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The Coral Reef Economy

The business case for investment in the protection, preservation and enhancement of coral reef health

CREDITS

This report was prepared by
The Prince of Wales' International Sustainability Unit (ISU)
United Nations Environment Programme (UN Environment)
International Coral Reef Initiative (ICRI)
S&P Trucost Limited, an affiliate of S&P Dow Jones Indices LLC (Trucost)

Coordination and Advisory Committee Convenors:
Kristian Teleki, ISU; Amandine de Schaetzen, ISU; and Jerker Tamelander, UN Environment.

The analysis was carried out by Trucost:
Rick Lord, Lead ESG Management and Value Creation; Jacqueline Jackson, Account Director; Miriam Tarin Robles, Senior Research Analyst; Rochelle March, Senior Research Analyst; David McNeil, Senior Research Analyst; P Gautham, Research Analyst; Steven Bullock, Global Head of Research.

Advisory Committee:
Francis Staub, ICRI; Kristin Rechberger, Dynamic Planet; Mark Spalding, The Ocean Foundation; Melissa Wright; Bloomberg Philanthropies; Ove Hoegh-Guldberg, Global Change Institute at the University of Queensland; Leah Karrer, Global Envrionment Facility; David Obura, CORDIO East Africa; Chris Knowles, European Investment Bank; Helen Fox, National Geographic Society; Anna Marsden, Great Barrier Reef Foundation; Dan Fairweather, Willis Towers Watson; Chip Cunliffe, AXA XL; Ameer Abdulla, IUCN; Rili Djohani, Coral Triangle Centre; Melanie McField, Healthy Reefs for Healthy People; James Spurgeon, Sustain Value; Tessa Friend, ISU; Lucy Holmes, ISU; Justin Mundy, ISU; Mark Spalding, The Nature Conservancy; Caleb McClennen, The Wildlife Conservation Society.

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INTERNATIONAL SUSTAINABILITY UNIT

The Prince of Wales' International Sustainability Unit

Established in 2007 by HRH The Prince of Wales, the International Sustainability Unit (ISU), which closed in March 2018, addressed critical challenges facing the world, particularly the question of how to sustain the health of the environment while advancing development goals. The ISU commissioned this report in order to reveal and demonstrate how economic growth and ocean conservation need not be in conflict, and how sustainable development depends upon a healthy marine environment, especially for those countries that were dependent upon ocean ecosystems.
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Executive summary

Proactive policies to protect and restore the health of the world's coral reefs could generate a substantial economic gain, provide important societal benefits, including to local communities, and help deliver the UN Sustainable Development Goals.

This study presents new analysis of the value, costs and benefits of the coral reef economy to highlight that shifting the trajectory of coral reef health from one of continuing decline towards a healthy state could unlock tens of billions of dollars in additional value. The findings show that this shift can be largely achieved through strategic interventions using available tools and methods, indicating that the goal of closing the gap between the forecast benefits of a healthy reef and the current trend towards coral reef degradation is within our reach.

A quantitative model of selected interactions between live coral cover and the economic returns generated by three sectors that benefit directly from coral reefs – tourism, coastal development and commercial fisheries – was applied to two case study regions: the Coral Triangle in South East Asia and the Mesoamerican Reef in the Caribbean. The analysis found that a healthy coral reef scenario is expected to deliver additional economic benefits amounting to $34.6 billion and $36.7 billion in the Mesoamerica Reef and the Coral Triangle, respectively, between 2017 and 2030.

While much of the added financial value would be captured by the private sector, these gains could also create opportunities for governments to develop policies that redistribute part of this wealth to those adversely affected by changes in reef management, such as local fishing businesses. In addition, the societal co-benefits of ecosystem restoration to promote healthy reefs could potentially exceed the private gains, for example through improvements to municipal sanitation, more sustainable local fisheries, reduced soil erosion, and enhanced cultural heritage values.

Today the management of coral reef ecosystems is primarily funded by the public sector, but this is proving insufficient even to maintain reef health, let alone meet internationally adopted targets. The need for new sources of financing is now widely recognised, including in UN Environment Assembly resolution 2/12 adopted in 2016.

There is a strong business case to be made for both the private and public sectors to invest more in the protection, preservation and enhancement of coral reef health. By quantifying the value of a healthy coral reef across three key sectors and highlighting the incentives for the private sector to finance interventions that improve coral reef health, this study is intended to support and inform active engagement and increased investment by governments and businesses alike.

Modelling a healthy coral reef future

The magnitude of change that could be achieved by enhancing coral reef health is due to the exceptional value of the ecosystem services they provide. Reefs are a key source of food, livelihoods and economic opportunity to people in more than 100 countries and protect shorelines around the world from erosion. They host a quarter of all known marine species and attract national and international tourists alike.

This study is centred around two components: a scenario analysis and an intervention analysis. The scenario analysis estimated the economic returns attributable to the coral reefs in the two regions today, and modelled expected changes under a healthy reef scenario compared to a degraded (i.e. business-as-usual) scenario. The intervention analysis modelled a range of policies that could be adopted to achieve healthy reef status and estimated the expected economic net-benefits and returns on investment.

The four strategic interventions studied are: no-take marine protected areas; constructed wetlands for enhanced wastewater management; afforestation for erosion management; and vegetative filter strips to reduce erosion on cropland.

The results of the scenario and intervention analysis were then combined to assess the degree to which these four interventions could close the gap between the forecast benefits of a healthy reef and the business-as-usual scenario. The findings are encouraging: by 2030, the interventions could potentially reduce the gap by 70% in the Coral Triangle and by 45% in Mesoamerica.

The models developed for this study represent a simplification of complex interactions between coral reefs and the economy and do not capture the full value of coral reefs. However, conclusions based on the results can inform future advocacy and, in particular, help encourage the private sector to play a more active role. They also provide a foundation for further efforts to extend the analysis in the future.

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The goal of transitioning toward healthy coral reef ecosystems links directly to the United Nations Sustainable Development Goals (SDGs), as do many of the interventions studied in this project.

KEY FINDINGS

The results of this study highlight that achieving improvements in coral reef health and unlocking major financial gains could be within reach.

Coral Reefs Underpin Significant Economic Value for the Private Sector

The private sector economic value of coral reefs across the tourism, commercial fisheries and coastal development sectors is linked to their health. Today, their economic value to these three sectors equals $6.2 billion per annum in Mesoamerica and $13.9 billion per annum in the Coral Triangle. If reefs continue to decline, their per annum value could fall by $3.1 billion in Mesoamerica and $2.2 billion in the Coral Triangle by 2030.

The Value of Future Healthy Coral Reefs is High

A shift toward a healthy state by 2030 could unlock an additional $35 billion (or $2.5 billion per annum) in additional value to the three sectors in Mesoamerica, and an additional $37 billion (or $2.6 billion per annum) in Indonesia. These potential returns highlight the financial business case for the private sector, along with governments and NGOs, to invest in coral reef health. Innovative and sustainable financing mechanisms will be essential to ensure investment flows.

Societal Co-Benefits of Healthy Coral Reefs Could Exceed Private Gains

The societal benefits of ecosystem restoration could be even greater than the financial gains of the private sector. For example, reducing the discharge of untreated municipal wastewater into coastal environments can create health benefits. Erosion management may reduce agricultural soil loss, while coastal afforestation can support sustainable forestry and increase carbon capture. The expansion of no-take zones promotes sustainable fisheries by preserving fish stocks and diversity. The results of this study should therefore not be taken as a reflection of the total value of coral reefs, but as one component of the broader economic, social and environmental benefits of protecting coral reef assets.

Policies to Enhance Coral Reef Health Generate a Financial Return on Investment

A range of policies and interventions that could produce financial net benefits are available to governments and the private sector. The potential return on investment ranged from 44:1 for the expansion of no-take marine protected areas in Mesoamerica, to 9:1 for better erosion management on agricultural land in Indonesia. These findings should encourage businesses, policymakers and NGOs to devise policies and initiatives to help grow a sustainable reef-dependent economy.

Interventions to Protect Coral Reefs Contribute to the Sustainable Development Goals

Action to enhance the health of coral reefs will help deliver the 2030 Development Agenda and SDGs. The four interventions analysed all directly deliver on SDG 14 to conserve and sustainably use the oceans, seas and marine resource, while also contributing to SDG 6 on ensuring water and sanitation for all, and SDG 15 on the sustainable use of terrestrial ecosystems.

Climate Change Poses Significant Risk and Adds Uncertainty

Efforts to enhance coral reef health must be considered within the longer-term context of climate change, which presents an existential threat to many reefs. Even if the objectives of the Paris Agreement are achieved, reports warn that up to 90% of all coral reefs could be lost by 2050. Acting on local threats (including overfishing, erosion, and pollution) in order to maximise reef resilience may help moderate impacts, but climate change effects, including ocean warming and altered cyclone and rainfall patterns, add uncertainty to the analysis presented in this report.

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Toward a Healthy Reef by 2030

This study shows that interventions targeting sustainable fisheries, wastewater and erosion management could have a positive impact on the health of coral reefs and the reef-dependent economy. In Mesoamerica, these interventions could close 45% of the gap between the estimated value derived from a degraded and a healthy reef by 2030. In the Coral Triangle, the interventions could close 70% of the gap. These results highlight that the goal of rapidly achieving major improvements in coral reef health could be within reach.

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Introduction

ABOUT THIS REPORT

Coral reefs are exceptionally valuable in terms of the ecosystem services they deliver. They provide food, livelihoods and economic opportunity to people in more than 100 countries around the world, and protect shorelines from erosion. They are a source of enjoyment for national and international tourists alike. Hosting a quarter of all known marine species they also play a critical role in the broader coastal ecosystem.

Protection and management of coral reef ecosystems is mainly funded by the public sector, but it is widely recognized that, at current levels, this is insufficient to maintain reef health and meet internationally adopted targets (UN Environment, ICRI and UN Environment-WCMC, 2018). The need for new and innovative financing for coral reefs has been recognized e.g. in UN Environment Assembly resolution 2/12, by the International Coral Reef Initiative, and in the Coral Reef Life Declaration adopted in 2017.

This study highlights the economic business case for the private and public sector to invest in the protection, preservation and enhancement of coral reef health. Initiated by the Prince of Wales's International Sustainability Unit (ISU) and United Nations Environment Programme (UN Environment) and implemented in collaboration with Trucost and the International Coral Reef Initiative (ICRI), the analysis maps the value, costs and benefits and financial flows of the coral reef dependent economy. An advisory committee composed of experts representing multilateral development agencies, funds, civil society organizations and finance and insurance companies guided the analysis.

Key steps of the analysis included:

- Development of a quantitative model of selected interactions between live coral cover (a key marker of coral reef health) and the economic returns generated by three sectors that benefit from coral reefs: tourism, coastal development and commercial fisheries;
- Applications of the model to two case study regions: the Coral Triangle, South East Asia and the Mesoamerican Reef in the Caribbean;

Two case study regions were selected on the basis of data availability, ecological significance of the reef, and the scale and composition of the reef dependent economy in each location.

- Estimation of current economic returns to each sector that are attributable to the coral reefs in each region, and modelling of the expected changes in economic returns under a healthy reef scenario, in which coral reefs recover over time, and a degraded reef scenario, in which the historical decline in coral reef health continues (i.e. business as usual);
- Selection of practical interventions from the scientific literature that could be implemented in each region to help alleviate key coral reef stressors in the short to medium term, such as overfishing, erosion and improper wastewater management;
- Modelling the costs and benefits of each intervention on the economic returns to each sector in each region, and calculating the net benefit and return on investment in each intervention;
- Drawing conclusions based on the results to inform future advocacy to protect and enhance coral reef health globally.

This report presents the results of the study. A brief overview of the approach including case study regions, sectors, interventions as well as limitations of the study is provided below, with further detail in Annex 2. Intervention analysis results are presented in detail as graphs and tables with annotations in the text, followed by a summary of main conclusions.

The models developed represent a simplification of the complex interactions between coral reefs and the economy and thus are subject to limitations and do not capture the full value of coral reefs to the economy and society. However, by quantifying the business value of a healthy coral reef across three key sectors and highlighting the potential business case for the private sector to play a more active role in financing interventions to improve coral reef health, this study can support and inform efforts by governments and businesses alike. It also provides a foundation for further efforts to extend and improve the analysis in the future.

CASE STUDY REGIONS

Two case study regions were selected for consideration in the study on the basis of data availability, ecological significance of the reef, and the scale and composition of the reef-dependent economy in each location. The Great Barrier Reef in the subject of a major economic analysis published in 2017 (Deloitte, 2017).

Coral Triangle

The Coral Triangle is one of the most highly biodiverse and ecologically important coral reef regions in the world, containing 76% of all known coral species and 37% of all reef fish species (WWF, 2017a). The Coral Triangle spans six countries (Indonesia, the Philippines, Malaysia, Papua New Guinea, Solomon Islands and East Timor), however, the largest area falls within Indonesian territorial waters.

Mesoamerican Reef

The Mesoamerican Reef is the second-longest barrier reef in the world, following the Great Barrier Reef in Australia, and spans Belize, Guatemala, Honduras and Yucatan province in Mexico.

SECTOR DEFINITIONS

The following four sectors were selected for consideration in the study based on their direct linkages to coral reefs, through dependence on coral reef ecosystem services and/or as a stressor to coral reef health:

Tourism

The scope of the tourism sector analysis includes both on-reef tourism, such as snorkelling, scuba diving and boat trips, and reef-adjacent tourism, including coastal tourism activities that benefit indirectly from coral reefs through the provision of calm waters, sandy beaches and attractive views. This analysis

captured both the direct returns to the tourism sector and the indirect economic multipliers generated across other sectors.

Commercial Fisheries

The scope of the commercial fisheries sector analysis includes the total value of reef-associated capture fisheries in each region. This analysis captured both the direct returns to the commercial fisheries sector and the indirect economic multipliers generated across other sectors. This does not include the value of reef-associated small-scale or artisanal fishing, for which data was more limited. This represents an important limitation of the study in that it does not capture the economic and social value of artisanal fishing to coastal communities.

Coastal Development

The scope of the coastal development sector analysis includes the value of protection afforded to coastal infrastructure by coral reefs, and changes in coastal infrastructure investment and construction in response to changes in on-reef and reef-adjacent tourism. This analysis captured both the direct returns to the coastal development sector and the indirect economic multipliers across other sectors.

Agriculture and Forestry

While the agriculture and forestry sector is not a key direct beneficiary of coral-reef-related services, the sector is considered to be a driver of potential coral reef stressors such as sedimentation. Several interventions have been developed to reduce the impact of the agriculture and forestry sector on coral reefs.

INTERVENTION DEFINITIONS

The following interventions to enhance the health of coral reefs were selected for consideration in this study based on data availability and the potential of each intervention to address one or more important coral reef stressors.

No-Take Marine Protected Areas

No-take marine protected areas may be an effective means of reducing pressure on coral-reef-associated fisheries and aiding the recovery of coral reefs over time. In this intervention, the expansion of existing no-take marine protected areas (to 30% of total marine protected area extent) is modelled to assess the effect on live coral cover and fishery biomass.

Constructed Wetlands for Enhanced Wastewater Management

Constructed wetlands may be a cost effective means of expanding access to domestic wastewater treatment and reducing the inflow of untreated wastewater into coastal environments. This intervention models the installation and operation of constructed wetlands of sufficient capacity to treat 50% of the currently untreated wastewater produced in the areas adjacent to the reef in each region.

Afforestation for Erosion Management

Afforestation projects may be an effective means of reducing erosion by providing enhanced land cover. This intervention models an increase in forest land cover (by 20% in Indonesia and 10% in Mesoamerica) from current levels within 6 kilometres of the reef-adjacent coastline, through afforestation of non-agricultural land.

Vegetative Filter Strips to Reduce Erosion on Cropland

Vegetative filter strips may be a cost effective means of reducing sediment run-off from agricultural land. This intervention models the implementation of vegetative filter strips on 50% of cropland within 6km of the reef-adjacent coastline in each region.

Economic value of coral reefs today

This section presents modelled estimates of the economic returns to tourism, coastal development and commercial fisheries from coral reefs in the Coral Triangle and Mesoamerica in 2017.

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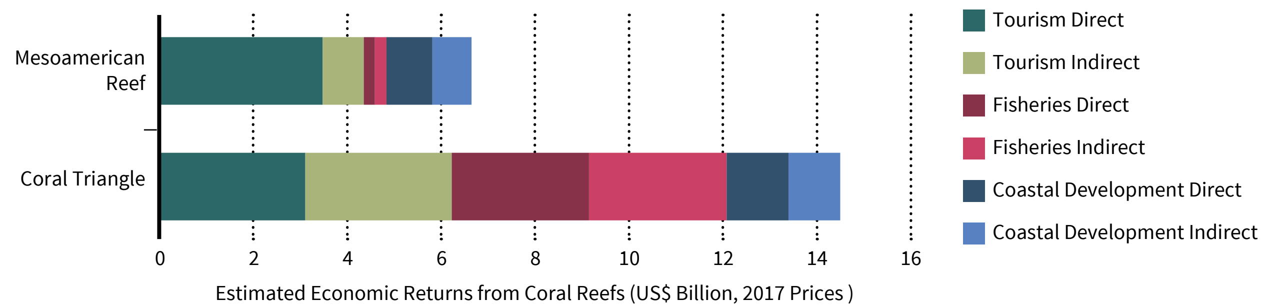
Figure 1 and Table 1 present the contribution of each sector to the total estimated economic returns in each region. This includes both the direct economic impact of increased income to tourism, commercial fisheries and coastal development, and the indirect economic impact of spending by each of these sectors on goods and services in other sectors on which they depend. For example, increasing income to the commercial fisheries sector may be associated with increased spending in related activities such as fish processing, logistics and other supporting sectors of the economy.

Economic returns to key sectors from the Mesoamerican Reef total an estimated $6.2 billion in 2017 and are dominated by the tourism sector at 70% of the total or $4.4 billion. Direct returns total $4.2 billion with indirect returns at $1.9 billion.

Table 1. Direct and Indirect Economic Returns from Coral Reefs in 2017: Coral Triangle and Mesoamerican Reef (US$ Million, 2017 Prices)

Sector		Mesoamerican Reef	Coral Triangle
Tourism	**Direct**	**$3,484**	**$3,113**
	Indirect	**$871**	**$3,113**
	Total	**$4,356**	**$6,225**
Commercial fisheries	**Direct**	**$240**	**$2,925**
	Indirect	**$240**	**$2,925**
	Total	**$480**	**$5,850**
Coastal development	**Direct**	**$975**	**$1,323**
	Indirect	**$837**	**$1,094**
	Total	**$1,813**	**$2,417**
All sectors	**Direct**	**$4,700**	**$7,361**
	Indirect	**$1,949**	**$7,132**
	Total	**$6,649**	**$14,493**

Figure 1. Direct and Indirect Economic Returns from Coral Reefs in 2017: Coral Triangle and Mesoamerican Reef (US$ Billion, 2017 prices)



In contrast, economic returns from the Coral Triangle total $13.9 billion in 2017 with a more even distribution across the key sectors – tourism at 45%, commercial fisheries at 42% and coastal development at 13%. Indirect returns are greater than direct returns at $7.1 billion and $6.7 billion respectively, due to the higher economic multiplier for non-tourism sectors in Indonesia.

These results reflect differences in the economic composition of countries in each region – commercial fisheries (excluding artisanal fishing) in the Coral Triangle accounted for over 11% of global capture fisheries in 2011 and an estimated 5% of the populations of countries in the Coral Triangle are dependent on fisheries for their livelihoods (ADB, 2014). Similarly, tourism accounted for 6% of Indonesian gross domestic product (GDP) in 2016 and is growing at 4.3% per annum (WTTC, 2017a). In contrast, the total contribution of the tourism sector to gross domestic product in the Caribbean was estimated at almost 15% in 2016 (WTTC, 2017c).

Scenario analysis: economic value of healthy and degraded reefs

This section presents a modelled comparison of the expected future returns to each of the key sectors between 2017 and 2030 under a future Healthy Reef Scenario or a Degraded Reef Scenario. Both scenarios are defined in terms of changes in live coral cover, which was identified more broadly as a key marker of coral reef health (Healthy Reefs for Healthy People, 2018).

Under a degraded scenario, live coral cover continues to decline in the Mesoamerican Reef and Coral Triangle in line with historical trends (linear extrapolation of historical trend) – this represents a business-as-usual scenario (Gardner et al, 2003; XL Catlin, n.d.). Under a healthy scenario, live coral cover recovers linearly over time to reach a healthy reef target, which was determined based on other scientific studies, by 2030 (Healthy Reefs for Healthy People, 2015; COREMAP, 2017). Details of live coral cover projections under each scenario are provided in Table 10, Annex 2.

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Under the Degraded Reef Scenario, live coral cover is assumed to decline from an average of 3.7% in 2017 to 1.6% in 2030 in Mesoamerica (Gardner et al, 2003; XL Catlin, n.d.) and from 16.6% to 11% in the Coral Triangle (Bruno and Selig, 2007; XL Catlin, n.d). Under the Healthy Reef Scenario, live coral cover is assumed to increase to 14.1% in Mesoamerica and 36.4% in the Coral Triangle by 2030 (Healthy Reefs for Healthy People, 2015; COREMAP, 2017).

Scenario Analysis: Mesoamerican Reef

Figure 2 and Table 2 present the annualised present value of economic returns from the key sectors in Mesoamerica over the period 2017-2030 under the Healthy and Degraded Reef Scenarios, while Table 2 also presents forecast returns in 2030.

Total economic returns from the Mesoamerican Reef between 2017 and 2030 under the healthy scenario are estimated at $108 billion to 2030 or $7.7 billion per annum annualised (present values, 2017 prices). This compares to $73 billion to 2030 or $5.2 billion per annum under the degraded scenario, representing a net-benefit from healthy reefs of $2.5 billion per annum or $34.6 billion in the 14 years to 2030. As shown in Figure 3, economic returns foregone across all

Table 2. Present Value of Economic Returns from the Mesoamerican Reef: Estimated 2030 and Annualised 2017-2030 (US$ Million, 2017 Prices)

Scenario		Tourism	Commercial Fisheries	Coastal Development	Total
Healthy Reef Scenario	Annualised	$5,153	$484	$2,047	$7,685
	Estimated 2030	$7,110	$490	$2,645	$10,245
Degraded Reef Scenario	Annualised	$3,279	$469	$1,461	$5,209
	Estimated 2030	$2,069	$459	$1,068	$3,596
Net-Benefit of Healthy Reef Scenario	Annualised	$1,874	$15	$586	$2,475
	Estimated 2030	$5,041	$31	$1,577	$6,649

Figure 2. Annualised Present Value of Economic Returns from the Mesoamerican Reef 2017-2030 (US$ Billion, 2017 Prices)

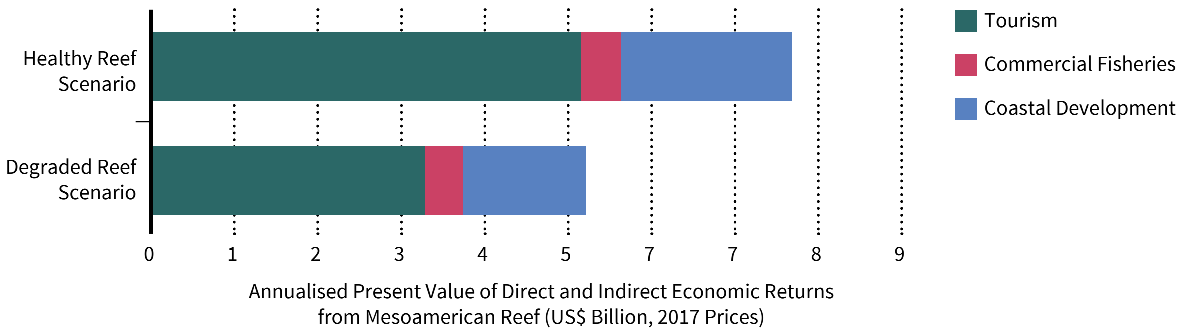
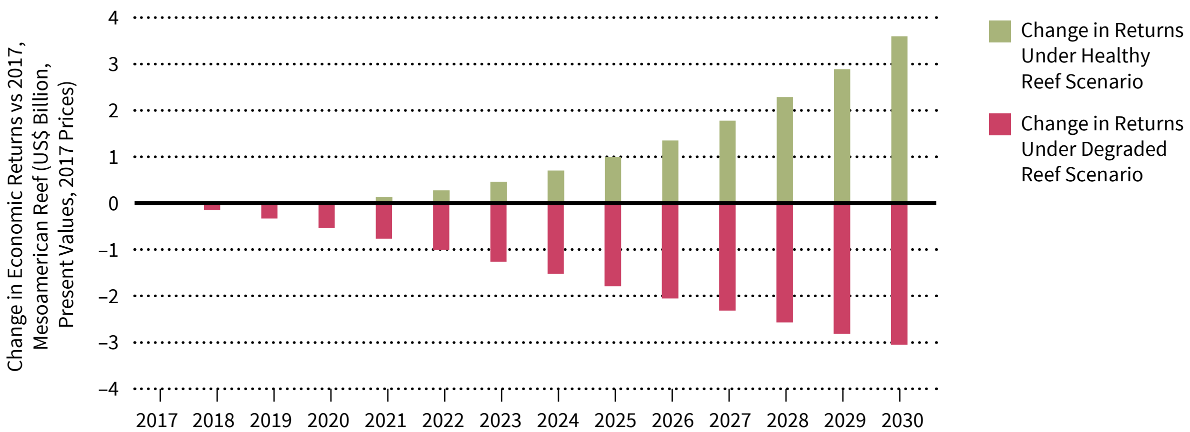


Figure 3. Change in Economic Returns from the Mesoamerican Reef Relative to 2017: US$ Billion, Present Values, 2017 Prices



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sectors under the degraded scenario are estimated to be $3.1 billion less than in 2017 ($4.6 billion in 2030 vs $6.7 billion in 2017) compared to an increase of $3.6 billion per annum ($10.3 vs $6.7 billion in 2017) under the healthy scenario. The trend in changes in economic returns under the healthy and degraded scenarios is driven primarily by the rate of change in live coral cover and the impact of discounting future values to 2017 prices.

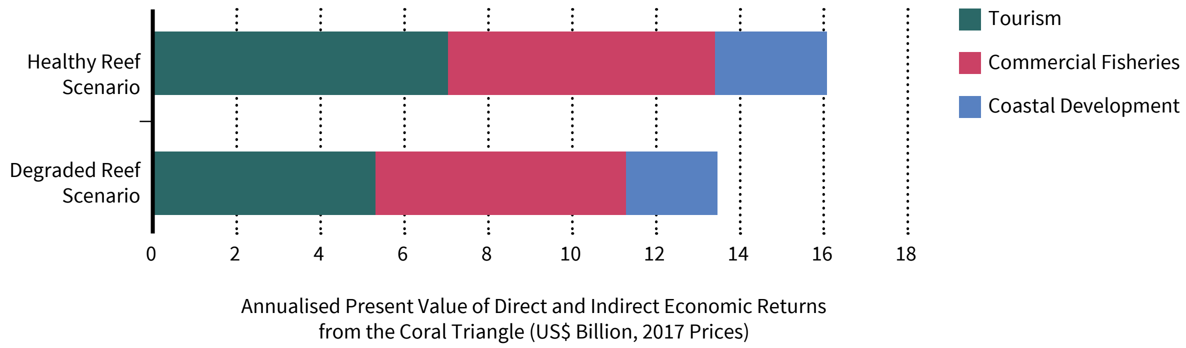
Scenario Analysis: Coral Triangle

Figure 4 and Table 3 present the annualised present value of economic returns from the key sectors in the Coral Triangle over the period 2017-2030, under the Healthy and Degraded Reef Scenarios, while Table 3 also presents forecast returns in 2030.

Table 3. Present Value of Economic Returns from the Coral Triangle: Estimated 2030 and Annualised 2017-2030 (US$ Million, 2017 Prices)

Scenario		Tourism	Commercial Fisheries	Coastal Development	Total
Healthy Reef Scenario	Annualised	$7,040	$6,365	$2,675	$16,081
	Estimated 2030	$8,520	$6,942	$3,124	$18,586
Degraded Reef Scenario	Annualised	$5,312	$5,971	$2,178	$13,461
	Estimated 2030	$4,145	$6,094	$1,866	$12,105
Net-Benefit of Healthy Reef Scenario	Annualised	$1,728	$395	$496	$2,620
	Estimated 2030	$4,375	$848	$1,258	$6,481

Figure 4. Annualised Present Value of Economic Returns from the Coral Triangle 2017-2030 (US$ Billion, 2017 Prices)

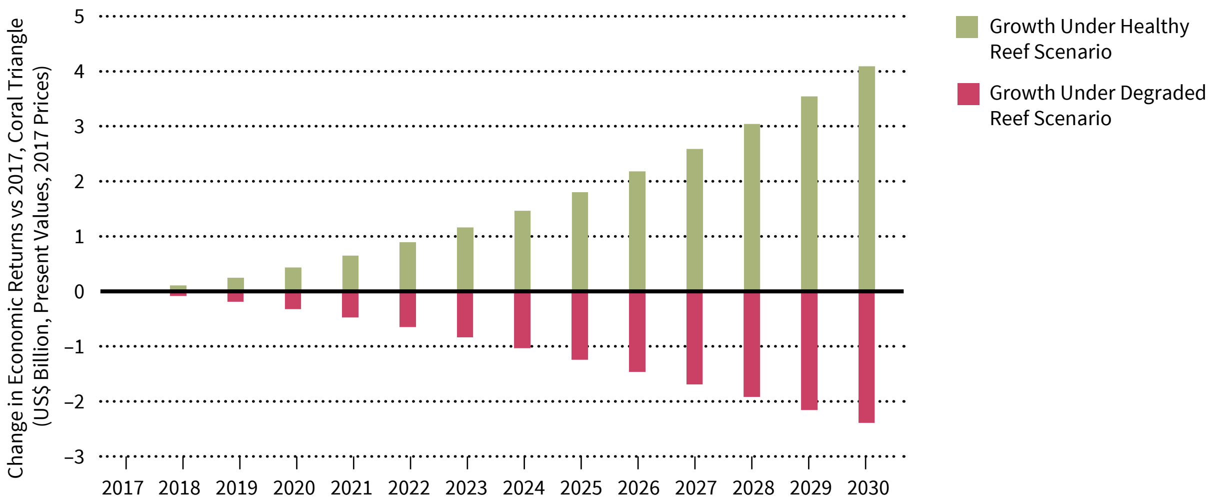


Total economic returns from the Coral Triangle between 2017 and 2030 under the healthy scenario are estimated at $225 billion to 2030 or $16.1 billion per annum annualised (present values, 2017 prices). This compares to $188 billion to 2030 or $13.5 billion per annum under the degraded scenario, representing a net- benefit of healthy reefs of $2.6 billion per annum or $36.7 billion in the 14 years to 2030. As shown in Figure 5, economic returns across all sectors under the degraded scenario are estimated to be $2.4 billion less than in 2017 ($12.1 billion in 2030 vs $14.5 billion in 2017) compared to an increase of $4.1 billion ($18.6 billion vs $14.5 billion in 2017) per annum under the healthy scenario. The trend in changes in economic returns under the healthy and degraded scenarios is driven primarily by the rate of change in live coral cover and the impact of discounting future values to 2017 prices.

A healthy reef in the Coral Triangle could unlock an additional $3.5 billion per annum in 2030 compared to today.

In summary, a shift toward a healthy coral reef is expected to deliver significant economic benefits across the three key sectors, totalling $34.6 billion and $36.7 billion between 2017 and 2030 in the Mesoamerica Reef and the Coral Triangle, respectively. This represents just part of the broader economic returns that may accrue to other sectors more indirectly linked to coral reefs, and the social and environmental benefits of restoring critical coral reef ecosystems such as biodiversity conservation and cultural heritage values. These findings highlight the significant economic prize that could be captured through proactive policies to protect and restore coral reef health.

Figure 5. Change in Economic Returns from Coral Triangle Relative to 2017: US$ Billion, Present Values, 2017 Prices



Intervention analysis results

This section presents the results of a modelled analysis of a range of potential coral health interventions that could be adopted to shift the status of coral reefs from their current path (to degradation) toward a healthy reef status. For each intervention, the following was evaluated:

- The expected impact of the intervention on improving live coral cover rates in each case study region;
- The expected costs of implementing and maintaining (including opportunity costs) the intervention between 2017 and 2030;
- The expected economic returns to the three key sectors associated with improving live coral cover in each case study region relative to the Degraded Reef Scenario; and
- The expected economic net-benefit and return on investment for each intervention relative to the Degraded Reef Scenario.

Results for each of the four intervention types are presented separately below.

INTERVENTION NET-BENEFITS

Figure 6 and Table 4 present a comparison of the estimated annualised costs, benefits and net-benefits of the modelled interventions in Mesoamerica.

Table 4. Annualised Present Value of Costs, Benefits and Net-Benefits of Healthy Reef Interventions in the Mesoamerica Reef (MSA) (US$ Million, 2017 Prices)

Intervention			Present Value			Return on Investment (%)
			Costs	Benefit	Net-Benefit	
Int. 3	MSA	Constructed Wetlands	-$8	$22	$14	2.8
Int. 5	MSA	Afforestation	-$7	$25	$18	3.5
Int. 7	MSA	Vegetative Filter Strip	-$5	$24	$20	5.1
Int. 1	MSA	No-Take Zone	-$30	$1,321	$1,291	44.0
Return on Investment colour coded from low (red) to high (green)						

Figure 6. Annualised Present Value of Costs, Benefits and Net-Benefits of Healthy Reef Interventions in the Mesoamerica Reef (US$ Billion, 2017 Prices)

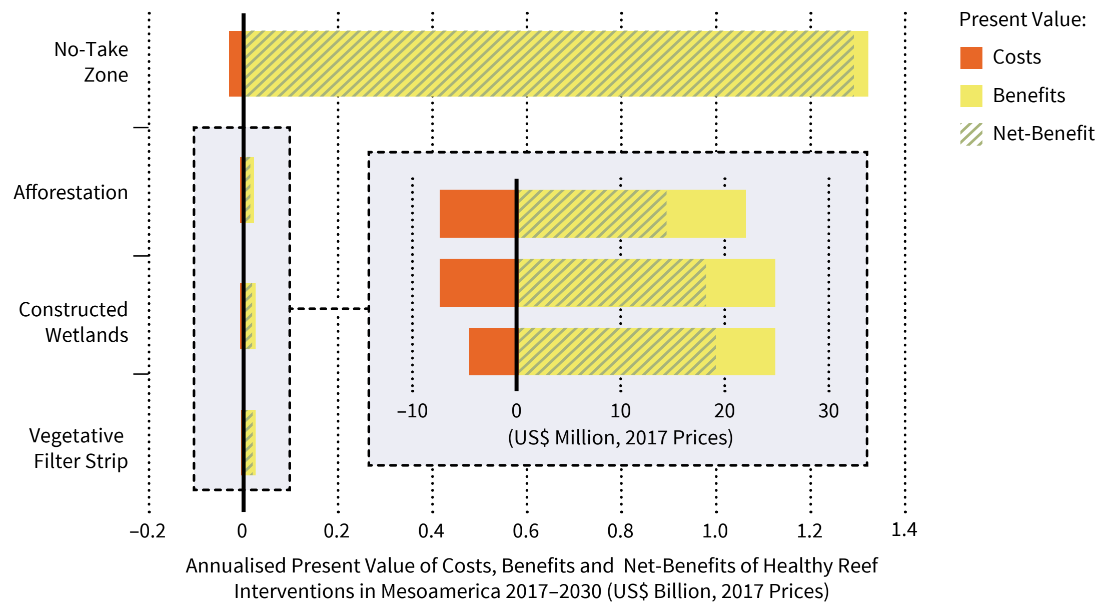


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Figure 7 and Table 5 present a comparison of the estimated annualised costs, benefits and net-benefits of the modelled interventions in Indonesia.

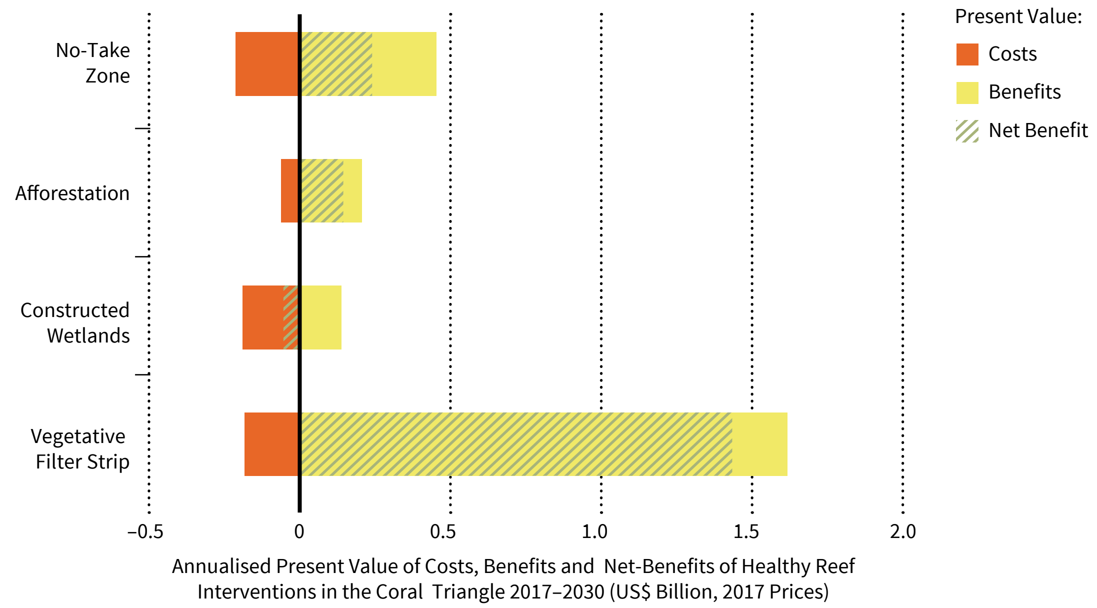
As shown, all of the modelled interventions except intervention 4 (Constructed Wetlands in Indonesia) produce a positive net-benefit and return on investment. Intervention 1 (No-Take Zones) generates the largest net-benefit for Mesoamerica due to the comparatively lower opportunity cost of lost fishery production and the large benefits of improved coral health to the tourism sector. Intervention 8 (Vegetative Filter Strips) generates the largest net-benefit for Indonesia due to its effectiveness in reducing the high sedimentation rates on the heavily cropped coastal regions of Indonesia. Interventions 3 (Constructed Wetlands in Mesoamerica) and 4 (Constructed Wetlands in Indonesia) produce the smallest net-benefits in each region due to the high cost of these interventions relative to their benefits to the key sectors – this does not include broader economic and social benefits of improved sanitation.

Intervention 1 (No-Take Zones in Mesoamerica) and Intervention 8 (Vegetative Filter Strips in Indonesia) produce the largest return on investment due to the high benefits, which offset the substantial costs.

Table 5. Annualised Present Value of the Costs, Benefits and Net-Benefits of Healthy Reef Interventions in the Coral Triangle (IDN) (US$ Million, 2017 Prices)

Intervention			Present Value			Return on Investment (%)
			Costs	Benefit	Net-Benefit	
Int. 4	IDN	Constructed Wetlands	-$193	$134	-$59	0.7
Int. 2	IDN	No-Take Zone	-$212	$453	$240	2.1
Int. 6	IDN	Afforestation	-$61	$206	$145	3.4
Int. 8	IDN	Vegetative Filter Strip	-$183	$1,618	$1,435	8.8
Return on Investment colour coded from low (red) to high (green)						

Figure 7. Annualised Present Value of the Costs, Benefits and Net-Benefits of Healthy Reef Interventions in the Coral Triangle (US$ Billion, 2017 Prices)



EXPANSION OF NO-TAKE MARINE PROTECTED AREAS

Figure 8 and Table 6 present the estimated impact of interventions to expand the coverage of no-take zones to 30% of the total existing marine protected area in each case study region. No-take zones may be an effective means of reducing fishing pressure on coral reefs and allowing space for live coral cover to recover over time.

Implementation costs for this intervention are assumed negligible since the intervention focused on the expansion of existing no-take zones that have already been established. Operational and maintenance costs (including the costs of enforcement and monitoring) are also relatively modest – estimated at $904 and $101 per square kilometre per annum in Mesoamerica and Indonesia, respectively. Marginal monitoring and enforcement costs are lower for Indonesia due to the economies of scale available to the larger no-take zones in Indonesia (McCrea-Strub et al, 2011). The most important cost of no-take zones is the opportunity cost of foregone production due to the exclusion of fishing activities within the zone. This cost is more significant in Indonesia due to the higher average productivity of the Coral Triangle (60 tonnes/km^2 vs 32 tonnes/km^2 in Mesoamerica).[1]

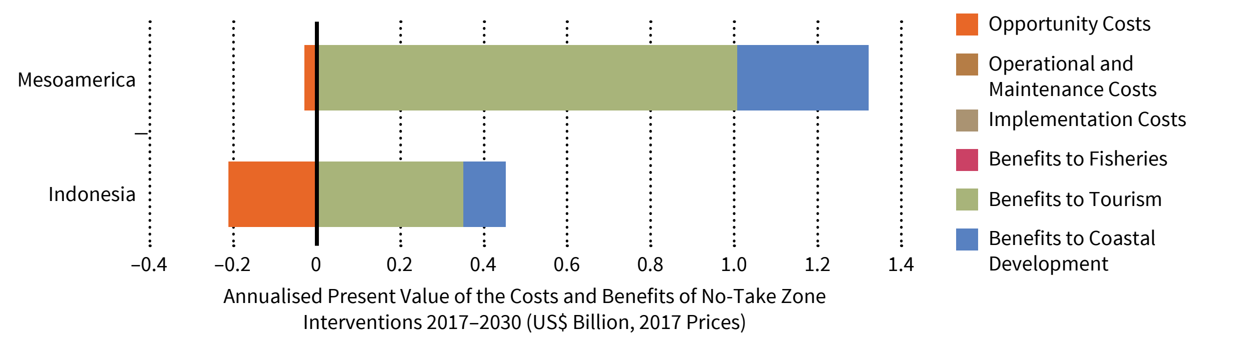
All but one of the interventions modelled produce a positive net-benefit and return on investment.

The costs of no-take zone implementation to commercial fisheries are partially offset by the spillover of rising fish biomass within the zone into the broader fishery; however, a larger gain is achieved through the benefits of increasing live coral cover in the tourism and coastal development sectors. Thus, this intervention creates a net economic loss to the commercial fisheries sector in both regions but significant benefits to other sectors, creating possible opportunities for financial transfers and compensation to the fisheries sector in order to achieve benefits for the broader reef economy. This intervention is also likely to create costs for artisanal fisheries, which would also be excluded from the no-take zone. Thus, the impact on household incomes and food security for communities that are dependent on artisanal fishing should also be considered when assessing future no-take zone policy choices.

Table 6. Annualised Present Value of the Costs, Benefits and Net-Benefits of No-Take Zone Interventions (US$ Million, 2017 Prices)

Costs / Benefits		Mesoamerican Reef	Coral Triangle
Cost	Implementation costs	–	–
	Operational and Maintenance Costs	<$1	<$1
	Opportunity Costs	-$30	-$212
Benefit	Benefits to Fisheries	–	–
	Benefits to Tourism	$1,006	$352
	Benefits to Coastal Development	$315	$101
Net-Benefit	Total Net-Benefit	$1,291	$240

Figure 8. Annualised Present Value of the Costs and Benefits of No-Take Zone Interventions (US$ Billion, 2017 Prices)



1 Trucost estimates based on FAO (FAO, n.d.) and other sources.

Improvements in live coral cover due to reduced coastal nutrient pollution deliver modest increases in commercial fishery returns and larger benefits to the tourism and coastal development sectors in each region.

CONSTRUCTED WETLANDS FOR ENHANCED WASTEWATER MANAGEMENT

Figure 9 and Table 7 present the estimated impact of interventions to expand access to municipal wastewater treatment through the construction of sufficient constructed wetlands capacity to treat 50% of the currently untreated wastewater in each region (756 million m^3 in Indonesia and 27 million m^3 in Mesoamerica).

Constructed wetlands may be a cost effective means of treating municipal wastewater and reducing the outflow of pollutants into the coastal environment where they can negatively affect coral reefs.

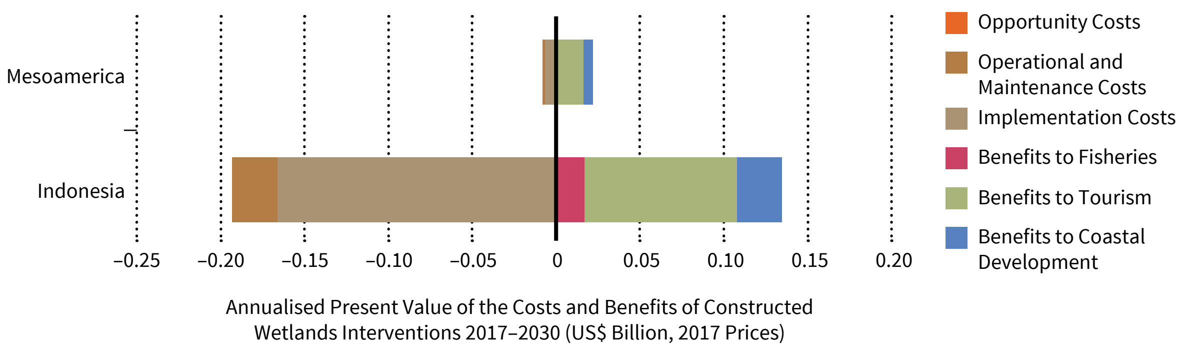
Implementation costs for this intervention are high and involve the construction of new constructed wetlands wastewater treatment facilities. Implementation costs are far higher in Indonesia due to its low levels of access to wastewater treatment and large quantities of untreated wastewater. Operation and maintenance costs are also significant but in proportion to the number of individuals served by the treatment facilities – estimated at 0.5 million in Mesoamerica and 14 million in Indonesia. Constructed wetlands were assumed to be constructed on marginal or unutilised (for agriculture) land to minimise any possible opportunity costs, with the intervention designed to occupy a small fraction of coastal land in each region.

Improvements in live coral cover due to reduced coastal nutrient pollution deliver modest increases in commercial fishery returns and larger benefits to the tourism and coastal development sectors in each region. The intervention in Mesoamerica produces a small net-benefit of $14 million per annum, however, the annualised benefits of this intervention in Indonesia are insufficient to offset the high establishment costs and thus result in a net loss of $59 million per annum. This result does not consider the likely significant public health and other environmental benefits of improved sanitation, which fall beyond the scope of this study. Furthermore, expansion of constructed wetlands may deliver habitat and biodiversity benefits. This intervention could produce a significant net-benefit if these co-benefits were included.

Table 7. Annualised Present Value of the Costs, Benefits and Net-Benefits of Constructed Wetlands for Enhanced Wastewater Management (US$ Million, 2017 Prices)

Costs / Benefits		Mesoamerican Reef	Coral Triangle
Cost	Implementation costs	-$7	-$166
	Operational and Maintenance Costs	-$1	-$27
	Opportunity Costs	-	-
Benefit	Benefits to Fisheries	$0	$17
	Benefits to Tourism	$17	$91
	Benefits to Coastal Development	$5	$26
Net-Benefit	Total Net-Benefit	$14	$59

Figure 9. Annualised Present Value of the Costs and Benefits of Constructed Wetlands for Enhanced Wastewater Management (US$ Billion, 2017 Prices)



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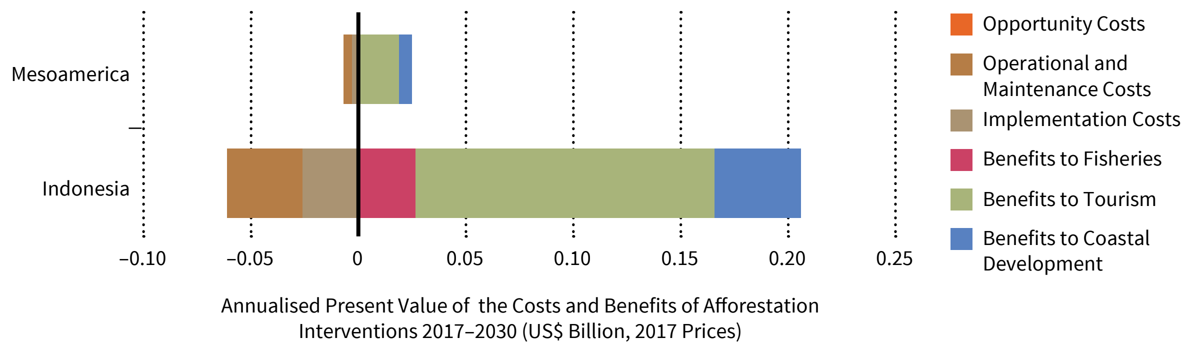
AFFORESTATION TO REDUCE EROSION

Figure 10 and Table 8 present the estimated impact of afforestation projects to increase forest cover on land within 5.8km of the coastline.[2] Enhanced forest cover can reduce erosion rates on coastal land and reduce the negative impact of sediment on coral health. This intervention models an increase in forest cover by 10% (1,769km^2) in Mesoamerica and 20% (17,173km^2) in Indonesia. Implementation costs for this intervention are moderate and involve the establishment of forest plantations. Operational and maintenance costs are also significant but in proportion to the area of land dedicated to afforestation. Opportunity costs are assumed negligible since afforestation is assumed to take place on land not currently used for agriculture or other purposes.

Table 8. Annualised Present Value of the Costs, Benefits and Net-Benefits of Afforestation to Reduce Erosion (US$ Million, 2017 Prices)

Costs / Benefits		Mesoamerican Reef	Coral Triangle
Cost	Implementation costs	-$3	-$26
	Operational and Maintenance Costs	-$4	-$35
	Opportunity Costs	$0	$0
Benefit	Benefits to Fisheries	$0	$27
	Benefits to Tourism	$19	$139
	Benefits to Coastal Development	$6	$40
Net-Benefit	Total Net-Benefit	$18	$145

Figure 10. Annualised Present Value of the Costs and Benefits of Afforestation to Reduce Erosion (US$ Billion, 2017 Prices)



2 The majority of coastal sedimentation is assumed to arise from land within 5.8km of the coastline (Soranno et al, 1996).

Improvements in live coral cover due to reduced coastal sedimentation deliver modest increases in commercial fishery returns and significant benefits to the tourism and coastal development sectors in each region. Total net-benefits are greater for Indonesia (at $145 million) than Mesoamerica (at $18 million) due to the larger scale of the intervention, lower baseline forest cover, and higher baseline erosion rates in Indonesia. This does not include other possible benefits to climate change mitigation and biodiversity of afforestation, which are beyond the scope of this study.

VEGETATIVE FILTER STRIPS TO REDUCE EROSION ON CROPLAND

Better erosion management on coastal agricultural land could produce net-benefits of $1.4 billion per annum in the Coral Triangle.

Figure 11 and Table 9 present the estimated impact of the implementation of vegetative filter strips on agricultural land within 5.8km of the coastline.[3] Vegetative filter strips installed along contours at a catchment-to-filter-strip ratio of 50:1 can reduce erosion rates by 50%, thereby reducing the negative impact of sediments on coral health (Helmers et al, 2008). This intervention models the adoption of vegetative filter strips on 50% of cropland within 5.8km of the coast in each region.

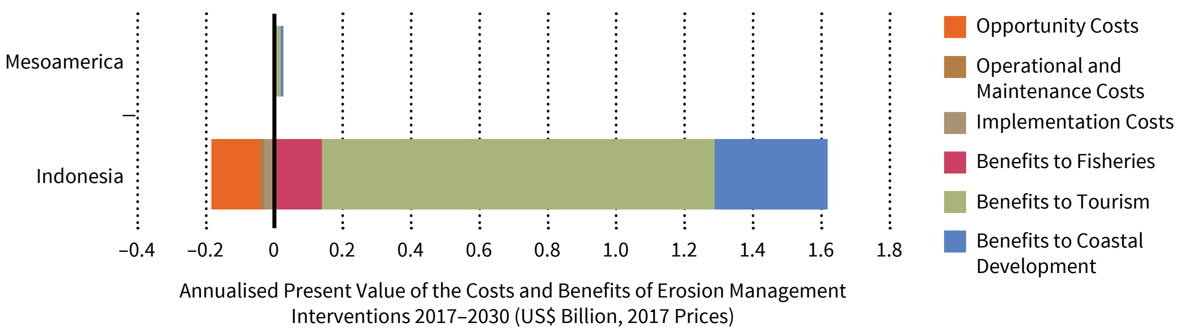
Implementation and maintenance costs for this intervention are low and relate to the initial planting of filter strip vegetation and then the ongoing cultivation and maintenance of the vegetation. The opportunity costs of this intervention are moderate and relate to the small proportion of arable land that must be taken out of production and dedicated to the filter strips.

Improvements in live coral cover due to reduced coastal sedimentation deliver moderate increases in commercial fishery returns and significant benefits to the tourism and coastal development sectors in Indonesia, and small net-benefits overall in Mesoamerica. Total net-benefits are greater for Indonesia (at $1.4 billion) than Mesoamerica (at $20 million) due to the higher proportion of coastal cropland (40% in Indonesia vs 7% in Mesoamerica) and higher baseline erosion rates in Indonesia.

Table 9. Annualised Present Value of the Costs, Benefits and Net-Benefits of Vegetative Filter Strips on Cropland to Reduce Erosion (US$ Million, 2017 Prices)

Costs / Benefits		Mesoamerican Reef	Coral Triangle
Cost	Implementation costs	-$2	-$30
	Operational and Maintenance Costs	-$1	-$13
	Opportunity Costs	-$2	-$140
Benefit	Benefits to Fisheries	$0	$139
	Benefits to Tourism	$18	$1,149
	Benefits to Coastal Development	$6	$329
Net-Benefit	Total Net-Benefit	$20	$1,435

Figure 11. Annualised Present Value of the Costs and Benefits of Vegetative Filter Strips on Cropland to Reduce Erosion (US$ Billion, 2017 Prices)



3 See footnote 2, p16.

TOWARD A HEALTHY REEF SCENARIO

The following section combines the results of the scenario and intervention analysis to assess the degree to which the modelled interventions could close the gap between the forecast benefits of a healthy reef in 2030, and those of a degraded reef. While it must be noted that the modelled interventions may not be fully compatible and additive when implemented together, the figures below provide an indication of the magnitude of change that could be achieved through strategic interventions to enhance coral reef health.

Figure 12 presents the contribution of each intervention to closing the gap between the forecast economic returns to the three sectors in 2030 under degraded (top) and healthy (bottom) reef scenarios in Mesoamerica. As shown, the modelled interventions could potentially reduce the gap between the degraded and healthy scenarios in 2030 by 45%. The majority contribution to this is associated with the expansion of no-take marine protected areas. Other interventions not considered in this study would be needed to close the residual gap between the healthy and degraded scenarios (shown in red).

Figure 13 presents the contribution of each intervention to closing the gap between the degraded and healthy reef scenarios in 2030 in Indonesia. As shown, the modelled interventions could potentially reduce the gap between the degraded and healthy scenarios in 2030 by 70%. The majority contribution to this gap closure is associated with the adoption of vegetative filter strips to reduce erosion on cropland. Other interventions not considered in this study would be needed to close the residual gap between the healthy and degraded scenarios (shown in red).

Figure 12. Contribution of Modelled Interventions to Closing the Gap between the Degraded and Healthy Reef Scenarios in 2030 – Mesoamerica (US$ Billion, Present Values (PV), 2017 Prices)

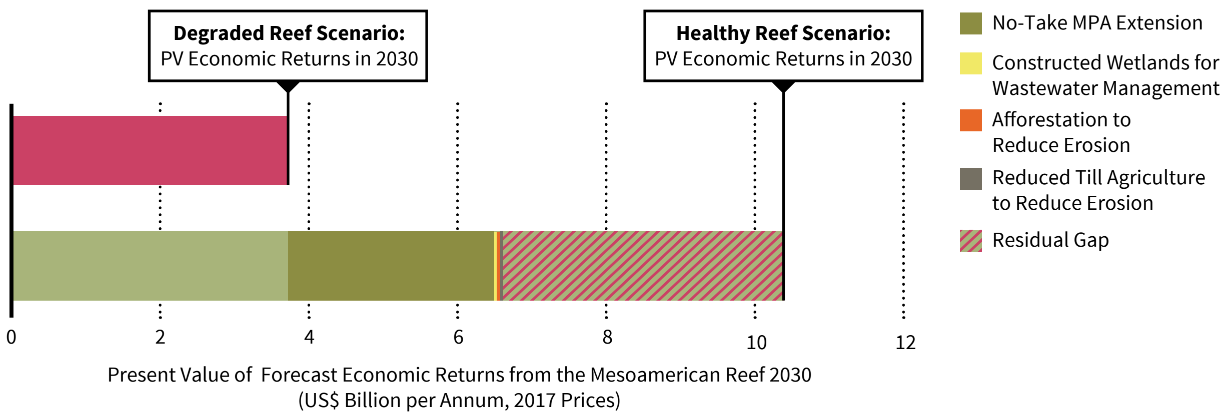
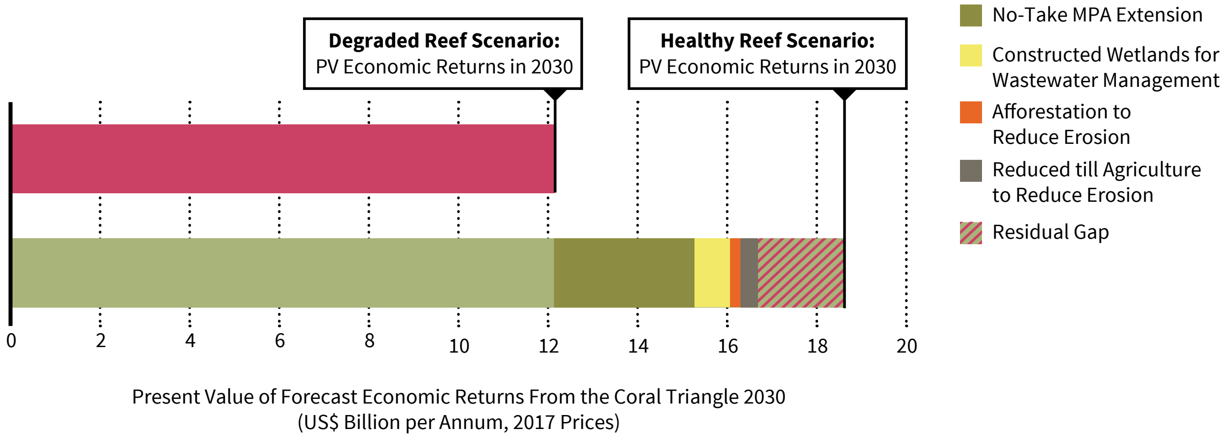


Figure 13. Contribution of Modelled Interventions to Closing the Gap between the Degraded and Healthy Reef Scenarios in 2030 – Coral Triangle (US$ Billion, Present Values (PV), 2017 Prices)



Key conclusions

Coral Reefs Underpin Significant Economic Value for the Private Sector

The results illustrate the private sector economic value across the tourism, commercial fisheries and coastal development sectors, which is linked to the health of coral reefs. While it was not possible to capture the full scope of economic value derived from coral reefs across the economy as a whole, the economic value to just three sectors totals $6.2 billion and $13.9 billion per annum in Mesoamerica and the Coral Triangle, respectively. If coral reefs continue to decline in line with historical trends, the value of the reef to these sectors could fall in real terms by $3.1 billion in Mesoamerica and $2.2 billion in Indonesia per annum by 2030 compared to today. Such losses could have profound follow-on effects on local livelihoods and government taxation revenues in each region, further compounding the potential losses to reef-dependent communities.

The Value of Future Healthy Coral Reefs is High

A shift in coral reef health trajectory from one of further decline toward a healthy state by 2030 could unlock an additional $35 billion (or $2.5 billion per annum) in additional value to the three sectors in Mesoamerica, and an additional $37 billion (or $2.6 billion per annum) in Indonesia. These potential returns highlight the potential financial business case for the private sector, along with governments and non-governmental organisations (NGOs), to invest in strategic interventions to protect and enhance the health of coral reefs. Furthermore, the increased value captured by the private sector may create opportunities for governments to develop policies that redistribute some of this wealth to compensate those adversely affected by changes in coral reef management, such as local fishing business that may lose some income through the expansion of no-take marine protected area policies. Innovative and sustainable financing mechanisms that address potential trade-offs between stakeholders will be critical to ensure that investment flows sustainably toward programmes and actions that increase or preserve reef health.

The Societal Co-Benefits of Healthy Coral Reefs Could Exceed Private Gains

While the focus of this study was on the expected financial value that could be captured by the private sector through the enhancement of coral reefs, the societal benefits of ecosystem restoration could be much greater. For example, interventions to reduce the discharge of untreated municipal wastewater into coastal environments may aid coral reef recovery, but are also likely to create significant public health benefits through improvements to sanitation systems. Better erosion management may reduce pressure on coral reefs but may also reduce soil loss on agricultural land, while greater afforestation of coastal land can support a sustainable forestry sector whilst supporting biodiversity and increasing carbon capture through forests. The expansion of no-take zones in sensitive areas of the reef can help support coral recovery but also promotes more sustainable fisheries, helping to preserve vital fish stocks and diversity into the future. As such, the results of this study should not be taken in isolation as a reflection of the total value of coral reefs, but rather as one component of the broader economic, social and environmental benefits of protecting coral reef assets.

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Policies to Enhance Coral Reef Health can Generate a Financial Return on Investment

The results of this study illustrate that a range of policies and interventions are available to governments and the private sector that could produce a financial net benefit and positive return on investment for stakeholders. The potential return on investment ranged from 44:1 for the expansion of no-take marine protected areas in Mesoamerica, to 9:1 for better erosion management on agricultural land in Indonesia, to 3.5:1 and 3.4:1 for afforestation projects in Mesoamerica and Indonesia, respectively. All but one of the interventions studied produced a positive net-benefit in our model. While this model is based on many assumptions, this finding highlights the potential of the ability of local interventions in targeting local reef threats that take into account local economic and social dynamics as well as projected climate change exposure. The authors hope that these findings serve to encourage businesses, policymakers and NGOs to devise innovative policies, programmes and initiatives that can help grow the reef-dependent economy whilst enhancing the capacity of the reef to support sustainable economic activity.

Interventions to Protect Coral Reefs Contribute to Delivering on the Sustainable Development Goals

This analysis highlights a number of opportunities provided by healthy coral reefs to deliver on the 2030 Development Agenda and Sustainable Development Goals (SDGs). The interventions that are the focus of this analysis directly deliver on SDG 14 to conserve and sustainably use the oceans, seas and marine resource, including in particular Target 14.1 on preventing and significantly reducing pollution, Target 14.2 on strengthening ecosystem resilience, and Target 14.5 on marine protected areas. Interventions targeting wastewater treatment, afforestation and erosion management also contribute to delivering on SDG 6, Target 6.3 on halving the proportion of untreated wastewater, Target 6.6 on restoring water-related ecosystems as well as SDG 15, Target 15.1 on restoring forests. The findings of the analysis can support efforts towards Target 14.7 on increasing economic benefits to Small Island Developing States from sustainable use of marine resources, Target 15.9 on integrating ecosystem and biodiversity values in planning and development processes as well as Target 15.a on increasing financial resources to conserve ecosystems. Action to enhance the health of coral reefs thus has a number of concrete societal and economic benefits, and contribute to progress towards the achievement of the SDGs.

Climate Change Poses Significant Risk and Adds Uncertainty

Efforts to preserve and enhance coral reef health must also be considered within the longer-term context of climate change, which presents an existential threat to reefs in many parts of the world. Even if the objectives of the Paris Agreement on climate change are achieved, as much as 90% of all coral reefs could be lost in the next 30 years (van Hooidonk et al, 2016; UN Environment, 2017, IPCC 2018). This highlights the urgent need to act on climate change so as to avoid global scale reef loss, and the loss of financial returns reefs can generate. Acting in parallel on local threats to coral reefs (including overfishing, erosion, and pollution) in order to maximise the resilience of reefs may at least for some time moderate climate impacts, and increase the likelihood that benefits can still be draw from reefs once the earth's climate has been stabilized. However, it is clear that climate change effects, including ocean warming as well as altered cyclone and rainfall patterns, add uncertainty to the analysis presented here.

Toward a Healthy Reef by 2030

The results of this study highlight that interventions targeting sustainable fisheries, wastewater management, and erosion management could have a significant and positive impact on the health or coral reefs and the reef-dependent economy. In Mesoamerica, the modelling suggests that a combination of sustainable fisheries, erosion management and wastewater management interventions could close 45% of the gap between the estimated value derived from a degraded and a healthy reef in Mesoamerica by 2030. Other policies would be required to close the remaining gap, but this result highlights that the goal of achieving significant improvements in coral reef health could be within reach. Similarly, in the Coral Triangle, the combination of interventions modelled could close 70% of the gap between the forecast economic value derived from a degraded and a healthy reef in 2030.

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TAKING ACTION

This paper shows a clear economic benefit to investing in healthy reefs, which can generate growth and protect livelihoods. Protecting and restoring coral reefs have clear economic benefits to the main sectors reliant on them, and to society as a whole. Because the coral reef economy is shared between many different actors, both private and public, and often spans different jurisdictions, solutions need to combine private and public interests and be specific to each place. Some solutions may be purely policy driven, whereas some areas provide opportunities to combine public solutions with private sector investments. Further action on the basis of this analysis may be guided by the following:

- A reef economy is a shared economy, and requires both public and private sectors to identify and collaborate on solutions.
- Educating businesses, citizens and tourists on the importance of the reefs to the economy, as well as their fragility, is critical to building a foundation for action.
- Policymakers can show the business case for protecting coral reefs and supporting their resilience, and work with the main private sector beneficiaries of the reefs to reduce pressures on them.
- Policy and economic instruments can be used to drive solutions. Some of the most cost-effective solutions to protecting reefs may be found in 'non-reef sectors' such as agriculture, and there are opportunity costs associated with all interventions. Policies may therefore be devised to partially redistribute wealth captured by the private sector in order to support implementation of interventions and to compensate stakeholders adversely affected by changes in coral reef management.
- Considering the broader societal benefits of protecting reefs can support public sector decision making. All but one of the solutions analysed here produce a positive return on investment and are therefore viable from a purely economic perspective, without consideration of the numerous additional societal benefits they bring. Explicitly considering such additional societal benefits will nonetheless be important in the context of establishing public policy, development and environmental management strategies, and investigation of additional potential interventions.
- Adopting appropriate business strategies within reef-dependent sectors can enhance the value of the reef as an asset to those sectors. For example, tourism and coastal development sectors can use sustainable solutions involving low impact, high value tourism and developments with low environmental footprints, whereas commercial fisheries can work with governments to set suitable limits on catch, methods and areas of operations that support sustainable fisheries.
- Closer study and piloting interventions may unlock additional solutions and benefits. Identifying the most promising solution to resilient reefs through economic analysis of private sector operations, combined with policy interventions, can get us a large part of the way to an optimal reef state.
- There is still a resilience gap. While potential returns from sustainable coral reef management and use are significant, long-term financial gains are unlikely to materialise unless climate change is successfully tackled. Collective global action on climate change is therefore critically needed in order to protect and grow the reef economy using local efforts as described here.

Annex 1: Key limitations

Key limitations of the study methodology are discussed below.

Transferability of Reef-Sector Relationships

The analysis relies on published research estimating the relationship between a measure of coral reef health and an indicator of relevance to the economic returns generated from the reef. In some cases, this research was not conducted in either of the case study regions and thus the relationship was assumed transferable to other locations.

Linear Rate of Recovery Toward Healthy Reef Status

The Healthy Reef Scenario is defined in terms of a future level of live coral cover that is assumed would be achieved by 2030 in each case study. In the absence of data on the typical recovery 'curve' for a coral reef, a linear improvement in reef health was assumed for the period to 2030.

Feedback and Non-Linear Effects

The scope of this analysis and the available data do not allow for the modelling of feedback effects that may influence future coral reef health under different scenarios or in intervention combinations.

Coral Health Assessment

This study uses average live coral cover as a measure of coral reef health across each of the case study regions due to its wide application in published scientific studies and the availability of data. Live coral cover is identified as an Essential Ocean Variable by the Global Ocean Observing System due to its relevance, feasibility and cost effectiveness as a measure of important attributes of ocean health (GOOS, n.d.). While coral cover is a useful metric, it may not necessarily reflect all aspects of reef health and, as a regional average, does not reflect local variation in coral health within a broader region.

Scope

This study is limited to the assessment of the economic linkages between coral reefs and three key sectors but does not fully capture indirect links to other sectors and thus is likely to underestimate the true business value of the reef.

Fishery Sector Scope

This study focused on commercial fishing of reef- associated species but did not consider small-scale and artisanal fishing for which data was less readily available. As such, the study does not cspture the economic and significant social value of artisanal fishing to coastal communities.

Socioeconomic and Environmental Co-Benefits

This study focused on the economic returns to the private sector from coral reefs but did not consider the broader, and potentially much larger, socioeconomic and environmental benefits of coral reef ecosystems. The results should therefore be taken as indicative of just one component of the value of coral reefs to society.

Annex 2: Methodology and data sources

This analysis seeks to assess the potential impact of future trajectories for coral health in the Coral Triangle and the Mesoamerican Reef, on economic returns to three key reef dependent sectors: tourism; commercial fisheries; and coastal development. To achieve this goal, two plausible future scenarios were created to represent:

- **A Healthy Reef Scenario** in which coral reef health improves over time to achieve a healthy state determined based on other scientific studies.
- **A Degraded Reef Scenario** in which coral reef health continues to decline in line with historical trends. This scenario represents a continuation of business as usual.

The difference between these two scenarios represents the potential economic benefits in each case study location of working toward healthy and sustainable coral reef ecosystems.

To help inform a roadmap to achieving healthy coral reefs in the future, a series of interventions were developed and modelled to assess their potential impact on coral reef health and economic returns to each key sector. The cost of implementing and maintaining each intervention as well as the returns it would provide were modelled to provide an estimate of the net economic benefits of action to protect coral reefs. Each intervention may contribute to mitigating coral reef decline and improving coral reef status in the future – moving toward the goal of achieving a Healthy Reef Scenario.

Scenario Analysis

Future scenarios for coral reef health were defined for each of the two case study locations. In each case, live coral cover was adopted as a more broad representative metric for coral reefs. This metric was chosen as live coral cover is associated with many of the valued attributes of coral reefs (such as fishery production and aesthetic values) and because live coral cover is often used to measure the impact of stressors or interventions on coral reefs in academic literature. Changes in live coral cover, presented as a three-year moving average to adjust for short-term variation, are provided in Table 10 for both the Healthy and Degraded Reef Scenarios.

KEY SECTORS

The following section describes the methods utilised to model the economic returns and losses to each key sector under the Healthy and Degraded Reef Scenarios.

Commercial Fisheries Sector

Trucost estimated the fishery yields from reef-dependent commercial fisheries based on total fishery catch data from the FAO (n.d.) and the share of reef-associated species in the total catch – 40% for Mesoamerica (Teh, Teh and Sumaila, 2013) and 30% for the Coral Triangle (ADB, 2014). The average value of fishery production per tonne was estimated based on data from the FAO (n.d.) and inflated for future years based on long-range GDP growth forecasts by the OECD (2012). Changes in the value of capture fisheries were modelled based on an estimate of the inverse relationship between coral loss and reef fishery productivity detailed in Sale et al (2014). This enables the estimation of changes to total capture fishery production associated with increasing (Healthy Reef Scenario) or declining (Degraded Reef Scenario) live coral cover.

Table 10. Healthy and Degraded Reef Scenarios: Live Coral Cover

Year	Mesoamerican Reef		Coral Triangle	
	Degraded Reef Scenario	Healthy Reef Scenario	Degraded Reef Scenario	Healthy Reef Scenario
2017	3.7%	3.7%	16.6%	16.6%
2018	3.6%	4.0%	16.4%	17.2%
2019	3.4%	4.6%	16.0%	18.3%
2020	3.2%	5.4%	15.4%	19.9%
2021	2.9%	6.3%	14.9%	21.6%
2022	2.7%	7.2%	14.4%	23.2%
2023	2.6%	8.0%	13.9%	24.8%
2024	2.4%	8.9%	13.4%	26.5%
2025	2.2%	9.8%	13.0%	28.1%
2026	2.1%	10.6%	12.6%	29.8%
2027	1.9%	11.5%	12.1%	31.4%
2028	1.8%	12.4%	11.7%	33.1%
2029	1.7%	13.2%	11.3%	34.7%
2030	1.6%	14.1%	11.0%	36.4%

Direct economic returns were estimated based on forecast capture fishery production and average prices per tonne in each region, adjusted for inflation. Indirect economic multipliers associated with fisheries sector growth or contraction were modelled based on data from Jacobsen, Lester and Halpern (2014).

Table 11 outlines the key assumptions and data sources included in the commercial fisheries sector model.

Coastal Development Sector

Coral reefs provide economically significant benefits for people living near coasts and the coastal development sector. The Nature Conservancy (2017) estimates that approximately $6 billion of property and infrastructure is protected from flooding each year by coral reefs. In terms of flooding and shoreline protection alone, reefs are incredibly valuable for reducing the magnitude of incoming waves and storm surges. Reefs typically reduce the energy of incoming waves by 75-97% and currently protect more than 150,000km of shoreline in 106 countries and territories (Burke et al., 2011; The Nature Conservancy, 2017). A study by the World Resources Institute estimated that degradation of reefs could lead to annual losses of $140 million to $420 million of coastal infrastructure and property within the next 50 years (Burke and Maidens, 2004).

Trucost estimated the economic value of coral reefs to the coastal development sector in two key areas: the value of coastal built assets protected by coral reefs; and changes in investment in coastal infrastructure associated with changes in inbound tourist numbers.

Trucost utilised estimates by The Nature Conservancy (Spalding et al, 2016) of the total value of coastal assets protected per metre of coral reef height in each case study as a baseline estimate and inflated these values for future years based on long-range GDP growth estimates from the OECD (2012). Changes in the value of protected coastal assets were modelled based on the relationship between live coral cover and coral height – a key factor in reducing the energy of incoming waves. Trucost utilised data from a paper by Edinger et al (2000) to model the relationship between live coral cover and coral extension rate in millimetres per year. Greater live coral cover extent is associated with more rapid coral extension rate on average (Edinger et al, 2000). This relationship was used to model the change in the cumulative coral extension rate over the forecast period associated with increasing (Healthy Reef Scenario) or declining (Degraded Reef Scenario) live coral cover. The change in cumulative extension rate was used to estimate the change in the value of coastal assets protected by the reef over the forecast period.

Changes in direct investment in travel and tourism assets and infrastructure was estimated based on the historical ratio of international and domestic tourist spending to capital investment in travel and tourism infrastructure. This includes capital investments in all industry sectors directly involved in travel and tourism, plus investment by governments on infrastructure for use by the tourism sector. This ratio was calculated by Trucost using data from the WTTC (2017b; 2017c). Trucost combined this ratio with modelled changes in tourism sector revenue to estimate the associated direct changes in coastal development investment. Indirect economic multipliers associated with the construction of new coastal assets were modelled based on data from Oxford Economics (2010).

Table 11. Key Assumptions and Data Sources: Commercial Fisheries Sector

Key assumption / Data Source	Parameter	Justification	Sources
Baseline (2017) Reef-Associated Commercial Fisheries Yield – Indonesia	747,949 tonnes	Calculated by Trucost based on published data	FAO (n.d.)
Baseline (2017) Direct Value of Reef-Associated Commercial Fisheries – Indonesia	$2,925 million	Calculated by Trucost based on published data	FAO (n.d.) Trucost analysis
Reef-Associated Commercial Fisheries as a % of Total Sector Value – Indonesia	30%	Based on review of relevant literature	ADB (2014)
Baseline (2017) Reef-Associated Commercial Fisheries Yield – Mesoamerica	38,532 tonnes	Calculated by Trucost based on published data	FAO (n.d.)
Baseline (2017) Direct Value of Reef-Associated Commercial Fisheries – Mesoamerica	$240.2 million	Calculated by Trucost based on published data	FAO (n.d.) Trucost analysis
Reef-Associated Commercial Fisheries as a % of Total Sector Value – Mesoamerica	40%	Based on review of relevant literature	Teh, Teh and Sumaila (2013)
Relationship Between Live Coral Cover and Commercial Fisheries Yield	Linear Regression Model	Calculated by Trucost based on published data	Sale et al (2014)
Fisheries Economic Multiplier	2	Based on a review of relevant literature	Jacobsen, Lester and Halpern (2014)

Table 12 outlines the key assumptions and data sources included in the coastal development sector model.

Tourism

Trucost utilised estimates by the Nature Conservancy (Spalding et al, 2017) of the total value of on-reef and reef-adjacent tourist visits and associated revenues for each of the case study regions. On-reef tourism refers to activities directly associated with the reef, such as diving and snorkelling, while reef-adjacent tourism includes visits and spending by coastal tourists within 30km of the reef. Full details of the modelling methodology is described in Spalding et al (2017). Trucost inflated average spend per tourist for future years based on long-range GDP growth estimates from the OECD (2012) for countries in each case study region. Changes in inbound tourist numbers due to changes in coral reef health were modelled based on a study by Schuhmann et al (2017), which surveyed visitors to Barbados on their likelihood to return for future visits under varying degrees of positive or negative change in coral health. Trucost used this data to model the weighted average return rate for tourists visiting each case study location under the Healthy and Degraded Reef Scenarios. Estimated tourist numbers were combined with average tourist expenditure per visit to estimate the total revenue to the tourism sector under each scenario.

Indirect economic multipliers associated with the tourism sector were modelled based on data from Cesar (1996).

Table 13 outlines the key assumptions and data sources included in the tourism sector model.

Table 12. Key Assumptions and Data Sources: Coastal Development Sector

Key assumption / Data Source	Parameter	Justification	Sources
Baseline (2017) Value of Reef-Protected Coastal Assets – Mesoamerica	$452 million per 1 metre reef height	Includes Mexico only	Spalding et al (2016)
Baseline (2017) Value of Reef-Protected Coastal Assets – Indonesia	$639 million per 1m reef height	Includes Indonesia only	Spalding et al (2016)
Relationship Between Live Coral Cover and Coral Extension Rate	Linear Regression Model	Calculated by Trucost based on published data	Edinger et al (2000)
Ratio of Tourism Foreign Exports to Travel and Tourism Investment – Indonesia	0.22	Calculated by Trucost based on published data	WTTC (2017b)
Ratio of Tourism Foreign Exports to Travel and Tourism Investment – Mesoamerica	0.15	Calculated by Trucost based on published data	WTTC (2017c)
Construction Economic Multiplier	2.6	Based on a review of relevant literature	Oxford Economics (2010)

Table 13. Key Assumptions and Data Sources: Tourism Sector

Key assumption / Variable	Parameter	Justification	Sources
Baseline (2017) Reef-Associated Tourist Visits – Indonesia	16,474,122	Coral Triangle	Spalding et al (2017)
Baseline (2017) Reef-Associated Tourist Revenue – Indonesia	$3,113 million	Coral Triangle	Spalding et al (2017)
Average Expenditure per Tourist Visit (2017) – Indonesia	$188	Coral Triangle	Spalding et al (2017)
Baseline (2017) Reef-Associated Tourist Visits – Mesoamerica	3,023,813	Combined for Belize, Honduras and Yucatan, Mexico	Spalding et al (2017)
Baseline (2017) Reef-Associated Tourist Revenue – Mesoamerica	$3,484 million	Combined for Belize, Honduras and Yucatan, Mexico	Spalding et al (2017)
Average Expenditure per Tourist Visit (2017) – Mesoamerica	$999	Combined for Belize, Honduras and Yucatan, Mexico	Spalding et al (2017)
Relationship Between Live Coral Cover and Tourist Return Rate	Various	Calculated by Trucost based on published data	Schuhmann et al (2017)
Tourism Economic Multiplier	2	Based on a review of relevant literature	Cesar (1996)

INTERVENTION METHODOLOGIES

The following section describes the methodology and data sources applied when modelling a series of healthy reef interventions.

Constructed Wetlands for Enhanced Wastewater Management

Constructed Wetlands (CW) are engineered systems that have been designed to utilise natural processes to aid in the treatment of wastewater (Verhoeven, 2006). CW can provide a cost-effective solution for the treatment of domestic (and other) wastewater. Trucost modelled the impact of the installation of constructed wetlands to treat 50% of the currently untreated wastewater in each case study region, removing excess phosphorus along with other common wastewater pollutants. CW installations are capable of removing an average of 62% of the phosphorus content of wastewater (Liu et al, 2009). Excess phosphorus concentrations in coastal environments are associated with reduced live coral cover (Liu et al, 2012) and thus phosphorus outflows were utilised to model the impact of improved wastewater treatment on live coral cover. While other wastewater pollutants are likely to impact upon coral reef health, it was not possible to distinguish the contribution of each pollutant to the negative stress on coral health.

Trucost estimated the quantity of untreated wastewater produced in each case study location based on data from the FAO AQUASTAT database (FAO, 2006) and apportioned this to the reef-adjacent coastal regions based on population (World Bank, 2018a). Trucost assumed that CW installations of sufficient capacity to treat half of the currently untreated wastewater would be installed and modelled the resulting change in phosphorus outflow and estimated coastal phosphorus concentration. The impact of reduced phosphorus loads on live coral cover was estimated based on Liu et al (2012) and used to model the impact of the CW intervention on economic benefits to the tourism, commercial fisheries and coastal development sectors. Live coral cover is assumed to recover over a period of seven years, slowly initially and then more rapidly in later years, based on Halford et al (2004).

Trucost estimates that CW installations totalling 6,446 hectares in area would be required in Indonesia to treat 756 million m^3 of untreated wastewater in the coastal region surrounding the Coral Triangle. CW installations totalling 239 hectares in area would be required in Mesoamerica to treat 27 million m^3 of untreated wastewater in the reef-adjacent region. Installation and operational costs associated with the CW intervention were modelled based on data published in Tsihrintzis et al (2007) and adjusted for inflation (World Bank, 2018b; OECD, 2012) and purchasing power parity (World Bank 2018c). Construction costs are estimated at $95 billion and $2.3 million for Mesoamerica and Indonesia, respectively, and operational costs are estimated at $1 million and $25 million, respectively, per annum (in 2017 prices).

Key assumptions and sources used to model this intervention are presented in Table 14.

Expansion of No-Take Marine Protected Areas

No-Take Zones (NTZ) are marine protected areas in which fishing, mining and all other extractive activities are prohibited. NTZs provide a protected habitat to support the regeneration of fish populations and increases in fish biomass due to reduced fishing pressure. Increasing fish populations within NTZs may spill over to surrounding fisheries (Brock and Mereles, n.d.), increasing fishery yields, and can aid in the recovery of live coral cover over time (Magdaong et al, 2014).

In this intervention, Trucost modelled the impact and potential benefits of expanding NTZs to cover 30% of the total marine protected area in the Coral Triangle and Mesoamerican Reef. Key costs of implementing a NTZ include the incremental cost of monitoring and enforcement and the opportunity cost of foregone fisheries associated with the reduced fishery area. Over time, fishery production is expected to partially recover

Table 14. Key Assumptions and Sources: Constructed Wetlands for Enhanced Wastewater Management

Key assumption / Variable	Parameter	Justification	Sources
Baseline Untreated Wastewater Per Annum – Indonesia	1,512 million m^3	Trucost calculated based on published data	FAO (2006)
Baseline Untreated Wastewater Per Annum – Mesoamerica	54.7 million m^3	Trucost calculated based on published data	FAO (2006)
Constructed Wetlands Phosphorus Removal Rate	62%	Based on a review of relevant literature	Liu et al (2009)
Relationship Between Coastal Phosphorus Concentration and Live Coral Cover	Exponential function	Trucost calculated based on published data	Liu et al (2012)
Constructed Wetlands Installation Costs – Indonesia (2017)	$546 per capita served	Trucost calculated based on published data	Tsihrintzis et al (2007)
Constructed Wetlands Operational Costs – Indonesia (2017)	$0.03 per m^3 treated	Trucost calculated based on published data	Tsihrintzis et al (2007)
Constructed Wetlands Installation Costs – Mesoamerica (2017)	$371 per capita served	Trucost calculated based on published data	Tsihrintzis et al (2007)
Constructed Wetlands Operational Costs – Mesoamerica (2017)	$0.04 per m^3 treated	Trucost calculated based on published data	Tsihrintzis et al (2007)

due to spillover of fish biomass from the NTZ into the surrounding waters, and live coral cover within the NTZ is expected to improve with benefits for the tourism and coastal development sectors. Key assumptions and sources used to model this intervention are presented in Table 15.

Methodology Summary

Trucost modelled reef-associated fishery yield and production value in each case study before and after the expansion of NTZ areas (to 30% of the total marine protected area) based on the average productivity per square kilometre and the fishable area. Fish biomass was modelled to increase within the NTZ over 10 years based on data from Lester et al (2009) and spillover into the surrounding fishery at a rate of 9.5% per annum based on Ounboundisane et al (n.d.). The net change in yield, including production foregone and the additional spillover catch due to the NTZ, was calculated as the total opportunity cost for the fisheries sector of the expanded NTZ intervention. Monitoring and enforcement costs were modelled based on the additional area of NTZ created under the intervention and the marginal additional cost of monitoring and enforcement for marine protected areas of equivalent size based on McCrea-Strub et al (2011).

Establishment of an NTZ is associated with recovery of live coral cover within the zone. Increases in live coral cover within the NTZ were modelled based on Magdaong et al (2014) and used to estimate the benefits accruing to the tourism and coastal development sectors based on the models described in the scenario analysis section.

Table 16. Mapped Datasets Used in Land Use Modelling

Mapped Variable	Source
Global Soil Texture Class Raster	IIASA/FAO (2008)
Monthly Rainfall Raster	WorldClim (n.d.)
Land Cover Raster	ESA (2005)
Topographic Slope Raster	IIASA/FAO (2008)
Coral Triangle Boundary Polygon	Coral Triangle Atlas (n.d.)
Country Maritime Boundary Polygon	VLIZ (2016)
Mesoamerican Reef Area Polygon	Trucost Analysis
Indonesia Country Boundary Polygon	GADM (n.d.)
Belize Country Boundary Polygon	GADM (n.d.)
Mexico Country Boundary Polygon	GADM (n.d.)
Honduras Country Boundary Polygon	GADM (n.d.)

Land Use Interventions

In order to model the effect of changes in land use and land management, Trucost undertook a GIS-based analysis of land cover in coastal regions surrounding the Coral Triangle and the Mesoamerican Reef case study areas. This analysis was used to estimate the weighted average sedimentation rate in each area before and after the implementation of each intervention. Sedimentation rate is correlated with live coral cover (Pastorok and Bilyard, 1985) and thus it is possible to model changes in revenues to key sectors in response to improving reef health. Table 16 describes the mapped datasets used in the GIS analysis.

Table 15. Key Assumptions and Sources: No-Take Marine Protected Areas

Key assumption / Variable	Parameter	Justification	Sources
Target NTZ Extent as a % of Total Marine Protected Area	30%	Trucost assumption	Trucost
Average Fishery Productivity – Indonesia	60 tonnes/km^2	Trucost calculated based on data from the FAO	Trucost
Average Fishery Productivity – Mesoamerica	32 tonnes/km^2	Calculated based on estimates by the Healthy Reefs for Healthy People Initiative	FAO (n.d.)
Target NTZ Area – Mesoamerica	2,965km^2 (630km^2 additional)	Calculated by Trucost at 30% of total marine protected area	Trucost
Target NTZ Area – Indonesia	2,965km^2 (630km^2 additional)	Calculated by Trucost at 30% of total marine protected area	Mcfield et al (2007)
Increase in Fish Biomass within NTZ Over 10 Years	446%	Published estimate	Lester et al (2009)
Fish Biomass Spillover Rate from NTZ to Surrounding Fisheries	9.5%	Published estimate	Nunes et al (2017)
Annual Incremental Increase in Live Coral Cover within NTZs	2.5%	Published estimate based on a meta- analysis of marine protected areas in the Philippines	Magdaong et al (2014)
Monitoring and Enforcement Costs – Indonesia	\$101 per km^2 (US\$ 2017)	Published analysis of monitoring and enforcement costs for marine protected areas of various sizes	Ounboundisane et al (n.d.)
Monitoring and Enforcement Costs – Mesoamerica	\$934 per km^2 (US\$ 2017)	Published analysis of monitoring and enforcement costs for marine protected areas of various sizes	McCrea-Strub et al (2011)

Afforestation Projects on Non-Agricultural Land to Reduce Sediment Run-Off

Erosion rates on land with forest cover are typically significantly lower than other land cover types, such as cropland or mosaic vegetation. Investments in afforestation and reforestation projects to increase forest cover in the coastal regions surrounding the Coral Triangle and Mesoamerican Reef may be an effective means of reducing sediment inflows into coastal waters. Since sediment can adversely affect coral health, afforestation projects could have a positive impact on improving live coral cover and coral reef health.

In this intervention, Trucost modelled the implementation of afforestation projects to increase the share of forest land cover within 5.8 km of the coastline (by 20% in Indonesia and 10% in Mesoamerica) compared to current levels. Afforestation was modelled to occur on non-agricultural land and would instead displace grassland and shrubland. The average sedimentation rate across the two case study regions was modelled before and after the implementation of afforestation and used to estimate changes in the sedimentation rate at the coast. The impact of reduced sedimentation on live coral cover was estimated and utilised to estimate the resulting benefits to the tourism, commercial fisheries and coastal development sectors. Key assumptions and sources used to model this intervention are presented in Table 17.

Methodology Summary

Trucost modelled the distribution of land cover types (using QGis) within 5.8km of the coastline surrounding the Coral Triangle and the Mesoamerican Reef. Land greater than 5.8km from the coast was deemed unlikely to contribute significantly to the coastal sedimentation rate (Soranno et al, 1996). Mapped datasets used to model land use are described in Table 16. The RUSLE equation (WRI, 2016) was used to estimate the erosion rate associated with each land cover type in each region, and then calculate a weighted average erosion rate for the region as a whole. To model the impact of afforestation project implementation, Trucost modelled a shift in land cover from grassland and shrubland to forest cover and recalculated the weighted average erosion rate for the region.

The change in sedimentation rate was used to model the change in live coral cover within each case study region based on a relationship between sedimentation rate and live coral cover defined in Pastorok and Bilyard (1985). Live coral cover is assumed to recover over a period of seven years, slowly initially and then more rapidly in later years, based on Halford et al (2004). The estimated change in live coral cover is then used to estimate the benefits accruing to the tourism, fisheries, and coastal development sectors based on the models described in the scenario analysis section.

Afforestation project establishment and maintenance costs were estimated based on published data from Kroeger et al (2014) and TEEB (2009) and adjusted for inflation and purchasing power parity exchange rates in each country. Opportunity costs were assumed zero since afforestation did not displace agricultural land.

Vegetative Filter Strips on Cropland to Reduce Sediment Run-Off

Vegetative Filter Strips (VFS) are areas of permanent vegetation located between agricultural land, or other forms of disturbed land, and the waterways into which they drain (Helmers et al, 2008). VFS are intended to intercept and slow the movement of

Table 17. Key Assumptions and Sources: Afforestation for Erosion Prevention

Key assumption / Variable	Parameter	Justification	Sources
Target % Increase in Coastal Forest Cover	20% Indonesia 10% Mesoamerica	Trucost assumption	Trucost
Total Area of Land Dedicated to Afforestation Projects – Indonesia	1.7 million hectares (9% of coastal land area)	Calculated by Trucost based on current land cover shares	Trucost See Table 16
Total Area of Land Dedicated to Afforestation Projects – Mesoamerica	176,934 hectares (7% of coastal land area)	Calculated by Trucost based on current land cover shares	Trucost See Table 16
Forest Growth Period – Indonesia	32 years	Average growth period for common tree species in Indonesia	FAO (2009)
Forest Growth Period – Mesoamerica	10 years	Average growth period for common tree species in Mesoamerica	Alix-Garcia et al (2009)
Cropland Retirement Opportunity Costs – Coral Triangle	Nil	Afforestation exclusively on non- agricultural land to minimise opportunity costs	Trucost
Cropland Retirement Opportunity Costs – Mesoamerican Reef	Nil	Afforestation exclusively on non- agricultural land to minimise opportunity costs	Trucost
Afforestation Project Establishment Costs	\$0.02-\$0.03 per m^2	Establishment cost estimate from the literature for seedlings	Kroeger et al (2014)
Afforestation Project Maintenance Costs per Annum	\$0.002 per m^s	Estimated at 10% of establishment costs	TEEB (2009)

sediments and other pollutants in surface water run-off with a view to improving water quality. Reducing the sedimentation rate and improving surface water quality may aid in reducing the negative impact of sediment on live coral cover in nearby marine environments.

In this intervention, Trucost has modelled the implementation of VFS on irrigated and rain fed cropland located within 5.8km of the coast and estimated the reduction in average sedimentation across the coastal region surrounding each of the case study locations. The impact of reduced sedimentation on live coral cover was estimated and utilised to estimate the resulting benefits to the tourism, commercial fisheries and coastal development sectors. Key assumptions and sources used to model this intervention are presented in Table 18.

Methodology Summary

Trucost modelled the distribution of land cover types (using QGis) within 5.8km of the coastline surrounding the Coral Triangle and the Mesoamerican Reef. Land greater than 5.8km from the coast was deemed unlikely to contribute significantly to the coastal sedimentation rate (Soranno et al, 1996). Mapped datasets used to model land use are described in Table 16. The RUSLE equation (WRI, 2016) was used to estimate the erosion rate associated with each land cover type in each region, and then calculate a weighted average erosion rate for the region as a whole. To model the impact of VFS implementation, Trucost adjusted the modelled erosion rate on irrigated and rain fed crop land cover types based on the assumptions detailed in Table 18, and then calculated a weighted average for the region.

The change in sedimentation rate was used to model the change in live coral cover within each case study region based on a relationship between sedimentation rate and live coral cover defined in Pastorok and Bilyard (1985). Live coral cover is assumed to recover over a period of seven years, slowly initially and then more rapidly in later years, based on Halford et al (2004). The estimated change in live coral cover is then used to estimate the benefits accruing to the fisheries, tourism and coastal development sectors based on the models described in the scenario analysis section.

VFS establishment and maintenance costs were estimated based on data from the Toronto and Region Conservation Authority (2010), adjusted for purchasing power parity exchange rates in each country. Opportunity costs of retiring agricultural land for use as a VFS were estimated based on an analysis of the weighted average producer price for the top 10 crops produced in each case study country (based on data from the FAO (2017)).

Table 18. Key Assumptions and Sources: Vegetative Filter Strips for Erosion Prevention

Key assumption / Variable	Parameter	Justification	Sources
Ratio of Catchment Area to VFS	50:1	Midpoint estimate from the literature	Helmers et al (2008)
% Adoption of VFS on Irrigated and Rain Fed Cropland	50%	Trucost estimate of reasonable adoption rate	Trucost
Reduction in Sedimentation Rate Due to VFS	50%	Midpoint estimate from the literature	Helmers et al (2008)
Lag in VFS Effectiveness Post-Establishment	Year 1: 50% Year 2: 75% Post-Year 2: 100%	Trucost assumption – data is limited in the literature	Trucost
VSF Establishment Cost	\$3.23-\$3.61 per m²	Literature estimate adjusted for inflation and purchasing power parity	Credit Valley Conservation (2010) World Bank (2018b; 2018c)
VFS Annual Maintenance Costs	\$0.4-\$0.6 per m² / year	Literature estimate adjusted for inflation and purchasing power parity	Toronto and Region Conservation Authority (2010)
Cropland Retirement Opportunity Costs – Coral Triangle	\$0.25 per m²	Trucost calculation based on weighted average producer price of top 10 crops produced in Indonesia	FAO (2017) Trucost
Cropland Retirement Opportunity Costs – Mesoamerican Reef	\$0.07 per m²	Trucost calculation based on weighted average producer price of top 10 crops produced in Mexico, Belize and Honduras	FAO (2017) Trucost

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