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Ecosystem Services Assessment of North Ari Atoll

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Ecosystem Services Assessment of North Ari Atoll

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Executive Summary

Coastal and marine ecosystems provide a wide variety of benefits to humans in the form of goods and services; collectively these are termed marine ecosystem services. In the Republic of the Maldives, coral reefs and associated habitats provide valuable ecosystem services such as fish and other food, natural hazard protection, climate regulation and the beaches, clear blue waters, and seascapes that are the basis for the thriving tourism industry. Globally approximately 60% of all ecosystem services — marine and terrestrial — are used unsustainably, with irreversible consequences that include shifts in regional climate, disease emergence and collapse of fisheries and nature-based tourism industries. Experiences from around the world have shown that the costs involved in restoring coastal systems to enable ecosystem services to flow from them once more is significantly more than the costs inherent in good management practices — yet ecosystems continue to be degraded. In the Maldives, careful development and effective marine management could ensure that its valuable ecosystem services do not suffer the same fate.

Ecosystem Service Assessment and Valuation can prioritise conservation and management efforts, be used as a tool for stakeholder negotiation, set prices and compensation packages and provide economic arguments for environmental conservation in political debates. One method of measuring the value of ecosystem services requires estimating the amount people are willing to pay to preserve or enhance these services, an amount that varies across space and with time. The potential for ecosystem services valuation to influence policy will depend on contextual, procedural and methodological factors integrated in the decision-making process.

This report presents a qualitative description of ecosystem services being provided by natural habitats. It lays the groundwork for a description of the factors affecting ecosystem services delivery – both favourably, in the sense of management to restore or enhance ecosystem services delivery, and negatively in the sense of summarizing human pressures and natural factors that contribute to a decline in ecosystem health or a decrease in ecosystem services delivery. Limited information regarding trends in ecosystem services delivery are available and where present, this information has both been summarized and used to discuss implications for future delivery of ecosystem services in the atoll and the wider Maldives region.

An assessment of ecosystem services of *Alifu Alifu Atholu* (North Ari Atoll) in the Maldives was undertaken in 2015. The assessment is based on published information, IUCN surveys carried out under Project Regenerate and interviews with key actors in Malé and North Ari Atoll. The preliminary assessment of this atoll was carried out in conjunction with a synthesis of benefits being delivered by the coastal and marine environment of the Maldives more generally. The key habitats that contribute to the delivery of valuable ecosystem services in the Maldives include coral reefs, tidal flats, seagrass beds, beaches, mangroves, as well as offshore pelagic areas and seamounts.

The main ecosystem services being provided by the coastal and marine natural habitats of North Ari include commercial, subsistence, and recreational fisheries; dive, snorkel, and other ecotourism support; shoreline stabilization and beach formation and maintenance; hazard mitigation; water quality maintenance; and spiritual and cultural benefits. Some data exist to quantify these values at the atoll level, but for most services economic information is only available at the national scale. For some sectors, economic data are difficult to obtain; for these services, a benefits transfer methodology can be used to present a range of potential values that services may be bringing to North Ari specifically, and to the Maldives more generally.
Coastal ecosystems are responsible for providing the land that comprises the whole of the country, but also specifically support tourism and fisheries of value. With 13 resorts and 24 guesthouses in the atoll at the time of writing, North Ari has the 3rd highest concentration of

tourism infrastructure of any atoll. North Ari is a preferred destination for liveaboard boats, and the atoll accommodates approximately 400 tourists per week on average on these boats according to IUCN surveys. The atoll is also important for fishing where nearshore areas support fisheries yield revenues of USD 1,000–3,000 per capita per month for approximately 400 North Ari fishers. The atoll also supports the highly lucrative handline yellowfin tuna fisheries that occur throughout Maldivian waters, since North Ari is a preferred location for acquiring baitfish used in the yellowfin tuna fishery.

Preliminary annual values were calculated for services from eco-based tourism[1], from bait fishing for the tuna fisheries and from reef fishing in North Ari. Additional services such as shoreline protection were not included in this analysis due to a lack of data. Given the lack of data at the local level, notably regarding accurate cost information in the tourism sector, the estimates provided in the table below are based on several assumptions and so are only indicative. Future analyses can contain new datasets in order to increase the accuracy of these estimates.

Table 1*.* Estimated total annual revenues, expenses and profits from different sectors associated with ecosystem services in North Ari Atoll

Economic Sector	Estimated Annual Revenue USD Million	Estimated Annual Expenses USD Million	Estimated Annual Profits USD Million
Resorts – dive related	42.26	33.81	8.45
Resort – non-dive	63.39	50.71	12.68
Guesthouses – dive	3.78	3.14	0.64
Guesthouses – non-dive	1.78	1.42	0.35
Liveaboard Boats	16.74	13.36	3.35
Bait Fishing	1.43	0.09	1.34
Reef Fishing	2.69	0.94	1.75
TOTAL	132.07	103.47	28.56

As the total coral reef area of North Ari Atoll is approximately 103.59 km^2 (not including platform sands[2]), the figures above translate to the following total economic values per km^2:

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[1] We define eco-based tourism as tourism that relies on healthy reefs, for example diving or snorkelling, as opposed to tourism based on luxuries and beach activities

[2] Defined as low relief undulating sedimentary bed-forms created by the accumulation of carbonate sands derived from the fore-reef and reef flat or barren lagoons

Table 2. Estimated annual revenue and profits per km^2 from different sectors associated with ecosystem services in North Ari

Economic sector	Estimated annual revenue USD per km^2	Estimated annual profits USD per km^2
Tourism	1,073,456	21,303
Bait Fishing	13,803	12,934
Reef fishing	25,965	16,892
Total	**1,113,224**	**51,129**

Of course, it must be noted that the values expressed here are not uniform across the reef system, and some coral reefs will provide more ecosystem services and will be more valuable for the economy than others. The value of a reef will depend on its ecological condition and productivity, perceived importance by different sectors and actual use by the stakeholders. More accurate values can be determined for North Ari with targeted economic studies. This preliminary analysis of economic values of services is supplemented with mapping that shows that some geographical areas within the North Ari Atoll may have more significant concentrations of ecosystem services than others. These areas can be flagged as needing protection – whether as newly established marine protected areas, or as core zones within a multiple use marine spatial plan or biosphere reserve. Areas that provide high levels of ecosystem services cover approximately 3.7% of the administrative area of North Ari Atoll. There are potentially five main regions in North Ari that provide the highest number of services. These include the Madivaru and Kuramathi-Rasdhoo Channels, Maathivereefinolhu, Gangehi Kan'du and the southern reef of Ranfaru. They all demonstrate a higher number of ecosystem services than other parts of North Ari and warrant careful management and conservation from the government in order to maintain the provision of these services.

A net present value (NPV) analysis was undertaken to explore various management scenarios and compare their potential impact on ecosystem service delivery. The results of the analysis, which estimated costs and benefits of creating new marine managed areas (MMAs)[3] and locally managed marine areas (LMMAs)[4], and is based on several assumptions and therefore can only be seen as speculative at this stage. Even so, these suggest that safeguarding ecosystem services could be done cost-effectively.

The following table summarizes the estimated economic benefits from investing in coral reef management based on four scenarios that include 'business as usual', 'more degraded', 'improved management' and 'significantly improved management' cases. The 'business as usual' (BAU) case projects what is likely to happen in the absence of improved marine management of the coral reef and other ecosystems of North Ari. The 'more degraded reef' case projects what is likely to happen under a set of more negative assumptions to the BAU case where increased damage to the coral reef ecosystems would result in further negative

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[3] Marine Managed Areas (MMAs) are house reefs of resorts where human activities are zoned and regulated under a management plan, and where the resort is responsible for developing and implementing the coral reef management plan.

[4] Locally managed marine areas (LMMAs) are coral reefs around community islands where human activities are zoned and regulated, and where local communities are responsible for developing and implementing the coral reef management plan.

impacts on the main economic activities over time. The ‘improved reef management’ case assumes the establishment of six MMAs in resort islands and of four LMMAs in community islands. The ‘significantly improved reef management’ case assumes that all the resorts (13) and communities (8) in North Ari Atoll would establish MMAs and LMMAs.

Table 3. Estimated net present values under different management scenarios and discount rates

Management Case	**NPV (6% discount rate) USD Million**	**Percentage of BAU case**	**NPV (13% discount rate) USD Million**	**Percentage of BAU case**
1. Business as Usual	773.67		411.42	
2. More Degraded Reef	485.13	63%	262.79	64%
3. Improved Reef Management	822.37	106%	427.20	104%
4. Significantly Improved Reef Management	849.35	110%	435.48	106%

As is evident, the NPV values of the improved and significantly improved management cases are superior to those of the BAU case, while those of the more degraded case are considerably inferior. While the differences between the improved and significantly improved cases and the BAU case are not that great in terms of the percentages (only 6% and 10% higher using a 6% discount rate, and 4% and 6% using a 13% discount rate), the total differences are not trivial within the context of the local economy: USD 48.7 million in benefits for the improved management case and USD 75.7 million in benefits for the significantly improved management case and the 6% discount rate scenario; USD 15.8 in benefits for the improved management case and USD 24.1 for the significantly improved management case.

Another way of comparing the cases and scenarios under the same set of assumptions is to contrast the NPV of the improved and much improved management cases to that of the BAU case versus the NPV of the costs associated only with the implementation of the MMAs and LMMAs, i.e. the main “additionality” of the proposed management cases. The analysis is presented in Figure 1.

The following graph depicts the relevant NPV costs and benefits of the two management case scenarios (using 6% and 13% discount rates) compared to the BAU case:

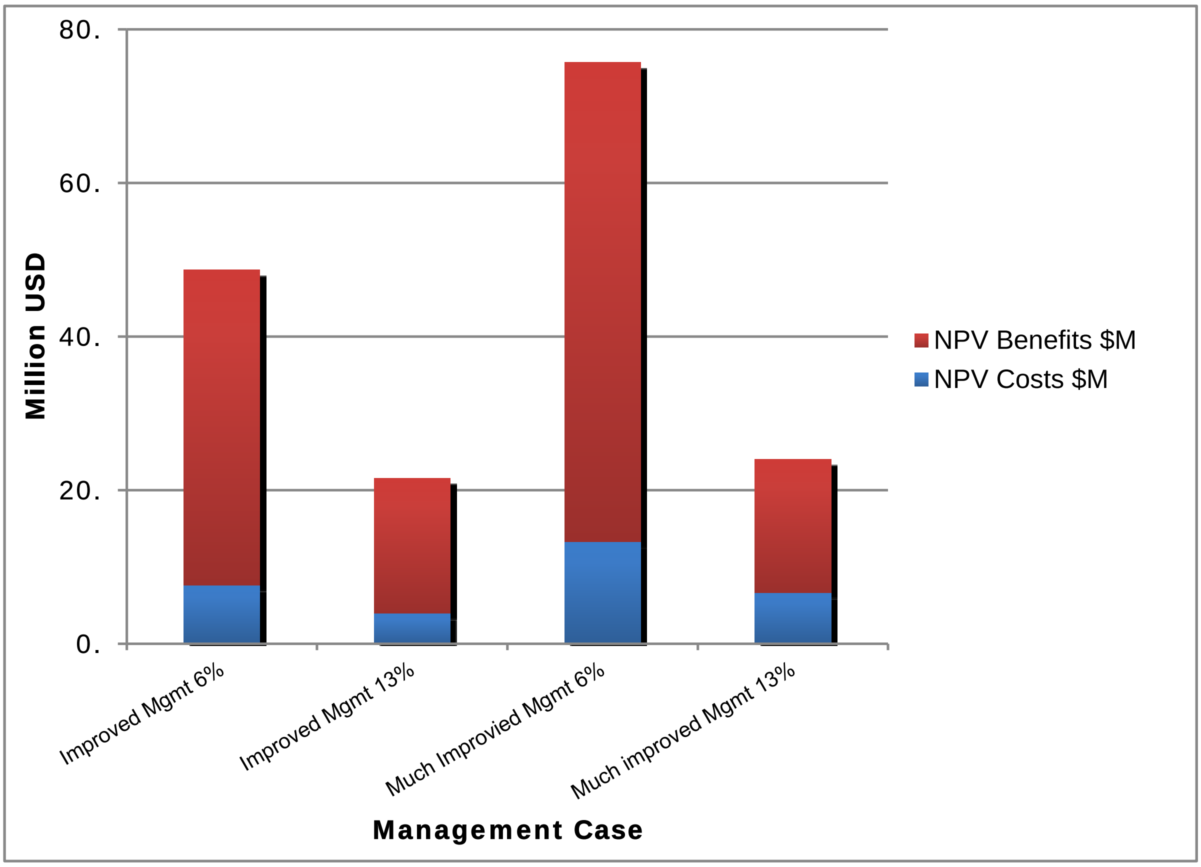

Figure 1. Estimated net present values under different management scenarios and discount rates

As can be seen when making this type of comparison, the additional expenses associated with the MMAs and LMMAs under the improved management case generate almost 6 times the benefits using a 6% discount rate and just over 4 times the benefits when using a discount rate of 13%. Under the significantly improved management case, the additional MMA and LMMA costs result in almost 5 times the benefits, using a 6% discount rate and in almost 3 times the benefits when using a 13% discount rate.

So, even assuming quite conservative annual changes in reef fishing and dive-tourism related to coral reef total area and the quality of reef ecosystems, the case for supporting investments in MMAs and LMMAS to promote marine management and conservation is compelling. Furthermore, given the relatively small difference in the costs (in present value terms) of the significantly improved management scenario to the improved management scenario, versus the much greater benefits that would be generated by the significantly improved management case over time, it is obvious that the significantly improved management case is the most cost-effective option.

The analysis presented in this report clearly shows that investing in coral reef management would be beneficial to the economy of North Ari Atoll. If coral reefs of North Ari Atoll were allowed to degrade and were not managed properly, this could impact both revenue from tourism and productivity from fisheries, leading to estimated losses of USD 148.54 million to USD 288.54 million (in NPV compared to the BAU estimates), depending upon the discount rates used, over a 30-year time horizon. However, investing in improved coral reef management would provide returns of between USD 15.78 million and USD 48.67 million over a 30-year time-period with the lower investment scenario, depending on the discount rates; and between USD 24.01 million and USD 75.69 with the higher investment scenario, depending on the discount rates used. These estimated values highlight the importance of managing coral reefs sustainably, so that they continue to support the economic pillars and livelihoods of the Maldives and Maldivians. A more comprehensive valuation of the ecosystem services of North Ari Atoll is recommended to refine the data, to fully understand the ecosystem values and to provide the necessary information for a more comprehensive NPV analysis.

1. Introduction

The Maldives is an archipelago comprising of approximately 1,200 low-lying islands in 26 atoll groups within a marine area of over 90,000 km^2. Maldives is thus very much a marine state; the combined land area of the islands (about 300 km^2) is less than a thirtieth of the nation's territory. Coastal lands provide areas for tourism development, recreation, agriculture, habitation and nature conservation, and marine areas offshore support vibrant tuna and reef fisheries, tourism, and a wide array of marine species representative of a unique biogeography.

Alifu Alifu Atolhu (North Ari Atoll) is the administrative northern portion of the Ari Atoll group, containing community islands, resort islands and smaller uninhabited islands. There are 8 islands with resident communities and guesthouses (24 guesthouses in total across the North Ari area at the time of writing, 3 of which are large and 21 of which are relatively small establishments), and 13 resort islands. The coral reefs in the atoll are in relatively good condition at the time of writing (predating the 2016 coral bleaching event), and support fisheries, subsistence use, and tourism. This study examines these benefits, known as ecosystems services, and how these benefits relate to the management costs to preserve them. The study falls under the wide variety of research and outreach activities being carried out by Project REGENERATE[5], which aims to bring information on reef resilience and management to decision makers to make development as sustainable as possible.

Although individual ecosystem services originating from natural habitats on land, along the coast and in the sea can be identified, assessed, mapped and analysed for real and potential economic value, it is important to note that no ecosystem service exists in isolation from other ecological processes and delivery of other services. Natural systems are highly interlinked, and human well-being is coupled to the existence of multiple ecosystem services, all being delivered simultaneously. These linkages and feedback loops mean that development decisions or impact that cause the loss of habitat or species will affect more than one ecosystem service of value and a multitude of stakeholder groups (see Figure 2).

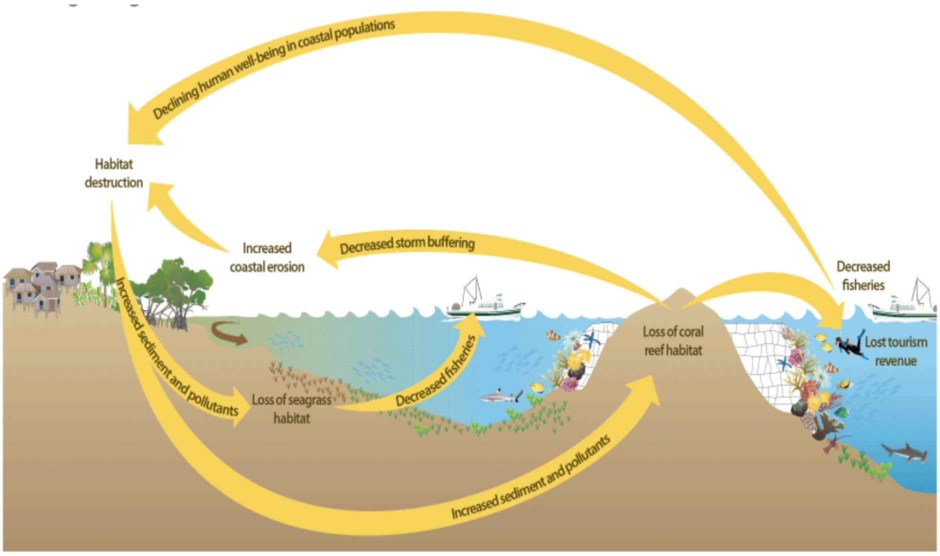

Figure 2. Connectivity between ecosystems, and linkages between ecosystems and human well-being (from Agardy *et al.* 2011)

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[5] Reefs Generate Environmental and Economic Resilience (Regenerate). This project is funded by USAID and implemented by IUCN in partnership with the Government of the Maldives

The Government of the Maldives has engaged in habitat classification, assessment and mapping under various initiatives and programmes, including work undertaken by IUCN under Project REGENERATE. Detailed studies and mapping have been done in Addu Atoll (see Dews *et al.* 2008), Baa Atoll (Emerton *et al.* 2009), and North Ari Atoll (current work being undertaken by IUCN). At the same time, published information on the full range of ecosystem services being provided by the country's biodiversity and ecosystems and where the economic values originate is difficult to obtain. The only major study at the atoll level done to date was undertaken in Baa Atoll as background for the creation of a trust fund to support conservation (see Emerton *et al.* 2009). Project REGENERATE has been collecting ecological and social data to develop a resilience-based management framework, and that can also be used to determine the value of ecosystem services based on assumptions about indicators. Proxy studies done in other countries also provide an indication of potential economic values, but additional social surveys will need to be conducted to ascertain true economic values, using the methods described in the next section.

Valuable ecosystem services in the Maldives include: *provisioning services* including fisheries resources, natural materials for crafts; *regulating services* including coastal protection (day-to-day shoreline stabilization and hazard mitigation), water quality maintenance, carbon sequestration; *supporting services* including nutrient cycling and oxygen production; and *cultural services* including education, ecotourism, recreation, scientific research, and general aesthetic values (see Infographic in Figure 3 below).

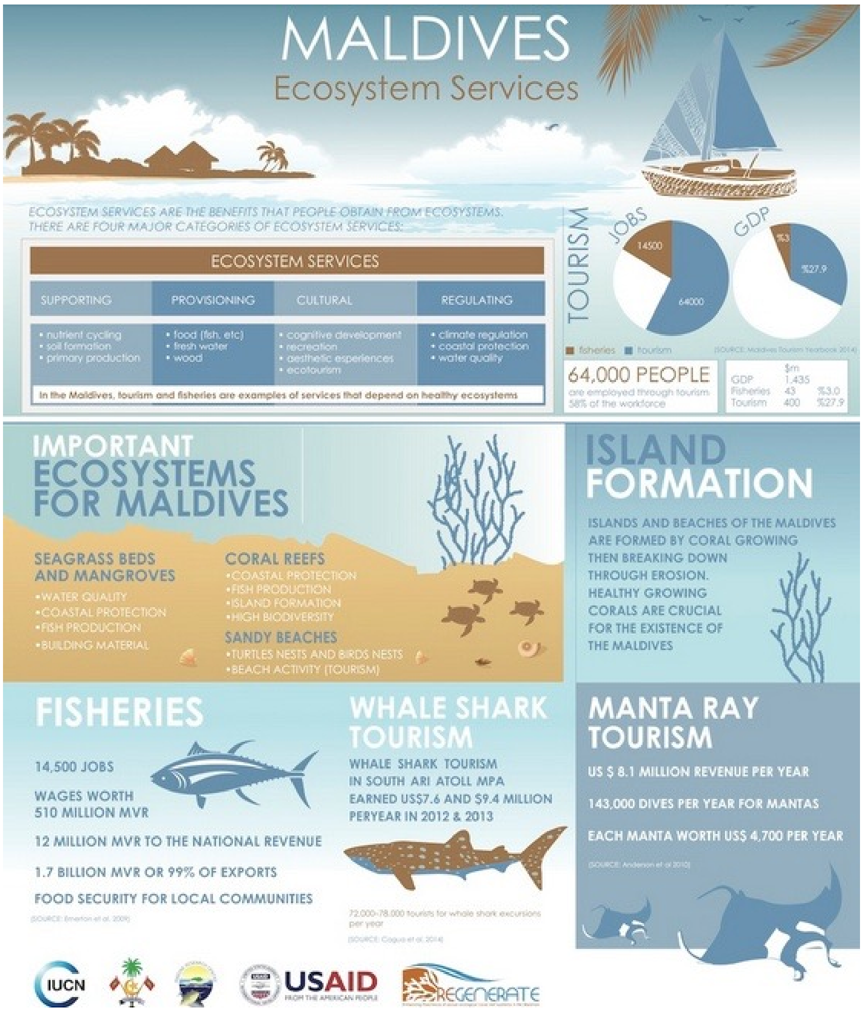
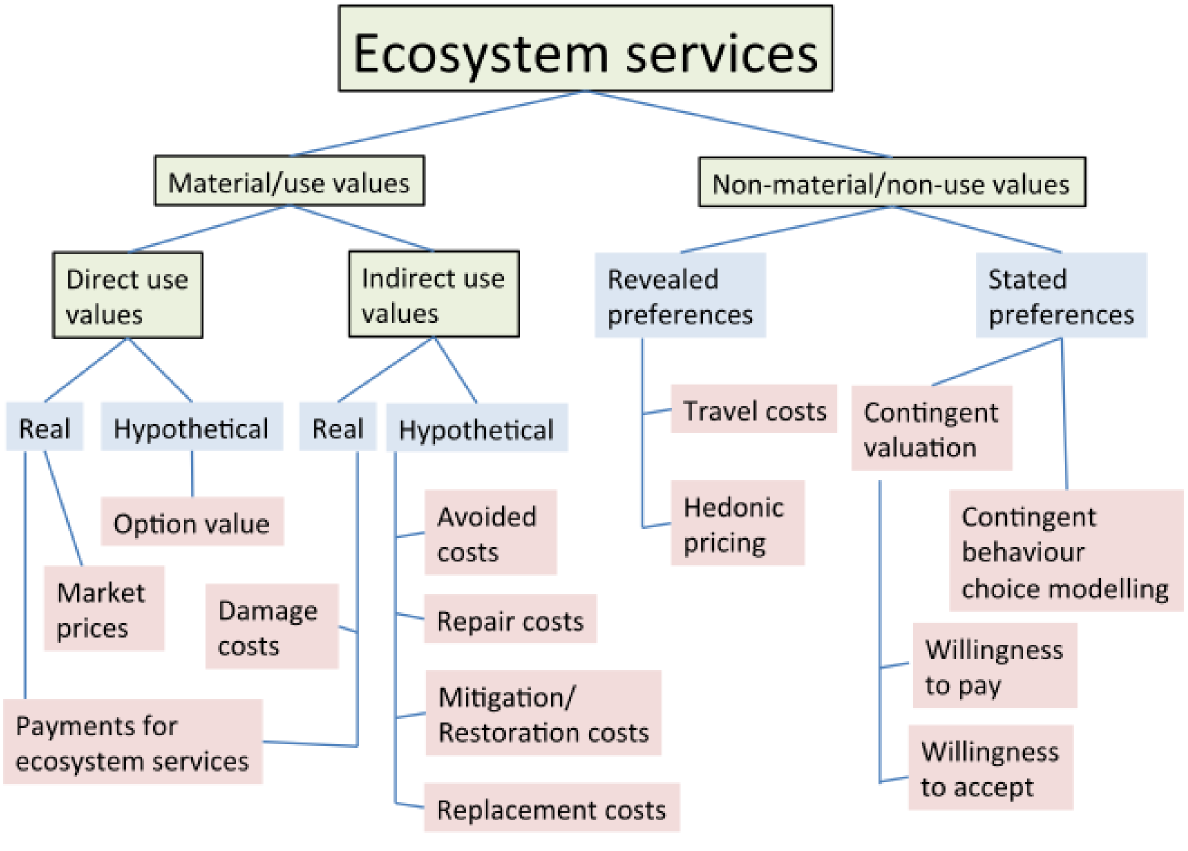


Figure 3. Ecosystem services of the Maldives infographic (IUCN)

Although neither a full assessment of all ecosystem services, nor valuation exercises to determine the true economic values of the services identified were within the scope of this study, this assessment highlights ecosystem services provided as co-benefits that have both market and non-market value. As "value" essentially relates to the realization of these benefits, valuation is however somewhat subjective and highly case-specific. As such, important benefits may be provided by natural habitats in the Maldives (as elsewhere), which have little apparent value because those benefits are not captured on the market or assessed by non-market valuation. As illustrated in Figure 4, values can be derived that reflect either real or hypothetical value. In the Maldives, the number of valuation studies undertaken to date is limited, therefore discussion of the value of natural habitats and insular ecosystems is at present hypothetical.



Adapted from: Spangenberg and Settele, 2010

Figure 4. Valuation framework (taken from Spalding 2013)

A robust valuation framework captures all values (market and non-market). The most common and most appropriate framework for aggregating the value of ecosystem services is Total Economic Value (TEV). According to Philcox (2007), TEV divides the value of ecosystem-based goods and services into two categories:

1) Use values: direct use value (e.g. provisioning services such as food, water); indirect use value (e.g. regulating services such as climate control, waste assimilation, water quality); and option value (i.e. the value derived from the option to make use of a resource in the future);

2) Non-use values (including existence value, bequest value and altruism value).

This approach allows a range of values, based on economic analyses undertaken for these ecosystem types elsewhere in the world, to be presented. With this potential range of values and knowing the areal extent of coral reef, mangrove, seagrass, tidal flats, as well as having some indication of their relative condition in North Ari, an estimate of total potential ecosystem services values has been generated by ecosystem type. To ensure robustness it is recommended that additional studies be undertaken to confirm these values, understand how they are being realized in North Ari and the Maldives more generally and use this information to inform investment in environmental protection and sustainable development strategies – including the design of the potential national Biosphere Reserve of the Maldives.

2. Ecosystem Services Assessment

The ecosystems of the Maldives are first and foremost responsible for the land's very existence. Without the coral reefs that support the atolls; sand, land and platforms for reclamation would not exist. These marine ecosystems also have a role in supporting the overall biodiversity, natural productivity and environmental health of the country. Many coastal and inland habitat types perform pivotal roles and their loss could create irreversible degradation and lost opportunities to take advantage of natural capital and its benefits. In particular, mangrove, seagrass, nearshore rock or shellfish reefs, macroalgae assemblages, and tidal flats with associated algal mats play a role in maintaining coastal water quality. This in turn allows for recreational and tourism use, reduces costs of desalination, diminishes the chance for public health problems relating to exposure to toxins (via bathing or seafood), and supports profitable and culturally important fisheries. Similarly, coral reefs, and – to some extent – mangroves and seagrass, maintain shorelines and navigation channels, reduce chronic erosion, and buffer land and property from storm surges. Coral reefs, tidal flats, mangrove and seagrass are particularly critical in supporting fisheries production – valued by commercial, traditional, and recreational fishers alike. Collectively, these natural ecosystems play a key role in contributing to a healthy, aesthetically pleasing, and resilient island environment in the Maldives. North Ari Atoll is a microcosm of the archipelagic country, and valuable as a focus for ecosystem services valuation due to the good condition of reefs and strong information base.

Typology of Marine Ecosystems

Coastlines and Beaches

Beaches are an important ecosystem for meiofauna. © Abdulla Fisam, IUCN

The coastline of the Maldives has been estimated at 644 km (CIA World Factbook, 2016), and includes sandy beaches and rocky/gravel shores. Beaches are sites for recreation, including swimming and picnicking, but also support a diverse fauna that includes shorebirds and seabirds, crustaceans, and meiofauna, *inter alia.* The distribution of tidal flats and sand banks is usually restricted to low-energy sheltered areas, like the interior of atolls. Tidal flats in the Maldives are distinguished by high primary productivity and, thus, provide valuable feeding grounds for a variety of resident and migratory seabirds and fishery species.

Mangrove

Mangrove refers to a group of salt-adapted trees that form mangrove fringes and forests across the tropical regions of the world. Due to the geomorphology of the Maldives, mangrove occurrence is restricted; and this is especially true in North Ari Atoll. Nonetheless, mangroves can act together with tidal flats to stabilize navigation channels and shorelines, prevent inundation from sea level rise and from wind-induced flooding of coastal property by the sea (Ellison, 2012). Mangroves are also one of the most important buffers against catastrophic flooding brought about by cyclones or tidal waves (Arkema *et al.* 2013).

Mangrove trees and other coastal vegetation can export nutrients to the nearshore environment, and they trap sediments. They also act to trap heavy metals and other toxins, and to some extent they can maintain salt balances. Thus mangroves play a critical role in maintaining water quality, even as groundwater, freshwater, and seawater become increasingly degraded (UNEP, 2014).

Mangrove channels and tide-inundated mangrove support a variety of fisheries species through provision of nursery habitat. These fisheries are of cultural and economic importance in the Maldives. Recent studies have quantified the contribution of mangrove nursery habitat to fisheries production, by gauging estimated losses in terms of fisheries yield and profitability once mangrove is deforested (Aburto-Oropeza *et al.* 2008). At the same time, mangrove supports broader avian, fish, crustacean, mollusc and sponge diversity, and may be one of the most important supporting service-providing ecosystems across the globe as well as at a local level.

Mangroves also fix carbon and sequester it in biomass and soils, making this habitat extremely important in climate change mitigation (UNEP, 2014). Emissions resulting from mangrove losses make up nearly one-fifth of global emissions from deforestation, resulting in economic damages of some USD 6 - 42 billion annually. Mangroves are also threatened by climate change, which could result in the loss of a further 10-15% of mangroves by 2100 (UNEP, 2014).

Seagrass

Seagrass provides feeding and breeding grounds for most neritic species that live in tropical and subtropical environments. It has been estimated that some 80% of coastal fisheries species rely on seagrass during some part of their life histories. The nitrogen-fixing ability of the seagrass rhizomes allows these aquatic flowering plants to thrive even in the low-nutrient conditions typical of tropical seas. Therefore, while the biodiversity of a seagrass meadow at any point in time may be relatively low (especially when compared with coral reefs, or with transitional ecosystems like estuaries and mangroves), the cumulative biodiversity can be high, with support to extensive food chains (van Lavieren *et al.* 2011). Component species of seagrass meadows, such as tunicates, exert controlling effects on phytoplankton production and thus support wider food webs (Agardy and Alder, 2005).

In North Ari, seagrass ecosystems are present but not extensive. Yet seagrass meadows provide habitat for finfish, molluscs, crustaceans, sea turtles and even marine mammals. Sea turtles (green and hawksbill sea turtles) are flagship and umbrella species, indicating ecosystem condition, and the herbivorous green turtles rely on intact and productive seagrass for feeding.

Seagrass, like mangrove, acts as a buffer against storm surge, tsunamis, and other catastrophic events. Plants retain the sediment on the soil, keeping it from being deposited along the shoreline in severe weather events. Similarly, seagrasses stabilize the sea floor, providing a stable environment for infauna (meiofauna and burrowing clams, worms, etc.) as well as demersal marine species. These functions are commonly lost when seagrass is physically damaged. Seagrass meadows can be directly damaged during dredging or infilling, and indirectly affected by pollution (particularly sediments and excessive nutrients), over-fishing, species invasions, and losses of key component species through collection or displacement by invasives. When these factors act in concert, as they do in most stressed coastal and marine ecosystems worldwide, the results can be catastrophic for seagrass. Damaged or degraded seagrass can be restored (Ganassin and Gibbs, 2008), but restoration takes time, is highly expensive, and is only successful under optimal conditions.

Seagrass meadows are also important for fixing carbon and sequestering it in soils; as such, seagrasses belong to a group of marine habitats known as Blue Carbon ecosystems. Recent research indicates protection of seagrasses may be an important policy response to climate change (Hejnowicz *et al*. 2015).

Algal Communities

Macroalgae similarly provide habitat to support a wide array of species (including commercially valuable fishery species), influence water quality, and sequester carbon. Red, green and small species of brown algae often intermingle in deeper waters, while the larger species of brown algae (especially *Sargassum*) are generally found in shallower waters (Sheppard and Borowitzka, 2011). Calcareous algae, found in shallow waters and often on reef flats, are another class of algae that provide ecosystem services. The calcium carbonate contained in calcareous algae is bioeroded and contributes to the formation of the spectacular white sand beaches of the Maldives. The ecosystem services delivered by algae are considered within the framework of the habitat type in which they occur (coral reefs, tidal flats, etc.).

Coral Reefs

The extensive coral reefs that can be found throughout the Maldives provide a wide variety of ecosystem services – in fact, these are the ecosystems that provide the most tangible value to humans. These values include shoreline stabilization and buffering land and lives from cataclysmic storm events, providing areas for diving and other recreation, and supporting biodiversity and fisheries or food security (Barbier *et al*. 2011; Moberg and Folke, 1999; TEEB, 2010). Coastal protection, food security and revenue from tourism can be especially important in allowing coastal communities to adapt to climate change threats such as sea-level rise, more extreme weather events and droughts or famine. An additional known value of coral reefs is the value of bioprospected pharmaceutical compounds.

In the Maldives, as in many parts of the world, coral reefs are the best understood in terms of ecosystem services values. The reefs of North Ari are valued by residents and visitors alike, and are in generally good condition (nearly 50% of reefs surveyed by Project REGENERATE showed relatively high coral cover- an indicator of coral reef health, although this was before the 2016 bleaching event). Reefs themselves and organisms associated in some way with reefs, such as manta rays, reef sharks, groupers and wrasses, etc., have been assessed elsewhere for the monetary and non-monetary values they provide. In Baa Atoll, studies indicated that reef-related tourism was a more significant contributor to revenues than fisheries. Contingent valuation using the travel cost method and willingness to pay surveys in other countries suggest that both local communities and tourists see value in reefs and reef-associated biodiversity, and that these values can far exceed the extractive values derived from fisheries harvest or use of reef materials for construction (see for example Anderson *et al*. 2010; Cagua *et al*. 2014; IUCN, 2013).

Physical, biogeochemical, and ecological interactions occur between mangroves, seagrasses, and coral reefs, making these known interconnected systems (Moberg and Ronnback, 2003). By dissipating wave and current force, reefs create shallow lagoons and bays that are suitable ecosystem for mangrove and seagrass growth. This is essentially a symbiotic relationship at the beta or habitat level, wherein mangroves and seagrasses then filter pollutants and sediments from the marine waters, allowing further development of the complex reef system. It has been thus hypothesized that the presence of these interlinked ecosystems within a region may considerably enhance the ecosystem services provided by one single ecosystem (Moberg and Ronnback, 2003).


Coral reef biodiversity is important for attracting tourists to the Maldives © Brian Zgliczynski, IUCN

Alongi (2008) suggests that the extent to which coral reefs and mangroves offer protection against catastrophic storm and wave events, such as tsunamis, may depend not only on the relevant features and conditions within the mangrove ecosystem, such as width of forest, slope of forest floor, forest density, tree diameter and height, proportion of aboveground biomass in the roots, soil texture and forest location (open coast vs. lagoon), but also on the presence of healthy foreshore ecosystems, such as coral reefs, seagrass beds and dunes. Other researchers hypothesize a similar systems interaction for coral reef, seagrass and tidal flat complexes (Koch *et al*. 2009; Mumby, 2006). Given the rapid rate of land reclamation and environmental change in the Maldives, the loss of coastal habitats and pressures that affect the health of these ecosystems will have concurrent opportunity costs (Sale *et al*. 2011).

In sum, the many marine habitats that comprise Maldives' ecosystems, including those of North Ari Atoll, provide many benefits to humans. A typology of these services is given in Table 4 below.

Table 4. Matrix of Broad Categories of Ecosystems and Services in the Maldives

	Coral Reef	Mangrove	Seagrass	Beach	Tidal flat	Seamount	Pelagic
Tuna Fisheries	X		X			X	XX
Reef Fisheries	XX	X	X		X		
Material (crafts)	X	X		X			
Coastal defence	XX	X	X				
Water quality		X	X			X	X
Carbon fixing		X	X				
Disease control	X	X	X				
Nutrient cycling	X	X	X			X	XX
Recreation	X	X		XX	X	X	X
Ecotourism	XX			X	X	X	X
Aesthetic values	XX	X		XX			
Science	XX	X	X	X	X	X	X
Education	XX	X	X	X	X	X	

3. Factors affecting Ecosystem Services delivery in the Maldives

3.1 Ecosystem Services delivery, listed by Ecosystem Service type

1. Biodiversity

The Maldives exhibits globally significant biodiversity *in situ* as the Chagos-Maldives-Laccadive ridge supports a globally unique biogeography worthy of protection (Abdulla *et al*. 2014), while contributing to the support of biodiversity in the wider Indian Ocean region. Reports documenting biodiversity generally treat biodiversity as either a characteristic of ecosystems/habitats, or a metric by which to evaluate ecological functioning. Herein we follow the Millennium Ecosystem Assessment model (MEA, 2005) and treat biodiversity as an important and valuable ecosystem service.

All natural habitats in the Maldives support floral and faunal species, of course, but certain marine ecosystems harbour more significant biodiversity. Coral reefs are especially biodiverse and the reefs of North Ari still exhibit high coral cover and the presence of large coral colonies suggest the ecosystems are relatively healthy and resilient (IUCN Project REGENERATE survey results 2015). Scleractinian corals in the Maldives themselves are represented by upwards of 250 species, and the reef fish and invertebrate diversity associated with coral reefs leads to even higher species counts for reef biota (Wilson *et al*. 2002).

Biodiversity at every level: genetic, species, and ecosystem or habitat level, has intrinsic value. In most assessments, the value of biodiversity is measured by how it enhances experiences: recreational use, tourism, cultural values embedded in a species or a suite of species, and maximised resilience of ecosystems in the face of large scale pressures and environmental changes. Most often, biodiversity values are determined by examining recreational use centred upon it, such as value to bird-watchers, whale watchers, or other eco-tourists (McDonald, 2009). Clearly the full suite of values must go beyond this.

2. Extractive resources: Fisheries

Fishing is an important source of revenue generation in the Maldives and a source of livelihood for many atoll inhabitants. Commercial fishing is generally of two types: offshore tuna fisheries, predominantly pole and line or handline for yellowfin (as opposed to purse seine or other net fisheries); and inshore reef fisheries. Atoll ecosystems support offshore tuna fisheries in that bait for line fishing is generally caught in nearshore waters within atoll boundaries. Fish are either consumed by local communities, sold to resorts or exported abroad.

In North Ari Atoll, approximately 400 fishers are engaged in reef fisheries (Maldives MRC Fisheries Survey 2015) and 400 fishers are engaged in bait and tuna fisheries (MoFA, 2013). Recent analysis by the IUCN suggests that the average per capita income generated is approximately USD 1,000-3,000 per month (this figure does not take into account expenditures by fishermen which reduce their profit margins). Bait fishing is also an important economic activity on coral reefs, as baitfish are caught around coral reefs and used for fishing of larger reef predators or pelagic tuna fishing away from the reef. Revenue from tuna fishing (both pole and line tuna fishing and handline yellowfin tuna fishing) for fishermen in North Ari, which is currently wholly dependent on the availability of live baitfish, is estimated to be about USD 11 million per year from selling skipjack and yellowfin tuna to tuna exporting companies, and from selling frigate tuna and little tuna (kawa kawa) on local island markets.

3. Provision of Fisheries Nursery Habitat

Coral reefs, soft-bottom habitats like tidal flats, seagrass, and mangroves are all essential for fisheries production in that they provide supporting services such as nutrient cycling and habitats for juvenile fishery species. It is well known that mangroves and other coastal ecosystems provide essential support to fisheries production (fish, shellfish, molluscs, etc.). Organic matter produced by mangroves and associated species can be exported to adjacent ecosystems or consumed in the mangrove ecosystem itself. In Mexico, estimates of the amount of organic matter produced range from 1,100 to 1,417 gm per year, providing food for economically important filter-feeding organisms such as clams and oysters. Export of this production also supports zooplankton in the Gulf of California, which in turn support higher trophic levels of organisms including commercially important species (Bouillon *et al.* 2002). Aburto-Oropeza *et al.* (2008) estimated the value of mangrove fish nursery habitat in the Gulf of California (Mexico): for every kilometre of mangrove forest fringe, an annual value of USD 25,149 of services was provided to the coastal fish and crab fisheries. Many fisheries species are also dependent for some or all of their life histories on seagrass. Some shark and ray species utilize mangrove or seagrass as nursery habitat, and some finfish species are obligate mangrove utilizers.

4. Water Quality Maintenance

Healthy marine ecosystems provide the vital ecosystem service of maintaining water quality, even in the face of significant pollution inputs that result from dumping, outfall discharge and run-off from land-based sources of pollutants. In the absence of these ecosystem services, threats exist to vulnerable species and humans alike. Human health is impacted by exposure to degraded water during bathing, ingestion of tainted seafood and indirectly by the cascading effects of poor water quality that often leads to algal blooms and fish kills. There is some evidence that tipping the water quality balance towards degradation can trigger pathogenic activity in marine dinoflagellates and in pathogenic bacteria like *Cholera vibrio* (Anderson, 2009). Gilbert *et al.* (2002) makes the link between eutrophication, harmful algal blooms, and bacterial disease, citing research in Kuwait. Degraded water also affects fisheries productivity, mariculture production and degrades recreational and tourism experiences, including creating the conditions that lead to beach closures (Robertson and Phillips, 1995).

The consequence of poor water quality that results from loss or decrease of these ecosystem services is also a feedback loop that causes ecosystem services impairment in associated ecosystems. If, for instance, salt marsh is destroyed to accommodate land reclamation, and if no additional offsetting or mitigation takes place, the impact of the resulting lowered water quality can be to cause degradation of seagrasses and coral reefs and declines in the delivery of the ecosystem services they provide.

Lowered water quality can occur when coastal ecosystems cannot keep pace with pollution inputs, as sometimes occurs with desalination operations. The reduction in water quality then bears costs for desalination, as more energy and effort needs to be put into extracting pollutants from the source water.

5. Shoreline Stabilization and island formation

Coastal and marine ecosystems are important for shoreline stabilization throughout the Maldives, as they are in other locations where they occur around the world (McIvor *et al.* 2012, 2013). Cyclonic events (see next section) are a threat along with sea level rise and chronic erosion. Aquatic vegetation such as seagrass, saltmarsh, and mangrove do act to stabilize landforms and channels, reducing the need for beach re-nourishment, dredging, and maintenance engineering. The biota (meiofauna) in tidal flats is thought to play a similar role, maintaining physical structure of the seafloor to buffer land from erosion.

Furthermore, the production of sand through the erosion of coral reef organisms is extremely important for island formation and the existence of the Maldives. Sand is formed by the breaking down of calcareous organisms on coral reefs, for example scleractinian corals or coralline algae such as *Halimeda*. The reef is broken down by wave action, but also importantly by bioeroding reef animals such as parrotfish (Perry *et al.* 2015), and the sand accumulates to form small islands that are colonized by vegetation. The land of the Maldives would not exist without the sand produced by the erosion of coral reefs.

6. Storm Impact Mitigation

Whilst shoreline stabilization is an issue in all coastal nations around the world, catastrophic events are nonetheless considered a greater risk because they are difficult to anticipate. The Intergovernmental Panel on Climate Change (IPCC) forecasting of increased intensity and frequency of storm events in a climate-changed future suggest vulnerabilities can be expected to increase. Earthquake-generated tsunamis and storm surges are also a threat to coastal property that can be mitigated by coastal ecosystems (Alongi, 2008).

Published investigations of elevation and modelling at the fine scale to evaluate the contribution of coastal ecosystems to surge buffering and mitigation against storm events have not been undertaken in the Maldives, however existing models can give some indication of risk reduction performed by natural habitats. The presence of coral reefs can be expected to mitigate such surge activity throughout the Maldives, including in North Ari (Shaig in review; Rao *et al.* 2012)

Many of the studies on ecosystem services derive value from costs accrued after the loss of the service (Agardy and Alder, 2005); existing ecosystem service value is thus thought of as avoided loss. For example, in Cancún (Mexico), the destruction of mangroves and poor building siting that did not obey set-backs has resulted in such severe erosion that the government spent over USD 70 million recently to re-nourish resort beaches, at likely significant but unquantified cost to the source environment and the coral reefs offshore. Sand is already eroding away, this after the third major re-nourishment in the last ten years. In recent years, sand erosion rates have been so high that hotels have had to close or limit access to grounds mid-season.

In SE Asia, the value of mangroves as a form of coastal protection was estimated at USD 367,900-470,000 per km^2 (McIvor *et al.* 2012; UNEP, 2014). Similar figures are obtained for the buffering capacity of fringing and barrier reefs.

In Fiji, another Small Island Developing State, investments in mangroves and coral reefs for protecting people and infrastructure from storm flooding were calculated to return USD 19.5 per USD 1 invested due to the high value of ecosystem services provided, while investments in infrastructure engineering solutions only returned USD 9 per USD 1 invested due to the high building and maintenance costs. Coral reefs were calculated to provide USD 658,487 in ecosystem services benefits per year to the economy of Lami Town, and mangroves were calculated to provide USD 158,920 per year (Rao *et al.* 2012).

7. Carbon Sequestration

There are habitats found in the Maldives that fix carbon. In some cases, for examples in mangroves and seagrass, this carbon is sequestered in the soils, and they play a role in mitigating the anthropogenic carbon dioxide release into the atmosphere that drives global climate change. However, no published research exists on carbon sequestration rates in the Maldives, so the assessment of this ecosystem service must rely on proxy figures from elsewhere.

Government investment in coastal infrastructures is increasing due to the degradation of coral reefs which act as natural coastal defence system. © Mohammed Fazeeh

One such proxy study was undertaken in the United Arab Emirates (UAE). The Abu Dhabi Blue Carbon Demonstration project undertaken in 2012-2013 assessed carbon stocks in mangrove, seagrass, saltmarsh, *sabkha* (salt flats) and algal mat habitats. Although there was some variation in the carbon fixing and carbon stock values from various places in the Emirate, the range of values is considered representative. The average and standard deviation of these values is given in Table 5 below.

Table 5. Carbon stock measurements from the Abu Dhabi Blue Carbon Demonstration Project (cited in Agardy *et al*. 2013)

Habitat	Median	Mean	Stn. Devn.	S.E.	± 95% C.I.	n
Algal flat	133.83	129.07	40.98	11.36	22.27	5
Mangrove	98.29	115.49	64.16	7.04	13.80	15
Sabkha	72.41	75.55	40.61	7.96	15.61	4
Saltmarsh	69.15	81.07	50.12	9.15	17.93	5
Seagrass	51.62	49.56	29.56	6.97	13.66	18

That mangroves sequester carbon at rates comparable to inland tropical forests is no surprise – carbon markets are already gearing up for the selling of carbon credits from mangroves, and many countries are incorporating avoided mangrove loss into national REDD+ strategies.

However, it can be assumed that the mangroves in the Maldives are on the lower end of the carbon storage spectrum due to the lack of input of organic matter from rivers or other freshwater sources; although more targeted studies are necessary to support this hypothesis.

8. Tourism and Recreation

Tourism is a significant income generator in the Maldives. Some 58% of the workforce is employed in tourism, representing 64,000 people employed, while contribution of tourism to Maldivian GDP is approximately USD 400,000,000 annually (Ministry of Tourism, 2014). The extent to which these numbers reflect interest in coral reefs or other natural habitats is not known, but it is clear that nature-based tourism has significant growth potential. There is also a distinction between resort tourists, who tend to be honeymoon couples that may or may not be interested in ecotourism, and live-aboard tourists who come to SCUBA dive and are mainly interested in ecotourism.

Ecotourism is perhaps under-developed despite the vast potential in the country. Natural habitats could present myriad opportunities for ecotourism centred on coral reefs, mangroves, sea grass beds, as well as cultural tourism built on observation of the traditional line fishing for tuna. Dive, snorkeler and bird-watching tourists could be directed to natural areas, and boost revenue generation needed for management through the institution of entry fees. Hanifaru Bay in the Baa Atoll Biosphere Reserve represents such a model, and designating more functioning Marine Protected Areas, Marine Managed Areas or Biosphere Reserves around the country could generate increased revenue from tourism and recreation.

9. Culturally Important Areas

The Maldives has a rich history, and culturally important historical artefacts as well as contemporarily used areas are either provided by natural processes or protected by them (Khalifa and Rice, 1986).

Many marine artefacts have cultural significance in the Maldives. The triton (*Sangu*) was used as a horn to call for community gatherings before loudspeakers were available in the islands. Black coral (*Endheri*) was commonly used in interior decoration, though the harvest was subsequently banned, while cowrie shells were traditionally used as currency. Although coral rock and limestone use as housing material was also banned, sand from beaches is still used as a construction material and as decoration for yards and public spaces. White coral sand is strewn on the ground of people's homes to welcome guests, especially during the holy month of Ramadan (Mohamed, 2012). Less pervasive, especially now with a government ban, is the use of Manta ray skin for *bodu beru* drums. *Bodu beru* drumming (originating in East Africa) is traditional at celebrations. There are annual '*Mas* races' during Ramadhan where teams of fishermen try and catch as many reef fish as they can and compete, and the national football team is known as the 'Red Snappers' in homage to the cultural importance of the sea.

10. Opportunities for Research and Education

The vast atoll ecosystems of the Maldives are a living laboratory to explore the effects of climate change and test the efficacy of management in promoting profitable yet sustainable development. Given the scale of the archipelago, there are myriad opportunities for taking the excellent baseline studies undertaken by the government and by initiatives like Project REGENERATE to further studies about the interlinkages of habitats, the factors that affect ecosystem health and service delivery, and the elements of resilience.

To summarize, the health of ecosystems and the extent to which their functional diversity and general biodiversity is maintained directly affects the degree to which they can provide goods and services of value to human beings. One critically important consideration is that these ecosystems and the services that they generate cannot be viewed in isolation. The delivery of goods and services from natural systems is dependent not only on the condition of the ecosystem but also its functional linkages to associated ecosystems. For mangrove forests to continue to provide nursery grounds for commercially and recreationally important fish populations, the two-way linkages between mangrove and offshore ecosystems such as seagrass beds, coral reefs and offshore landform features must be maintained. Similarly, offshore systems such as coral reefs create the sheltered conditions necessary for inshore systems such as seagrasses to thrive; while mangroves and saltmarsh act to trap sediments and nutrients that might smother or degrade seagrasses. When strategies for sustainable development are furthered in the Maldives, it will therefore be important to consider the full suite of services, their values, and the impacts that human activities in any sector will have on continued delivery of these services. This is especially true as climate change adds to the spectre of cumulative impacts and threatens to undermine the resilience of all marine and coastal ecosystems.

Five general conclusions can be drawn about ecosystem services, individually and as co-benefits, in North Ari Atoll as with the rest of the Maldives:

1) Ecosystem services being delivered from coastal habitats have both market and non-market values;

2) Certain areas that have a mosaic of habitats that generate ecosystem services that are in their proximity, or are in particularly good condition and are therefore very productive, can be flagged as delivering a concentration of ecosystem services;

3) The costs of losing the valuable ecosystem services being generated from marine ecosystems will be high and felt for many generations to come, and while some restoration may be possible, full ecosystem function is rarely achieved even despite significant investment of time and resources;

4) Intact reef and associated ecosystems can be considered as providing risk minimization for existing and prospective investments, as the country continues to develop and as it diversifies its economic base; and

5) Maintaining connections between various valuable natural habitats will allow maximum service delivery, maintenance of values, and maximum resilience in the face of climate change.

4. Values of Ecosystem Services

4.1 Ecosystem Services Valuation

Knowing the relative quantity of services being delivered by ecosystems provides an important base for marine spatial planning. Knowing the economic values associated with those services can provide decision-makers with even more robust information. Undertaking Ecosystem Service Valuation (ESV) can be a complex and time-consuming task as the ecological and social information required to accurately calculate the different facets that determine the monetary value of a particular service can be difficult to collect and analyse. Developing direct measures of the value of each service is challenging due to either lack of scientific understanding on ecosystems or lack of available data on the economic conditions associated with the commodities.

Wetlands play a vital role in climate change mitigation by sequestering carbon dioxide. © Munshidha Ibrahim, IUCN

ESV has however been shown to be a critical component of decision-making in a variety of situations (from Agardy *et al.* 2013):

a) ESV can help prioritize conservation and management efforts in the context of constrained budgets and personnel. Options can be identified to maximize benefits to people by protecting and maintaining specific ecosystem services over others;

b) ESV can also be used as a negotiation tool, a basis for discussion, where stakeholders can participate to discuss the assumptions and parameters of ESV;

c) Monetary values for ecosystem services can be formally included in Cost Benefit Analyses that are the foundation of making decisions on trade-offs (see for instance Costanza *et al.* 2006). In this way, ESV can allow decision-makers to optimize social well-being by making choices that emphasize the benefits over the costs;

d) ESV can be used to set prices and determine the amount payable within the context of a willingness-to-pay or receive approach. Payments for Ecosystem Services (PES) such as entrance fees to MPAs or World Heritage Sites can be built on ESV;

e) In the case of environmental damage such as ship grounding on reefs or oil pollution from a leaking vessel, ecosystem service degradation can be compensated for before (in anticipation) or after (remediating and restoring damage) environmental accidents. Ecosystem service values can also provide guidance in administrative prosecution or court proceedings and rulings;

f) ESV has been used for awareness raising, justification, and persuasion as it provides clear economic arguments by placing monetary values on services that then bolsters environmental arguments in political debates and is more likely to influence choices and decision-making.

A holistic understanding of ecosystems, the services that they provide in a concise socio-economic context, and their importance (ecosystem values) is essential for developing an ecosystem-based management approach (McLeod and Leslie, 2009). Economists sometimes measure the value of ecosystem services to people by estimating the amount people are willing to pay to preserve or enhance these services. Values are always context specific as they change across space and time.

Different actors use such ESV in several different ways. The schematic in Figure 5 shows the entry points of information and the potential uptake of it by private individuals, public entities and commercial actors.

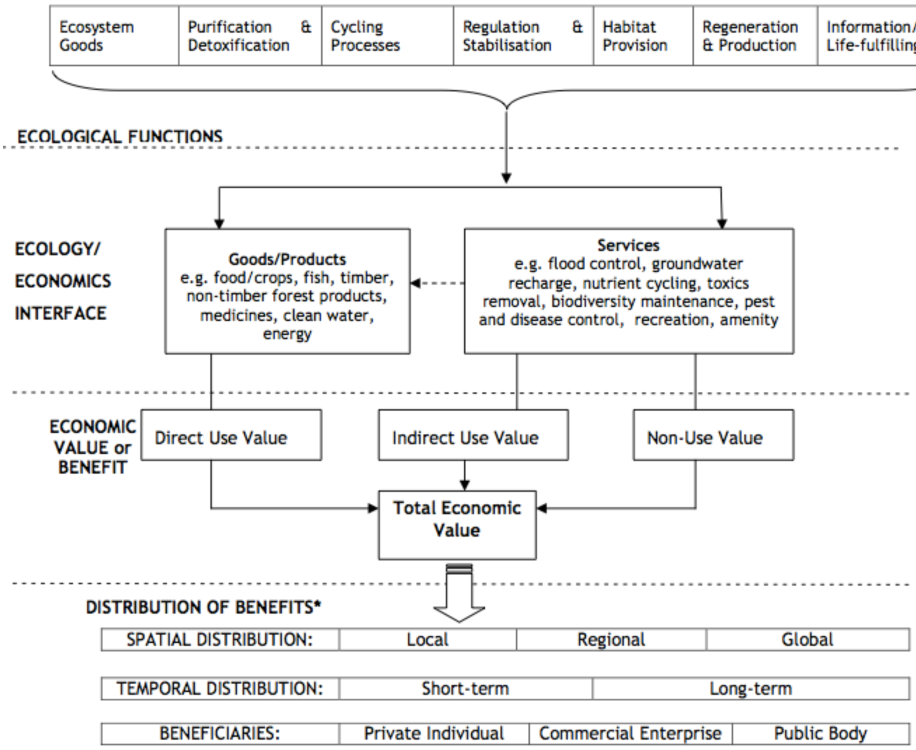


Figure 5. Integrated use of ESV (taken from Eftec, 2005).

4.2 Methods of Marine ES Valuation and lessons for the Maldives

A review of the information that exists to support valuation, ecosystem services modelling, cost-benefit analyses, and other ways to estimate ES values suggests that there are few North Ari-specific data to undertake valuation at this point in time. In the absence of contingent valuation surveys of residents, visitors, and businessmen, estimates of the range of values provided by a particular ecosystem service must rely on benefits transfer, i.e. information derived from studies of that service in other parts of the world. There are, however, serious limitations of benefits transfer (Plummer, 2009). Targeted research in the Maldives could fill data gaps and contextualize ecosystem services valuation to the point that ecosystem services assessment and valuation could be effectively used in decision-making.

An ecosystem services approach is a well-accepted method for quantifying the values nature provides (Pendleton *et al.* 2015a; MEA, 2005). Ecosystem services are variously defined, but the broadest possible definition, i.e. ecosystem services as the benefits of nature to households, communities, and economies (Boyd and Banzhaf, 2007), is used in this study.

There are currently 1,041 scientific papers on marine and coastal ecosystem services valuation on the Marine Ecosystem Services Partnership website (www.marineecosystemservices.org); this literature currently yields over 2,000 valuations of ecosystem services from 800 studies worldwide. The vast majority of these are focused on coral reefs, mangroves, and temperate salt marshes. Ideally, the measure of economic value is derived from estimates of the net economic value (e.g., consumer surplus and producer surplus or profit) resulting from the provision of these services. However, such data are rarely available (Pendleton *et al.* 2015b).

Thus, very few of the papers in the global literature represent studies of actual values of ecosystem services. The authors in most studies instead utilized benefits transfer in which the values derived from contingent valuation, travel cost, willingness to pay surveys and revenue estimations from sale of commodities are calculated and then assumed to be transferable to other, similar biomes. The weakness in this method is that values are very context-specific, reflecting not only the health and productivity of particular ecological communities, and the interactions of processes that underlie each particular ecosystem service in a place, but also how humans perceive the benefits that flow from such ecosystems.

Pagiola *et al.* (2004) argue that benefits transfer only makes sense in cases where the services are identical, the affected human populations are similar, and the original valuation is robust and meaningful. Others argue that even appropriate benefits transfer that is done on an ecosystem service by ecosystem service basis will not capture the comprehensive benefits or Total Economic Value, and can therefore be misleading (Philcox, 2007; Plummer, 2009).

The lack of context-specific and robust valuation studies around the world limits the utility of ecosystem services information in decision-making. In fact, much ecosystem services information remains stuck in the scientific and conservation realms. This is not new, of course – the Millennium Ecosystem Assessment and the preceding Pilot Assessment of Global Ecosystems devoted significant effort to describing ecosystem services in a way that would resonate with decision makers and the public, and both documents met significant challenges in bridging the science-policy divide. Language remains an issue, as does scientific uncertainty about ecosystem services delivery in changing environmental conditions. However, there are demonstrable ways to promote better uptake of information on ecosystem services, their worth to society, and the necessity of protecting our valued natural capital.

Valuations can raise awareness, inform planning, and generate the political will to take concrete steps to protect ecosystems and maintain ecosystem services delivery. Yet certain suspicions remain about economic studies. When focused on a single ecosystem service (provisioning of a particular commodity, such as carbon, or on a single regulating services, such as protection of valuable coastal properties from storms), local communities can begin to fear that 'their' ecosystems will be taken over by those profiting from the service. For this reason, economic valuations should be performed in the broadest possible way: across all ecosystem services and at the largest possible geographical scale, while still remaining context-specific. Economic assessments should be complemented by valuations that take non-monetary values into account.

Coral reefs are perhaps the best studied ecosystem in this respect. Beukering *et al.* (2010) examined the value of ecosystem services provided by Bermuda's coral reefs with a focus on the valuations of six ecosystem services: shoreline stabilization, tourism, fisheries, culture and recreation, amenities, and research/education. Other coral reef valuation studies have concentrated on the tourism values of reefs and the biodiversity they support (de Groot *et al.* 2011). Mangrove systems have also been assessed for their contribution to revenue generation through fisheries, or their role in risk reduction by buffering coastlines from storms. These studies are however, generally conducted in areas where these biomes are extensive: for instance, in Indonesia, where coral reefs and mangroves cover hundreds of thousands of square kilometres, or in Mexico where mangrove forests cover thousands of square kilometres. To assume that values are transferable from areas where these biomes are extensive and heavily utilized (and appreciated) for their role in supporting tourism, fisheries, and shorelines stabilization to areas where these habitats are less prevalent and where awareness of values is limited, is questionable.

Healthy coral reefs are immensely important to the Maldives as they provide socio-economic and ecological benefits. © Brian Zgiczynski, IUCN

A survey of methodology used in valuation shows that different methods are used to assess different ecosystem services. In general, there are market approaches, and non-market approaches. Market approaches include market price, replacement cost, avoided cost or production function. Non-market approaches include revealed preference, travel cost, hedonic pricing. Further there are stated preference methods that include contingent valuation and choice modelling (Schuhmann, 2012). Depending on the service being evaluated, or the biome providing the service(s), different approaches are taken. Thus, it is useful to review common methods that could potentially be used to value each major marine ecosystem service of relevance to North Ari and the rest of the Maldives.

Shoreline stabilization / buffering land from storms

Methods for determining the value of natural habitats in stabilizing shorelines, as well as buffering land from storm or cyclone events, generally use avoided cost or replacement cost methods. Studies typically estimate what it would cost to build breakwaters, levees and other infrastructure to protect coasts in the absence of natural habitats providing these services. Other studies done in the aftermath of catastrophic storms or tsunamis, researchers have calculated costs of having lost ecosystems in terms of the damages wrought in areas where such natural habitats once existed. Clearly, such approaches rely on assumptions, some of which may be questionable. A more appropriate method may be to study and model the wave attenuation and other buffering features of marine and coastal habitats, couple that with the value of shoreline property (public or private), and estimate the extent to which those economic values are safeguarded by the ecosystems. This method is time-consuming, and highly localized.

Over the long-term, protection from storm action and the associated stabilization of shorelines and formation of islands through the production of sand are very important ecosystem services provided by coral reefs in the Maldives. Without the protective wall of corals around the islands, and without the sand produced by biological and physical erosion, the Maldives would not be suitable for human habitation. However, the correlation between the ecological health of coral reefs and the protective and island-forming functions that they provide is not always straightforward, as even degraded reefs protect coastlines from storms and produce sand for islands for a period of time. Also, as humans alter coastal processes on coral islands, coastal protection becomes reliant on human intervention, at very high economic cost, rather than on natural processes. This makes it very difficult to understand which additional costs of coastal protection are caused by the degradation of coral reefs, and which additional costs are caused by coastal modifications and infrastructure built by humans. On the longer timescale scale of decades to centuries, however, as the sea level continues to rise, the ecological health of coral reefs will determine the protective and island-forming services that they provide, and consequently the future of the Maldives as a viable area for human habitation. The extent to which coral reef growth and accretion can keep up with predicted sea level rise will be a major factor in determining this outcome.

Contribution to fisheries production

Ecosystems contribute to fisheries production (commercial, subsistence, and recreational) both directly and indirectly. Economic value of ecosystems in providing fisheries resources may be tabulated by examining fish catch and price data; and for recreational fishing, revenues from angling trips. However, ecosystems also provide fisheries value by providing nursery habitat and food for fisheries species. In Mexico, for instance, mangroves were estimated to provide support for the bulk of fisheries stocks caught in Gulf of California fisheries, with an estimated worth of USD 37,500 per hectare annually. Coral reefs similarly support nearly all the fisheries in archipelagic nations such as Indonesia.

In the Maldives, one can assume that the majority of the catch is reliant on coral reefs and associated ecosystems, either for direct use or because these ecosystems provide the live bait used in offshore tuna fishing. To determine a total extraction use value for coral reefs and mangroves, one would also include non-fishery resources (limestone, timber, fuelwood, mud). This added to the fisheries catch values (where appropriate) would yield estimates closer to total market value (Vegh *et al.* 2014).

The fishing industry is a major economic activity in the Maldives. © Frederic Ducarme, IUCN

For fishing alone, the reefs and associated habitats of the marine environment in the Maldives are crucial for employment and revenue generation. Nearly 15,000 people work in the commercial fishing sector, targeting both tuna and reef fisheries. Fisheries products account for practically all the exports (99%), and even offshore tuna fisheries rely on intact coastal environments, since pole and line tuna fisheries use live bait harvested from nearshore waters.

Tourism and recreation

The benefits that ecosystems provide directly to users include recreation and tourism. In the marine realm, the focus is on dive tourism, sports fishing, and beach use (the latter when beaches are not manmade but occur naturally, and support not only human recreational use but a wider biodiversity as well). Determining the value of rich, diverse, clean and clear marine areas in which to recreate is not difficult, and researchers typically utilize hedonic pricing or contingent valuation. However, care must be taken to evaluate how ecosystem services directly benefit users, since gross miscalculations can occur when respondents confuse the value they see in a place with the values being provided by nature. (Case in point: if a resort is created on reclaimed land, with artificial beaches and built infrastructure providing bathing / diving areas, and that resort is in a region where there are also natural environments that provide ecosystem services, it would be misleading to use travel cost or tourism revenues from that resort to calculate the value of the region overall).

The most robust studies looking at the value of marine ecosystems to support tourism/recreation directly generally combine analyses of tourism revenues with surveys to determine Willingness to Pay (WTP). One example is the valuation study of the coral reefs of the Phi Phi Islands in Thailand in which the travel expenses (as an indicatory of the value of a trip) were determined to be 8,216 million Baht (USD 205 million) per year. In addition, visitors' willingness to pay to increase biodiversity at Phi Phi was estimated to be 287 Baht (about USD 7) per visit (Eftec, 2005). Another even more relevant example is the valuation study done in the Baa Atoll of the Maldives, where WTP from a previous study (Mohamed, 2007) was combined with accounting of marine-based revenues to value local reefs and associated ecosystems (Emerton *et al*. 2009).

Cesar *et al*. (2003) estimated the total global contribution of coral reefs to tourism at USD 9.6 billion. In compilations of economic studies, values are generally given per region and across many ecosystem services (for example, Conservation International 2008 lists studies from both regions and islands, where tourism is the driver of most value).

The Maldives is known as a dive destination and a significant proportion of visitors come to take in the natural beauty and see charismatic marine megafauna such as manta rays, whale sharks and sea turtles. It has been estimated that manta ray tourism generates upwards of USD 8 million annually (Anderson *et al*. 2010) while whale shark tourism brings in close to USD 10 million annually (Cagua *et al*. 2014). As some 58% of the Maldivian workforce is employed in the tourism sector, the dependency on intact and productive ecosystems is significant (Ministry of Tourism, 2014).

Water quality maintenance

The role that salt marsh and other wetlands, oyster and other shellfish reefs and seagrass meadows and tidal flats play in removing sediments, nutrients and toxins from the water column is well understood. The rates of filtration can be quantified and are generally transferable to other areas where the same biota and similar oceanographic/hydrological conditions are present. The economic value of this ecosystem service, however, is more context-specific. In general, valuation of the water quality maintenance service uses hedonic pricing or willingness-to-pay: measures that reflect how much people (landowners, visitors, users) value clean, clear water (see, for instance, Costanza *et al*. 2006). Alternatively, valuation can reflect efficiencies in reaching regulatory limits on pollution, or avoided costs in terms of not having to build infrastructure for removing sediments/nutrients or undertake methods of remediation.

Carbon sequestration

Of all the ecosystem services, carbon sequestration is the most easily valued, as carbon is a market good. To determine the per hectare value of mangrove, seagrass, or saltmarsh in fixing and storing carbon, scientists must assess storage capacity (carbon in above ground biomass, though easily derived, is not an accurate measure of carbon sequestration). Once proper sequestration rates are determined, the value can be determined by current price on the carbon market.

Biodiversity

Biodiversity is an ecosystem service and a characteristic of ecosystems, as well as something that people value to greater or lesser degrees. As a supporting service, the suite of plants, animals, and microbes in an area plays a key role in ensuring that all other services are being delivered. Determining the value of that service, however, is difficult. Approximations of the value of biodiversity as a supporting service have been attempted through an 'avoided damage' approach – that is, when biodiversity is lost, scientists can measure decreases in all related services and tabulate the sum. Examining all the revenues generated from the use of a biome like coral reefs, does give a coarse idea of the per area value of that habitat. For instance, Burke *et al.* (2002) estimate the total potential sustainable annual economic net benefits per km^2 of healthy coral reef in Southeast Asia as ranging from USD 23,100 to USD 270,000. Comprehensive accounting of all possible values of all ecosystems, as was carried out in Costanza *et al.*'s landmark paper in which they calculated the total global worth of ecosystem services at USD 145 trillion annually (Costanza *et al.* 2014), can give an idea of the enormous value of nature; but these gross estimates need careful refining to be applicable in a country-specific policy context.

4.3 Benefits transfer for habitats found in the Maldives

In the absence of economic valuations, including studies that investigate perceptions of value and willingness to pay for services of value, the quantification of ecosystem services in North Ari could rely on studies from other regions. Included in *Table 6* are summaries of some of the economic assessments of coastal ecosystem services from other areas, as presented in the literature review undertaken by Barbier *et al.* (2011). Some of these studies determined net present value for services that support marketable commodities (fisheries nursery habitat, for instance). Other studies model risk to hypothesize on the risk-reduction value provided by ecosystem services (shoreline stabilization and risk reduction in light of sea level rise and storm damage). For instance, Arkema *et al.* (2013) estimated that over the next 90 years, mangroves, coral reefs, and seagrass beds, if left intact, would protect USD 4 billion in properties from sea level rise in Florida alone. A multi-institutional review of ecosystem services values of coral reefs and associated ecosystems (Conservation International, 2008) similarly presents very high economic values for a wide range of services from sites around the world. However, these services are usually aggregated and benefits transfer to other areas may be problematic. As Ruffo and Kareiva (2009) point out, ecosystems and habitats must be individually assessed in order to make a case that a particular service is in fact being generated.

Table 6. Examples of ecosystem services and values of coastal habitats (taken from Barbier *et al*. 2011)

a) Mangroves

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Generates biological productivity and diversity	Vegetation type and density, habitat quality	USD 484-585 ha-1yr-1 capitalized value of collected products, Thailand (Barbier, 2007)
Coastal protection	Attenuates and/or dissipates waves and wind energy	Tidal height, wave height and length, wind velocity, beach slope, tide height, vegetation type and density, distance from sea edge.	USD 8,966 – 10,821 ha-1 capitalized value for storm protection, Thailand (Barbier, 2007)
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, tidal stage, fluvial sediment deposition, subsistence, coastal geomorphology, vegetation type and density, distance from sea edge.	USD 3,679 ha-1yr-1 annualised replacement cost, Thailand (Sathirathai and Barbier, 2001)
Water purification	Provides nutrient and pollution uptake, as well as particle retention and deposition	Mangrove root length and density, mangrove quality and area.	Estimate unavailable.
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Mangrove species and density, habitat quality and area, primary productivity.	USD 708 – USD 987 ha-1 capitalized value of increased offshore fishery production, Thailand (Barbier, 2007)

b) Seagrass

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Generates biological productivity and diversity	Vegetation type and density, habitat quality	Estimates unavailable
Coastal protection	Attenuates and/or dissipates waves and wind energy	Wave height and length, water depth above canopy, seagrass bed size and distance from shore, wind climate, beach slope, seagrass species and density, reproductive stage	Estimates unavailable
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, subsistence, tidal stage, wave climate, coastal geomorphology, seagrass species and density	Estimates unavailable
Water purification	Provides nutrient and pollution uptake, as well as particle retention and deposition	Seagrass species and density, nutrient load, water residence time, hydrodynamic conditions, light availability	Estimates unavailable
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Seagrass species and density, habitat quality, food sources, hydrodynamic conditions	Loss of 12,700 ha-1 of seagrasses in Australia; associated with lost fishery production of AUD 235,000 (McArthur and Boland, 2006)

c) Shoreline habitats (dunes, beaches, etc.)

Ecosystem Services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Provides sand of particular grain size, proportion of minerals	Dune and beach area, sand supply, grain size, proportion of desired minerals (e.g., silica, feldspar)	Estimates unavailable for sustainable extraction
Coastal protection	Attenuates and/or dissipates waves and reduces flooding and spray from sea	Wave height and length, beach slope, tidal height, dune height, vegetation type and density, sand supply	Estimates unavailable.
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, subsistence, tidal stage, wave climate, coastal geomorphology, beach grass species and density	USD 4.45/household for an erosion control program to preserve 8 km of beach for Maine and New Hampshire beaches, USA (Huang *et al.* 2007)
Water catchment and purification	Stores and filters water through sand; raises water table	Dune area, dune height, sand and water supply	Estimates unavailable.
Maintenance of wildlife	Biological productivity and diversity, habitat for wild and cultivated animal and plant species	Dune and beach area, water and nutrient supply, vegetation and prey biomass and density.	Estimates unavailable.

d) Coral reefs

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials	Generates biological productivity and diversity	Reef size and depth, coral type, habitat quality	Estimates unavailable.
Coastal protection	Attenuates and/or dissipates waves, sediment retention	Wave height and length, water depth above reef crest, distance from shore, coral species, wind climate	USD 174 $ha^{-1}yr^{-1}$ for Indian Ocean (Wilkinson *et al.* 1999)
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Coral species/ density Habitat quality, food sources, hydrodynamic conditions	USD 15-45,000 $km^{-2}yr^{-1}$ in sustainable fishing for local consumption and USD 5-10,000 $km^{-2}yr^{-1}$ for live fish export (White *et al.* 2000)
Nutrient cycling	Provides biogeochemical activity, sedimentation, biological productivity	Coral species/ density Sediment deposition Subsidence, coastal geomorphology	Estimates unavailable.
Tourism, recreation, education, and research	Provides unique and aesthetic landscapes, suitable habitat for diverse fauna and flora	Lagoon size, beach area, wave height, habitat quality, coral species and density, diversity	USD 88,000 total consumer surplus for 40,000 tourists to marine parks Seychelles (Mathieu *et al.* 2003) and meta-analysis of recreational values (Brander *et al.* 2007)

The previously listed table in which Barbier *et al.* (2011) summarize valuations can be combined with more recent studies (de Groot *et al.* 2012) to gauge the possible ecosystem service values for atolls within the Maldives. This benefits transfer information must be adapted to the particular circumstances of the ecology and environment of the Maldivian atolls and the current and prospective uses of goods and services.

Given that the North Ari Atoll is well-studied and mapped, determinations of not only habitat extent but also condition can be used as a basis for suggesting a range of indicative ecosystem services values that could exist. It should be noted that these values are estimates, and estimates of potential, not realized values. Further study will be needed to determine how local communities, fishers, visitors, and investors view marine ecosystems and the goods and services they provide.

Nevertheless, given that nearly one quarter of the approximately 103 km^2 of coral reef surveyed in North Ari is in good condition, with coral cover (an indicator of coral reef health and productivity) of over 30%, the total values being generated by those reefs is in the millions of dollars annually.

It is probably of limited use to present the ranges of value for reefs, beaches and tidal flats based on benefits transfer, since this valuation is contextual and precision can only be achieved with contingent valuation and other targeted economic studies. Instead, estimated values can be used to highlight the locations that provide the most ecosystem services. If the relative value of different areas in North Ari is assessed according to the number of multiple services being delivered, then there are clear coral reef areas in the atoll that are readily identified as having the highest potential value (see *Figure 6*).

A rigorous analysis of ecosystem services values must both appraise net present value and perceptions of value; and must also look into the future. The two considerations that must be addressed in this regard are how value changes over the passage of time (including, but not limited to, discount rates) and the sustainability of stocks (for goods) and services (Bateman *et al.* 2011). In a subsequent section of this report the net present value is presented. It is based on estimated costs and benefits of various potential management measures over time and within the limitations of what is known about actual values of marine ecosystems in North Ari (see Section V below).

There are some important assumptions that must be stated when using these values, however. First, not all habitats, even when intact and relatively pristine, deliver the same benefits in different regions or contexts. A hectare of coral reef in good condition (with coral cover of greater than 30% coral cover), for instance, is likely to yield significantly greater values than low condition reef elsewhere. In part this is because high values come from places where benefits are being realized: e.g. where there is a thriving ecotourism (especially dive tourism) industry, where coral reef fisheries are a critical source of revenue and livelihood, and where perceptions of the value of reefs are widespread and central to government policy and localized decision-making.

Information on ecosystem services potentially being delivered from coral reefs, seagrasses, mangroves, beaches, and other habitats can be used to identify areas where the likely values, across all benefits, are maximized. Calculating a total value of all marine ecosystem services for Maldives however would yield a number that is completely theoretical and fraught with compounded error. The values that are presented in Tables 5 and 6 and on the map in Figure 6 are indicative values that demonstrate the potential economic value of marine habitats. Further targeted economic studies, including user surveys, contingent valuation, etc. will likely yield more robust results on actual values of habitats, which could then be used as a foundation for marine spatial planning and monitoring of management effectiveness.

The conservation and protection of specific areas due to the potential of habitats in these areas to provide a high variety of services thus becomes important. Areas that provide high concentrations of ecosystem services cover approximately 3.7% of the administrative area of North Ari Atoll. There are potentially five main areas of North Ari that provide the highest number of services (see Figure 6). These include the Madivaru and Kuramathi-Rasdhoo Channels, Maathivereefinolhu, Gangehi Kan’du and the southern reef of Ranfaru. They all demonstrate a higher number of ecosystem services than other parts of North Ari and warrant careful management and conservation from the government in order to maintain the provision of these services.

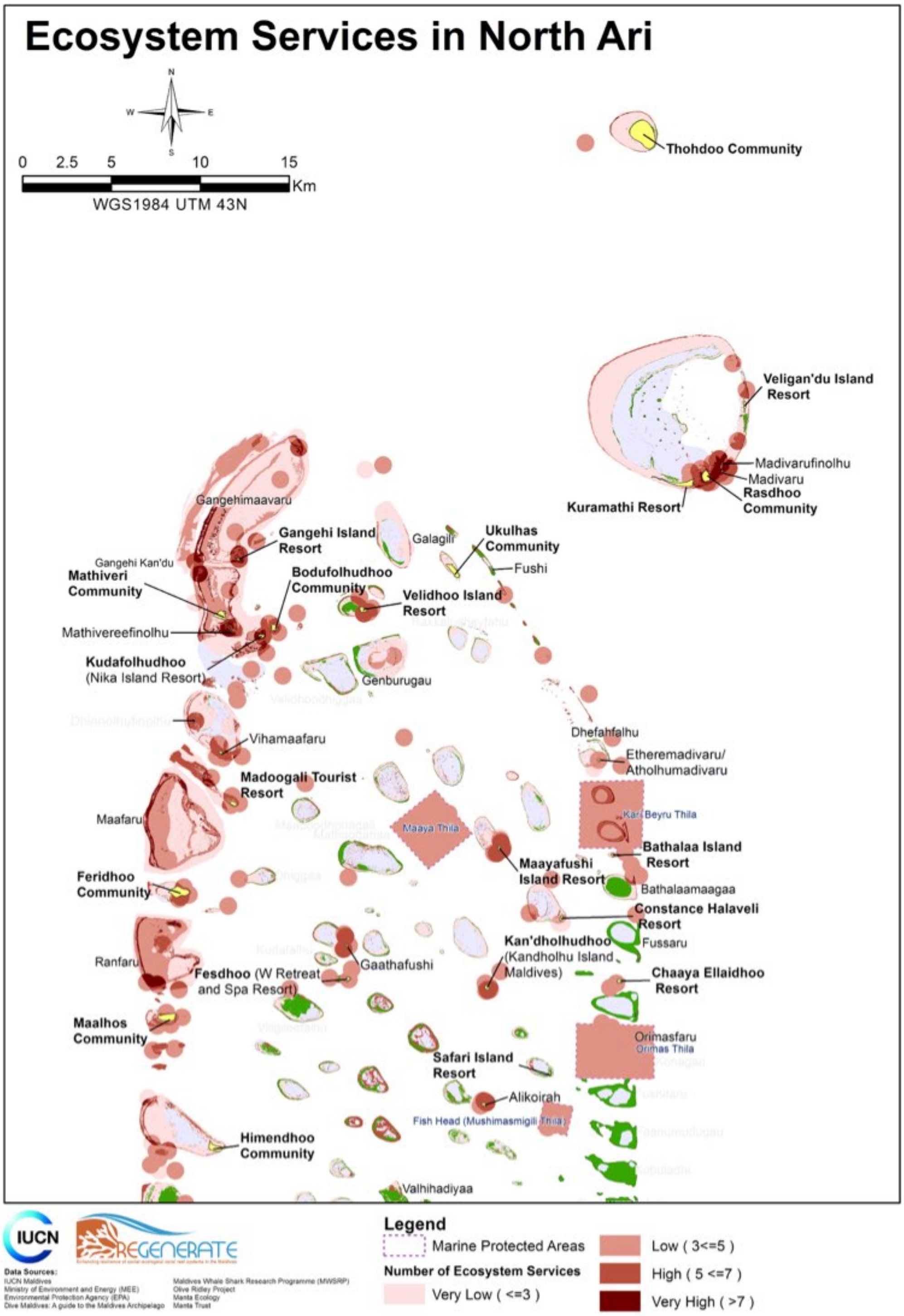


Figure 6. Concentration of ecosystem services in North Ari Atoll.

5. Net Present Value Analysis

5.1 Alternative Marine Management Cases and Scenarios

When considering the potential for promoting improved marine management in North Ari Atoll, it would be instructive to focus on a comparative financial analysis of several alternative management cases.

This analysis compares the projected future cash inflows from the main economic activities in North Ari Atoll with projected future cash outflows to assess the comparative net benefits of the various management options. The analysis is based on a 30-year period for these projections, which is considered a relatively long timeframe for such analysis (with 20-year periods being more common). The longer timeframe is used in order to align better with ecological resilience and changes in coral reef ecosystems that are on the scale of decades. Given the lack of some key data in this instance the analysis is based on many estimates and assumptions.

The primary economic activities that are strongly associated with the health of the local coral reef ecosystems are dive tourism, bait fishing and reef fishing. While there are other important economic benefits that can be associated with the coral reef environment, notably island formation and shoreline stabilization, the causality of the connection of these benefits to changes in the area and quality of coral reefs, as well as the existing data sets to measure this within the 30-year timeframe is considered too tenuous and uncertain; and so these have been excluded from this analysis. Similarly, the demand for non-dive (and snorkelling) tourism is unlikely to be tied closely to the relative health of the coral reef systems in the atoll, at least within the analytical timeframe, with other factors such as the prevailing world economy and the relative attraction/comparative costs of alternative tourism likely being stronger determining factors.

In addition, while the impacts of climate change are likely to be highly significant in North Ari over time, other factors are of equally immediate concern. Indeed, the Maldives has become the “poster child” for regions that are under threat from sea-level rise; yet those catastrophic impacts will likely not be felt for decades. Widespread bleaching events, including the current effects of the El Niño year of 2015-2016 can cause major coral mortality and reef degradation, but they are just one of many stressors. In the short- to medium-term the extent and quality of the coral reef ecosystems in the atoll is also affected greatly by land reclamation and the activities of tourists and local community members. These include the damage they inflict directly, such as by untrained snorkelers and divers, boat anchor and other damage, and fishing techniques. The activities also have indirect damages, such as via sand dredging, sewerage and other runoff, waste disposal and fishing pressures. That said, climate change-related coral bleaching effects due to changes in ocean temperatures will most likely have serious negative effects on the atoll in the short- to medium-term (as evidenced during the 2016 mass bleaching event), and it is not clear how resilient the system will be to such shocks with increasing human populations and pressures. In the longer term, ocean acidification caused by increased concentrations of atmospheric greenhouse gases will also likely cause severe stress to coral reefs. Ocean acidification is predicted to lead to reduced calcification and reproductive capacity in reef-building corals, and if pH continues to drop eventually to the erosion of reefs as the corals become unable to form their calcium carbonate skeletons.

The assumptions of this study are that the main economic costs in North Ari are those borne by: a) the tourism resorts, guesthouses and the liveaboard boats that visit the atoll (approximately 700 beds on average per week), b) the operating expenses incurred by local fishermen (13 boats) engaged in reef fishing in North Ari, and c) the operating expenses incurred by local fishermen engaged in the capture of baitfish for the tuna fishery in North Ari. The other primary costs are those that would be associated with the proposed development of marine managed areas (MMAs), where the resorts would be supported to expand and improve their current management practices, and locally managed marine areas (LMMAs), where the local communities would be supported to manage marine areas close to the inhabited islands within North Ari Atoll. These managed areas are likely to involve some combination of “no take” fishing zones, the use of designated diving areas, and seasonal and species/size limit bans on fishing/marine resource use.

The revenue estimates for the resort tourism sector are based on data contained in the Maldives Statistical Yearbook for 2014, whereas those for guesthouses and liveaboard boats are based on surveys and analysis conducted by IUCN personnel in North Ari Atoll. It was not possible to obtain cost information from the various types of tourism establishments in North Ari, as this is considered confidential by the owners; therefore estimates were made of the profits (or more technically earnings before interest, taxes, depreciation and amortization, or EBITDA) for the hotel and leisure industry as a whole. Similarly, there are no national or atoll-level statistics published on reef fish catch (the focus is on various species of tuna), so the estimates are also based on surveys and interviews of local reef fishers conducted by IUCN personnel. The tuna fishing industry in Maldives relies on live-bait fish capture for its operations. Revenue from baitfish capture was considered to be equal to the percentage of total revenue from the different types of tuna fisheries (primarily skipjack and yellowfin tuna) that can be attributed to the cost of live baitfish capture as a percentage of total tuna fishing trip costs (based on the average reported percentage of total fishing trip time devoted to this activity). This is 3% for the shorter duration skipjack tuna fishing trips and 11% for the longer duration yellowfin tuna fishing trips. Tuna revenue for local fishermen in North Ari Atoll is based on atoll level reported by the Ministry of Fisheries and Agriculture in its 2013 Statistics Book (MoFA, 2013). However, no detailed information exists of the costs incurred by bait fishers from their operations, and so these were estimated based on interviews conducted with fishers by IUCN staff. Similarly, the costs associated with the initial start-up and ongoing annual operations of MMAs and LMMAs have been estimated by IUCN personnel based on interviews with various stakeholders and their experience and professional judgment.

In North Ari Atoll there are currently 13 tourism resorts and 24 guesthouses (3 relatively large and 21 smaller establishments at the time of writing), with the guesthouses being located on several of the 8 inhabited islands and the resorts on separate islands. There are also currently 13 small-sized boats/crews dedicated primarily to reef fishing activities within the atoll, as well as 21 mechanised ‘*masdhaoni’* vessels and 401 fishers engaged in bait and tuna fishing. The number of resort beds has remained stable on the island at 1,988 for the past 5 years, while the number of guesthouse beds has increased significantly (currently estimated as 180 rooms or 360 beds). In addition, there are also some 30 liveaboard diving boats that visit the atoll on a regular basis (with an average of 700 passengers per week). There are significant seasonal variations in the number of tourists and the resort and guesthouse room rates. For the purposes of this analysis an average room price and occupancy rate have been used.

Tuna and bait fishing

It is important to note that commercial offshore tuna fishing is one of the main economic activities in the atoll, and that this also includes bait fishing. Baitfish are a crucial component of pole and line (and handline) tuna fisheries throughout the Maldives. Without live baitfish, these lucrative fisheries -- a major contributor to GDP -- could not exist (IPNLF, 2012). Yet despite the importance of this foundational element of Maldivian commercial fisheries, baitfish in the Maldives are not well-studied, and the sustainability of use can only be surmised.

Around the world, various pelagic and neretic finfish species are used as livebait. In the Maldives, a smaller variety of small and mostly neretic species are used. The most common bait species throughout the archipelago include sprat (*Spratelloides* spp.), known locally as *Rehi*; cardinalfish from the genus *Apogon*, locally known as *Boadhi*; fusiliers or Caesionids, known locally as *Muguraan*; and two species of scad (*Decapterus punctatus* and *Selar crumenopthalmus*) (Anderson, 1997; Commonwealth of Australia, 2005). In North Ari, bait fishers also target redtoothed triggerfish (*Odonus niger*) and bluestripe herring (*Herklothsichthys quadrimaculatus*). Whether the latter bait fish species have become targets for the live bait fishery due to a decrease in the availability of sprat, fusiliers, and other bait species traditionally used in the Maldives is unknown, since the population dynamics of bait fish species has not been comprehensively studied (Anderson, 2009).

The precise quantitative link between the availability of bait fish for the tuna fisheries and reef condition has not been ascertained – though all the above species spend some part of their life cycle either on the reef itself or within the lagoons formed by the atoll reefs. Cardinalfish, fusiliers, and reef triggerfish are all obligate reef dwellers for most or all of their life histories. Sprat, inshore anchovy species, and the bluestripe herring concentrate in lagoons and on the back reef. It is interesting to note that in a recent literature search for scientific studies linking bait availability to reefs, the majority of scientific publications focused on the Maldives (see Adam *et al*. 2003; Anderson, 1997, 2009; Blaber, 2009; Commonwealth of Australia, 2005; IPNLF, 2012; Naseer, 1997). Thus, the indisputable connection between health of the reefs and profitability of the pole and line tuna fisheries is widely recognized, and Maldives is held up as the demonstration of this connection.

As coral reefs degrade and rugosity and complexity are reduced, there is often a time lag observed in the effects on reef fish populations. Fish that are lost through natural mortality and fishing are not replaced in the population by juveniles that are dependent on reef complexity in the early stages of their life history, and so several years after coral mortality events decreases in reef fish populations can be observed. This affects fisheries productivity, including baitfish, and studies have shown that planktivore populations (as many baitfish species tend to be) are often highly impacted over time (Graham *et al*. 2007).

There is one other way that reefs provide the foundation for the Maldivian tuna fisheries by providing live bait, and this has to do with fishers' behaviour. Throughout the Maldives, and especially in North Ari Atoll, tuna fishers gather bait on their way offshore. The 'detour' to retrieve live bait typically adds ½ to 2 hours, but can be up to 3 full days if baitfish are unavailable, to each fishing trip. The availability of reef-based and nearshore baitfish in highly concentrated schools allows tuna fishers to harvest bait at essentially little cost. Were nearshore baitfish unavailable due to reef degradation or overfishing, the tuna fishers would have to invest in targeted bait fisheries offshore, at significant expense that would cut heavily into their profit margins.

Limitations

A significant limitation of this study is that shoreline protection services and island formation are not taken into account, again because the data to assess these over a 30-year time period are unavailable, and the causality of the connection of these benefits to changes in the area and quality of coral reefs within the 30-year timeframe is considered too tenuous and uncertain. Importantly, in North Ari Atoll nearly all inhabited or resort islands have some sort of coastal modification and as a result many islands' coastal processes have been altered; forcing the complete reliance on human intervention to manage the shoreline. The scale of these issues could have been avoided if a long-term resilience-based approach had been used for coastal management (Shaig, in review). As natural coastal processes have been altered to such an extent in North Ari already, it becomes difficult to measure the additional costs caused by the degradation of coral reefs. Again, this means that the analysis presented below is conservative, and that coral reefs in North Ari can be assumed to provide even higher economic values than the ones presented.

Revenue and profit

The estimated current annual revenue and expenses for the tourism sector, with an indicative division between dive-related versus non-dive related tourism and the reef and bait/tuna fisheries sectors, are presented in the following table (note that expense information for the tourism sector was not available and so is based on international resort hotel industry statistics):

Table 7. Estimated total annual revenues, expenses and profits from different sectors associated with ecosystem services in North Ari Atoll.

Economic Sector	Estimated Annual Revenue USD Million	Estimated Annual Expenses USD Million *	Estimated Annual Profits USD Million
Resorts – dive related	42.26	33.81	8.45
Resort – non-dive	63.39	50.71	12.68
Guesthouses – dive	3.78	3.14	0.64
Guesthouses – non-dive	1.78	1.42	0.35
Liveaboard Boats	16.74	13.36	3.35
Bait Fishing	1.43	0.09	1.34
Reef Fishing	2.69	0.94	1.75
Total	**132.07**	**103.47**	**28.56**

* Not available for tourism establishments; estimated at 80%, based on international resort hotel industry statistics

As the total coral reef area of North Ari Atoll is 103.59 km^2 (not including platform sands, defined as low relief undulating sedimentary bed-forms created by the accumulation of carbonate sands derived from the fore-reef and reef flat, or barren lagoons), the figures above translate to the following total economic values per km^2:

Table 8. Estimated annual revenue and profits per km^2 from different sectors associated with ecosystem services in North Ari

Economic sector	Estimated annual revenue USD per km^2	Estimated annual profits USD per km^2
Tourism	1,073,456	21,303
Bait fishing	13,803	12,934

Reef fishing	25,965	16,892
Total	**1,113,224**	**51,129**

It must be noted that the values expressed here are not uniform across the reef system, and some coral reefs will provide more ecosystem services and will be more valuable for the economy than others (see figure 5 for concentrations of ecosystem services). The value of a reef will depend on its ecological condition and productivity, perceived importance by different sectors, and actual use by the stakeholders.

5.2 Comparative financial analysis

The comparative financial analysis outlined below uses net present value (NPV) calculations. NPV is based on the *time value of money* concept. This is that money available in the present is worth more than money available in the future, as money available in the present can be invested and earn interest, whereas the future purchasing power of money will be eroded due to the effects of inflation. NPV calculations convert the difference between a projected stream of future benefits and costs into the equivalent of the present value of these amounts, by using a discount rate. Discounting is thus needed to express future costs or benefits at today's equivalent value, and though mechanically easy, no agreement exists on the correct discount rate to be used in all cases.

Market rates (rates of return on capital) that reflect social preferences constitute appropriate discount rates, but these can range from 1% to 10% or more, in real terms versus nominal terms which are higher and adjusted for annual inflation, depending on whether the rate of return is from the public domain (e.g. a treasury bond) or the private domain (e.g. the return on a private investment). NPV analysis is typically based on a desired rate of return by investors (which is the discount rate used), but in the case of assessing investments for conservation it is more common to use several different discount rates to demonstrate the impact, or sensitivity, that the choice of discount rate has on the financial valuation. Therefore, while environmental discount rates are typically around 7-8%, for our comparative analyses we use two values above and below those values: 6% and 13% in nominal terms, respectively. These discount rates are based on the returns that treasury bills currently yield of 4.6% and the marginal rate of return on investments of 12% in the Maldives. These rates are both adjusted by the consumer price index (CPI) of 1.1%, which is a proxy for annual inflation, and then rounded to the nearest whole number.

If the NPV is positive this indicates that the investment involved is worthwhile, whereas a negative value indicates the opposite. In general terms, a higher discount rate is associated with high-consumption and/or rapidly growing economies, or with the higher risks and shorter-time preferences that tend to prevail in developing economies. The use of a higher discount rate results in a lower NPV.

The formula for NPV is as follows:

$$NPV = \sum_{t=0}^{n} \frac{(\text{Benefits-Costs})t}{(1+r)^{t}}$$

where:
t = discount rate
r = year
n= analytic horizon (in years)

In conducting the NPV analysis the two discount rates are used and for each management case two scenarios are created using these different rates. All benefits and cost projections are also based on an estimated average annual inflation rate using the current CPI.

Healthy coral reefs have a higher abundance, diversity and biomass of fish than degraded ecosystems. © Brian Zgliczynski, IUCN

In this manner, the financial values projected into the future are indicative of the actual sums that would be generated/incurred at the time. It is also worth noting that the NPV calculations are presented in USD, based on a conversion rate of the Maldivian Rufiyaa (MVR).

The following assumptions are made in constructing this model. First, it is assumed that a linear relationship exists between relative ecosystem condition (coral cover), delivery of services, and ecosystem service values (similar to other studies, see for example Emerton *et al.* 2013). These values are presented in USD per annum, using two nominal discount rates (6% and 13%). It is assumed that the real value of ecosystem services does not change over time, and that consumption rates do not decline under the various management cases.

While IUCN and others have made major strides in mapping and assessing the condition of the coral reefs of North Ari Atoll; the connection between the area, physical location and quality of these reef areas to the biomass of reef fish and other fish/marine product production still needs to be determined, and will require further scientific investigation. Similarly, the connection between the health of various coral reefs in the area and tourism will also need to be determined in the future. As noted earlier, in the short- to medium-term the impacts of the global economy and trends within the tourism sector are likely to have greater effects on the demand for tourism in the Maldives and North Ari Atoll. Already in the past decade, the relative demand for diving and snorkelling tourism has declined in the Maldives with the number of Asian tourists increasing and the number of European tourists declining.

In general terms, the coral reef areas that are relatively intact and healthier would be expected to be more resilient to future physical damage and climate change shocks and to "bounce back" more quickly over time, while the less intact and more degraded areas would likely be significantly less resilient to such impacts and are likely to take longer to recover or to further decline over time. These changes are likely to have significant implications for the major economic activities in North Ari Atoll, but the exact relationships will need to be determined based on further research.

Thus, in order to project the likely future economic benefits and costs of the proposed alternative management cases, a number of assumptions have been made about the likely impacts of the different management options. The analysis assumes annual increases and decreases in the benefits and costs related to tourism and reef or bait fishing, based on the likely results that the alternative management options would have. In general terms, improved management of coral reef areas via the establishment of MMAs and LMMAs is assumed to have a positive impact on reef fish production and a reduced cost associated with reef fish and baitfish capture, as well as a positive effect on dive/snorkelling based tourism with other forms of tourism ("sun and sand beach tourism") remaining unaffected. Conversely, the lack of improved management is assumed to have a negative effect on reef fishing, bait fishing and dive/snorkelling-based tourism, and to both decrease the volume of reef and bait fish captured and to increase the associated costs. For the sake of simplicity in developing the financial models for the NPV analysis, the annual rates of change are assumed to be constant and independent of each other, whereas they would likely vary significantly from year to year and be highly interdependent.

Although these assumptions are conservative, based on the experience of establishing marine protected areas and MMAs/LMMAs elsewhere (e.g. McCrea-Strub *et al.* 2011) as well as the degradation of coral reefs in other regions, the figures used are still speculative.

Given the lack of information about some of the key relationships between coral reef area, location and condition, and several the key economic data, the results of the NPV analysis under the various management cases need to be viewed as preliminary and only as indicative. Even so, the financial analysis of the various cases can help to inform planning and decision regarding marine conservation and improved livelihoods in North Ari Atoll. Ideally, in the future the underlying financial models and the analysis can be modified and improved based on additional data that can be collected in North Ari.

Based on input from IUCN and the Ministry of Environment and Energy (MEE), 4 management cases have been developed, each with two scenarios using the different discount rates mentioned above.

The Cases

1. The business as usual (BAU), or counterfactual, case. This case projects what is likely to happen in the absence of improved marine management of the coral reef and other ecosystems of North Ari. This case assumes that those tourism resorts in the atoll that support some form of marine conservation on the reefs in their vicinity continue to invest relatively modest sums in such activities in the future, and that the current rather modest response of local police to illegal fishing and other incidents is maintained. It also assumes that the same number of reef and bait fishing boats continue to fish within the coral reef area of the atoll at approximately the same level of effort. Under this case, it is assumed that there is an annual decrease of 1% in the total weight of reef fish and baitfish captured and a 1% increase in the cost of capture, and that the number of dive-based tourist visits declines by a rate of 0.5% per year. In reality these increases and decreases in ecosystem services would not occur in a linear fashion and could change more quickly or less quickly depending on ecological and economic tipping points; however, for the purposes of this study and to show a general trend, a steady yearly change has been used for the calculations.

2. The increased reef degradation case. This case projects what is likely to happen under a set of more negative assumptions to the BAU case where increased use of the marine resources and the associated damage to the coral reef ecosystems would result in further negative impacts on the main economic activities over time. This case assumes a 2% annual decrease on the annual total reef fish and baitfish weight and an increase in the cost of capture, and a 1% decline in annual dive-tourism visits.

3. The improved reef management case. This case assumes the establishment of 6 MMAs (involving 50% of the resorts in the atoll) with a new area being implemented each year over a 6-year period and of 4 LMMAs (involving 50% of the 8 inhabited island communities), where two areas would be implemented each year during the first and second years. The average start-up cost in year 1 of the MMAs is estimated at USD 55,000 and for LMMAs at USD 25,000, with the annual operation costs being USD 29,000 for both areas. The case also assumes a positive impact of 1% per year on annual total reef fish and baitfish weight, a 1% decrease in capture costs, and a 0.5% increase in annual dive-tourism visits.

The MMAs and LMMAs are based on the minimal "on water presence" required for the effective monitoring and response to non-approved activities, in addition to some support for awareness/education, and capacity building for local communities/entities.

4. The significantly improved reef management case. This case assumes that all the resorts and communities would establish MMAs and LMMAs within the same timeframe as above. It further assumes a positive impact of 2% per year on total annual reef fish and baitfish weight, a 2% decrease in capture costs, and a 1% increase in annual dive-tourism visits.

The NPV analysis for the 4 cases, under two discount rate scenarios is summarized in the following table:

Table 9. NPV analysis for 4 scenarios

Management Case	NPV (6% discount rate) USD Million	Percentage of BAU case	NPV (13% discount rate) USD Million	Percentage of BAU case
1. Business as Usual	773.67		411.42	
2. More Degraded Reef	485.13	63%	262.79	64%
3. Improved Reef Management	822.37	106%	427.20	104%
4. Significantly Improved Reef Management	849.35	110%	435.48	106%

As is evident, the NPV values of the improved and significantly improved management cases are superior to those of the BAU case, while those of the more degraded case are considerably inferior. While the differences between the improved and significantly improved cases and the BAU case are not that great in terms of the percentages (only 6% and 10% higher using a 6% discount rate, and 4% and 6% using a 13% discount rate), the total differences are not trivial within the context of the local economy: USD 48.7 million in benefits for the improved management case and USD 75.7 million in benefits for the significantly improved management case and the 6% discount rate scenario; USD 15.8 in benefits for the improved management case and USD 24.1 for the significantly improved management case.

Another way of comparing the cases and scenarios under the same set of assumptions is to contrast the NPV of the improved and much improved management cases to that of the BAU case versus the NPV of the costs associated only with the implementation of the MMAs and LMMAs, i.e. the main “additionality” of the proposed management cases. The analysis is presented in the table below:

Table 10. The economic case for management in North Ari, with net benefits of MMAs and LMMAs

Management Case	Difference of NPV with BAU Case (USD Million)	NPV of MMA and LMMA expenses (USD Million)	Net Benefit of MMA and LMMA expenses
Improved Management Case (6% discount rate)	48.67	7.64	41.03
Improved Management Case (13% discount rate)	15.78	3.76	12.02
Significantly Improved Management Case (6% discount rate)	75.69	13.26	62.43
Significantly Improved Management Case (13% discount rate)	24.01	6.67	17.34

The following graph (Figure 7) depicts the relevant NPV costs and benefits of the two management case scenarios (using 6% and 13% discount rates) compared to the BAU case:

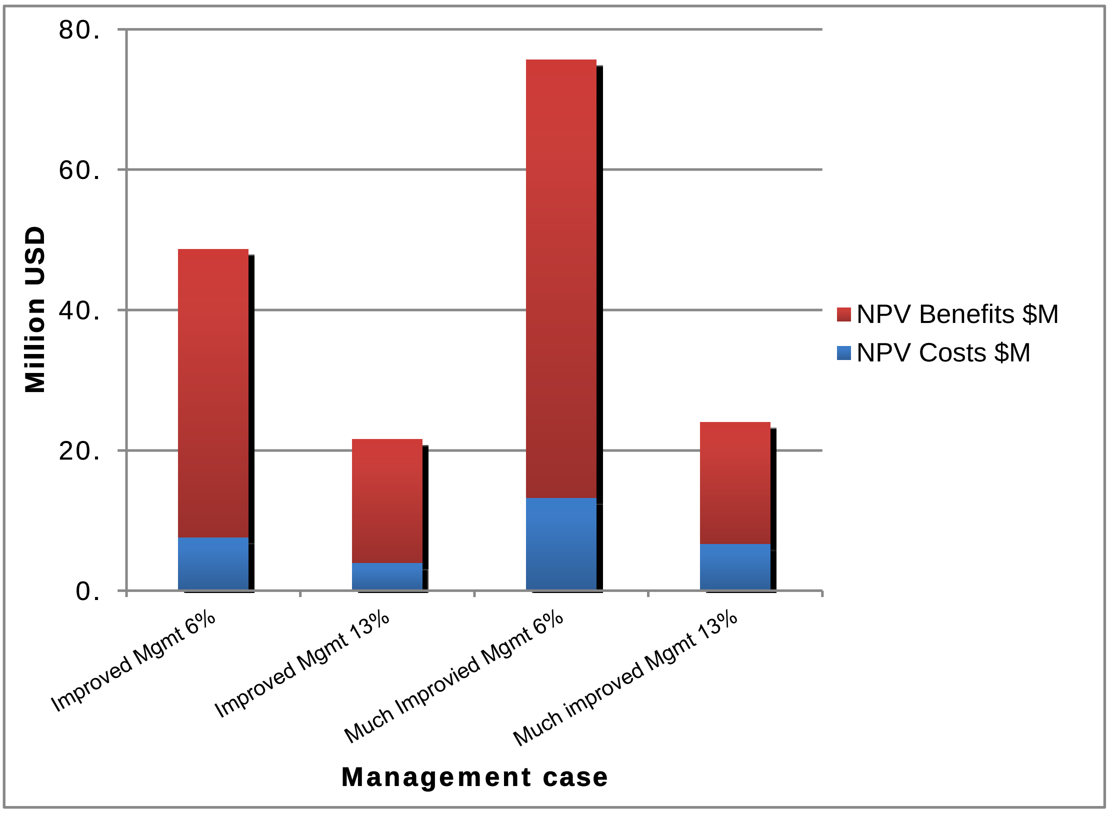


Figure 7. Costs and benefits of two management cases, as compared to the Business as Usual case, under 6% and 13% discount rates.

As can be seen when making this type of comparison, the additional expenses associated with the MMAs and LMMAs under the improved management case generate almost 6 times the benefits using a 6% discount rate and just over 4 times the benefits when using a discount rate of 13%. Under the significantly improved management case, the additional MMA and LMMA costs result in almost 5 times the benefits, using a 6% discount rate and in almost 3 times the benefits when using a 13% discount rate.

So, even assuming quite conservative annual changes in reef fishing and dive-tourism related to coral reef total area and the quality of reef ecosystems, the case for supporting investments in MMAs and LMMAS to promote marine management and conservation is compelling. Furthermore, given the relatively small difference in the costs (in present value terms) of the significantly improved management scenario to the improved management scenario, versus the much greater benefits that would be generated by the significantly improved management case over time, it is obvious that the significantly improved management case is the most cost-effective option.

Recommendations for the future

Clearly, the marine ecosystems of the Maldives provide valued ecosystem services, some of which are already being realized locally. Nonetheless, many habitats and ecosystems are at risk from land reclamation and coastal engineering, pollution (including dumping at sea), overfishing and climate change-related environmental effects.

More precise economic values that these ecosystems generate for the Maldives and its inhabitants can be determined with future targeted economic studies and surveys, now that the information on ecosystem coverage and potential ecosystem services has been synthesized. Some of these values can be estimated by examining market values; others relate more to perceived value and can only be determined by 'willingness to pay' and other contingent valuation information derived by interviewing users. However, as Wilson *et al.* (2002) state, no single methodology can capture the total value of goods and services.

For the future, it is recommended that targeted research be undertaken in relation to economic studies, as well as more detailed modelling, mapping and surveys in other atoll groups. As stressed by Daily *et al*. (2009), production functions in these ecosystems must be fully understood before the continued rates of services delivery can be predicted. In the absence of this, and even if economic values are ascertained, policy decisions rest on shaky ground. It would also be useful to conduct a referent group analysis to identify net ecosystem services benefits to every stakeholder group (e.g. government, fishermen, resorts, island communities, guesthouses and others). This could be helpful in identifying potential environmental compensation schemes.

The potential for ecosystem services valuation to influence policy will depend on contextual, procedural and methodological factors integrated in the process. A clear policy question and objective is necessary to trigger robust Ecosystem Services Valuation. In addition, it is also recommended that this be based on a local demand for ecosystem services valuation and assessment, including strong local partnerships and stakeholder engagement, that allows discussion of the assumptions behind value calculations and dialogue regarding the perceived values of the services presented.

Relevant to the issue of how science can most effectively be used to promote development that is sustainable and profitable, there are several ways that Project REGENERATE working with national and local governments as well as community stakeholders, with support from international partners and donors, could promote marine conservation and sustainable local development in North Ari in the future.

One option is to support the implementation of the proposed MMAs and LMMAs, and the associated environmental awareness, education and livelihood development activities, directly under the framework of the National Biosphere Reserve proposed by the Government of the Maldives.

The following approach is proposed via the creation of and support for the following organizations and financial mechanisms:

1. Support for a local NGO that can work closely with the various island and North Ari Atoll councils, and various community organizations in the atoll, to promote local economic development. This would be tied to commitments by these entities to support the implementation of and respect for the operations of the proposed MMAs and LMMAs.

This NGO would need to establish an independent board. The NGO would need to develop and present an annual work plan for approval by the board and then to share the results achieved/variance against the plan in an open, transparent manner with the board, and at least on an annual basis with the local communities and tourism resort owners/managers. One particularly relevant consideration could be the selection of local community members who could be supported via the NGO to conduct various day-to-day activities necessary for marine management. One option could be payment for various local fishermen to engage in LMMA monitoring and protection activities, perhaps on a per day/week rotational basis.

2. Under the auspices of the NGO, to establish a local integrated conservation and development fund, including a revolving loan fund for pilot commercial activities. The fund could have a separate committee, with a combination of local, national and international representatives, that could identify and support a range of activities using both grant and loan funds. The NGO and development fund personnel would need to establish clear criteria and selection procedures for local organizations to gain access to grant and loan funds. In addition to proactively seeking to identify and implement initiatives, the NGO/development fund could hold competitions, perhaps twice a year, to select several organizations to implement environmentally friendly project and commercial activities. Those selected could also obtain funds for technical and other assistance to further develop and implement their plans. Priority should be given to those initiatives that involve the commitment of cash and/or in-kind contributions (such as labour, materials, transportation services, etc.) by the candidate proponents.

3. Over time, ideally as positive results have been demonstrated, the development fund could be converted into a more formal Trust Fund with a separate legal identity from the NGO, with its own board. This organization could seek to obtain contributions from tourist resorts, guesthouses, liveaboard boats, airlines, banks, and other relevant national and international organizations, to complement initial donor funds that could help establish the Trust Fund. This entity could build on the lessons learned from the existing Baa Atoll Trust Fund, where contributions from various commercial activities directly linked to the marine conservation efforts and areas in North Ari could help to support annual operation costs and funds for local development and conservation, using both grant and loan finance.

Effective communication and information flows to decision makers is imperative if the economic argument is to bolster or influence political considerations. Strong governance by an authority institution over the site/ecosystem in discussion will enable implementation of the decisions that are made. Opportunities for raising revenue such as payments for ecosystem services (e.g. park entry or use fees) will facilitate the uptake of the Ecosystem Services Valuation results. Finally, a clear presentation of methods, assumptions, and limitations is critical throughout the process to manage expectations and perceptions.

A rigorous analysis of ecosystem services values must both appraise net present value and perceptions of value; and also look into the future. The two considerations that must be addressed in this regard are how value changes over the passage of time (including, but not limited to, discounting rates) and the sustainability of stocks (for goods) and services (Bateman *et al.* 2011). It is thus recommended that future work target the development of predictive models that can better elucidate trade-offs. The result will lead to conserving and enhancing as much as possible of the Maldivian natural habitats and ecosystems, which will in turn yield valuable ecosystem services for many years to come.

Economic value of ecosystem services thus provides a set of measures that can help inform strategies for biodiversity conservation, and evaluate trade-offs for future development. In this context, ecosystem services assessment and subsequent economic valuation can be used to site and design marine and terrestrial protected areas, integrated protected area networks that span inland, coastal and offshore areas, and land use or marine spatial plans (Agardy *et al.* 2011). Such studies can also be used to develop strategies and regulations that promote ecological resilience (Admiraal *et al.* 2013). This information is also extremely useful in determining compensation fees for damages to natural habitats, such as is required when ship groundings damage valuable coral reefs or seagrass beds, or when oil spills affect fisheries nursery grounds (Kennedy and Cheong, 2013).

However, further economic studies will be needed to more fully support decision-making and ensure uptake (see Pendleton *et al.* 2015b). Such additional investigations will require: 1) identification and parameterization of the links between utility and the extent and condition and 2) estimates of how ecosystem services supply will change with increase or decrease in extent and improvement or decline in condition (Bateman *et al.* 2011). Ecosystem services flows, and the economic values associated with services must also be appraised. In the Maldives, both the Ministry of Environment and Energy and IUCN have data and analyses that can support such targeted studies, to result in a more robust understanding of the current and prospective benefits provided by ecosystems in North Ari Atoll.

Rather than striving for absolute total values for ecosystem services being generated from a site, it may be more effective to use the economic valuations to complement qualitative information on what matters to resident and users. Mixed method analyses are likely to yield the kind of information needed for decision-making. A triage approach can be used before atoll-specific valuations of services are carried out to ensure that the information that flows from valuation is accessible and informative to planners (Pendleton *et al.* 2015b).

Regarding more detailed, atoll-specific studies, it will be critical to have the following basic information to value services provided by a site or an ecosystem and to be able to spatially map them in the future (Agardy *et al.* 2013):

a) Fisheries: Landed biomass, net present value of fish and shellfish, and distribution of landings and value to communities;

b) Aquaculture: Harvested biomass and net present value of fish and shellfish, distribution of biomass and value to communities;

c) Coastal protection: Avoided area of land eroded or flooded, avoided beach nourishment and costs, avoided damages to property and infrastructure, number of people affected by erosion or flooding;

d) Wave energy conversion: Captured wave energy, value of captured wave energy, and environmental impact from storms;

e) Recreation: Economic value of recreational activities, visitation rates, and community access to activities; and

f) Water purification: Filtration capacity of organisms and costs of human made water processing plants and filter systems.

Valuations, including contingent valuation, choice experiments, and travel cost methods (inter alia) should be done in tandem, across the relevant ecosystem services listed above. Such studies should focus not only on stocks of ecosystem services (values available to beneficiaries), but also on ecosystem services flows (who benefits, and how do the services available change over time). Collectively, these types of studies will allow planners to be able to highlight the relatively most valuable areas – information which can then be used in marine spatial planning, coastal planning, marine protected area siting and design and trade-off analysis. Performing the broadest possible valuations, and presenting the data in a way that can logically and easily be incorporated into planning and decision-making, will promote better uptake of ecosystem services information.

The identification of valuable benefits of ecosystem management allows a focus on coastal and marine areas that may need additional protection in the future, including those outside of house reefs. An objective assessment of management effectiveness within house reefs and protected areas is recommended, especially as it relates to compliance with regulations, and whether the regulations themselves address the highest priority threats to ecosystem function and health. Additionally, there are areas that fall outside protected areas that exhibit high ecosystem services values, in particular those in close proximity to high value assets. If a national level Biosphere Reserve plan is undertaken, these areas will need to be considered as core areas to ensure that ecosystem services are not sacrificed.

It is recommended that future work target the development of predictive economic models that can better elucidate trade-offs, taking into account not only growth projections and opportunity costs incurred when certain atoll areas are left undeveloped, but also economic risks inherent in restricting available options for future livelihoods and industries. In fact, these risks may far outweigh the short-term economic benefits of land reclamation and resort development in atolls like North Ari, for as the tourism industry shifts (in perhaps unpredictable ways) over time, lost options like the development of an expanded and profitable ecotourism industry could spell more market risk. Analyses that point to such results make a strong case for environmental management and conservation to go hand-in-hand with development. Conserving and enhancing as much habitat as possible will not only benefit biodiversity but also ensure yields of valuable ecosystem services for many years to come, and options for a diversified economy as well.

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