INPUT TO THE REPORT OF THE HIGH-LEVEL PANEL ON GLOBAL ASSESSMENT OF RESOURCES FOR IMPLEMENTING THE STRATEGIC PLAN FOR BIODIVERSITY 2011-2020

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CLUSTER REPORT ON RESOURCE REQUIREMENTS FOR THE AICHI BIODIVERSITY TARGETS

TARGET 6, 7, 10, 11: MARINE CLUSTER

AUTHORS:
SIMON HARDING (TARGET 10), MARJO VIERROS (TARGET 7), WILLIAM CHEUNG (TARGET 6), IAN CRAIGIE AND PIPPA GRAVESTOCK (TARGET 11)
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ASSESSING THE FINANCIAL RESOURCES NEEDED TO IMPLEMENT THE STRATEGIC PLAN FOR BIODIVERSITY 2011-2020 AND ACHIEVE THE AICHI BIODIVERSITY TARGETS

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INTRODUCTION TO TARGET CLUSTER

The marine cluster of is made up of four targets, specifically:

- Target 6 – fish and invertebrate stocks sustainably managed by 2020
- Target 7, as related to aquaculture (sustainable aquaculture management)
- Target 10, as related to vulnerable marine ecosystems, in this case warm water coral reefs (threatened by ocean acidification and coral bleaching).
- Target 11, to achieve at least 10% coverage of marine protected areas by 2020

The full text for each target is provided at the start of each target section.
The research team for these marine-based targets consists of Simon Harding (Marine Cluster Lead and Target 10 – Coral Reefs), Marjo Vierros (Target 7 – Aquaculture), William Cheung (Target 6 – Fisheries) and Ian Craigie / Pippa Gravestock (Target 11 – MPAs).

TARGET 6: FISH AND INVERTEBRATE RESOURCES (William W.L. Cheung)

Target 6 Text: *By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.*

Overfishing is considered the primary driver of biodiversity loss in marine ecosystems (Dulvy et al. 2003; Hoffman et al. 2010; Baillie et al. 2010). Of the 133 local, regional, and global extinctions of marine species documented worldwide mainly in the last two centuries, with a few dating as far back as the 11th century, 55% were caused by unsustainable exploitation, with the remainder driven by habitat loss and other threats (Dulvy et al. 2003). Currently, over 550 species of marine fishes and invertebrates are listed as threatened (Critically endangered, Endangered, and Vulnerable) in the IUCN Red List. Of these species, the majority (80%) is threatened by “fishing and harvesting of aquatic resources”. This is an underestimate because only a small proportion of marine organisms have been assessed for their conservation status and many species do not have sufficient data (categorized as “data deficient”) to be classified under any threatened status. Currently, many fisheries in the world are considered over-exploited i.e., abundance of exploited stocks are below the level that can achieve Maximum Sustainable Yield (MSY) (FAO 2010), although the extent to which are under debate in recent literature (Froese *et al*. 2012; Watson *et al*. 2012; Worm *et al*. 2009).

On the other hand, fisheries are clearly important, both economically and in terms of food security, especially when it is considered that the human population is increasing and is projected to rise to more than 9 billion by 2050, with almost all this growth occurring in developing states (UN-DESA, 2009). Gross revenues from marine capture fisheries worldwide are currently estimated at between US$ 80 – 85 billion annually (FAO 2010). Fisheries support the well-being of nations through direct employment in fishing, processing, and ancillary services, as well as through subsistence based activities at the community level amounting to US$ 220 to 235 billion in 2003. Globally, fish provide nearly 3.0 billion people with 15 percent of their animal protein needs (FAO 2010), and not only to people who reside in the 144 maritime countries of the world because international fish trade has made fisheries truly global. When post-catch activities and workers' dependants are considered, the number of people directly or indirectly supported by marine fisheries is about 520 million, or nearly 8% of the world's population. In most low-and middle-income maritime countries, fisheries employment is crucial as it provides safety net to some of the world’s poorest, providing them cash income and nutrition, especially during times of economic hardship. Thus, there is a clear need to maintain fishing sustainably, while minimizing impacts to biodiversity.

To conserve marine biodiversity, it is important to effectively manage fishing so that at least over-exploited stocks are recovered and all fish stocks are managed sustainably. Thus, one of the Aichi Biodiversity Targets (Target 6) is to have, by 2010, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

This section aims to provide an estimate of the financial cost required to achieve this target globally. The scope of the analysis focuses on the cost associated to rebuild over-exploited or depleted fish stocks back to a level that can achieve MSY, and to manage fisheries so that the level of biomass is at or above the MSY level and that impacts on threatened species and vulnerable ecosystems are minimized. Generally, abundance thresholds of species and stocks that would trigger conservation concerns (e.g., classifying as vulnerable, endangered or critically endangered under the IUCN Red List of Endangered Species) are below MSY. Thus, it is reasonable to assume that the biomass of stocks and species at the MSY level are within safe ecological limits, which are less well-defined and may vary widely between systems. For this broad-brush cost estimation, we assume a fixed percentage increase in the current fisheries management cost that would be required to ensure fisheries being managed within such limits. We then propose approaches that may improve the estimates in the future. We also assume that the necessary socio-economic and political conditions to implement rebuilding and sustainable fisheries management plans are ready. For example, we assume that the reported US$19 billion of annual harmful and ambiguous subsidies (Sumaila et al. 2010) are to be eliminated within the project period.

Conservation actions required to achieve Target 6 may overlap with those for Target 10 (coral reef) and 11 (Marine Protected Area or MPA). Specifically, fishing is an important human activities affecting biodiversity in coral reef. Thus, achieving Target 10 would inevitably involve sustainable management of fishing activities. Moreover, MPA is considered a tool for fisheries management as it limits and manages fishing activities spatially. MPA contributes to rebuilding over-exploited and depleted stocks and continuous sustainable management of fisheries. Thus, there may be some overlap in the cost associated with achieving Target 6 and 11. In this report, we discuss the potential extent of such overlap and its implications to the estimated costs to achieve these Targets.

ACTIONS

In this assessment, two main types of actions are considered to be required to achieve Target 6. Firstly, all exploited fisheries stocks that are over-exploited or depleted need to be rebuilt to a level that can achieve MSY. We assume that this will be achieved by reducing global fishing capacity. The second component of is improving fisheries management. In financial terms, the first component is the investment (or transition) cost while the second component is the operation (or running) cost. We assume a project period of 8 years (from now to 2020) by when at least all the required actions to achieve Target 6 are implemented.

We assume that stock recovery would take 10 years. Because of the simultaneous reducing in fishing effort, we assume that landings would decline in the first 5 years and then gradually increase in the subsequent 5 years from the start of the project period. Thus, the flow of benefits from building such fish stocks would not be realized until multiple decades after rebuilding plans are implemented. In this assessment, we also calculate long-term (from 2013 to 205) gains and benefit-to-cost ratio to highlight the importance of the long-term perspective in assessing rebuilding plans.

METHOD OF ASSESSMENT

The method to estimate the cost of rebuilding over-exploited/depleted stocks and ensuring sustainable fisheries management was based largely on the method described in Sumaila *et al* (2012). The method is divided into four components:

1. Estimating size of global fishing fleet

The FAO estimates that there are currently 35 million people engaged in capture fisheries on either a part- or full-time basis (FAO 2010). The same report indicates that 90% of these fishers participate in the small-scale sector, while the remaining 10% can be classified as large-scale. The FAO also reports that the world's fishing fleet is comprised of 4.3 million vessels, 59% of which are motorized and 14% of motorized vessels (8% of all vessels) are greater than 12 meters in length (FAO 2010). In this study, we take a broad definition of large-scale vessels that includes all motorized vessels over 12 m in length, which is of sufficient size to represent considerable fishing pressure and potential impact on the environment. Under this criterion, we estimate the number of large-scale fishing vessels world-wide to be 355,000, with the remaining 3.94 million vessels classified as small-scale.

2. Estimating effort reductions required to achieve MSY

We model the global fishery using the Schaeffer surplus-production model commonly applied to single-stock fisheries (Gordon 1954). We estimated MSY using the method documented in Srinivasan *et al*. (2010) which has produced estimates that are very close to MSY estimated from conventional stock assessment methods (Srinivasan *et al*. 2010). For example, the empirical relationship between MSY estimated from catch time-series and stock assessments, albeit for 26 Northeast stocks, was statistically strong ($R^2 = 0.84$, $p < 0.001$) and therefore has predictive power (Srinivasan *et al*. 2010). More recent analysis based on 50 fully assessed stocks in the Northeast Atlantic shows strong ($R^2 = 98\%$) linear relationship between catch-based estimates and MSY from stock assessment (Froese *et al*. 2012). These provide strong support for the validity of the use of catch-based MSY estimates in this study.

Since many fish stocks around the globe are either fully- or over-exploited, the global fishery is currently using more effort than needed to produce maximum sustainable yields, which we use as a global proxy for sustainable fisheries. In order to achieve maximum sustainable yields, effort will need to be reduced from current levels to a lower level that is consistent with maximum sustainable yield (E_{msy}). At effort levels consistent with E_{msy}, the total cost of fishing is reduced from TC_0 to TC_{msy}. For our calculations, we make the simplifying assumption that there is no substitution between labor and capital, so the shares of components of fishing costs (i.e., fuel, wages, etc.) remain constant.

Recognizing that large- and small-scale fisheries have different fishing power, and in order to minimize the effect of effort reductions on fishers (labor), who are predominantly in the small-scale sector, we weigh effort reductions more heavily on large-scale operations. We express total fishing effort in the global fishery as:

$$LSF * P_l + SSF * P_s = \delta_0 \qquad (1)$$
$$P_l = \gamma P_s$$

where LSF and SSF are the number of large- and small-scale fishers, respectively. The parameters P_l and P_s represent the fishing power of large- and small-scale fishers, while γ represents the power of large-scale fishers relative to small-scale fishers. Total current fishing effort is δ_0. By re-expressing LSF, SSF and δ_0 as terms that are relative to the total current fishing effort (i.e., dividing both LHS and RHS of eq. 1 by δ_0), we have:

$$LSF' * P_l + SSF' * P_s = 1 \qquad (1b)$$

Using an estimate of γ from Pauly (2006) which places the fish catching power of large-scale fishers at 18 times[1] that of their small-scale counterparts, we are left with a system of two equations with two unknowns that can be solved for P_l and P_s, which are used to estimate the proportions of large- and small-scale fishers required to reduce overall fishing effort:

$$LSF' * P_l * x + SSF' * P_s * y = \delta \qquad (2)$$
$$w_l * LSF' * P_l * x = w_s * SSF' * P_s * y$$

The parameters *LSF'*, *SSF'*, P_l and P_s are defined as in the system of equations (2) above, while δ represents the ratio of current effort required to rebuild fisheries, while w_l and w_s represent the weight of effort cuts levied on large- and small-scale fishers, respectively. The parameters x and y, which represent the proportion of large- and small-scale fishing activity to be cut, are estimated from equations (3) and used to estimate the total reductions in large- and small-scale fishers as:

$$LSF_{cut} = LSF' * x \qquad (3)$$
$$SSF_{cut} = SSF' * y$$

Lastly, we use our earlier estimates of the current number of large- and small-scale fishers and fishing vessels to estimate the number of large- and small-scale fishers and vessels that must be removed from the global fishery corresponding to our estimates of required reductions. We explore a range of weights (w_l and w_s) that represent equivalent total effort reductions. The trade-off between the cost of fishing effort reduction per fisher is non-linear, while the number of total fishers reduced is linear in the weighting placed on large-scale fishing effort. We suggest that by placing 80% of the weight of fishing effort reduction on large-scale fishing operations, it is consistent with cutting 60% of large-scale and 30% of small-scale fishing activity.

3. Estimating the cost of fisheries management to ensure sustainable fisheries (operation cost)

We use the database from Sumaila *et al*. (2010) to extract the estimated amount of existing fisheries management cost (categorized as "beneficial subsidies" in Sumaila et al. 2010). Recognizing the lack of information and uncertainty on the required increased cost to ensure sustainable fisheries management, we raise this cost by a range of percentage: 10%, 25% and 50% to US $ 8.8, $10.0 and $12.0 billion a year, respectively, in order to support effective management.

4. Estimating the cost of rebuilding global fisheries to achieve MSY (transition cost)

We estimate the costs necessary to reduce fishing capacity to levels required to allow fish stocks to rebuild. These costs are estimated based on the cost of effort reductions described earlier in the methods. We estimate wages, profits, resource rent and increase in resource rent from rebuilding for the six major FAO regions (Africa; Asia; Europe; North America; Oceania; South and Central America plus the Caribbean).

Since the real cost of rebuilding fisheries is foregone resource rent that may occur as fishing effort is reduced initially, we estimate the cost of achieving MSY for global fisheries as the difference between current fisheries resource rent and that which is realized through the period of transition. We hold the assumption that all harmful capacity-enhancing and

[1] Pauly reports that 12 million small-scale fishers landed a total of 30 million t of fish in the early 2000s, while 500,000 of their large-scale counterparts landed 60 million t of fish for both reduction and human consumption.

ambiguous subsidies must be cut immediately or re-directed as beneficial subsidies towards managing the rebuilding process.

Policy makers generally prefer to minimize the employment impact while managing fisheries. It would therefore be attractive to target effort reductions on large-scale vessels only, as they employ less people per unit of fish landed (Gabriel *et al*. 2005). While the goal of matching global fishing capacity with the productive capacity of the resource by cutting only large-scale vessels seems theoretically possible, it would be ineffective in areas that are overfished but dominated by small-scale vessels. Available gear-related data (Gabriel *et al*. 2005; Anticamara *et al*. 2011) reveal that the split between large- and small-scale vessels in the developed world is about 50:50, while it is 25:75 in developing countries. Our analysis of fishing effort cuts show that permanently removing around 213,000 large-scale and 1.2 million small-scale vessels (60% and 30% reductions, respectively), would halve the world's fishing capacity. This weighting between large- and small-scale fishing capacity is supported by evidence that large-scale vessels currently land roughly two-thirds of the world's annual reported marine landings (Pauly 2006).

Cost data (Lam *et al*. 2011) reveal that crew from large- and small-scale fisheries earn, on average, wages of US$20,000 and US$10,000 per year, respectively. Furthermore, vessels in large- and small-scale fisheries pay, on average, US$11,000 and US$2,500 per year for capital. Based on vessel and crew data from the European Union (European Commission 2006), we estimate that the average cost of a vessel buyback is roughly equal to the average interest payments on a vessel for five years, and the average cost of crew retraining is estimated at 1.5 times the average annual crew wages. Therefore, the average cost of decommissioning large- and small-scale fishing vessels would be US$55,000 and US$12,500, respectively. Likewise, payout/retraining costs for large- and small-scale fishers to leave fishing permanently would be US$30,000 and US$15,000 per person, respectively. Clearly, decommissioning costs for the extremely large industrial vessels with global roaming abilities would be higher than the above vessel averages.

ASSESSMENT OF RESOURCE NEEDS

This assessment is based on published or publicly available databases. For the catch data, the main source of which is the FAO global capture production database supplemented by several more detailed regional catch data sources, allocates the reported fish landings to a global system of 30-minute latitude by 30-minute longitude cells (just under 180,000 marine cells globally) using the intersection of statistical reporting areas, biological taxon distributions of reported taxa, general habitat preferences, global fishing access agreements and fishing patterns of reporting countries. Details of the methods and procedures of this spatial allocation are described in Watson et al. (2004).

The global ex-vessel fish price database used here, described by Sumaila et al. (2007), covers annual average ex-vessel prices for all marine fish taxa by country reported as caught from 1950 to 2006. Through their extensive search of publicly available, but widely scattered and incompatible, national and regional statistical reports and grey literature, Sumaila et al. (2007) accumulated over 31,000 records of observed ex-vessel prices in 35 countries, representing about 20 percent of the global landings over the 60 year period. In order to 'fill the gaps' in the database, a series of rules were developed whereby all catches with no reported prices were inferred to have an estimated price computed from the reported prices from related taxa, similar markets or years. Since the database was first presented, new reported prices have been included from various additional sources, and rules as to how prices relate across taxa, markets or years have been modified to improve the quality of the estimated prices. The time series of landed values of the world's marine fisheries, computed through the combination of the spatially allocated catch data with the ex-vessel price database (country-specific landed values by FAO region) have been used in various analyses, such as the estimation of global subsidies (Sumaila *et al*. 2010) and costs of marine protected areas (Cullis-Suzuki & Pauly 2008).

Lam *et al*. (2011) developed a global database of fishing costs by country and gear types, capturing two types of fishing cost, variable (operating) and fixed costs in 144 maritime countries, representing approximately 98% of global landings in 2005. Each record in the database represents a country and gear type combination. The gear types included in the database are based on the gear categorization system of the *Sea Around Us* Project (Watson *et al*. 2006).

Fishing cost data were collected from secondary sources in major fishing countries in each of the six FAO regions. In order to include as many data of observed cost as possible, Lam et al. (2011) accessed all available sources, irrespective of publication year, thus extending their efforts in collecting cost data from 1950 to the most recent year for which data were available. The data were then converted to 2005 real values using the consumer price index (CPI) for each country obtained from the World Bank. To make the comparison of fishing cost among different regions and countries possible, they converted all fishing costs from local currencies to US dollars by using currency exchange rates provided by the World Bank, and standardized the original cost to annual cost in US$ per tonne of catch.

A process of progressive refinement (Sumaila *et al*. 2007, 2010) was then used to estimate the cost of all gear types in each fishing country from the observed, collected cost. Therefore, Lam et al. (2011) ensured that all gear types in each maritime country of the world were assigned a cost, either the observed value where available, or an appropriate average estimated cost.

The fisheries subsidies database defines subsidies as financial transfers, directly or indirectly, from government to the fishing industry (Sumaila *et al*. 2010). This database is the most comprehensive collection of publicly available data on fisheries subsidies at the global level, spanning the years 1990 to 2006. Each record in the database represents expenditure in one of twenty-six identified subsidy categories for a given country and year combination. Where qualitative information indicates the presence of a subsidy program, yet quantitative data are not available, the database records the expenditure data as 'missing' for later estimation.

Estimation of 'missing' subsidy data follows the method of Sumaila et al. (2010) who utilize the strong relationship between fisheries subsidies and landed value to estimate subsidy expenditure in cases where programs are documented without quantitative information. We use this procedure to estimate existing but un-quantified fisheries subsidies for any of the twenty-six subsidy categories in any of the 144 maritime countries of the world, and summarize these globally by three general categories: 'beneficial' (lead to 'investment' in the natural capital of fishery resources, thus enhancing growth of fish stocks through conservation programs, and control and surveillance measures), 'harmful' (lead to 'disinvestments' in the natural capital of the fishery resources, including all forms of capital inputs and infrastructure investments from public sources that reduce cost or enhance revenue) and 'ambiguous' (have the potential to lead to either 'investment' or 'disinvestment' in the fishery resources, and lead to resource enhancement or to resource overexploitation).

RESULTS

Cost of reducing fishing effort (investment/transition cost)

The world's current fishing capacity is estimated to be up to 2.5 times more than what is needed to land the Maximum Sustainable Yield (MSY) (Sumaila *et al* 2012). This suggests that to rebuild global fisheries, we need to trim excess capacity from the current 4.3 million fishing boats. Accounting for latent capacity (unused fishing effort), we assumed that current capacity is between 1.5 and 2.5 times the level needed to maximize sustainable catch. Thus, to achieve MSY, fishing effort needs to be reduced by between 40% and 60% (50% on average), or up to 2.6 million boats. Fisheries currently employ more than 35 million people globally. If we simplify by assuming linearity between boats and people, this implies that between 15 and 22 million fishers would need to be moved to other livelihood activities in order to rebuild global fisheries. This is a challenge, but one that is surmountable. For instance, even though in some fisheries most fishers may see fishing as a way of life and therefore may not want to exit fishing, it has been reported that up to 75% of fishers in Hong Kong would be willing to leave the industry if suitable alternatives or compensation were available (Teh *et al*. 2008). Similar sentiments are likely to also occur in many other countries.

Using the unit cost of reducing fishing effort calculated in the methods section, the total amount that governments need to invest to rebuild world fisheries ranges between US$130 and US$292 billion in present value, with a mean of US$203 billion (Table 1,2). This total transition cost would be spread over eight years (from 2013 to 2020) required to rebuild fisheries within each country.

Cost of management

The existing fisheries management costs (categorized as "beneficial subsidies" in Sumaila *et al*. 2010) were estimated to be US$ 8 billion a year. Raising this by 10%, 25% and 50%, the estimated management cost required to ensure sustainable fisheries (as specified in Target 6) would be US $ 8.8, $10.0 and $12.0 billion a year, respectively (Table 1,2), or US$ 0.8, $1.2, $3.2 billion a year more than the current cost of management. With a discount rate of 3%, the NPV of additional management cost required for sustainable fisheries management over a time-frame of 8 years become US $5.6 – 28.1 billion.

Table 1: Key economic figures on cost of achieving Target 6. NPV: Net Present Value

Key indicators	Current	To achieve Target 6: Scenario 1 (Lower)	Scenario 2 (Mean)	Scenario 3 (Upper)
Annual catch (million t)	80.2	82.7	88.7	99.4
Annual catch value (US$ billions)	87.7	90.4	97.0	108.7
Annual management cost (US$ billions)	8.0	8.8	10.0	12.0
Transition costs[a] (US$ billions)	-	129.9	202.9	292.2
Other subsidies (US$ billions, annual)	19.2	0	0	0
Project time-frame (2013 – 2020)				
NPV of total cost[b] (US$ billions)	-	135.5	216.9	320.3
NPV of resource rent [c] (US$ billions)	-88.9[d]	-11.3	35.9	81.7
NPV of gain in rent (US$ billions)	-	77.6	124.8	170.6
Project time-frame (2013 – 2050)				
NPV of total cost[b] (US$ billions)	-	148.2	248.5	383.4
NPV of resource rent[c] (US$ billions)	-289.0[d]	520.5	815.9	1176.4
NPV of gain in rent (US$ billions)	-	791.3	1076.5	1424.0

a. Transition costs include the costs to society of reducing current fishing effort to levels consistent with maximum sustainable yield and the payments governments may decide to employ to adjust capital and labour to use outside the fisheries sector. Such payments may include vessel buyback programs and alternative employment training initiatives for fishers.

b. Total cost = Additional management cost + transition cost, assuming a discount rate of 3% and timeframe of 8 years.

c. The (resource) rent is the return to 'owners' of fish stocks, which is the surplus from gross revenue after total cost of fishing is deducted and subsidies taken into account.

d. Status quo scenario assuming no rebuilding plan is implemented.

Total cost of achieving Target 6

Summing the costs of reducing fishing effort and ensuring effective fisheries management, the total present value of cost of achieving Target 6 was estimated to be US $216.9 billion ($135.5 – 320.3 billion) over eight years with a discount rate of 3% per annum (Table 3).

Table 2. Estimated resource needs (US $ billion)

Activity	Investment (year 2013)			Recurrent annual expenditure			Recurrent total (2013 to 2020)		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Fishing capacity reduction	129.9	202.9	292.2	0	0	0	0	0	0
Additional annual management cost	0	0	0	0.8	1.2	3.2	5.6	14.0	28.1
Total	129.9	202.9	292.2	0.8	1.2	3.2	5.6	14.0	28.1

Table 3. Total resource needs (US $ billion)

Activity	Total for the whole period (2013 – 2020)			Average annual (for period 2013 – 2020)		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Fishing capacity reduction	129.9	202.9	292.2	16.2	25.4	36.5
Additional annual management cost	5.6	140	28.1	0.7	1.8	3.5
Total	135.5	216.9	320.3	16.9	27.2	40.0

Economic benefits from achieving Target 6

The society is expected to gain from sustainably managing global fisheries through increases in resource rent. Currently, annual fisheries catch globally is around 80.2 million tonnes, providing a catch value of US $87.7 billion. The estimated potential catch at MSY is 88.7 million tonnes (82.7 – 99.4 million tonnes), or US $97.0 billion ($90.4 – $108.7 billion) in value. The current level of subsidies that do not contribute to sustainable fisheries (bad subsidies) is US$ 19.2 billion. These result in a net present value (NPV) of resource rent over 8 years under the status quo to be a loss of US$ 88.9 billion. In contrast, assuming that Target 6 is successfully achieved by 2020, and that bad subsidies are eliminated, NPV of resource rent was estimated to be US $35.9 billion ($-11.3 – $81.7 billion). This results in a net gain of resource rent by achieving Target 6 relative to the status quo to be US$ 124.8 billion ($77.6 – 170.6 billion) by 2020. The resulted benefit-to-cost ratio is 0.58 (0.24 – 1.26) times over the 8 years of the project.

As noted earlier, full benefits of rebuilding would not be realized until multiple decades after the rebuilding plan is implemented. The long-term (from 2013 – 2050) gain in resource rent from rebuilding is calculated to be US $1,076.5 billion (US $ 791.3 – 1,424 billion). The cost of rebuilding, including the initial transaction cost and the additional management cost, is US $ 248.5 (US $ 148.2 – 383.4). Thus, the long-term benefit-to-cost ratio becomes 4.3 (2.0 – 9.6) times.

Funding opportunities

A range of options to finance the cost of achieving Target 6 are available. The UNEP's Green Economic Report for fisheries proposes a range of options for financing fisheries rebuilding plans (UNEP 2012). These options, broadly, include public investment, national investment, regional investment, private investment and public-private partnerships.

Public investment includes direct funding from national budgets, contributions from multilateral funds, resources raised from capital markets backed by government guarantee and a share of government taxes, levies or revenues earmarked at a national level for a fisheries fund. For example, a fund, similar to Global Environmental Facility run by international bodies such as the United Nations, can be set up into which funding from various public sources can be pooled for achieving Target 6.

National investment may include environmental fiscal reform and redirection of government subsidies. Environmental fiscal reform refers to a range of taxation and pricing measures which can raise revenue while furthering environmental goals. For example, imposing levies on catches, in combination to effective sustainable management measures, can help generate revenue to compensate for the cost of achieving Target 6. Moreover, elimination and/or redirecting existing harmful subsidies in the fisheries sector can provide a significant additional source of financing for the cost of fisheries rebuilding.

Regional investment, through a regional fund managed by a regional organization, similar to one discussed under public investment, for a specific region can be an option to finance the plan for achieving Target 6.

Private investment may be possible when markets for sustainable products and services such as eco-tourism and certified seafood become attractive sources of income for specific fisheries resources. This is particularly applicable when ownership of or right to access to the fish stocks are clearly delineated. For example, when fisheries are managed under inter-transferrable quota system, sustainable management of the resources can increase the market value of the quota or license, providing incentives for the private parties who hold the quota/license to invest into managing the resources.

Public-private partnership (PPPs), where the public sector's investment is leveraged to attain private sector participation in projects with public good characteristics, can provide incentive to raise private investment and combine it with public investment to finance the cost of achieving Target 6.

DISCUSSION

The task of estimating the global cost of achieving Target 6 is inherently challenging given the available data and resources for this study, thus the estimates presented in this section are inevitably uncertain. However, we synthesized data from some of the most comprehensive databases of global fisheries catch, effort and economics that were available to use. Thus, it is supported by robust evidence. A previous preliminary analysis estimating the cost of achieving Target 6 through the certification and promotion of sustainable fisheries and rebuilding of over-exploited/deleted fish stocks suggest a total cost of $US 2 billion ($1 – 3 billion) (Global Environmental Facility, unpublished data). This is much lower than the cost estimated by this study. Part of the reason is that certification is a mean to encourage sustainable management of fisheries. Yet, certification and the cost associated with it do not include the necessary cost for sustainable fisheries management. As for the cost of rebuilding fisheries, this previous study made an assumption that a total of 5 – 15 recovery plans with a minimum investment of $US 25 million per investment plan is needed. We could not find the rationale or quantitative support for the number of recovery plan needed or the cost per recovery plan. Based on the quantitative analysis in our study, it is likely that this previous estimation may substantially under-estimate the cost of achieving Target 6.

We acknowledge that there are data gaps in the databases that we used for this assessment. For example, even though estimates from the databases are consistent with other estimates about the extent of subsidies, excess fishing pressure and the potential for increased biological yield; however, when one looks at the country by country analysis, one may find results that differ from expectations (see Sumaila *et al*. 2012). This is to be expected because our analysis produces estimates with ranges, and therefore computing midpoint estimates may over- or under-estimate numbers for some countries. This is likely to happen more in small developing countries, where observed data are limited, and therefore we had to rely on statistical methods to produce estimates for these countries. The key to improving our estimates is for the collection of economic data for fisheries to be given priority by maritime countries.

A component of our estimate that appears to be most uncertain is on the management cost required to maintain sustainable fisheries. We made broad assumption on a range of increase in current level of management cost to ensure sustainable management of fisheries that is based on low level of evidence. However, we attempted to come up with a more robust estimate of management cost by comparing the level of government investment and their performance in meeting the FAO Code of Conduct For Responsible Fisheries (CCRF). Specifically, country level management investment were extracted from the subsidies database (Sumaila *et al*. 2010) while the performance of meeting the CCRF was measured by an index calculated by Pitcher *et al*. (2009). However, we did not find any statistically significant relationship between the two attributes. Management cost required to ensure sustainable fisheries may vary largely between fisheries because of the differences in characteristics of the exploited stocks, management strategy and tactics. Thus, quantitative estimation of such cost may require detailed country-by-country analysis of these attributes, which may be conducted in future studies.

Our estimates provide support on large economic benefits to be obtained from achieving Target 6. The increased benefits come from restoration of productivity of over-exploited and depleted stocks to maximum sustainable yield, as well as reduction of excess capacity and elimination of “bad” subsidies. This is evidenced from the positive resource rents from fisheries that are under-exploited or fully-exploited, contrary to negative resource rents from over-exploited and depleted fisheries (Sumaila *et al*. 2012). On the other hand, it takes years (a decade in this assessment) for fish stocks to recover while landings and landed values would decrease in the initial years after implementing the rebuilding plan because of the reduced fishing effort as fish stocks are still recovering. As such, the benefit-to-cost ratio of rebuilding would be low in the short-term (8 year). However, the long-term (2013 – 2050) net economic benefit of achieving Target 6 is large, even without accounting for the potential boost to recreational fisheries, processing, retail and non-market values that would likely increase. On the other hand, it is possible that changes in ecosystem structure resulted from factors such as climate change may affect the scope for recovery of over-exploited or depleted stocks (Cheung *et al*. 2012; Sumaila *et al*. 2011), and the economic benefits from stock rebuilding. However, it is likely that over-exploited stocks are more vulnerable to climate change impacts, thus consideration of climate change effects may add to the economic benefits of sustainable fishing (Cheung *et al*. unpublished data).

Turning current “bad” subsidies to finance the cost of achieving Target 6 would be good investment and economics. The current level of “bad” subsidies is US$19.2 billion per year, or a NPV of US$ 134.8 billion over 8 years with a discount rate of 3% per annum. This could be used to contribute 62.2% (42.1% - 99.5%) of the cost required to achieve Target 6. Moreover, given the long-term benefits that the sustainably managed fisheries resource will bring to the society, it is reasonable for national government to be responsible for the remaining part of the cost and view that as an investment to natural capital. This would be good investment economically, with positive return on investment over long-term (decadal).

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TARGET 7: AQUACULTURE (Marjo Vierros)

INTRODUCTION TO THE TARGET

Target 7 text: *By 2020 areas under agriculture,* ***aquaculture*** *and forestry* ***are managed sustainably, ensuring conservation of biodiversity.***

Definition and interpretation

The analysis presented here will relate to attaining target 7 with a focus on marine and coastal aquaculture. Marine and coastal aquaculture (sometimes called mariculture) incorporates the farming of a diverse range of species, including molluscs, echinoderms, crustaceans, marine aquatic plants and finfish. It also involves a number of different farming techniques including vertical, rack or hanging culture, suspended culture, bottom culture, cage culture, pen culture, tank culture, pond culture, raceway culture and sea ranching.

While there is no precise definition for sustainable aquaculture, sustainable management in the context of target 7 means minimizing negative impacts on the environment and biodiversity (including on the level of ecosystems, wild species and genetic diversity), while maximizing human livelihoods benefits. In addition to environmental sustainability, aquaculture operations would also need to be socially sustainable. Aquaculture that conserves biodiversity ensures that biodiversity is not unduly degraded or destroyed. In some circumstances aquaculture may also enhance the biodiversity and other environmental values of an area.

According to the report of the CBD Ad Hoc Technical Expert Group on Mariculture (July 2002), all forms of mariculture affect biodiversity at the genetic, species and ecosystem level, but under certain circumstances mariculture could also enhance biodiversity locally. The main impacts of mariculture include habitat degradation, disruption of trophic systems, depletion of natural seedstock, transmission of diseases, and reduction of genetic variability. The biodiversity effects of pollutants, such as chemicals and drugs, are not very well studied, though are generally assumed to be negative.

There are many available methods and techniques for avoiding the adverse effects of aquaculture on biodiversity, and a number of those are incorporated in the report of the above-mentioned Ad Hoc Technical Expert Group on Mariculture, as well as in the resulting decision VII/5 of the Conference of the Parties (COP). They include, most importantly, proper site selection, as well as optimal management including proper feeding. Other mitigation measures include culturing different species together (integrated aquaculture), and the use of enclosed, and especially re-circulating, systems. Many other impacts can be avoided with better management practices and other technological improvements. A number of aquaculture-specific international and regional principles, standards and certification processes exist, such as the Global Aquaculture Alliance Best Aquaculture Practices standards, and these can be drawn from.

Guidance on priority activities can also be found in Article 9 (Aquaculture Development) of the FAO Code of Conduct for Responsible Fisheries. This Article, if applied, will help ensure that potential social and environmental problems associated with aquaculture development are duly addressed and that aquaculture develops in a sustainable manner. Additionally, the FAO

Technical Guidelines on Aquaculture Certification provide minimum substantive criteria for environmental integrity, as well as for social responsibility, animal health and welfare, and food safety and quality. The Ecosystem Approach to Aquaculture (EAA) contains guidance on undertaking aquaculture development in an ecosystem context. Sustainability indicators have also been developed under the EU-funded CONSENSUS programme, and these provide further guidance. It should be noted that the purpose of this study is to look at sustainability only from a biodiversity perspective, and thus it is not possible to provide cost estimates for all other aspects of sustainability.

Challenges and limitations to estimating the resource needs associated with delivering the Target

This study was limited by the availability of published data, which resulted in the scaling up of few case studies to produce a global estimate of costs. Thus the estimate should be considered only as indicative of the magnitude of investment required, not an absolute and final figure. There is always a danger in scaling up local examples to produce global estimates. The national circumstances of each country can be vastly different. Costs of the proposed activities vary by country, as do the status and character of existing aquaculture operations, environmental conditions, and the level of already ongoing spending on sustainability initiatives. What works in one country may not necessarily be suitable for another. The examples of activities highlighted and costed in this study are ones that could, with some modifications, be applied in a wide range of countries. They are also ones that, despite an initial investment, can produce positive revenues for the operator in the long run. However, it should be left to each individual country to do their own national assessment of costs according to their own priorities, status and future vision for sustainability.

Links to CBD COP decisions

Target 7 is linked to multiple programmes of work within the CBD including those on marine and coastal biodiversity, biodiversity of inland water ecosystems, forest biodiversity, and, to an extent, agricultural biodiversity. The most relevant COP decision is decision VII/5, and in particular paragraphs in this decision related to mariculture. Target 7 is also linked to CBD's work on the ecosystem approach (particularly decisions V/6 and VII/11), the Addis Ababa Guidelines on sustainable use, and impact assessment (in particular decision VIII/28 containing voluntary guidelines on biodiversity-inclusive impact assessment).

Links to other policy areas

Because proper siting of aquaculture facilities is of great importance for their sustainability, target 7 is closely linked to implementation of integrated coastal and marine area management, marine spatial planning, watershed and riverbasin management, as well as to the implementation of the ecosystem approach. In that regard, the new Ecosystem Approach to Aquaculture developed by the FAO is of relevance.

Aquaculture and capture fisheries are also closely interlinked through (i) impact on fisheries from land-based aquaculture activities (for example mangrove clearance or restoration, nutrient pollution); (ii) interactions between wild and escaped cultured fish; (iii) transfers of parasites and diseases between wild and cultured species; and (iv) the use of fishmeal in aquaculture feeds. The FAO Code of Conduct for Responsible Fisheries provides relevant policy guidance that also applies to aquaculture.

Other related policy areas include rural development, health, agriculture and poverty alleviation.

How delivering this target will affect costs for delivering other targets

Delivering target 7 will reduce the costs of delivering target 6 on sustainable fisheries by reducing certain impacts on wild fisheries (interactions between wild and farmed species, transfer of parasites, restoration of mangrove nursery grounds). Target 7 and target 10 are also related in that reducing aquaculture-related pollution in tropical areas will improve the health of coral reefs. Target 7 as it relates to aquaculture is also related to the forestry component of the same target, particularly in regards to the integrated shrimp/mangrove systems and abandoned shrimp pond restoration considered here. Additionally, the implementation of integrated coastal management was costed as part of target 10, and this expenditure will also help deliver target 7, particularly in relation of appropriate siting of aquaculture facilities.

ACTIONS

Identification of main actions / activities required to meet the Target 7

Major actions required to reach target 7 have been discussed in literature related to sustainable aquaculture, and included in the FAO Code of Conduct for Responsible Fisheries and Ecosystem Approach to Aquaculture. Specific actions were also put forward in the report of the CBD Ad Hoc Technical Expert Group on Mariculture (and included in decision VII/5). These actions are summarized by species groups in the table below.

Species group	Farming methods	Main impacts	Main activities to prevent or minimize impact
Crustaceans	Pond culture; raceway culture; cage culture; sea ranching	- Habitat destruction and degradation - Excessive nutrients leading to eutrophication - Use of wild seeds - Use of antibiotics and chemicals	- Improved site selection in the context of integrated coastal management - Improved shrimp pond management - Mangrove and other coastal habitat recovery and restoration - Mariculture that increases habitat structure - Integrated aquaculture - Changes in nutrition - Reducing stocking density - Reducing use of chemicals - Enclosed or recirculating systems, biofilters - Broodstock management - Capacity building
Finfish	Cage culture (inshore, offshore); pen culture; pond and raceway culture (flow-through and recirculation	- Pollution from waste and effluents - Transmission of diseases and parasites from cultured to wild stocks	- Improved site selection in the context of integrated coastal management - Enclosed and re-circulating systems - Changes in nutrition and improving efficiency of feeding - Improved filtration and fallowing - Reducing the use of hormones, antibiotics

	systems); sea ranching.	- Reduction in genetic diversity - Increasing demand on capture fisheries - Use of wild seeds	and other chemicals - Reducing stocking density - Culturing different species together (polyculture or integrated aquaculture) - Farming primarily native species - Reducing dependence on fish meal - Preventing escapes - Developing and implementing proper broodstock management plans - Adoption and implementation of international codes of practice and procedures for introductions and transfers of aquatic organisms - Capacity building
Molluscs	Vertical or rack culture; hanging culture; bottom culture; land-based tank culture; sea ranching.	- Excessive removal of nutrients and planktonic biomass - Excessive sediment accumulation - Use of wild seeds - Introduction of invasive species	- Improved site selection in the context of integrated coastal management - Integrated aquaculture - Broodstock management - Safe transfer of organisms - Use of native species
Other animals (e.g. echinoderms)	Tank culture, cage culture, sea ranching.	- Introduction of invasive species - Use of wild seeds	- Improved site selection in the context of integrated coastal management - Broodstock management - Safe transfer of organisms - Use of native species
Marine plants	Suspended culture; bottom culture; tank culture	- Introduction of invasive species	- Improved site selection in the context of integrated coastal management - Safe transfer of organisms - Use of native species

In general terms, the activities in the above table can be simplified to include the following:

1. Giving priority to farming of lower trophic level species, such as filter feeders and herbivores
2. Farming native species where possible
3. Minimising habitat modification during aquaculture development and operation
4. Minimising or preventing biological, chemical and organic pollution
5. Preventing escapes

The first two points were considered to be outside the scope of this study given that decisions about what species to farm are driven by market forces and national policy decisions. However, it is possible to address the remaining three actions, the implementation of which would make both existing and new aquaculture operations more sustainable.

Minimising or preventing pollution can be achieved through better waste treatment, including through biofilters, as is the case with integrated multitrophic aquaculture. Closed containment systems, though currently expensive, also show promise in preventing pollution and escapes. Habitat modification has been a particular issue in shrimp aquaculture, and the study will examine the costs of more “mangrove-friendly” aquaculture as well as costs of restoring mangrove areas cleared for aquaculture. The study will focus on the farming of finfish and crustaceans, because the farming of molluscs, echinoderms and marine plants are thought to have relatively smaller environmental impacts.

Finally, there is need for capacity building and investment in environmentally, socially and economically sustainable small-scale aquaculture, which improves rural livelihoods and alleviates poverty. Rough cost estimates for such capacity building and investment will also be provided.

METHOD OF ASSESSMENT

An overview of the method of assessment

The general method is as follows:

1. Determine current global production levels for different farmed species using methods that have substantial biodiversity impacts;

2. Determine the per unit (tonne) cost (both investment and running) of producing the different species using these existing methods;

3. Use 1 and 2 to calculate the current investment and running cost of producing current production using the existing methods.

4. Determine the per unit (tonne) cost (both investment and running) of producing the different species using alternative, 'biodiversity friendly' methods;

5. Use 1 and 4 to calculate the investment and running cost of producing current production using 'biodiversity friendly' methods.

6. Use 3 and 5 to calculate the additional investment and running cost of producing current production using 'biodiversity friendly' methods.

The production quantities were obtained from FAO publications, while the cost per unit numbers were found in published literature. All prices used were 2012 prices with a discount rate of 3% applied.

Method for determining cost of implementing integrated multitrophic aquaculture (IMTA)

Integrated multitrophic aquaculture (IMTA) is a practice which combines, in the appropriate proportions, the cultivation of fed aquaculture species (e.g. finfish/shrimp) with organic extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental sustainability (biomitigation), economic stability (product diversification and risk reduction) and social acceptability (better management practices). In particular, IMTA is known as a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities particularly in marine waters (Soto, 2009). The concept is not new, however, and this approach to farming and aquaculture has long been in use in Asian countries. Japan and China have used this technique for the co-culture of rice and fish for millennia (Neori *et al.*, 2004).

At the present time, at least Canada, Chile, China, Ireland, South Africa, the United Kingdom of Great Britain and Northern Ireland (mostly Scotland) and the United States of America have IMTA systems near commercial scale, or at commercial scale. Pilot scale operations are being undertaken in a number of countries. In Asian countries integrated aquaculture is commonly practiced, including through traditional methods and by small-scale farmers.

IMTA for finfish

Economic analysis of the costs and benefits of IMTA for finfish operations have been undertaken by Chopin et al, 2001; Whitmarsh, Cook and Black, 2006; and Ridler et al, 2007. These analyses were conducted in Chile, Scotland and Canada respectively. The table below provides information about the details relating to each study.

Study	Location	Species integrated	Information provided
Chopin et al, 2001	Chile	Salmon and seaweed	Net present value (NPV) for different stocking densities of salmon
Whitmarsh et al, 2006	Scotland	Salmon and mussels	Annualised equivalent costs for monoculture and integrated systems, NPV
Ridler et al, 2007	Canada	Salmon, mussels and seaweed	Total fixed and variable costs for monoculture and integrated system, investment costs, revenues, NPV

The calculations were made using figures from Ridler et al, 2007, which were the most complete regarding to detail about investment and running costs, and were then compared to the costs cited in other studies. The input figures relating to the differences in investment and running costs of monoculture operations are shown in the table below. These figures indicate the costs above and beyond what it would cost to run the existing salmon monoculture operation. FAO statistics were used for the calculations. According to the FAO (2012), 1.9 million tonnes of salmon was farmed in 2010.

Additional investment cost per tonne for integrated aquaculture (in 2012 US $) –	**Additional running costs per tonne for integrated aquaculture** (in 2012 US$) –	**Total production of salmon (tonnes)**
468	1076	1,9 million

IMTA for shrimp

Integrated systems are also commonly used in shrimp aquaculture. Many of these are small scale operations, and cost figures for those are unpublished and difficult to find. However, Valderrama and Engle (2002) have undertaken a study that included cost calculations for an integrated shrimp farm-mangrove forest system in Nicaragua, which provides estimates for investment and running costs, as well as net present value, for both a monoculture and an integrated system. The integrated system consists of the shrimp pond and constructed mangrove wetlands, which act as a biofilter, allowing for partial or complete recirculation of effluents back into the production ponds, and greatly reduce the impact of discharges. While this technique is considered experimental, it is included here because of its potential to achieve the twofold objective of effluent treatment and mangrove conservation in areas where mariculture is practiced.

The table below provides a summary of the costs estimated by Valderrama and Engle (2002) above and beyond the costs of operating a shrimp monoculture system.

Investment cost per ha in addition to those of shrimp monoculture (in 2012 US $) – range of values (mean value)	**Running costs per ha in addition to those of shrimp monoculture** (in 2012 US$) – range of values (mean value)	**Total are covered by shrimp ponds globally** (ha)
702-941 (829)	276-77 (179)	1.3 million

Closed containment systems

The majority of salmon and other marine finfish are currently farmed in open net pens and cages, resulting in a release of nutrients and other pollutants, escapees and transfer of parasites and diseases from farmed to wild populations. Closed containment systems have been suggested as a more sustainable alternative. Three main types of closed containment systems exist, and include marine floating bag systems, land-based saltwater flowthrough systems, and land-based freshwater recirculating systems. Marine floating concrete tank systems have also been proposed (Liu and Sumaila, 2007).

The cost of such systems is still high, and this remains the steepest obstacle to their widespread adoption by industry. They are considered financially profitable only when they produce fish that achieve a price premium (Liu and Sumaila, 2007). At the present time, closed containment systems operate as pilot projects, and a life cycle analysis of these projects will provide further information about economic and environmental costs and savings. Closed containment salmon farming on a small scale has been practiced at least in Canada, USA, Norway and Tasmania.

Economic analysis of closed containment systems have been undertaken by Lisac and Muir, 2000; Liu and Sumaila, 2007; Bijo, 2007; and Boulet et al, 2010. The details about these studies are provided in the table below.

Study	Location	Type of system	Species	Information provided
Lisac and Muir, 2000	Mediterranean	Land-based	Seabass/ seabream	Investment and operating costs, internal rate of return (IRR),
Liu and Sumaila, 2007	Canada	Seabag	Salmon	Capital investments, running costs, NPV
Bijo, 2007	Malaysia	Land-based recirculating	Seabass	Start-up and annual operating costs
Boulet et al, 2010	Canada	Land-based recirculating	Salmon	Investment costs and running costs, NPV

Based on the figures in these it is possible to calculate the differences in investment and running costs between open net cage/pen culture systems and closed containment systems using the general method presented above. The range of input figures are given in the table below. It should be noted that only systems that have the potential to produce positive revenues and get return for the original investment were considered in this study.

Method	Per tonne difference in investment costs in 2012 US$– range of values (mean)	Per tonne difference in running costs in 2012 US$ yearly – range of values (mean)
Seabag system	2550 – 2318 (2343)	1043- 2667 (1855)
Recirculating systems (land based)	8041-9351 (8696)	179-1622 (900)

Closed containment systems are currently also being contemplated for shrimp farming, particularly in the USA. However, explicit financial analysis is not yet available for these systems, although it would be expected that the costs would be similar to the finfish systems presented here.]

Other estimates made

a. Capacity building for implementing best management practices

In addition to the new and promising technologies that were described above, there is a need to ensure that funding is available for the implementation of best management practices, particularly in developing countries, and to meet the standards for aquaculture certification. The GEF Needs Assessment estimates the financial need for this purpose to be US$100 - 150 million, of which the GEF would expect to cover US$30 - 45 million.

b. Restoration of mangrove cover in abandoned shrimp ponds

The productive life of shrimp farms is only 5-10 years, after which they are often abandoned. According to estimates derived from published literature by the Mangrove Action Network, there are over 250,000 ha of abandoned shrimp ponds found in the mangrove forest zones of Asia and Latin America. (Lewis, R., unpublished data and Stevenson et al, 1999; Lewis et al, 2003; Sammut and Hanafi, 2002). However, the figure is relatively old, and may be a conservative figure. Up-to-date estimates of area covered by abandoned shrimp ponds are lacking.

The cost of mangrove restoration also varies. According to Lewis (2001), the costs to successfully restore both the vegetative cover and ecological functions of a mangrove forest have been reported to range from USD$225/ha to USD$216,000/ha. Unpublished data would indicate that the even higher costs, as much as USD$500,000/ha, has been spent on individual projects. Hydrologic restoration of abandoned shrimp ponds can be done for $100-$200/ha. Planting should only be done if natural recolonization fails, and can double the cost of a project. Barbier (2000) estimated that hydrologic restoration in Thailand could be undertaken for USD$200/ha, or USD$700/ha if planted. Scientific data indicates that using this method, ecological functions are quickly restored, with fish populations typically reaching reference site diversity and densities within 5 years. Natural recolonization of areas with restored hydrology, such as reconnected abandoned shrimp aquaculture ponds, occurs quite rapidly if mangrove forests are present in the vicinity and natural production of propagules is sufficient (Stevenson et al. 1999).

Considering the conservative estimate of 250,000ha of abandoned shrimp farms globally, and provided that all of those ponds are located in mangrove areas, the total cost of restoration (at US$200/ha) would be $50 million. However, the figure could be twice this given that the information relating to area covered by abandoned shrimp ponds is old, and is likely now much higher.

Scenarios

The scenarios presented here allow for the gradual scaling up of promising new technologies (integrated multitrophic aquaculture and closed containment systems) that are currently at a pilot stage. It is expected that with further investment in research and development, these technologies can become more effective, affordable and widely practiced, and thus have the potential of greatly improving the sustainability of the rapidly expanding aquaculture industry.

Because of the current expense of closed containment systems, their adoption makes sense only for high value species, which would include salmon, seabass and seabream. Thus the calculations in the scenarios were made for the combined production of salmon (1.9 million tonnes) and European seabass and gilthead seabream (265,100 tonnes). The two systems included in the scenario are those that have shown to have positive net present value (NPV) for high value species: land-based recirculating systems and seabag systems. Because of their high expense, the target values in the scenario are set relatively low at 5% and 10% of the tonnage of salmon, seabass and seabream produced.

Integrated aquaculture systems are generally less costly, and are already widely applied in Asia. Integrated systems do not require high value species, and examples from Asia show that they can be successfully applied by small-scale farmers. The scenarios here relate to application of IMTA for salmon/mussel/seaweed systems and shrimp/mangrove systems. The reason for selecting these species has to do both with the availability of data and with the high and/or growing market share of the species. According to the FAO, in 2010 aquaculture of crustaceans made up a total of 9.6 percent (5.7 million tonnes) of total world aquaculture production. Of these, shrimp are the dominant farmed species for both marine and brackish water systems. Salmonid production, particularly Atlantic salmon, increased dramatically from 299 000 tonnes in 1990 to 1.9 million tonnes in 2010, at an average annual rate exceeding 9.5 percent. Other finfish species also increased rapidly, from 278 000 tonnes in 1990 to 1.5 million tonnes in 2010, at an average annual rate exceeding 8.6 percent.

Because the relatively high net present values of finfish IMTA systems, the targets for adoption in the scenarios are higher than for closed containment, and are set at 20% and 30% of the tonnage of salmon and shrimp produced. Because shrimp/mangrove systems are still relatively experimental, the target is set lower at 5% and 10%. Investing in these systems would not only bring immediate biodiversity benefits, but would also provide for their future upscaling where appropriate.

The scenarios are as follows:

By 2020:

Scenario 1: 20% IMTA for salmon; 5% IMTA for shrimp; 5% closed containment for salmon and seabream/seabass

Scenario 2: 30% IMTA for salmon; 10% IMTA for shrimp; 10% closed containment for salmon and seabream/seabass

In both scenarios, it is considered that half of the closed containment systems will be land-based recirculating systems, and half seabag system

Comparison with GEF Needs Assessment for target 7

The method for estimating resource needs for this target differs from the GEF Needs Assessment in that the present study aims to look at specific aquaculture methods that apply for both developed and developing countries, rather than just capacity building needs of developing countries. However, the GEF estimate is incorporated into this study to give an estimate of capacity building needs for implementing best management practices.

RESULTS

The table below provides a breakdown of the estimated resource needs.

Activity	Investment Needs (2013 – 2020)		Recurrent Annual Expenditure		Recurrent Total (2013 – 2020)	
	Scenario 1 (20% IMTA finfish, 5% IMTA shrimp, 5% closed containment)	Scenario 2 (30% IMTA finfish, 5% IMTA shrimp, 10% closed containment)	Scenario 1	Scenario 2	Scenario 1	Scenario 2
IMTA salmon	177,840000	266,760000	408,880000	613,320000	3271,040000	4906,560000

IMTA shrimp	53,885000	107,770000	93,080000	186,160000	146,965000	293,930000
Closed containment (seabag and RS) salmon, seabrem, seabass	597,513472.5	1,195,026945	111468820.3	222937640.6	891750562.5	1783,501125
Capacity building and best practices			18,750000	18,750000	150,000000	150,000000
Mangrove restoration			62,50000	62,50000	50,000000	50,000000
Total	829,238,473	1,569,556,945	638,428,820	1047417641	4,509,755,563	7,183,991,125

As the table above demonstrates, the largest costs relate to implementing closed containment systems, which was to be expected given the expensive technology involved. Integrated aquaculture systems present a more cost effective option, and also provide profits through revenues from the lower trophic level species that are farmed together with the main cultured species. The amount of money required for restoring mangroves in abandoned shrimp pond areas is low in comparison, and is an activity that could provide large biodiversity benefits.

The table below provides an estimate of total resource needs for the period of 2013-2020.

Activity	**Total for the whole period (2013 – 2020)**		**Average annual (for period 2013 – 2020)**	
	Scenario 1 (20% IMTA finfish, 5% IMTA shrimp, 5% closed containment)	**Scenario 2 (30% IMTA finfish, 5% IMTA shrimp, 10% closed containment)**	**Scenario 1**	**Scenario 2**
IMTA salmon	3,448,880000	5,173,320000	431,110000	646,665000
IMTA shrimp	146,965000	293,930000	18,370625	36,741250
Closed containment (seabag and RS) salmon, seabrem, seabass	1,489,264035	2,978,528070	186,158004	372,316009
Capacity building	150,000000	150,000000	18,750000	18,750000
Mangrove restoration	50,000000	50,000000	62,50000	62,50000
Total	5,285,109,035	8,645,778,070	660,638,629	1,080,722,259

The total estimates for scenarios 1 (approximately 5.3 billion) and scenario 2 (approximately 8.6 billion) provide an indication of the large global investment that is required to make aquaculture environmentally sustainable on a global scale. At the same time, aquaculture has great potential to provide food for a growing global population, and for alleviating poverty in many developing countries. Thus it is important to ensure that the expansion of aquaculture takes place in a sustainable manner and that environmental and social impacts are reduced in the long term. It should also be noted that all of the technologies tested here provide revenues that help offset the costs, and this aspect is introduced in more detail under the "discussion" section of this paper.

DISCUSSION

General trends

The cost estimates provided in this study should be considered a step forward on the longer road towards sustainability. It unlikely that full and absolute sustainability can be achieved in eight years when most environmental management projects take much longer than that to implement. At the same time, substantial progress can be made by 2012, and it is likely that through scaling up promising pilot operations and technologies they also become more efficient and cost-effective. With investment in developing such technologies, it is likely that their future costs of implementation will decrease and further scaling up becomes more financially viable.

Confidence in the estimates produced

The cost estimates in this study have been based on a few case studies from a limited number of countries. Therefore, they may not be directly transferable to other countries or regions globally. In addition, costs and inflation rates vary by country, and it was not possible to take such differences into account in the calculations beyond an attempt to include data from both developed and developing countries where possible. The vast majority of published studies originated from developed countries, however, and this has resulted in a bias towards North American and European information, which is likely to influence the cost estimates. For example, labour costs are likely to be cheaper in developing countries, while some capital costs may be more expensive. Inflation rates may also differ. Thus, the figures given here should be treated as rough estimates only. Ideally, global estimates should be based on a wider range of cost information from different regions, and should take into account local conditions.

The estimates also do not take into account existing efforts, many of which are extensive. There has been a great deal of recent work related to developing best management practices and certification standards, which has in turn resulted in country-level efforts of implementation. Because of these efforts, and due to increasing regulation of pollution in many countries, aquaculture operations are becoming more sustainable. Given that these efforts are taking place, this study purposely focused on the scaling up of new, pilot-level technologies that could have major impact on further reducing the environmental impacts of aquaculture.

Finally, the study is focused on the commercial farming of higher value species, such as salmon, other finfish and shrimp. This focus has to do with the large and rapidly growing market share of these species. However, the study does not address in detail the extensive number of small-scale and subsistence aquaculture operations which are common in developing countries, and which are important for providing income for local communities. The needs of such operations are included under the funding for capacity building. It is important to recognise that many small-scale operations foster a high degree of innovation, experimentation and adaptive learning that has value on a broader regional scale. Many sustainable traditional aquaculture systems, including integrated systems, could be scaled up more broadly. There have been some efforts to transfer the principles of such traditional systems to larger-scale operations. These efforts include currently ongoing work in Thailand, the USA, Ecuador, and Brazil to diversify aquaculture production so that two or more mutually compatible species are cultivated in a particular pond (Soto, 2009). However, many such systems are highly adapted to local conditions, and have been developed for a specific place. They may need to be tested before being transferred and implemented in a different region or locality.

The business case for implementing actions to reach target 7

Aquaculture is first and foremost a business venture, and those entering the business expect to gain revenue from its operation. Thus, the technologies discussed under this target were selected due to their potential to provide return for investment and long-term profits. For example, integrated multitrophic aquaculture is likely to lead to an increase in revenue particularly if the other cultivated species (such as shellfish and/or marine algae) are also marketed. Preliminary data (Ridler *et al.*, 2007), in which net present value (NPV) calculations are conducted over 10 years to portray long-term variability, show that the addition of seaweed and mussel to salmon farming is more profitable and helps reduce risks through diversification. A preliminary economic scenario for the Bay of Fundy in Canada showed that IMTA could provide approximately $44.6 million in extra revenue and 207 new jobs (Chopin *et al*, 2008).

Similarly, while the investment in closed containment systems is initially expensive, the NPV for the technologies discussed in this study is positive in the long term. This is particularly true when environmental costs of the aquaculture operation are taken into account and internalised. It is also likely that consumers in many countries are willing to pay a higher price for a product that has been farmed using environmentally friendly practices.

Additional resource needs

Recent decades have seen improvements in water and waste management, which have often been driven by the implementation of standards (both national and international), better management practices and a move towards certification of aquaculture products. At the same time, many environmental impacts still remain to be addressed on a global scale and aquaculture is growing at a fast pace. It is therefore expected that a combination of regulation, incentives and capacity building will be required in the future well beyond 2012 to keep pace with the growing importance of aquaculture.

Further research needs

Future research needs include the following:

- Identification of best practices that are likely to have the greatest combined biodiversity and livelihoods impacts. These may include ways in which traditional aquaculture practices can be scaled up.
- Making closed containment systems more cost-effective and efficient.

- Establishing the economic and environmental value of IMTA systems and their co-products.
- Selecting the right compatible species for IMTA systems that are appropriate to the habitat and produce the desired effects. This may include study of traditional IMTA systems.
- Promoting effective government legislation/regulations and incentives to facilitate the development of best aquaculture practices, IMTA and closed containment.

Benefits of delivering the target

Delivering the target will result in substantial benefits, including:

- **Improved income for the farmer**. Integrated systems often have a higher profitability than monoculture systems. For example, systems that associate aquaculture to livestock breeding may show a contribution of fish to net income higher than 50%. These trends are encountered in several areas worldwide (Soto, 2009). Implementation of better management practices can lead to increased efficiency, better survival rates of species, and increased revenue. For example, a study in Costa Rica found that there would be approximately a 20% increase in revenue, depending on size of the farm, with increased survival rate of shrimp due to improved management practices (Bryand et al, 2006).
- **Improved resiliency**. Integrated systems are better able to cope with market fluctuations and failures in production. The approach makes the harvest more resilient to disease as it is unlikely that all the harvest in an integrated system would be wiped out by a given disease, as is the case in single species aquaculture (Soto, 2009).
- **Restoration of ecosystem services.** For example, mangrove forests provide at least $1.6 billion per year in ecosystem services worldwide, and it is estimated that almost 80% of global fish catches are directly or indirectly dependent on mangroves. Thus, aquaculture that has minimum impact on mangroves, or even restores mangrove forest for biofiltration purposes, will have broader biodiversity and ecosystem services benefits.
- **Increase in global food supplies and employment**. Sustainable aquaculture can deliver increased supplies of seafood to meet the needs of a growing human populations, increased economic growth, employment, and relaxation of fishing pressure.

Gap analysis

	Target 7: Aquaculture
Evidence on costs	Strength of evidence - medium Extent to which further research is required - some
Evidence on current levels of expenditure	Strength of evidence - low Extent to which further research is required - considerable
Other Targets	
Links to other Targets	Yes - both within the overall marine cluster and with other Targets
Evidence on potential	Yes - both within the overall cluster and between Targets

	Target 7: Aquaculture
co-benefits	Strength of evidence - medium Extent to which further research is required - some
Other policy areas	
Related policy areas outside of biodiversity	Integrated coastal management, watershed management, marine spatial planning, poverty, food security, health, fisheries, agriculture, forestry, pollution

Sources of funding

Both integrated aquaculture and closed containment systems require industry buy-in, and thus government incentives and regulation will help their implementation. At the present time, most aquaculture operations do not take into account their true environmental costs, and instead the costs of remediation come out of public funds. It is therefore desirable that industry takes the leading role and provides most of the funding for implementing technologies that internalise the environmental costs of their operation (the polluter pays principle). The techniques discussed in this study provide one way to accomplish this while still maintaining the overall profitability of the aquaculture business. In fact, in some cases, such as with many types of integrated aquaculture, revenues are likely to increase when compared to monoculture operations, while risk will decrease.

For capacity building and implementation of best management practices in developing countries, it is hoped that funding from GEF, the World Bank and other funding and development agencies can be put in place. It is likely that such funding will increase the profitability of aquaculture operations, as well as lessen their environmental impact, resulting in improved community livelihoods.

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TARGET 10: CORAL REEF ECOSYSTEMS (Simon Harding)

INTRODUCTION TO TARGET

Target 10 Text: *By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.*

Interpretation of target

For this target assessment we specifically focussed on **tropical shallow water coral reef ecosystems** and not any other ecosystems that are vulnerable to climate change. A separate assessment of activities and costs for cold water coral reef ecosystems will need to be undertaken. Further assessment of the financial resources needed to minimise anthropogenic pressures on other vulnerable ecosystems such as those at high altitude or latitude is also required under this target but not addressed in this study. Throughout this report section when discussing Target 10 we are referring only to warm water coral reef ecosystems predominantly found in the tropics.

The deadline for the target of 2015 is widely regarded as unachievable given that it is only a few years away. Therefore the deadline for Target 10 in this case has been extended to 2020. Where possible, resource needs to meet the target will therefore be estimated for the period 2012 – 2020.

For Target 10 the level of activity needed to minimise an anthropogenic pressure needs to be defined. For this assessment we propose to make the assumption that the term 'minimised' is equivalent to reducing the anthropogenic pressure to 80% of its initial level or to increasing integrated management approaches to encompass 80% of the coastal zone or coral reefs by area.

To meet Target 10 all anthropogenic pressures affecting coral reefs must be minimised through a coordinated approach to address all stressors. The most recent global assessment of threats to coral reefs in Reefs at Risk Revisited (Burke et al., 2011) identified four main 'local' threats:

- **Coastal development**, including coastal engineering, land filling, runoff from coastal construction, sewage discharge, and impacts from unsustainable tourism;
- **Watershed-based pollution**, focusing on erosion and nutrient fertilizer runoff from agriculture delivered by rivers to coastal waters;
- **Marine-based pollution and damage**, including solid waste, nutrients, toxins from oil and gas installations and shipping, and physical damage from anchors and ship groundings;
- **Overfishing and destructive fishing**, including unsustainable harvesting of fish or invertebrates, and damaging fishing practices such as the use of explosives or poisons.

Target 10 is linked to multiple programmes of work within the CBD including those on marine and coastal biodiversity and climate change and biodiversity. There are a number of COP decisions that Target 10 is linked to. These include:

- Decision X/33 (Biodiversity and Climate Change);
- Decision IX/16 (Biodiversity and Climate Change: A. Proposals for the integration of climate-change activities within the programmes of work of the Convention; B. Options for mutually supportive actions addressing climate change within the three Rio Conventions; C. Ocean Fertilization; D. Summary of the findings of the Global Assessment on Peatlands, Biodiversity and Climate Change);
- Decision VIII/30 (Biodiversity and climate change: guidance to promote synergy among activities for biodiversity conservation, mitigating or adapting to climate change and combating land degradation);
- Decision VII/15 (Biodiversity and Climate Change);
- Decision VIII/23 on Agricultural biodiversity addressed cross-cutting initiatives on biodiversity for food and nutrition and proposed a corresponding framework;
- Decisions VII/5 and X/29 regarding marine and coastal biodiversity and specifically coral reef ecosystems through the adoption of, and reporting on the specific work plan on coral bleaching.

Target 10 is also linked to a number of policy areas including marine resource management (e.g. fisheries), land-based pollution and management, social and ecological resilience in the coastal zone and the health, poverty and food security of coastal populations, particularly in less developed countries. Achieving Target 10 will only be possible if other related targets are met, most notably for fisheries management and land-based pollution. The activities being undertaken for Target 10 in this assessment will be beneficial for the policy areas mentioned above by providing the required frameworks necessary for integrated management in the coastal zone.

Potential overlaps and synergies exist between Target 10 and both other targets within the marine cluster and other broader targets. Within the marine cluster there is a strong overlap with Target 6 in terms of the sustainable management of coral reef fisheries and with Target 11 for the establishment and management of marine protected areas in coral reef regions to reduce or prevent marine resource extraction and protect coral reef habitats. There is also the potential for overlap with Target 7 (for sustainable aquaculture) in terms of the pollution generated by coastal or inland aquaculture which can have an impact on coastal water quality if not managed effectively. Overharvesting of species from coral reefs or associated ecosystems such as mangroves, estuaries or seagrass beds for use in mariculture may also have an impact on ecosystem integrity. Other targets where overlap is likely or possible are Target 5 (Habitat loss), Target 7 (Agriculture), Target 8 (Pollution), Target 9 (Invasive Species), Target 12 (Threatened Species) and Target 14 (Ecosystem Restoration). Of these the greatest potential for overlap in cost estimations is with Target 8 for pollution in terms of wastewater management and to a lesser extent agriculture (Target 7) in terms of watershed or catchment management.

Consultation with other researchers in the marine cluster for Targets 6, 7 and 11, and with other clusters for Targets 8 (pollution) and 14 (ecosystem restoration) has ensured that the estimates of resource needs produced in this study will not overlap significantly with any of the aforementioned studies. However it is likely that the activities costed for other closely-related targets covering fisheries and pollution will not meet the ‘minimising’ standard set for Target 10 of reducing stressors by 80%. For example Target 6 is focussed on large-scale fisheries management and less attention is paid to small-scale inshore fisheries, meaning that unsustainable fishing practises will continue in some tropical inshore waters. One of the activities costed for Target 8 is to reduce nutrient runoff from agriculture by 50% which falls short of the Target 10 standard by 30%.

Delivering the activities costed here for Target 10 may influence costs for a number of other related targets by providing management frameworks in which the other related activities can operate. A reduction in the costs of inshore fisheries management, land-based pollution management and sustainable coastal aquaculture are likely if effective management frameworks are in place for the coastal zone and inshore waters.

ACTIONS

To address the key threats mentioned above, the main actions or activities have been identified as integrated coastal zone management, sustainable marine resource use (e.g., fisheries), integrated watershed and wastewater management and the use of marine protected areas to conserve biodiversity, habitats and exploited populations.

As both fisheries and MPAs are already covered by other targets (6 and 11), the costs for these actions for coral reefs were not assessed within work completed for Target 10. Instead the cost estimation mainly focussed on habitat degradation caused by pollution and inadequate watershed and coastal zone management. However, a preliminary assessment of the costs of establishing and supporting community-based fisheries management for tropical inshore waters was also undertaken to complement the analysis conducted for Target 6 within this cluster, which has a bias more towards large-scale commercial fisheries management.

METHOD OF ASSESSMENT

The method of assessment consisted of two main types of approach, an assessment and extrapolation of existing costs and a relative estimation of spending needs to reduce anthropogenic pressures for all coral reef nations.

Assessment of Existing Costs

Firstly, to assess the costs of action, a review of current and recent large-scale projects to establish or improve both Integrated Coastal Zone Management (ICZM) and Integrated Water Resource Management (IWRM) involving watershed or wastewater management, implemented by the World Bank or UNDP / UNEP in coral reef countries, often with GEF support, was undertaken to determine the costs of such actions. The projects identified included the current ICZM project in India (World Bank) and the Integrated Coastal Management (ICM) projects in East Asia implemented by PEMSEA (Partnerships in Environmental Management for the Seas of East Asia), the Integrating Watershed and Coastal Area Management (IWCAM) in small island development states of the Caribbean project and the on-going GEF Integrated Water Resource Management (IWRM) project in Pacific Island nations implemented by the UNEP and UNDP. Costs for tropical IWRM were also assessed for more developed nations such as Australia and the U.S.A. Additionally the costs of implementing ecosystem-based management programmes in coral reef nations were investigated.

Using the examples for ICZM and IWRM from the Caribbean and Pacific mean unit costs for the implementation of ICZM and watershed / wastewater management were then calculated for selected metrics, these were, cost in U.S. Dollars per km of coastline or per population size (e.g. cost/person) for the coastal populations involved in each project. Unit costs were then adjusted for inflation since the project inception using the GDP deflator index to produce a current cost estimate (2012)

The costs of implementing and maintaining community-based marine resource management (CBRM) were also investigated for Pacific Island Nations, mainly through the Locally Managed Marine Area (LMMA) initiatives. Both site-based and area-based costs were obtained as well as country estimates to support a national system of community-based management over the long-term. National estimates were then converted into support costs per km^2 of coral reef for that country.

Extrapolation of Unit Costs

The unit costs for some of the project examples were sufficiently detailed to enable an extrapolation of costs required to minimize an anthropogenic pressure (i.e. reduce it by 80%) or increase management coverage to 80% of the coastline or coral reef area. Extrapolations were made for some examples of ICZM, IWRM and wastewater management at a number of spatial levels (city, sub-national, national, regional).

Two of the unit costs for integrated management (ICM and CBRM-LMMA) were also extrapolated further to provide an estimate of resource needs for the majority of coral reef countries and territories:

Activity 1: PEMSEA Regional ICM costs per km of coastline were extrapolated to estimate the cost of establishing coastal management frameworks for 120 coral reef countries or territories for the total length of coastline that is up to 5 km from coral reefs[2].

Activity 2: The costs of establishing and supporting community-based marine resource management through the use of LMMAs per km^2 of coral reef were extrapolated to estimate resource needs for 83 coral reef countries covering 74% of coral reefs globally. The average unit costs used were those reported for the Fiji LMMA network (Govan, 2009). Coral reef area data by country or territory was provided by the World Resources Institute Reefs at Risk Programme.

For both the above near global estimates, two scenarios are provided:

Scenario 1; the resource needs to manage 80% of the national coastline or reef area by ICM or LMMAs respectively

Scenario 2: the resource needs to manage 50% of the national coastline or reef area by ICM or LMMAs respectively.

An important caveat for both estimates above is that existing efforts or progress made to manage the coastal zone or inshore waters by ICM or CBRM in coral reef countries and territories are not taken into account. Such an analysis would need to be conducted at the national level to calculate the remainder of coastline or reef area that needs to be managed to meet the 80% coverage target.

Relative Estimation of Expenditure Needs

It was initially thought that, using selected Reefs at Risk data-sets and a range of unit costs for different actions, it would be possible to come up with some crude global estimates of the overall cost for meeting Target 10 provided that sufficient information on existing or previous

[2] Coastline data provided by the World Resources Institute and based on National Geospatial Intelligence Agency, World Vector Shoreline, 2004

costs was available. The World Resources Institute (WRI) provided a number of data-sets used for the Reefs at Risk Revisited report. These included, for each coral reef nation or territory, the area of coral reef (km^2), integrated level of local threat and vulnerability index[3]. However, although some cost estimates were identified for actions such as ICZM, watershed and wastewater management there still remained a number of threats or pressures that were not accounted for. These include management actions to minimise the use of pesticides, the impact of mining and other forms of land-based industrial pollution. In addition, management actions to minimise marine-based pollution (as defined by Reefs at Risk Revisited) were also not assessed in this study but were partly addressed by the assessment for Target 8 for marine debris.

Although there is not sufficient information available for a preliminary overall cost analysis, we can still use the WRI data to predict the relative level of spending required for each coral reef nation or territory and identify which countries and regions will require the greatest amount of investment to meet the target.

For each coral reef country or territory two types of estimates were made:

1. A relative estimate of the effort required to meet the target, calculated from the area of coral reef (km^2) at a medium, high or very high level of integrated local threat and the vulnerability index also divided into four categories (low, medium, high and very high) i.e. **which countries have the highest levels of financial resource need.**

   Estimate 1 = ((M RA x MT) + (H RA x HT) + (VH RA x HT)) x VI

2. A relative estimate of the need for assistance, calculated from the percentage area of coral reefs at a medium, high or very high level of threat and the vulnerability index i.e. **which countries have the highest priority in terms of financial resource needs**.

   Estimate 2 = ((M R% x MT) + (H R% x HT) + (VH R% x HT)) x VI

Where: RA = Reef Area (km^2); R% = Percentage of Reefs (by area); L = Low threat level; M = Medium threat level; H = High threat level; VH = Very high threat level; VI = Vulnerability Index.

For the calculations the four categories for integrated level of local threat and vulnerability index (low, medium, high and very high) were assigned the numerical values of 1 to 4 (low = 1, medium = 2, high = 3, very high = 4).

Comparison with GEF Needs Assessment for Target 10

The method of assessment for this study differs from that used in the GEF Needs Assessment for estimating total global costs of Target 10 in the following ways:

- The GEF Needs Assessment covers four years (2014-2018) while this study covers 8 (2013-2020);
- GEF funding is restricted to GEF eligible countries whilst this assessment in part provided estimates for all coral reef countries and territories;

[3] The Vulnerability Index is a combination of reef dependence, adaptive capacity and threat exposure. Further details are provided in the Reefs at Risk Revisited report

- The level of total spending by GEF is restricted to a maximum of $200 million over four years for 10 projects. Our assessment produced a global estimate for ICM in coral reef countries that was considerably higher;
- The GEF Needs Assessment appears to be spatially limited by highlighting particular reef systems in eligible countries but ignoring others such as the East African / Western Indian Ocean region or South Asia (e.g. India and Sri Lanka);
- There is some similarity in the activities to be funded such as developing and implementing ICZM but other activities to be funded by GEF are more about preparation and planning for action than actually reducing the stressors in question.

RESULTS

Assessment of Existing Costs

Cost estimates for ICZM, ICM or Ecosystem-based Management (EBM) are provided in Annex 1a. Cost estimates for ICZM (ICM) vary considerably when expressed as the cost per km of coastline and reflect the range of activities that can fall within a single project. For example the high unit costs for the World Bank ICZM project in India at the State level can be partly explained by the greater number and variety of demonstration projects implemented in each State. Conversely, the ICM projects implemented by PEMSEA were more concerned with building an overall management framework to enable ICZM at a number of levels (local, provincial, national). When the total spending for the PEMSEA initiative over a period of 16 years is expressed as a unit cost then the cost of setting up and running integrated coastal management is considerably less.

Only one example of a large-scale EBM project for a coral reef ecosystem was identified after an extensive search, in the Maldives. Unit costs are expressed per the atoll population and not per km of coastline in this case. However, the LMMA or community-based approach to marine resource management is also considered to be one key part of an EBM approach (see below)

A range of wastewater and watershed management cost examples were identified (Annex 1b) which were mainly part of regional GEF supported projects in the Pacific (Pacific IWRM) and Caribbean (IWCAM). Unit costs are also expressed per the affected population which is probably more relevant for wastewater than watersheds. Examples from developed countries are also provided for the Florida Keys (wastewater) and the Great Barrier Reef (watersheds and water quality).

For developing nations wastewater management unit costs ranged between 164 and 610 USD per person. A comprehensive wastewater management process in the Florida Keys was considerably more expensive at almost 9500 USD per person. Country-based demonstration projects of the Pacific IWRM initiative tackled a range of water quality issues and unit costs were generally higher than for projects solely focussed on wastewater treatment or management. Unit costs for watershed management initiatives were the lowest, ranging from 11 to 68 USD in Caribbean and Pacific island countries, and were also relatively low in Australia for the Great Barrier Reef.

Community-based approaches to marine resource management have proliferated in the last two decades in the Western Pacific and Coral Triangle regions, mainly through the LMMA networks at the national level. Annex 1c summarises the costs of setting up and running a community-based / LMMA approach per site (community or village) and per area (km^2) of managed fishing ground. The unit costs provided are for managed areas but not for no-take areas which have generally higher costs per km^2. LMMA costs per site range from $380 on

Kadavu, Fiji to $3459 for sites in the Solomon Islands. The lower cost on Kadavu compared to other LMMA sites in Fiji has been attributed to using a more decentralised approach (island-based) and a reduced monitoring programme. For costs / km^2 these range from $42 to over $2000 with the highest cost found in Samoa for a more centralised government run programme.

There have also been some estimates of setting up and/or supporting national systems of community-based resource management with examples provided for the Solomon Island and Fiji (Annex 1c). The figures for the Solomon Islands are estimated annual costs for an establishment period of at least 10 years. A rough estimate of annuals costs over the long-term for Pacific SIDs was calculated as $0.1 – 0.5 million per nation.

Extrapolation of Unit Costs

A number of the project examples highlighted previously were sufficiently detailed to enable further preliminary analysis to extrapolate unit or total costs. Examples are provided for wastewater treatment, IWRM in the Pacific and regional ICM for East Asia (Table 1). Extrapolations were made to predict costs for an 80% level of reduction in the associated stressor or 80% management coverage as this was assumed to minimise the anthropogenic pressure or pressures in question. Further values are also provided for 50 and 100% for comparison. For the Florida Keys examples we make the assumption that the comprehensive wastewater plan to meet strict standards as part of State legislation[4] will result in this stressor being completely minimised (i.e. 100% reduction).

The examples for IWRM in the Pacific were also converted into a total cost of implementing IWRM at the national level for 80% of the population, with values ranging from 7 to 160 million. The range in national estimates is related to both population size and the number of activities undertaken within the IWRM project at the national level which can vary considerably between projects.

At the regional level, extrapolation of ICM to cover 80% of the East Asia region (234,000 km of coastline) within the PEMSEA umbrella would cost just over 1 billion dollars.

Table 1. Selected examples of extrapolated costs for Wastewater management, IWRM and ICM.

Action	Location	Cost	Units	% change	50% Cost	80% Cost	100% Cost	80% National Cost*
Wastewater treatment	Xiamen, P.R. China	201	Per person	30	335	536	670	n/a
Wastewater treatment	Florida Keys. U.S.A	8536	Per person	100	4268	6829	8536	n/a
Pacific IWRM	Cook Islands	164	Per person	35 (30-40)	234	375	469	7.18 million
	F.S. Micronesia	307	" "	35	439	702	877	77.19 million

[4] Section 6 of chapter 99-395, Laws of Florida

				(30-40)				
	Niue	4327	" "	35 (30-40)	6181	9890	12363	13.85 million
	Rep. Marshall Islands	1324	" "	35 (30-40)	1891	3026	3783	160.87 million
	Samoa	70	" "	35 (30-40)	100	160	200	28.64 million
	Tuvalu	780	" "	35 (30-40)	1114	1783	2229	18.80 million
	Vanuatu	59	" "	35 (30-40)	84	135	169	30.28 million
ICM - PEMSEA	East Asian Region	144.86 million	Total Core funds	11.5 (2010)	631.73 million	1010.77 million	1263.46 million	n/a

*: 80% cost multiplied by the national population

Global estimates of resource need for the integrated management of coral reef ecosystems through the processes of ICZM (ICM) and CBRM by the use of LMMA networks in less developed countries are provided below (Table 2). Costs for setting up ICM frameworks for 80% of coastlines adjacent to coral reefs using the PEMSEA approach were estimated as $1.05 billion USD for the eight year period up to 2020. Compared to ICM, the costs of setting up and running LMMA networks at the national level were smaller by a factor of 10 with an estimate of $100 million to manage 80% of each nation's coral reefs by area for the 83 countries assessed. There is however quite a large range in investment costs for setting up LMMA sites (Table 3) which contributes to the overall cost range for each scenario.

A total figure of resource needs has been provided but may not be applicable if the ICM framework aims to incorporate CBRM into the overall programme of coastal management for that location.

Table 2: Total Resource Needs (USD Million)

Activity	**Total for the whole period (2013 – 2020)**		**Average annual (for period 2013 – 2020)**	
	Scenario 1 (80%)	**Scenario 2 (50%)**	**Scenario 1 (80%)**	**Scenario 2 (50%)**
ICM Frameworks	1052.79	657.99	131.60	82.25
CBM-LMMA National Networks	99.66 (88.97 – 118.75)	62.29 (55.60 – 69.51)	12.46 (11.12 – 14.84)	7.79 (6.95 – 9.28)
Total (if applicable)	**1152.45**	**720.28**	**144.06**	**90.04**

Note: Figures adjusted for inflation using a generic annual rate of 3%.

Table 3: Estimated Resource Needs – Breakdown (CBM-LMMA Networks only)

Investment Needs (2013 – 2020)		Recurrent Annual Expenditure		Recurrent Total (2013 – 2020)	
Scenario 1 (80%)	**Scenario 2 (50%)**	**Scenario 1 (80%)**	**Scenario 2 (50%)**	**Scenario 1 (80%)**	**Scenario 2 (50%)**
12.44 (2.81 – 29.61)	7.77 (1.76 – 18.51)	9.65	6.03	77.23	48.27

Note: Estimates above are not adjusted for inflation

The vast majority of the costs identified were either solely establishment costs such as capital costs to build wastewater treatment facilities or were a combination of establishment and on-going management or support. This was often the case for processes such as ICZM or community-based resource management although there was some separation of investment and recurrent costs for the LMMA examples (Table 3). In this case the investment needs are the costs of setting up the LMMA sites and networks while the recurrent expenditure represents the on-going support to the networks at the national level. All estimates are based on unit costs (USD/km^2) for the setting up and support of the LMMA network in Fiji (Govan, 2009). The lack of recurrent expenditure costs for many of the other project examples may be related to the selection of demonstration projects which are more focussed on starting up an initiative or building capacity.

Relative Estimation of Expenditure Needs

The relative estimates of financial resource need were calculated for 102 coral reef countries and territories. The highest scoring fifty countries are depicted in Figures 1 and 2 for estimates of overall resource need (Estimate 1) and highest priority (Estimate 2) respectively. The highest scoring ten countries for each estimate are presented in Tables 4 and 5.

Table 4. The highest ranked expenditure needs for Coral Reef Nations (Estimate 1)

Rank	Global	**Caribbean**	**Indian Ocean / Red Sea**	**East Asia / Coral Triangle**	**Pacific**
1	**Indonesia**	Cuba	Madagascar	Indonesia	Solomon Islands
2	**Philippines**	Haiti	Maldives	Philippines	Fiji
3	**Papua New Guinea**	Panama	Mozambique	Papua New Guinea	Kiribati
4	**Solomon Islands**	Dominican Republic	India	Malaysia	Vanuatu
5	**Fiji**	Bahamas	Saudi Arabia	Vietnam	New Caledonia
6	**Madagascar**	Jamaica	Yemen	Taiwan	Australia

7	**Tanzania**	Belize	Kenya	P.R. China	Fed. States of Micronesia
8	**Cuba**	Bermuda	Mauritius	Thailand	Rep. Marshall Islands
9	**Kiribati**	U.S.A. (Florida Keys)	Comoros	East Timor	French Polynesia
10	**Vanuatu**	Puerto Rico	Mayotte	Cambodia	Samoa

Figure 1 indicates that spending levels for the two highest countries (Indonesia and the Philippines) are substantially greater than then next highest country (Papua New Guinea). In fact the first three countries make up more than half (56%) of the expenditure need for the whole 102 countries in this analysis. At the global level there are two Indian Ocean countries in the top ten (Madagascar and Tanzania) but only one from the Caribbean (Cuba). Pacific Island nations make up the remaining four places (Table 4).

At the regional level, developed and rapidly developing nations are also represented in each region. For example the Florida Keys of the United States, Saudi Arabia, Taiwan and Australia are all in the top ten expenditure needs for their respective regions while emerging nations such as India and P.R. China are also present.

For the Estimate 2 analysis, at the global level, eleven countries scored the maximum value possible indicating that all their coral reefs are threatened (100% medium to very high threat level) and they have a very high vulnerability index (Figure 2, Table 5). These countries should be given the highest priority for financial resources to reduce anthropogenic pressures on their reefs over the next decade. Eight of these are SIDS located in the Caribbean (6) and Pacific (2) regions.

In terms of regions the ten highest scoring countries for the Caribbean and Pacific are all SIDS, while the Philippines and Indonesia are both in the top ten regionally (and top 20 globally). As well requiring the most financial resources globally (Figure 1, Table 4) they also score very highly in terms of prioritisation according to overall threat level and vulnerability.

Table 5. The highest priorities for expenditure to meet Target 10 at the National Level (Estimate 2)

No.	Global	Caribbean	Indian Ocean / Red Sea	East Asia / Coral Triangle	Pacific
1	**Bermuda**	Bermuda	Comoros	East Timor	Nauru
2	**Comoros**	Dominican Republic	Djibouti	Philippines	Samoa
3	**Djibouti**	Grenada	Mayotte	Indonesia	Vanuatu
4	**Dominican Republic**	Haiti	Tanzania	Vietnam	Niue
5	**East Timor**	Jamaica	Madagascar	Taiwan	Kiribati

6	**Grenada**	St. Kitts and Nevis	Sri Lanka	Thailand	Solomon Islands
7	**Haiti**	Anguilla	Yemen	Malaysia	N. Marianas Islands
8	**Jamaica**	Antigua and Barbuda	Burma	Papua New Guinea	Fiji
9	**Nauru**	Aruba	Kenya	Cambodia	Tokelau
10	**Samoa**	Dominica	Mozambique	P.R. China	American Samoa
(11)	**St. Kitts and Nevis**				

Figure 1. Relative level of Financial Resource Need to meet Target 10: Top 50 Coral Reef Countries and Territories.

(Note the Log scale)

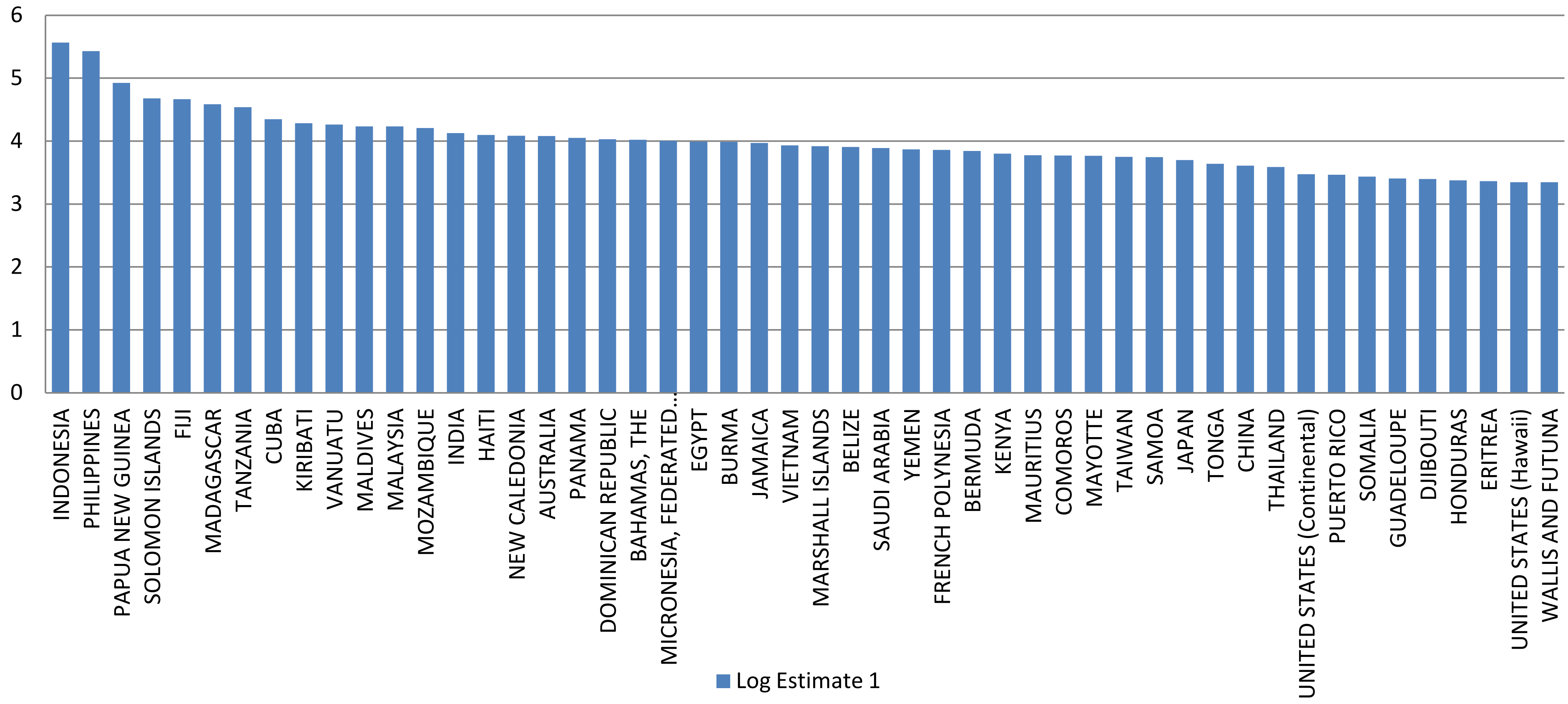
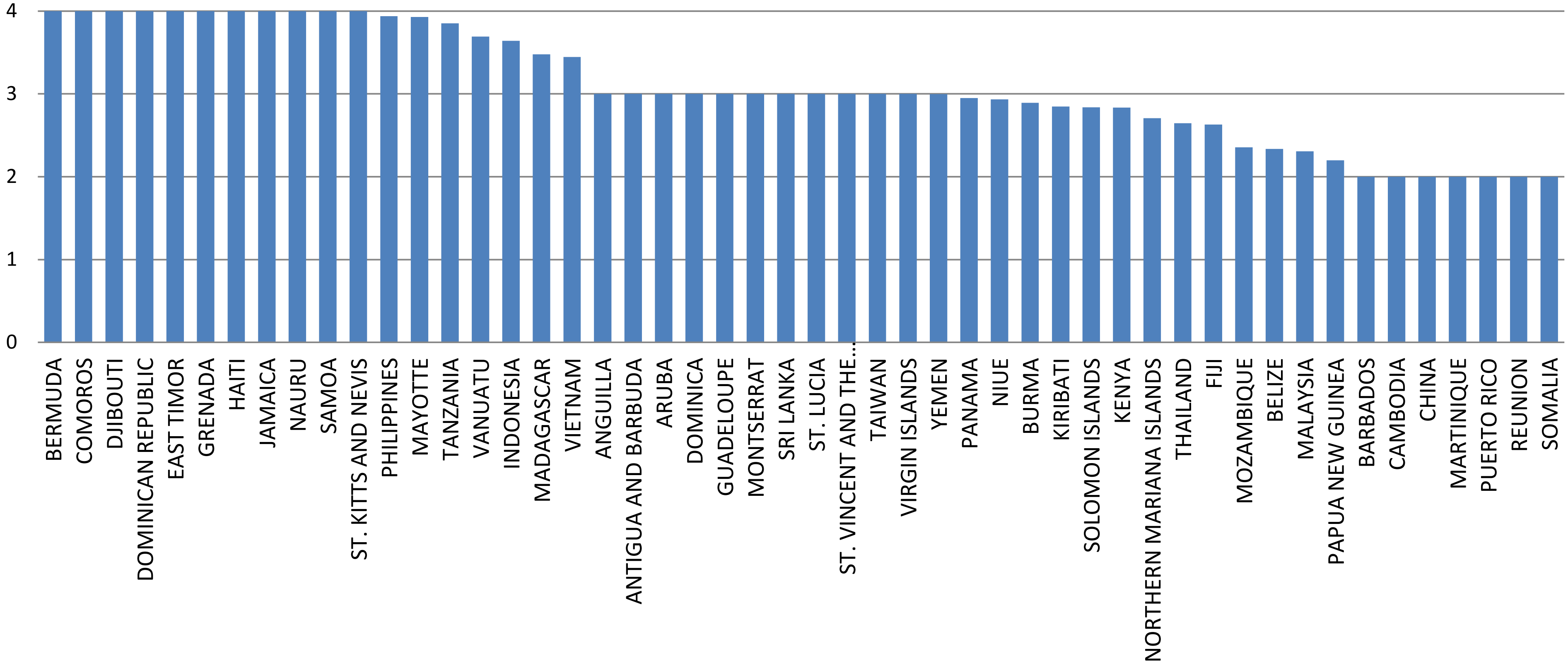


Figure 2. Highest Priorities for Financial Resource Need to meet Target 10: Top 50 Coral Reef Countries and Territories



Note; The first 11 Countries all scored the maximum rating of 4.

DISCUSSION

Although no complete estimate of the financial resources required to meet Target 10 for tropical coral reef ecosystems has been produced in this study we have provided some global estimates of resource needs for coral reef management as part of ICM or CBRM frameworks and networks. The various project examples provided also give an indication of the costs to establish and support some of the actions required to meet the target. We have examined the costs of ICZM (ICM) and IWRM with particular attention paid to wastewater and watershed/catchment management and CBRM mainly through the LMMA approach.

ICM costs, estimated at the regional level, for East Asia suggest that substantial investment is required to increase ICM coverage to 80% of the region's coastline i.e. over $1 billion. It should also be noted that these costs do not include in-kind support to the PEMSEA initiative which was estimated to be more than $4.5 billion for the second phase of the project between 1999 and 2006 (PEMSEA, 2006). Another point to mention regarding ICM (or ICZM) is that the costs are mainly for putting a robust management system in place which can be at one or more levels (local, provincial, national, regional). The specific actions to tackle anthropogenic pressures that are then added on to this ICM process will need to be costed separately e.g. wastewater treatment or inshore marine resource management. In addition although the ICM system has been put in place for 11.5% of the PEMSEA region there is no guarantee that this management system will be completely effective, with variation in management effectiveness is likely within and between countries. Although almost $145 million core funding was spent on ICM since 1995 (2012 prices), the East Asian region still contains the largest threatened coral reef areas and some of the highest integrated local threat ratings.

The cost estimates identified also show that there can be a wide range in unit costs for actions such as wastewater management depending on the approach taken. For example the unit cost in the Florida Keys for implementing comprehensive wastewater management plan is more than ten times the unit cost in Tuvalu for a establishing a composting toilet system. An even greater range in cost was found between decentralised community based resource management using the LMMA approach in Kadavu (Fiji) and a more centralised, but still community-based, management system in Samoa.

Confidence in the estimates produced

On the whole we believe that the unit cost estimates produced are accurate but may be underestimated in some cases where relevant data was lacking and available data was used instead. For example, the unit cost for the IWRM project in the Cook Islands was calculated using the whole population of Rarotonga although the demonstration projects probably cover a proportion of this island population. Unit costs may also be under-estimated when generic inflation rates were used instead of national GDP deflator figures which was the case for the PEMSEA regional cost estimate for ICM. The choice of unit cost may also be improved through selecting different metrics. We used human population for watershed management calculations when it may be more accurate to use the catchment area in km^2. The choice of cost/person was partly decided by the lack of available information for catchment areas for some of the selected examples.

The large-scale cost extrapolations for setting up management frameworks for ICM or LMMA networks did provide some global estimates of resource needs. The ICM estimate covered all coral reefs by area (km^2) that are located up to 5 km from the coast. The LMMA network approach covered 74% of global coral reefs by area and was focussed on developing countries that were assumed to be conducive to the community-based management approach at the national level. As expected, there was a large difference between the two estimates in the amount of resources needed to set up management structures. The ICM approach is designed to set up management systems to tackle a wide range of anthropogenic pressures including fisheries, coastal development and pollution. The use of LMMA networks as part of ecosystem-based management (Jupiter and Egli, 2011) is a more bottom-up approach but has also been costed out as a national government endorsed and supported process in recent years (Govan, 2009, 2011). **It is important to note that these large-scale estimates are for total resource needs and do not take into account the degree of coastal or coral reef management already in place for each coral reef nation**. This is particularly relevant for the ICM estimate as coral reefs in both developed and less developed nations are assessed. Management effectiveness has also not been investigated for ICM or LMMAs at the national level in this assessment.

For ICM the estimates represent the resources needed to set up and run management frameworks and networks that aim to deliver sustainable coastal zone management over the long-term. The costs of activities to enable sustainable ICZM need to be added on to these framework costs and are likely to be substantial. For example the cost of such activities as part of the implementation of the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) by 11 East Asian countries was estimated to be $4.5 billion over seven years (PEMSEA, 2006).

Another important point for the global estimates is that the extrapolations are based on a few unit costs only. Although the unit costs used were from long-running programmes (PEMSEA – 18 years; Fiji LMMA Network– 15 years) and based on a number of project sites at either the regional or national level they are both region-specific (East Asia and the Western Pacific) and may not be directly transferable to other regions globally. Ideally, the estimates should be based on a wider range of unit costs, and regional variation in management approaches and costs should be taken into account.

Using coastline and reef area data may also underestimate the expenditure needed. The coastline adjacent to coral reefs but at a distance of up to 5 km from the reefs may not adequately represent all of the land-based pressures affecting coral reefs i.e. reefs further offshore may still be affected by pollution or sediments especially after heavy rainfall There will also be coral reefs more than 5 km from a coastline and the ICM costs for these coasts have not been assessed in this study. Using the area of coral reef may also underestimate costs in that local fishing areas are not just directly over coral reefs but also over other benthic habitats such as seagrass beds or on sand and rock dominated substrata. For example the LMMA network in Fiji covers roughly 11,000 km^2 of inshore waters representing about a third of all Fijian traditional fishing grounds but the total area of coral reef in Fiji is some 6,700 km^2[5].

Annual resource needs were only estimated for the activity of CBRM through the LMMA approach. These annual costs were for supporting a national system of CBRM at the Government level which is a relatively new approach to inshore fisheries management. As this approach becomes more established there will be scope to reduce the cost profile through greater decentralisation and streamlining (Govan, 2009; 2011).

As mentioned previously, the unit costs for the global estimates are based on costs for one regional programmes for ICM (PEMSEA) and LMMA costs for one coral reef nation in the Pacific (Fiji), and should therefore be considered with due caution. Resource needs are likely to differ between different regions according to national and regional characteristics in terms of social structures at the community and local government level, the degree of infrastructure present to enable travel and communication, the cost of local goods and services and spatial characteristics of the nation's coral reefs.

[5] Reefs at Risk Revisited data for reef area

Further research needs

One of the main reasons for not attempting to make a total estimate of resource needs for all activities falling under Target 10 is the large number of data gaps and future research needs for this topic. Some of the main knowledge gaps and information needs are listed below:

- the costs of government run small-scale fisheries management for inshore water of coral reef countries (which were not addressed in the Target 6 analysis) and the resource needs to enable sustainable management;
- Cost estimates for the sustainable management of coastal zone activities such as coastal development (construction) and tourism;
- Water quality information for coral reef catchment areas and associated management costs
- Information on other forms of pollution such as solid domestic waste (e.g. plastics), industrial waste and pollution from land or marine-based activities (e.g. mining or oil and gas);
- Current levels of wastewater treatment for coastal populations in coral reef regions or countries;
- Further information on innovative and often more cost-effective actions to reduce stressors such as the use of composting toilets, vermiculture and bio-gas generation from livestock waste;
- The current levels of ICZM or CBM in each coral reef country in terms of coastline or reef area under management
- The effectiveness of ICZM, CBM or other types of management (e.g. fisheries) for each coral reef country
- Annual maintenance costs for processes such as ICZM (or IWRM) which were often lacking from the selected examples.

This assessment has also focussed on one type of marine ecosystem vulnerable to climate change; tropical coral reefs. Other vulnerable ecosystems will also need to be costed for Target 10 for both the terrestrial and the marine environment. These include high latitude ecosystems such as those in the Arctic and Antarctic circles and also high altitude ecosystems. Deep water ecosystems are also of concern such as cold water coral reefs.

Table 4: Gap Analysis Summary

	Target 10: Tropical Coral Reef Ecosystems
Evidence on costs	Strength of evidence - medium Extent to which further research is required - considerable
Evidence on current levels of expenditure	Strength of evidence - low Extent to which further research is required - considerable
Other Targets	
Links to other Targets	Yes - both within the overall marine cluster and with other Targets
Evidence on potential co-benefits	Yes - both within the overall cluster and between Targets Strength of evidence - medium Extent to which further research is required - some

Target 10: Tropical Coral Reef Ecosystems	
Other policy areas	
Related policy areas outside of biodiversity	Climate change, coastal development, poverty, food security, health, agriculture, watershed management, pollution, fisheries
Evidence on potential benefits to other policy areas	Extent of potential benefits - medium Extent to which further research is required – some.

Relative Estimates of Expenditure and Resource Need

The analyses undertaken using the Reefs at Risk Revisited dataset indicates which countries and regions require the most immediate action in order to reduce threat levels on coral reefs. The relative level of expenditure required was also estimated and clearly showed that the Coral Triangle countries of Indonesia, the Philippines and Papua New Guinea are global priorities for action. Although this region is receiving significant funding through programmes such as the Coral Triangle Initiative there is a clear need to rapidly escalate both funding and management action in the region. This is a global priority both in terms of marine biodiversity, as the most biodiverse region for the global marine environment, but also in terms of the high dependence of millions of people on coral reef ecosystems, especially in countries such as the Philippines and Indonesia.

Timescales

Timescales for action to achieve Target 10 also need to be taken into consideration. This assessment has found that many management actions or processes have taken or are designed to take at least 10 years to become established and make progress. The PEMSEA initiative took 17 years to cover 11.5% of the region's coastline in ICM while implementing the wastewater plan in the Florida Keys is predicted to take 15 years instead of the originally proposed 10. The Reef Plan implemented by the Queensland Government is over a 10 year period whilst cost projections for establishing a LMMA style approach to marine resource management at the national level are costed for the long-term (10+ years). Given that the aim of Target 10 for coral reef ecosystems is to minimise multiple anthropogenic pressures, which we have assumed to mean a stressor reduction of 80%, it seems prudent to make plans to estimate the costs of action over a longer time period, for example at least 10-15 years. Assuming there are adequate financial resources to tackle local stressors, it is also critically important to find ways of rapidly scaling up the level of action required.

Benefits of delivering the Target

This section will briefly summarise the benefits of delivering the two main activities used to calculate global resource needs to meet Target 10 for coral reef ecosystems, ICM and CBM through the use of LMMAs. Benefits associated with meeting other Targets for fisheries, aquaculture, MPAs and pollution will not be discussed here.

The PEMSEA programme has reported a range of benefits attributed to ICM initiatives in the East Asian region. In terms of economic benefits some of the best examples are for the projects at Xiamen in the People's Republic of China and at Chonburi in Thailand (PEMSEA, 2006). Cost-benefit analyses have shown that in the city of Xiamen, socioeconomic benefits of ICM based on estimated incremental revenues in ports and shipping, marine fisheries and tourism, real estate and property development and direct nature and environmental services were estimated to be $3.6 billion in 2006. Net benefits were $3.4 billion and the benefit-cost ratio was roughly 15:3. In Chonburi, coastal rehabilitation in one municipality was estimated to produce benefits of THB 31.4 Billion while total costs were THB 849 million, amounting to a benefit-cost ratio of 37. Successful implementation of ICM can therefore lead to multiple benefits in the coastal zone, including the rehabilitation of coral reefs provided the key stressors are addressed.

Evaluation of the LMMA initiatives (Govan, 2009), mainly in the Western Pacific, has identified a range of benefits which are listed below[6]:

- Biodiversity conservation: localized recovery or protection of vulnerable species such as large food fish or marine turtles;
- Improved fishery landings: experiences from within the Pacific region and the Philippines show that, depending on species, catches may be sustained or increased;
- Governance: communities may improve decision-making processes, links to other organizations and institutions, influence policy development, reduce internal conflicts and improve compliance and enforcement;
- Community organization: simple resource planning and facilitation processes are being used to support community endeavours in other fields. Community institutions used for management may be used for other purposes or be adapted to handle other types of projects;
- Resilience and adaptation: supporting local stewardship and promoting understanding of people's potential impact on resources provides a basis for response to new threats in the context of adaptive management and helps provide local security;
- Health: improving or securing the supply of marine protein has a direct impact on community well-being aside from the potential to use the same planning process for other community priorities including health.
- Integrated resource management: addressing a wide range of issues such as watersheds, waste management, community events, availability of building materials and erosion control;
- Cultural survival: the considered use of traditional management measures and knowledge may slow the loss of valuable aspects of culture and improve management success, for example the use of, and respect for, tabu areas or other traditional closures;
- Improved social and human capital: Knowledge, awareness and capacity for resource management and sustainable development in general may be increased as well as governance and other linkages;
- Security of tenure: Pacific Island communities usually regard the traditional rights of ownership and access to resources as vital to their livelihoods, and indeed identity, and perceive that these are being eroded. Community based management may be seen as a means of re-asserting these rights.

In terms of socio-economic benefits, improving the status of coral reefs through the use of LMMAs has provided clear economic benefits for communities in terms of increased fish catches. Increases in average household income have been documented at a number of LMMA sites in Fiji. For example, at Navakavu, income from fishing was three times greater at LMMA fishing sites compared to non-LMMA sites (Van Beukering et al., 2007). Over the

[6] all the points listed are supported by peer-reviewed papers – see Govan, 2009 for these and additional examples of benefits

first five years of the project, the increase in catches amounted to benefits of $37,800 for the community (O'Garra, 2007) and a doubling of average household income (Leisher et al., 2007).

Delivering Target 10 for coral reef ecosystems is likely to benefit other policy areas such as marine resource management, social and ecological resilience in the coastal zone and the health, poverty and food security of coastal populations. Improving coral reef ecosystem health by reducing local anthropogenic pressures will help to safeguard biodiversity and rebuild marine resource populations and biomass. In turn the latter should provide improved food supplies and higher incomes for resource users which can help to strengthen coastal communities and reduce food insecurity, poverty and health issues. Funding for health, poverty alleviation and for building resilience to climate change for tropical coastal populations should therefore become less. Tackling land-based pollution issues will also result in improved health of coral reefs but also for closely associated ecosystems such as mangroves and seagrass beds. Improving coral reef resilience will also safeguard or enhance coastal tourism and help to provide consistent or increased revenue through eco-tourism in coral reef countries.

Funding opportunities / Sources of funding

The following text has been extracted from the GLOBE Action Plan for Coral Reefs (Harding et al., 2010) and provides a summary of funding opportunities and sources for coral reef ecosystems. There may additional funding opportunities or sources that have become available since 2010 that are not included below.

A large range of funding sources is potentially available to coral reef countries which can be split into two main categories; Donor-based funding and Innovative and Market-based funding:

1. **Donor-based Funding Sources**

- **Climate change related** - Examples include the UNFCCC Adaptation Fund, the German Government's International Climate Initiative (ICI), the World Bank's Climate Investment Fund's Pilot Programme for Climate Resilience (PPCR) and the European Union's Global Climate Change Alliance (GCCA).

  Funding from the Global Environment Facility, namely the GEF Small Grants Programme (SGP), which is part of the Strategic Priority on Adaptation (SPA). This supports community-based adaptation (CBA) interventions that increase resilience to the adverse impacts of climate change of vulnerable countries, sectors, and communities. CBA interventions are also funded by the two funds managed by GEF that are part of the UNFCCC — the Least Developed Countries Fund and the Special Climate Change Fund.
- **Watershed management and pollution related** - The GEF International Waters programme provides funding to improve the management of trans-boundary water systems and increase multistate cooperation in reducing coastal pollution (and rebuild marine fisheries). Another GEF programme, the Land Degradation Strategy, can also contribute to improving coral reef ecosystems through the management of land-use practices and watersheds.
- **Biodiversity-related funding** - The GEF is one of the main sources of explicit biodiversity funding, for the conservation and sustainable use of biodiversity and the maintenance of ecosystem goods and services both within and outside of (marine) protected areas. This funding is also available to strengthen management and capacity building related to ecosystem conservation.

- **Development-related funding –** available from a mix of bilateral aid agencies and multilateral agencies including the World Bank. Such funding is suitable for capacity building and environmental education needs in national and regional action plans for coral reefs but also qualifies for use as part of coastal management programmes within agreed development plans. Protection of coral reef ecosystems should be written into the national development plans of coral reef nations.

2. Innovative and Market-based funding sources:

- Payments for ecosystem services (PES) schemes for tropical coastal ecosystems including REDD-type approaches for coastal carbon sink ecosystems associated with coral reefs such as mangrove forests and sea-grass beds (blue carbon initiatives);
- Establishment of dedicated national level Trust Funds for protected area management, enabled through legislation to generate revenue from various economic instruments and from trust fund financing from donors to launch the fund and then supplemented through other mechanisms including those below:
- Revenue through direct user fees for access to on-site benefits in marine parks and reserves or through stakeholder taxes for coastal zone access;
- The use of environmental bonds for climate resilience and adaptation projects such as the World Bank Green Bond or the Great Barrier Reef Foundation's Coral Reef Bond;
- Private sector partnerships such as Marine Conservation Agreements (MCAs) including private marine parks that may involve compensation for local resource users, or self-financing Marine Protected Areas;
- Polluter pays principle (PPP) for both chronic and acute pollution of coral reef ecosystems, incorporating upstream polluters in watersheds or in neighbouring coastal countries;
- Other fees or green taxes that would specifically generate money to capitalise the funds

Of the above categories the climate change adaptation funds will be a key target for enhancing coral reef resilience and enabling social adaptation over the long-term. Other forms of funding which are more market-based, such as PES or blue carbon schemes are currently in their infancy but are also expected to provide significant funding within the next decade.

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Annexe 1: Details of cost estimates for selected activities to reduce anthropogenic pressures on tropical coastal ecosystems

1a: Integrated Coastal Zone Management (ICZM) / Integrated Coastal Management (ICM) / Ecosystem-based Management (EBM)

Project name	**Executed by**	**Level**	**Region / Country / State**	**Years**	**Component**	**Cost (Million USD)**	**Km Coastline**	**Cost / km**	**Cost / km (2012)**	**Notes**
Integrated Coastal Zone Management Project	World Bank / Indian Government	National	India	2010 - 2015	1. National ICZM Capacity Building	87.3	7500	11640	12664	Establish and support a National institutional Structure for ICZM Coordination
"	"	State	Gujarat	" – "	2. State ICZM Capacity Building and 7 Pilot Projects	74.1	166.3	445580	484791	Development and implementation of ICZM Plans; Capacity building and Project Management. Pilot investments: conservation and protection of coastal resources; environment and pollution management; livelihood security of coastal communities
"	"	State	Orissa	" – "	3. State ICZM Capacity Building and 9 Pilot Projects	49.3	63	782540	851403	
"	"	State	West Bengal	" – "	4. State ICZM Capacity Building and 9 Pilot Projects	75	26	2884615	3138462	
ICM Xiamen Demonstration Project	GEF/UNDP/ IMO PEMSEA	City	Xiamen, PR China	1995 - 2001	ICM Development and Implementation	7.78	234	32589	56579	
ICM Batangas Demonstration Project	GEF/UNDP/ IMO PEMSEA	Province	Batangas, Philippines	1996 – 1999	ICM Development and Implementation	1.69	92	18331	44120	
ICM PEMSEA Regional Programme	GEF/UNDP/ IMO PEMSEA	Regional	East Asia	1996 - 2012	Three phases of the PEMSEA Initiative	115.363	26829 (June 2010)	4300	5399 (generic 3% inflation)	Total cost does not include estimated in-kind support which is substantial, for example, USD 4586 million for Phase 2 (2000-2006)
Atoll Ecosystem-	UNDP/GEF/ Maldives	Island	Baa Atoll, Maldives	2005 - 2010	Atoll Ecosystem-based Conservation	8.292 (5.97 –	15000	552.82 (397.89)	811.59 (584.14)	Mainstreaming Biodiversity, Development

based Conservation of Globally Significant Biological Diversity in the Maldives' Baa Atoll.	Government				(AEC)	atoll based only)				and implementation of Atoll EBM Plan, sustainable resource management and provision of alternative livelihoods

1b: Integrated Water Resource Management (IWRM) / Wastewater Management

Project name	**Executed by**	**Level**	**Region / Country / State**	**Years**	**Detail**	**Cost (Mill. USD)**	**Population affected**	**Cost / person**	**Cost / person (2012)**	**Notes**
ICM Xiamen Project	Municipal Government	City	Xiamen, PR China	1995-2001	Investment in large-scale wastewater treatment plants	173.8	1500000	115.83	201.1	60% wastewater treatment achieved by 2001 (~30% increase since 1995)
Sewerage Planning and Wastewater Treatment for Sabang.	GEF/UNDP/IMO - PEMSEA	Barangay	Puerto Galera, Philippines	2006 -	Investment in sewerage collection system and central wastewater treatment facility	2.03	10935	195.49	241.8	Includes establishment costs (1.78 million) and annual maintenance costs (0.25 million)
Coastal Cities Project	GEF / World Bank	City	Quy Nohn, Vietnam	2008-2012	Wastewater treatment and management	25.5	60000	425.6	610.33	Investment in a chemically enhanced primary treatment (CEPT) plant and improved sewerage system
Keys Wastewater Plan	Monroe County Government / Florida State Government	County	Florida Keys, U.S.A	2000-2015	To provide an equitable, ecologically sound, and economical implementation strategy for managing wastewater and improving water quality in the Florida Keys	939*	110000**	8536.4	9461.9	*Capital costs only ** Average Functional Population
Implementing sustainable	UNDP/UNEP/SOPAC (GEF)	Island / National	Cook Islands	2008-2013	Integrated freshwater and coastal	2.16	14153 (Rarotonga)	152.31	164.2	Capacity building and wastewater management

water resources and wastewater management in Pacific Island Countries (Pacific IWRM)	(Demonstration Projects)				management on Rarotonga					with at least 2 demonstration projects on Rarotonga
		Island / National	Federated States of Micronesia (FSM)	"	Ridge to Reef; Protecting water quality from source to sea in the FSM	9.35	35000 (Pohnpei)	267.25	306.7	Includes components on watershed protection and improvement; and protecting fresh and marine water quality (including bio-gas demonstration).
		National	Niue	"	Integrated land use, water supply and wastewater management for Alofi town	2.64	700	3770	4327 (2011)	Includes sewage, solid waste, piggery effluent and hazardous waste management improvements, oil and agro-chemical storage improvements and road run-off improvements.
		Island / National	Republic of the Marshall Islands	"	Integrated water management for Laura groundwater lens, Majuro Atoll	3.8	3000	1267.53	1324	Improved water resources management, reduction in groundwater pollution from inadequate waste water facilities, piggeries and landfills and improved water supply
		Island / National	Samoa	"	Rehabilitation and sustainable management of Apia Catchment	2.56	37708 (Apia)	67.94	69.92	Includes conservation and rehabilitation of degraded areas to reduce water pollution; awareness and capacity building to prevent water pollution and wastage
		Island / National	Tuvalu	"	Integrated sustainable wastewater management for Tuvalu	3.68	10544 (Funafati Atoll)	727.35	780.4	Reduce groundwater and marine / coastal contamination, install dry eco sanitation systems (composting toilets / bio-digesters), water supply protection
		Island / National	Santo, Vanuatu	"	Sustainable Management of the Sarakata Watershed	1.11	~20000	55.29	58.96	Prepare and implement Integrated Sarakata Watershed Management Plan.
Integrating	GEF/UNDP/	Island /	St Lucia	2005-	Fond D'Or	2.69	12710	211.93	300.75	Included implementation of

Watershed and Coastal Areas Management (IWCAM) in Small Island Developing States of the Caribbean	UNEP/CEHI (Demonstration Projects)	National		2011	Watershed management					wastewater wetland treatment system (WWTS)
		Island / National	Cuba	“	Model for IWCAM – Cienfuegos Bay	2.53	270000	9.36	10.89 (2011)	Fully integrated model with examples of best practise and use of innovative technology
		Island / National	Portland, Jamaica	“	Integrated approach to managing marine, coastal and watershed resources	1.23	24860	49.49	89.76	Watershed Model Development and implementation using existing best practises
Reef Water Quality Protection Plan (Reef Plan)	Queensland Government	State	Great Barrier Reef, Australia	2003-2013	To address non-point source pollution from broad-scale land use	192.4	850000	226.31	266.9	Improve water quality by reducing pollution and improving land use practises and rehabilitating damaged wetlands
Reef Rescue Package	Australian Government	Region	“	2009-2013	Improve the water quality of the GBR lagoon by increasing land management practices that reduce the run-off of nutrients, pesticides and sediments	139.4	850000	163.95	174.5	Made up of five integrated components that work together to achieve the overall objective. Includes Water Quality Grants, Reef Water Quality Research and Development and Water Quality Monitoring and Reporting.
Reef Plan + Reef Rescue			“	2003-2013		331.8	850000	390.27	441.4	

1c. Integrated Marine Resource Management – Community-based or LMMA approaches (adapted from Govan et al., 2009; Govan et al., 2011)

Country	**Organisation**	**Level**	**Region**	**Year**	**Cost / Site (USD)**	**Cost / km^2 (reef area)**	**Cost / Site 2012**	**Cost / km^2 (2012)**	**Notes**
Fiji	IAS, USP[7]	National		2001-2011	713 (500-900)	66 (15-158)	902 (663-1139)*	84 (19-200)*	Establishment and support for 170 LMMA sites. All costs are annual costs for the first five years *Calculated from 2006
Fiji	LMMA Network	Provincial	Kadavu	2001-2011	~300	~33	380*	42*	More cost-effective approach – decentralisation and reduced monitoring. Annual cost shown

[7] Institute of Applied Science, University of the South Pacific

									*Calculated from 2006
Solomon Islands	FSPI[8]	Provincial	Malaita, Gela, Guadalcanal	2006	1851-2569	n/a	2942-3459	n/a	Implementing LMMAs. Averages the start-up and on-going costs for 20 communities in 2006
Solomon Islands	Worldfish Center	Provincial	Isabel and Western Province	2008	3000	~100	3399	113	Average costs for establishment and on-going support over 3 years for two large areas
Samoa	Samoan Government (GEF funded)	National		2006	1350	1862	1549	2136	On-going support for >50 sites with 1-2 new ones added each year. Costs provided are for 2006.
Solomon Islands	Worldfish	Provincial	Lau, Malaita	2008-2010	9000-18000	n/a	10198-20396	n/a	Implementing community-based resource management in two clusters of fishing communities
Multiple	LMMA Network	Multi-regional	Pacific + East Asia	2001 - 2007	n/a	226.9	n/a	263.5*	Total LMMA Network Operational Costs *using an averaged inflation rate of 3.81%
PROJECTED COSTS									
Country	**Source**	**Level**	**Region**	**Year**	**Cost (USD)**	**Cost / km² (reef area)**	**Cost (2012)**	**Cost / km² (2012)**	**Notes**
Fiji	Govan et al 2009	National	n/a	2009	300000 - 400000	n/a	357385 - 476513	n/a	Estimated yearly cost of management support to all traditional fishing grounds in Fiji
Solomon Islands	Govan et al 2011	National	n/a	2011	360000 – 430000	n/a	386280 - 461390	n/a	Annual cost for establishing and running a national integrated resource management system over the long-term i.e. 10 years
'Generic' Pacific Island Nation	Govan et al 2009	National	n/a	2009	100000 - 500000	n/a	107761-538803*	n/a	Annual cost of establishing a national decentralised system of support for community-based management for a period of at least 10 years. *using an averaged inflation rate of 3.81%

[8] Foundation of the Peoples of the South Pacific

TARGET 11: MARINE PROTECTED AREAS (Ian Craigie and Pippa Gravestock)

INTRODUCTION TO THE TARGET

Target 11 text: *By 2020, at least 17 per cent of terrestrial and inland water areas and* ***10 per cent of coastal and marine areas****, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider lands.*

Interpretation of target

This section of the report deals solely with the 10% marine coverage portion of Target 11.

There are four sections of the target that are open to interpretation:

1) 'Marine areas'

There are several possible interpretations of the 'marine areas' specified in the target. These could include a wide range of area-based management strategies from formally designated no-take or no-go protected areas to less formal community run marine areas that are focussed as much on fisheries management and sustainable livelihoods outcomes as biodiversity conservation. The different types of marine areas will have different management objectives and associated actions and thus different costs. Data limitations mean that in this report it has not been possible to quantitatively explore the resource implications of achieving the target with different types of Marine Protected Area (MPA).

This report assumes that Target 11 is to be achieved with marine areas that meet the IUCN definition of a marine protected area (see Table 7 for full descriptions of IUCN MPA categories). To qualify for one or more of the IUCN categories, a site must meet the following IUCN definition of a protected area:

"A protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values"

It is ultimately the primary purpose of the area that dictates whether it meets the IUCN definition of an MPA (Day et al. 2011). Areas whose primary purpose is sustainable extraction of marine products (e.g. coral, fish, shells, etc.) do not qualify. However in practice when written management objectives are often absent it is difficult to decide whether a marine area qualifies as an IUCN protected area. This is often true of community managed marine areas in developing countries which have multiple objectives.

2) ‘Areas of particular importance for biodiversity and ecosystem services’

There are no generally agreed spatially explicit data on the location of where these marine areas may be at the global scale. The areas of importance selected will vary according to the chosen metrics of biodiversity e.g. species richness or primary productivity. Comprehensive spatial data are only available for a small proportion of marine taxa, among the better studied groups are birds, mammals and corals, but even here new species are discovered frequently. Additionally, the level of congruence between areas that are important for biodiversity and also for ecosystem services is unknown but may be low in some cases; this presents a challenge for area selection. For example, seagrass beds have been shown to be important for carbon sequestration (Kennedy et al. 2010), an important ecosystem service, but compared to coral reefs (often located nearby) they have low species richness, a common biodiversity metric.

Due to limited data on what constitutes ‘areas of particular importance’ and possible conflicts between the measures of importance that are available this report does not directly consider the cost implications of locating MPAs in areas of greater or lesser importance.

3) ‘Ecologically representative’

A system of MPAs may be considered ecologically representative when all the features of conservation interest are adequately protected within MPAs. Typically this will mean that all ecosystems and perhaps even species in the World should have some portion of their ranges covered by MPAs.

For the purposes of estimates produced by this report the meaning of representative was taken to be 10% area coverage of each of the Marine Ecoregions Of the World (MEOW) (Spalding et al. 2008) and Global Open Ocean and Deep Seabed (GOODS) regions (Vierros et al. 2009). This is a crude measure of representativeness because it implies that the whole suite of biodiversity can be captured by 10% coverage of each of these 261 broad-scale regions. In reality biodiversity shows substantial spatial variations at a much finer scales within and across ecoregions but this level of detail is beyond the scope of this report. Creating a network with 10% coverage of each ecoregion will run into conflict with point (2) above because some ecoregions, especially those on the high seas, have low biodiversity and ecosystem service values. In practice an improved MPA network would be one that is designed to exceed 10% coverage in those ecoregions with high biodiversity and ecosystem service value at the expense of regions with lower importance. This data needed to carry out this more sophisticated weighting of MPA coverage was not available for this report and so it was not evaluated.

4) ‘Well connected’

Biological connectivity is a challenging area of research and the few data available at the moment have demonstrated that connectivity varies greatly depending on the ecosystem and species being studied (Harrison et al. 2012).

For the purposes of this report connectivity has not been assessed as it is not clear what the cost implications would be for a network that achieves more or less effective connectivity.

Additional assumptions

Implicit in this report is an assumption that all countries are equally willing and able to create marine protected areas within their Exclusive Economic Zone (EEZ). There is also an implicit assumption that all MPAs have equally effective management. Datasets such as those from Reefs at Risk Revisited (Burke et al. 2011) show this is not the case, but there is no quantitative link made between MPA management effectiveness and the management costs. Without this link it is hard to see how to incorporate management effectiveness into cost estimates.

Links to other targets

Marine protected areas are a tool that can be used to achieve the objectives of several of the CBD targets: it is one of the main mechanisms used to protect coral reefs (Target 10) and can be used as a tool for fisheries management (Target 6). MPAs also have a contributing role to play in endangered species protection (Target 12) and indigenous knowledge and local participation (Target 18).

COP Decisions

There are numerous decisions on Protected Areas: Protected areas – In-Situ Conservation: Decision X/31, IX/18; VIII/24, VII/28, III/9, II/7-8 Ex-Situ and In-Situ Conservation. COP 10 Decisions X/31 on protected areas especially sections A: strategies for strengthening implementation and B: issues that need greater attention and Decision X/29 on marine and coastal biodiversity, the marine protected areas component provides impetus for undertaking activities for achieving the target.

ACTIONS REQUIRED TO MEET TARGET 11

Marine protected area coverage needs to be increased from its current level of around 8.94 million km^2 (2.5%)* of the world's coasts and oceans to 36 million km^2 (10%). The total MPA coverage of the world's Exclusive Economic Zones (EEZs) currently stands at 5.5%. The rate of MPA establishment has increased rapidly since the last comprehensive assessment by Wood et al. (2008) which recorded 2.35 million km^2 of MPA. The number of PAs recorded in the World Database of Protected Areas (WDPA) at June 2012 that included marine coverage was 6307. These have a mean area of 2361 km^2 and median of 4.56 km^2, showing there are a few very large MPAs and many very small MPAs. These figures are undoubtedly an underestimate of current coverage due to delays in reporting new MPAs to the WDPA. Assuming the size frequency distribution of MPAs remains similar into the future then a network that meets the 10% target will contain around 23,000 MPAs of which over 17,000 are yet to be established.

** See methods section for details of the methods used to produce these summary statistics.*

METHOD OF ASSESSMENT

The process of increasing protected area coverage incurs three types of costs: establishment costs, management costs and opportunity costs. The three costs associated with achieving the 10% marine target were assessed individually with a focus on establishment and management costs.

Calculation of statistics from the World Database of Protected Areas

There are a number of methods that can be used to estimate global marine protected area coverage and other MPA statistics from the WDPA. These have the potential to substantially change the estimates presented in this report so the methods are described here. The MPA statistics used were estimated from all the MPAs designated up to June 2012 listed in the World Database of Protected Areas (WDPA 2012). Sites listed under international conventions (e.g. UNESCO World Heritage Convention 1972, RAMSAR Convention 1971) were excluded because of near-complete overlap with nationally designated sites. Sites whose status was recorded as ‘proposed’ were excluded. The WDPA contains two pieces of information that can be used to estimate total area protected: the spatial boundary information and a self-reported marine coverage estimate (in km^2) for each MPA. Many MPAs lacked one of these pieces of information, 1181 had no spatial boundary information and 1420 had no self-reported marine area information. We produced global coverage estimates using two different methods. Method 1 summed all of the self-reported marine area estimates. Method 2 used a GIS to calculate the areas from those sites with boundary information following the removal of any terrestrial component of the protected areas and then added these values to the self-reported marine areas for those MPAs lacking boundary information. The two methods produced broadly similar results (see Table 1), but the two summary datasets had different MPA size frequency distributions as evidenced by the different means and medians. For the remainder of the report we used the size frequency distributions of the existing MPA network as the basis for our cost estimates. Therefore we present cost estimates based on the size frequency distributions calculated from both methods.

Table 1. Summary of the MPA data from the WDPA using two different methods of calculation.

	Method 1	Method 2
Method	Sum of self-reported marine areas	GIS areas and self-reported areas for remainder
Number of MPAs	6307	5521
Total area in km^2	8.94m	8.61m
% Ocean coverage	2.5%	2.4%
Mean km^2	2361	1824
Median km^2	4.56	4.91

Comparison to GEF needs assessment

The GEF used a similar method to the one used in this report to estimate both establishment and management costs, with one key difference. The difference is that the GEF assumed the coverage targets were met with MPAs all of an identical size of 500km^2. This assumption while expeditious is also statistically hard to justify given the highly non-linear relationship between MPA size and per-unit-area costs. As the results of this report make clear the effect of size on the costs of individual MPAs is very powerful, so to treat all MPAs as equal is to make any cost estimates from this methodological short cut highly questionable.

Establishment costs

Background

The duration of the establishment phase is difficult to define and can vary substantially between MPAs. Theoretically, it begins with the idea that a particular location deserves protection, and ends sometime after the official designation of the MPA. Funding for planning and development during this period is typically derived from multiple sources located within and/or outside of the host country, including governments, non-governmental organizations (NGOs), private individuals and corporations. Additionally, the establishment phase precedes the formation of the dedicated management entity usually responsible for the maintenance of financial records. Instead, existing records of monetary, as well as volunteer and in-kind contributions to the establishment process are likely to be spread across various funding entities. Finally, institutional memory tends to be limited, and the likelihood that financial records will be lost increases over time.

In theory establishment costs are non-recurrent once the MPA is established. However there are cases such as the Great Barrier Reef Marine Park in Australia where the MPA was essentially re-established by complete re-zoning in 2004. This process involved extensive public consultation, stakeholder negotiation and scientific evaluation, all at considerable cost over a number of years (cost estimates could not be obtained for this report). Despite this exception for the purposes of this report we have assumed that establishment of MPAs are non-recurrent.

Methods

There are two peer-review sources of information on MPA establishment costs, the most useful of which is McCrea-Strub et al. (2011) because it incorporates the data from the second publication (Butardo-Toribio et al. 2007). McCrea-Strub et al. (2011) modelled the factors that influenced MPA establishment costs and using a sample of 13 MPAs they discovered that the key factors were MPA size and the duration (in years) of the establishment phase. Here we use two of the McCrea-Strub et al. (2011) models to extrapolate the possible establishment costs of achieving target 11:

(1) $\log10\ (\text{Establishment Costs}) = 3.74 + 0.28\ (\text{time in years}) + 0.26\ \log10\ (\text{Area in km}^2)$

which included the length of the establishment phase and explained 94% of the variation in their sample and model:

(2) $\log10$ (Establishment Costs) per $km^2 = 4.66 - 0.48 \log10$ (Area in km^2)

which is a simpler model as it does not include the length of the establishment phase but only explained 72% of the variation in the McCrea-Strub et al. sample. In order to use equation (1) we assumed a fixed length establishment phase of 3 years for all MPAs. We calculated establishment costs using each equation separately. The equations being logarithmic in both variables (i.e. highly nonlinear), the establishment costs of the MPAs must be calculated for each MPA separately, then added up rather than adding up the MPA areas beforehand, then applying the equation to the total. We used each model to calculate the predicted establishment costs of each of the current MPAs listed in the WDPA as of June 2012. The predicted costs of each MPA are then summed to give a total global estimate. To turn this current estimate (i.e. 2.4% coverage) into an estimate for 10% coverage it is then multiplied by the ratio of the existing area to 10% (i.e. 10/2.4 which is 4.2). The assumption implicit in this method is that the future MPA network with 10% coverage will have the same size frequency distribution of MPAs as the network currently recorded by the WDPA.

We calculated four estimates; first, the estimated costs of establishing the current MPA network as recorded in the WDPA. Second, the total predicted establishment costs of a network with 10% coverage. Third, the extra or marginal establishment cost to go from current coverage to 10% coverage, and fourth, the annualised marginal cost assuming linear MPA establishment over the next 8 years. We calculated the four estimates for both sets of WDPA data, those with GIS areas (Table 2) and those with only self-reported areas (Table 3).

Results

The results differ substantially between equations 1 and 2. The estimates from equation 2 which does not include the length of the establishment phase are around 10 times higher than equation 1. If the length of the establishment phase was increased in equation 1 from 3 years to 5 years the estimated costs would increase by around 60% but would still be well short of the estimates from equation 2.

Table 2. Establishment cost in millions 2012 USD using WDPA data from method 2 (GIS areas)

	Total establishment costs for current MPA network (2.4% coverage)	Total establishment costs for MPA network (10% coverage)	Total establishment costs to be spent by 2020 (to go from 2.4% to 10% coverage)	Annual establishment costs between now and 2020 assuming linear MPA establishment
Equation 1.	467.4607	1955.797	1488.336	186.042
Equation 2.	3036.432	12704.05	9667.615	1208.452

Table 3. Establishment cost in millions 2012 USD using WDPA data from method 1 (Self-reported areas)

	Total establishment costs for current MPA network (2.4% coverage)	Total establishment costs for MPA network (10% coverage)	Total establishment costs by end 2020 (to go from 2.4% to 10% coverage)	Annual establishment costs between now and end 2020 assuming linear MPA establishment
Equation 1.	378.8982	1526.601	1147.702	143.4628
Equation 2.	2632.192	10605.24	7973.047	996.6309

Key caveat

The models in McCrea-Strub et al. (2011) make it technically possible to estimate the establishment costs of achieving Target 11. However in practice this means extrapolating establishment costs from a biased sample of 13 protected areas (of which 6 were very similar Philippine MPAs) to predict the costs of establishing a global network consisting of over 23,000 MPAs. The results of this extrapolation should be viewed with a substantial amount of caution.

Management costs

Background

Management costs are recurrent annual expenditures that include staff expenses, regular operational costs and recurrent capital costs. Staff expenses include salaries, overhead costs and training. Regular operational costs are associated with day-to-day management such as fuel, maintenance of equipment and education. Regular capital expenses include purchase of vehicles, vessels and their replacement. The primary management activities in MPAs are generally related to rule enforcement and compliance, in some cases there will also be visitor management and education and outreach. This is different from terrestrial PAs which generally have a much wider range of management activities that include active ecosystem management and visitor infrastructure provision.

Management costs are the best studied of the three types of cost associated with achieving Target 11. The key paper in this area is Balmford et al. (2004) which estimated the costs of managing a global MPA network with worldwide coverage of 20-30% at between $ 5 billion and $19 billion. This work has been built on by Cullis-Suzuki and Pauly (2010) who used the model derived from Balmford et al. to estimate annual managements costs of $25 to $37 billion for 20-30% coverage (all figures in year 2000 US dollars). Balmford et al. demonstrated that the size of the individual MPAs is the key determinant of cost, explaining 80% of the cost variations in their dataset of 81 MPAs. The difference between the estimates of Balmford et al. and Cullis-Suzuki is due to the different size frequency distributions of the projected MPA networks they used. Cullis-Suzuki extrapolated costs from the data available on the existing MPA network (data from 2008) which contained a larger proportion of small MPAs than the network modelled by Balmford et al.

Methods

We used several related methods to derive an estimate of management costs of achieving Target 11:

a) The simplest method used was to estimate management costs based on individual MPA areas and the model presented by Balmford et al. This approach is similar to the method used by Cullis-Suzuki and Pauly (2010) but updated to use the latest data on individual MPAs sizes from the WDPA. The management cost model derived by Balmford et al was:

(3) $$\log10(\text{Cost}) = 5.02 - 0.8 \cdot \log10(\text{Area})$$

The equation being logarithmic in both variables (i.e. highly nonlinear), the cost of the MPAs must be calculated for each MPA separately, then added up rather than adding up the MPA areas beforehand, then applying the equation to the total. We used this model to calculate the predicted management costs of each of the current MPAs listed in the WDPA as of June 2012. The predicted costs of each MPA are then summed to give a total global estimate. To turn this current estimate, for 2.4% global coverage, into an estimate for 10% coverage it is then multiplied by the ratio of the existing area to 10% (i.e. 10/2.4 which is 4.2) (Table 4).

b) It has been proposed that future expansion of the MPA network will be encouraged through the establishment of a greater proportion of larger MPAs than exist in the current network. We created a scenario to crudely simulate this by removing all MPAs in the current WDPA size frequency distribution that had an area less than the median value (~5km^2). The effect of this was to remove half of the MPAs but only lower total coverage by 2%. We then used this new larger size frequency distribution to estimate management costs using the Balmford et al. model (Table 4).

c) In recognition of the fact that management costs will vary from country to country due to changing purchasing power of the local currency relative to the US$ we attempted to adjust the cost estimates from method (a) using Purchasing Power Parity (PPP) values (PPP values sourced from World Bank year 2005 data). PPP estimates were found to be a useful factor to improve management cost estimates by Balmford et al. (2004). First we calculated an average PPP value for each of the 261 MEOW and GOODS regions. We did this by creating an area-weighted average of the PPP values of the national EEZs that intersected with each ecoregion. For the high seas GOODs regions that did not intersect with national EEZs we assumed a mean global PPP value. Next we assumed that the global 10% coverage target was achieved by distributing MPAs evenly into each ecoregion so that each ecoregion had 10% coverage. Then by multiplying the PPP value for each ecoregion by the area of the region expressed as a proportion of the global protected area we were able to adjust the global estimate by area-weighted ecoregional PPP values (Table 4).

For each method the year 2000 US$ used by Balmford et al (2004) were adjusted for inflation to year 2012 US$. We calculated four estimates; first, the estimated annual costs of managing the current MPA network as recorded in the WDPA. Second, the total predicted annual management costs of a network with 10% coverage. Third, the total increase in annual management costs to go from current coverage to 10% coverage, and fourth, the annualised marginal increase in managements costs assuming linear MPA establishment over the next 8 years.

Results

The two size frequency distributions from the WDPA data produced marginally different results with the GIS areas giving higher estimates. The size frequency distribution adjusted to exclude MPAs less than $5km^2$ was around a third cheaper to manage than that of the original size frequency distribution. The PPP adjusted estimate was around 45% cheaper to manage than the original estimate, this is because in most countries US$ will purchase a larger basket of goods and services than the USA.

Table 4: Management costs in millions 2012 USD

	Total annual management costs for current MPA network (2.4% coverage)	Total annual management costs of future MPA network (10% coverage)	Total increase in annual management costs required by end 2020 (going from 2.4% to 10% coverage)	Annual marginal increase in management costs between now and end 2020 assuming linear MPA establishment
Method (a) WDPA GIS areas	1129.459	4725.512	3596.054	449.5067
Method (a) WDPA self-reported areas	910.7881	3669.613	2758.825	344.8531
Method (b) Large MPAs	836.1536	3663.625	2508.461	313.5576
Method (c) PPP adjusted	580.6752	2418.307	1837.632	229.704

Opportunity costs

This report does not quantitatively assess the opportunity costs of meeting Target 11. These costs are likely to be highly dependent on the context of each individual MPA and as such are beyond the capacity of this analysis. The most important opportunity costs related to MPAs will be loss of access to fisheries (Smith et al. 2011). High seas MPAs are likely to have lower opportunity costs than MPAs within EEZs and territorial waters (Sumaila et al. 2007). Opportunity costs are a contentious issue in the MPA literature at present because there is some evidence that MPAs can produce net fishery benefits (Harrison, Williamson et al. 2012) which would imply zero opportunity cost. However the issue is complicated because opportunity costs will vary through time: no-take MPAs initially remove access to fisheries but as time passes stock levels inside the MPAs will recover and this may generate either adult spill-over or extra larval recruitment in the remaining fished areas, leading to a net benefit for the fishery (Cullis-Suzuki and Pauly 2010). Some fisheries scientists dispute the value of MPAs for fisheries and challenge the idea that they can have a net fishery benefit once the loss of fishing area is accounted for (Kearney et al. 2012). The question of whether MPAs can provide a net benefit to fisheries is currently under debate and is unlikely to be fully resolved until fish stocks in a range of MPAs have been allowed to fully recover and their effect on the stocks in surrounding waters can be measured (Russ and Alcala 2011), i.e. 10+ years.

Overall results

The total levels of investment required to achieve Target 11 according to the estimates in this report are summarised in Table 5 and Table 6.

Table 5. Estimated resource needs – breakdown to achieve Target 11 by 2020 assuming linear MPA network expansion from current 2.4% to 10% global coverage by 2020, billions 2012 USD.

	Investment needs total (2013 – 2020)	**Recurrent annual expenditure (increasing through time)**		**Recurrent total to end 2020**	
		Scenario 1 (low -PPP)	Scenario 2 (high- GIS)	Scenario 1 (low- PPP)	Scenario 2 (high- GIS)
Establishment costs	1.5-9.7	NA	NA	NA	NA
Management costs	NA	0.58 – 2.4	1.1 – 4.7	12.9	25.2
Total	1.5-9.7	0.58 – 2.4	1.1 – 4.7	12.9	25.2

Table 6. Total resource needs - Annual and total cost estimates to achieve Target 11 by 2020 assuming linear MPA network expansion from current 2.4% to 10% global coverage by 2020, billions 2012 USD.

	Total additional investment required by end 2020	**Annual Costs (2013 -2020)**
Establishment costs	1.5 – 9.7	0.19 – 1.2
Management costs	12.9 – 25.2	0.58 – 4.7
Total	14.4 – 34.9	0.77 – 5.9

DISCUSSION

The estimates provided here are limited by the data available at the global scale, but despite the many caveats required for these estimates they appear to be commensurate with the estimates from other workers. Balmford et al. (2004) estimated that a global MPA network with coverage of 20% would incur annual management costs of $5.4b to $12.5b, adjusting these values for 10% coverage and year 2012 USD gives estimates of $3.5b to $8.1b. This compares to the values in this report of $2.8 to $4.7b. A possible reason our estimates are at the lower end of the range of Balmford’s estimates is because the 2012 WDPA MPA size class distribution includes some very large MPAs such as the Chagos Islands (640,000 km^2) and South Georgia and Sandwich Islands (1,070,000 km^2). These two MPAs together account for 20% of the total area of MPA but only 0.12% of the estimated total management costs, illustrating the powerful effect of MPA size on costs per unit area.

Previous work has shown that the size of individual MPAs is one of the key drivers of costs: It would be much cheaper to meet the 10% coverage target with a small number of large MPAs than to use a large number of small MPAs. However there are several factors that limit the practicality and feasibility of meeting the Target 11 with only large MPAs. These factors include creating a network that is ‘ecologically representative and well-connected’, in order to adequately represent biodiversity MPAs will be required in a range of sizes and in order to be well connected they will l have to be spaced at distances that can be traversed by the organisms (or their larvae) being protected. Another factor pushing against very large MPAs is that they should be ‘effectively and equitably managed’. In locations where livelihoods depend on local fisheries it is not equable to create large no-take MPAs that would threaten livelihoods, in these locations only small MPAs that still allow fishers access to local waters will be successful. Small MPAs may be effectively managed by local communities who have a sense of ownership over their local resources and this may only require unsophisticated boats and equipment. Large MPAs may lose these advantages.

Benefits of achieving Target 11

The estimated costs presented here are substantial, however relative to the benefits of achieving the 10% coverage target and the size of the global economy they appear easily affordable. Assuming the current global GDP is $70 trillion then the annual costs of managing a MPA network covering 10% of the oceans is only 0.0067% of the value of the world’s economy. The total estimated cost is also less than the annual global fisheries subsidy (Cullis-Suzuki and Pauly 2010).

No-take MPAs have been shown to offer numerous benefits that most other marine conservation strategies cannot claim. They include:

- Preservation of representative samples of biological diversity;
- Protection of critical sites for reproduction and growth of species;
- Protection of sites with minimal direct human stress to maximise their resilience or self-repair from other stresses such as increased ocean temperature;
- Settlement and growth areas providing spill-over recruitment to fished stocks in adjacent areas;
- Focal points for education about the nature of marine ecosystems and human interactions with them;
- Sites for nature-based recreation and tourism; and
- Undisturbed control or reference sites serving as a baseline for scientific research and for design and evaluation of management of other areas.

Relative costs of establishment costs and management costs

Table 6 shows that both per-unit-area establishment costs and management costs decrease rapidly as MPA size increases. The decrease with size is less for establishment costs which makes logical sense as certain processes and procedures will be required for establishing an MPA regardless of its size, these procedures will have costs that might be fairly fixed and will not scale with MPA size.

Table 6. Table illustrating the effect of MPA size on the predicted establishment costs and management costs. Figures calculated from equations in McCrea-Strub et al. (2011) and Balmford et al. (2004). Table adapted from McCrea-Strub et al. (2011).

MPA size	**Establishment costs**		**Management costs**	
km^2	**2012 USD**	**2012 USD per km^2**	**2012 USD per year**	**2012 USD per km^2 per year**
0.5	36657	73314	168842	337685
5	121383	24276	273830	54766
50	401941	8038	444101	8881
500	1330951	2662	720247	1440
5000	4407194	880	1168104	233
50000	14593593	292	1894443	38
500,000	48323929	96	3072426	5.8
1,000,000	69294353	69	3553839	3.5

Caveats to the estimates presented in this report

- All of the models used here have required large extrapolations from existing data with small sample sizes.
- The WDPA contains an under representation of small MPAs, which has biased our cost estimates downwards. For example, the Philippines has an unusually complete national database of marine areas which contains 1558 reserves, of these only 182 are present in the WDPA.
- The quality of data reported to the WDPA is variable and there will be errors in the MPA boundary data and the reported marine areas which is turn will affect the size frequency distribution used to produce estimates in this report.
- The rate of inflation used to calculate 2012 US dollar values from older estimates was the rate of inflation for the USA. This inflation rate is lower than for many countries around the world. The rate of inflation for various components of management costs such as fuel will also be substantially above the average rate of inflation. It is difficult to take account of these variable inflation rates in the estimates produced without knowing more information about the components and locations of costs, which are in most cases unknown.

Directions for future research

As previously mentioned the small sample sizes used to create the models used in this report place limits on the confidence in the global cost estimates. A primary aim of future research should be the collation and collection of more data on the historical costs of MPA establishment and management that would allow the models such as those created by Balmford et al. (2004) and McCrea-Strub (2011) to be recreated with more confidence in their parameters. Ban et al. (2011) have pointed out that the linear model of Balmford et al. (2004) is unlikely to hold true at the extreme sizes of some new MPAs i.e. ~1m km^2 for the newly proposed Coral Sea MPA in Australia. They suggest that a polynomial relationship is more likely where the per-unit-area costs asymptote and stop declining past a certain (very large) area. More data is required to explore whether the relationship between cost and area is really non-linear.

Several factors have been shown in the literature to be important in driving MPA costs but have not been explored in this report, these would be worthy of further investigation. One of these factors is visitor numbers, Gravestock et al. (2008) showed that increasing visitor numbers increased the income requirements of MPAs. It is challenging to predict likely visitor numbers for future MPAs as it will be highly context dependent. However as an important driver of costs it is definitely a factor that should be considered when planning MPAs at the national or local scale. Establishment costs of MPAs in developed countries often include compensation to fishers for loss of income or commercial opportunities. These costs will vary greatly from MPA to MPA but can be significant i.e. the Great Barrier Reef Marine Park where substantial payments to fishers were used as a political bargaining chip as much as for genuine compensation. Some MPAs have multiple zones within them that permit different activities in each zone offering a range of biodiversity protection. Ban et al (2011) showed that multiple zones increase the management costs as compliance activities are more challenging. It is likely that increasing numbers of future MPAs will contain multiple zones to appease stakeholders and increase support for MPA establishment, the influence of this trend on MPA management costs would be worthy of further investigation.

There are two more related factors that affect management costs but that have not been evaluated in this report. These are the severity of threats affecting the MPAs and the vulnerability of the ecosystem type being protected. Balmford et al. (2004) showed that distance to inhabited land was a driver of costs, with MPAs further from land having lower management costs; in this case distance from land could be viewed as a proxy for the strength of local human threat process such as over fishing or water quality degradation. Halpern et al. (2007) showed that marine ecosystems have differing susceptibilities to a wide range of threat processes. If an MPA is protecting a particularly robust or vulnerable ecosystem type then this will drive the need for more or less intensive management with its associated cost implications. Socio economic factors such as poverty and corruption may also play an important role in influencing both threat processes and costs however quantifying their effect in a global scale analysis is challenging.

Table 7. Definition and objectives of IUCN protected areas

IUCN Category	Definition	Primary Objective
Ia	Category Ia are strictly protected areas set aside to protect to protect biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.	To conserve regionally, nationally or globally outstanding ecosystems, species (occurrences or aggregations) and/ or geodiversity features: these attributes will have been formed mostly or entirely by non-human forces and will be degraded or destroyed when subjected to all but very light human impact.
Ib	Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition	To protect the long-term ecological integrity of natural areas that are undisturbed by significant human activity, free of modern infrastructure and where natural forces and processes predominate, so that current and future generations have the opportunity to experience such areas.
II	Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities .	To protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation.
III	Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine caverns, geological feature such as a caves or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.	To protect specific outstanding natural features and their associated biodiversity and habitats.
IV	Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.	To maintain, conserve and restore species and habitats.
V	A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.	To protect and sustain important landscapes/seascapes and the associated nature conservation and other values created by interactions with humans through traditional management practices.
VI	Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in natural condition, where a proportion is under sustainable natural resource management and where low-level non industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.	To protect natural ecosystems and use natural resources sustainably, when conservation and sustainable use can be mutually beneficial.

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