Data needs to support decision-making relevant to coral reefs
Summary report

February 28, 2020

By Lauretta Burke and Elizabeth McLeod

This report is the product of a collaboration among researchers from the following organizations:

- World Resources Institute (WRI) – Lauretta Burke, Carolyn Savoldelli, Peter Kerins, Namrata Ginoya
- The Nature Conservancy (TNC) – Elizabeth McLeod, Petra MacGowan, Mark Spalding, Cherie Wagner, Steve Schill
- National Geographic Society (NGS) – Helen Fox, Brian Free, Steven Brumby, Samantha Hyde
- Vulcan Inc. – Emily Amundson

This work was produced with the support of National Geographic Society.
Questions and comments should be directed to Lauretta Burke (lauretta@wri.org).

Contents

List of Tables –

List of Figures –

List of Annexes

Audience Summaries in PDF for Annexes A1-A5

A1 – Audience Summary - Coastal Risk and Insurance Sector
A2 – Audience Summary – Coastal Planning and Management Authorities
A3 – Audience Summary – Marine Protected Area Managers and Authorities
A4 – Audience Summary – Conservation NGOs implementing marine and coastal protection and restoration
A5 – Sea Surface Temperature (SST) Data Needs to Inform Coral Reef Management Decisions

Spreadsheets

A6 – Data Priorities and Details by Audience.XLS - spreadsheet with detailed scoring from survey and interviews by audience
A7 – Integrated Data Priorities and Sources.XLS - spreadsheet displaying data priorities across the four audiences (tab 1) and data source recommendations (tab 2)

PDF for Annexes B1-B2

B1 - Interview templates
B2 - Survey instrument

Executive Summary

This collaborative research has produced detailed descriptions of some of the key data needs for decision-making relevant to coral reefs for four audiences – 1) coastal hazard / risk analysts and the insurance sector, 2) coastal planning and management authorities, 3) marine protected area managers and authorities, and 4) scientists and practitioners from NGOs implementing marine and coastal protection and restoration. Through interviews, an online survey and literature review, we explored the types of decisions each audience is making and key data needs for decision making – both regarding data currently used and data desired to inform decisions. The research also explored how users prefer to interact with the data: what tools or models are commonly used for a specific type of decision; and what (other than data) is currently impeding better decision-making for better protection of coral reefs. We also explore the data needs of international targets relevant to coral reefs (e.g. the Convention on Biological Diversity and the Sustainable Development Goals). Results of this research will be used to improve information platforms to support decision-making in coastal areas. Existing platforms which could benefit from this research include NGS's Geographic Visualization Lab's Earth Pulse, Vulcan Inc.'s Allen Coral Atlas, WRI's Resource Watch, and TNC's Mapping Ocean Wealth.

For each of the four audiences we identified 40-50 key data needs. (See tables 3-6 in this summary and annexes A1-A4 for results by audience.) The key data needs of the four audiences were integrated to identify the most common requests (resulting in a list of 60 priority data needs (Table 7). Of the top ten priority data sets, three are **ecological** (coral reef locations, mangrove locations, live coral cover), three are **oceanographic** (sea surface temperature, bathymetry, wind and wave exposure), and one each from the data categories **threat and impact** (nutrient and sediment runoff), **global change** (sea level rise projections), **social and economic** (population density), and **ecosystem services** (fisheries / food provisioning value).

We explored the availability of global spatial data sets to fulfill these data needs (including stated technical requirements) and classified each data need as to whether A) a global data set exists which adequately fulfills the requirements; B) a global data set exists which partially fulfills the need and could be considered for inclusion on a data platform; C) a global data source does not currently exist, but there might be an opportunity to catalyze development of a data set fulfilling this need; or D) no viable data source has been identified.

- For half (30 of 60) priority data needs we identified a global data which we deem the best currently available to fulfill the need, though most are classified as B because the spatial or temporal resolution did fulfill requirements (See Table 9).
- For 11 of the data needs we propose opportunities where collaboration, data consolidation, or development of a derivative product or indicator could help fulfill the data need (see Table 10).
- The 19 data needs for which an adequate source could not be identified are listed in Table 11.

This summary report provides an overview of the research methodology and results for the four audiences –types of decisions being made, data needs to support those decisions (including technical specifications), data use, and other factors and needs inhibiting better decision-making. The summary ends with conclusions and recommendations – both related to data needs, as well as other needs - such as training in use of data and communication of results.

For additional details on these results, please see the annexes accompanying this summary report.

Introduction

We are awash in data, but often lack data at the relevant scale to inform a decision. Data sets and data platforms are the most useful when compiled with the needs of the end user in mind. Technological advances, including a proliferation of satellites, drones and other modes of remote sensing / earth observation, coupled with the power of cloud computing and our unprecedented ability to access data over the internet results in much of the world being overwhelmed with data. These advances do not mean it is easy for most people to find and utilize the data they need to inform critical decisions. The reasons for this are many. An overwhelming number of platforms provide some data on a given topic. People do not necessarily know what data exist, nor where to find them, nor have data at the appropriate scale to support decision-making. Some data are scattered (not compiled) and not readily accessible. Some data exist in raw form and are not processed in the way that users need.

Coral reefs are a complex ecosystem with many people benefiting from the goods and services they provide, as well as many people making decisions relevant to their future condition. The data-related challenges described above are certainly true for coral reefs. Many data sets are required, for example, for coastal zone planning, marine protected area design and management, evaluation of coastal flood risk, or for designing nature-based solutions to reduce flood risk. Many data platforms provide some data or information about coral reefs, and yet, much of the information needed for these types of decisions does not exist or is not accessible - for most areas.

During August – January 2020, with support from National Geographic Society (NGS), researchers at the World Resources Institute (WRI), The Nature Conservancy (TNC), and Vulcan, Inc. collaborated on research to explore the information needed to support decision-making relevant to coral reefs for four specific audiences:

a. Coastal hazard / risk analysts and insurance sector (RISK)
b. Coastal planning and management authorities (CZM)
c. Marine Protected Area managers and authorities (MPA)
d. Scientists and practitioners from NGOs implementing marine and coastal protection and restoration (NGO)

Through interviews, an online survey and a literature review, the team explored the types of decisions each audience is making and key data needs for decision making – both data currently being used and data desired to inform decisions. This process included collecting information on the characteristics of the data desired (e.g. spatial and temporal resolution) as well as any recommendations on a potential data source. The integrated results identify key data gaps which are impeding more effective decision-making. The research also explored how specific data sets would be used to inform a decision; how users like to interact with the data; what tools or models are commonly used for a specific type of decision; and what (other than data) is currently impeding better decision-making and better protection of coral reefs. Results of this research will be used to improve information platforms to support decision-making in coastal areas – with emphasis on coral reefs. Existing platforms which could benefit from this research include NGS's Geographic Visualization Lab's Earth Pulse, Vulcan Inc.'s Allen Coral Atlas, WRI's Resource Watch, and TNC's Mapping Ocean Wealth.

Method / Approach

In collaboration with NGS, the research team agreed on the four audiences to be the focus of user needs assessments based on importance of the audience for influencing coral reef condition and likely availability of information about the data needs of the audience. WRI (the principle investigator) was responsible for two audiences (RISK and CZM) and overall project coordination and execution, while TNC was responsible for the MPA and NGO audience summaries. Vulcan Inc. provided expert input on survey design and implementation. NGS provided guidance on overall direction and desired results. Each audience summary is a synthesis of inputs from interviews, an online survey, and literature review.

1) **Interview template** – A generalized interview template was developed by WRI. It was shared with partners for review, revised, tested and then adapted for specific audiences. (One template was used for the NGO and MPA audiences, while another was used for the RISK and CZM audiences. See Annex B-1 for the interview templates.)

The interview template collects information on:

- The **key informant**; organization;
- The **types of decisions** they are involved in that are relevant to coral reefs;
- The data they need to make these decisions – both
    - What **data they are currently using**, and
    - what additional **data they wish they had** to better support decision-making;
- <u>For their top three data needs only</u> –
    - the **spatial resolution** (level of detail) required
    - whether they only need data for the **present** or need **historic data or projections**
    - Whether they have recommendations on **a dataset / source**;
- **How the data would be used** to inform a decision; Whether they would be combined with other data (for an analysis);
- Whether any **summary indicators** might be useful to support their decisions;
- Whether there Is a particular **analytical method or tool** they use to support analysis / decision-making;
- Whether **map visualization** would be helpful for decision-making, and whether there are particular desired features;
- Aside from data, **what inhibits better decision-making** or better protection of coral reefs;
- Recommendations on platforms/ papers / reports which provide insights on data needs;
- Recommendations on additional people to interview.

2) **Survey instrument** – A single survey instrument covering the four audiences was developed with questions similar to those in the interview, with a few exceptions –
    a. respondents self-select their primary professional role and can select multiple answers and/or select “other” and write in a professional role. (See Figure 1.)
    b. the question on datasets used or desired is not asked as an open-ended question in the survey. Rather it is presented as a matrix - with one question for data category where respondents check either “currently use” or ”would use if available” for any dataset they feel is important for their decision making. Ten data categories were explored. (See Figure 2.)

Figure 1- Self-identification of professional role in Survey

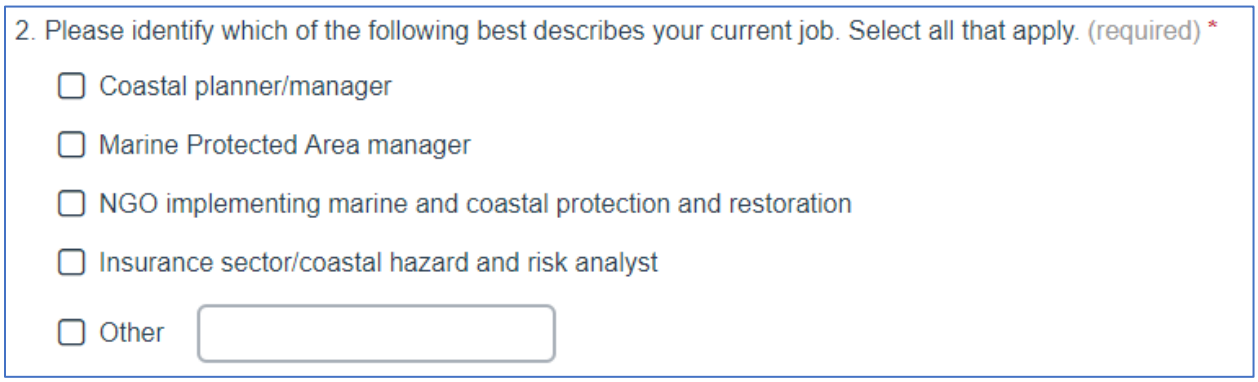


Figure 2- List of Data Categories in Survey

Physical/Oceanographic Data
Climate Data
Global Change Data
Ecological
Threats and Impacts
Social and Economic
Built Environment
Ecosystem Services
Administrative
Indicators / Model outputs

The survey was drafted as a Word document, reviewed by the team and other experts in survey design, revised, implemented in the Survey Gizmo software, tested and revised. Survey Gizmo was selected because of its functionality – allowing multiple data matrixes as tables, and because it works well on laptops and tablets, as well as reasonably well on smartphones. The survey instrument can be found in Annex B-2.

3) **Literature reviews** were executed for each of the four audiences. As the team members all work on some aspects of coral reefs, we initially selected reports, papers and articles from our own libraries, and complemented these through literature search and recommendations from both the interviewees and survey respondents. The literature review focused on identifying what decisions were being addressed; what datasets were used in the analysis to inform decisions (including data sources and data characteristics); what data limitations, data needs, or data gaps were mentioned; and what analysis or decision support tools were used.

4) **Interview implementation.** A minimum of five interviews were executed for each audience. Interviewees were selected based on expertise within the given topic area, as well as diversity of roles and types of decisions within each audience. Hence, the interviews included analysts, tool developers and technical experts, as well as end-users and senior decision makers. The individual audience summaries in Annexes A1-A4 describe the roles and types of decisions made for all interviewees.

5) **Online survey execution.** The online survey, *Questionnaire on information needs to support decision-making relevant to coral reefs,* was announced widely through the Reef Resilience Network, Coral Reef Listserv, International Coral Reef Initiative, Open Communications for the Ocean (OCTO), the Partnership for Environment and Disaster Risk Reduction (PEDRR), PreventionWeb and through personal email requests.

   Survey respondents could select which description(s) best reflects their current job / professional role. Of 201 survey responses which were clean and sufficiently complete to be included in the results, 43 selected more than one category of job description. These were reviewed and assigned to a primary role based on organization type, role in organization and type of decision being made. These job categories are synonymous with audience category.

6) **Develop Audience Summaries.** For each audience, results from the interviews, surveys and literature review were integrated to compile a profile of key decisions, data use, data needs and preferences for analysis tools and modes of visualization. Many of the findings were compiled as text but the interviews and surveys were used in a quantitative way as well - with responses scored and integrated. Surveys were scored based on the percentage of respondents within an audience who selected that they either currently use the data or would use it if available. Scoring interviews containing open ended questions was more complicated. Responses needed to be interpreted and harmonized. For example, “elevation”, “DEM” and “topography” would all be counted as elevation data. The dataset names were matched to those from the survey, with any new entries added. The interviews were scored based on the percentage of interviewees within the audience who mentioned the dataset as being important to the decision-making (currently using or as a data need, or in some cases - both - currently using but wish they had better quality data.)

   The percentage scores from the interviews and surveys were integrated to arrive at the final score reflecting the importance at each data set for the given audience. In the case of the MPA and NGO audiences, the percentages were combined (averaged) with equal weight. In the cases of the RISK and CZM audiences, the interview responses were weighted 2:1. This was done in part because of the relatively low number of survey responses (especially for the risk and insurance audience).

   The datasets were sorted and ranked by average score, with the 40 - 50 data sets classified as priority data sets for each audience and top 13 to 17 classified as top priority. The thresholds for cutoff were based on the distribution of the scores (no cutoff between tied or very close scores), as well as the degree of emphasis on the dataset within the interview or citation in the “top three datasets needed” in the survey.

   Technical details of data used, or data needed from the interview, survey or literature review were recorded and compiled in a spreadsheet that included resolution needed, periodicity (if relevant), time period (present, historic, projections), time period for projection, and suggested data source (when available). (See Annex A6.)

   The individual audience summaries include a list of priority data sets with the top priorities highlighted. These are included in this summary report, with additional detail in Annexes A1 to A4.

7) **Commonalities of data needs** across audiences were calculated. Many datasets such as coral reef and mangrove locations, bathymetry, and sea surface temperature are needed by multiple audiences. However, the characteristics of the data need (e.g. resolution) may vary by audience and by type of decision.

a) We integrated the data needs by tallying the priority data lists for the four audiences (assigning 1 point for being on the list and 2 for being a top priority).
b) We tried two approaches for integrating the lists - one used equal weights for the four audiences and the other a weighting which provided slightly more emphasis on RISK (the risk analysis and insurance audience) because the other three audiences have more overlap in priorities and perspectives, while the RISK audience has some fairly specific, high resolution data needs. In the end we used a weight of 1.5 for RISK and a weight of 1 for the other three audiences. Using those weights, we tallied the scores to produce an overall score reflecting demand for a given dataset across the four audiences. Data sets scoring at least 3 were included as "high priority" in the integrated results section and on the spreadsheet where we compile the technical details required by each audience. (Data sets scoring 2.5 were also included as "medium priority".) We also took authors privilege and made a few exceptions. We included any datasets which we felt slipped through the cracks because of some artifact of the way the question was asked, or responses were evaluated, as well as any data needs which we wanted to highlight to the readers of this summary report. There were only 5 exceptions and they are noted as such.
c) We compiled available information on the technical requirements for each data set - audience pairing and information on potential data sources. This hard reality of availability of data to fulfill these technical needs informs the conclusion and recommendations of this summary report.

Results

The four summaries of data needs by audience rely on a synthesis of information from interviews of experts within each audience, a review of literature relevant to the types of decisions made by each audience and results from an online survey covering all audiences. Within the survey respondents self-selected job / role (which we use to assign to an audience) and note the types of decisions they are involved in which are relevant to coral reefs. Results from the survey, interviews and literature were compiled separately and then synthesized for each audience. Table 1 provides a summary of the number of interviews and surveys included for each audience.

Table 1- Number of interviews and survey responses by audience

Audience	Number of Interviews[1]	No. of survey responses[2]
1. Coastal hazard / risk analysts and Insurance sector (RISK)	12	4
2. Coastal planning and management authorities (CZM)	8	39
3. Marine Protected Area managers and authorities (MPA)	6	49
4. Scientists and practitioners from NGOs implementing marine and coastal protection and restoration (NGO)	5	109

[1] See audience summaries (Annex A1-4) for descriptions of interviewees.
[2] The survey respondents sometimes selected multiple job types but were assigned to a single audience to avoid double counting.

The following pages present a summary of findings from the four audience summaries (Annexes A1-A4), followed by an integration of these results. Some considerations for interpretation of results:

- **There are some noteworthy differences between our sources** - In the surveys, respondents can select whether they "currently use" a data set or "would use if available" but not both. In the interviews it became apparent that many analyses / decisions rely on the best data currently available for the location but are not of satisfactory resolution / accuracy. So, within interviews, many data sets are listed as both "data used" and "data desired". For this reason, we summarize "key data sets" required for the analysis / decision. (Note: information on data used vs. data desired is in the spreadsheet in Annex A-6.)
- **Some decisions require a progression of scales of data** - Within a single decision category (such as marine spatial planning, or coral restoration project planning), different scales of data might be required for different phases of analysis. For example, a multilateral development bank (MDB) might only require relatively coarse global data for a broad priority-setting analysis for potential of nature-based solutions to reduce flood risk. But, if that project moves to the design phase, much higher resolution data would be required to evaluate the costs and benefits of the options under consideration to reduce flood risk.
- **Audiences are not entirely distinct** – Many survey respondents self-identified as being a member of several audiences, which is understandable. An individual might work for an NGO but support the planning and management of an MPA. Or, a coastal planner might design fisheries management zones, no-take areas, or multiple use zones for an MPA. Some NGO marine staff lead coastal zone management activities. Or a coastal planner might work on coastal flood risk reduction by using nature-based solutions, including coral restoration. We assigned individual responses to an audience based on apparent primary role, organization, job title, responsibilities and the decisions they are involved in. Respondents in three of four audiences are involved in some sort of zoning decisions. Three of four audiences are engaged in the evaluation, design or implementation of nature-based solutions to reduce risk from waves and storms.

Table 2- Types of decisions addressed by different audiences

Types of decisions addressed by the Risk / Insurance audience • Planning investments to reduce flood risk, including the use of nature-based solutions • Working with the insurance sector on insurance mechanisms which take the protective role of coral reefs into account • Developing insurance products to incentivize good behavior for protecting coral reefs • Conducting research to understand the role of wetlands and coral reefs for flood risk reduction • Mapping coastal vulnerability to flooding – to support adaptive action • Using risk analysis to help governments develop climate-smart plans (local and national)
Types of decisions addressed by the ICZM / Planning audience • Integrative coastal planning – integrating activities on land and effects in the sea • Sustainable land use planning – designation of economic use and development zones, habitat and species protection zones, restoration zones, buffer zones, etc. • Marine spatial planning / marine zoning - designation of many types of protection, use and exclusion zones, including conservation and protected areas, fisheries management zones, wildlife viewing areas, aquaculture areas, shipping lanes / routes, anchoring areas, etc. • Planning investments in coastal protection / designing nature-based solutions • Prioritization of restoration investments • Climate adaptation planning / coastal risk reduction

Types of decisions addressed by MPA managers

- Management actions to reduce threats to reefs (e.g., pollution, sedimentation, overfishing, climate change), fisheries management, and restoration activities
- Environmental and ecological monitoring (e.g., spawning aggregations, indigenous values, reef health and recovery, water quality, coastal dynamics, restoration)
- Policies and regulations (e.g., permit review, developing legislation, drafting / reviewing/ implementing management plans)
- Working with traditional values and indigenous heritage
- Collaboration on ecotourism activities
- Managing the carrying capacity of reef and sustainable use of reef resources
- Education, stewardship, and stakeholder engagement activities (awareness raising of importance of reefs)

Types of decisions addressed by the NGO Practitioner audience

- Guiding management interventions based on local conditions (governance, environment, climate, etc.) to reduce threats to reefs
- Managing a marine sanctuary to protect coral reefs
- Modeling coastal vulnerability to propose priority conservation sites
- Monitoring and evaluation of conservation impacts and management actions
- Supporting government initiatives to protect coral reefs
- Ensuring coral restoration programs follow protocol on correct operations
- Large-scale marine spatial planning to identify networks of MPAs to meet national targets
- Fisheries management
- Assess the role that women play on reefs and the role of gender in fisheries

1. Coastal hazard / risk analysts and insurance sector (RISK) Summary

Key informants for Risk and Insurance Audience – Interviewees include senior staff from multi-lateral development banks planning investments to reduce flood risk, including the use of nature-based solutions; disaster risk management specialists; analysts working with the insurance sector on insurance mechanisms which take the protective role of coral reefs into account; researchers developing insurance products to incentivize good behavior for protecting coral reefs; analysts developing models of coastal risk reduction by coral reefs and wetlands; program officers working on adaptation to climate change in coastal and marine areas.

Key Data Needs to support decisions

The interviewees have projects, analyses and interests which span from global to regional to local scale. Some global projects have relied on innovative use of global data sets to develop metrics of risk. The local risk reduction projects (risk assessment or planning of hard, natural or hybrid infrastructure solutions) tend to use more local data – both data from government and local sources, as well as data collected specifically for the given project location (via drone, side-scan sonar, in situ data collection, or locally ground-truthed satellite data). Government agencies, lenders, private entities and engineering companies doing coastal infrastructure design need detailed data - particularly on bathymetry, elevation, coral reef characteristics (depth below mean sea level (MSL) and reef rugosity), and location of built assets. Such data sets do not currently exist on a global basis. Some of these data sets exist at coarser scale globally. Others could be developed through partnership with the lead organizations / experts working on these topics.

Table 3- Summary of key data sets for coastal risk analysis and insurance sector

<table>
<tr>
<td>
Oceanographic Data
• bathymetry
• exposure – wind and waves
• ocean circulation
• tidal data
• Sea surface temperature (3D)

Physical Data
• Elevation
• coastline (and changeover time)
• beach profile
• Land cover
• Shoreline geology

Climate Data
• Historic cyclones \ storm tracks and probabilities
• Storms – historic and projections
• Storm surge \ wave height probabilities
• Rainfall – historic and projections

Ecological Data
• Coral Reef locations
• Mangrove locations (and historic / change over time)
• Coral rugosity / structure
• Coral condition indicator
• Live coral cover
• Mangrove characteristics (density, canopy height)
• Seagrass beds / locations
• Coastal Erosion
</td>
<td>
Threats and Impacts Data
• Water quality data (including E coli)
• Nutrient or sediment runoff / turbidity / LBS
• Change in ecosystem before and after storm

Global Change Data
• Sea level rise projections

Social and Economic Data
• Population Density (and projections)

Built Environment
• Existing Development / built environment/ housing
• Infrastructure locations – roads, water treatment, sewage treatment, airports, ports, communication infrastructure)
• Building footprints
• Building construction materials / type
• Historic flooding
• Flood defense (characteristics)

Ecosystem Service Data
• Tourism Values
• Wave attenuation value
• Fisheries / food provision value
• Stored Carbon

Indicators / models
• Coastal flood risk (by storm event) / number of people affected by floods (under different scenarios / return periods)
• Exposure of built assets
• Reef resilience likelihood / index
• Projected impact of sea level rise
</td>
</tr>
<tr>
<td colspan="2">For details on specific data requests (e.g. desired scale, time period (historic \ current \projection), periodicity of data and recommended sources, please see Annex A-6, the second tab in the spreadsheet on Data Priorities and Data Details by Audience.</td>
</tr>
</table>

Overarching Scale or Time Period Comments

- Historic data - For many topics, including cyclones and other storms, land cover, coastline change, coral reef and mangrove locations, historic and current data are desired – ten years minimum.
- Projections – For some data sets, particularly climate data, decadal projections going 20 – 50 years out are desired. For sea level rise, projections to 2100 are desired.
- Spatial Resolution – Requirements vary widely by data set and intended use. Global data sets will be useful for priority-setting and some initial scoping analyses. Very high-resolution bathymetry and

coral reef data (1-2m resolution) are desired for local flood risk mapping, while data on waves and storms can be of coarser resolution.

Data Use in Analysis

Much is happening in the modeling space examining the risk reduction benefits of coral reefs – across scales from local projects to global assessments - and this is doing a lot to support consideration of nature-based solutions (NbS) as an alternative to hard infrastructure. This awareness and quantification of NbS has not had much influence on or uptake by the insurance sector. Some "innovation wings" of insurance companies are beginning to think about the role of coastal ecosystems and "insuring them" using parametric insurance so that reefs have funds for repair after damaging events. But insurance companies are not yet including coral reefs as a factor in their models - they are not yet considering coral reefs as natural infrastructure with a value which could influence risk (and associated premiums.)

Coastal flood risk analysis and evaluation of NbS require integration of many data sets to evaluate storm hazard, exposure and vulnerability of assets (people and built assets). Risk analysts combine these data using a variety of modeling methods and tools described in the audience summary (Annex A-1). Analysis results are relevant to decision-makers, e.g., number of people affected / lives lost / value of damage to assets under storm events with different return periods (e.g. 1 in 50 yr.), with and without the coastal intervention.

Functionality \ Tools

- **Data access.** The coastal risk modelers tend to couple multiple models to evaluate risk. This is technically complex. Most modelers simply want access to the data. See Annex A-1.
- **Google Earth** – Several respondents rely heavily on Google Earth. It is useful for visualization and can be used for data creation, such as on-screen digitizing of shoreline changes over time.
- **Visualization** is an important tool in general for exploring land cover change, sediment plumes, shoreline change over time (erosion and accretion), coastal inundation with and without reefs, and relative value of coral reef ecosystem services, amongst others.

Other factors and needs inhibiting better decision-making

Beyond data, the Risk and Insurance audience requested several composite indicators and analytical outputs (reef resilience, reef structural stability, ecosystem service values, coastal flood risk); wider availability of local depth-damage functions; consolidated knowledge on topics (coral recovery time after damage, coral restoration costs and effectiveness, comparisons of how reefs respond to hazards compared with hard infrastructure). The greatest needs inhibiting improved risk modeling and the development of early-warning systems for flooding on reef-lined coasts include coral reef bathymetry and island topography; in situ wave, water level, and flooding observations to calibrate and validate numerical models; and records from past flooding events to define local event thresholds.

Key initiatives relevant to data and opportunities for collaboration

Exploring the role of coral reefs in coastal risk reduction is multi-faceted, complex, and brings together data from many sectors and practices. Several existing platforms offer key data or highlight important aspects of risk and resilience (e.g., Coastal Resilience.ORG and the Natural Capital Project). In addition, several initiatives are collaborating in this space – striving to mainstream nature-based solutions or to lower the barriers for the insurance sector to begin to consider the risk-reduction benefits of healthy

coral reefs. (See Annex A-1). Partnering with such initiatives is probably the most efficient means of gaining access to data sets relevant for our audiences. Engineering / modeling companies and organizations are doing cutting-edge analysis modeling flood risk and coral reefs, which appear to be open to collaboration and data sharing (possibly of derivative products.) Several of the interviewees expressed openness to either immediate sharing of data or exploration of sharing some derivative product. These include JBA Consulting, Deltares, XLX XL, and the Coastal Resilience Lab at UC Santa Cruz.

2. Coastal planning and management authorities (CZM) Summary

Key informants for Coastal Planning and Management Authorities **-** Interviewees included the lead Natural Resource Management Specialist at the InterAmerican Development Bank, who is responsible for advising government officials and bank staff on coastal management investments, coastal zoning, coastal protection and NbS; the founder of a small, international consulting firm focused on advising government agencies and funders about marine spatial planning; Director of an NGO collaborating with governments on coastal zone planning and management within the Mesoamerican Reef (MAR) countries; Lead Scientist for Coastal Resilience at Stanford University who develops tools and implements projects supporting decisions on coastal and marine zoning, siting of natural coastal infrastructure, prioritization of restoration investments, and climate adaptation planning; the Director of a coastal zone planning authority, which is responsible for development of a national CZM plan; and a marine biologist working on payments for ecosystem services and EbA.

Key Data Needs to support CZP / MSP - Spatial planning, be it coastal zone planning (CZP) or MSP, have large data requirements –providing input on where things are located (e.g. housing, infrastructure), where activities are currently happening (e.g. tourism, fishing, transport), what locations are suitable for different uses and what levels of use are sustainable – now and in the future, in light of development and changing climate. These data often come from local sources (ministries responsible for the given industry, or from a mapping / surveying / planning agency), though in some cases they can be derived through remote sensing.

Table 4- Summary of key data sets for coastal zone planning and management

<table>
<tr>
<td>
Oceanographic Data
• bathymetry
• exposure – wind and waves
• ocean circulation
• sediment transport \ resuspension
• SST – historic and current
• Ocean acidity \ pH \ carbonates

Physical Data
• coastline (and changeover time)
• Elevation
• Land Cover
• Shoreline geology

Climate Data
• Historic cyclones \ storm tracks and probabilities
• Storm surge \ wave height probabilities
• Rainfall – historic and projections

Ecological Data
• Coral Reef locations
• Mangrove locations (and historic / change over time)
• Seagrass beds / locations
• Coral Condition Indicator
• Live coral cover
• Coral disease
• Mangrove characteristics (density, canopy height)
• Fish abundance / biomass

Threats and Impacts Data
• Water quality data (including E coli)
• Nutrient and Sediment runoff / turbidity / change in nutrients due to storm / pollution events
• Sewage Management / sewage impacts / CSO / storm drain locations
• Coastal erosion
• Change in ecosystem before and after storm
• Impacts from tourism
</td>
<td>
Global Change Data
• Sea level rise projections
• Ocean acidification projections
• Coral bleaching (historical observations)

Social and Economic Data
• Population Density (and projections)
• Land Use
• Tourism / recreation intensity / use data - including from social media
• Small vessel locations
• Fish catch / fishing boat locations
• Damage from storms / flooding (historic)

Built Environment
• Existing Development / built environment/ housing
• Infrastructure locations – roads, water treatment, sewage treatment, airports, ports, communication infrastructure)
• Building footprints
• Building elevation
• Tourist infrastructure (hotels, airports, etc.)

Ecosystem Service Data
• Tourism Values
• Wave attenuation value
• Fisheries / food provision value

Administrative / Zoning
• Coastal Zoning
• MPAs – boundaries and type

Indicators / models
• Coastal flood risk (by storm event)
• Exposure of built assets
• Reef resilience likelihood / index
• Percent of coral reef area inside MPA / certain zones
• Sewage treatment (capacity, need, level, pct. Of population served)
</td>
</tr>
<tr>
<td colspan="2">For details on specific data requests (e.g. desired scale, time period (historic \ current \projection), periodicity of data and recommended sources, please see Annex A-6, the 4th tab in the spreadsheet on Data Priorities and Details by Audience.</td>
</tr>
</table>

Comments on scale and time periods –

- Historic data were requested in several data categories, including land use change, water quality, beach dynamics, and coral condition, with a 10-year minimum, but longer is desirable.
- Periodicity – for several oceanographic and climate data sets (such as currents, waves, precipitation, cyclone activity, wind-generated sediment resuspension) seasonal or monthly data are desired.
- Projections – for climate and other global change projections, decadal summaries were commonly requested – generally to 2040 or 2050, and to 2100 for sea level rise.
- Spatial scale – The desired scale varies by data set topic and by decision / use. (See Annex A-2 and Annex A-6 for details.)

Data Use in Analysis and desired functionality

For CZP and MSP large numbers of data are combined – either in visual overlay for participatory planning or in a modeling / optimization software. Visual overlay can also be used to explore co-location / sources of impact on coral reefs. Some respondents:

1. Just need data - People are often working with their preferred tool (often very specialized), and only want access to data sets – to put in their own tool. For example, **NatCap's InVEST** is used for MSP – evaluation of different scenarios, while **MARXAN** is commonly used for MPA network planning.
2. Just want to see it – For about a 30 – 40 % of respondents, **visualization** of data – and ability to do visual overlay is enough, provided it works even in low-bandwidth environments. This would support participatory planning, and visual analysis of co-location of threats and habitat condition.

Other factors and needs inhibiting better decision-making

Beyond data, respondents noted the need for training, improved coordination, better enforcement, improved communication of importance of reefs, consolidated knowledge, and ….. better maps! (See Annex A-2 for details.)

Key Links to tools / initiatives

Some important coastal decision support tools are available through the Reef Resilience network, Climate Central, and the Natural Capital project. (Details are in Annex A-2.) NatCap have developed an excellent coastal risk visualization for the Bahamas. It is worth exploring potential collaboration with the Natural Capital project to see if it is possible to apply some of their algorithms more broadly - to develop some global data sets for visualization on a map-based platform.

3. Marine Protected Area managers and authorities (MPA) Summary

Key informants for MPA authorities and managers audience - Interviewees include MPA authorities and managers who oversee protected areas and human activities within marine parks, lead management planning efforts, lead threat mitigation, draft national marine legislation, conduct stakeholder engagement, lead and coordinate monitoring, conduct permit review, lead education and outreach to policy makers, government, and communities, integrate cultural heritage in MPA management, and guide research for MPAs.

Key Data Needs to support MPA Managers:

Data required by MPA managers differs based on management objectives but often includes data on the health and threats facing coastal and marine ecosystems such as coral reef, mangroves, seagrasses, and fisheries. Threat data include impacts from a variety of human activities (overharvest, destructive fishing methods, tourism impacts, etc.) and also from climate change (e.g., coral bleaching). Data on human use

is also needed to inform zoning and marine management efforts. There was significant overlap between priority data needs of MPA managers and NGO practitioners as many of the NGO practitioners were supporting the planning and management of MPAs. MPA managers also discussed the importance of change over time data (change in condition, change in threat) to monitor the condition of marine ecosystems and species, to assess the effectiveness of management efforts and inform adaptive management.

Table 5- Summary of key data sets for MPA Managers

<table>
<tr>
<td>
Oceanographic/Physical Data
• Currents (connectivity)
• Ocean circulation
• Bathymetry
• Exposure (wind, wave)

Climate Change Data
• Coral bleaching (historic observations)
• Coral bleaching (decadal projections)
• Sea-surface temperature (current)
• Sea-surface temperature (projections)
• Sea-surface temperature (historic)
• Ocean acidification (projections)
• Coral bleaching (alerts of current risk)
• Storms (historic)
• Storms (projections)
• Sea-level rise (projections)

Ecological Data
• Reef location and extents
• Live coral cover
• Fish abundance and biomass
• Mangrove locations (aerial extent/change over time)
• Change through time (extent, condition, status)
• Larval connectivity
• Biodiversity
• Vegetation
</td>
<td>
Threats and Impacts Data
• Nutrient or sediment runoff
• Damage from fishing gear
• Coral disease
• Impacts from tourism
• Dynamite fishing
• Anchor damage on coral
• Water quality impacts
• Fisheries pressure
• Impact from trash/plastics

Social, Economic, Governance Data
• MPA type and area
• Population density
• Coastal zoning
• Marine zoning
• Fish catch (max sustainable yield)
• Damage from storms / flooding

Ecosystem Service Data
• Fisheries/food provisioning
• Tourism value

Indicators / models
• Reef resilience index
</td>
</tr>
<tr>
<td colspan="2">See Annex A-5 for additional detail on the use of sea surface temperature data (past, present and projections) for coral reef management decisions.</td>
</tr>
</table>

Comments on scale and time periods –

- Historic data – The timing and frequency of data collection is determined by management objectives and species-specific considerations. Historical data (of at least 10 years) are important to observe trends (e.g., particularly to assess changes in species abundance, changes in ecosystem cover or condition, demographic changes, attitudes and reef use) and key events (e.g., bleaching events and storm impacts). Annual data is necessary to inform management actions to address threats. Multi-

decadal historic climate data (e.g., SSTs, storms, coral bleaching) are useful to assess patterns in climate impacts on reefs.

- Periodicity – Seasonal and monthly data are used for both oceanographic and climate data; for threat data, periodicity depends on frequency of stress events (e.g., coral bleaching events, sediment entering coastal zone from upland during flooding)
- Projections – Decadal summaries were used to assess climate and other global changes, typically between 30-50 years in the future. Decadal projections were also noted to consider changes in ocean circulation, current patterns, coral recruitment and settlement, economic projections for tourism and fisheries industries.
- Spatial scale – Requirements vary widely by data set and intended use. Specifically, the spatial scale needed is determined by the desired management objective, the system of interest (e.g., catchment, mangrove forest, coral reef, etc.), and the scales of decision making which can range from local to regional.

Data Use in Analysis and desired functionality

MPA managers use a wide variety of data to support decision making including oceanographic, climate, physical, ecological and social data. Overlaying data through GIS can inform zoning and management efforts, as can the integration of data into decision-support tools such as MARXAN. MPA managers often combine data to inform management efforts (e.g., fish surveys, life history, larval duration to inform zones for protection; integration of social and ecological data to inform feedbacks and interactions and to prioritize management interventions). The importance of simple indicators is preferable to inform management, unless trainings on tools and platforms are provided. Data is also used for assessing compliance to management regulations and informing fisheries management actions (e.g., harvest bans on target species, fish reproduction data to inform size limits).

Other factors and needs inhibiting better decision-making – MPA

In addition to data needs, key stumbling blocks to better decision-making include lack of funding, capacity, and political will to support coral reef protection and restoration, and lack of enabling legislation and ineffective management. The importance of having data at the appropriate scale to inform management and in the appropriate format to be used by decision-makers was highlighted, in addition to the need for institutional frameworks to integrate data. Additional important needs mentioned included rapidly scaled reef restoration, improved enforcement, better coordination to support effective management between government agencies, NGOs, communities, and improved legislation. Providing alternatives to exploitation for reef users, education around the benefits of reefs, and engagement of stakeholders in participatory processes for planning and management are all needed to inspire behavior change and greater protection of coral reefs.

Key initiatives relevant to data and opportunities for collaboration

A number of initiatives and platforms provide critical data to support MPA design and management (see Annex A-3). For MPAs to be effective in the future, the integration of climate data, especially SST data, is critical. The IPCC provides a suite of model ensembles that can be used to derive projections of SST and changes in other oceanographic data. Groups such as NOAA's Coral Reef Watch utilize these and other sources of data to generate downscaled projections of climate impacts. In addition, regional data hubs to support the establishment and management of protected areas have been developed (e.g., Coral Triangle Atlas, Caribbean Protected Areas Gateway). Global Networks to support MPA managers, such as the Reef Resilience Network help to share cutting edge science to improve reef management, knowledge sharing across reef regions, and capacity building through targeted trainings for the improved conservation and restoration of coral reefs and reef fisheries globally.

4. Conservation NGOs implementing marine and coastal protection and restoration (NGO) Summary

Key informants for scientists and practitioners from NGOs audience **-** Interviewees include senior staff from global and regional conservation NGOs who lead coral reef conservation, research, and restoration efforts, work with governments to protect reefs, manage marine sanctuaries, lead community engagement and education campaigns, lead marine ecosystem monitoring, and advance coral reef policies and public funding.

Key Data Needs to support NGO practitioners

Data required by NGO practitioners are determined by the scale at which management decisions are made - fine resolution to inform threat mitigation, the location of protected areas, and use zones within protected areas and coarser data to inform policies and spatial plans over larger areas. Data reflecting change over time (condition and threats) are important to monitor the condition of marine ecosystems and species (reef, mangroves, fisheries), to assess the effectiveness of management efforts and inform adaptive management, and to communicate priorities to governments and reef users.

Table 6- Summary of key data sets for the NGO sector

Oceanographic/Physical Data • Ocean circulation/current patterns • Bathymetry Climate Data • **Sea surface temperature (current)** • Sea-surface temperature (historic) • Sea-surface temperature (projections) • Coral bleaching (decadal) • Coral bleaching (historical observations) • Coral bleaching (alerts of high risk) • Sea-level rise projections Ecological Data • **Live coral cover** • **Reef location and extents** • **Reef condition** • **Biodiversity** • **Fish abundance / biomass** • **Mangrove locations/condition** • **Change over time of condition/extent/status of mangroves, reefs, seagrasses and key fisheries** • Benthic habitat type/cover/abundance Ecosystem Service Data • **Fisheries / food provisioning** • Wave attenuation/coastal protection • Tourism value	Threats and Impacts Data • **Water quality impacts** • **Impacts from tourism** • **Coral disease** • **Nutrient or sediment runoff** • **Sewage management / impacts** • **Changes over time of threats (pollution, sedimentation, overfishing/destructive fishing)** • Impacts from watersheds • Damage from fishing gear • Impact from trash/plastics • Anchor damage on coral • Coastal erosion Social, Economic, Governance Data • **Marine Protected Area type and area** • Resource use/dependence • Land use • Fish catch • Tourism/recreation intensity • Marine zoning • Population density • Damage from storms/flooding Indicators / models • **Fishing pressure** • Coastal flood risk (by storm event)

(See Annex A-5 for additional detail on the use of sea surface temperature data (past, present and projections.)

Comments on scale and time periods –

- Historic data – Historical data over multiple decades are necessary to assess thermal history at sites and changes in reef condition over time, especially considering climate change and natural disasters. Historical data collected annually can inform habitat protection and restoration efforts.
- Periodicity – Climate data may be required in decadal, monthly, or weekly time frames depending on the management objective (e.g., determining projections of future bleaching risk may require decadal SST data whereas weekly/monthly SST data may be required to inform bleaching response monitoring). For threat data periodicity depends on frequency of threat occurrence (e.g., blast fishing, bleaching events, coral disease outbreaks).
- Projections – Projecting changes in climate and other oceanographic conditions typically requires decadal data (>30 years). Climate projections that extend to 50 years into the future are important to build resilience into marine protected area design.
- Spatial scale - Requirements vary widely by data set and intended use and are determined by the scale that the management decision is made. National level data may be used to support national marine spatial planning or zoning and siting of large MPA networks. The importance of fine resolution habitat data and data over time are useful to monitor species and habitat changes, management effectiveness, and restoration success.

Data Use in Analysis and desired functionality

NGO practitioners utilize a wide variety of data to support many different types of management decisions from zoning plans, to siting of MPAs, to informing where restoration efforts are most likely to be successful. Highly accurate benthic habitat maps that show the coverage of different habitats (e.g. coral reefs, mangroves, seagrasses etc.) are extremely useful to inform MPA site selection, zoning, and restoration projects. The use of satellite data combined with field surveys can provide broad coverage of social and ecological data that helps design robust coral reef management programs. A key need is guidance on how to utilize existing data to inform management decisions. For example, when NGO practitioners have access to projections of SST data, guidance may be required regarding how to use that data to inform prioritization of MPAs (e.g., do you prioritize areas predicted to heat up more slowly in the future or select areas of high thermal variability which may be adapted to heat stress?). While some global guidance is available to support the identification of sites likely to be more resilient to climate change, regionally specific thresholds and indicators are also needed. For example, summary indicators of reef health (e.g. https://www.healthyreefs.org/cms/healthy-reef-indicators/) can be helpful to prioritize areas for protection. Another stated need is for a coral restoration index to help prioritize areas for outplanting coral. Finally, NGO practitioners mentioned the need for guidance for assessing and communicating the trade-offs between different management strategies in terms of their costs and social, economic, and ecological benefits (e.g., prioritizing reducing overfishing of herbivores vs. reducing coastal pollution). Tools such as InVEST can be used to assess tradeoffs associated with different management actions.

Other factors and needs inhibiting better decision-making

Data limitations are exacerbated by the difficulty of maintaining a sustainable online hub that includes tools, guidance, and resources. It is difficult to secure long-term funding for monitoring and online data platforms over time. This challenge is increased due to the need for multiple data hubs to address needs

at national to regional scales (e.g., regional data hubs such as the Coral Triangle Atlas and CaribNode help to ensure use data inform national policies and management efforts). In addition to data management challenges, NGO practitioners need to translate complex data tools into simple to use approaches. Lack of technical capacity is often a key limitation of using existing data from global datasets (e.g., NOAA's CRW) and decision support tools (e.g., MARXAN). Local trainings that introduce tools to show practitioners how they can be applied locally using existing datasets can help to mainstream the use of existing tools and data. Finally, because lack of political will is one of the greatest barriers to improved coral reef management, simple visualizations that highlight the threats facing reefs, management effectiveness, and inform national policies are particularly important. Therefore, efforts to support coral reef data development should include funds and capacity for communication, marketing, and policy expertise to ensure that outputs intended to inform decision making can be designed effectively to do so.

Key initiatives relevant to data and opportunities for collaboration

NGO practitioners utilize many initiatives to support increased collaboration and improved decision-making (See Annex A-4). NOAA's Coral Reef Watch creates products that can be used to help predict and respond to coral bleaching events, assess coral disease risk, the impact of solar radiation, ocean color, thermal history, and larval connectivity. Global initiatives exist to support education campaigns and community actions to protect reefs, and volunteer networks to monitor reefs (e.g., Reef Check) and consolidate reef monitoring data into global databases (e.g., ReefBase). The global Reef Resilience Network supports knowledge sharing and capacity building for coral reef practitioners and managers to improve coral reef management. Global reef threat analysis efforts include Reefs at Risk which assesses the status of and threats facing the world's coral reefs. Some global initiatives support improved decision making, such as the Alliance for Conservation Evidence and Sustainability (ACES). ACES is an NGO-led collaboration focused on generating, synthesizing, and using evidence for community-based conservation. A number of regional initiatives support research and management of coastal and marine environments (e.g., Coastal Oceans Research and Development – Indian Ocean (CORDIO) East Africa; Healthy Reefs for Healthy People in the Mesoamerican Reef; Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security).

Data priorities across the four audiences

The information on data priorities for each audience was integrated, with results in Table 7. This table shows whether a given data set scored as important (1) or very important (2) for each audience. The table also tallies those scores with equal weights (simple tally) and with the RISK audience weighted at 1.5. The color coding in the "priority" column reflects whether a data set is a high priority across the audiences (aqua shading means the tally with the 1.5 weighting for RISK was at least 3.0); or a medium priority (yellow shading reflects a score of 2.5 – 2.9). Dark blue shading reflects data sets flagged as "exceptions" which the authors wanted to retain in the following review of data sources and the final discussion. Table 7 reflects these results by data category, while Table 8 reflects the same results sorted by the weighted score.

Table 7- Data priorities integrated across the four audiences

All Data	RISK	CZM	MPA	NGO	Simple Tally	Tally with 1.5 for RISK	Exception	Priority
Oceanographic Data								
• bathymetry	2	2	1	1	6	7		
• exposure – wind and waves	2	2	1		5	6		
• ocean circulation	1	2	1	1	5	5.5		
• tidal data	1				1	1.5		
• Currents (connectivity)			1		1	1		
• Sea surface temp. (3D, historic and current)	1	2	2	2	7	7.5		
• Ocean acidity \ pH \ carbonates		1			1	1		
• sediment transport \ resuspension		1			1	1		
Physical Data								
• Elevation	2	2			4	5		
• coastline (and changeover time)	1	1			2	2.5		
• beach profile	1				1	1.5		
• Land cover	1	1			2	2.5		
• Shoreline geology	1	1			2	2.5		
Climate and Global Change Data								
• Historic cyclones \ storm tracks and probabilities	2	1			3	4		
• Storms – historic and projections	1		1		2	2.5		
• Storm surge \ wave height probabilities	1	1			2	2.5		
• Rainfall – historic and projections	1	1			2	2.5		
• Sea-level rise (projections)	2	2	1	1	6	7		
• Sea-surface temperature (projections)			2	1	3	3		
• Ocean acidification (projections)		1	2		3	3		
• Coral bleaching (historic observations)		1	2	1	4	4		
• Coral bleaching (decadal projections)			2	1	3	3		
• Coral bleaching (current risk alert)			1	1	2	2	X	
Ecological Data								
• Coral Reef locations	2	2	2	2	8	9		
• Mangrove locations (and historic / change over time)	2	2	2	2	8	9		
• Seagrass beds / locations	1	1		1	3	3.5		
• Coral rugosity / structure	2				2	3		
• Coral condition indicator	1	1		2	4	4.5		
• Live coral cover	1	2	2	2	7	7.5		

• Coral disease		1	1	2	4	4		
• Larval connectivity			2		2	2	X	
• Mangrove characteristics (density, canopy height)	1	1			2	2.5		
• Vegetation			1		1	1		
• Fish abundance and biomass		1	2	2	5	5		
• Biodiversity			1	2	3	3		
• Coastal Erosion	1			1	2	2.5		
• Change through time (extent, condition, status)			2	2	4	4		
Threats and Impacts Data								
• Water quality data (including E coli)	1	1	1	2	5	5.5		
• Nutrient and Sediment runoff / turbidity	1	2	2	2	7	7.5		
• Sewage Management / sewage impacts		1		2	3	3		
• Coastal erosion		1			1	1		
• Change in ecosystem before/after storm	1	1		1	3	3.5		
• Impacts from tourism		1	1	2	4	4		
• Fisheries pressure			1	2	3	3		
• Damage from fishing gear			2	1	3	3		
• Dynamite fishing			1		1	1		
• Anchor damage on coral			1	1	2	2		
• Impacts from trash / plastics			1	1	2	2		
• Changes over time of threats				2	2	2		
Social and Economic Data								
• Population Density (and projections)	2	2	1	1	6	7		
• Land Use		2		1	3	3		
• Tourism / recreation intensity		1		1	2	2	X	
• Small vessel locations		1			1	1		
• Fish catch / fishing boat locations		1	1	1	3	3		
• Damage from past storms/flooding		1	1	1	3	3		
• Resource use/dependence				1	1	1		
Built Environment								
• Existing Development / built environ.	2	1			3	4		
• Infrastructure locations	2	1			3	4		
• Building footprints	2	1			3	4		
• Building construction materials / type	1				1	1.5		
• Building elevation		1			1	1		
• Historic flooding	1	2			3	3.5		
• Flood defense (characteristics)	1				1	1.5		

Ecosystem Service Data								
• Tourism Values	1	1	1	1	4	4.5		
• Wave attenuation value	1	1		1	3	3.5		
• Fisheries / food provision value	1	1	2	2	6	6.5		
• Stored Carbon	1				1	1.5		
Administrative / Zoning								
• Coastal Zoning		1	1		2	2		
• MPAs – boundaries, area, and type		1	2	2	5	5		
• Marine zoning			1	1	2	2		
Indicators / models								
• Coastal flood risk (by storm event)	1	2		1	4	4.5		
• Exposure of built assets	2	1			3	4		
• Reef resilience likelihood / index	1	1	2		4	4.5		
• Projected impact of sea level rise	1				1	1.5		
• Pct. of coral reef area inside MPA		1			1	1	X	
• Sewage treatment		1			1	1	X	

Table 7 reveals the relative importance of data within each data category. Once these data sets are sorted by the tally of audience scores (Table 8) we can more clearly see which data sets are the top priorities across the four audiences. Of the top ten priority data sets, three are **ecological** (coral reef locations, mangrove locations, live coral cover), three are **oceanographic** (sea surface temperature, bathymetry, wind and wave exposure), and one each from **threat and impact** (nutrient and sediment runoff), **global change** (sea level rise projections), **social and economic** (population density), and **ecosystem services** (fisheries / food provisioning value).

Table 8- Data priorities across the four audiences - sorted by weighted priority

All Data	RISK	CZM	MPA	NGO	Simple Tally	Weighted Tally (with 1.5 for RISK)
· Coral Reef locations	2	2	2	2	8	9
· Mangrove locations (change over time)	2	2	2	2	8	9
· Sea surface temp. (3D, historic and current)	1	2	2	2	7	7.5
· Live coral cover	1	2	2	2	7	7.5
· Nutrient and Sediment runoff / turbidity	1	2	2	2	7	7.5
· bathymetry	2	2	1	1	6	7
· Sea-level rise (projections)	2	2	1	1	6	7
· Population Density (and projections)	2	2	1	1	6	7
· Fisheries / food provision value	1	1	2	2	6	6.5
· exposure – wind and waves	2	2	1		5	6
· ocean circulation	1	2	1	1	5	5.5
· Water quality data (including E coli)	1	1	1	2	5	5.5
· Elevation	2	2			4	5
· Fish abundance and biomass		1	2	2	5	5
· MPAs – boundaries, area, and type		1	2	2	5	5
· Coral condition indicator	1	1		2	4	4.5
· Tourism Values	1	1	1	1	4	4.5

·	Coastal flood risk (by storm event)	1	2		1	4	4.5
·	Reef resilience likelihood / index	1	1	2		4	4.5
·	Historic cyclones /storm tracks /probabilities	2	1			3	4
·	Coral bleaching (historic observations)		1	2	1	4	4
·	Coral disease		1	1	2	4	4
·	Change through time (extent, condition)			2	2	4	4
·	Impacts from tourism		1	1	2	4	4
·	Existing Development / built environment	2	1			3	4
·	Infrastructure locations	2	1			3	4
·	Building footprints	2	1			3	4
·	Exposure of built assets	2	1			3	4
·	Seagrass beds / locations	1	1		1	3	3.5
·	Change in ecosystem before and after storm	1	1		1	3	3.5
·	Historic flooding	1	2			3	3.5
·	Wave attenuation value	1	1		1	3	3.5
·	Sea-surface temperature (projections)			2	1	3	3
·	Ocean acidification (projections)		1	2		3	3
·	Coral bleaching (decadal projections)			2	1	3	3
·	Coral rugosity / structure	2				2	3
·	Biodiversity			1	2	3	3
·	Sewage Management / sewage impacts		1		2	3	3
·	Fisheries pressure			1	2	3	3
·	Damage from fishing gear			2	1	3	3
·	Land Use		2		1	3	3
·	Fish catch / fishing boat locations		1	1	1	3	3
·	Damage from storms / flooding (historic)		1	1	1	3	3
·	coastline (and changeover time)	1	1			2	2.5
·	Land cover	1	1			2	2.5
·	Shoreline geology	1	1			2	2.5
·	Storms – historic and projections	1		1		2	2.5
·	Storm surge \ wave height probabilities	1	1			2	2.5
·	Rainfall – historic and projections	1	1			2	2.5
·	Mangrove characteristics	1	1			2	2.5
·	Coastal Erosion	1			1	2	2.5
·	Coral bleaching (alerts of current risk)			1	**1**	2	2
·	Larval connectivity			2		2	2
·	Anchor damage on coral			1	1	2	2
·	Impacts from trash / plastics			1	1	2	2
·	Changes over time of threats				2	2	2
·	Tourism / recreation intensity		1		1	2	2
·	Coastal Zoning		1	1		2	2
·	Marine zoning			1	1	2	2
·	tidal data	1				1	1.5
·	beach profile	1				1	1.5
·	Building construction materials / type	1				1	1.5
·	Flood defense (characteristics)	1				1	1.5
·	Stored Carbon	1				1	1.5
·	Projected impact of sea level rise	1				1	1.5
·	Currents (connectivity)			1		1	1
·	Ocean acidity \ pH \ carbonates		1			1	1
·	sediment transport \ resuspension		1			1	1
·	Vegetation			1		1	1

·	Coastal erosion		1			1	1
·	Dynamite fishing			1		1	1
·	Small vessel locations		1			1	1
·	Resource use/dependence				1	1	1
·	Building elevation		1			1	1
·	Percent of coral reef area inside MPA		1			1	1
·	Sewage treatment (capacity)		1			1	1

Data sets relevant to international targets and coral reefs (as of February 28th)

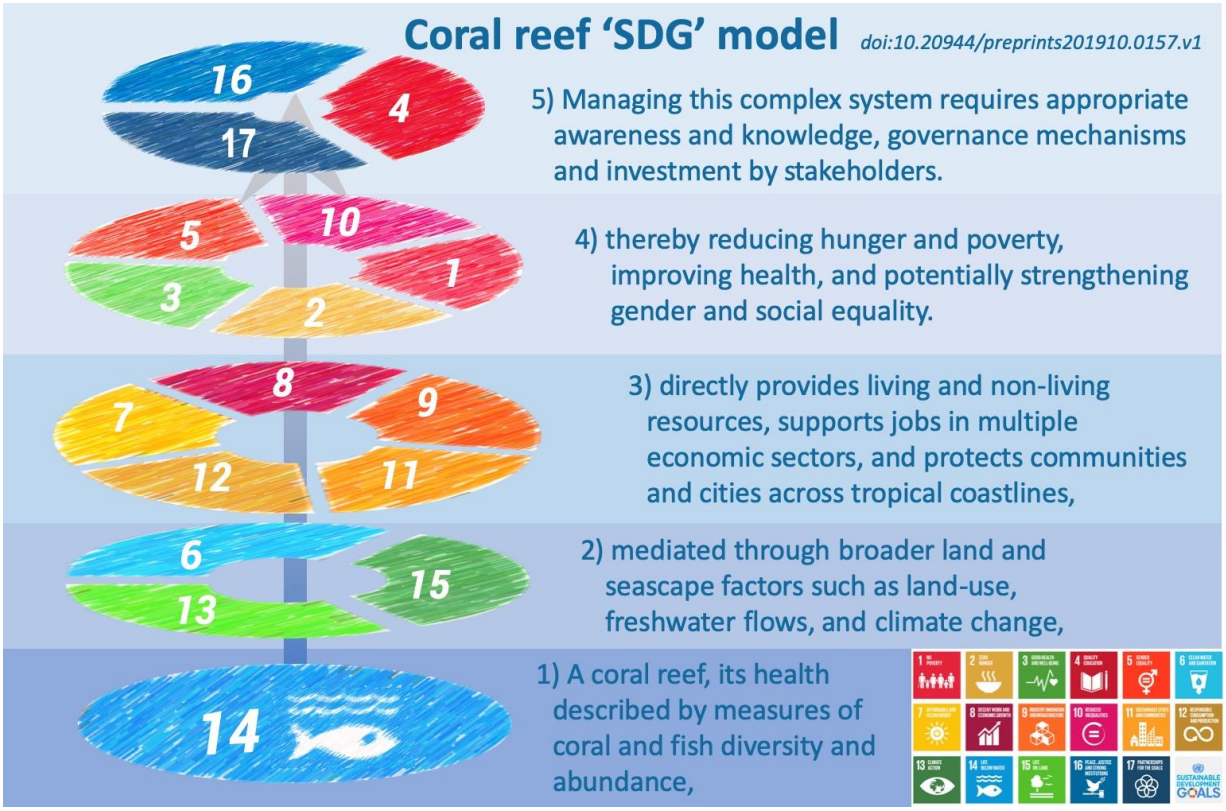
Although the four audiences described above were the primary focus of this research, we also explored which data are important for the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (SDGs). We conducted two interviews with members of the International Coral Reef Initiative's (ICRI) **Ad hoc committee for developing a recommendation on a coral related target for the CBD post-2020 framework** for global biodiversity targets - Emily Corcoran, who leads the ad hoc committee, and David Obura (CORDIO).

Although **SDG 14***, Life Below the Water* **-** *conserve and sustainably use the oceans, seas and marine resources for sustainable development* – is the most directly relevant for coral reefs, all SDGs have some relevance to coral reefs . Figure 3 and the following text summarize these relationships.

Coral reefs and links to the SDGs: Coral reefs are most often thought of in relation to (G14 – life below the water), but coral reef "health, described by measures of coral and fish diversity and abundance, provide key services and benefits to people. These services directly support 10s of millions of jobs in multiple economic sectors {G8} in coastal and distant states, protect and harbor communities and cities {G11} across tropical coastlines, sustain use of living and non-living resources{G12}, provide transport infrastructure and valuable natural products {G9}, and in future may provide energy solutions {G7}. Through these multiple benefits, coral reefs contribute to reducing hunger {G2} and poverty {G1}, thus improving health {G3}, and potentially strengthening gender {G5} and social equality {G10}. However, access and use result in pressures that may drive decline in coral reef health. Broader land and seascape factors also affect reef health, including land-use change {G15} and altered freshwater flows {G6}, as well as climate change {G13}. Managing this complex system requires appropriate awareness and knowledge {G4}, governance mechanisms {G16} and investments by stakeholders {G17}".[3]

[3] Obura, D.O. (2019) *A plot for sustainability -the Sustainable Development Goals as a narrative*. Preprints 201910.0157

Figure 3- Coral Reefs in Relation to the SDGs



From: Obura, D.O. (2019) *A plot for sustainability -the Sustainable Development Goals as a narrative*. Preprints

The ICRI Ad Hoc Committee is in the process of refining recommendations to the CBD, so the indicators listed below are not final. Many indicators which are relevant to evaluation of the post-2020 CBD Framework, as well as the SDGs, are not currently available on a global basis. This list of six indicators include those which are aspirational on a global basis, however the first three are possible and will be included in the GCRMN 2020 status report.

- **Live coral cover -** Live coral cover is an existing indicator for the Aichi Targets of the CBD and is an Essential Ocean Variable (EOV).
- **Algal cover –** also provides information on the health, function and integrity of coral reefs. Macroalgal canopy cover and composition is the most closely related EOV.
- **Percent of reefs protected -** Area (or pct.) of coral reefs within functioning MPAs or under other effective area-based conservation measures. This is also an Aichi Target. (This is an indicator which can be calculated if reliable data exist on coral reef locations (coral reef map) and on MPAs and effectiveness of management.
- **Water quality** (and/or data on land-based sources of pollution) – pollution from the land, including runoff from agriculture and un- or under-treated sewage (amongst others) are important threats to coral reefs. Nutrients is an EOV, though this does not cover the full range of pollutants relevant to coral reefs.
- **Fish abundance -** Reef fish abundance and biomass are important indicators of coral reef health. Estimation of this indicator includes consideration of which species to include. Fish abundance and distribution is an EOV.
- **Structural complexity of coral reefs -** Coral structural complexity is important for wave mitigation, fish habitat, and for coral health. Hard coral cover and composition is the most closely-related EOV.

Evaluation of data requirements and potential data sources

The 60 data needs rated as high priority, medium priority or an exception[4] were further reviewed to evaluate the data requirements for each audience (e.g., what resolution of coral reef location data is required by each audience, etc.) as well as whether data are available to fulfill this requirement. The compilation below is based on input from experts throughout this research effort (interviewees, survey respondents, and spatial data experts). It reflects our initial conclusions and will benefit from further review by project partners and other experts working on these topics. The full compilation of potential data sources is in Annex A7 – Data Priorities and Data Sources, with conclusions listed in Table 9. As part of this effort, we have classified each data need into one of the following classes:

A. a data set exists which adequately fulfills requirements;
B. a global data set exists, but not with the desired resolution, accuracy, or other characteristics (but, is currently the best available) and could be considered for inclusion on a data platform;
C. Some data currently exist, but not in a complied form; or data don't currently exist, but there might be an opportunity to catalyze development of this data set;
D. No viable data source has been identified - but maybe technology, collaboration, and concerted effort will change that in the future.

Table 9 provides a list of Class A and Class B data sources as defined above. These are data which could be considered for inclusion on a data platform supporting decision-making relevant to coral reefs. The data sources listed are our current recommendation, though additional data sources could be identified (or published) in the future.

Table 9- Data needs for which likely data source have been identified (A&B)

Data Category / Need	Demand Score	Rating	Recommended data source(s) and comments	Note:
Benthic Habitat				
Coral reef locations	9	B	UNEP-WCMC (for now); Vulcan ACA once available.	Habitat change over time is desired.
Mangrove locations	9	B	Global Mangrove Watch	
Seagrass locations	3.5	B	UNEP-WCMC (for now); Possibly Vulcan ACA once available.	
Sea surface temperature (SST) and coral bleaching				
SST – historic	7.5	B	NOAA Coral Reef Watch – (3 indicators) Number of Severe Heat Stress Events (DHW≥8): and SST Variability (annual variability and warmest month variability)	
SST – current	7.5	B	NOAA Coral Reef Watch – (3 indicators) - SST, Anomaly, and SST trend	
Coral bleaching alerts	2	B	NOAA Coral Reef Watch – (3 indicators) - Alert Area – 7 day, Degree Heat Weeks (DHW) and HotSpot	

[4] Five data sets which did not score as a high or medium priority were never-the-less included in the list of 60 data sets. These are data sets the authors feel are important but might have scored poorly because of some artifact of the way the question was asked or how responses were evaluated.

SST – projections	3	B	NOAA Coral Reef Watch projections using the RCP8.5 scenario and severe bleaching frequency of 2x and 10x per decade. (These data are also available in multiple formats through UNEP.)	
Oceanographic				
Bathymetry	7	B	GEBCO - data are 15 arc seconds (about 500 m resolution)	
Ocean circulation / currents	5.5	B	HYCOM – data are at 5 minute (roughly 10 km resolution)	
Larval connectivity	2	B	University of Queensland / 50 Reefs project (data available from authors)	
Exposure – wind and waves	6	B, C	NOAA WAVEWATCH III – Significant wave height	(See cyclones below.)
Tidal Range	Exception	B	AVISO+ Global Tide	
Climate and global change				
Sea level rise (past)	5	B	European Space Agency (ESA) Global Sea Level ECV Product (available through email request)	
Sea level rise (projections)	7	B	Integrated Climate Data Center AR5 Sea Level Rise	
Historic Cyclones (tracks and frequency)	4	B	UNEP/DEWA/GRID-Europe – Global Risk Data Platform (GRDP) – • Winds - tropical cyclone frequency and intensity (and tracks if desired for context) • Storm surge - frequency and exposure (physical and economic)	
Ocean acidification	3	B	Aragonite Saturations State (ΩAR) projections from NOAA CRW (using RCP 8.5) • percent decline in ΩAR by year and • year ΩAR concentration goes below 3.0, 3.25, 3.5, 3.25, 3.0, 2.75, and 2.5. (Another source which could be considered is either CMIP5 or the forthcoming CMIP6.)	
Coastal Interface (land and sea)				
Nutrient and sediment runoff / turbidity	7.5	B	ESA's Globcolour (which is moving to here) – Total suspended solids (TSS). (Need to confirm that these data are being maintained.)	
Elevation	5	B	Climate Central's CoastalDEM from Climate Central – based on NASA 30 m SRTM data, with reduced median errors.	
Coastline (and change over time)	2.5	B	Jean-Francois Pekel et. al. High-resolution mapping of global surface water and its long-term changes (1984-2018) available through the Joint Research Centre. (30m resolution).	(over time)

Land cover	2.5	B	ESA Climate change Initiative (CCI) Land Cover provides a time series of consistent global land cover maps at 300 m spatial resolution on an annual basis from 1992 to 2015.	
Social and economic				
Population Density	7	A	WorldPop offers 1km global datasets (annually from 2000); 100m available nationally.	(over time)
Economic Density	N.A.	B	Socioeconomic Data and Applications Center (SEDAC) – Gridded Global GDP (Global 15 x 15 Minute Grids of the Downscaled GDP Based on the SRES B2 Scenario, v1 for 1990 and 2025)	
Administrative / zoning				
MPAs – boundaries, area, type	5	A	MPA Atlas - These data are an enhanced marine and coastal subset of WDPA.	Need to be requested, as down-load not working
International boundaries	N.A.	N.A.	A platform could include international maritime boundaries, subject to the host organization's policies on territorial disputes. Flanders Marine Institute's Maritime Boundaries.	
Ecosystem Services				
Fisheries / food provisioning	6.5	B	Mapping Ocean Wealth – Modeled coral reef fisheries catch	Data sets are not down-loadable. Available through the authors.
Tourism value	4.5	B	Mapping Ocean Wealth – Modelled total value of reef tourism. (Also include "on reef" and "reef adjacent" tourism values.)	
Wave attenuation / shoreline protection value	3.5	B	Mapping Ocean Wealth – a) The "Global Coral Protection index" provides an indicator of the relative protection coastal and barrier reefs provide from wind and swell waves. (The mapping is comparable to MOW fisheries and tourism indications.) b) A point data set at 20km spacing (from Beck et al. 2018) provides estimates of the annual expected benefit from coral reefs for flood protection ($US millions). The values are the difference in annual expected damages with and without (the top 1m) of reefs for the 20 km coastal study units.	
Built Environment and Risk				
Existing development / built environment	4	B	Global Human Settlement-BUILT from the European Commission JRC. Provides 30 m resolution data reflecting whether an area is developed (by time period – by 1975; 1990; 2000; 2014).	

Exposure of built assets	4	B	UN Office for Disaster Risk Reduction (UNDRR) Global assessment report on disaster risk reduction (GAR 2015) Events and Hazards – Storm surge hazard (by return period) and average annual loss and average relative loss.	
Infrastructure	4	A/B	Many types of infrastructure could be included – roads, airports, ports, water and wastewater treatment facilities, pipelines, infrastructure for oil and gas, communications, etc. Data sources for these generally exist but are regarded as a lower priority than many of the data sets listed above.	

Opportunities to collaborate to fulfill a data need (C)

There are many data gaps beyond those fulfilled by data sources listed in Table 9. Table 10 presents some of the most promising opportunities for collaboration to fill some of these data gaps.

Table 10- Indicator needs and opportunities for collaboration (C)

Data Category / Need	Demand Score	Rating	Situation / Opportunity
Ecological Data			
Live Coral Cover	7.5	C	These data might become available on a regional basis through GCRMN. They are available for some regions (sub-global) - e.g. AGRRA, HRI, CORDIO. The Ocean Data Foundation (ODF) might be able to play a role in consolidation.
Coral Condition	4.5	C	
Coral bleaching (historic observations)	4	C	Disparate data would need to be combined. ReefBase is an outdated starting point. Would require broad collaboration. Perhaps ICRI or GCRMN could lead. Potentially accomplished through GCRMN regional nodes.
Coral Disease	4	C	Disparate data would need to be combined. These data, developed for Reefs at Risk in 2011, and now available through UNEP-WCMC are an outdated starting point.
Threats and Impacts Data			
Sewage impacts / Sewage treatment	3	C	This is an important global need but addressing it would be a significant undertaking. The threat is inadequately mapped, and damages are poorly understood. Addressing this would involve collecting and consolidating widespread information on sewage treatment; coupling that with mapping of population (by settlement or density); and complimenting this with information on coastal water quality and impacts to coral reefs, especially coral disease. Several organizations could partner on development of a pilot – WRI, TNC, CORAL, HRI, and the UNEP / IDB / GEF CReW project. (Such an effort would inventory, review and build upon any existing efforts.)

Fishing pressure	3	C	Some proxy indicators are available. Mark Spalding suggests the best available starting point is a crude input developed for the MOW Fisheries model. This would need to be enhanced and published.
Social and Economic Data			
Tourism / recreation intensity	2	C	This data need has overlap with "Tourism Value" which is being fulfilled by a static MOW data set. It might be possible to have a complimentary, dynamic indicator using data from national tourism authorities, web-based photo repositories (e.g. FLICKR), of via NatCap InVEST's Tourism module.
Indicator - Coastal Management			
Percent of coral reef area inside MPA	1	C	This indicator is important for some international targets (e.g. CBD and SGDs). If the indicator is not already available through the MPA Atlas, it can be calculated using the best available map of coral reefs, overlaid with MPA boundaries. This can also be done for various protection zones (e.g. No take areas).
Indicators / Coastal Risk			
Coastal flood risk (by storm event)	4.5	C	There are several engineering companies and organizations doing cutting-edge analysis modeling storm \ flood risk and risk reduction from coral reefs, which appear to be open to collaboration and data sharing (possibly of derivative products.) These include JBA Consulting, Deltares, XLX XL, and the Coastal Resilience Lab at UC Santa Cruz. In addition, it might be possible for the Natural Capital project to apply some of their algorithms more broadly to develop some global data sets for visualization of risk on a map-based platform. These options could offer great added value but will require investment (in collaboration and $$).
Storm surge / wave height probabilities	2.5	C	
Exposure – wind and waves	6	B/C	

Outstanding Data Needs

For roughly one-third of the priority data needs we were unable to identify an adequate global data source nor recommend an analysis or collaboration to help fulfill the data need. Table 11 summarizes these outstanding data gaps and our reasoning.

Table 11- Data needs for which no global source has been identified (D)

Data Need	Conclusion / Status
• Coral rugosity / structure	Data available on a very limited basis. Not globally.
• Mangrove characteristics (density, canopy height)	
• Coastal Erosion	
• Water quality data (including E coli)	
• Change in ecosystem before/after storm	
• Impacts from tourism	
• Damage from fishing gear	
• Damage from storms/flooding (historic)	
• Historic flooding	
• Shoreline geology	Data not available globally at sufficient resolution. Detailed data available for some areas.
• Land Use	
• Building footprints	Although Google Earth and Open Street Map hold considerable data, the coverage is not global currently.
• Fish abundance and biomass	Not aware of a global source specific to coral reef-associated fish.
• Fish catch / fishing boat locations	
• Biodiversity	Insufficiently defined. Although data exist on this topic, there are too many options and variations – depending on the specific decision (and technical details). Skipped at this time.
• Rainfall – historic and projections	
• Storms – historic and projections	We identified a source for cyclone data only.
• Change through time (extent, condition, status)	This is an overarching request. It has been applied to several data needs, especially habitat data and SSTs.
• Reef resilience likelihood / index	Development of such an index is still in a research phase. Some potential indicators are under development.

Conclusions and Recommendations

Evolving Data Needs. While many datasets that have been traditionally used in the management of coral reefs are still vitally important (e.g., areal extent of habitat, habitat condition, protection status, human use, local threats), there are a number of more recent data needs due to the changing landscape of threats facing reefs and the increasing awareness of the value of coral reefs to people. These datasets include coral disease, climate-related threats (including sea-level rise, ocean acidification, and ocean temperature) and data on ecosystem services (tourism, fish provisioning, coastal protection value, etc.). The increase in storm impacts on coastal communities, for example, coupled with the recent recognition of the coastal protection value of reefs has led to increasing requests for storm and exposure data and ecosystem services data. Further, the increasing degradation of coral reefs globally has stimulated an interest in reef restoration, which requires data to inform where restoration projects are most likely to be successful (e.g., consider ecological connectivity with larval sources, areas less vulnerable to climate impacts, etc.).

This research developed detailed descriptions of some of the key data needs for decision-making relevant to coral reefs for four audiences (See tables 3-6 and Annexes A1-A4.) For each audience, we identified 40-50 key data needs, of which approximately 15 were flagged as "top priority" for that audience, based on the number of interviews or survey responses which mentioned the given data need. The key data needs of the four audiences were integrated (tallied) to identify the most commonly requested data sets, resulting in a list of 60 priority data needs to be evaluated.

Data Findings. Initial recommendations on data sources to fulfill these 60 priority data needs came from the interviews, survey, and literature review. Further research was conducted to both evaluate these recommendations and identify additional data sources. Rarely were we able to identify a global data set which fulfills all the technical requirements described by the respondents (class A). The most common shortcoming of the global data sets identified is inadequate spatial resolution. However, for 30 priority data needs a source was identified and deemed the best currently available global data set to support the given need and could be considered for inclusion on a global data platform (class B). For 11 data needs, we make recommendations on analysis, data consolidation, or collaboration which could fulfill the data need (class C). For 16 priority needs, we were not able to identify a suitable global data source, or felt additional research was needed to refine the data requirements (class D).

Data limitations and considerations. Global data often is of adequate detail for global and national summary statistics for initial prioritization and coarse scale analysis, however it is often inadequate for local-level planning and management (e.g. implementation of NbS for coastal defense or site-specific coral restoration planning.) A key message from this analysis was the tremendous diversity in coral reef planning and management decisions that require different datasets at different resolutions (i.e., data needs are highly variable depending upon the given management objective). This research has focused on identifying the best available global data sets which broadly address the data needs across the four audiences. These data sets, however, often fall short of meeting the spatial or temporal resolution desired for a given decision. However, the data recommended provide what we believe is the best global starting point to support reef management decisions. They can help to fill in some gaps until higher resolution data become available.

The consolidation and inclusion of the most highly desired and currently available global data (A and B) on a global platform (such as the Allen Coral Atlas, Earth Pulse, or Resource Watch) provide a critical

contribution to support improved coastal planning and management. Key benefits are that doing so 1) eliminates the current challenge of knowing which is the best global source to use for a given indicator (if better local data are not available); 2) eases access to a broad suite of relevant data; and 3) supports simultaneous visualization of multiple data sets. Ability to visualize data (ideally in concert with other data sets) was identified as a key need by many respondents. Easing data access was also identified as an important need by many respondents who have preferred models.

Beyond global data, platforms such as the Allen Coral Atlas, Earth Pulse, or Resource Watch could consider developing regional versions to allow use of some higher-resolution data sets which might be available for more limited geographic extents (e.g., Caribbean, Western Indian Ocean, Coral Triangle or Pacific).

Catalyze data development, consolidation and access. The research identified several opportunities where collaboration and innovation could result in increased access to key data sets. For example, collaboration with companies and organizations doing modeling of storms, flood risk and risk reduction from coral reefs could result in public access to data sets which would be very valuable for disaster risk and adaptation planning, prioritization of investments, and for coastal and marine spatial planning in general. This could achieve a significant advance on this topic. Collaboration would also be required to consolidate many existing, disparate data sets, particularly related to coral condition, and past events – bleaching and disease. Global access to such data would be valuable but would require investment.

Other needs. Data were not the only critical need identified through this research. For many marine practitioners, analysts, and decision makers, guidance is needed on how to utilize existing data to inform management decisions. Many marine practitioners (whether MPA managers, NGO marine staff, etc.) are not "data experts" and even when data are available, capacity gaps can prevent an understanding of how to use existing data to inform management. An example is the use of climate data. Even when sea-surface temperature data are available, there is still a need for guidance on how to use it to prioritize areas for protection or restoration. This highlights the need for three things: 1) greater interaction between data developers and data users to provide guidance for the end users to better understand how certain datasets can and should be used; 2) targeted trainings and capacity building for marine practitioners on using data to address local management priorities; and 3) engagement of end users prior to data/tool development to ensure that the data developed is the appropriate scope and scale to address management needs.

Data needs for decision-makers (e.g., to inform policies or regulations) are often different than those required for supporting a site-specific management intervention. Visual data platforms are critically important, such as dashboards showing the percent of coastal and marine area protected; progress toward meeting national conservation targets; or overall marine ecosystem health (e.g., report cards showing coral reef, mangroves, seagrass health and status of threats facing these ecosystems). Simple communication materials that summarize key data findings, including health of key marine ecosystems and change over time in threats or management effectiveness, is necessary to help countries better evaluate performance. Data developers interested in having their data used to inform policy must consider the funding and capacity required to support efforts such as those outlined above, including the engagement of policy and communication experts to inform the ways that the data can be summarized and presented.

Another key finding is that often lack of data is not the most critical barrier to better decision making and more effective management in coastal areas. Lack of funding, capacity, political will and community

engagement are key barriers that need to be addressed in parallel to increasing and improving data availability and access. Capacity is needed to support the integration of social and ecological data to inform feedbacks and to prioritize management interventions. (This was a commonly noted challenge among marine conservation practitioners.)

Final Thoughts from the Authors. As anyone working to protect coral reefs knows, the challenges are many. Improved access to and integrated visualization of global data relevant to coral reefs would be a valuable contribution. But higher resolution, local data are needed for site-specific planning and management, as is training on how to interpret and use the data and how to best summarize data for effective communication. Another common challenge to data access is the continuity of funding for data platforms. Donors often favor funding new, innovative solutions. Long-term, sustainable financing for data platforms is elusive. Considering this challenge, this research effort endeavors to inform potential enhancements to existing platforms (e.g. Allen Coral Atlas, Earth Pulse, or Resource Watch) rather than the development of a new one. Platform enhancement should occur with end uses in mind – the decisions they wish to address, their data needs and preferred modes of interaction with data, as well as the types of outputs that are needed to inform the decision. We hope this research contributes to this goal.