complete no-take area in the Coral Sea would be less expensive to manage than several smaller (30% total) no-take areas. These estimates are the same order of magnitude as the top-down estimate, although the 100% scenario is more costly (by ~$5million/yr) and the 30% scenario less costly (by ~$1million/yr) in the bottom-up approach. Compliance-related activities comprise the biggest proportion of the bottom-up management cost estimates. Because the Coral Sea is so remote, any surveillance activities will be expensive. We suspect that such enhanced compliance costs could not be predicted through the top-down modeling approach.

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