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Beneficiaries and Sustainability of Rapid Response Reef Risk Financing in the MAR

Prepared by Willis Towers Watson and MAR Fund

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Supplementary Report:

Cost-Benefit Analysis Summary and Sensitivity Analysis

October 2019

Cost-Benefit Summary

Initial cost-benefit analysis shows that immediate response to reef damage by tropical cyclones at selected sites along the Mesoamerican Reef (MAR), which leads to a 50% improvement in the speed of the restoration of ecosystem services (i.e. a halving of the time to full service restoration), results in a cost-benefit ratio of close to 1:10, compared to no intervention.

While there is little evidence yet available to support some key assumptions, we believe this estimate to be robust given the very high value of the ecosystem services provided by coral reefs relative to the cost of re-instating those services more quickly via early, pro-active interventions after interruption through damage by tropical cyclones. This section documents the data and assumptions used to reach this conclusion.

Ecosystem service values and restoration costs for the MAR were derived from two studies:

- A valuation study prepared by the Prince of Wales' International Sustainability Unit, the United Nations Environment Programme, the International Coral Reef Initiative, and S&P Trucost Limited, an affiliate of S&P Dow Jones Indices LLC[1]; and
- A restoration cost study[2] prepared by Whiterock Natural Capital & Environment, consulting to the Reef Rescue Initiative of the MAR Fund, largely based on the Puerto Morelos Alert and Response Protocol[3].

The valuation study estimates the economic value of the entire Mesoamerican reef to tourism, commercial fisheries, and the coastal development sector. Table 1 summarises the values in terms of direct economic returns from the entire MAR in 2017.

To the commercial fishing sector	$240 million
To the tourism sector	$3,484 million
To the coastal development sector (protection value)	$975 million

Table 1 The direct economic value of the entire MAR in 2017, by sector[4]. Values in US$.

[1] UN Environment, ISU, ICRI and Trucost, 2018. The Coral Reef Economy: The business case for investment in the protection, preservation and enhancement of coral reef health.
[2] MAR Fund and Whiterock Natural Capital & Environment, 2019. Required actions, and their cost, for reef restoration and emergency response, after damages caused by hurricanes in selected reef sites of the MAR region. The study includes: 1. A description of the levels of damage, post-storm; 2. A description of the minimum and optimum restoration scenarios after the immediate response for each level of damage; 3. A description of the actions required by level of damage, according to ranges of effort in the designated sites. Because the costs may vary, depending on the distance from a site to the services required for the immediate response and damage repair, it was necessary to evaluate the costs for 7 demonstrative sites in the region.
[3] Zepeda-Centeno C., et al., 2019. Early Warning and Rapid Response Protocol: Actions to mitigate the impact of Tropical Cyclones on Coral Reefs. The Nature Conservancy. http://reefresilience.org/wp-content/uploads/Early-Warning-and-Rapid-Response-Protocol_compressed.pdf
[4] UN Environment, ISU, ICRI and Trucost, 2018. The Coral Reef Economy: The business case for investment in the protection, preservation and enhancement of coral reef health.

The restoration cost study calculates the cost of restoration for target reef sites; further details can be found in a summary presentation of the report cited above, which is provided as part of the materials accompanying this and its associated reports.[5] The aggregated cost of restoration of all of the selected reef sites is US$2,886,542, with the costs of immediate, optimal response following a severe hurricane differing for the various sites, ranging between the most inexpensive site, Punta de Manabique in Guatemala, at a cost of US$120,663, to US$564,971 for the most expensive site, Roatán in Honduras.

Key Assumptions

Using these values and costs, our cost-benefit calculation (the simple model for which also accompanies this supplementary report) is underpinned by the following assumptions. Given the lack of data to do better, our assumptions are made based on looking at all selected sites in the aggregate.

- Based on the characteristics of the selected reef sites, in total they have been estimated to account for a proportion of the ecosystem services of the entire MAR as follows:
  - Fishing sector - 5% of the total economic returns for the full MAR;
  - Tourism sector - 1% of the total returns; and
  - Coastal development sector (protection value to terrestrial assets) - 1% of the total returns.

  Table 2 summarises these ecosystem service values to each key sector.

Sector	Annual value provided by the entire MAR	Monthly value provided by the reef sites
Fishing	$240,000,000	$1,000,000
Tourism	$3,484,000,000	$2,903,333
Coastal Development	$975,000,000	$406,250
Total	**$4,699,000,000**	**$4,309,583**

Table 2 Value of the ecosystem services provided by the reef, by sector and geography. Values in US$.

- The aggregated cost of restoration of all of the selected reef sites is used to calculate the cost of intervention, as the value of the benefits of the reef is also aggregated across all of the selected sites.
- Reefs are restored to their pre-hurricane state 50% more quickly with proactive early response following a hurricane than with no intervention.

[5] Because the selection of the pilot sites in Mexico was finalised after this cost analysis had initiated, one of the sites, Xcalak, is not included in the analysis. The full study considered more than the seven pilot sites, collecting a variety of data on the restoration costs for different type of sites (i.e. very near to shore, further off shore, etc.) for demonstration purposes and to inform the development of a simple tool that calculates the restoration costs for any potential site. That tool calculates the response costs based on the percentage of live coral cover and is also available on request.

- Ecosystem services are restored at different rates depending on the sector, as described below:
  - Fishing sector - a binary function is used, which fully reinstates the ecosystem service value after a selected portion of the full reef recovery time has passed. In the base case, ecosystem services to the fisheries sector are fully restored after 70% of full recovery time has elapsed following a hurricane, meaning there are no services being provided for the first 70% of the recovery period and full services are provided for the last 30%;
  - Tourism sector - a linear function is used, such that the value of ecosystem services provided increases linearly through the full recovery period, meaning that half way through the recovery period, half the ecosystem service value is being provided; and
  - Coastal development sector (including coastal protection) - a stepped function is used, as outlined in Table 3.

% time to full recovery	% of value restored
0%	10%
25%	25%
50%	50%
75%	100%

Table 3 Timeline for the restoration of ecosystem services to the coastal development sector.

The rationale for using different approaches to restoring ecosystem service value across different sectors is summarised below. We note that any of the three approaches used could be applied to any of the three main sectors benefiting from the reef, depending on local circumstances and, further, the parameters of the binary and stepped function approaches can also be adjusted to reflect local circumstances.

- Fisheries sector: While there is little good data on the recovery profile of reef / nearshore fisheries after hurricanes, the MAR Fund's Reef Rescue Initiative itself, and similar approaches being developed elsewhere, make an assumption that applying no-take rules to reef areas after hurricane damage supports faster and more comprehensive reef recovery. The use of a binary function in our analysis captures this assumption; while a no-take zone is enforced, there is no value being provided by the reef to the fisheries sector, but when that no-take zone is removed, the reef immediately is able to provide full value to the fisheries sector, even while it completes its full recovery.
- Tourism sector: We use a linear function here, to represent the fact that different tourism uses will be differently impacted by damaged reefs. Some specialist tourism sectors – especially those supporting the proactive interventions to aid reef recovery – will be fully functioning immediately, while others will take longer to recover depending on both the extent of reef recovery and the re-invigoration rate of the tourism market in the impacted area.
- Coastal Development sector: We use a stepped function here, to reflect the fact that there are a only a few characteristics of a reef which dictate the protection value that reef provides, and in

recognition that coastal infrastructure itself is likely to be of less value immediately after a hurricane (meaning that the protection provided by the reef is less 'valuable').

Results

Table 4 contains the results of the simple cost-benefit analysis based on the input data and assumptions described above. The benefit to immediate response materialises through the earlier re-instatement of ecosystem services provision – and therefore value - thanks to quicker reef recovery.

Cost of Response	$2,886,542
Benefit of immediate response	$28,040,313
Cost Benefit Ratio of early response	**1 : 9.7**

Table 4 Summary of cost-benefit analysis. Values in US$.

Sensitivity Analysis

Here we present a sensitivity analysis of our cost-benefit calculations for the assumptions with the least supporting literature and data available- namely the timing of ecosystem service restoration.

Timing of ecosystem service restoration

Overall reef restoration time

Base-case assumption: Reefs are restored 50% more quickly with early response following a hurricane than with no intervention

While the main Beneficiary report outlines the evidence available to support the quantification of the benefits of early response, there is no data available to support the direct comparison of early response and 'no intervention' in terms of the time it takes for the reef to recover to its pre-hurricane state. Therefore, we have assumed, in our base case, that early response would result in complete recovery of the reef at a rate that is 50% faster than with no intervention. Put differently, we assume that early intervention halves the time to full reef recovery.

The cost-benefit results are, obviously, extremely sensitive to the assumption that early response does in fact decrease reef recovery time, compared to 'no intervention.' To demonstrate the degree of sensitivity, Table 5 shows the cost-benefit ratios associated with various 'recovery time improvement percentages,' all other assumptions remaining the same as in the base case described above.

Recovery time improvement percentage ***(% improvement in recovery time with early response vs. no intervention)***	**Cost-benefit ratio** **(*cost of early response : cost of no intervention)***
10% (9 months instead of 10)	1 : 1.7
25% (9 months instead of 12)	1 : 4.8
75% (3 months instead of 12)	1 : 14.5

Table 5 Sensitivity of cost-benefit ratio to recovery time ratio.

Service restoration timing

Here we are looking at the assumptions around the re-instatement of ecosystem service provision – and therefore value provision – relative to the recovery rate of the reef itself. In our model, the timing of ecosystem service restoration is applied individually to each sector to which service is provided, and, for each, is sensitive to two assumptions:

- The type of ‘restoration timing function’ that is assumed (i.e. linear, binary, or stepped); and
- The particular restoration timing of that function.

Table 6 presents the results of a sensitivity analysis testing the effect on the cost-benefit ratio of a range of options within each type of restoration timing function. For this testing, we have applied the same timing function to all three sectors; all other assumptions are as per the base case.

<table>
<tr><th>Function type</th><th>Restoration timeline</th><th>Cost-benefit ratio</th></tr>
<tr><td>Linear</td><td>Value increases from 0% on day 1 to 100% at full recovery</td><td>1 : 9</td></tr>
<tr><td>Binary 1</td><td>Value switches from 0% to 100% at 75% of recovery</td><td>1 : 13.4</td></tr>
<tr><td>Binary 2</td><td>Value switches from 0% to 100% at 50% of recovery</td><td>1 : 9</td></tr>
<tr><td>Binary 3</td><td>Value switches from 0% to 100% at 25% of recovery</td><td>1 : 4.5</td></tr>
<tr><td>Stepped 1</td><td>Value increases in steps, non-linearly, as defined below:
<table>
<tr><th>% of time to full recovery</th><th>% of value restored</th></tr>
<tr><td>0%</td><td>0%</td></tr>
<tr><td>25%</td><td>10%</td></tr>
<tr><td>50%</td><td>25%</td></tr>
<tr><td>75%</td><td>50%</td></tr>
<tr><td>100%</td><td>100%</td></tr>
</table></td><td>1 : 14.1</td></tr>
<tr><td>Stepped 2</td><td>Value increases in steps, non-linearly, as defined below:
<table>
<tr><th>% of time to full recovery</th><th>% of value restored</th></tr>
<tr><td>0%</td><td>0%</td></tr>
<tr><td>25%</td><td>50%</td></tr>
<tr><td>50%</td><td>75%</td></tr>
<tr><td>75%</td><td>90%</td></tr>
<tr><td>100%</td><td>100%</td></tr>
</table></td><td>1 : 8.3</td></tr>
<tr><td>Stepped 3</td><td>Value increases in steps, non-linearly, as defined below:
<table>
<tr><th>% of time to full recovery</th><th>% of value restored</th></tr>
<tr><td>0%</td><td>0%</td></tr>
<tr><td>25%</td><td>10%</td></tr>
<tr><td>50%</td><td>50%</td></tr>
<tr><td>75%</td><td>90%</td></tr>
<tr><td>100%</td><td>100%</td></tr>
</table></td><td>1 : 11.2</td></tr>
</table>

Table 6 Cost-benefit sensitivity to function and timing of ecosystem service restoration.

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