



Required actions, and their cost, for reef restoration and emergency response, after damages caused by hurricanes in selected reef sites of the MAR region





INTRODUCTION

BACKGROUND

MAR Fund proposes a parametric insurance to cover the costs for the reparation of damages on hurricane-impacted reefs at key sites across the Mesoamerican Reef System (MAR) region

The design of this insurance requires a list of specific (short- and medium-term) intervention actions largely based on the Puerto Morelos Alert and Response Protocol

To adequately design this insurance, it is critical to determine the costs of all intervention actions

White Rock was engaged to determine the above-mentioned inputs on selected "model" locations throughout the four MAR countries

CURRENT PROTOCOL

Zepeda-Centeno C., Nava-Martínez G., García-Salgado MA. 2018. **Protocolo de alerta temprana y respuesta inmediata al impacto de los ciclones tropicales en los arrecifes del Parque Nacional Arrecife de Puerto Morelos: Acciones para mitigar el impacto de los ciclones tropicales en los arrecifes coralinos.** The Nature Conservancy. 82 p

Prior to Hurricane

1 PLANNING AND PREPARATION

2 EARLY ALERT

PRELIMINARY ACTIONS

Training of emergency response team, elaboration of vulnerability map, purchase and storage of material and equipment necessary for the intervention

After Hurricane Impact (Damage Repair Protocol)

3 RAPID ASSESSMENT OF DAMAGES



1 to 5 days after hurricane impact

4 PRIMARY RESPONSE



6 to 30 days after hurricane impact

5 SECONDARY RESPONSE



30 after hurricane impact

OBJECTIVES

To select "model" locations at the four MAR countries for estimating the cost of actions aimed at repairing damages caused by hurricanes on reefs

To define impact categories describing damages caused by hurricanes as based on quantitative descriptors suggested by experts.

To define intervention scenarios or level of damage reparation

To determine specific activities for each stage of the intervention protocol: Immediate Response, Primary Response, Secondary Response and Medium-Term Response

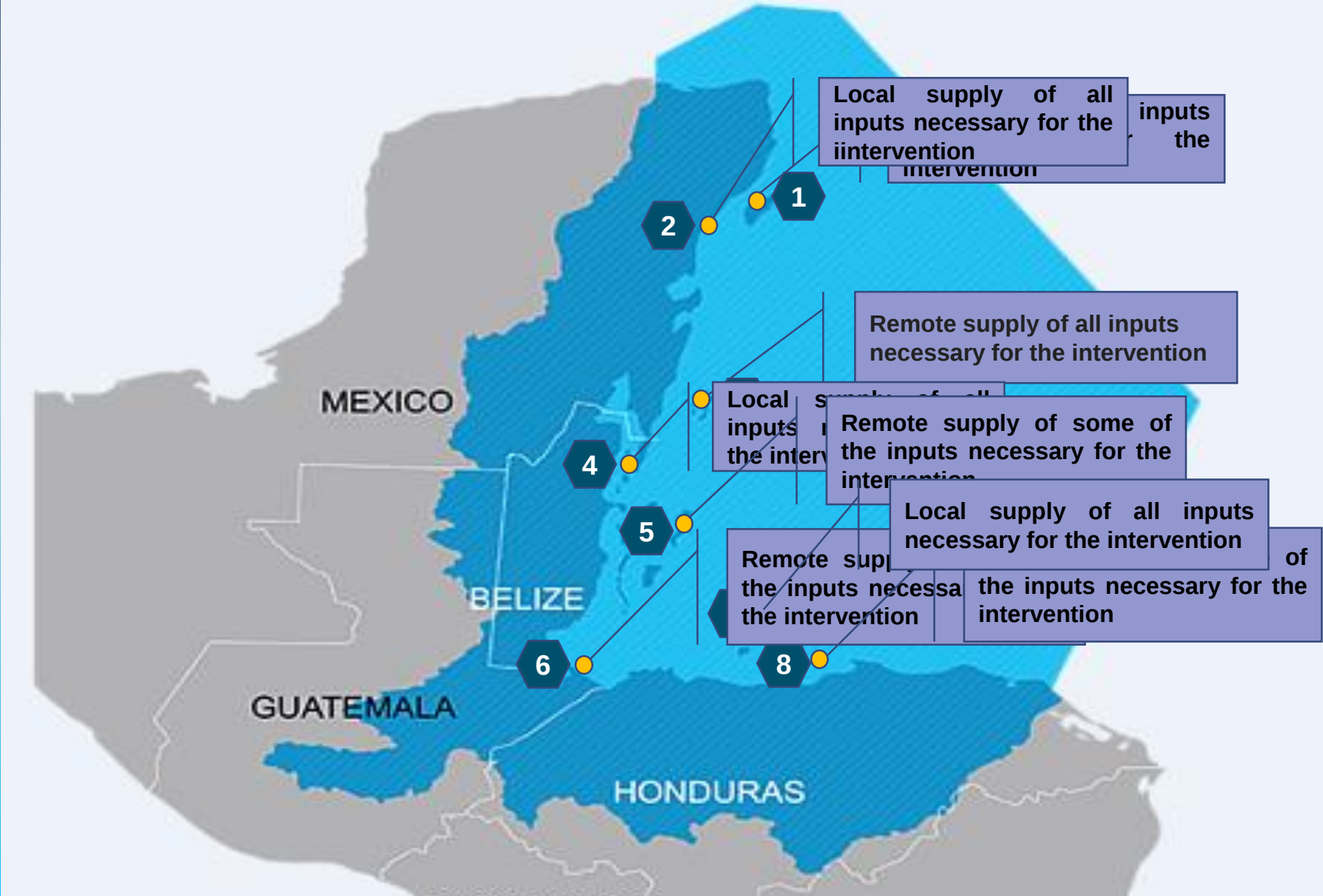
To determine the costs of all activities for all impact categories and intervention scenarios

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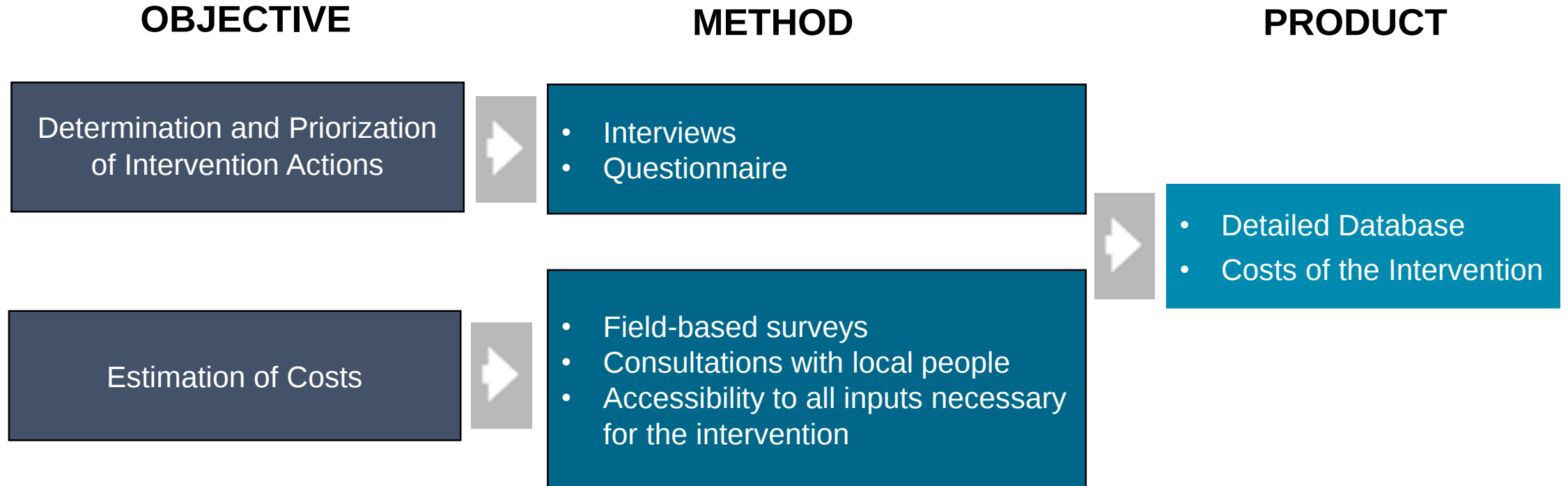
METHODOLOGY

SELECTED “MODEL”
LOCATIONS

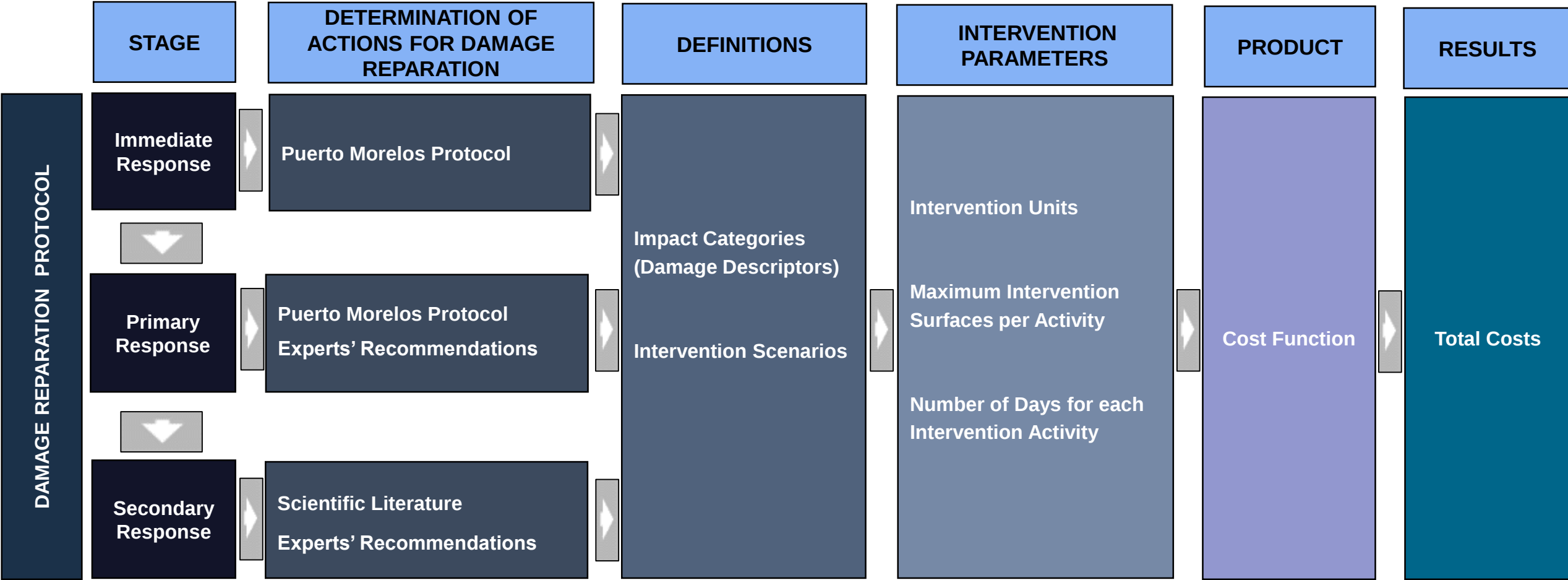
- 1. Cozumel
- 2. Akumal
- 3. Banco Chinchorro
- 4. Hol-Chan
- 5. Turneffe
- 6. Punta de Manabique
- 7. Roatán
- 8. Cayos Cochinos



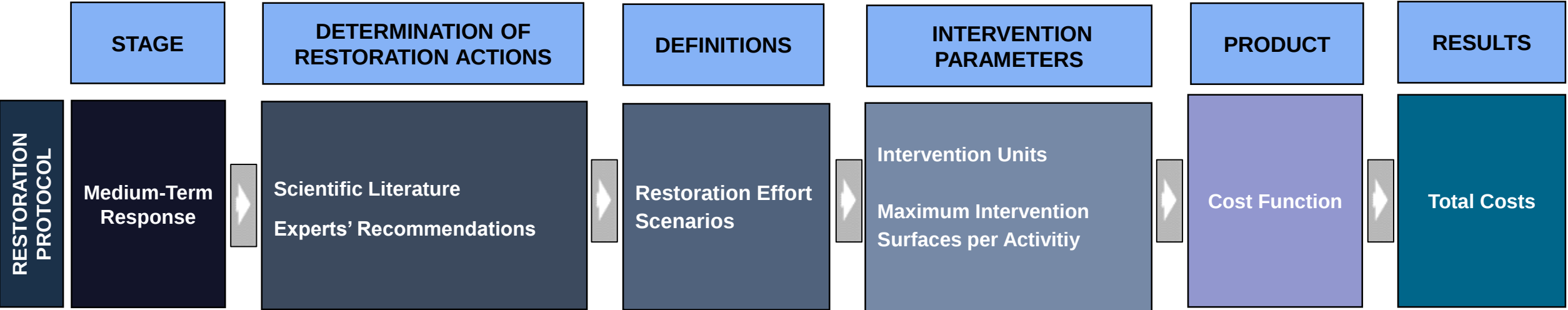
General Approach



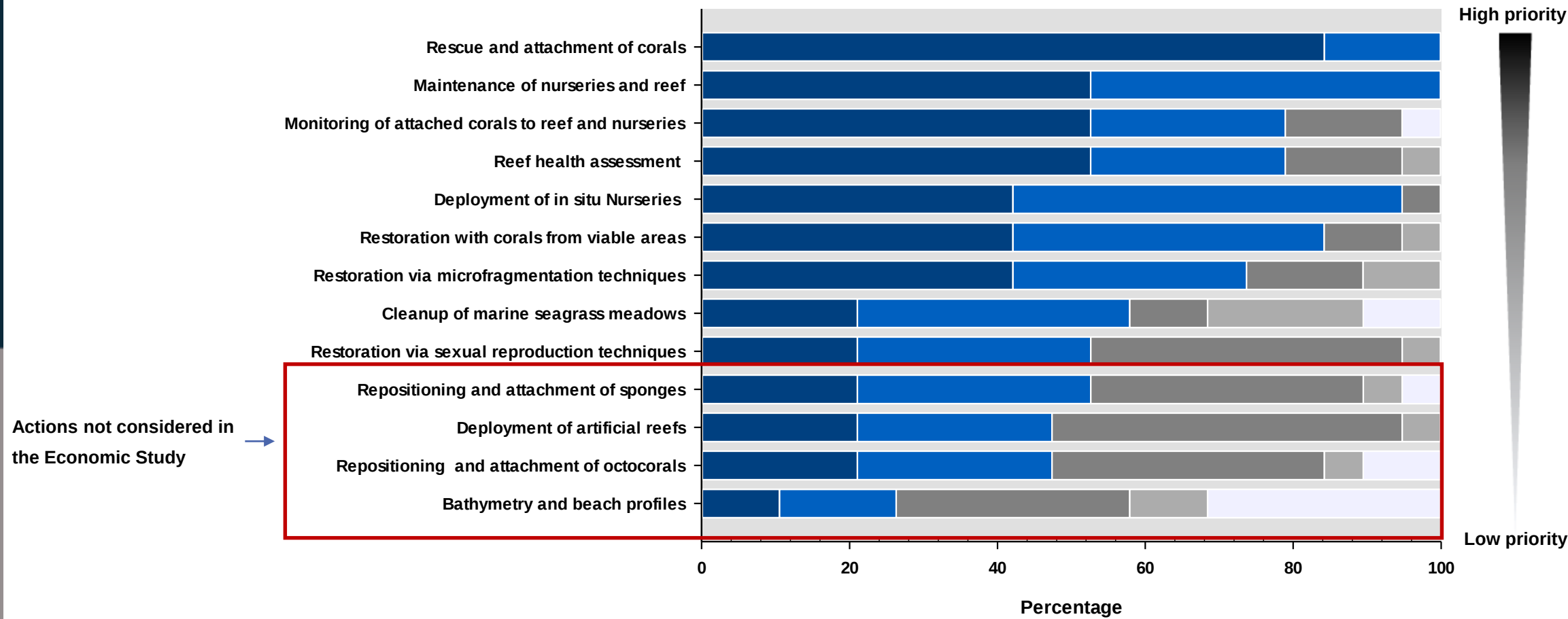
METHODOLOGY (SHORT TERM)



METHODOLOGY (MEDIUM TERM)



PRIORIZATION OF INTERVENTION ACTIONS ACCORDING TO EXPERTS



ACTIONS AIMED AT DAMAGE REPARATION

IMMEDIATE RESPONSE	RAPID DAMAGE ASSESSMENT		1. Determination of Damages (Impact Category) 2. Prioritization of Sites for Primary Response 3. Environmental Diagnosis
	Drone-Based Damage Assessment		
	Manta Tow-Based Damage Asssesment		
	PRIMARY RESPONSE		
	Cleanup and Debris Removal		1. Reduction of risks and damage propagation
	Repositioning and Attachment of Buried, Fragmented, Detached, Displaced and/or Flipped Corals		2. Intervention at prioritized sites and attention to damaged yet viable, coral colonies
	Stabilization of Additional Living Coral Fragments		3. Stabilization of coral fragments and small coral colonies (to be mounted on <i>in situ</i> nurseries)
	SECONDARY RESPONSE		
	Repair of Structural Coral Fractures		1. Stabilization of structural fractures of living coral colonies to reduce damage propagation
	Deployment of <i>in situ</i> Coral Nurseries		2. Deployment of <i>in situ</i> nurseries to attach coral fragments stabilized during the Primary Response
	Attachment of Additional Coral Fragments to <i>in situ</i> Coral Nurseries		3. Attachment of coral fragments (not attended during the Primary Response stage) on <i>in situ</i> nurseries
	Monitoring and Maintenance of Rescued Corals Attached to Reef and Nurseries		4. Health assessment and maintenance of corals attached to the reef and mounted on nurseries
	Cleanup of Marine Seagrass Meadows		5. Sand removal from seagrass area and stabilization of seagrass torn by hurricane
	CLOSURE OF IMMEDIATE RESPONSE STAGE		
	Evaluation of Protocol Success		1. Success assessment of the protocol for damage renaration
	Assessment of Remaining Damage		2. Environmental diagnosis of damages left unattended
	Elaboration of Medium-Term Restoration Plan		3. Elaboration of medium-term strategy for coral restoration and selection of restoration scenarios

DETERMINATION OF RESTORATION ACTIONS

MEDIUM-TERM RESPONSE	IMPLEMENTATION OF MEDIUM-TERM RESTORATION PLAN
	Deployment of <i>ex situ</i> Coral Nurseries for Microfragmentation Techniques (5 years)
	On-The-Reef Deployment of Colonies Grown Through Microfragmentation Techniques
	Implementation of Sexual Reproduction Techniques in <i>ex situ</i> Coral Nurseries (5 years)
	On-The-Reef Deployment of Colonies Generated through Sexual Reproduction Techniques
	Monitoring and Maintenance of Corals Grown During the Medium-Term Response
	Evaluation of Protocol Success

1. Use of low-cost mobile ponds buried in the sand
2. On-the-reef attachment of coral colonies grown in *ex situ* nurseries in viable reef areas
3. Use of mobile ponds buried in the sand
4. On-the reef attachment of coral colonies grown in ..
5. Coral health assessment of corals grown in *ex*
6. Assessment of viability of the Medium-Term Response as an Impact mitigation strategy

DAMAGE DESCRIPTORS

Descriptor A

Percentage of buried, fragmented, detached, displaced and/or flipped corals

Descriptor B

Percentage of damaged coral structure surface: structural fractures of living coral colonies

DAMAGE CATEGORY	RANGE
MODERATE	Percentage
Descriptor A	5-10
Descriptor B	0-5
INTERMEDIATE	Percentage
Descriptor A	10-40
Descriptor B	5-10
SEVERE	Percentage
Descriptor A	40-60
Descriptor B	10-20

INTERVENTION SCENARIOS (IMMEDIATE RESPONSE)

MINIMUM

Intervention covering 20% of total affected area*

INTERMEDIATE

Intervention covering 40% of total affected area*

OPTIMUM

Intervention covering 60% of total affected area*

* Total affected area: total reef surface, seagrass area, coral surface, etc.

INTERVENTION SCENARIOS	PERCENTAGE
MINIMUM	20
INTERMEDIATE	40
OPTIMUM	60

For all intervention scenarios, all actions involved in the “Rapid Damage Assessment Stage” will be carried out to 100%, (covering the entire insured polygon), thus the costs for these activities for all intervention scenarios are identical

RESTORATION SCENARIOS (MEDIUM-TERM RESPONSE)

MINIMUM

Microfragmentation-Based and Sexual Reproduction-Based Coral Restoration for 3 Years

INTERMEDIATE

Microfragmentation-Based and Sexual Reproduction-Based Coral Restoration for 4 Years

OPTIMUM

Microfragmentation-Based and Sexual Reproduction-Based Coral Restoration for 5 Years

COST FUNCTION

Costs are a function of several parameters specific to each locality, damage category and intervention scenario

PARAMETERS
Reef Parameters
Insured Polygon Surface
Total Living Coral Surface
Seagrass Meadow Area Neighboring the Reef
Damage Parameters
Total Surface of Impacted Living Corals (Descriptor A)
Total Surface of Damaged Living Coral Structure (Descriptor B)
Intervention Parameters
Intervention Scenarios
Restoration Scenarios via Microfragmentation Techniques
Restoration Scenarios via Sexual Reproduction Techniques

COST FUNCTION

$$C_T = (C_{RI} + C_{RP} + C_{RS} + C_{RMP}) * N^{interv}$$

where:

$$C_{RI} = \sum_i^n ((d_i^{RI} \cdot C_i^{RI}) + C_{fi}^{RI})$$

$$C_{RP} = \sum_i^n ((d_i^{RP} \cdot C_i^{RP}) + C_{fi}^{RP})$$

$$C_{RS} = \sum_i^n ((d_i^{RS} \cdot C_i^{RS}) + C_{fi}^{RS})$$

$$C_{RMP} = \sum_i^n ((d_i^{RMP} \cdot C_i^{RMP}) + C_{fi}^{RMP})$$

N^{interv} = Intervention Level or Restoration Level (percentage)

NOMENCLATURE

C_T	Total Costs of Damage Reparation
C_{RI}	Total Costs of Immediate Response
C_{RP}	Total Costs of Primary Response
C_{RS}	Total Costs of Secondary Response
C_{RMP}	Total Costs of Medium-Term Response

d_i^{RI}	Days of intervention for activity "i" of the Immediate Response
d_i^{RP}	Days of intervention for activity "i" of the Primary Response
d_i^{RS}	Days of intervention for activity "i" of the Secondary Response
d_i^{RMP}	Days of intervention for activity "i" of the Medium-Term Response
C_i^{RI}	Total daily cost for the "i" activity of the Immediate Response
C_i^{RP}	Total daily cost for activity "i" of the Primary Response
C_i^{RS}	Total daily cost for the "i" activity of the Secondary Response
C_i^{RMP}	Total daily cost for the "i" activity of the Medium-Term Response
C_{fi}^{RI}	Total fixed cost related to activity "i" of the Immediate Response
C_{fi}^{RP}	Total fixed cost related to activity "i" of the Primary Response
C_{fi}^{RS}	Total fixed cost related to the "i" activity of the Secondary Response
C_{fi}^{RMP}	Total fixed cost related to the "i" activity of the Medium-Term Response
n	Number of Activities in each Phase: Immediate, Primary or Secondary

DAILY INTERVENTION UNITS

Field Activities	Type of Response Team	Number of Teams
Manta Tow-Based Rapid Damage Assessments	A	3
Cleanup and Debris Removal	B	3
Repositioning and Attachment of Fragmented Corals	C	3
Stabilization of Additional Living Fragments	B	3
Repair of Structural Fractures	C	3
Deployment of <i>in situ</i> nurseries	D	3
Attachment of Additional Coral Fragments to <i>in situ</i> Coral Nurseries	D	3
Monitoring and Maintenance of Rescued Corals Attached to Reef and Nurseries	D	3
Cleanup of Marine Seagrass Meadows	D	3
Assessment of Remaining Damage	E	3
On-The-Reef Deployment of Colonies Grown Through Microfragmentation Techniques	D	1
On-The-Reef Deployment of Colonies Generated through Sexual Reproduction Techniques	D	1
Monitoring and Maintenance of Corals Grown During the Medium-Term Response	D	3

Definition of Response Teams

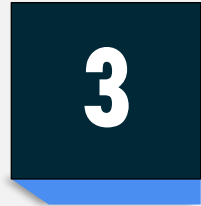
Team A = 1 boat, 1 coordinator and 4 snorkelers

Team B = 1 boat, 1 coordinator, 4 divers, 2 snorkelers and 3 dives per day per diver

Team C = 1 boat, 1 coordinator, 4 divers, 4 snorkelers and 3 dives per day per diver

Team D = 1 boat, 1 coordinator, 4 divers and 3 dives per day per diver

Team E = 1 boat, 4 SCUBA divers and 3 dives per day per diver



RESULTS

ALL LOCALITIES

Reef Parameter		Units	Magnitude
I.	Insured Polygon Surface	m ²	1,000,000
II.	Living Coral Surface within the Insured Polygon	m ²	250,000
III.	Percentage of Living Coral Surface	%	HRI
IV.	Percentage of Detached, Buried or Torn Living Coral Surface	%	DDA
V.	Percentage of Detached Living Coral to Be Re-Attached During the Primary Response	%	97
VI.	Percentage of Detached Living Coral to Be Re-Attached in <i>in situ</i> nurseries During the Secondary Response	%	3
VII.	Percentage of Damaged Coral Structure	%	DDB
VIII.	Surface of Seagrass Meadows **	m ²	100,000
IX.	Percentage of Impacted Surface of Seagrass Meadows ***	%	50

HRI: Data taken from the 2018 MAR Report Card published by the Healthy Reefs Initiative

DDA: Damage Descriptor A

DDB: Damage Descriptor B

***** We assume that the reef massif that includes both living and dead coral represents 25% of the insured polygon surface

****** We assume that the surface covered by seagrass meadows represents 10% of the insured polygon surface

******* We assume that 50% of the surface covered by seagrass meadows was impacted by the hurricane

MEXICO

AKUMAL 12% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	8,284	8,284	8,284
	PRIMARY RESPONSE	20,555	41,110	61,665
	SECONDARY RESPONSE AND CLOSING	77,101	132,398	187,695
	MEDIUM-TERM RESPONSE	123,226	220,996	318,766
	TOTAL	229,166	402,788	576,410
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	8,284	8,284	8,284
	PRIMARY RESPONSE	66,119	132,238	198,356
	SECONDARY RESPONSE AND CLOSING	195,432	369,059	542,686
	MEDIUM-TERM RESPONSE	123,226	220,996	318,766
	TOTAL	393,060	730,576	1,068,092
SEVERE	RAPID ASSESSMENT OF DAMAGES	8,284	8,284	8,284
	PRIMARY RESPONSE	96,756	193,513	290,269
	SECONDARY RESPONSE AND CLOSING	281,548	541,292	801,036
	MEDIUM-TERM RESPONSE	123,226	220,996	318,766
	TOTAL	509,814	964,084	1,418,355

Local supply of all
inputs necessary for
the intervention

MEXICO

COZUMEL 20% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	8,800	8,800	8,800
	PRIMARY RESPONSE	34,032	68,064	102,096
	SECONDARY RESPONSE AND CLOSING	118,449	215,094	311,739
	MEDIUM-TERM RESPONSE	124,869	224,282	323,695
	TOTAL	286,150	516,240	746,330
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	8,800	8,800	8,800
	PRIMARY RESPONSE	117,671	235,343	353,014
	SECONDARY RESPONSE AND CLOSING	340,565	659,326	978,087
	MEDIUM-TERM RESPONSE	124,869	224,282	323,695
	TOTAL	591,906	1,127,751	1,663,597
SEVERE	RAPID ASSESSMENT OF DAMAGES	8,800	8,800	8,800
	PRIMARY RESPONSE	172,856	345,712	518,569
	SECONDARY RESPONSE AND CLOSING	501,272	980,739	1,460,206
	MEDIUM-TERM RESPONSE	124,869	224,282	323,695
	TOTAL	807,797	1,559,533	2,311,270

Local supply of all
inputs necessary for
the intervention

MEXICO

BANCO CHINCHORRO 10% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	8,518	8,518	8,518
	PRIMARY RESPONSE	22,878	45,757	68,635
	SECONDARY RESPONSE AND CLOSING	76,201	130,597	184,993
	MEDIUM-TERM RESPONSE	127,508	229,561	331,614
	TOTAL	235,106	414,433	593,760
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	8,518	8,518	8,518
	PRIMARY RESPONSE	70,477	140,953	211,430
	SECONDARY RESPONSE AND CLOSING	196,138	370,472	544,805
	MEDIUM-TERM RESPONSE	127,508	229,561	331,614
	TOTAL	402,641	749,504	1,096,367
SEVERE	RAPID ASSESSMENT OF DAMAGES	8,518	8,518	8,518
	PRIMARY RESPONSE	102,209	204,417	306,626
	SECONDARY RESPONSE AND CLOSING	282,821	543,838	804,855
	MEDIUM-TERM RESPONSE	127,508	229,561	331,614
	TOTAL	521,057	986,335	1,451,613

Remote supply of all inputs necessary for the intervention

Fuel and additional boats are necessary for transporting tanks and cement from Mahahual

BELIZE

HOL-CHAN 6% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	12,750	12,750	12,750
	PRIMARY RESPONSE	19,555	39,110	58,664
	SECONDARY RESPONSE AND CLOSING	79,370	132,159	184,948
	MEDIUM-TERM RESPONSE	154,329	279,675	405,021
	TOTAL	266,005	463,695	661,384
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	12,750	12,750	12,750
	PRIMARY RESPONSE	54,002	108,003	162,005
	SECONDARY RESPONSE AND CLOSING	168,892	311,203	453,513
	MEDIUM-TERM RESPONSE	154,329	279,675	405,021
	TOTAL	389,973	711,632	1,033,290
SEVERE	RAPID ASSESSMENT OF DAMAGES	12,750	12,750	12,750
	PRIMARY RESPONSE	77,758	155,516	233,274
	SECONDARY RESPONSE AND CLOSING	234,432	442,282	650,132
	MEDIUM-TERM RESPONSE	154,329	279,675	405,021
	TOTAL	479,269	890,224	1,301,178

Local supply of all
inputs necessary for
the intervention

BELIZE

TURNEFFE ATOLL 7% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	16,664	16,664	16,664
	PRIMARY RESPONSE	29,758	59,517	89,275
	SECONDARY RESPONSE AND CLOSING	87,816	147,363	206,911
	MEDIUM-TERM RESPONSE	171,336	307,585	443,833
	TOTAL	305,575	531,129	756,683
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	16,664	16,664	16,664
	PRIMARY RESPONSE	86,603	173,206	259,809
	SECONDARY RESPONSE AND CLOSING	213,289	398,310	583,331
	MEDIUM-TERM RESPONSE	171,336	307,585	443,833
	TOTAL	487,893	895,765	1,303,637
SEVERE	RAPID ASSESSMENT OF DAMAGES	16,664	16,664	16,664
	PRIMARY RESPONSE	123,385	246,770	370,155
	SECONDARY RESPONSE AND CLOSING	305,181	582,093	859,006
	MEDIUM-TERM RESPONSE	171,336	307,585	443,833
	TOTAL	616,566	1,153,112	1,689,658

Remote supply of all inputs necessary for the intervention

Fuel and additional boats are necessary for transporting cement from Belize City

GUATEMALA

PUNTA DE MANABIQUE 5% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	8,263	8,263	8,263
	PRIMARY RESPONSE	10,023	20,045	30,068
	SECONDARY RESPONSE AND CLOSING	49,017	75,137	101,257
	MEDIUM-TERM RESPONSE	121,358	216,698	312,039
	TOTAL	188,660	320,144	451,627
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	8,263	8,263	8,263
	PRIMARY RESPONSE	26,489	52,978	79,467
	SECONDARY RESPONSE AND CLOSING	91,196	159,495	227,795
	MEDIUM-TERM RESPONSE	121,358	216,698	312,039
	TOTAL	247,306	437,435	627,564
SEVERE	RAPID ASSESSMENT OF DAMAGES	8,263	8,263	8,263
	PRIMARY RESPONSE	37,467	74,933	112,400
	SECONDARY RESPONSE AND CLOSING	121,023	219,150	317,277
	MEDIUM-TERM RESPONSE	121,358	216,698	312,039
	TOTAL	288,111	519,045	749,979

Remote supply of all inputs necessary for the intervention

Fuel and additional boats are necessary for transporting cement and other inputs from Puerto Barrios

HONDURAS

ROATAN 15% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	12,253	12,253	12,253
	PRIMARY RESPONSE	38,605	77,209	115,814
	SECONDARY RESPONSE AND CLOSING	135,388	247,304	359,220
	MEDIUM-TERM RESPONSE	146,813	265,820	384,827
	TOTAL	333,059	602,587	872,114
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	12,253	12,253	12,253
	PRIMARY RESPONSE	125,263	250,527	375,790
	SECONDARY RESPONSE AND CLOSING	379,102	734,732	1,090,362
	MEDIUM-TERM RESPONSE	146,813	265,820	384,827
	TOTAL	663,432	1,263,332	1,863,232
SEVERE	RAPID ASSESSMENT OF DAMAGES	12,253	12,253	12,253
	PRIMARY RESPONSE	184,239	368,479	552,718
	SECONDARY RESPONSE AND CLOSING	554,011	1,084,549	1,615,088
	MEDIUM-TERM RESPONSE	146,813	265,820	384,827
	TOTAL	897,317	1,731,101	2,564,886

Local supply of all
inputs necessary for
the intervention

HONDURAS

CAYOS COCHINOS 10% CORAL COVER		MINIMUM INTERVENTION (20 %)	INTERMEDIATE INTERVENTION (40 %)	OPTIMUM INTERVENTNION (60 %)
DAMAGE CATEGORY	ACTIVITY	USD	USD	USD
MODERATE	RAPID ASSESSMENT OF DAMAGES	12,622	12,622	12,622
	PRIMARY RESPONSE	31,251	62,502	93,752
	SECONDARY RESPONSE AND CLOSING	103,306	183,139	262,973
	MEDIUM-TERM RESPONSE	151,816	275,826	399,836
	TOTAL	298,995	534,090	769,184
INTERMEDIATE	RAPID ASSESSMENT OF DAMAGES	12,622	12,622	12,622
	PRIMARY RESPONSE	95,376	190,751	286,127
	SECONDARY RESPONSE AND CLOSING	277,893	532,313	786,734
	MEDIUM-TERM RESPONSE	151,816	275,826	399,836
	TOTAL	537,707	1,011,513	1,485,320
SEVERE	RAPID ASSESSMENT OF DAMAGES	12,622	12,622	12,622
	PRIMARY RESPONSE	138,126	276,251	414,377
	SECONDARY RESPONSE AND CLOSING	402,882	782,291	1,161,701
	MEDIUM-TERM RESPONSE	151,816	275,826	399,836
	TOTAL	705,446	1,346,991	1,988,536

Remote supply of all inputs necessary for the intervention

Fuel and additional boats are necessary for transporting tanks and cement from La Ceiba

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CONCLUSIONS

The costs depend to a large extent on the percentage of live coral cover recorded for each locality, so only direct comparisons can be made between Banco Chinchorro and Cayos Cochinos whose average live coral cover is identical according to the HRI database.

The locality with the highest cost is Roatán followed by Cozumel, both tourist destinations have a well-consolidated SCUBA diving industry and register the highest live coral coverages of the eight selected locations (15 and 20%, respectively)

Punta de Manabique is the locality with the lowest cost due mainly to the low live coral coverage (5%) and the moderate boat rental costs with respect to other locations.

The market cost of supplies specific to each locality, **as well as the accessibility of all inputs necessary for the intervention (fuel, diving tanks, cement, etc.)** play a very important role in the total cost of each intervention stage

The costliest inputs identified are human resources (salary of the members of the response team and coordinators) followed by the total rental costs of boat and diving gear.

The percentage of live coral cover used in this study is a semiquantitative estimate of the live coral cover prevalent in each locality. For each percent point of discrepancy between the percentage of live coral coverage reported by HRI for each locality and the actual percentage prevailing within the insured polygon, a 2.5% variation of the total costs is expected.

The overall uncertainty of the costs reported in the present study is estimated to be of the order of $\pm 5\%$.

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