GCRMN
Global Coral Reef Monitoring Network

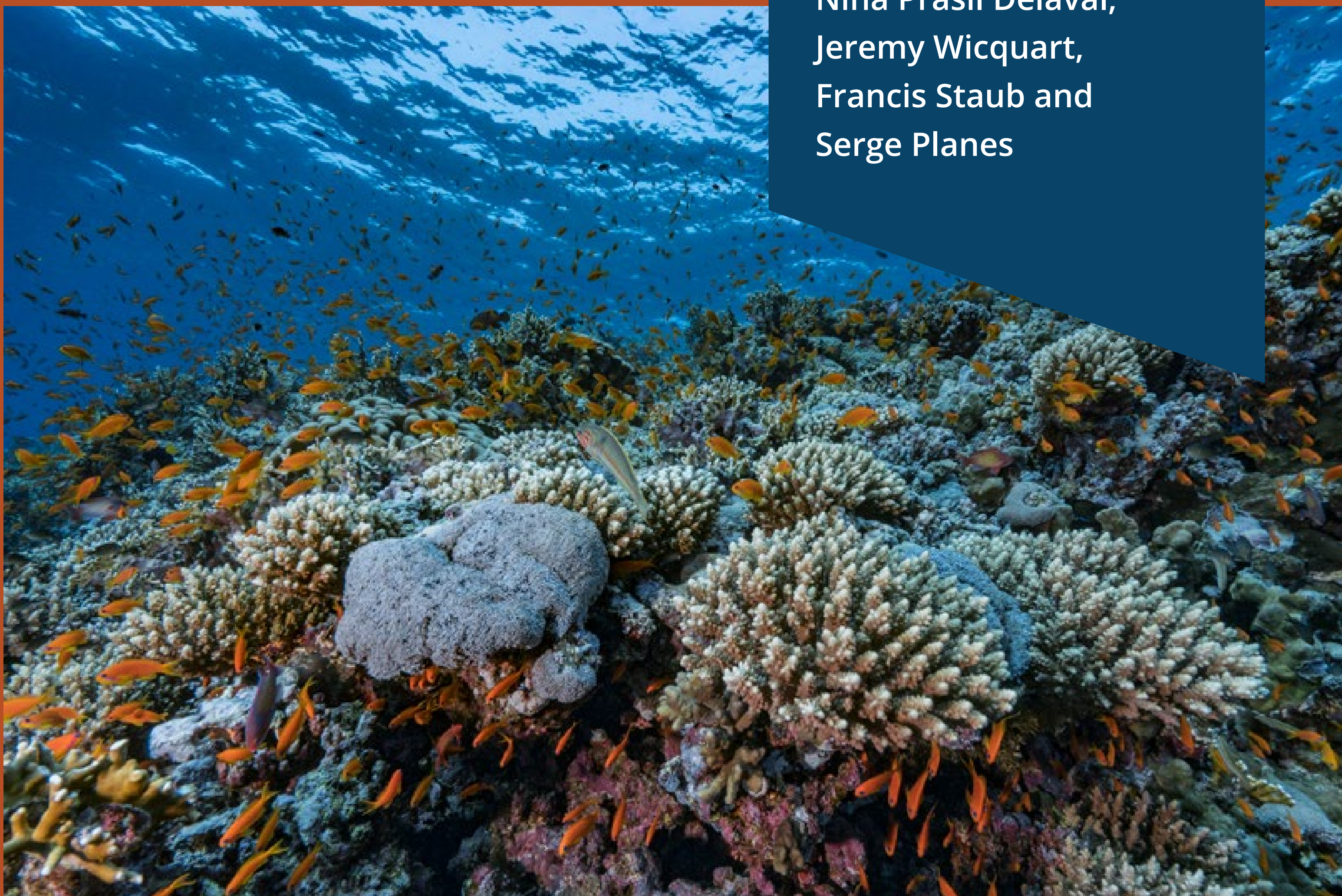
ICRI
International Coral Reef Initiative

STATUS OF CORAL REEF MONITORING:

An Assessment of Methods and Data at the National Level

Edited by:

Nina Prasil Delaval, Jeremy Wicquart, Francis Staub and Serge Planes



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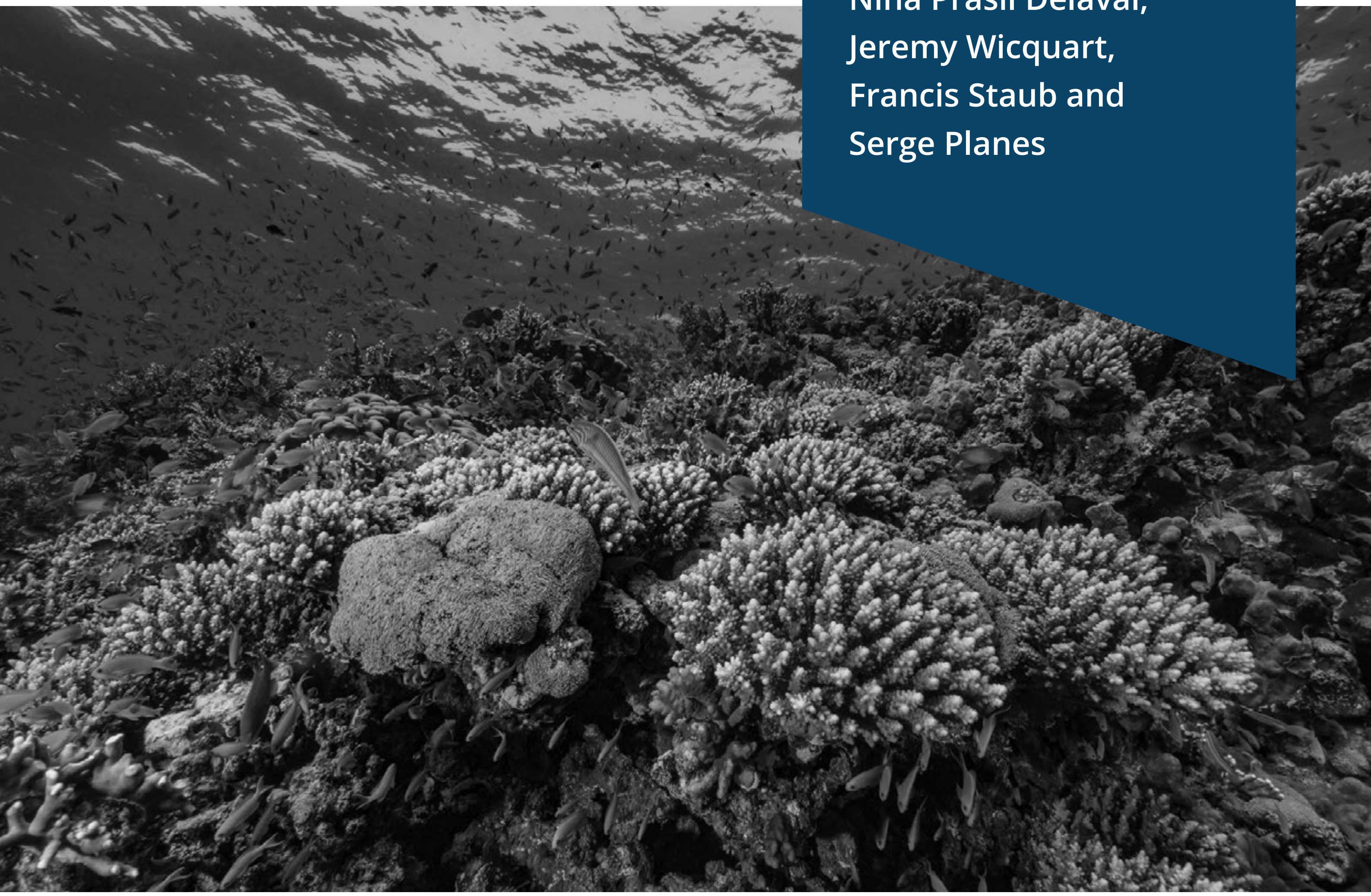

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ABBREVIATIONS AND ACRONYMS

BIOT: British Indian Ocean Territories

COTS: Crown Of Thorns Starfish (*Acanthaster plancii*)

EEZ: Economic Exclusive Zone

FSM: Federated States of Micronesia

GCRMN: Global Coral Reef Monitoring Network

GDP: Gross Domestic Product

ICRI: International Coral Reef Initiative

LIT: Line Intercept Transect

MPA: Marine Protected Area

NGO: Non-Governmental Organisation

NOAA: National Oceanic and Atmospheric Administration

OT: Overseas Territory

PIT: Point Intercept Transect

UKOTs: United Kingdom Overseas Territories

WRI: World Resources Institute

EXECUTIVE SUMMARY

Coral reefs represent biodiversity hotspots and cumulate numerous ecosystem services. However, these unique ecosystems are facing massive degradation and decline with pessimistic trajectories, which makes them emblematic targets in conservation priorities.

To start, all conservation strategies require an accurate estimate of the state and current trends of a given ecosystem. For coral reefs, monitoring programs provide the data necessary to determine trends and to enhance our ability to understand the responses of these ecosystems to anthropogenic stressors, which thereby allows for management practices to be adapted as needed. In order to better manage and protect coral reefs, it is thus necessary to evaluate the current status of existing monitoring programs and to make improvements when needed.

Within this context, we provide the first global and quantitative assessment of the state of coral reef monitoring for 30 pilot countries which collectively account for almost 90% of the world's coral reefs. Next, we provide results from an analysis of the status of the implementation of the ICRI recommended indicators "Live Coral Cover", "Fleshy Algae Cover and Cover of Key Benthic Groups" and "Fish Abundance and Biomass" and the progress of the 30 pilot countries towards meeting these targets. Finally, we have outlined recommendations to help meet the targets set by ICRI and the implementation of the ICRI recommended indicators at the country level. All of these analyses were based on the data and the metadata contributed by the members of the GCRMN consortium. These data were first cumulated by the GCRMN as part of the *Status of Coral Reefs of the World: 2020* report.

The database for the 30 pilot countries selected for this specific analysis encompasses 12,653 sites, cumulating 37,012 surveys and 1,682,943 observations. The point intercept transect method was the most used method in 14 countries, followed by the photo-quadrat method (6 countries), and finally the line intercept transect method and the visual census method (1 country each). Taxonomically speaking, more than 50% of the observations were recorded to at least the subgroup level for 28 out of 30 countries. Interestingly, the duration of the monitoring appeared highly heterogeneous, since among the 30 countries, data ranged from 1 year to 36 different years.

The key indicator "Live Coral Cover" is already available at the country level for 21 countries, and could quickly become available in all 30 countries, provided that the spatial coverage of the monitoring is increased. This indicator is mostly absent in some provinces of the Central Indo-Pacific and the Eastern Indo-Pacific. In these provinces, most countries have extensive marine territories, or are made of several islands isolated from one another, where coral reefs are abundant and widespread. In such places, we suggest involving more local communities in monitoring activities, and providing technical training to these local communities in order to increase their ability to collect quality data on a regular basis.

The availability of the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" at the country level is limited to a mere 13 of the pilot countries. This is mainly due to the combination of an insufficient spatial coverage and the lack of inclusion of the organisms targeted by this indicator in monitoring protocols.

This report provides a first look at the monitoring programs in the countries which collectively host 90% of the world's coral reefs. While it is clear that the monitoring programs and associated data already provide a good overall vision of the state and trends of live coral cover, more effort should be invested to improve the collection of data on live coral cover and even more so for "Fleshy Algae Cover and Cover of Key Benthic Groups" to enable a more accurate evaluation of trends on coral reefs and to help to prioritize conservation strategies.

INTRODUCTION

The International Coral Reef Initiative (ICRI)

Coral reefs are emblematic ecosystems as they combine biodiversity hotspots and cumulate unique ecosystem services over relatively small areas. The total surface of coral reefs has been estimated at 284,300 km², which represents less than 0.1% of the ocean's surface (Spalding, Ravilious, Green, & UNEP-WCMC, 2001). While they occur in more than 40% of countries around the world (83 out of 193[1]), they are unevenly distributed between the different countries that host coral reefs. Half of the world's coral reef surface is distributed between only five countries – Australia, Indonesia, Philippines, France and Papua New Guinea.

While representing only 0.1% of the ocean's surface, coral reefs are considered as one of the most diverse ecosystems in the world and play an important role in the functioning of other adjacent marine ecosystems, such as seagrass meadows or mangroves. Estimates of the overall species richness of coral reefs is around 830,000 multi-cellular species[2], within an interval between 550,000 and 1,330,000 species (Fisher et al., 2015).

Lastly, even if they represent less than 0.1% of the ocean's surface, coral reefs are highly valuable ecosystems and provide numerous ecosystem goods and services to human populations (Moberg & Folke, 1999). These services include the revenues generated by tourism activities, which are estimated at US$36 billion annually (Spalding et al., 2017). They represent a source of protein and income through fisheries, thus supporting the livelihoods of coastal communities. They also provide coastal protection against storm surges and limit coastal erosion. It has been estimated that about 1 billion people depend directly on coral reefs (Rivera, Chan, & Luu, 2020), and as the human population continues to grow, this estimation might have to be re-evaluated.

Despite their importance to people, coral reefs are highly threatened by the rapid expansion of anthropogenic activities, which significantly impact the functioning of coral reef ecosystems. Anthropogenic stressors can affect coral reefs directly at the local scale, such as over-exploitation of key marine species, destructive fishing practices, unsustainable tourism, land-based pollution or eutrophication. Human activities also have indirect effects at the global scale, through climate change resulting from greenhouse gas emissions (Hughes et al., 2017). For coral reefs, the most dramatic threats associated with climate change stem from global warming, which causes abnormally high sea surface temperatures and leads to mass bleaching events which cause a breakdown of the symbiosis between the coral host and the zooxanthellae it shelters (van Oppen & Lough, 2018). The dramatic and rapid loss of coral reefs worldwide, resulting from direct or indirect anthropogenic activities, requires swift and decisive action to better manage these ecosystems in order to ensure their persistence and to secure the ecosystem services they provide.

In a context of increasing disturbances and in order to federate research and conservation on coral reefs, the International Coral Reef Initiative (ICRI) was founded in 1994 by 8 governments: Australia, France, Jamaica, Japan, the Philippines, Sweden, the United Kingdom and the United States of America. Today, ICRI has expanded to include over 90 members. To date, ICRI remains the only international partnership between Nations and organisations that solely

1 Number obtained by adding Iraq and Pakistan to the 81 countries obtained by joining data from the World Resources Institute (WRI) (Institute for Marine Remote Sensing - University of South Florida (IMaRS-USF) et al., 2011) and Flanders Marine Institute 2019. One hundred and ninety-three (193) is the number of recognized countries by the United Nations in 2021.

2 This estimation does not include fungi.

focuses on the conservation of coral reefs and their related ecosystems. In May 2020, ICRI members agreed to sign the recommendation “Inclusion of coral reefs and related ecosystems within the Convention on Biological Diversity (CBD) Post-2020 Global Biodiversity Framework”. The signing of this recommendation highlights the important technical contribution by the ICRI which lead to the inclusion of coral reefs in the global biodiversity framework of the CBD, and set then the next generation of biodiversity and coral reef conservation targets.

The creation of the Global Coral Reef Monitoring Network (GCRMN) initiated by the ICRI in 1995 was part of the ICRI “Call for Action”, signed by all ICRI members. The primary tasks of this ICRI-led operational network are to provide independent syntheses on the status and trends of coral reefs at a regional (Jackson, Donovan, Cramer, & Lam, 2014; Obura et al., 2017; Moritz et al., 2018) or global scale (Wilkinson, 1998, 2000, 2002, 2004, 2008), and to build local and national capacity in coral reef monitoring. The GCRMN also aims to identify coral reef management priorities at multiple levels and to provide appropriate recommendations to sustain coral reefs. Recommendations made by the GCRMN are data-driven and are founded on global monitoring data acquired from a wide variety of stakeholders including researchers, Non-Governmental Organisations (NGO), and citizen science or countries-led programs. Aggregating and providing such data and knowledge is crucial to enable quick and appropriate responses for coral reef management. The pivotal role of the GCRMN as the global operational network for coral reef data aggregation is recognized by the Group on Earth Observations Biodiversity Observation Networks (GEOBON), the Global Ocean Observation System (GOOS) and the Biodiversity Indicators Partnership (BIP).

The five global reports conducted between 1998 and 2008 by the GCRMN (Wilkinson, 1998, 2000, 2002, 2004, 2008) were mostly qualitative assessments on the state of coral reefs based on the local and regional expertise of the members of the GCRMN network. Since 2014, there has been a strong push by the GCRMN to promote numerical approaches and quantitative assessments on the state of coral reefs. As such, the centralization of coral reef monitoring-related data by the GCRMN, which depends directly on the active contribution of GCRMN members and the individuals and organisations responsible for monitoring coral reefs around the world, is essential. The first three quantitative reports on the status and trends of coral reefs, which were released during the last decade (Jackson et al., 2014; Obura et al., 2017; Moritz et al., 2018), each targeted a single region of the world. The GCRMN report *Status of Coral Reefs of the World: 2020* (Souter et al., 2021) is the first report to provide a quantitative analysis on the state of coral reefs worldwide.

In order to homogenize monitoring programs at the global scale and to support a coherent monitoring effort, the Recommendation adopted by ICRI members in May 2020 includes a set of indicators (Table 1), selected for their relevance with respect to measuring the health, integrity and functioning of coral reefs. With the exception of the indicator « Live coral cover », which is already included in the Preliminary Draft Monitoring Framework, we recommend the inclusion of 5 additional indicators.

Table 1: Description of the ICRI recommended coral reef indicators. Reference to Goals and Targets relates to the structure presented in the Zero Draft of the Global Biodiversity Framework published in January 2020 (CBD/WG2020/2/3).

Indicator	Relevant to Goal/ Target	Rationale for ICRI recommendation	Baseline/Reference year
Live Coral Cover	Goal A Target 1	Critical: this is the most important coral reef indicator for use in national to global policy.	The GCRMN report on the status of coral reefs has been published in 2021. This report provides a global baseline for coral reefs status and trends, and gives the most up-to-date assessment of quality and coverage of data compared to any earlier baseline that might be selected. For that purpose, three preliminary regional reports were published, to develop the approach in the Caribbean, in the Pacific and in the Western Indian Ocean.
Fleshy Algae Cover and Cover of key benthic groups	Goal A Target 1 Target 6	Fleshy algae are a dominant competitor to corals, indicating decline in coral reef health; algae-dominated reefs are the most likely alternative state for corals. Data on other key benthic groups is collected simultaneously with coral and algae cover, but with more variable methods (e.g. bare substrate, crustose coralline algae, cyanobacteria, other invertebrates, rubble, sand, seagrass, soft coral). Greater standardization of these will enable a more comprehensive assessment of reef health and status.	The GCRMN report *Status of Coral Reefs of the World:2020*.
Fish Abundance and Biomass	Goal A Target 1	Critical for understanding reef productivity, functioning of food webs, potential fisheries yields.	At present, data on fish biomass is being collected and reported on by many different agencies and organisations at varied levels. There are persistent challenges in aggregating these for a global assessment. This is an important indicator and work needs to be accelerated to overcome current challenges.
Coral Reef Extent	Goal A	This is a key metric for understanding the area and changing extent of coral reef ecosystems at national and higher levels.	Sources of coral reef extent can be determined from a variety of existing data at regional and national scales. Initiatives are underway to develop a global extent layer.
[Percentage/ area] of coral reefs included in [effectively managed] MPAs and OECMs	Target 2	Recommended as a measure of representativity of coral reefs as a key ecosystem.	Determined from the World Database on Protected Areas.

Indicator	Relevant to Goal/ Target	Rationale for ICRI recommendation	Baseline/Reference year
Index of coastal eutrophication	Target 4	Recommended to ensure that information on key pollution pressures on reefs and changes in pressure levels are measured.The ICEP methodology is based on the collection of water samples from rivers as they reach a coastline. Further studies would be needed to determine whether the ICEP could be used for coral reef nations or territories without major rivers.	The ICEP is a new methodology that is not yet being used globally, and so there is no current baseline. In the interim, for SDG Target 14.1, chlorophyll-a concentration (surface waters) is to be used as a proxy indicator for eutrophication. This is already used as an indicator for eutrophication in some regions and is measured using remote sensing. Further work would be needed to determine whether this would be useful in the case of coral reefs.

By signing the Recommendation, ICRI members and CBD Parties demonstrate their willingness to include these indicators in coral reef monitoring protocols and to homogenize monitoring efforts around the world. By creating a coherent framework for the monitoring of coral reefs, these indicators will ensure the consistency of the collected data and will facilitate the overview of the evolution of coral reef ecosystems at a local and global scale. This will ultimately help to inform management policies and interventions to improve the state of reefs by providing a common basis for decision-making. However, while some of these indicators might already be included in current monitoring protocols, a global review of their implementation status would provide a global vision of the effectiveness of today's monitoring programs.

By reviewing the data contributed to the GCRMN *Status of Coral Reefs of the World: 2020* report, the overarching objective of the present report is to provide a global and quantitative assessment of the status of coral reef monitoring at the country level with regards to the ICRI recommended indicators. In order to support a unified coordination effort, we also provide a contact list of coral reefs monitoring referents in each country. The 30 countries with the highest coral reef surface were selected as pilot countries for this analysis (Table 2). Together, these 30 countries represent almost 90% of the world's coral reef surface.

Table 2. Coral reef surface per country ranked according to their relative contribution to the world's coral reef surface, based on data from WRI (Institute for Marine Remote Sensing - University of South Florida (IMaRS-USF), Institut de Recherche pour le Développement (IRD), UNEP-WCMC, The WorldFish Center, & World Resources Institute, 2011).

Ranking	Country	Coral reef surface (km^2)	Relative contribution (%)	Cumulative coral reef surface (%)
1	Australia	44,485	16.88	16.88
2	Indonesia	40,209	15.26	32.14
3	Philippines	25,677	9.74	41.88
4	France	16,494	6.26	48.14
5	Papua New Guinea	14,990	5.69	53.83
6	United States	7,128	2.71	56.54
7	Fiji	7,053	2.68	59.22

Ranking	Country	Coral reef surface (km²)	Relative contribution (%)	Cumulative coral reef surface (%)
8	Solomon Islands	6,918	2.63	61.85
9	Saudi Arabia	5,927	2.25	64.10
10	Maldives	5,331	2.02	66.12
11	Cuba	5,320	2.02	68.14
12	Micronesia	5,004	1.90	70.04
13	United Kingdom	4,623	1.75	71.79
14	Bahamas	4,518	1.71	73.50
15	Madagascar	4,160	1.58	75.08
16	Marshall Islands	3,629	1.38	76.46
17	India	3,583	1.36	77.82
18	Malaysia	3,383	1.28	79.10
19	Egypt	3,148	1.20	80.30
20	Kiribati	3,064	1.16	81.46
21	Tanzania	3,034	1.15	82.61
22	Mozambique	2,536	0.96	83.57
23	Sudan	2,313	0.88	84.45
24	Eritrea	2,288	0.87	85.32
25	Japan	1,982	0.75	86.07
26	Seychelles	1,935	0.73	86.80
27	Belize	1,921	0.73	87.53
28	Vanuatu	1,888	0.72	88.25
29	Tonga	1,775	0.67	88.92
30	Mexico	1,672	0.64	89.56

The present report includes a summary of the status of coral reef monitoring that was produced for each country presented in the table above (Table 2). This summary includes a short presentation of the country's coral reefs, a representation of the monitoring effort in terms of spatial and temporal distribution, methods used and taxonomic resolution reached. Based on these results, we then discuss the implementation and availability of ICRI recommended indicators "Live Coral Cover", "Fleshy Algae Cover and Cover of Key Benthic Groups" and "Fish Abundance and Biomass" and provide recommendations[3]. Analyses were based on the global dataset built for the GCRMN report *Status of Coral Reefs of the World: 2020* (Souter et al., 2021).

3 While this global dataset represents one of the most comprehensive datasets on benthic coral reef monitoring data, some data may have not been integrated and we are aware that monitoring exists in places that were not included in the database during the data aggregation process. Thus, some recommendations and conclusions provided in this report might not be perfectly representative of coral reef monitoring in some locations.

Finally, the main elements provided in this report include:

1. A first global and quantitative assessment of the condition of coral reef monitoring for the 30 selected pilot countries (i.e., the 30 countries with the largest amount of coral reef surface).
2. A first global assessment of the status of implementation of the ICRI recommended indicators "Live Coral Cover", "Fleshy Algae Cover and Cover of Key Benthic Groups" and "Fish Abundance and Biomass" and the progress of the 30 pilot countries towards meeting these targets.
3. A list of coral reef monitoring referents in each country to improve coordination and communication between the different actors.

The production of this report sought the active participation of the countries named within it (i.e., 30 countries with the largest amount of coral reef surface). Each country section was sent to at least one local focal point for feedback and revisions were made according to local information provided by the local focal point. For some countries, due to time constraints, availability or the lack of a local focal point, we could not get local feedback. This report will help to serve as a first step in the promotion of interactions with local focal points and countries to gather more knowledge on the status and trends of coral reefs in order to better adjust future recommendations. This report should be viewed as a starting point for discussions and interactions aiming to orient and to help further management recommendations.

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DEFINITIONS AND METHODS

Definitions

Throughout the report, the following definitions were used.

An **observation** corresponds to a row (i.e., an observation) in a database.

A **monitoring site** (or simply a **site**) is a unique combination of coordinates (i.e., longitude, latitude).

A **survey** refers to the action of monitoring at a given site and at a given date.

A **method** is the description of how the information is collected (e.g. photo-quadrat) (Hill & Wilkinson, 2004).

A **protocol** defines the way data are acquired in the field and thus provides additional information on the method used (i.e., metadata). This information may include the number of replicates, the length of transect lines or specific information gathered, such as benthic organisms that were counted or measured (Hill & Wilkinson, 2004).

Monitoring can generally be defined as "the repetitive measurement of a specified set of variables at one or more locations over an extended period of time according to prearranged schedules in space and time" (Vos, Meelis, & Ter Keurs, 2000).

A **monitoring program** consists of a series of monitoring protocols that together provide a manager with the information needed to manage their reefs (Hill & Wilkinson, 2004).

A **quadrat** is a square or rectangular sampling unit in which organisms are counted or measured (Hill & Wilkinson, 2004).

A **transect** is a line put on the reef floor where corals and other components are counted underneath (Hill & Wilkinson, 2004).

Monitoring strategies

Two main coral reefs monitoring strategies are distinguished:

1. the first strategy uses permanent sites and leads to monitor the same sites (i.e., fixed sites) at a given frequency. This strategy provides high temporal but low spatial extents.
2. the second strategy uses non-permanent sites (i.e., random, haphazardly selected sites) and consists to monitor different sites within an area at a given frequency. This strategy provides low temporal but high spatial extents.

Methods used to monitor coral reefs

A variety of methods are used to monitor coral reefs, mostly depending on the targets of the monitoring. The following methods are the ones that were identified in the 2020 GCRMN world report database, which aim to provide information on the percentage cover of benthic communities. The provided definitions are all from Hill and Wilkinson 2004.

Line Intercept Transects (LIT): The length of the transect line covering each type of substrate (or benthic organism) is measured (Figure 1A). The percentage of benthic cover for each substrate type is then estimated from the cumulated length of each type of substrate relative to the total transect length.

Point Intercept Transects (PIT): Punctual observations are made at fixed intervals along the transect and the type of substrate is identified and recorded for each measurement point (Figure 1B). The number of observations for the different types of substrates is then summed, and their proportion relative to the total number of observations is calculated to estimate the cover for each type of substrate along the transect.

Photo-quadrats: A quadrat is placed at a set interval and a photograph is taken for each interval (Figure 1C). The percentage cover for each benthic category can then be estimated in the lab using either random points or by digitizing the photos. Photographs can be archived and thus re-used for further analysis.

Video-transects: The transect is surveyed with an underwater camera (Figure 1D). The resulting video can then be analyzed in the lab using random points or by recreating virtual transects. The speed and distance from the substrate should be maintained between the different transects since the width of the belt is determined by the distance between the camera and the benthos. Like photo-quadrats, videos can be archived and thus re-used for further analysis.

Visual census: The proportion of different substrates and benthic community coverage is estimated visually by the diver as he/she swims along the transect. A common type of visual census is the manta tow method. While visual census methods are less time consuming and provide an instantaneous measure of percent benthic cover, the data generated using this method are highly vulnerable to observer bias. Moreover, identifying organisms with high taxonomic resolution is nearly impossible.

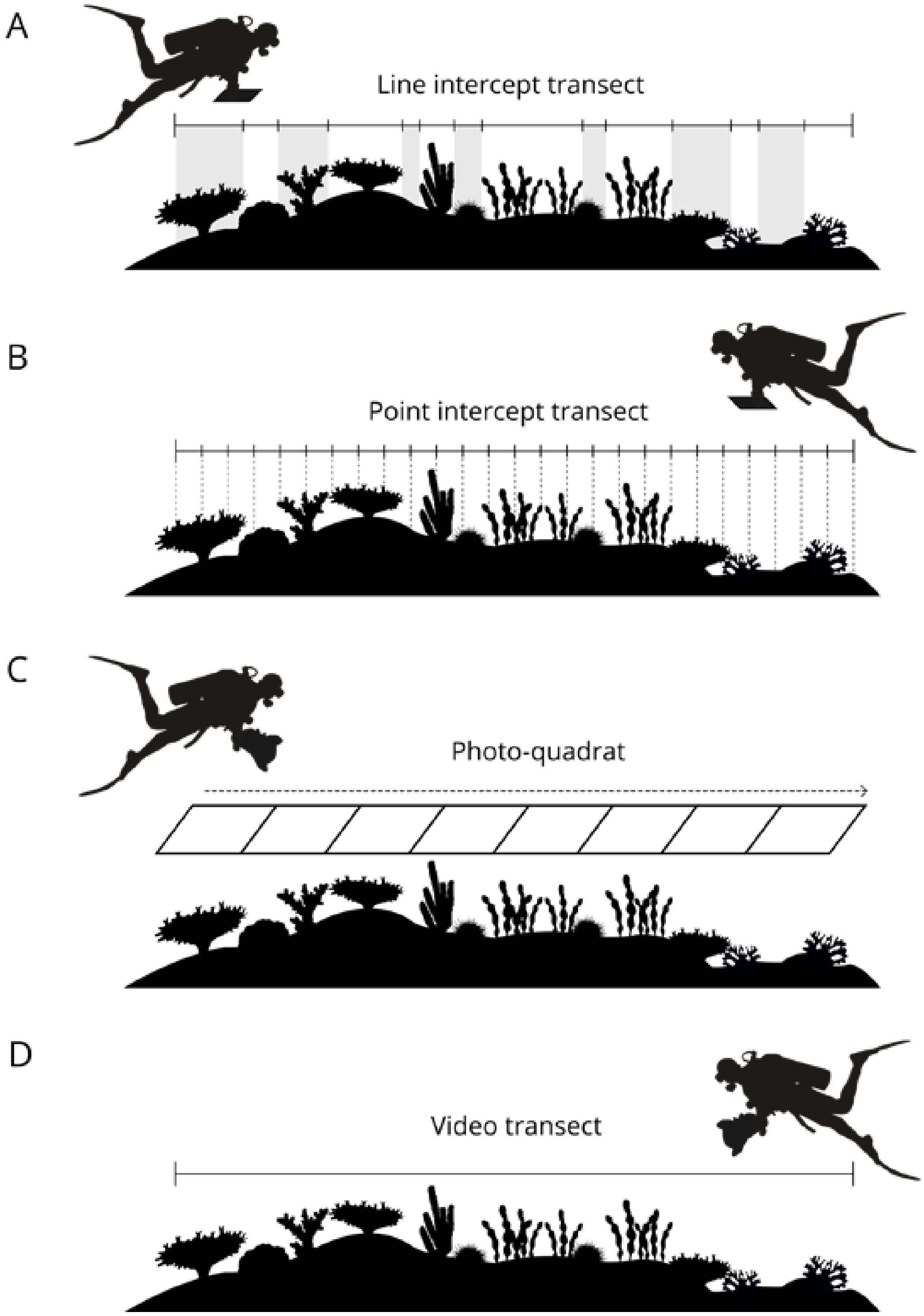

Figure 1. Illustration of four methods used to monitor benthic cover in coral reefs.

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MATERIALS AND METHODS

This section aims to provide details for the materials and methods that were used to compile each country's summary, and in particular, the data used for the figures. This section includes a list of all the datasets used and the different analyses performed. This section also provides a guide to explain how the availability of the ICRI recommended indicators "Live Coral Cover" and "Fleshy Algae Cover and Cover of Key Benthic Groups" was evaluated at the country level.

Datasets used

The figures and tables presented in this report were made using the seven following datasets:

Background maps. The background maps data of land, minor islands and atolls as 1:10 m shapefiles (v. 4.1.0) were obtained from Natural Earth Data (Natural Earth Data, 2018).

Economic Exclusive Zone (EEZ). The EEZ shapefile (v.11) was obtained from the Flanders Marine Institute 2019.

Coral reefs distribution. The distribution of coral reefs of the world shapefile was obtained from the WRI (Institute for Marine Remote Sensing - University of South Florida (IMaRS-USF), Institut de Recherche pour le Développement (IRD), UNEP-WCMC, The WorldFish Center, & World Resources Institute, 2011). This dataset was used to ensure consistency with the GCRMN report *Status of Coral Reefs of the World: 2020* (Souter et al., 2021), which also uses this dataset.

Hard coral species richness. The number of hard coral species in each country was estimated based on the IUCN Red-List Database (IUCN, 2021).

Coral reef fish species richness. The number of fish species associated with coral reefs in each country was estimated based on the Fishbase database (Froese & Pauly, 2020).

Marine Protected Areas. Marine Protected Area shapefiles were obtained from the Marine Protection Atlas Database (Marine Conservation Institute, 2020). Marine Protection Atlas uses the World Database on Protected Areas (UNEP-WCMC & IUCN, 2020) as the starting point for its database, conducting an independent, third-party review of the data and making additions and corrections if necessary.

2020 GCRMN world report database. The database built for the 2020 GCRMN Report *Status of Coral Reefs of the World: 2020* (Souter et al., 2021) was used to describe the monitoring within the different countries. Thousands of raw datasets, provided by numerous contributors worldwide, were homogenized and aggregated based on a dedicated workflow detailed in the 2020 GCRMN world report in order to produce a unique and homogeneous database. This workflow (Figure 1) is composed of four main steps:

1. the acquisition of raw data from different contributors,
2. individual data reformatting aimed at homogenizing variables and units,
3. the grouping of all individually reformatted datasets and the re-categorization (see Table 1) of their taxonomic levels, and
4. a quality assurance and quality control (QAQC) step to remove potential errors.

Due to constraints associated with the confidentiality of some of the raw datasets included, this database is not publicly available, but can be provided on demand with a local agreement.

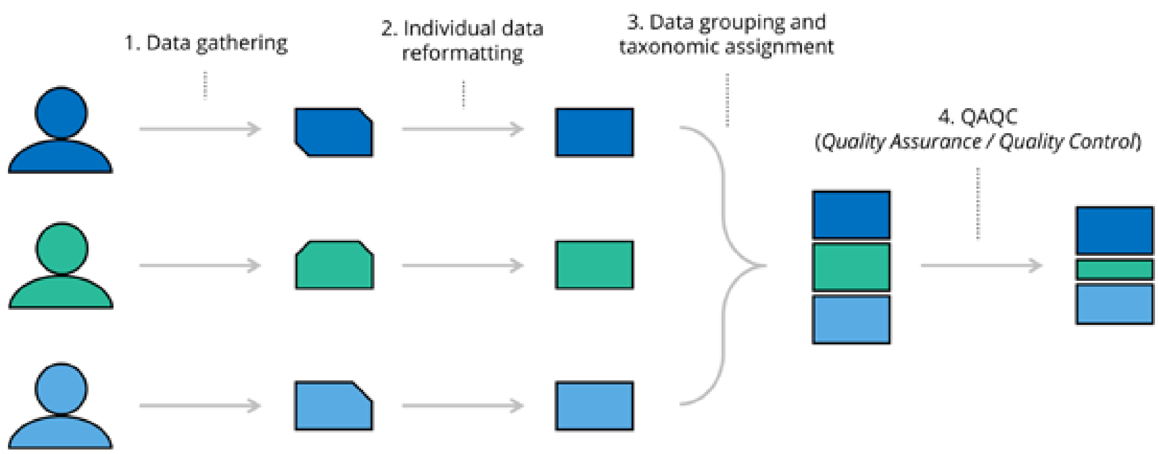


Figure 1. Simplified illustration of the workflow used to integrate the different datasets provided by the GCRMN members to produce the 2020 GCRMN world report.

During the third step (i.e., data grouping and taxonomic assignment), all observations were re-categorized for homogenization and analytic purposes. During this step, they were all assigned to a group and to a subgroup when the taxonomic resolution of the data was sufficient. The groups and subgroups that were designed for these purposes are presented in Table 1.

Table 1. Levels of factor of the taxonomic variables “Group” and “Subgroup” used to re-categorize the taxonomic levels provided by the data contributors.

Group	Subgroup
Abiotic	Rock Rubble Sand Silt
Algae	Coralline algae Macroalgae Turf algae
Hard bleached coral	
Hard dead coral	
Hard living coral	
Other fauna	Actiniaria Alcyonacea Antipatharia Asteroidea Bivalvia Bryozoa Corallimorpharia Crinoidea Decapoda Echinoidea Gastropoda Holothuroidea Hydrozoa Ophiuroidea Polychaeta Porifera Sessilia Tunicata Zoantharia
Seagrass	

Data analyses

Estimation of coral reef surface by country

The reef polygon data were taken from the Reefs at Risks Revisited Database, WRI (Institute for Marine Remote Sensing - University of South Florida (IMaRS-USF) et al., 2011). The “GIS Data Sets - Base Data” shape file was used. A spatial join was performed with the EEZ shape files from the Marine Regions “Database -World EEZ v11 (2019-11-18)” (Flanders Marine Institute, 2019), in order to assign each reef polygon to a country. The World Plate Carree projection was used to take into account the tropical repartition of coral reefs when calculating surfaces. Then, the reef area was calculated for each polygon and summed per country. The country’s ranking and contribution to the global reef surface were also calculated.

Hard corals species richness by country

The number of hard coral species in each country was estimated based on the IUCN database (IUCN, 2021). A spatial analysis based on the overlap of the country's EEZ and the distribution of the different species of hard corals was performed in order to assign each species to the EEZ of each country they belong to. The number of hard coral species per country was then summed.

Coral reef fish species richness by country

The number of coral reef fish species was estimated based on the Fishbase database (Froese & Pauly, 2020) through the rfishbase R package (Boettiger, Lang, & Wainwright, 2012). For each country, the species categorized as affiliated to coral reefs were filtered and the sum of species per country was then calculated.

Socio-economic data of coral reefs

To illustrate the socio-economic importance of coral reefs for each country, we provided estimated values of ecosystem services from the literature. The three services chosen were tourism, fisheries and coastal protection provided by coral reefs. When absent, the contribution of these different services to the GDP was calculated in order to assess their economic importance at the country level. Here, we used the GDP value for the year in which the observations were conducted to calculate this percentage when the year was specified. If the year for which the services values were calculated was not specified, we assumed that the values were calculated for the year of the publication release. GDP values were retrieved from the World Bank website (the World Bank, n.d.).

Inclusion of coral reefs in MPAs

In order to estimate the surface of coral reefs included in Marine Protected Areas (MPA) established and listed in the 30 pilot countries, we used two datasets, namely the Marine Protection Atlas database (Marine Conservation Institute, 2020) and the previously mentioned Reefs at Risks Revisited Database, WRI (Institute for Marine Remote Sensing - University of South Florida (IMaRS-USF) et al. 2011). From the Marine Protection Atlas database, we first excluded the terrestrial protected areas. We then performed a spatial overlap between the two datasets to assign to each coral reef polygon the MPA identifier that contains it. We then estimated the surface of coral reefs included in MPAs for each country, using the "World Plate Carree" projection, which is particularly adapted to calculate surfaces around the equator. Finally, we calculated the percentage of coral reefs included in MPAs relative to the coral reef surface at the country level.

Description of monitoring by country

All of the data used to describe the monitoring within each country came from the 2020 GCRMN world report database. Note that while this database does not include all known data for each country, and additional digging will be required in the future, it does represent the most comprehensive database on benthic coral reef monitoring compiled so far.

<u>Number of sites per country:</u> The total number of sites per country was calculated and defined as a unique combination of latitude and longitude values. Thus, if values were slightly different, they were considered as different sites.

<u>Relative contribution to the 2020 GCRMN world report database:</u> The total number of rows affiliated to each country was summed and the relative contribution of the country to the 2020 GCRMN world report database was then calculated.

Duration of monitoring sites: The difference between the first and last years of survey were calculated for each site. These values were categorized in five different time categories: 1 year, 2 to 5 years, 6 to 10 years, 11 to 15 years and more than 15 years.

Temporal distribution of surveys: We defined a survey as a unique monitoring event and thus, the number of surveys was calculated as the number of sites surveyed per year. The percentage of surveys conducted each year was then calculated based on the total number of surveys conducted in the country.

Methods used: The number of surveys was summed by the type of method used. Six categories were considered, including “Photo-quadrat”, “Line Intercept Transect”, “Point Intercept Transect”, “Video transect”, “Visual census” and “Unknown”, when method-type was unavailable. The percentage of surveys that used a given method was then calculated based on the total number of surveys conducted in the country.

Methods used by time period: The number of surveys was summed by the type of method used (“Photo-quadrat”, “Line Intercept Transect”, “Point Intercept Transect”, “Video transect”, “Visual census” and “Unknown” when method-type was unavailable) and by 3 time periods: 1970-1999, 2000-2009 and 2010-2019. The percentage of surveys using a given method in a given time-range was then calculated based on the total number of surveys conducted in the given country.

Taxonomic precision by time period: Five taxonomic levels were defined to describe the taxonomic precision for which observations were identified: the group level, the subgroup level, the family, the genus and the species. The group and subgroup levels were defined during the homogenization process (see Figure 1, Table 1). The highest taxonomic level reached was first assessed for each row and the number of rows by highest taxonomic level time period was then calculated.

Taxonomic precision of “Algae”: The “Algae” group includes 4 levels of subgroup, namely “Macroalgae”, “Coralline algae”, “Turf algae” and “Unknown” when observations were identified only up to the group level. The number of rows affiliated to each level of subgroup was calculated and the associated percentage was calculated based on the total number of rows from the group “Algae”, per country.

Taxonomic precision of “Other fauna”: The “Other fauna” group was re-categorized in 5 levels of subgroup for analytic purposes, namely “Alcyonacea”, “Porifera”, “Tunicata”, “Other subgroups” and “Unknown” when observations were identified only up to the group level. The number of rows affiliated to each level of subgroup was calculated and the associated percentage was calculated based on the total number of rows from the group “Other fauna”, per country.

Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

The aim of this report is to provide, for the 30 countries with most coral reefs, a first evaluation on the availability of the ICRI recommended indicators "Live Coral Cover" and "Fleshy Algae Cover and Cover of Key Benthic Groups" at the national level[1]. The indicator's availability was estimated based on four criteria derived from the analyses on the monitoring of coral reefs conducted using data from the 2020 GCRMN world report database (Souter et al., 2021). The four chosen criteria and the associated requirements were formulated as following. For framework, we used a symbol for each criterion and a colour to show the state of compliance for each criterion according to our evaluation. This evaluation is based on available data (i.e., in the 2020 GCRMN world report database) and may be subject to revision as additional data and programs become available. In this perspective, future collaborations with local contributors and focal points will be essential in the ongoing effort by the GCRMN to centralize all available data for further broad-scale analyses and to then share this data with the ICRI for future associated management proposals.

Spatial extent:

The spatial extent of the monitoring is sufficient and can be considered as representative of the country's coral reefs.

The spatial extent of the monitoring is limited and not enough to be considered as representative of the country's coral reefs.

There is no information in the 2020 GCRMN world report database regarding the spatial extent of the monitoring.

Temporal extent:

The temporal distribution of surveys over the last 10 years is sufficient enough to provide information about the temporal trend of the country's coral reefs and several medium-term monitoring sites, which are sites surveyed for more than 5 years, are provided.

The temporal distribution of surveys over the last 10 years is limited and not enough to provide information about the temporal trend of the country's coral reefs and not enough medium-term monitoring sites, are provided.

There is no information in the 2020 GCRMN world report database regarding the temporal extent of the monitoring.

Monitoring methods:

At least 50% of surveys were conducted using either LIT, PIT, photo-quadrats or video-transects, as these methods are less subjected to observer bias.

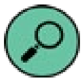
Less than 50% of surveys were conducted using LIT, PIT photo-quadrats or video-transects, and the method is available for more than 25% of surveys.

The methods used were not recorded in the 2020 GCRMN world report database for more than 75% of surveys.

1 The indicator "Fish Abundance and Biomass" is represented, but its status is not available as this indicator was not included during the data acquisition and the homogenization process prior to the elaboration of the 2020 GCRMN world report database.

Taxonomic resolution:

The criterion "Taxonomic resolution" focuses mostly on the taxonomic precision at which organisms belonging to the groups "Algae" and "Other fauna" were identified. The indicator "Live Coral Cover" is always measured and does not require a precision level above the group level. However, the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is based on the composition of benthic communities and thus requires a taxonomic resolution to at least the subgroup level when identifying benthic organisms.



Both "Algae" and "Other fauna" groups are represented and 50% or more of observations in each group were identified to at least the subgroup level.

Both of the groups "Algae" and "Other fauna" are represented and less than 50% of observations for one or both groups were identified to at least the subgroup level.

Observations of organisms belonging to at least one of the two groups were identified only to the group level or are missing from the 2020 GCRMN world report database.

While all 4 criteria are important and provide useful insights on the quality of the data contributed to the 2020 GCRMN world report database, only 2 criteria were selected in order to determine the final status of the indicators "Live Coral Cover" and "Fleshy Algae Cover and Cover of Key Benthic Groups" at the country level. The spatial extent and the taxonomic resolution of the data were the two criteria selected and they were selected because they were the most limiting when evaluating whether an indicator is available at the country level. The spatial extent of the monitoring should be representative of the coral cover at the country level. The taxonomic resolution is also important, as the indicator "Flesh Algae Cover and Cover of Other Benthic Groups" focuses on the composition of benthic communities other than hard coral species, requiring a taxonomic precision to at least the subgroup level. As indicators, the temporal extent and the methods used are not as effective, as they impact the availability of time series for analysis or the way data are collected but not the fact that an indicator can be considered as available or not. The decision tree that was designed to evaluate the status of the indicators is presented in Figure 2.

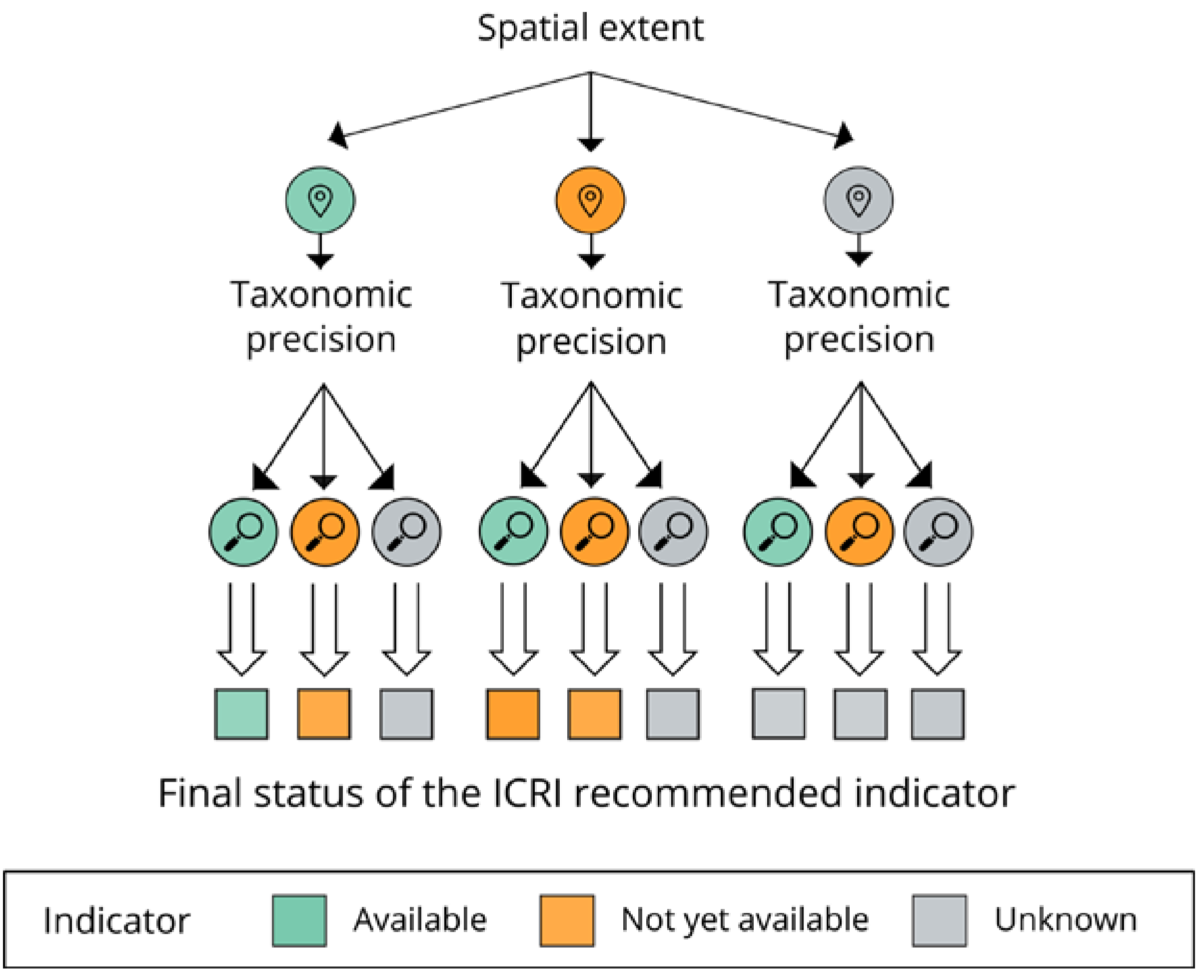


Figure 2. Decision tree used to assess the availability of the ICRI recommended indicators based on the two prevalent criteria selected, which are the spatial coverage and the taxonomic resolution of the data provided.

An indicator is considered *available* if the two chosen criteria are fulfilled. It is considered as *not yet available* if some data has been collected already but the current status of the data (according to the 2020 GCRMN world report database) is not yet enough for the indicator to be considered as *available*. In that case, more efforts are needed, in order to increase either the spatial extent or the taxonomic resolution of the collected data. If there are no data or not enough data, we cannot evaluate the status of the indicators based on the available data and thus their status is classified as *unknown*.

The resulting status of the indicators is represented in the Figure 3 of the template.

Peer reviewing of the summaries

Each country's summary was sent to correspondents in their respective countries for review and updated accordingly.

Software and packages used for the data analyses

All analyses, maps and graphs were conducted using the R software version 4.1.0 (R Core Team, 2021) and RStudio IDE version 1.4.1717 (RStudio Team, 2021). The following packages were used for the analyses: "DT" v. 0.19 (Xie et al., 2021), "formattable" v. 0.2.1 (Ren & Russel, 2021), "ggpubr" v. 0.4.0 (Kassambara, 2020), "magick" v. 2.7.3 (Ooms, 2021), "magrittr" v. 2.0.1 (Bache, Wickham, & Henry, 2020), "readxl" v. 1.3.1 (Wickham, Bryan, et al., 2019) "tidyverse" v. 1.3.1 (Wickham, Averick, et al., 2019), and "sf" v. 1.0.2 (Pebesma, 2018). The code used for the analyses is publicly available at https://github.com/JWicquart/gcrmn_ctry.

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PRESENTATION OF THE TEMPLATE

This section presents the framework in which all of the available data for the different types of information for each of the country summaries are presented.

1. Introduction – General context

In this section, general information and statistics about coral reefs in the named country are described to provide an overarching view of coral reefs and associated hard corals and fish species richness, their importance for human populations, the threats they are facing and the protection they are granted. Information for this section comes from the literature as well as some specific datasets, which are all described in the Methods section.

2. Description of available data

In this section, general figures describing the monitoring data for coral reefs are provided. These include the number of sites, their distribution and the relative contribution of the country to the 2020 GCRMN world report database (Souter et al., 2020). It should be noted that the number of rows is directly linked to the precision of the data, as the number of rows increases with the number of categories of organisms monitored.

Figure 1 shows the spatial distribution of monitoring sites within the country and the time range for which the sites were surveyed.

Figure 2 provides a characterization of the monitoring effort itself through 6 sub-figures:

1. Temporal distribution of the monitoring effort: The distribution of sites monitored from 1970 to 2020 is presented in Figure 2A. This provides information about the temporal distribution of the data and the consistency of the monitoring effort.
2. Monitoring methods: Figure 2B displays the percentage of surveys conducted with each type of method. It provides insights on preferential use of some methods over the others but also on the level of homogeneity of the protocols used to monitor the reefs at the country level.
3. Evolution of monitoring methods used through time: Figure 2C displays the evolution of the percentage of surveys conducted using the different monitoring methods in relation to the total number of surveys over time, grouped into three time periods. It provides insights into the consistency of the methods used over time and reveals potential shifts in the preferential use of the methods.
4. Taxonomic precision: Figure 2D displays the evolution of the taxonomic precision for which benthic observations were identified over the three time periods (same as the one for Figure 2C). It also provides information on the consistency of the identification effort over time.

5. Percentage of "Algae" observations identified to at least the subgroup level: Figure 2E displays the proportion of observations belonging to the "Algae" group that were identified to at least the subgroup level. "Algae" observations were divided into 4 subgroups: "Coralline algae", "Macroalgae", "Turf algae" and "Unknown". The subgroup level is the minimum level of precision required to characterize the evolution of benthic communities, and this figure thus provides insight into the availability of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".
6. Percentage of "Other fauna" observations identified to at least the subgroup level: Figure 2E displays the proportion of observations that belong to the "Other fauna" group that were identified to at least the subgroup level. "Other fauna" observations were divided into 5 subgroups: "Alcyonacea", "Other subgroups", "Porifera", "Tunicata" and "Unknown". The subgroup level is the minimum level of precision required to characterize the evolution of benthic communities, and this figure provides insight on the availability of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations in benthic cover monitoring

The results presented in the figures above are discussed in this section, with a particular interest on the four chosen criteria that are the spatial and temporal extent of the data available, the methods used and the taxonomic precision of the observations. Recommendations were formulated to efficiently improve the quality of the monitoring based on the data recorded in the 2020 GCRMN world report database (Souter et al., 2020). We also highlight situations where additional data might be available in the different countries as the 2020 GCRMN world report database might not include all existing benthic coral reef monitoring data within a country.

3.2 Status of ICRI recommended coral reef indicators

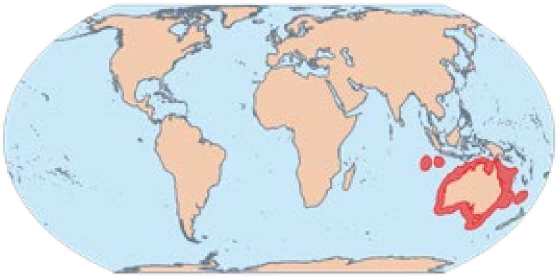
In this section, we evaluate whether the ICRI recommend indicators "Live Coral Cover" and "Fleshy Algae Cover and Cover of Key Benthic Groups" are available at the country level. An indicator is considered available at the country level when the data recorded in the database is abundant enough (both temporary and spatially) to provide a robust and representative estimate of the cover of a target benthic organism at the country level. As such, the spatial extent of the data recorded in the database needs to represent adequate coverage of the reefs and the taxonomic precision at which organisms were identified needs to be good enough to characterize the targeted group.

Figure 3 provides a schematic synthesis of the level at which the different criteria previously discussed and the status of the different indicators for each country, were achieved. The different requirements that were defined to evaluate the status of the criteria and the indicators are presented in the Methods section.

3.3 Main contacts

Communication and the visibility of the different actors of the monitoring is key in designing monitoring guidelines at the country level. In this section, we provide a (non-extensive) list of contacts related to the supervision of the monitoring of coral reefs in each country. These people are either focal points for the GCRMN, people in charge of the monitoring programs or people in charge of the centralization of the data.

Once again, this report should be viewed as a starting point for discussions and interactions and further additions and contributions will be welcomed and encouraged for a revised and updated version in the future.



AUSTRALIA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 44,485 km²

Proportion of the world's coral reefs: 16.881%

Ranking based on reef area: 1st

Australia shares its coastlines with the Indian and Pacific Oceans. Coral reefs are present along Australia's tropical coastlines and northern EEZ. The most well-known reef is the Great Barrier Reef (GBR), located off the coast of Queensland. Coral reef are also abundant in Western Australian waters, particularly Ningaloo Reefs, which is the world's longest fringing reef.

Coral reefs in Australia are home to 470 hard corals species (IUCN, 2021) and 2,079 species of reef fishes (Froese & Pauly, 2020). Several types of coral reef can be found in addition to the Great Barrier Reef complex, including patch reefs, fringing reefs and high intertidal reefs (Kordi & O'Leary, 2016; O'Mahoney et al., 2017).

Several Australian coral reefs are listed as UNESCO World Heritage sites, such as the Great Barrier Reef, Ningaloo and the coral communities around Bernier, Dorre and Dirk Hartog Islands. However, the evaluation of ecosystem services focused almost solely on the Great Barrier Reef, designated a UNESCO World Heritage site since 1981. This Australian icon is considered one of Australia's most valuables assets due to its incredible biodiversity and the ecosystem services it provides. In 2016, the value of the GBR was estimated at US$56 billion, which represented 4.6% of the country's GDP, supporting more than 64,000 jobs. Most of these jobs are tourism related, but fishing, recreational and scientific activities also employ thousands of people. The Great Barrier Reef tourism industry generated approximately US$5.7 billion in 2015-2016 (0.5% of the GDP in 2016) while the total value of commercial fisheries and aquaculture amounted to US$199 million (O'Mahoney et al., 2017), which represents 0.02% of the country's GDP. In 2003, the annual value of coastal protection by coral reefs in Australia was estimated at US$629 million (Cesar, Burke, & Pet-Soede, 2003), which was equivalent to 0.1% of Australia's GDP at that time.

Coral reefs in Australia face several threats. Climate change and the associated bleaching events are the greatest threat. Coral reefs are also prone to storms, cyclones, COTS outbreaks and diseases. In terms of anthropogenic threats, there are some differences between the reefs in Queensland and those in Western Australia, which are mainly due to differences in coastal development. As Queensland is more populated, the reefs are under greater pressure than their western counterparts due to coastal development, poor water quality and illegal fishing (O'Mahoney et al., 2017; Gilmour et al., 2019). In Western Australia, the level of anthropogenic pressure is lower, with fishing, pollution, and localized unsustainable recreational use of the reefs being the main human-related threats. The Western Australian coral reefs are also prone to outbreaks of the coral eating snail *Drupella* (Gilmour et al., 2019).

Marine protected areas in Australia span 3 million km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 36,701 km² of coral reefs within their boundaries, thus placing 82.5% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). While every effort was made to ensure as comprehensive a dataset as possible from Australia, some gaps are acknowledged (e.g. manta-tow surveys of the GBR that date back to 1985, Ningaloo). Monitoring effort provides good coverage of the coral reefs around Australia, with data from a total of 758 sites included within the GCRMN dataset. These observations represent 13.5% of the total global dataset compiled by the GCRMN (287,397 rows).

Sites from which data were provided occur mainly on the Great Barrier Reef along the east coast, and along the coast of Western Australia. Medium and long-term monitoring sites within Australia are common, with time series at the majority of sites exceeding 6 years. Sites in more remote locations on Cape York and the Kimberley coast tend to have been surveyed only once (Figure 1).

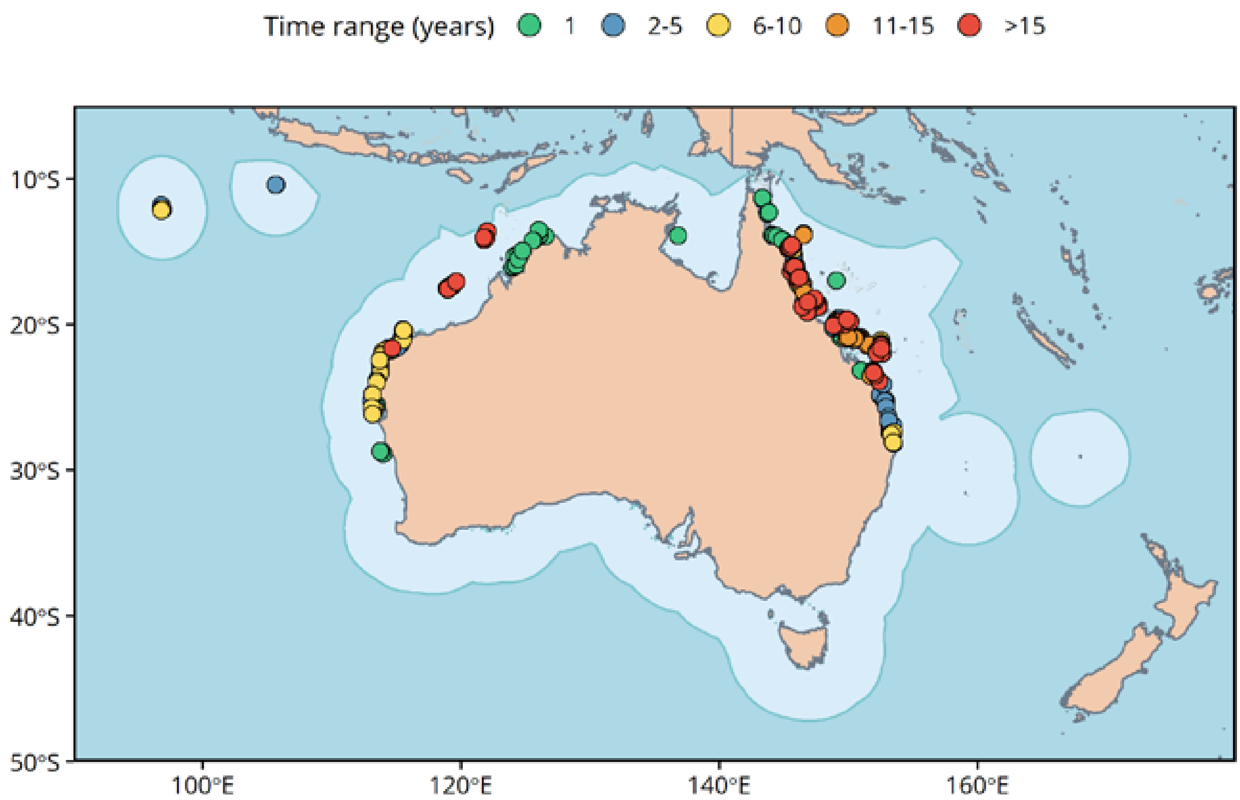


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1994 to 2019. The monitoring effort has increased since 1996 (Figure 2A).

The majority (73%) of surveys contributed to the 2020 GCRMN database were conducted using photo-quadrats. Point intercept transects were used on 15% of the surveys, while the method used for 12% of the surveys remains unknown (Figure 2B).

Between 1994 and 1999, 558 surveys were conducted using photo-quadrats and 30 surveys with point intercept transects. The total number of surveys greatly increased during the 2000-2009 period, and photo-quadrats were used in 1,454 surveys. The point intercept transect method was used on 328 surveys. From 2010 to 2019, the number of surveys increased again, with 1,580 surveys conducted with photo-quadrats and 392 with point intercept transects (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with more than 96% of identifications made at the subgroup level or above. While the proportion of observations identified to at least the subgroup level increased over time to reach 95%, the proportion of identifications conducted at the family level or above decreased from 63% in 1970-1999 to 40% in 2010-2019 (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 98% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Further, observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 73% of the observations (Figure 2F).

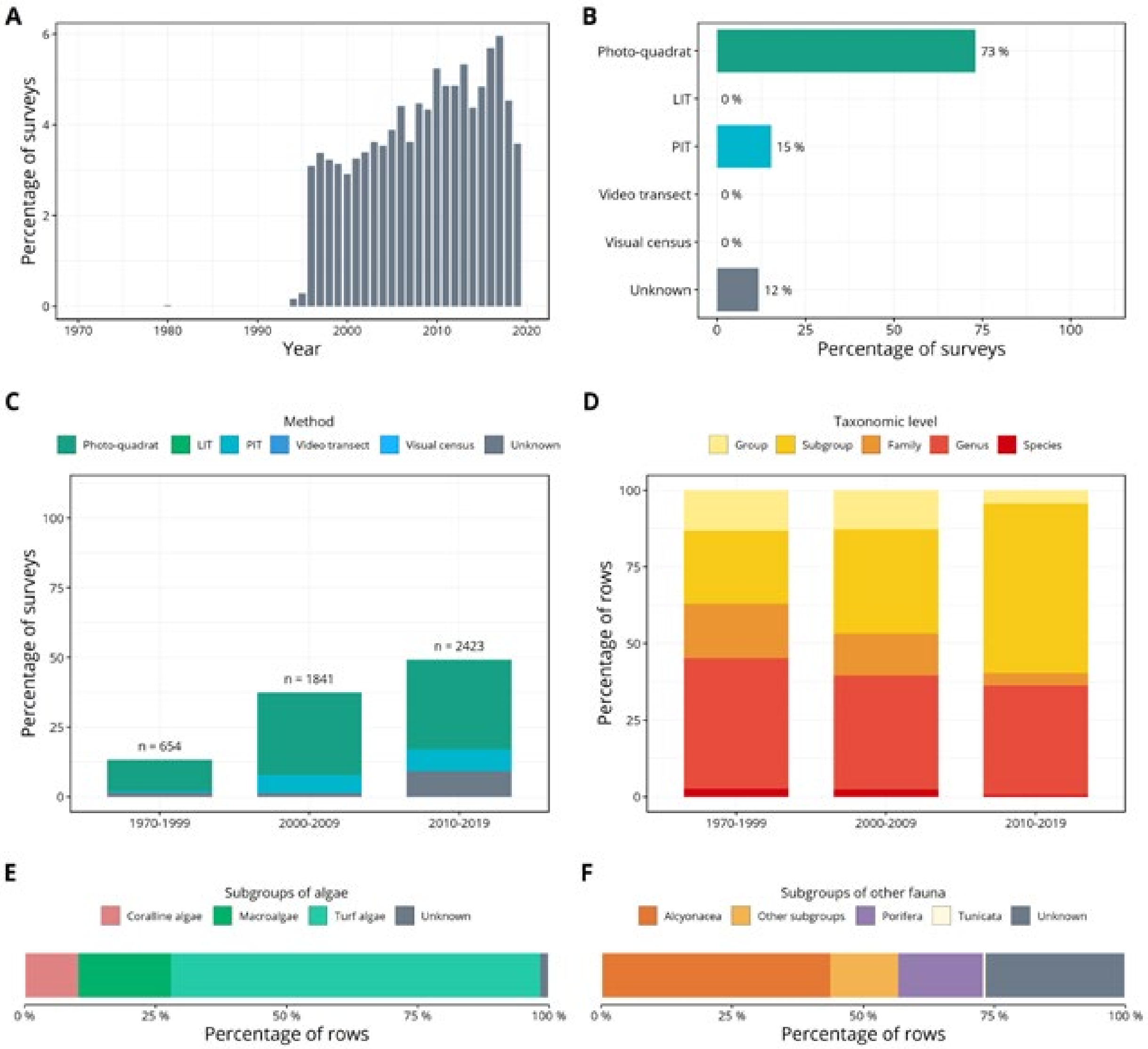


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent, especially in the Great Barrier Reef region and in Western Australia. Accessibility to data from surveys conducted in Elizabeth and Middleton Reefs could be improved.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 10 years, representing a valuable long-term record for trends in coral reefs. Unfortunately, in some cases, the data were not provided to the GCRMN and therefore do not appear in the analysis while long-term monitoring is already established, such as in Elizabeth and Middleton Reefs.

Methodology. The vast majority of data provided were collected using photo-quadrats. The use of image-based methods is valuable as high quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the data provided have a level of taxonomic precision at the subgroup or genus levels, which is sufficient to assess changes in benthic composition over time. However, 27% of "Other Benthic fauna" observations were only identified to the group level. This level of detail could be improved by recoding data at the subgroup level. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that the surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored in all surveys of the 758 sites throughout Australia since 1994, which is certainly enough to consider that it is implemented and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding algae and the other benthic groups is sufficient for this indicator to be considered in use in the country.
3. **Fish Abundance and Biomass[1]**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

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1 Owing to the great variation in the way in fish surveys are conducted on coral reefs throughout the world, fish abundance and biomass were not able to be assessed by the GCRMN in a globally consistent way. However, it is known that fish species abundance and biomass are standard components of monitoring conducted on Australian coral reefs (see GBR Outlook Report). This indicator is used in this country.

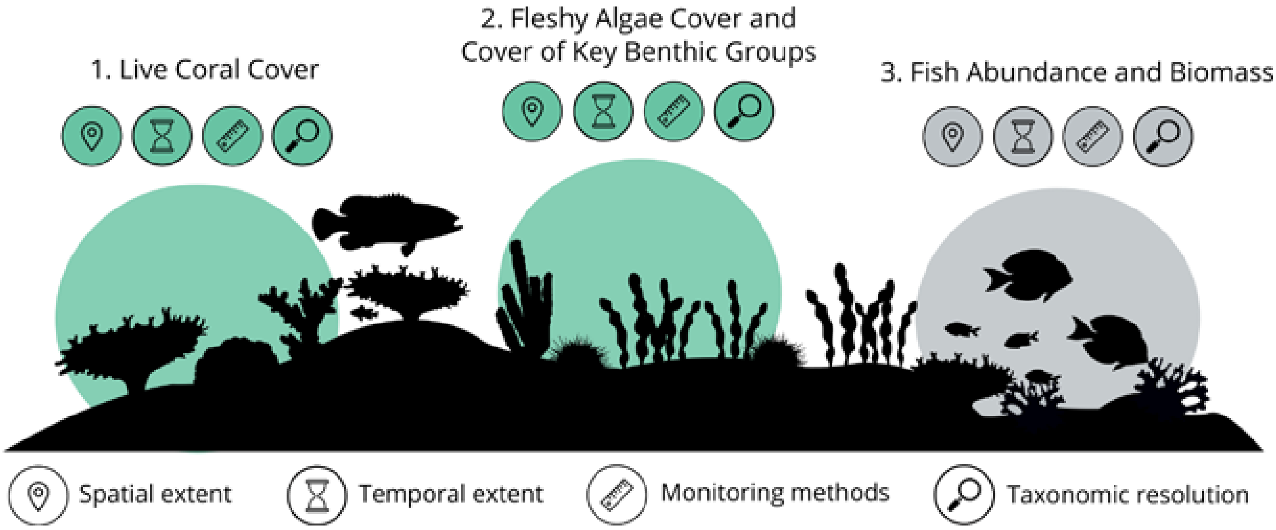

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover", "Fleshy Algae Cover and Cover of Key Benthic Groups" and "Fish Abundance and Biomass" presented in figure 3 are measured at the country level and are available on request for most of the datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Australia, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Damian Thomson	damian.thomson@csiro.au	Team Leader of the Ningaloo Outlook Program, Oceans and Atmosphere - CSIRO
David Souter	d.souter@aims.gov.au	Research Manager at the Australian Institute of Marine Science, Townsville, Australia
Claire Ross	claire.ross@dbca.wa.gov.au	Research Scientist (coral communities), Biodiversity and Conservation Science Department of Biodiversity, Conservation and Attractions, Kensington, Australia

This summary has been reviewed by the focal points.

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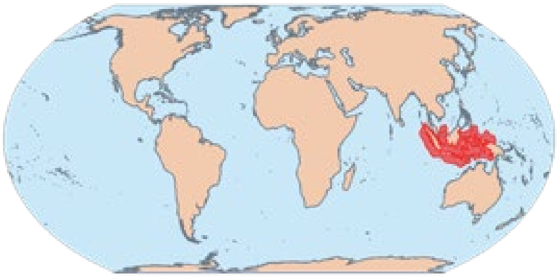

INDONESIA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 40,209 km²

Proportion of the world's coral reefs: 15.259%

Ranking based on reef area: 2nd

Indonesia encompasses more than 17,000 islands, which makes it the largest archipelagic nation in the world. Approximately 6,000 of these islands are inhabited.

Located in the heart of the Coral Triangle, Indonesia is home to some of the most biodiverse coral reefs on the planet, as illustrated by the very high number of hard coral and fish species observed in its waters. There are 621 species of hard corals (IUCN, 2021) and 2,117 species of reef fishes that are known to inhabit the reefs (Froese & Pauly, 2020). There are several endemic corals from Indonesia, including *Acropora suharsonoi*, *Euphyllia baliensis*, *Isopora togianensis* and *Cynarina macassarensis* (Best & Hoeksema, 1987; C. Wallace, 1994; C. C. Wallace, 1997; Turak, Devantier, & Erdmann, 2012). Coral reefs around Indonesia can be classified into four categories. Fringing reefs are the most abundant, followed by patch reefs, barrier reefs and atolls (Susanto, Suraji, & Tokeshi, 2015). The reefs spread from Rondo Island (the outermost island in the northwest) to the north of Jayapura (eastern). Both the big and small islands are commonly surrounded by fringing reefs (Continental shelf and oceanic fringing reefs). Patch reefs occur mostly in the Java Sea (Banten Bay, Seribu Islands, Indramayu, Tegal, Jepara, Rembang, Pasir Putih, Baluran and Banyuwangi) and Natuna Sea. Takabonerate is the world's third-largest atoll, located in the south of Sulawesi Island. In the eastern part, the reefs are well developed; a combination of a long geological process that has created both a complex topography of islands and the Indonesian Throughflow, a continuous water flow, enables the reefs to thrive (Tomascik, Mah, Nontji, & Moosa, 1997; Suharsono, 2017). In some areas, such as the east coast of Sumatra and Borneo (Kalimantan), coral reefs are not well developed due to high fresh water input from big rivers resulting in low salinity and high turbidity (Hadi et al., 2020).

Coral reefs in Indonesia provide extremely valuable services to local communities. They act as an important source of income for the local populations as they support one of the largest marine fisheries in the world, accounting for 2.6% of the country's GDP in 2016 and employing approximately 2.7 million workers (CEA, 2018). Tourism and recreational activities are also supported by the presence of coral reefs. In 2017, reef tourism represented around 0.34% of Indonesia's GDP (Spalding et al., 2017). In this region where storms and volcanic seismic activity are frequent, coastal protection is very important and was estimated at US$314 million in 2002 (Burke, Selig, & Spalding, 2002), but this estimate, which represented 0.2% of the country's GDP, was likely underestimated.

While the marine resources provided by the adjacent coral reefs have been sustainably harvested by coastal communities, population growth and unsustainable fishing practices have greatly damaged the reefs in some places, depriving some communities of their means of subsistence. In addition to overfishing and climate change, the reefs are also threatened by coastal development and pollution (Burke, Reytar, Spalding, & Perry, 2012).

In order to protect these valuable ecosystems, Indonesia designed a national action plan for the conservation of Biodiversity (IBSAP) that includes coral reefs. The country is also an active member of the Coral Triangle Initiative (Yudiarso, 2019). Marine protected areas in Indonesia span 221,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 12,142 km² of coral reefs within their boundaries, thus placing 30.2% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Indonesia, with data from a total of 1,460 sites included within the GCRMN dataset. The observations recorded represent 2.5% of the total global dataset compiled by the GCRMN (52,474 rows).

Sites from which data were contributed occur mainly around the eastern part of the archipelago, which is better represented in the database than its western counterpart, where monitoring is limited to a smaller number of locations. However, some regions are not covered in the database, such as Borneo (Kalimantan) or Papua[1]. The majority of sites were surveyed only once, but several of the sites included within the GCRMN database were monitored for more than 2 years (Figure 1).

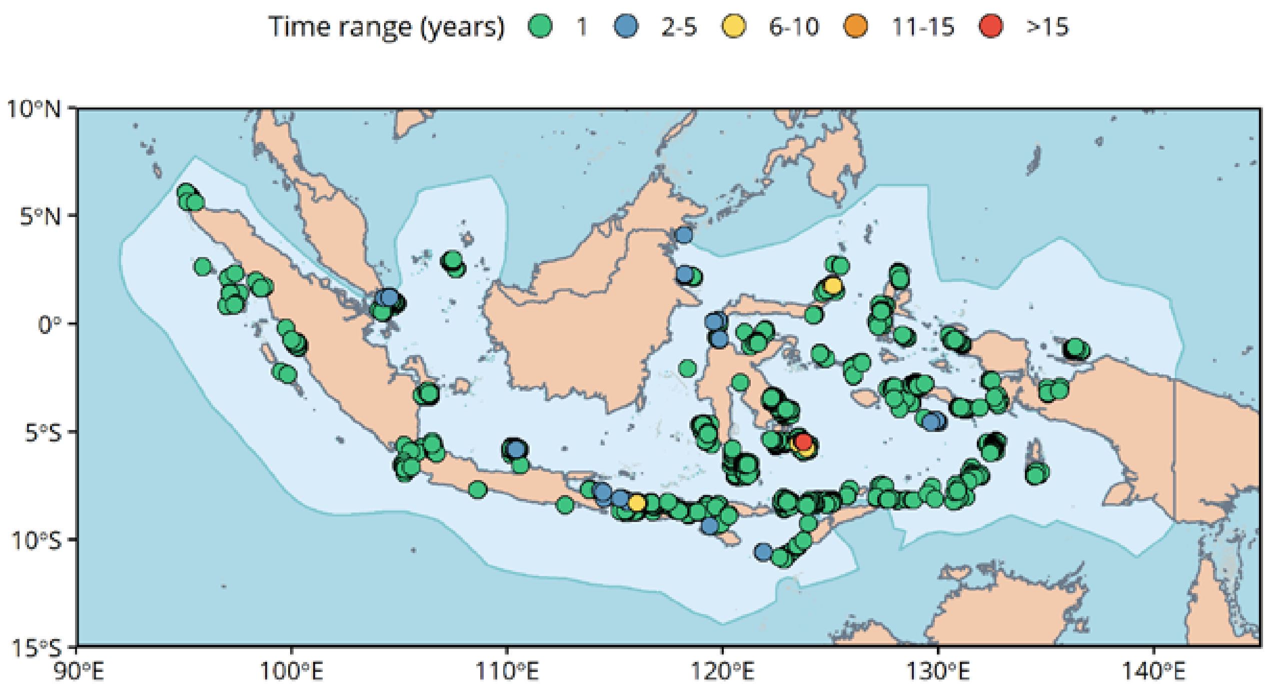

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1987 to 2019. The monitoring effort has increased since the 2000s. From the data available, no monitoring effort was recorded between 1992 and 2000, and almost no monitoring was recorded for the 1998 major global bleaching event. Monitoring effort increased significantly during the 2010-2019 period, with almost 70% of the recorded surveys conducted during this period (Figure 2A).

The majority (80%) of surveys included within the 2020 GCRMN database were conducted using the point intercept transect method[2]. The photo-quadrat method[3] was the second most used method, as it was used on 14% of surveys. The line intercept transect method[4] came third, and was used on 6% of the surveys. For 1% of the data, the survey method used remains unknown (Figure 2B).

1 In these regions, the reefs are not well developed due to intensive river discharge from both islands, making silt and mud dominate the inshore areas. Hence, coral reef surveys on those areas are not the main priority.

2 For more information, please refer to (Hill & Wilkinson, 2004; Yulianto et al., 2012).

3 For more information, please refer to (Hill & Wilkinson, 2004; Giyanto et al., 2014).

4 For more information, please refer to (English, Wilkinson, & Baker, 1994; Giyanto et al., 2006).

Between 1970 and 1999, 84 surveys were conducted using the line intercept transect method, and 40 surveys were conducted using the point intercept transect method. Point intercept transect was used in 416 surveys between 2000 and 2009. From 2010 to 2019, the number of surveys conducted with point intercept transect doubled, as it was used 962 times during this period. During the same period, photo-quadrats started to be implemented as a method for surveying benthic communities in coral reefs and was used in 246 surveys. Only 15 surveys were conducted using the line intercept transect method during this time period (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups[5], which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, with 73% of identifications made at the subgroup level or above. The taxonomic resolution slightly decreased from 80% of observations recorded at the subgroup level or above to 70% over the 3 time periods. Observations at the genus level and above remained around 15% over time (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 69% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Further, the observations of benthic fauna other than hard corals were identified to at least the subgroup level for 98% of the observations (Figure 2F).

5 Originally, the categorization of monitoring data in Indonesia refers to a simplified version of English et al (1994). In this case, the data are classified into hard coral (Acropora and Non Acropora), recently dead coral, dead coral with algae, soft coral, sponge, fleshy seaweed, others, rubble, rock, silt, and sand. However, for GCRMN data record, an adjustment has been made.

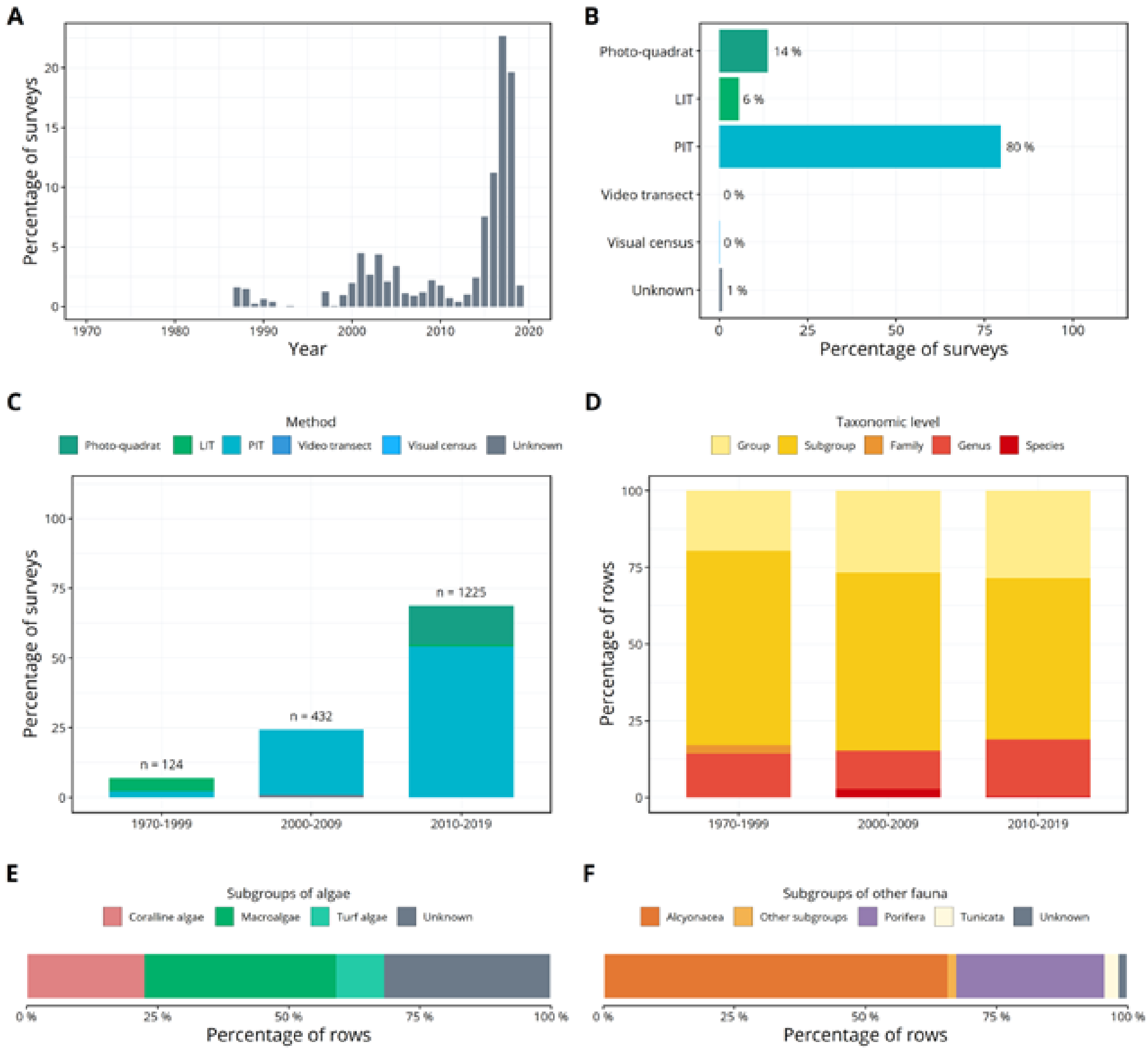

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent, especially in Eastern Indonesia. To better include the western component of the archipelago, we recommend that additional monitoring sites be established, such as on the West coast of Sumatra.

Temporal Extent. The temporal extent of most of monitoring sites is low. Thus, we recommend that more fixed monitoring sites be established, and that monitoring in existing sites be extended.

Methodology. Most monitoring sites were surveyed using the point intercept transect method. However, a shift towards the use of photo-quadrats happened from 2010-2019. We recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution Around 75 % of the benthic organisms were identified to the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. The slight drop in precision during the 2010-2019 period should be addressed in order to keep a high level of precision when identifying benthic organisms. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that the surveying these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator has been monitored on 1,460 sites throughout Indonesia, with data available for 25 different years from 1987 to 2019. Further, all criteria are met for the indicator "Live Coral Cover" to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered as integrated into national monitoring program, as recommended by ICRI. Further, all requirements are met for this indicator to be considered as available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

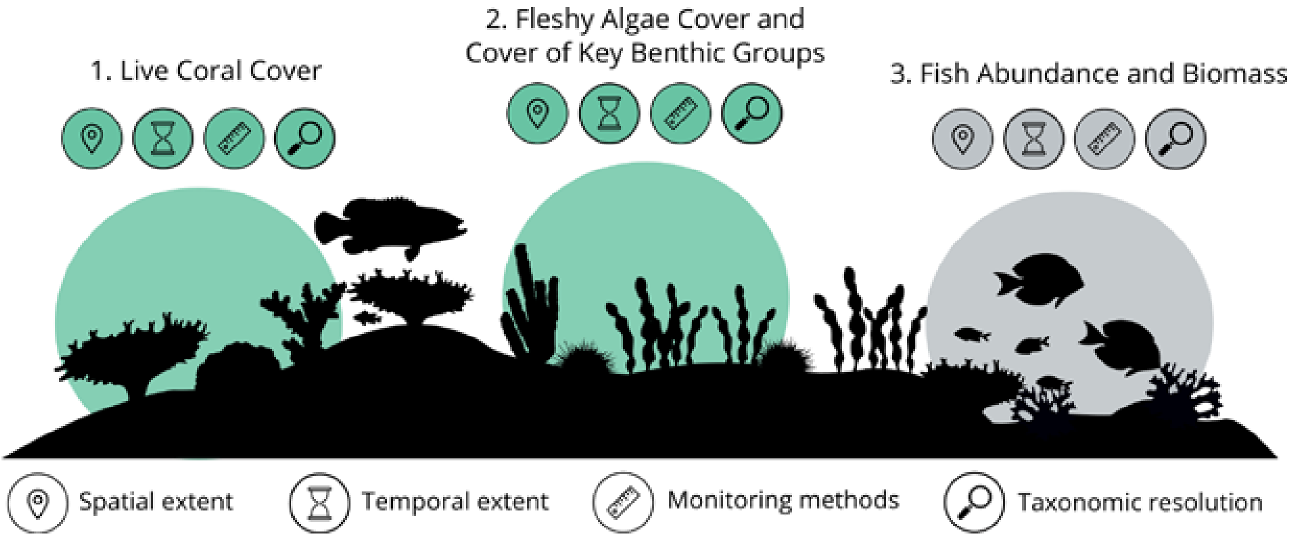

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators “Live Coral Cover” as well as “Fleshy Algae Cover and Cover of Key Benthic Groups” presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Indonesia, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Firdaus Agung	firda_ku@yahoo.com	Directorate of Marine Conservation and Biodiversity, Ministry of Marine Affairs and Fisheries
Muhammad Abrar	abrarlipi@yahoo.co.id	Research Centre for Oceanography, National Research and Innovation Agency
Tri Aryono Hadi	ari_080885@yahoo.com	Research Centre for Oceanography, National Research and Innovation Agency

This summary has been reviewed by the focal points.

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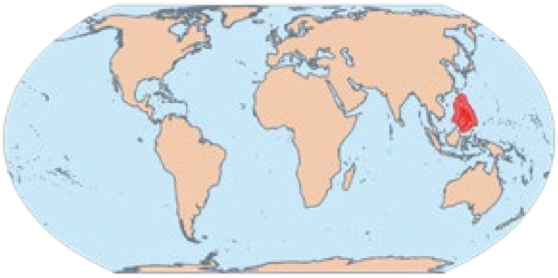
PHILIPPINES



1. Introduction – General context

CORAL REEF CARD

Estimated area: 25,677 km²

Proportion of the world's coral reefs: 9.744%

Ranking based on reef area: 3rd

The Philippines is a nation comprised of about 7,100 islands and is located at the Northern corner of the Coral Triangle. This is the second largest archipelagic state in the world.

All major reef types are present, hosting high levels of biodiversity characteristic of the Coral Triangle (Hoeksema, 2007). Coral reefs in the Philippines account for 593 species of hard corals (IUCN, 2021) and are home to 1,883 fish species (Froese & Pauly, 2020). The most abundant type of reef is the fringing reef, which develops along the coastlines. Barrier reefs, atolls and patch reefs are also found in the Filipino waters (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Coral reefs in the Philippines are highly valuable as they attract tourists, provide food, employment and income through fisheries, and protect the coast from storm surge and coastal erosion. In 2018, their total economic value was estimated at US$4 billion per year, which represented 1.2% of the Philippines GDP. Reef fisheries generate more than US$1.1 billion per year, which represents 0.3% of the 2018 GDP (Tamayo, Anticamara, & Acosta-Michlik, 2018), and employ more than 1.3 million people (Cabral & Geronimo, 2018). Reef fisheries catches remain the main source of protein for numerous coastal communities in the Philippines. In 2017, the total tourism value of reefs was estimated at US$1.4 billion per year, which represented 0.6% of the country's GDP (Spalding et al., 2017). In 2002, the value of the coastal protection provided by coral reefs was estimated at US$326 million (Burke, Selig, & Spalding, 2002), which represented 0.4% of the GDP at the time the study was released. As the GDP was much lower in 2002 than today, new estimates might differ.

Coral reefs in the Philippines are primarily threatened by overfishing and destructive fishing practices. Coastal development and watershed-based pollution, which lead to siltation, also represent an additional source of anthropic pressure for coral reefs (Kimura, Tun, & Chou, 2014). In terms of natural threats, coral reefs in the Philippines are also subject to thermal stress and coral bleaching. In addition, the country is located in the typhoon belt, and cyclonic storms are frequent in the area (Burke, Reytar, Spalding, & Perry, 2012).

Marine protected areas in the Philippines span 39,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 2,330 km² of coral reefs within their boundaries, thus placing 9% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the Philippines, with data from a total of 568 sites included within to the GCRMN dataset. These observations represent 1.1% of the total global dataset compiled by the GCRMN (24,119 rows).

Sites from which data were provided occur mainly around the islands of Palawan, Mindoro and Negros. While more than half of sites were surveyed only once, several sites were surveyed from 2 to 5 years, and a few sites were surveyed for 6 years or more (Figure 1).

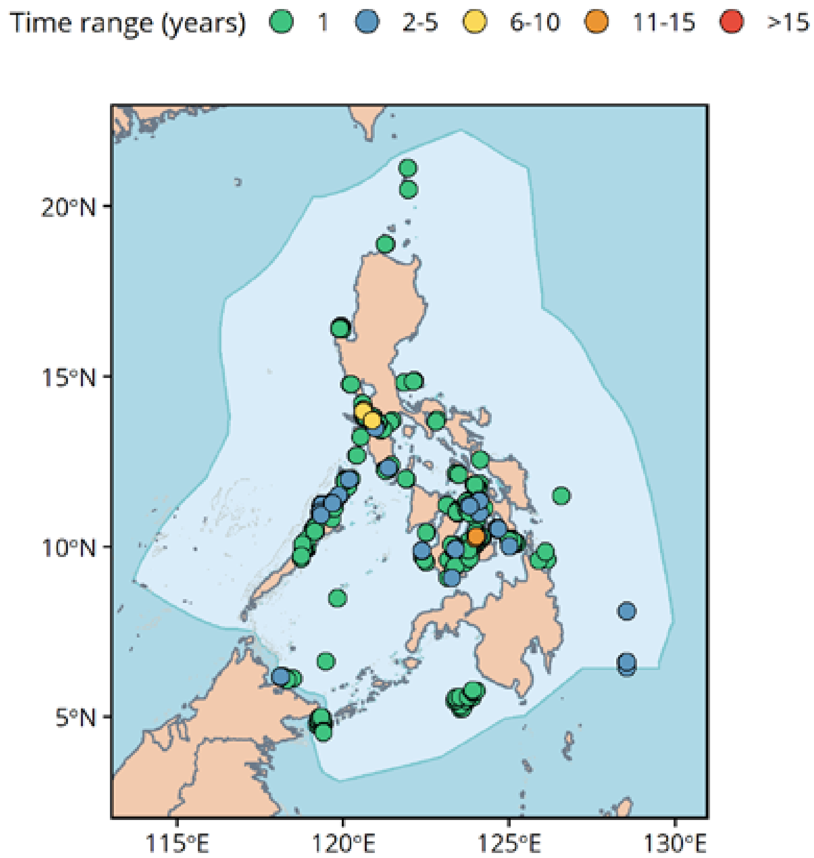


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1986 to 2019. The recorded monitoring effort is irregular, with sites monitored between 1986 and 1992 and then no effort recorded until 1997, when data once again became available (Figure 2A).

The majority (84%) of surveys included within the 2020 GCRMN database were conducted using point intercept transects, followed by line intercept transects (11%) and photo-quadrats (5%) (figure 2B).

Between 1979 and 1999, the line intercept transect method was the main method used (85 surveys), followed by point intercept transects (20 surveys). However, the point intercept transect method became the main method used during the next two time periods, as 304 surveys used this method between 2010 and 2019. The photo-quadrat method started to be used between 2010 and 2019, and was used in 40 surveys (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, with 68% of identifications made at the subgroup level or above. However, the precision level of the identifications decreased over the three time periods, starting with more than 80% of the identifications made at the subgroup level, and finishing with only 68% (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented, although only 23% were identified to at least the subgroup level (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 98% of the observations (Figure 2F).

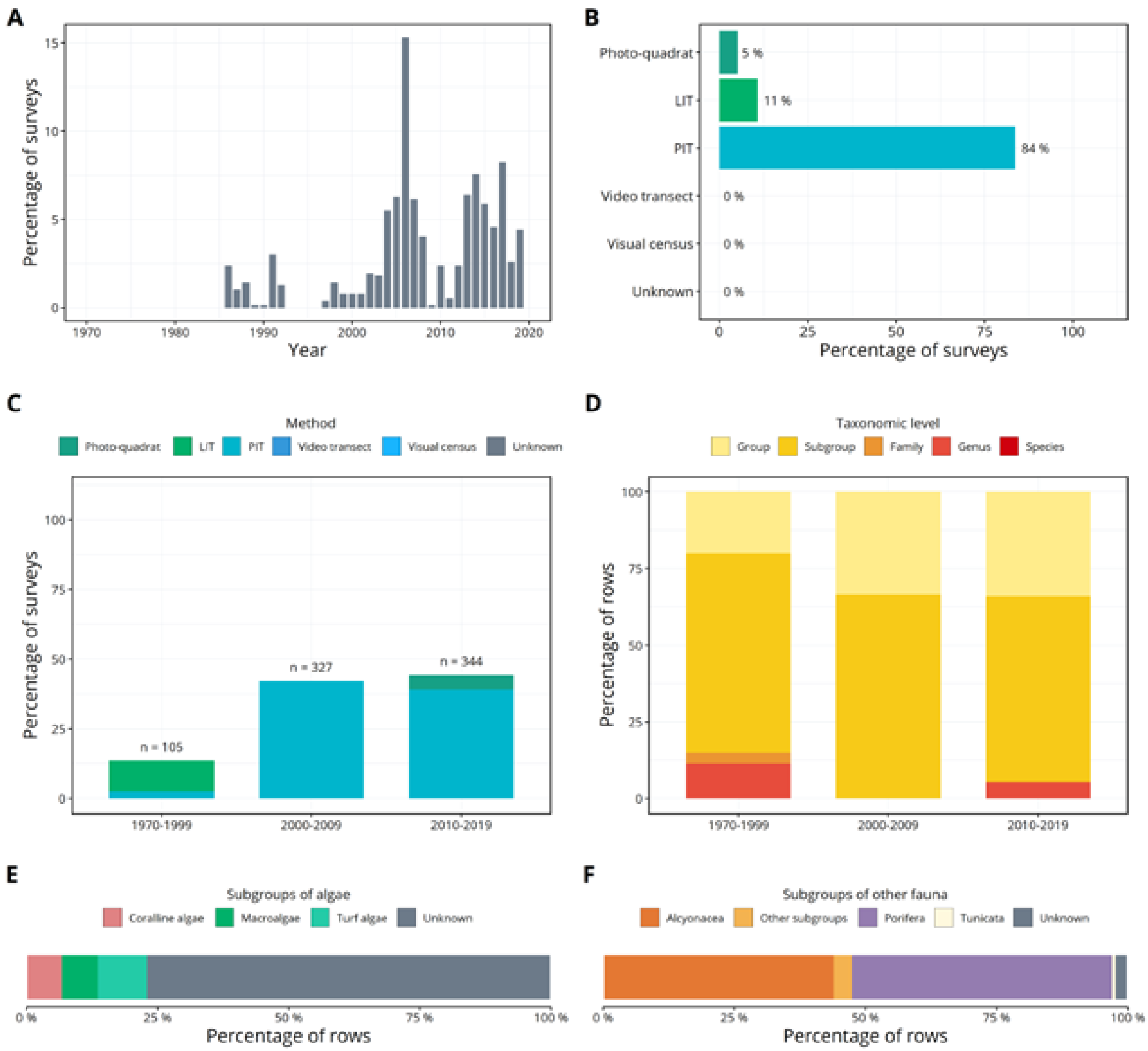


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent[1]. The spatial coverage of the monitoring recorded in the database is already good, especially around Palawan and around the Sibuyan Sea. To further increase the spatial coverage of the monitoring, we recommend that additional monitoring sites be established, especially around the Sulu Archipelago.

Temporal Extent. The temporal extent of most monitoring sites is low. Thus, we recommend that long-term monitoring sites be established, and that current monitoring efforts be continued.

Methodology. We recommend that the use of photo-quadrats, which began during the 2010-2019 period, be continued when possible. The use of image-based methods is valuable, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in the taxonomic composition of benthic communities.

Taxonomic precision. Around 70% of benthic organism identifications were made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that the surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, the subgroup is unknown for 77% of algae observations. As this percentage is low, we recommend that the taxonomic precision of identifications be improved to at least the subgroup level.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 568 sites throughout the Philippines for 30 different years between 1986 and 2019, which is enough to consider that this indicator available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observation regarding the algae is not sufficient for this indicator to be considered in use in the country. Thus, we recommend that the identification of algae be improved in future monitoring protocols in order for this indicator to become available.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

1 We are aware that there are additional sites and monitoring data that were not included in the 2021 GCRMN database. As such, an effort should be made to make this additional data available. For more information, please refer to Licuanan et al. 2019.

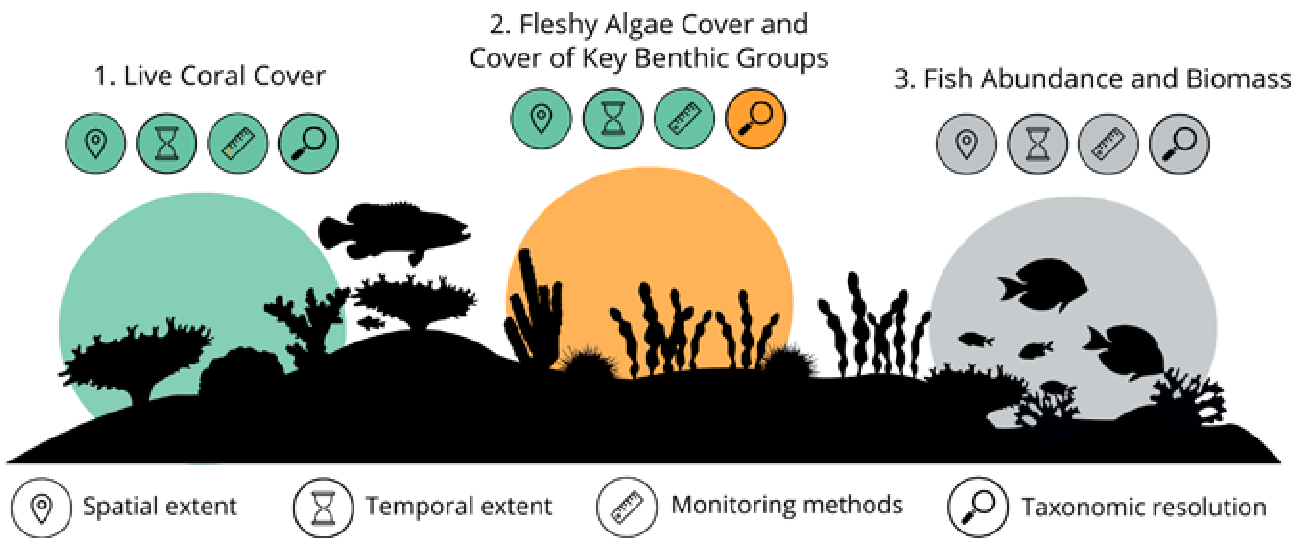


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

To conclude, the ICRI recommended coral reef indicator "Live Coral Cover" presented in Figure 3 is measured and is available on request for most of the existing datasets identified at the country level, while the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is not available. However, it could quickly become available, provided that algae identifications are more effectively included in future monitoring protocols.

3.3 Main contacts

A coral reef monitoring focal point for the Philippines has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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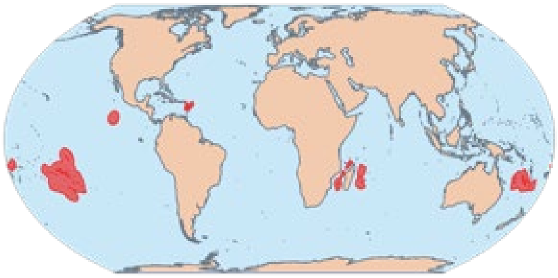
FRANCE



1. Introduction – General context

CORAL REEF CARD

Estimated area: 16,494 km²

Proportion of the world's coral reefs: 6.259%

Ranking based on reef area: 4th

France hosts about 6% of the coral reefs of the world through its overseas territories which are spread across all oceans, and which provide multiple uses and services. Found in different biogeographic regions, French coral reefs are geomorphologically diverse and high in specific diversity.

There are 553 species of hard corals (IUCN, 2021) and 2,150 species of reef fishes that are known to inhabit the reefs of the tropical French overseas territories (Froese & Pauly, 2020). Reef building corals in French overseas territories form barrier reefs, fringing reefs, atolls and patch reefs (Gardes & Salvat, 2008).

These ecosystems provide numerous services to overseas French populations, that were valued at US$1.4 billion in 2015, and represent on average 2% of an overseas territory's GDP. The benefits that coral reefs bring through tourism are estimated at US$350 million, which represents approximately 0.5% of the French overseas territories' GDP, generating more than 2,800 direct and 35,000 indirect jobs. Fisheries and aquaculture are estimated to generate US$240 million, which represents approximately 0.3% of the GDP and provides jobs for 14,000 fishermen. Coral reefs also provide the main source of protein for 90,000 households. Whilst often forgotten, the coastal protection provided by coral reefs is estimated at US$660 million, which represents 0.9% of the GDP. This sole service amounts to US$370 million for the islands of French Polynesia, where most islands are prone to hurricanes and tropical storms (Pascal, Leport, Allenbach, & Marchand, 2016).

Due to their large geographic distribution and their inherent differences, not all territories face the same threats, but they all face the same global threat that is climate change. Some of the most common threats at the local level are pollution, overfishing, coastal urban development and COTS outbreaks (Gardes & Salvat, 2008; Bambridge et al., 2019; IFRECOR, 2021).

Marine protected areas in France span 2.2 million km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 5,200 km² of coral reefs within their boundaries, thus placing 31.5% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the French overseas territories, with data from a total of 386 sites included within the GCRMN dataset. These observations represent 3.6% of the total global dataset compiled by the GCRMN (75,414 rows).

Sites from which data were provided occur in all of the French overseas territories except for the island of Tromelin. The monitoring is relatively homogeneous between the different territories, while differences exist. Some territories are extensively surveyed, such as New-Caledonia, La Reunion or Moorea, an island located in French Polynesia, while other territories, such as the French Antilles, Clipperton and numerous atolls of French Polynesia, are much less represented in the database. Nevertheless, most of the sites recorded in the database were surveyed for more than 5 years and sometimes for more than 15 years, providing time series for analysis (Figure 1).

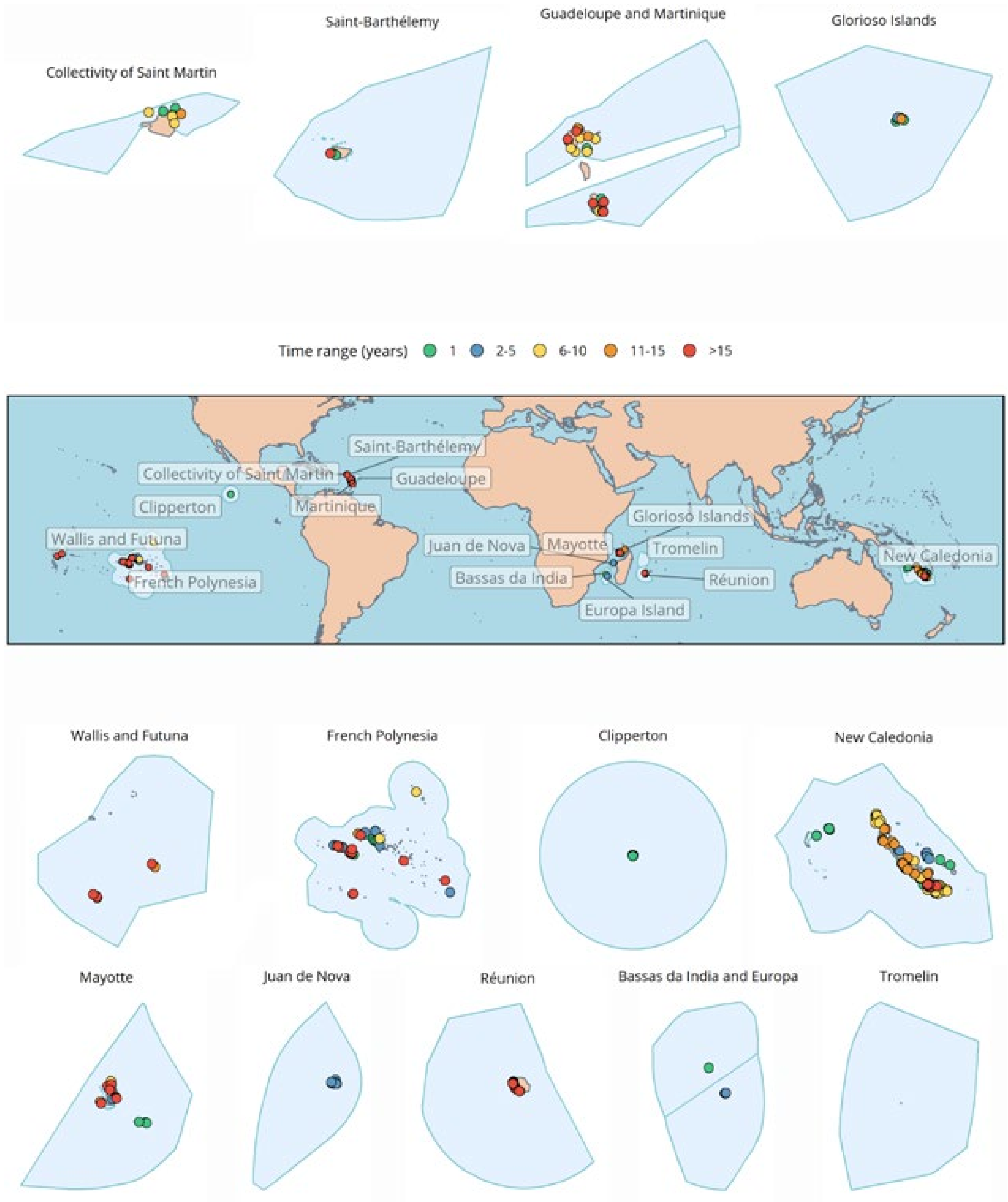


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1987 to 2019. From 1990 to 2003, monitoring effort slowly increased. Since 2005, the proportion of sites annually surveyed oscillated between 4% and 7% (Figure 2A).

The majority (53%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by line intercept transects (38%) and photo-quadrats (8%) (Figure 2B).

The point intercept transect method remained the primary method used to monitor coral reefs throughout the three time periods, and it was used in 784 surveys between 2010 and 2019. The point intercept transect method was first used during the 1979-1999 period and the number of surveys conducted using this method increased over the 3 time periods, to a maximum of 508 surveys between 2010 and 2019. The photo-quadrat method was used since the 1970-1999 period but its relative importance remained low compared to the other methods (86 surveys between 2010 and 2019) (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with 85% of identifications made at the subgroup level or above. There has been a general decrease in the precision level over the years. The proportion of observations recorded at the genus level or above decreased from 45% for the 1979-1999 period to approximately 24% for the 2010-2019 period, while the proportion of observations made at the subgroup level increased. The latter represented approximately 42% of the observations for the 1979-1999 period and increased to 54% of the observations made between 2010 and 2019 (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 72% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 95% of the observations (Figure 2F).

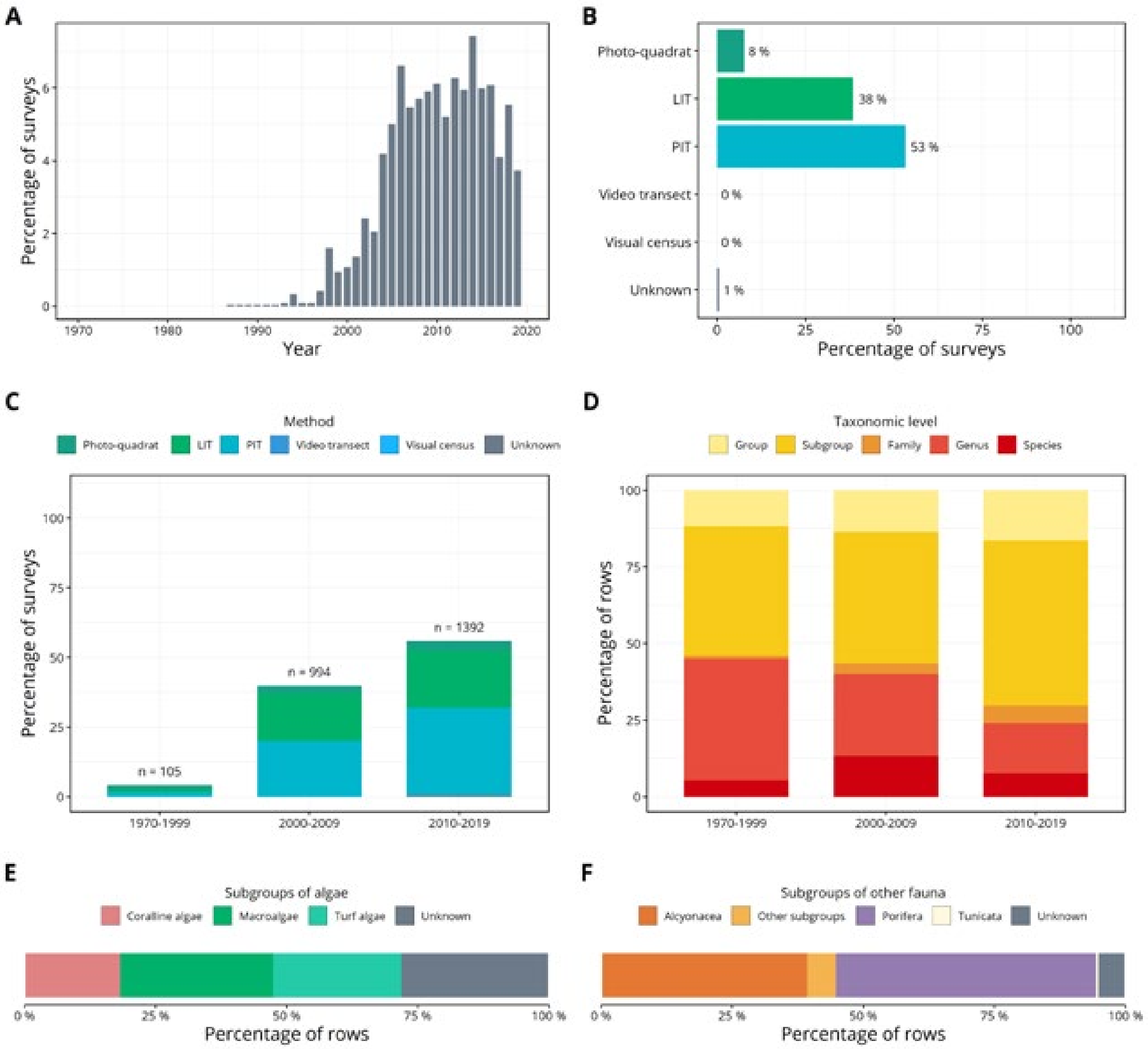


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and general recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage varies significantly between the different French overseas territories, with certain territories being less monitored than others. To increase the spatial coverage of monitoring programs, we recommend that additional monitoring sites be established for the reefs around Tromelin and in French Polynesia, notably in the Marquesas and the Austral islands.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 10 years, representing a valuable long-term record for trends in coral reefs. Such efforts are highly valuable and should be continued.

Methodology. Line and point intercept transects are predominantly used to monitor coral reefs in the French overseas territories. While these methods provide useful data, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. More than a third of the data provided corresponds to a true taxonomic classification (family or above), which enables changes in benthic composition to be characterised over time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that the surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, 28% of algae observations were only identified to the group level. While this precision level is sufficient, we recommend that the taxonomic precision be improved to at least to the subgroup level.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored throughout the French overseas territories for 386 sites and is available for 33 different years from 1987 to 2019. Furthermore, all requirements are met. Thus, this indicator can be considered in use at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** Based on the analysis of the four criteria (Figure 3), all of the requirements are met in order for this indicator to be considered as measured when monitoring coral reefs at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

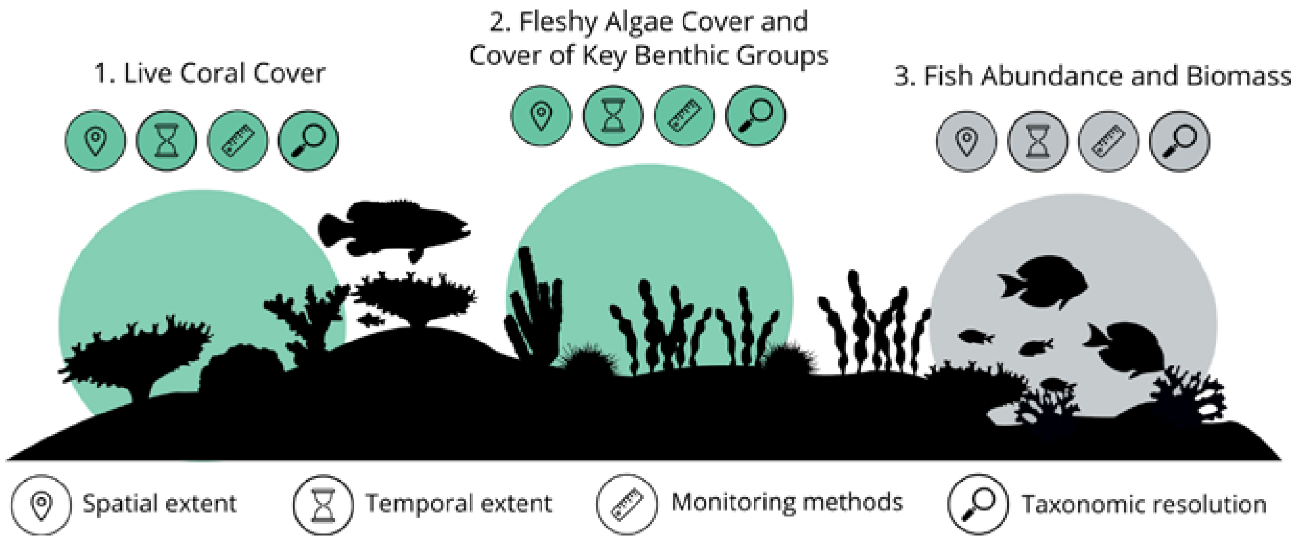


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators “Live Coral Cover” as well as “Fleshy Algae Cover and Cover of Key Benthic Groups” presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in the French overseas territories, please contact the focal point, whose contact information is available in the following table.

Name	Contact	Organisation
Antoine Pebayle	antoine.pebayle@developpement-durable.gouv.fr	Ministry for the Ecological Transition

This summary has been reviewed by the focal points.

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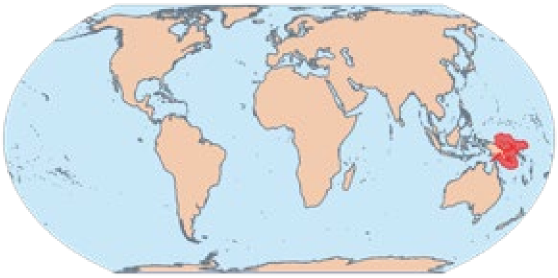

PAPUA NEW GUINEA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 14,990 km²

Proportion of the world's coral reefs: 5.688%

Ranking based on reef area: 5th

Papua New Guinea is located at the Western corner of the Coral Triangle and includes the Eastern part of the largest equatorial island and around 60 additional islands. Due to its latitudinal position, Papua New Guinea is located outside of the typhoon belt, which explains why the islands are rarely impacted by cyclonic storms and extreme high seas.

Coral reefs in Papua New Guinea are highly diverse and they host 566 species of hard corals (IUCN, 2021) and are home to 1,671 fish species (Froese & Pauly, 2020). The most abundant coral reef formations are fringing reefs, patch reefs and barrier reefs (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

The socio-economic importance of coral reefs in Papua New Guinea has yet to be formally estimated despite their importance for local communities. Coastal communities are highly dependent on fishing activities for subsistence and income. Fish remain the main source of dietary protein in numerous coastal and rural communities and it is estimated that between 250,000 and 500,000 people are involved in coastal subsistence fisheries (Preston & Gillett, 1997). Tourism is not very developed in Papua New Guinea, with the exception of the diving sector, which relies on coral reefs to attract visitors. According to a visitor survey conducted in 2001, 68% of tourists come to Papua New Guinea for the diving (Asian Development Bank, 2014). Although reef-tourism represented only 0.21% of Papua New Guinea's GDP in 2017 (Spalding et al., 2017), it is projected to grow significantly over the coming years. Nature and Adventure-based Tourism is expected to grow and is estimated to reach between US$11.9 and US$13.8 billion in terms of Total Socio-Economic and Environmental Value by 2035 (Coral Triangle Sustainable Nature-Based Tourism, 2017), which represents between 52% and 61% of the country's 2017 GDP.

Despite their crucial importance for coastal communities, coral reefs around Papua New Guinea face multiple pressures. Overfishing, destructive fishing practices and increased levels of sedimentation due to poor land management practices inflict severe damage on the reefs. Coral bleaching due to increasing sea temperatures, ocean acidification and COTS outbreaks add to anthropogenic threats, placing additional pressure on coral reefs (Burke, Reytar, Spalding, & Perry, 2012).

Marine protected areas in Papua New Guinea span 4,600 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 497 km² of coral reefs within their boundaries, thus placing 3.3% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides an incomplete coverage of the coral reefs around Papua New Guinea, with data from a total of 58 sites included within the GCRMN dataset. These observations represent 1.7% of the total global dataset compiled by the GCRMN (36,745 rows).

Sites from which data were provided occur mainly in Kimbe Bay, New Britain, as well as on the eastern part of New Guinea island, and offshore of Kavieng, New Ireland. All of the sites were surveyed only once, with the exception of 8 sites in Kimbe Bay, which have been surveyed for more than 20 years (Figure 1).

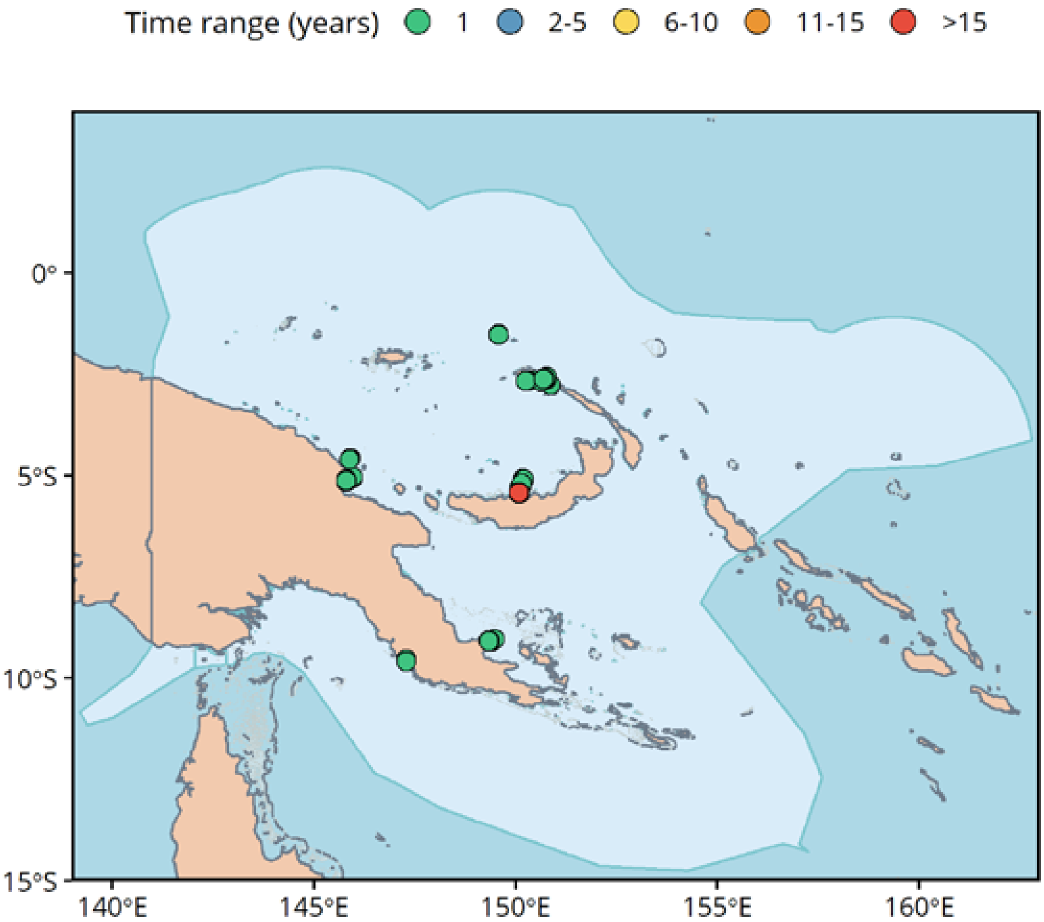

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1998 to 2019. The monitoring effort has been consistent over the years, with the exception of a few years when more surveys were conducted (Figure 2A).

The point intercept transect was the only method used to monitor coral reefs and it did not change over the years (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: "Abiotic", "Hard living coral cover", "Hard bleached coral", "Hard dead coral", "Algae", "Other fauna" and "Seagrass". Some of these groups are further divided into subgroups, such as the group "Other fauna", which encompasses the subgroups "Alcyonacea", "Porifera" and "Tunicata" in addition to "Other subgroups" (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with more than 98% of identifications made at the subgroup level or above. The resolution even increased over the three time periods, as the proportion of observations recorded to the genus level increased from 60% in 1979-1999 to 71% in 2010-2019 (Figure 2D).

The 3 algae subgroups ("Coralline algae", "Macroalgae" and "Turf algae") are represented. Algae were identified to at least the subgroup level for 98% of the observations (Figure 2E).

The 4 "Other fauna" subgroups ("Alcyonacea", "Porifera", "Tunicata" and "Other subgroups") are represented. The observations for benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

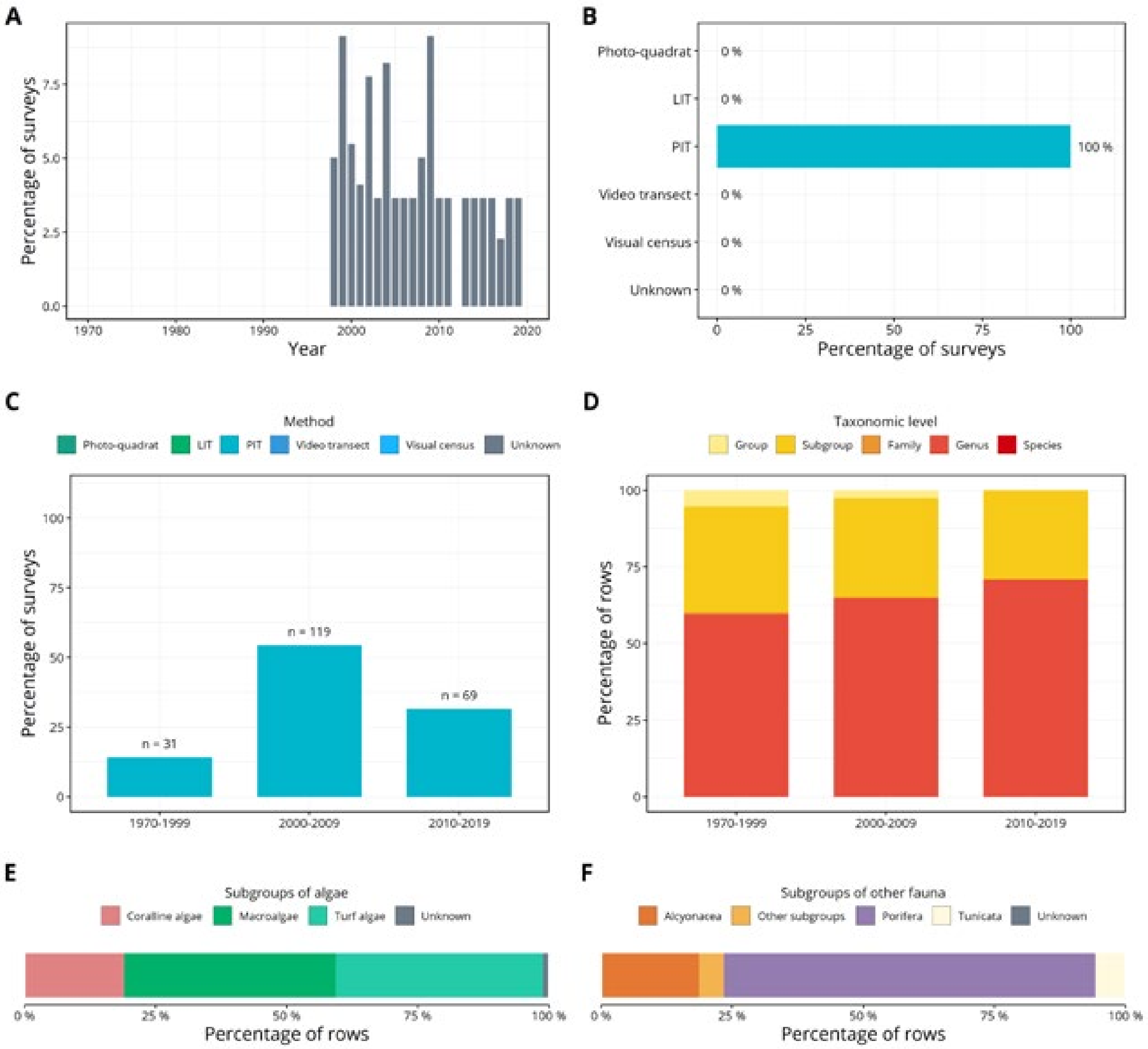

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. Monitoring is lacking in numerous areas rich in coral reefs. To increase the spatial coverage of monitoring programs to include the entire archipelago, we recommend that additional monitoring sites be established on the south-eastern tip of New Guinea, as well as around the islands of Bougainville, Manus and New Ireland.

Temporal Extent. The temporal extent of some of the monitoring sites recorded in the database is greater than 15 years, representing a valuable record on coral reef trends, which should be continued in conjunction with the establishment of new long-term monitoring sites.

Methodology. Point intercept transects were systematically used. Although this method provides relevant data, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in the taxonomic composition of benthic communities.

Taxonomic resolution. Nearly all of the benthic organisms were identified to the subgroup level or above, which enables changes in benthic composition to be characterised through time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 58 sites around Papua New Guinea for 21 different years between 1998 and 2019. However, the spatial coverage of the data contributed to the database is not sufficient for us to consider this indicator available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observation regarding the other benthic groups is sufficient for this indicator to be considered in use in Papua New Guinea. However, the spatial coverage of the data provided is too limited for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

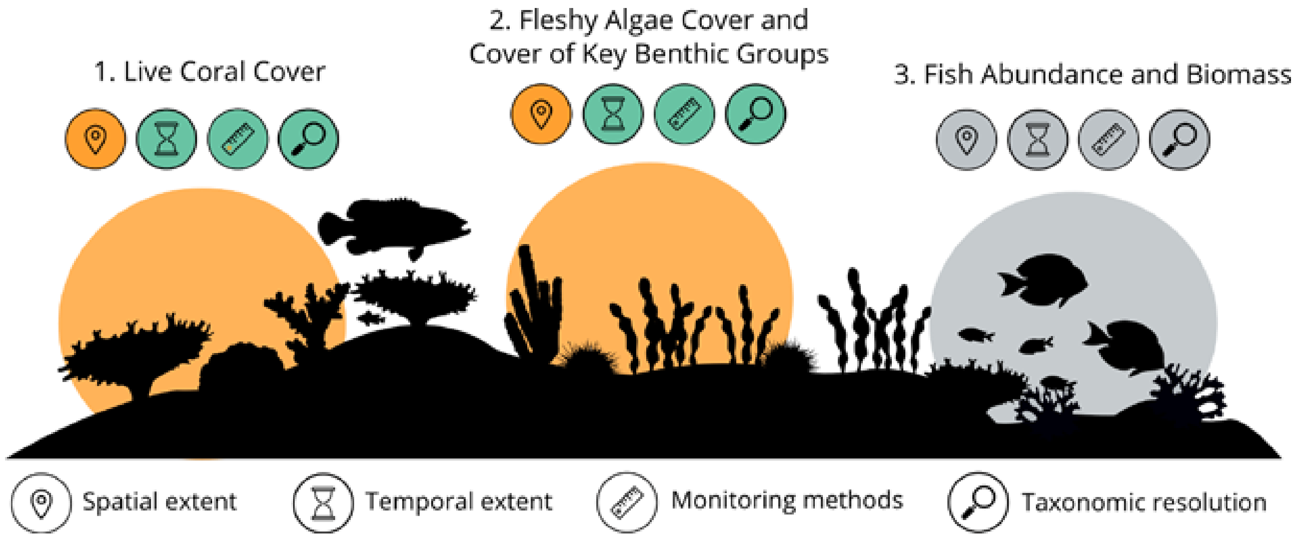

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Based on the data contributed to the 2020 GCRMN database, we can assume that the indicators "Live Coral Cover" and "Fleshy Algae Cover and Cover of Key Benthic Groups" are monitored in Papua New Guinea. However, the limited spatial extent of the monitoring effort recorded in the database, compared to the repartition of coral reefs at the country level, does not allow us to consider that these indicators are available at the country level. This might be addressed by implementing new monitoring sites around the archipelago.

3.3 Main contacts

A coral reef monitoring focal point for Papua New Guinea has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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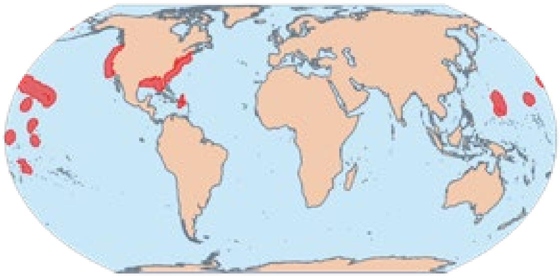

UNITED STATES OF AMERICA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 7,128 km²

Proportion of the world's coral reefs: 2.705%

Ranking based on reef area: 6th

Coral reefs in the United States are scattered between several overseas territories. American coral reefs are found in the Atlantic, Caribbean, and Gulf of Mexico, as well as in the Pacific. The American coral reef jurisdictions encompass American Samoa, Florida, the Flower Garden Banks, Guam, Puerto Rico, Hawaii and the Northwest Hawaiian Islands, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands, as well as the Pacific Remote Island Areas (Baker, Howland, and Jarvis Island; Johnston, Wake, and Palmyra Atoll; and Kingman Reef).

Coral reefs in the USA are highly diverse and some sites are recognised worldwide for their extraordinary biodiversity. In terms of specific diversity, the American reefs host 443 species of hard corals (IUCN, 2021) and are home to 1,766 fish species (Froese & Pauly, 2020). All major types of reefs, such as fringing reefs, barrier reefs, patch reefs and banks, as well as atolls, are represented through the different American coral reef jurisdictions (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

The different American coral reef jurisdictions are characterized by different levels of economic development and urbanization. However, coral reefs provide valuable ecosystem services to each of these territories. Coral reefs generate huge income through tourism. In 2002, the United States National Oceanic and Atmospheric Administration (NOAA) estimated that 45 million people visited coastal areas with coral reefs, generating an estimated US$17.5 billion (NOAA, 2002), which represented 1.6% of the GDP in 2002, and employed over 345,000 people in 2015 (Abt Project Team & NOAA, 2019). The U.S. reefs are a major destination for snorkellers, divers, recreational fishers and other sea users. Coastal fisheries related to coral reefs generate income that is one order of magnitude lower than tourism as they represent hundreds of millions of dollars per year. Coral reefs are all the more important as more than 50% of federally managed fisheries interact with coral reefs for at least a part of their life cycle (NOAA, 2002). Coral reefs also play an important role in protecting the coasts from storms and flooding, saving 18,000 lives per year. The annual value of coastal protection by coral reefs against flood risk was estimated at US$1.8 billion (Storlazzi et al., 2019), which represented 0.01% of the country's GDP in 2019.

Coral reefs in the different jurisdictions face different threats since the dynamics vary between regions. However, all coral reefs face threats related to climate change, which is responsible for increasing sea temperatures which lead to bleaching, coral diseases, and increased frequency and intensity of tropical storms and hurricanes. The fast development of coastal areas, when poorly managed, may lead to increased sediment and nutrient runoff that negatively affect coral reefs. Overfishing and unsustainable fishing practices also represent a threat to coral reefs (Wilkinson, 2008).

Marine protected areas in the United States span 3.4 million km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 5,293 km² of coral reefs within their boundaries, thus placing 74.3% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the different American coral reef jurisdictions, with data from a total of 4,790 sites included within the GCRMN dataset. These observations represent 46% of the total global dataset compiled by the GCRMN (982,066 rows).

While sites from which data were provided occur in all of the jurisdictions, data included in this GCRMN report were mostly from a single survey mission, with the exception of some longer-term monitoring programs. Time series data are available in this GCRMN report for some jurisdictions, like the Southeast coast of the continental U.S. and American Samoa (Figure 1).

Data contributed to the database spans the period from 1990 to 2019. The increase in monitoring effort has not been regular over the years. Very few sites were surveyed on an annual basis before 1996, and the monitoring effort slightly increased until 2012. A second increase in the number of sites surveyed occurred in 2013[1] (Figure 2A).

The majority (70%) of surveys contributed to the 2020 GCRMN database were conducted using photo-quadrats, followed by video-transects (20%) and point intercept transects (9%). The methodology was labelled as “Unknown” for 1% of the surveys contributed to the database (Figure 2B).

There has been a shift from the use of video-transects towards the use of photo-quadrats over the three time periods. During the 1970-1999 period, the video transect method was the main method used to survey the sites (415 surveys) and it has been used through all time periods (1,234 surveys between 2010 and 2019). However, the use of photo-quadrats began during the 2000-2009 period and greatly increased in the 2010-2019 period to become the most frequently used method (7,050 surveys between 2010 and 2019). During the 2010-2019 period, point intercept transects (PIT) were also used in 1,037 surveys to monitor reefs (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with more than 98% of identifications made at the subgroup level or above. The proportion of identifications made at the subgroup level or above increased from over 80% to almost 100% over the three time periods. Identifications at the genus level became more common and represent around 23% of the observations since the 2000-2009 period. However, while the proportion of identifications at the genus level increased, the proportion of identifications made at the species level decreased from over 35% to 16% over the three time periods (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 99% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata”, and “Other subgroups”) are represented. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 89% of the observations (Figure 2F).

1 This corresponds to the formal creation of NOAA’s National Coral Reef Monitoring Program (NCRMP). Since 2013, the monitoring effort through NCRMP has been consistent, although the global COVID-19 pandemic reduced the amount of surveying that occurred in 2020.

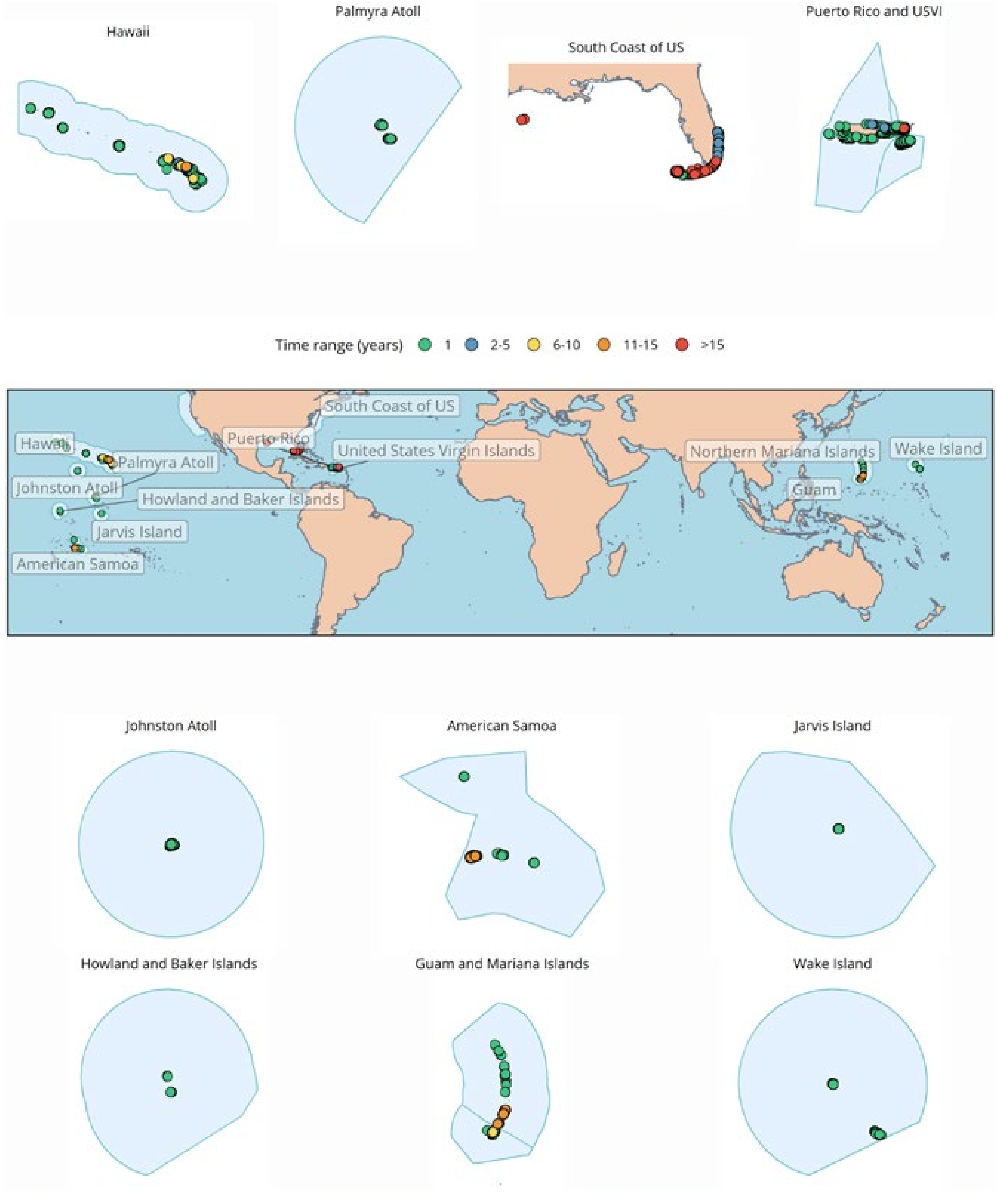

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

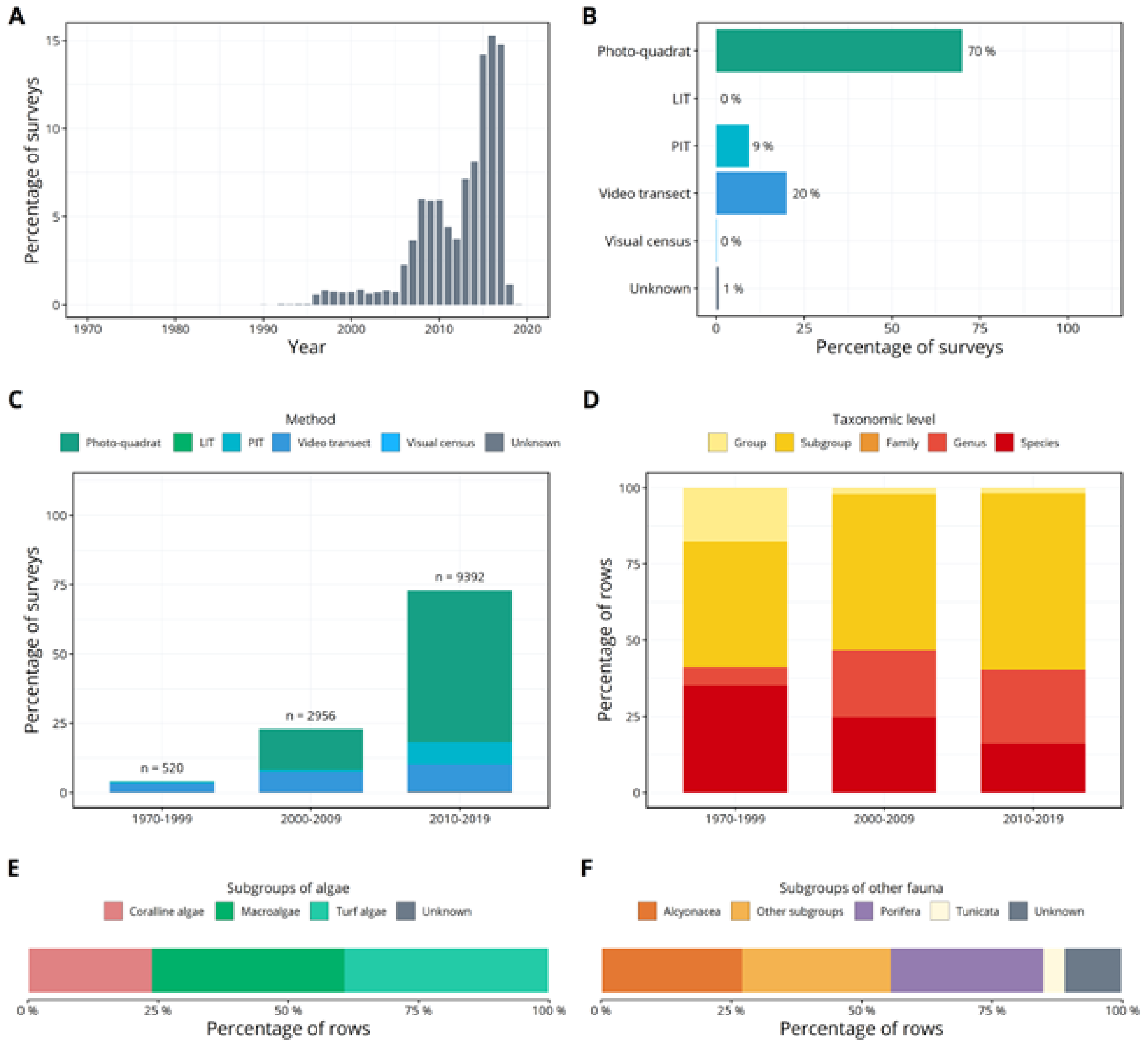

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is well spread across the U.S. jurisdictions. Such efforts are highly valuable and should be continued.

Temporal Extent. Most of the sites provided were surveyed for only one year and some jurisdictions do not have fixed monitoring sites. Unfortunately, in some cases, such as in Palmyra atoll, the data were not provided to the GCRMN and therefore are absent from the analysis, even though long-term monitoring data is available.

Methodology. The vast majority of data provided were collected using photo-quadrats. The use of image-based methods is valuable, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the data provided have a level of taxonomic precision at the subgroup level or above, which is sufficient to assess changes in benthic composition over time. Different subgroups belonging to the groups “Algae” and “Other fauna” were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 4,790 sites around the different American jurisdictions for 29 different years between 1990 and 2019. Further, all requirements are met for the indicator “Live Coral Cover” to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observation regarding algae and the other benthic groups is sufficient for this indicator to be considered as measured. Further, all requirements are met for the indicator “Fleshy Algae Cover and Cover of Key Benthic Groups” to be considered in use and available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

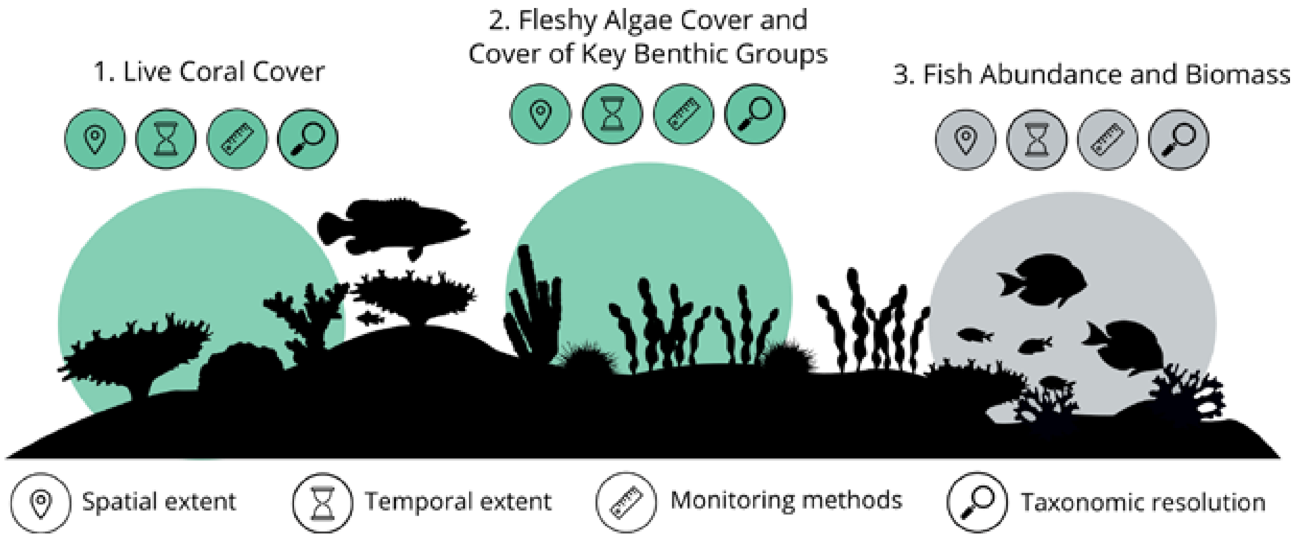

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators “Live Coral Cover” as well as “Fleshy Algae Cover and Cover of Key Benthic Groups” presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in the United States of America, please contact the focal points, whose contact details are available in the following table.

Name	Contact	Organisation
Erica Towle	erica.towle@noaa.gov	NOAA Coral Reef Conservation
Jennifer Koss	jennifer.koss@noaa.gov	NOAA Coral Reef Conservation

This summary has been reviewed by the focal points.

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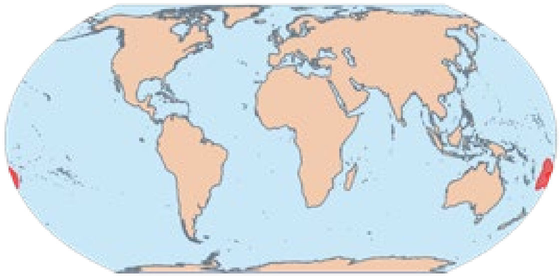
FIJI



1. Introduction – General context

CORAL REEF CARD

Estimated area: 7,053 km²

Proportion of the world's coral reefs: 2.677%

Ranking based on reef area: 7th

Fiji is an archipelagic nation made up of more than 800 islands and islets located in the middle of the Pacific Ocean. Out of the 332 islands, 150 are inhabited.

The Fijian waters are home to 416 species of hard corals (IUCN, 2021) and 925 species of reef fishes (Froese & Pauly, 2020). Coral reefs around Fiji form various different types of reefs, including fringing reefs, barrier reefs, platform reefs, oceanic ribbon reefs, atolls and near-atolls (Sykes & Morris, 2009).

Fiji's coral reef ecosystem is the most extensive in the South Pacific and provides fisheries and tourism opportunities that are primary GDP earners. They are an integral part of the well-being, culture, and livelihoods of Fijian communities (Gonzales et al., 2015). Like other countries that are highly dependent on tourism, tourism is the largest generator of overseas income in the country. In 2006, the income generated by tourism represented 23% of Fiji's GDP (United Nations - ESCAP, 2010). In 2007, the tourism industry was estimated to provide jobs to 40,000 people (Harrison & Prasad, 2013). In 2017, reef-tourism in Fiji represented 5.9% of the GDP (Spalding et al., 2017). Fiji's reef systems are also highly important for the large proportion of the population that depend on them for subsistence or for small-scale commercial fishing. The value of subsistence fisheries has been estimated at US$29.6 million per year (0.6% of Fiji's GDP in 2014), while the value of small-scale inshore artisanal fishing has been estimated between US$7.3 and US$26.9 million per year (Gonzales et al., 2015), which accounted for 0.2-0.6% of the country's GDP in 2014. Fisheries also represent an important source of employment, with 3,300 people working in in the fisheries sector in 2016 (FAO, 2017). The annual value of coastal protection provided by Fiji's coral reefs and their associated ecosystems was estimated to be between US$6.4 to US$10.6 million per year (Gonzales et al., 2015), which represented 0.1-0.2% of their GDP in 2014.

Coral reefs in Fiji face several threats at the local and global levels. The primary threat is global warming, that leads to the bleaching of coral reefs. These reefs are also under anthropogenic pressures which threaten reefs at the local scale, such as increasing coastal development, watershed-based pollution and sedimentation, in particular due to mining and vegetation clearance for agriculture and forestry, overfishing as a result of higher population density and use of destructive fishing techniques, and threats from over-harvesting of corals[1] and marine fish for the marine aquarium trade (Fiji Government, 2020).

Marine protected areas in Fiji span 12,300 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 2,226 km² of coral reefs within their boundaries, thus placing 31.6% of the country's coral reefs under protection.

1 The export of corals has been banned since 2020 under the Customs (Prohibited imports and exports) Regulations 1986.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides a limited coverage of the coral reefs around Fiji, with data from a total of 249 sites included within the GCRMN dataset. These observations represent 0.4% of the total global dataset compiled by the GCRMN (9,221 rows).

Sites from which data were provided occur mainly around the two main islands of Viti Levu and Vanua Levu, with little monitoring recorded in the rest of the archipelago. Some sites were surveyed for more than 10 years, and provide a time series for analysis (Figure 1).

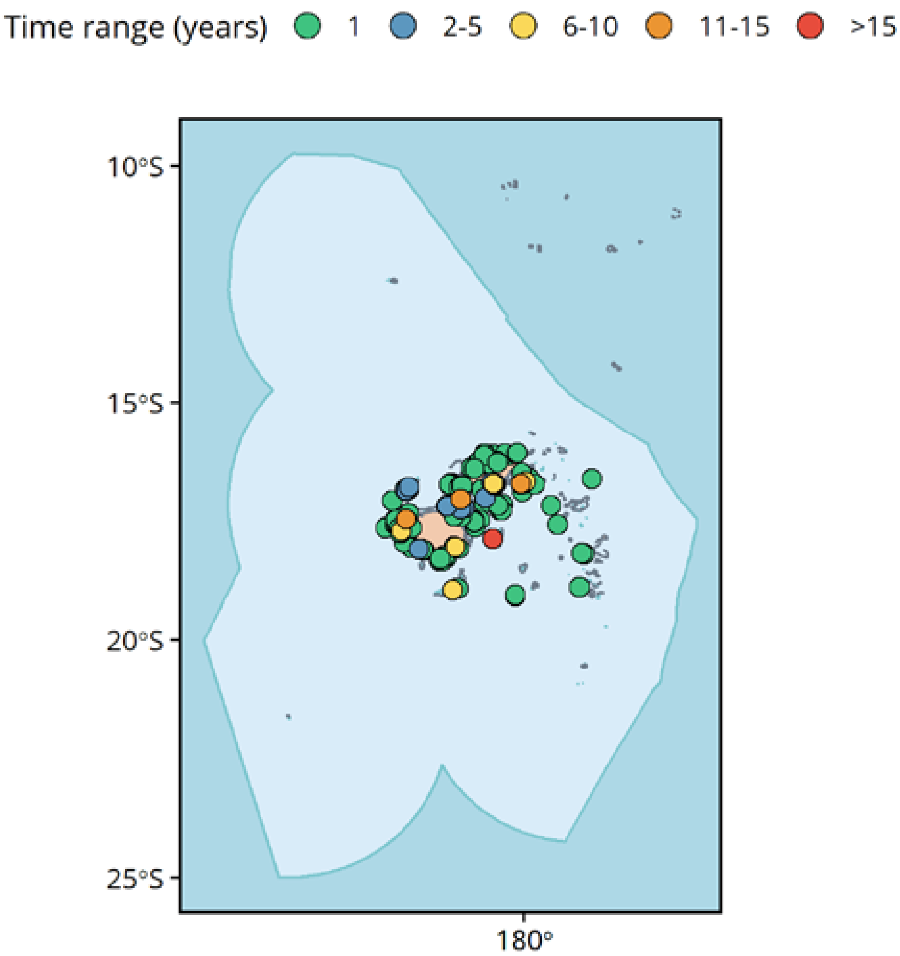


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1998 to 2019. Since 1998, the number of sites monitored each year has fluctuated greatly. No to almost none monitoring effort was recorded in the database between 2012 and 2015, while some years were characterized by a very high monitoring effort, such as 2004 (Figure 2A).

The majority (89%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects. Unfortunately, the method used was not recorded for 11% of surveys. (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: "Abiotic", "Hard living coral cover", "Hard bleached coral", "Hard dead coral", "Algae", "Other fauna" and "Seagrass". Some of these groups are further divided into subgroups, such as the group "Other fauna", which encompasses the subgroups "Alcyonacea", "Porifera" and "Tunicata" in addition to "Other subgroups" (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, with almost 70 % of identifications made at the subgroup level or above. The proportion of identifications made to the subgroup level increased from around 64% to 69% over the 3 time periods. The proportion of identifications conducted to the genus level is negligible (Figure 2D).

The 3 "Algae" subgroups ("Coralline algae", "Macroalgae" and "Turf algae") are represented. Algae were identified to at least the subgroup level for 15% of the observations (Figure 2E).

Organisms belonging to 2 out the 4 "Other fauna" subgroups ("Alcyonacea", "Porifera", "Tunicata" and "Other subgroups") are represented in the database. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 99% of the observations (Figure 2F).

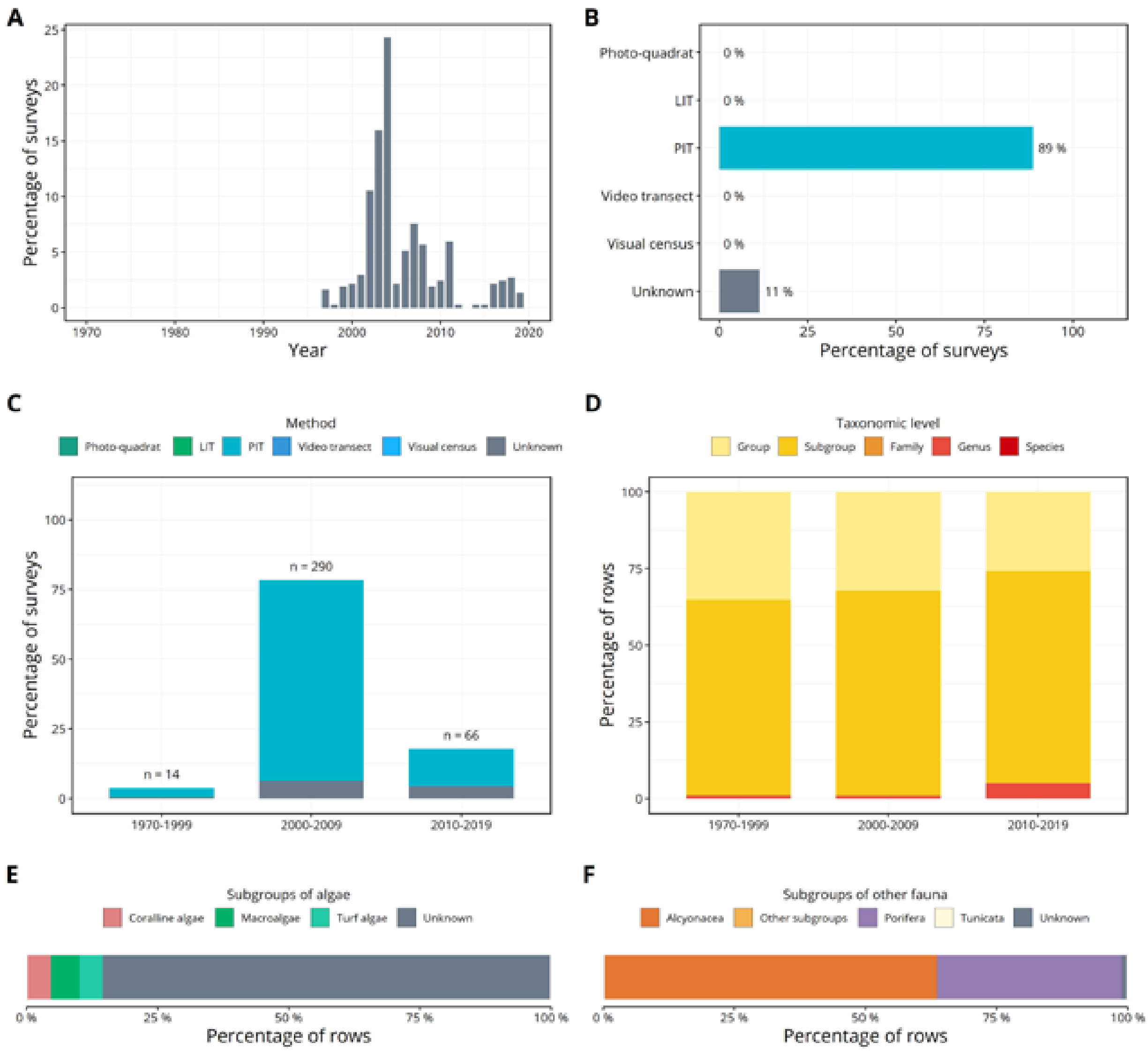


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already good, especially around Viti Levu and Vanua Levu, the two main islands. To further increase the spatial coverage of the monitoring, we recommend that additional monitoring sites be established outside the main islands to better include the Mamanuca's, Malolos and the Lau Groups.

Temporal Extent. The temporal extent of some monitoring sites is greater than 10 years, representing a valuable record for trends in coral reefs, which should be continued.

Methodology. While the majority of sites were surveyed using point intercept transects, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the available data have a level of taxonomic precision at the subgroup or above, which is enough to assess changes in benthic composition through time. However, 85% of "Algae" observations have only been identified to the group level, which is not sufficient. Thus, we recommend that the precision of the identifications be improved to at least to the subgroup level. Further, the subgroups "Other groups" and "Tunicata" belonging to the group "Other fauna" are not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were only recorded to the group level, or because they were not included in monitoring protocols. If the last two cases were to be true, it would be recommended that they be included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level has been evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator has been monitored on 249 sites located around Fiji, with data available for 21 different years from 1998 to 2019. Thus, this indicator can be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** While the other requirements are met, the taxonomic precision of the identification of benthic organisms belonging to the subgroups of "Algae" and "Other fauna" is not sufficient for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

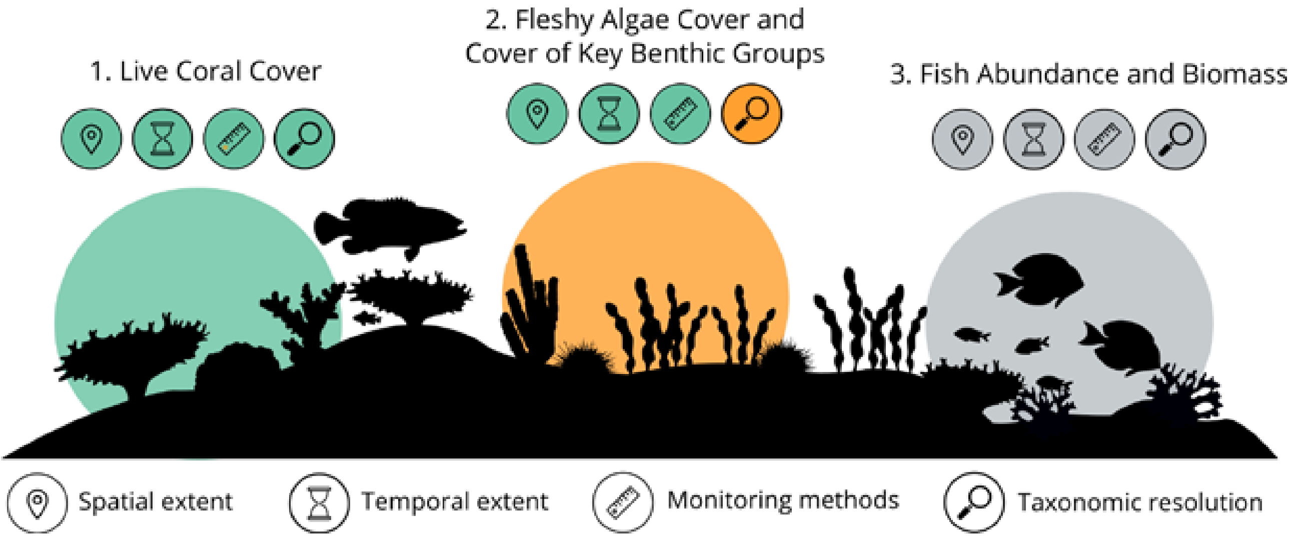


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

To conclude, the ICRI recommended coral reef indicator "Live Coral Cover" presented in Figure 3 is measured and is available on request for most of the existing datasets identified at the country level, while the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is not yet available. However, this indicator could quickly become available, provided that identifications of algae and organisms that are part of the key benthic groups are better included in future monitoring protocols.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Fiji, please contact the focal points, whose contact details are available in the following table.

Name	Contact	Organisation
Joshua Wycliffe	joshua.wycliffe@govnet.gov.fj	Permanent Secretary for Ministry of Environment
Sandeep K. Singh	singhsk@govnet.gov.fj doenvfiji@gmail.com	Director of Environment, Ministry of Environment

This summary has been reviewed by the focal points.

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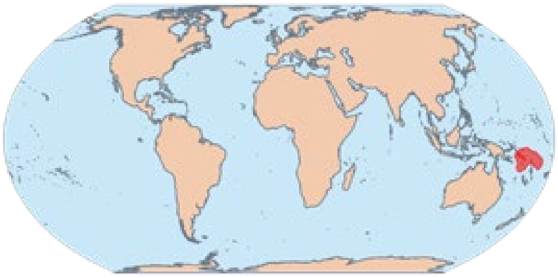

SOLOMON ISLANDS

1. Introduction – General context

CORAL REEF CARD

Estimated area: 6,918 km²

Proportion of the world's coral reefs: 2.625%

Ranking based on reef area: 8th

The Solomon Islands are located in the Pacific Ocean and are part of a huge arc of islands that delimit the northeast boundary of the Coral Sea. The nation is made up of 992 islands, islets and atolls. The islands are mainly of volcanic origin, as the islands are located along the Western margin of the Pacific plate.

Located in the Coral Triangle, the Solomon Islands are home to some of the most biodiverse coral reef systems in the world. Around 510 species of hard corals (IUCN, 2021) and 778 species of reef fishes inhabit its coral reefs (Froese & Pauly, 2020). Coral reefs can be found forming fringing reefs around the main volcanic islands but they also form barrier, patch and lagoon reefs. Coral-raised islands and atolls, though relatively uncommon, can also be found within the Solomon Islands (Sulu, Hay, Ramohia, & Lam, 2003).

Solomon Islanders rely heavily on nearshore coral reefs for their livelihoods. Subsistence fisheries provide households with up to 92% of their protein intake (Hoegh-Guldberg et al., 2016) and also provide income and employment for many islanders. In 2009, coastal artisanal fisheries employed around 30,000 people and represented 6.8% of the country's GDP (Gillett, 2009). Tourism in the Solomon Islands is rather limited compared to other Pacific Island countries. It represented 10.5% of the country's GDP in 2019, which amounts to US$132.8 million, sustaining around 30,500 jobs (World Travel & Tourism Council, 2020). Tourism is highly dependent on healthy coral reefs, as they actively attract tourists. More than 50% of tourists come for snorkeling, and around 30% come for diving (Acorn Tourism Consulting Ltd, 2014; Development Bank, 2014). Coastal protection against storms and erosion is another valuable ecosystem service provided by coral reefs. A community-based case study estimated the value of the coastal protection service from US$18,000 to US$270,000 per km² of reef per year, by using the cost of replacing shoreline protection as a proxy (Albert, Trinidad, Boso, & Schwarz, 2012).

Coral reefs in the Solomon Islands are mainly threatened by overfishing and destructive fishing practices. Land reclamation has also started to become a problem as the population continues to grow, leading to pollution issues (Development Bank, 2014).

In order to protect coral reefs, a network of 50 MPA zones was established, covering approximately 1,300 km². Out of the 50 MPA zones, 27 include coral reefs within their boundaries.

Marine protected areas in the Solomon Islands span 1,300 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 365 km² of coral reefs within their boundaries, thus placing 5.3% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides an incomplete coverage of the coral reefs around the Solomon Islands, with data from a total of 111 sites included within the GCRMN dataset. These observations represent 1% of the total global dataset compiled by the GCRMN (21,097 rows).

Sites from which data were provided are found mainly around New Georgia Islands, between Choiseul and Santa Isabel and on the remote Temotu archipelago. The sites were surveyed for 1 to 10 years at most (Figure 1).

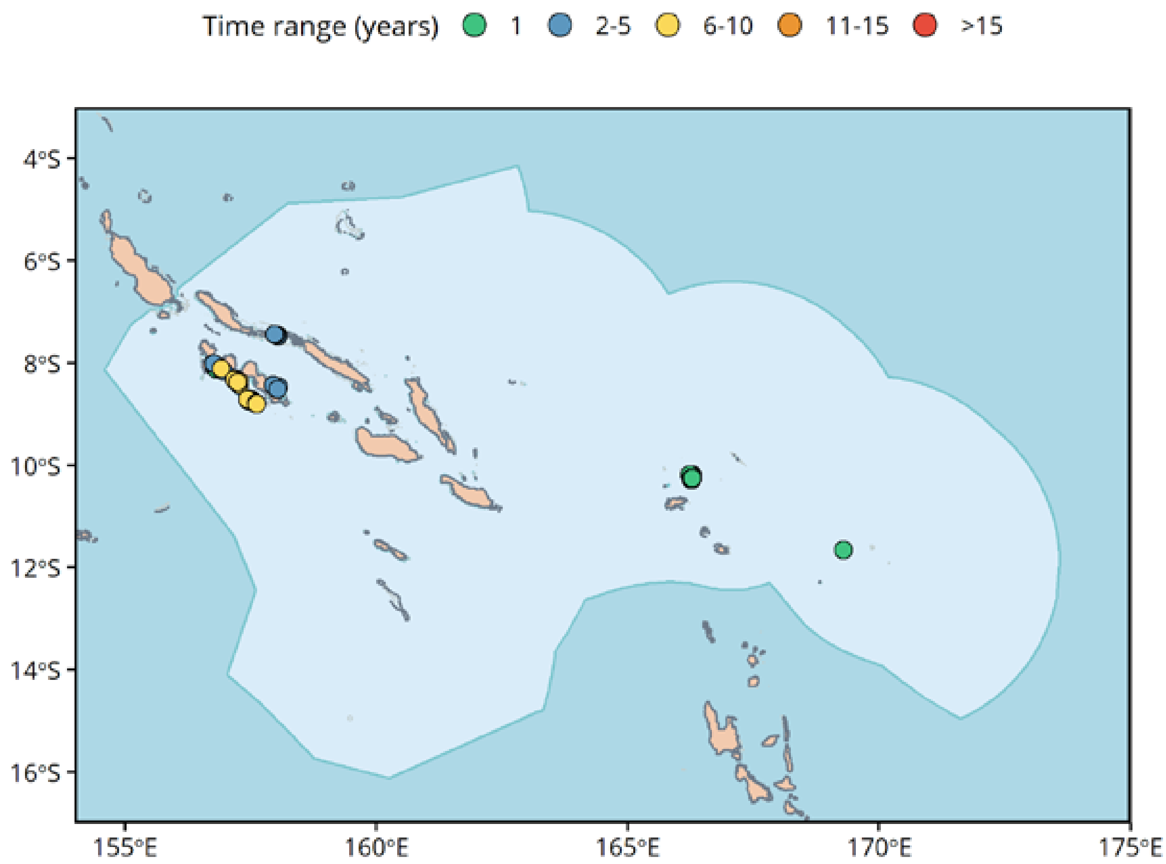

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2004 to 2013. The monitoring effort has been heterogeneous over the years (Figure 2A).

The method used is mainly unknown, as it is not available in the database for 93% of the surveys. Point intercept transects were used for 33% of the surveys, and photo-quadrats were used for 5% of the remaining surveys (Figure 2B).

The point intercept transect method was the main method used during the 2000-2009 period. During this period, photo-quadrats were used in 12 surveys but did not remain in use during the next period. Between 2010 and 2019, 42 out of the 106 surveys were conducted using the point intercept transect method (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with 85% of identifications made at the subgroup level or above. The taxonomic resolution was also very consistent over the two time periods. Although most of the observations were recorded at the subgroup level, identifications at the genus level represented almost 25% of the observations (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 64% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 99.5% of the observations (Figure 2F).

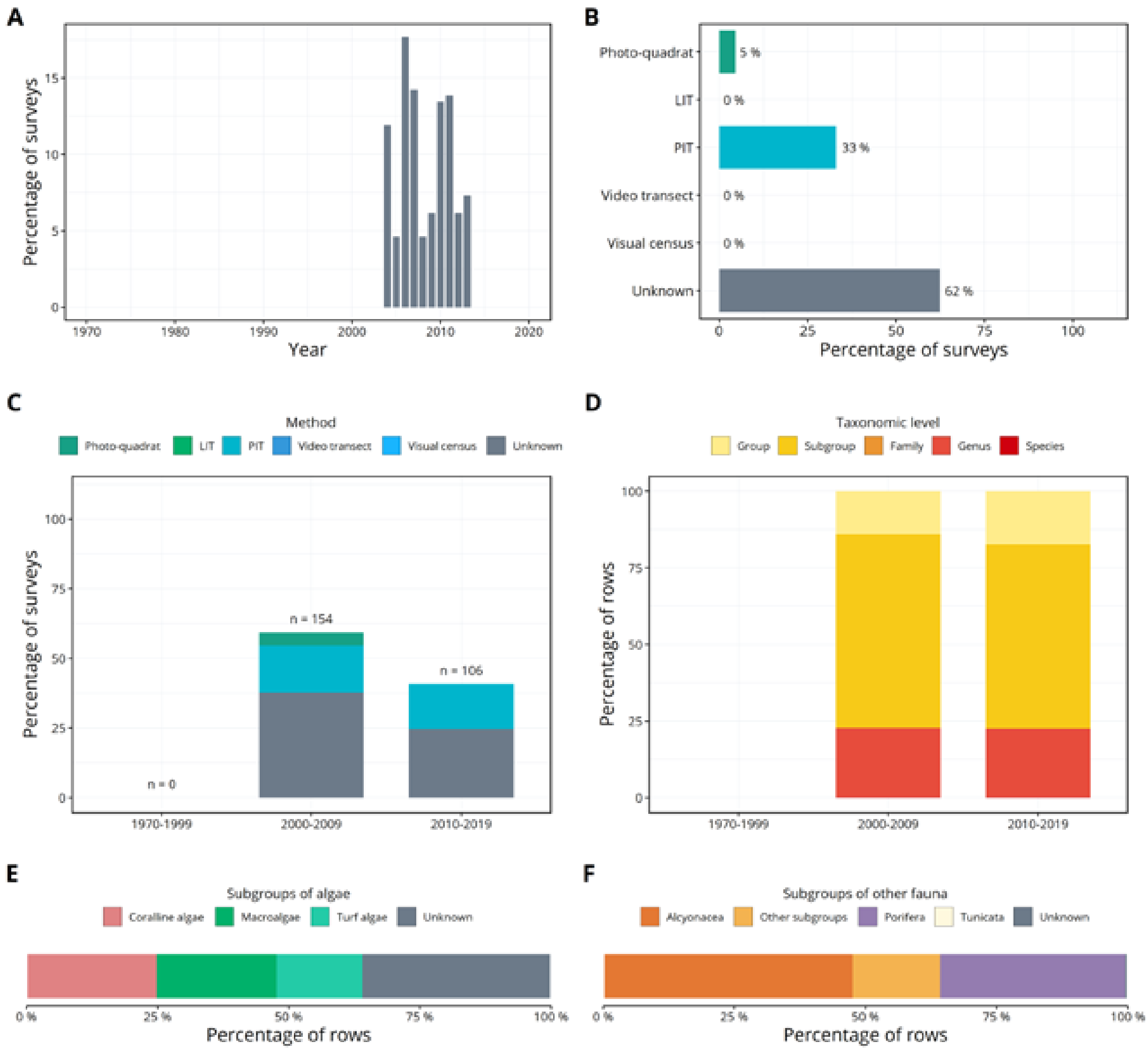

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of monitoring programs in the Solomon Islands is not representative enough of the coral cover around the archipelago. In order to increase the spatial extent of the monitoring, we recommend that additional monitoring sites be established around the islands of the Central Islands Province.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 6 years, representing a valuable medium-term record for trends in coral reefs. Such efforts are valuable and should be continued.

Methodology. The methods used are unknown for most surveys and photo-quadrats were used for only 5% of the surveys. We recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. More than 80% of the identifications of benthic organism were made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. This level of precision when identifying benthic organisms is highly valuable and should be pursued. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, the subgroup "Tunicata" belonging to the group "Other fauna" is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level, or because they were not included in monitoring protocols. If the last two cases were to be true, we recommend that better identification of these organisms be included in future monitoring protocols, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator has been monitored on 111 sites throughout the Solomon Islands, with data available every year from 2004 to 2013. The spatial coverage of the monitoring, for which most sites are located in the Western Province, is not yet enough to consider that this indicator is available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered measured. However, the spatial extent of the monitoring is not sufficient for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

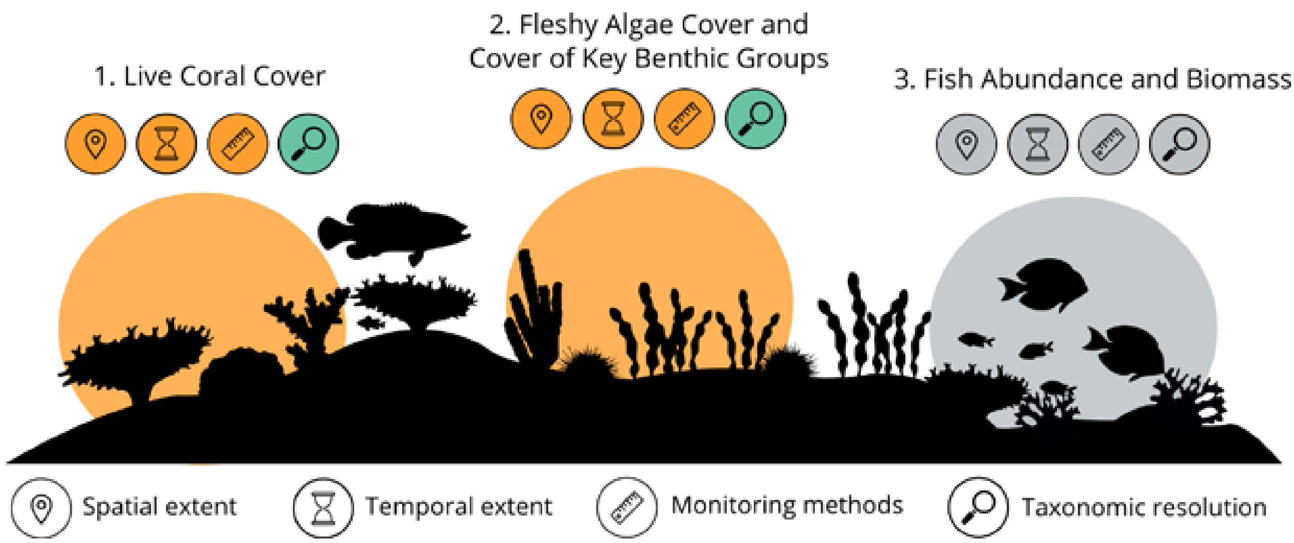

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, two of the four ICRI recommended coral reef indicators presented in Figure 3 are measured but are not yet implemented widely enough to be considered available at the country level. The spatial extent of the monitoring should include the other provinces of the archipelago in order for the monitoring to be representative of the state of the coral reefs at the country level.

3.3 Main contacts

A coral reef monitoring focal point for the Solomon Islands has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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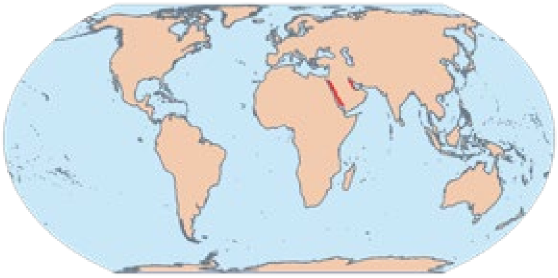

SAUDI ARABIA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 5,927 km²

Proportion of the world's coral reefs: 2.249%

Ranking based on reef area: 9th

Saudi Arabia is bordered by the Red Sea and the Gulf of Aden to the West and by the ROPME area to the East. Coral reefs are known to thrive in both marine areas, even though they are subjected to high salinity levels and extreme temperature variations compared to other coral reefs.

There are 331 species of hard corals (IUCN, 2021) and 509 species of reef fishes that are known to inhabit the Saudi reefs (Froese & Pauly, 2020). Coral reef formations around Saudi Arabia differ depending on their location. While patch reefs, extensive fringing reefs and barrier reefs, such as the Bank, can be found in the Red Sea (Devantier, Turak, Al-Shaikh, & De'ath, 2000), the ROPME area is characterized by abundant coral communities but relatively little extensive coral reef formations. Instead, they form small fringing reefs, coral carpets (or biostromes), patch reefs and stringer reefs (Riegl & Purkis, 2011).

Coral reefs provide numerous ecosystem services to the country, by sustaining fisheries and promoting tourism in the region and by protecting the shoreline and mitigating coastal erosion. Coral reefs play a great role in enhancing tourism in Saudi Arabia as the country is trying to diversify its economy. Tourism and travel in Saudi Arabia represented 9.5% of the country's GDP in 2019, generating US$71.1 billion (World Travel & Tourism Council, 2020). In order to further increase tourism, the Red Sea Project, which is a US$2.7 billion project, aims at building high-end resorts across a lagoon with 50 untouched islands (Albara'a Alwazir, 2019). Tourism in the Gulf is not as developed as in the Red Sea and is based less on the attractiveness of coral reefs and more on coastal features that have been modified for economic and touristic purposes (Gladstone, Curley, & Shokri, 2013). Coral reefs also sustain Saudi fisheries. With 7,611 and 1,825 artisanal fishers in the Red Sea and in the ROPME area, respectively, verses 149 and 34 industrial fishers, the large majority of the fleet is comprised of artisanal fishers. They mainly fish in shallow coastal waters and their catch directly contributes to food security, in addition to providing more than 20,000 jobs (FAO, 2000). Though the benefits of shoreline protection have yet to be formally quantified, the presence of reefs has been proven to protect the coasts of Saudi Arabia against waves, which might even represent a bigger threat than sea level rise if the reefs were to disappear (Langodan et al., 2020).

Coral reef cover and their associated dynamics vary greatly between the Red Sea and the ROPME area. The Red Sea coast is less urbanized than the Eastern Coast of Saudi Arabia, which has been greatly impacted by oil production and land reclamation, causing damage to coral reefs and coastal ecosystems. Apart from the deleterious effects of climate change, land reclamation, dredging and coastal urbanization are among the greatest threats to the Saudi coral reefs.

Marine protected areas in Saudi Arabia span 15,500 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 688 km² of coral reefs within their boundaries, thus placing 11.6% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the Saudi Red Sea coast, with data from a total of 106 sites included within the GCRMN dataset. These observations represent 0.2% of the total global dataset compiled by the GCRMN (4,279 rows).

Sites from which data were provided occur mainly on the western coast of Saudi Arabia. There are no records of monitoring for the Persian Gulf in the database. Sites tend to have been surveyed only once (Figure 1).

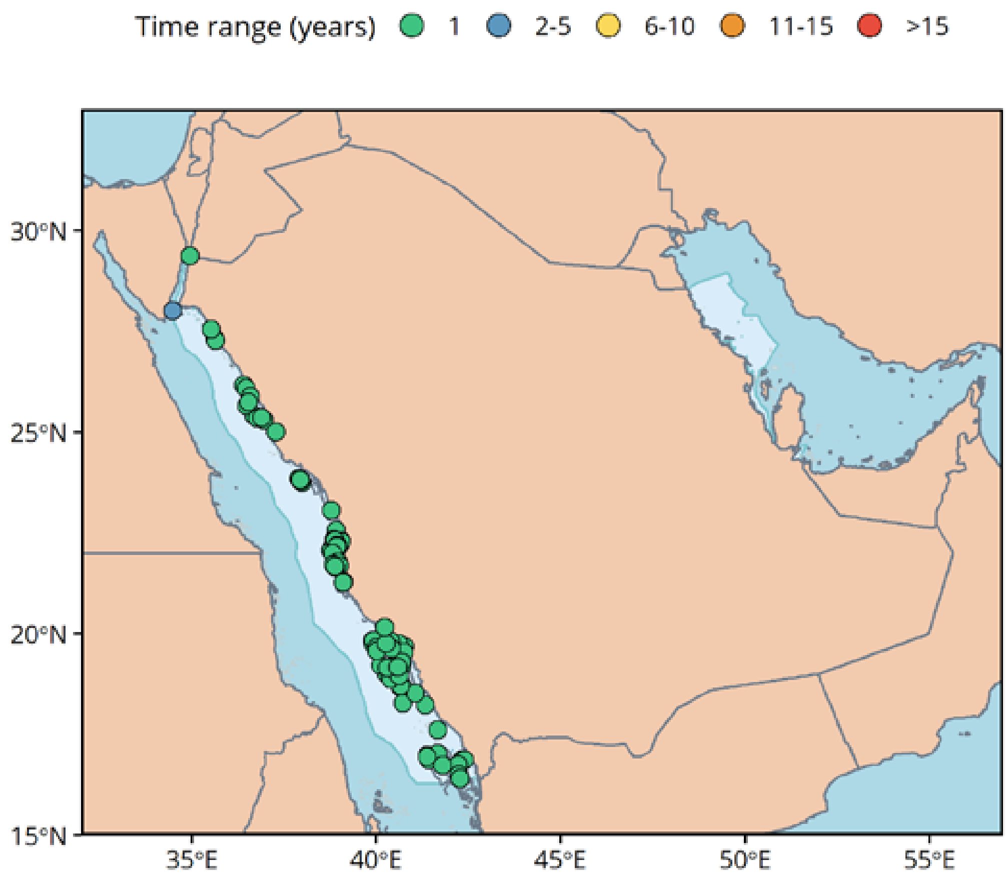

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1997 to 2018. The monitoring effort recorded in the database is not consistent over the years. The percentage of sites surveyed per year ranges from 0% for several years, to 35% in 2018 (Figure 2A).

The majority (66%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by line intercept transects (12%). The method is not specified in the database for 21% of the surveys (Figure 2B).

There was an improvement in the availability of the methods used. While the method is unknown for 20 out of the 30 surveys recorded between 2000 and 2009, the method is available for 77 out of the 81 surveys recorded between 2010 and 2019. Point intercept transects were used for 63 surveys and line intercept transects were used for 14 surveys between 2010 and 2019 (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with 77% of identifications made at the subgroup level or above. The precision at which identifications were made increased between the 2000-2009 and the 2010-2019 periods. Indeed, the proportion of observations identified to the group level only decreased from 31% to 21%, and 47% of observations were identified to the genus level (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 62% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

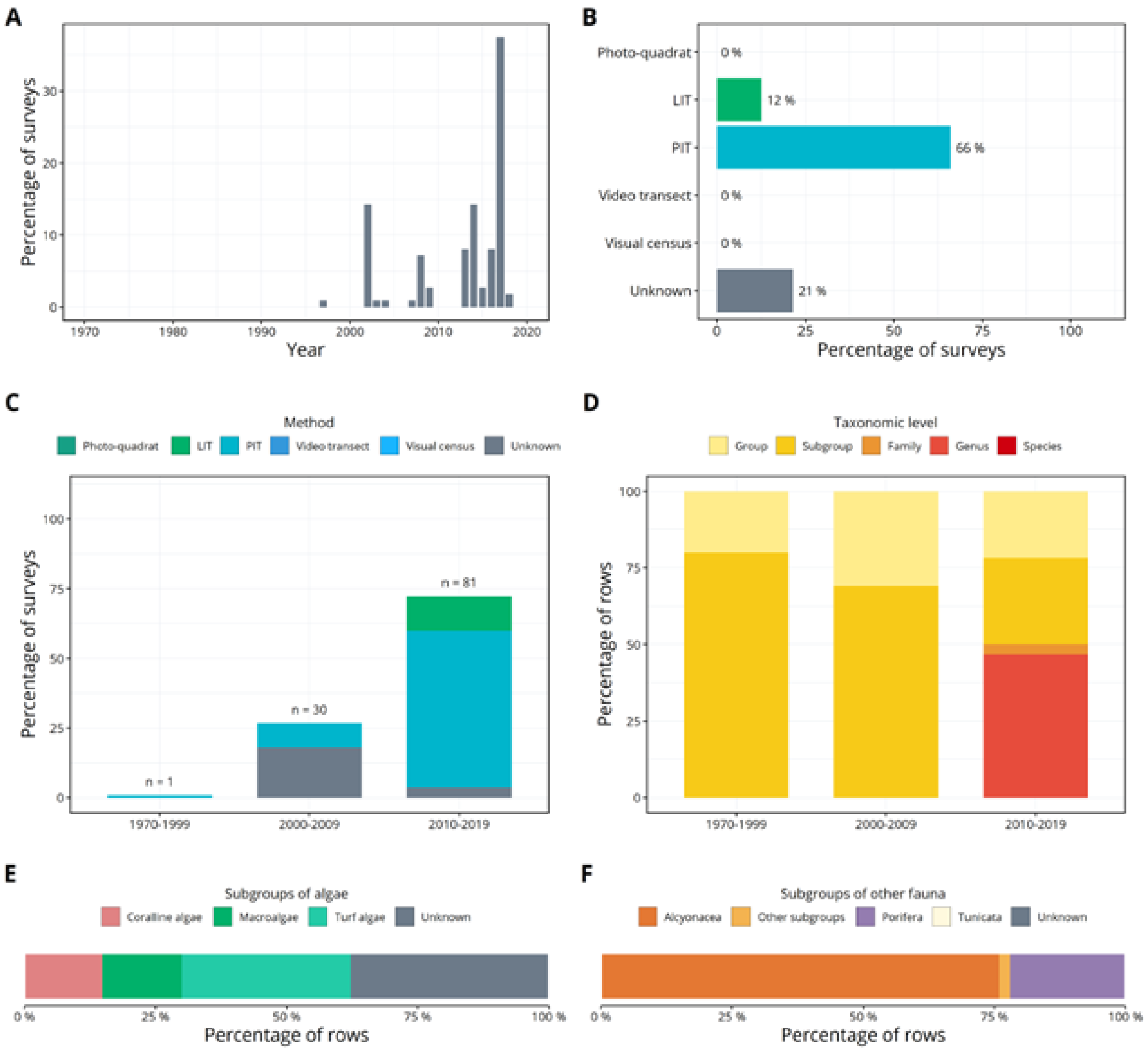

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring in the Red Sea is good. However, there are no records of monitoring in the Persian Gulf in the GCRMN database. Though the extent of coral reefs might be smaller than in the Red Sea, we recommend that additional monitoring sites be established on the coast bordering the Persian Gulf to further increase the spatial coverage of monitoring programs in Saudi Arabia.

Temporal Extent. Almost all of the sites were surveyed only once. Thus, we recommend that fixed monitoring sites be implemented in order to generate valuable long-term record for trends in coral reefs.

Methodology. Most of monitoring sites are based on the point intercept transect method, but, when implementing new monitoring sites, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the data provided have a level of taxonomic precision at the subgroup or genus levels, which is sufficient to assess changes in benthic composition over time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, 38% of algae observations were identified only to the group level. Further, the subgroup "Tunicata", belonging to the group "Other fauna", is not represented in the database. This might be due to the fact that these organisms were absent from the sites, or because they were not included in monitoring protocols. In the last case, we recommend that better identification of these organisms be included in the monitoring protocols, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 106 sites on the Red Sea coast, with data available for 13 different years from 2002 to 2018. Thus, all major criteria are met for the indicator "Live Coral Cover" to be considered in use and available at the country level. However, implementing additional fixed sites for monitoring would prove a valuable asset for the monitoring of coral reefs in Saudi Arabia.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered in use at the country level. However, better algae identifications should be included in the monitoring protocols, as 38% of "Algae" observations in the database were only identified up to the group level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

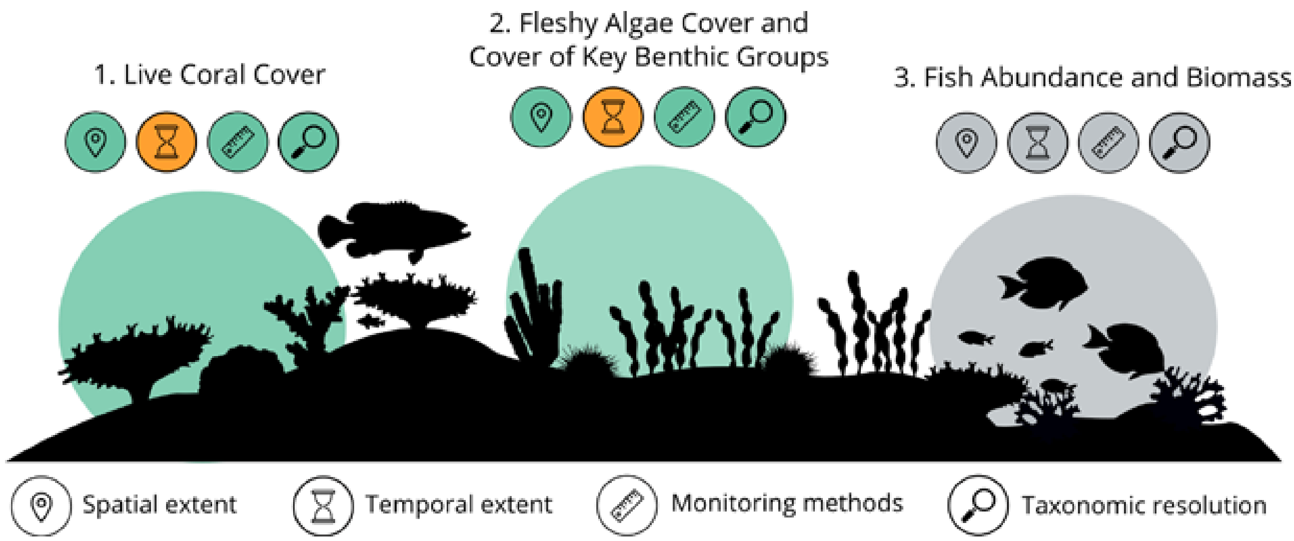

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

A coral reef monitoring focal point for Saudi Arabia has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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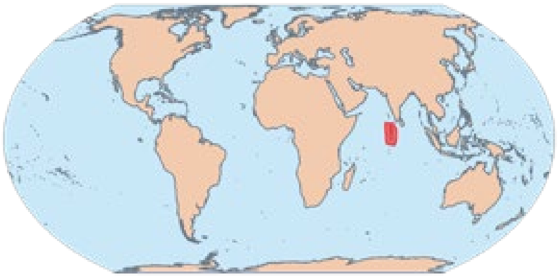
MALDIVES



1. Introduction – General context

CORAL REEF CARD

Estimated area: 5,331 km²

Proportion of the world's coral reefs: 2.023%

Ranking based on reef area: 10th

The Maldives is a nation comprised of 16 complex atolls, 5 oceanic faros and 4 oceanic platform reefs and approximately 1,190 islands, which makes it the largest group of coral reefs in the Indian Ocean. Of all of these islands, only 188 are inhabited.

Coral reefs in the Maldives host 248 species of hard corals (IUCN, 2021) and are home to 909 fish species (Froese & Pauly, 2020). Several types of coral reefs formations are found in the Maldives, including atolls, faros (ring-shaped atolls), oceanic platform reefs as well as lagoon patch reefs (Naseer & Hatcher, 2004).

Coral reefs are of great importance in the Maldives and the people depend mainly on biodiversity-based services for their livelihoods. The two main economic activities in the Maldives are tourism and fisheries. Tourism accounts for 149,100 jobs (World Travel & Tourism Council, 2021) and 17,589 people are involved in fisheries (FAO, 2019). Healthy coral reefs are extremely important for tourism, as reef tourism represented 43.17% of the country's GDP in 2017 (Spalding et al., 2017), while fisheries as a whole accounted for 5.1% of the country's GDP in 2013 (FAO, 2019). Coral reefs also provide essential shoreline protection services to this nation which is made up of low-lying coral islands, the value for which was evaluated using the replacement cost method. Depending on the replacement measure chosen, the shoreline protection value of coral reefs ranged between US$1.6 and US$2.7 billion (Emerton, Baig, & Saleem, 2009), which represented 68% and 115%, respectively, of the country's GDP at the time of the study's publication.

The Maldives is threatened at a local level by human activities, including reef reclamation, overfishing and pollution. However, global warming and the environmental threats it generates are the most concerning issues for the future of the nation (Ministry of Environment and Energy, 2015).

Marine protected areas in the Maldives span 625 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 236 km² of coral reefs within their boundaries, thus placing 4.4% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the Maldives, with data from a total of 228 sites included within the GCRMN dataset. These observations represent 0.5% of the total global dataset compiled by the GCRMN (11,147 rows).

Sites from which data were provided occur on almost all of the atolls, with at least one site monitored per surveyed atoll. The temporal coverage ranges from sites surveyed once to sites that have been surveyed from 11 to 20 years (Figure 1).

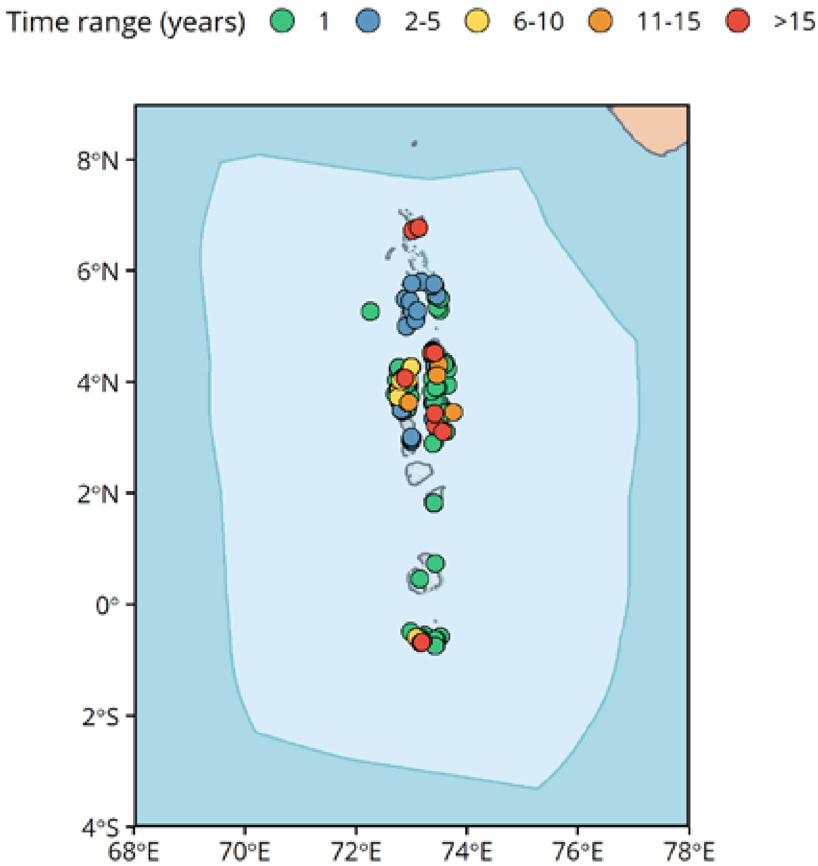


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1997 to 2019. The monitoring effort recorded in the database is not consistent over the years, with an increase in the recorded data punctuated by years characterized by either less data, no data or more data than usual (Figure 2A).

The majority (77%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by line intercept transects (15%), visual censuses (2%) and photo-quadrats (1%). The method is not specified for 5% of the surveys in the database (Figure 2B).

The point intercept transect method remained the most used method over the 3 time periods, with 295 surveys conducted using this method between 2010 and 2019, with the exception of the 2000-2009 period, when a few more surveys used line intercept transects than point intercept transects. Some of the sites were surveyed using visual census between 2000 and 2009 (8 surveys) and some with photo-quadrats between 2010 and 2019 (4 surveys), although their contribution is minimal (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, with 71% of identifications made at the subgroup level or above. There has been a general increase in the precision at which identifications were made. The proportion of observations recorded to the subgroup level increased from 60% to 73% over the three periods of time (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Observations of algae have been identified to at least the subgroup level for 75% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

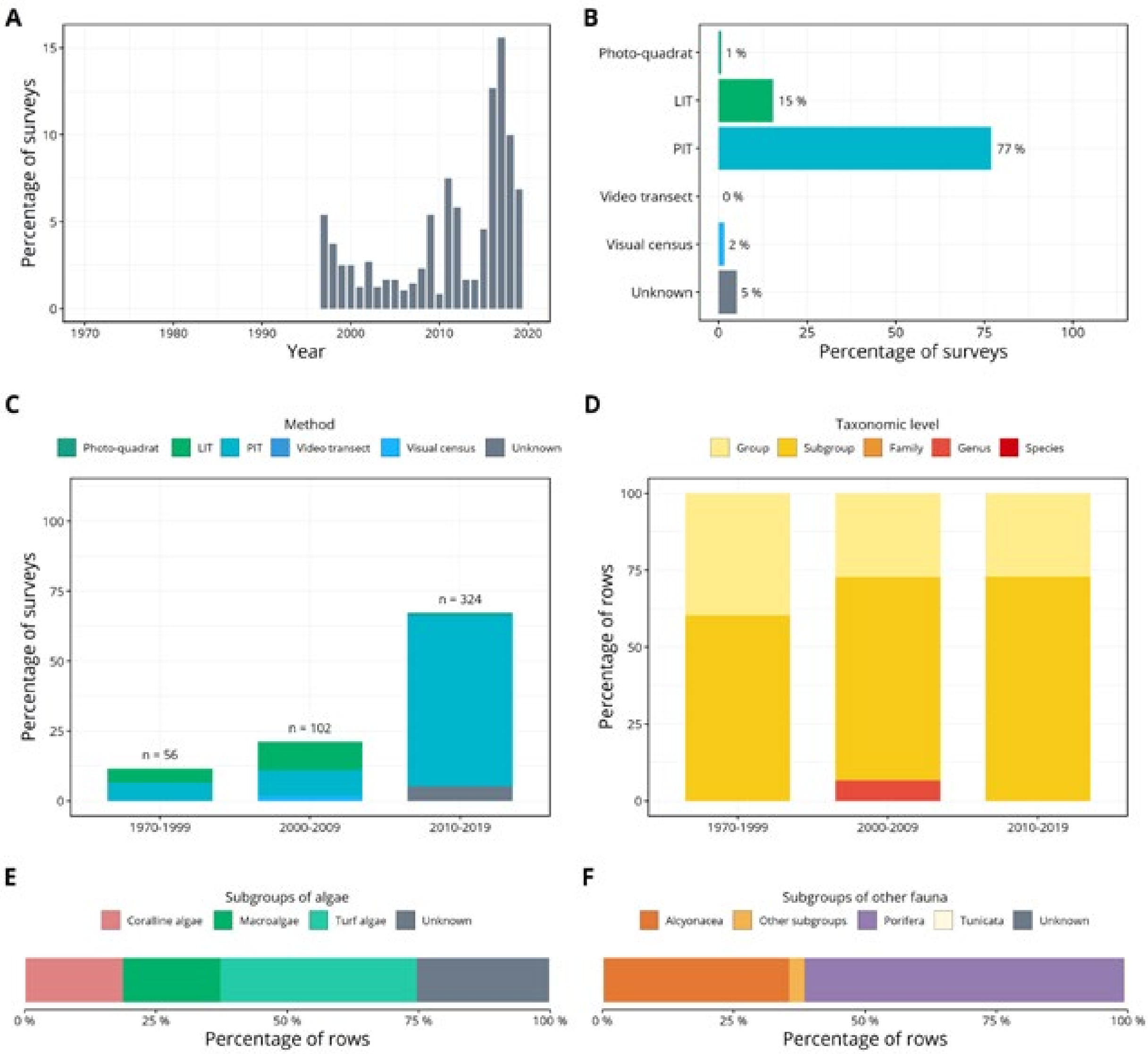


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent. To further increase the spatial coverage of monitoring programs, we recommend that additional monitoring sites be established for Kolhumadulu and Hahdhunmathi atolls.

Temporal Extent. The temporal extent of numerous monitoring sites is greater than 5 years, representing a valuable record for trends in coral reefs, and should be pursued. The establishment of long-term monitoring sites in Kolhumadulu and Hahdhunmathi atolls could be an important improvement.

Methodology[1]. Most of the monitoring sites are based on the point intercept transect method, but, when possible, we recommend that that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution[2]. Most of the available data have a level of taxonomic precision at the subgroup or genus levels, which is enough to assess changes in benthic composition through time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, 25% of "Algae" observations were recorded only to the group level. Thus, we recommend that algae identification be better included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 228 sites throughout the Maldives, with data available for 22 different years from 1997 to 2019. Further, all criteria are met for the indicator "Live Coral Cover" to be considered in use and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups[3].** The taxonomic resolution of the observation regarding the other benthic groups is sufficient for this indicator to be considered as measured. Further, all requirements are met, thus the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" can be considered in use and available at the country level.

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1 For national coral reef assessment programs conducted through MMRI, photo-quadrats have been collected as routine compulsory protocol since 2017 (though surveys have used photo-quadrats before) and plans are to continue to do so.

2 Such improvements are already starting to be implemented through the National Coral Reef Monitoring Program and coral reef assessments of other coral reef research program within MMRI.

3 For assessments carried out as part of various national coral reef programs conducted by MMRI, algae are recorded to genera when possible.

3. **Fish Abundance and Biomass**[4]. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

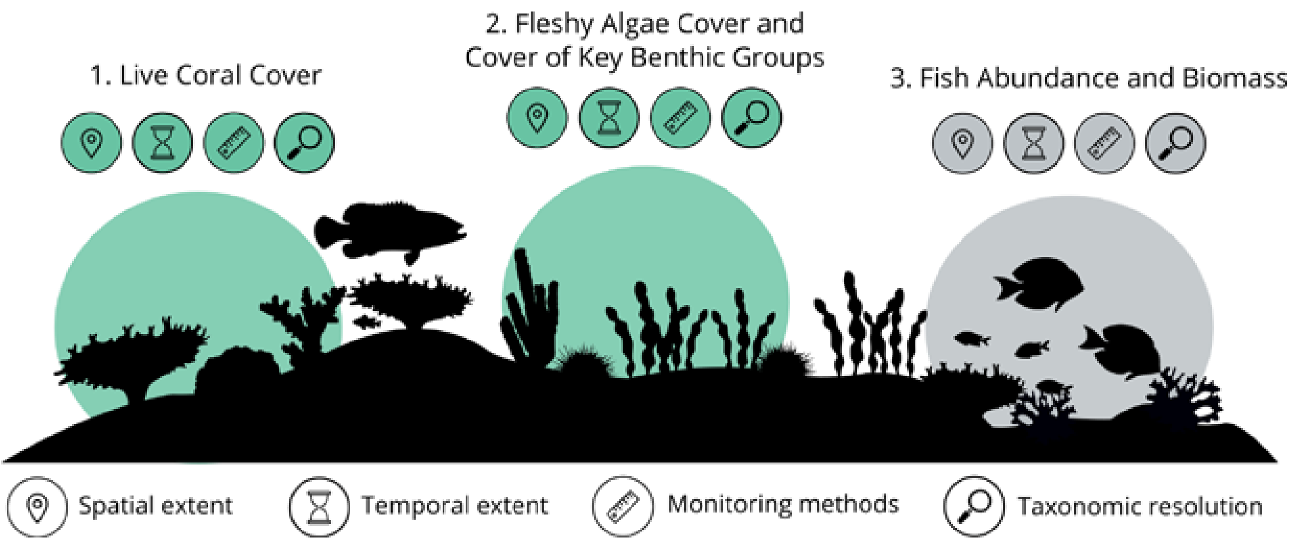

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in the Maldives, please contact the focal points, whose contact details are available in the following table.

Name	Contact	Organisation
Fathimath Hana Amir	Hana.amir@mmri.gov.mv	Maldives Marine Research Institute
Nizam Ibrahim	Nizam.ibrahim@mmri.gov.mv	Maldives Marine Research Institute

This summary has been reviewed by the focal points.

4 Fish abundance for key indicator species and families are recorded during national coral surveys by MMRI and while it is less consistent than benthic data, data is available from 2009 to 2021. This indicator will be included in the upcoming publication on coral reefs from MMRI.

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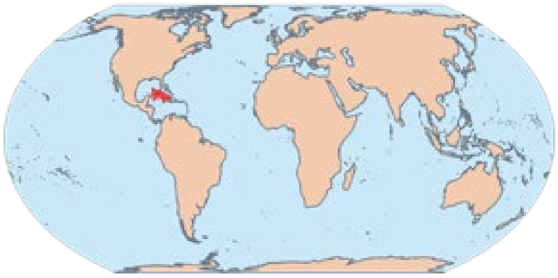
CUBA



1. Introduction – General context

CORAL REEF CARD

Estimated area: 5,320 km²

Proportion of the world's coral reefs: 2.019%

Ranking based on reef area: 11th

The Republic of Cuba is part of the Caribbean archipelago, comprised of the islands of Cuba and the Isla de la Juventud, as well as several other minor archipelagos. The country is located in the Northern Caribbean, at the intersection between the Gulf of Mexico, the Caribbean Sea and the Atlantic Ocean. It is often referred as the "Crown jewel" of the Caribbean Sea due to its beauty and its thriving biodiversity.

There are 61 species of hard corals (IUCN, 2021) and 478 species of reef fishes that are known to inhabit Cuba's reefs (Froese & Pauly, 2020). Coral reefs around Cuba can be classified into four categories, with fringing reefs as the most abundant, followed by patch reefs, reef flats and reefs on muddy substrates (Alcolado et al., 2003).

Coral reefs provide valuable services to the Cuban communities through tourism, fisheries and coastal protection. In 2018, the incomes generated by tourism were estimated at US$170 million, which represented 0.2% of the country's GDP. Around 25,000 jobs are sustained by healthy coral reefs, including tourism and fisheries related jobs (ICRI, 2018). Fisheries in Cuba are mainly state-related, with 14 state enterprises operating more than 70 boats in Cuban waters. A second fleet, with approximately 3,600 smaller boats that are also under contract with the state, contributes to the fishing effort (Puga et al., 2018). Coral reef fishes are highly prized by fishermen and they represent around 40% of the commercial catches (Roman, 2018). Whilst often forgotten, coral reefs provide coastal protection against storm surges and waves. While coastal erosion in Cuba is a growing issue due to sea level rise and tropical storms, the value of this ecosystem service has yet to be quantified.

Cuba's coral reefs are threatened at the local level by human activities, such as overfishing, pollution, unsustainable tourism and coastal development, that lead to habitat destruction (González-Díaz et al., 2018; Roman, 2018). At the global level, sea level rise, increasing water temperatures and the increase in frequency of tropical storms due to climate change are also growing issues for the country (Alcolado et al., 2003; Kitz, 2016).

Marine protected areas in Cuba span 28,700 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,856 km² of coral reefs within their boundaries, thus placing 34.9% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides a partial coverage of the coral reefs around Cuba, with data from a total of 65 sites included within the GCRMN dataset. These observations represent 0.03% of the total global dataset compiled by the GCRMN (686 rows).

Sites from which data were provided occur are mainly concentrated in the South of Cuba, in *Les Jardines de la Reina*, the largest Cuban MPA, but other sites around the archipelago were also contributed to the database. Monitoring sites around Cuba tend to have been surveyed only once (Figure 1).

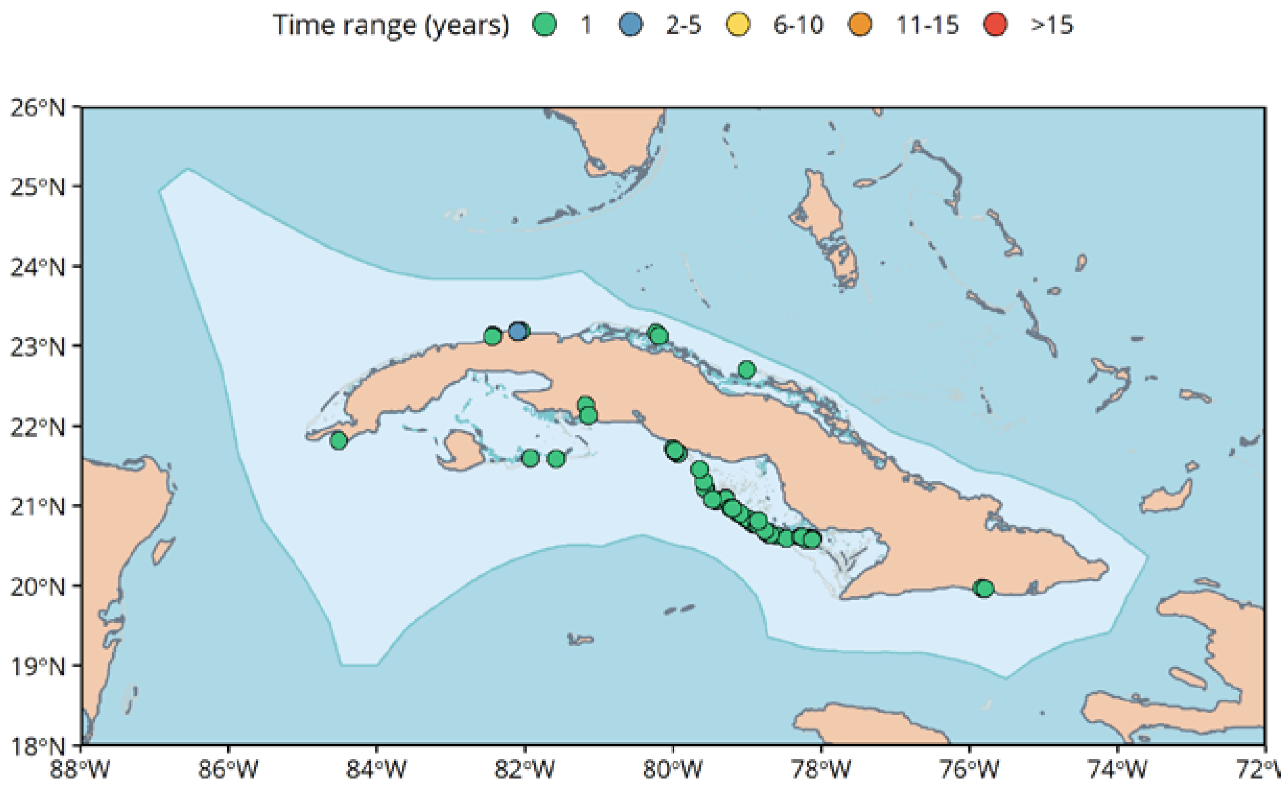


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2001 to 2005 (Figure 2A).

The methods used to monitor the sites were not included in the 2020 GCRMN database for 68% of the surveys. The remaining surveys (32%) were conducted using point intercept transects (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, with 57% of identifications made at the subgroup level or above. The remaining observations were identified to the subgroup level (Figure 2D).

Only 1 out of the 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) is represented. Algae were identified to at least the subgroup level for 31% of the observations (Figure 2E).

Organisms belonging to 2 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented in the database. When recorded, the observations of benthic fauna other than hard coral species were all identified to at least the subgroup level (Figure 2F).

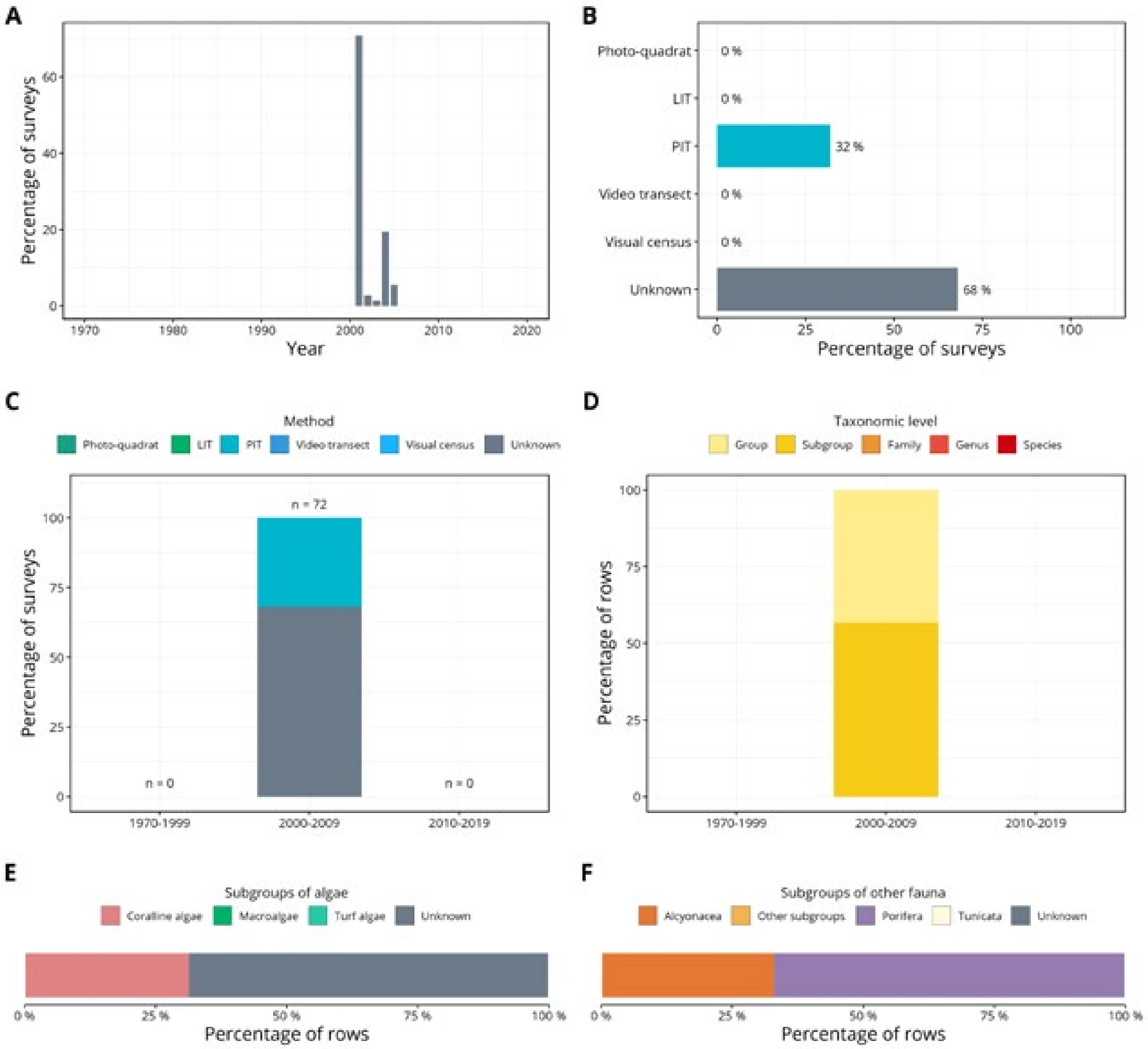


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is heterogeneous, as some areas, such as *Les Jardines de la Reina*, are well surveyed, while other areas, such as the archipelago of Sabana, are less surveyed. To increase the spatial coverage of monitoring programs, we recommend that additional monitoring sites be established around the island, particularly the archipelagos of Sabana and Camaguey on the North coast, as well as around the islands of Cuba Southwest.

Temporal Extent. The temporal extent of all the monitoring sites recorded is low. We recommend that new long-term monitoring programs be established, and that existing programs be extended.

Methodology. We do not have information about most of the methods that were used, and thus cannot provide any specific recommendations. However, when implementing new sites, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. The taxonomic precision of the data is low, as observations to the group level represent almost half of the observations. Furthermore, only 31% of algae were identified to the subgroup level and two out of the three subgroups of algae are not represented in the database. This might be due to the fact that organisms were absent from the sites, or because they were present but were only recorded to the group level or because they were not included in monitoring protocols. For the last two cases, we would recommend that the identification of these organisms be better included in future monitoring protocols, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 65 sites, mostly distributed throughout *Les Jardines de la Reina*, and only between 2001 and 2005, which is not enough to consider that this indicator is available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The spatial coverage and the general taxonomic resolution of the data provided are not sufficient for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

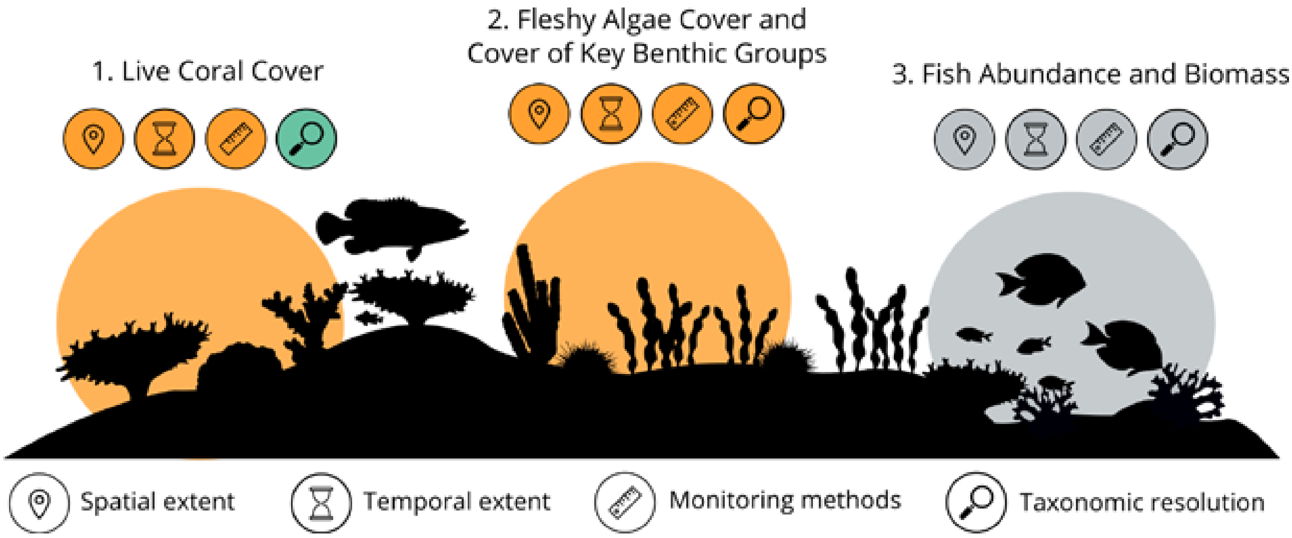


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Based on the data contributed to the 2020 GCRMN world report database, the spatial coverage of the monitoring and the taxonomic resolution of the data provided[1] are not yet enough for the indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" to be considered available at the country level. This might be addressed by implementing new monitoring sites around Cuba and by better including benthic organisms other than hard corals in future monitoring protocols.

3.3 Main contacts

A coral reef monitoring focal point for Cuba has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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1 We are fully aware that the GCRMN 2021 Database does not give an accurate view of all monitoring efforts in Cuba as only a few datasets were included.

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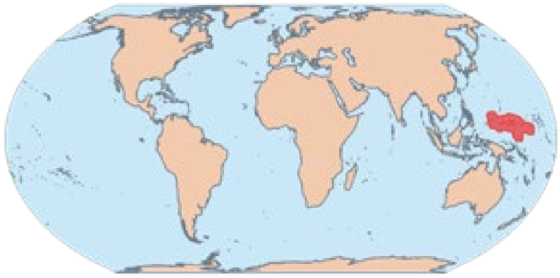

MICRONESIA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 5,004 km²

Proportion of the world's coral reefs: 1.899%

Ranking based on reef area: 12th

The Federated States of Micronesia (FSM) regroups 607 islands between the states of Yap, Chuuk, Pohnpei and Kosrae. Only 70 islands are inhabited. Most of them are small coral or coralline islands and high, volcanic islands are in the minority.

Coral reefs in the FSM are characterized by high levels of biodiversity. The FSM reefs host 427 hard corals species (IUCN, 2021) and are home to 1,081 fish species (Froese & Pauly, 2020). Coral reef formations in FSM are mainly fringing reefs, barrier reefs and atolls (Hasurmai, Joseph, Palik, & Rikim, 2007).

The people of FSM depend heavily on marine resources. Coastal fishing for subsistence represents the main source of protein for numerous households, who also depend on the sale of marine resources to cover average expenses, such as the cost of imported food and fuel (Micronesia Conservation Trust, 2020). Subsistence and commercial coastal fisheries in 2014 were valued at US$8.8 million (2.8% of GDP) and US$5 million (1.6% of GDP) respectively (Gillett, 2016; FAO, 2018). In 2016, 6,200 people were involved in subsistence fisheries (FAO, 2018) and more than 70% of households engaged in fishing activities (Micronesia Conservation Trust, 2020). Tourism, though less developed than in other neighboring countries, is full of potential. It represented 1% of the total employment in 2012, with 681 people employed in hotels and restaurants (Government of the Federated States of Micronesia, 2015). Its annual value has been estimated at US$16 million (Micronesia Conservation Trust, 2020), which represents 3.9% of the GDP. Coastal protection provided by coral reefs is a crucial service against coastal erosion and flooding, which are threatening most islands in the FSM. However, the value of this ecosystem service has yet to be quantified.

Coral reefs in the FSM are under threat by the effects of climate change and coral bleaching, as well as by physical destruction caused by tropical storms, that are frequent in the area. However, the most critical threat is overfishing and the overharvesting of marine resources, leading to a loss of biodiversity of the coral reefs. Unsustainable coastal development, dredging and pollution place further stress on near shore coral reefs around the inhabited islands of the FSM (George et al., 2007; Micronesia Conservation Trust, 2014; Rhodes et al., 2018).

Marine protected areas in Micronesia span 181,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 467 km² of coral reefs within their boundaries, thus placing 9.3% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides a partial coverage of the coral reefs around Micronesia, with data from a total of 81 sites included within the GCRMN dataset. These observations represent 0.3% of the total global dataset compiled by the GCRMN (6,895 rows).

Sites from which data were provided occur mainly on the main islands of each state where monitoring programs are centred: Yap Island, the Chuuk Atoll, as well as the islands of Pohnpei and Kosrae respectively. Sites tend to have been surveyed intermittently, for 1 to 7 years (Figure 1).

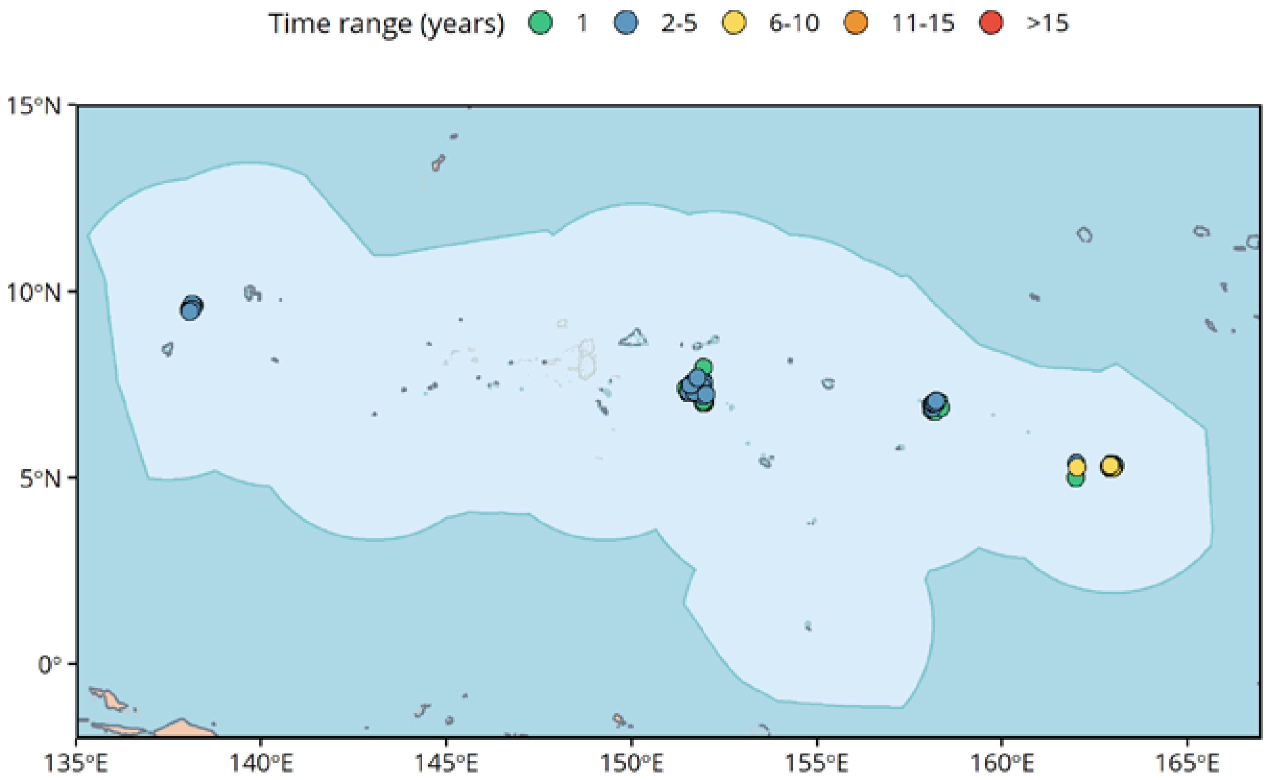

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2000 to 2016. The monitoring intensity increased after 2011 when the regional Micronesia Challenge monitoring program began (Figure 2A).

The majority (63%) of surveys contributed to the 2020 GCRMN database were conducted using photo-quadrats, followed by point intercept transects (37%) (Figure 2B).

Between 2000 and 2009, the main method used was the point intercept transect method, which was used for 53 out of the 55 surveys. Between 2010 and 2019, all of the surveys were conducted using the photo-quadrat method (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution is excellent, as organisms recorded at the subgroup level or above represent 80% of the data provided. The taxonomic resolution increased between the two time periods, as the proportion of observations identified to the group level decreased over time to reach 4%, and the proportion of identifications conducted at the genus level or above increased from 6% in 2000-2009 to 67% in 2010-2019, in accordance with the changing methods (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 85% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified at least to the subgroup level for 97% of the observations (Figure 2F).

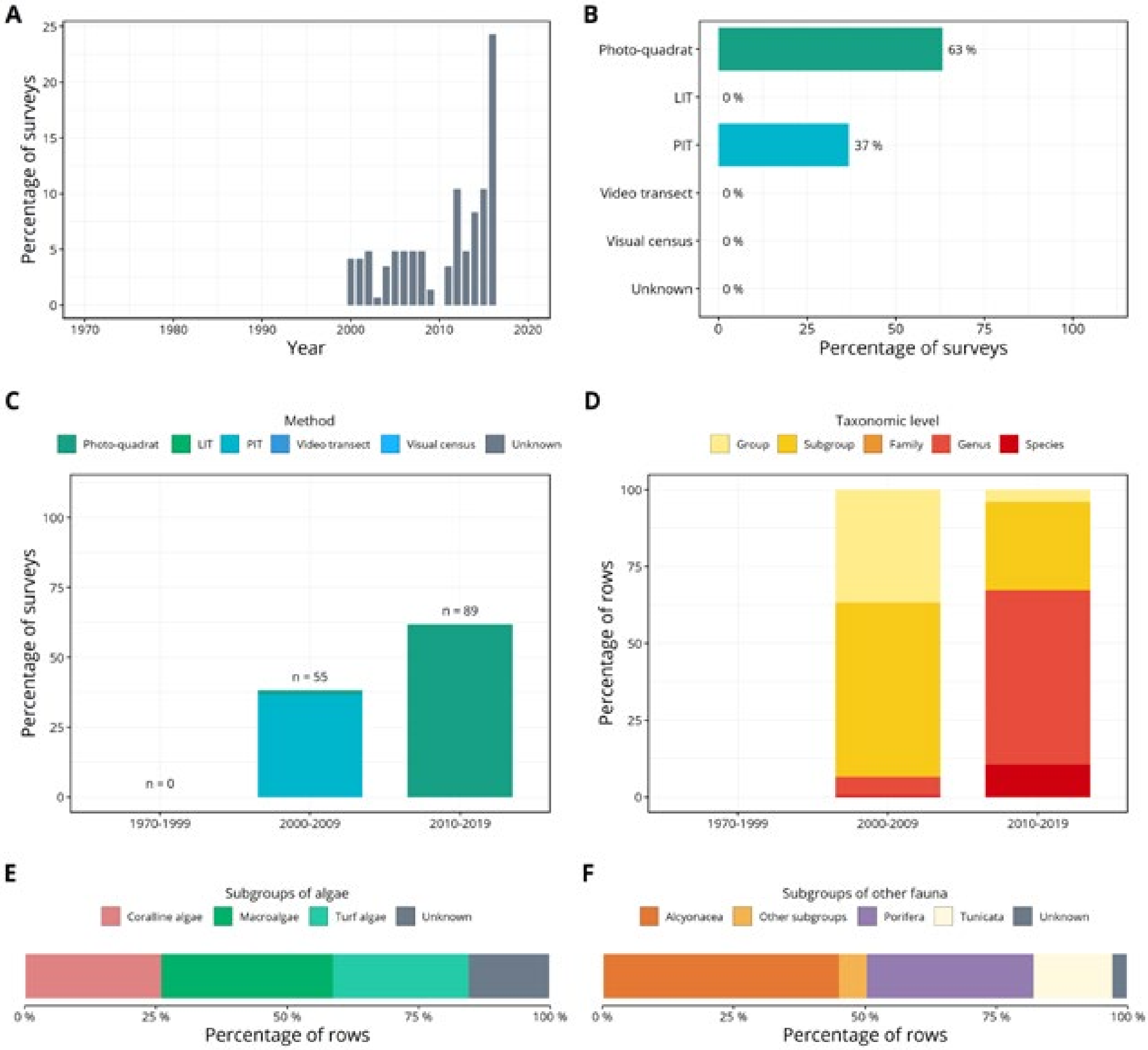

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial covering of the monitoring is limited, as consistent monitoring is lacking in remote sparsely inhabited islands and atolls where some areas rich in coral reefs exist. To increase the spatial coverage of monitoring programs to include the entire archipelago, we recommend that additional monitoring sites be established in the eastern islands of the State of Yap and in the southern part of the State of Chuuk.

Temporal Extent. For numerous monitoring sites, the temporal extent of most of monitoring sites is low. Thus, we recommend that new fixed sites be established and that existing monitoring in existing sites be extended[1].

Methodology. We recommend that the shift towards the use of image-based methods be continued, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Almost 80% of the identifications of benthic organisms have been made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 81 sites throughout the Federated States of Micronesia, with data available for 17 different years from 2000 to 2016. However, monitoring is lacking around islands other than the main islands. Thus, this indicator cannot be considered available at the country level[2].
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered in use. However, the spatial coverage of the monitoring is not sufficient for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

1 Core sites and one-off sites are monitored as part of the Micronesia Challenge monitoring program. Core sites have good temporal coverage, while one-off sites do not. Together, core sites represent all habitats and management regimes for an island.

2 Unless more resources are provided for monitoring, the spatial cover of the monitoring will remain insufficient, as large boats with tenders would be required to access remote islands.

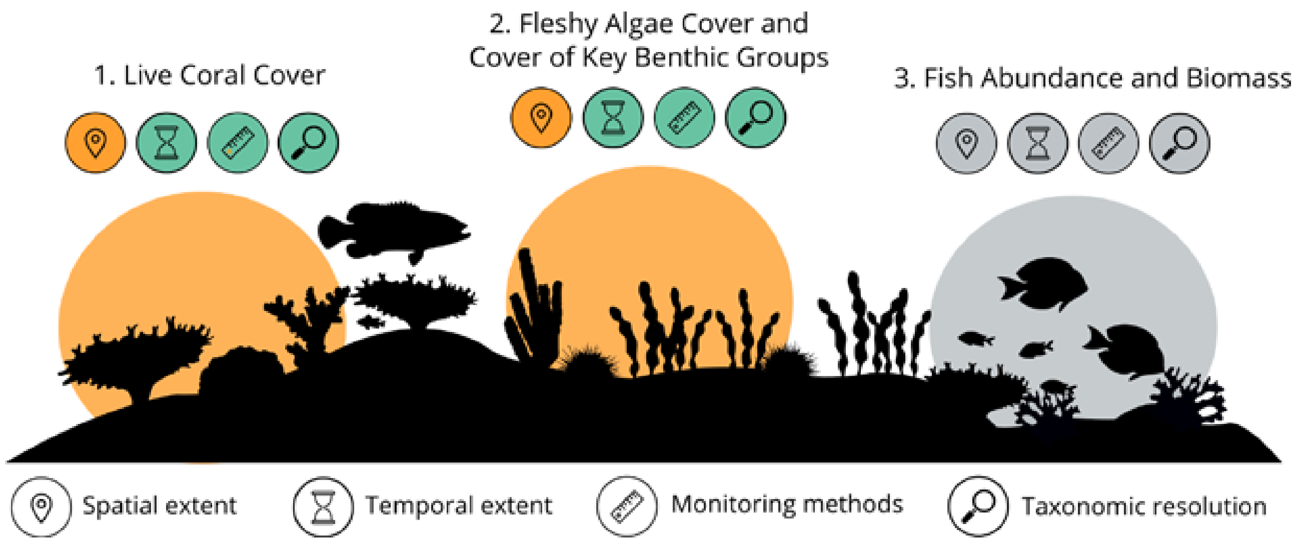

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Based on the data contributed to the 2020 GCRMN database, the spatial coverage of the monitoring is not yet enough for the indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" to be considered available at the country level. This might be addressed by implementing new monitoring sites around the archipelago.

3.3 Main contacts

For additional information on the monitoring of coral reefs in the Federated States of Micronesia, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Ms. Vanessa Fread – Assistant Secretary	freadv@yahoo.com	FSM Department of Resources and Development – Division of Marine Resources
Mr. Dave Mathias – Marine Conservation and Management Specialist	dmathias@fsmrd.fm	FSM Department of Resources and Development – Division of Marine Resources

This summary has been reviewed by the focal points.

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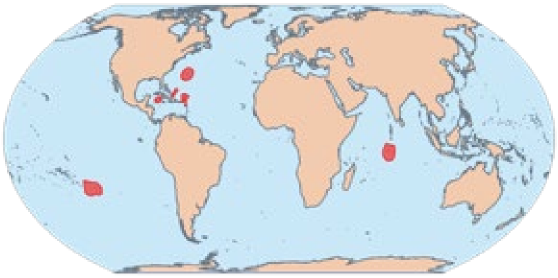
UNITED KINGDOM



1. Introduction – General context

CORAL REEF CARD
Estimated area: 4,623 km²
Proportion of the world's coral reefs: 1.754%
Ranking based on reef area: 13th

Eight of the 14 Overseas Territories (OTs) display extensive coral reefs, located both in the Pacific Ocean, the Indian Ocean and the Caribbean.

Coral reefs in the UK OTs contain 409 species of hard corals (IUCN, 2021) and are home to 1,257 fish species (Froese & Pauly, 2020). Depending on the location, coral reefs form barrier reefs, banks, atolls as well as fringing and patch reefs (Hamylton & Andrefouet, 2013).

Coral reefs provide important ecosystem services to local communities in each of the UKOTs (United Kingdom Overseas Territories). They are important on a local scale, as the services they provide can represent up to 12% of a territory's GDP, as in the Bermuda islands (Sarkis, Van Beukering, & Mckenzie, 2010). Tourism is the ecosystem service that contributes the most to the territory's GDP. Reef-associated tourism generates incomes that ranges from US$80 million in the Turks and Caicos Islands (Economics for the Environment Consultancy Ltd, 2018) which represented around 7% of the GDP, to US$406 million in Bermuda (Sarkis et al., 2010), equivalent to 6% of the territory's GDP in 2007. Fisheries are the second most important service. They are for the most part artisanal or subsistence and are primarily consumed locally, and are thus socially important but of lower economic importance. Their importance varies locally, from US$20,000 in Pitcairn Island (Gillett, 2016) to US$21 million in the Turks and Caicos Islands (Economics for the Environment Consultancy Ltd, 2018), where they represent 2% of the GDP. The value of coastal protection also varies considerably, ranging from a few million US$, as in the Cayman Islands where the value of coastal protection has been estimated at US$6 million (Guzman et al., 2017), representing 0.1% of the GDP, to the Bermuda Islands, where they were valued at US$266 million in 2007 (Sarkis et al., 2010) and represented 4% of the GDP.

Considering the large spatial extent of the UKOTs, the types of threats and their intensity differ according to location. At the global scale, climate change represents the main threat to coral reefs in the UKOTs. On a local scale, they face a variety of anthropogenic threats, including coastal development, pollution, overfishing and illegal fishing. Environmental threats occurring on a local scale should also be considered, such as hurricanes and volcanic activity, which lead to reef damage and habitat loss (Forster, Lake, Watkinson, & Gill, 2011; O'Leary et al., 2019; BlueBelt Report Card, 2021).

Marine protected areas in the United Kingdom span 3.9 million km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 2,978 km² of coral reefs within their boundaries, thus placing 64.4% of the UKOTs' coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the UKOTs, with data from a total of 427 sites included within the GCRMN dataset. These observations represent 0.7% of the total global dataset compiled by the GCRMN (15,249 rows).

Sites from which data were provided occur around the 8 OTs that possess coral reefs. The duration of the monitoring varies greatly between the Islands, as sites in the Cayman Islands were surveyed only once, while some sites in the British Virgin Islands were surveyed for more than 20 years (Figure 1).

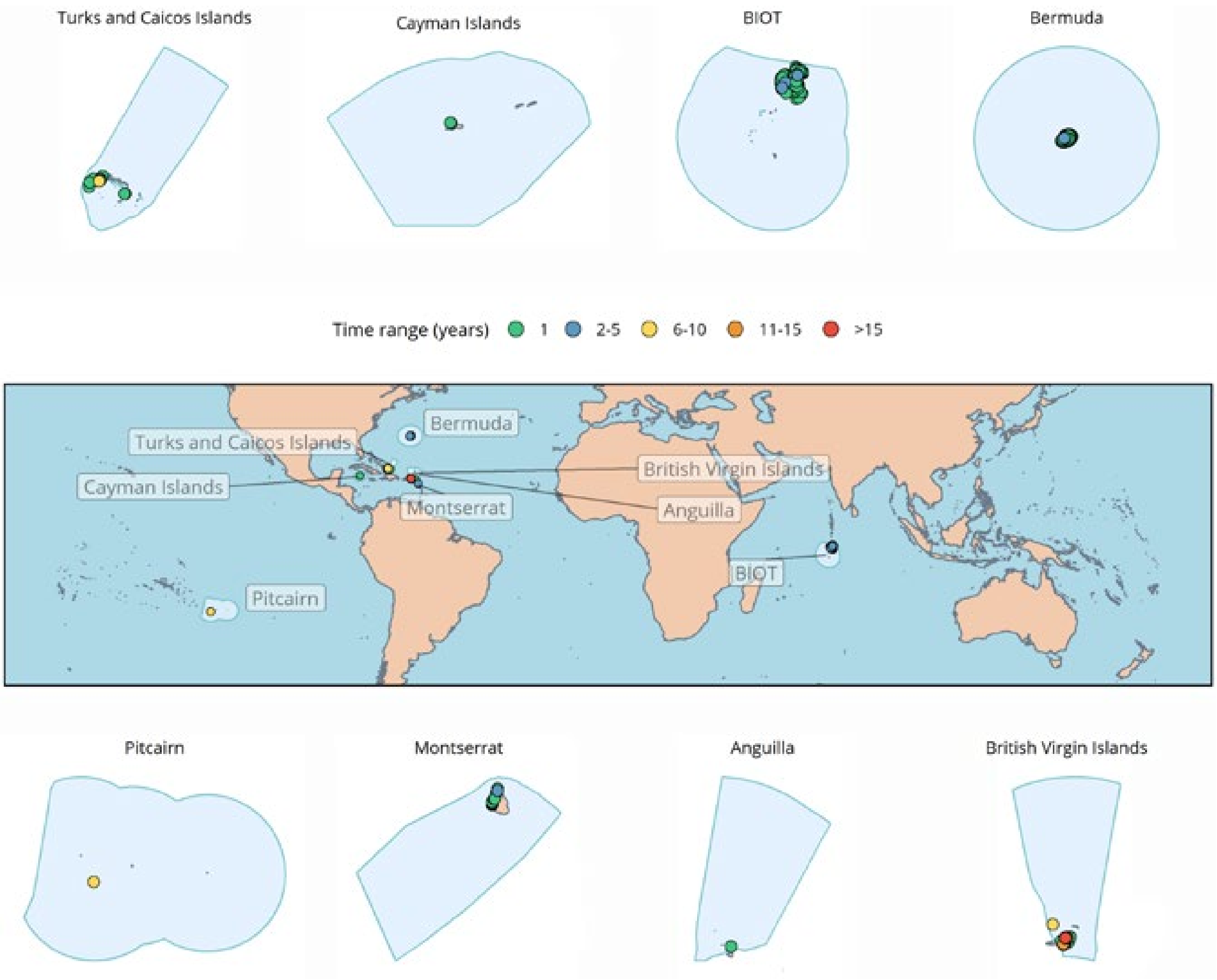


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1992 to 2019. The monitoring effort recorded is relatively constant over the years, with the exception of a few years where the proportion of surveys conducted is much higher. This is especially the case for 2005, 2007 and 2010 (Figure 2A).

The majority (48%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by photo-quadrats (28%) and visual censuses (24%) (Figure 2B).

Prior to the 2000s, 72 out the 95 surveys were conducted with point intercept transects. The remaining 23 surveys were conducted using the visual census method. Between 2000 and 2009, the point intercept transect method remained the most used, with 115 surveys, followed by the photo-quadrat method (125 surveys), and the visual census method (72 surveys). Between 2010 and 2019, the point intercept transect method remained the most used (104 surveys), but the visual census method became the second most used (74 surveys), followed by the photo-quadrat method (69 surveys) (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the provided is excellent, with 90% of the identifications made at the subgroup level or above. While the proportion of observation identified to the subgroup level or above remained constant, the proportion of observations identified to the genus level and above decreased from 43% in 1979-1999 to 37% in 2010-2019 (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 87% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 97% of the observations (Figure 2F).

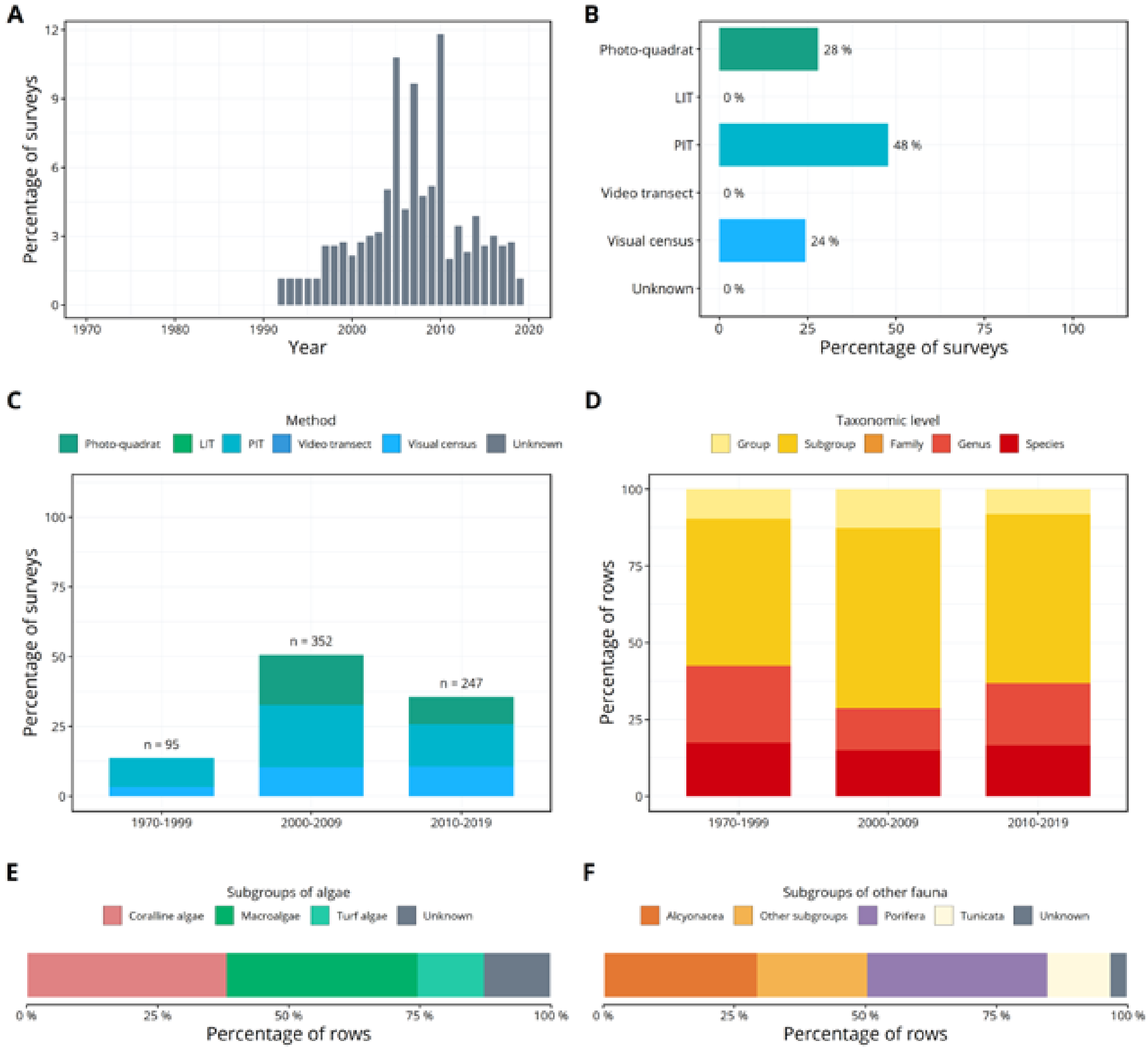


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already very good, especially in the British Virgin Islands and in the British Indian Oversea Territory. To further improve the coverage of the monitoring, we recommend that additional monitoring sites be added in the Cayman Islands and Anguilla, as well as in the Turks and Caicos Islands.

Temporal Extent. The temporal extent of the monitoring between the different sites is highly heterogeneous, with the number of years for which sites were surveyed ranging from one year to more than 20 years. We thus recommend that existing time series be pursued, and that new fixed sites be implemented, so as to monitor trends in coral reefs over time.

Methodology. The shift from the use of point intercept transects to the use of photo-quadrats that started during the 2000-2009 period should be continued when possible, as the use of image-based methods is valuable. High quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. The taxonomic resolution of the data provided is excellent. Most of the data provided have a level of taxonomic precision at the subgroup or genus levels, which is sufficient to assess changes in benthic composition over time. Different subgroups belonging to the groups “Algae” and “Other fauna” were commonly represented, indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 427 sites throughout the United Kingdom’s OTs every year between 1992 and 2019, which is enough to consider that it is implemented and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding algae and the other benthic groups is sufficient for this indicator to be considered implemented and available in the country.
3. **Fish Abundance and Biomass**. This indicator was not considereed for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

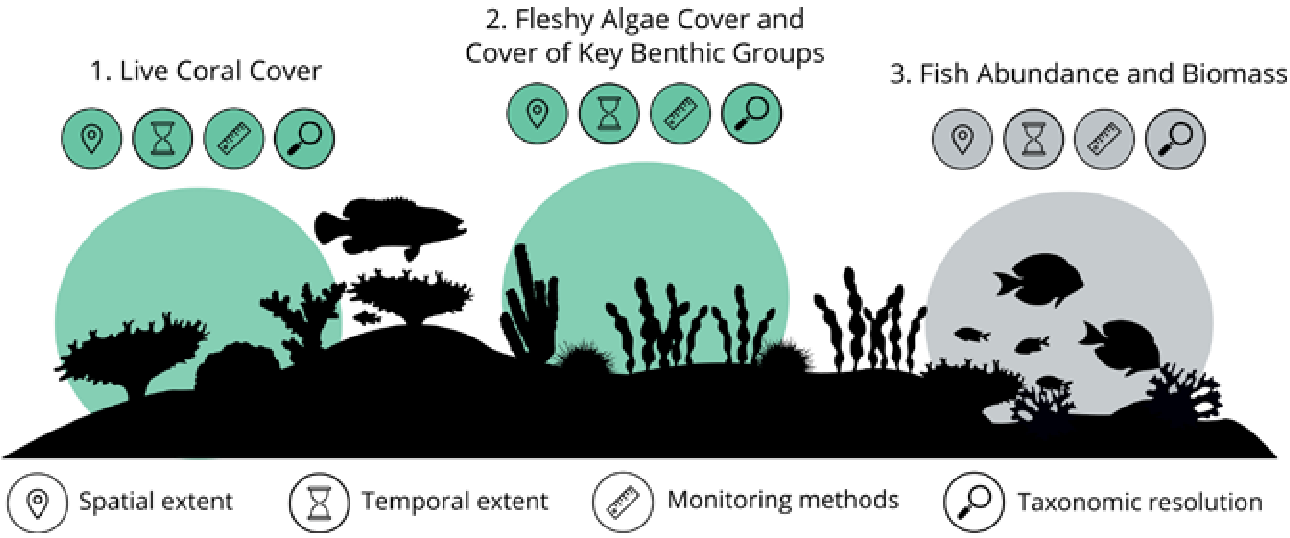


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover", "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in the United Kingdom's OTs, please contact the focal points, whose contact details are available in the following table.

Name	Contact	Organisation
N/A[1]	UKOverseasTerritories@jncc.gov.uk	Joint Nature Conservation Committee

This summary has been reviewed by the focal points.

1 This will be a monitored mailbox.

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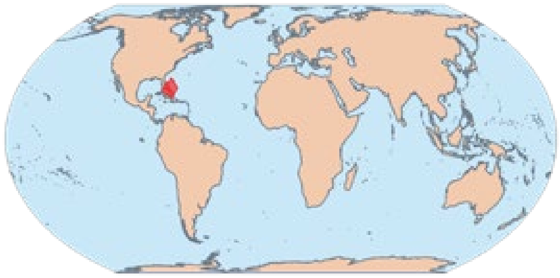
BAHAMAS



1. Introduction – General context

CORAL REEF CARD

Estimated area: 4,518 km²

Proportion of the world's coral reefs: 1.714%

Ranking based on reef area: 14th

The Bahamas are host to more than 700 islands, scattered throughout the Caribbean, making it one of the most extensive archipelagic states in the world.

There are 58 hard corals species (IUCN, 2021) and 462 fish species (Froese & Pauly, 2020) that can be found in the Bahamian waters. Coral reefs in the Bahamas are mainly fringing reefs, even though the third largest barrier reef in the world can be found in Andros Island (Wilkinson, 2002).

Coral reefs are very important for the Bahamian economy as they sustain 19,000 jobs (ICRI, 2018). Reef-related tourism generates the largest income of the three main services provided by coral reefs. In 2017, reef tourism was estimated to account for 6.39% of the country's GDP (Spalding et al., 2017). They also generate income through reef fisheries, that are estimated at US$20.6 million and up to US$64 million depending on the sources (ICRI, 2018; Heck, Narayan, & Beck, 2019), which represents between 0.2% and 05% of the country's GDP. Coral reefs also play a vital role in protecting the coast from storm surges and erosion, although the benefits provided have yet to be quantified (Kramer et al., 2013).

Coral reefs in the Bahamas are threatened by climate change and bleaching events, but also by unsustainable development, pollution, overfishing and destructive tourism practices (Kramer et al., 2013).

Marine protected areas in the Bahamas span 51,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 672 km² of coral reefs within their boundaries, thus placing 14.9% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the Bahamas, with data from a total of 463 sites included within the GCRMN dataset. These observations represent 1.3% of the total global dataset compiled by the GCRMN (26,637 rows).

Sites from which data were provided are well distributed around the archipelago. Most of the sites tend to have been surveyed only once, but some of them have been surveyed for more than 6 years (Figure 1).

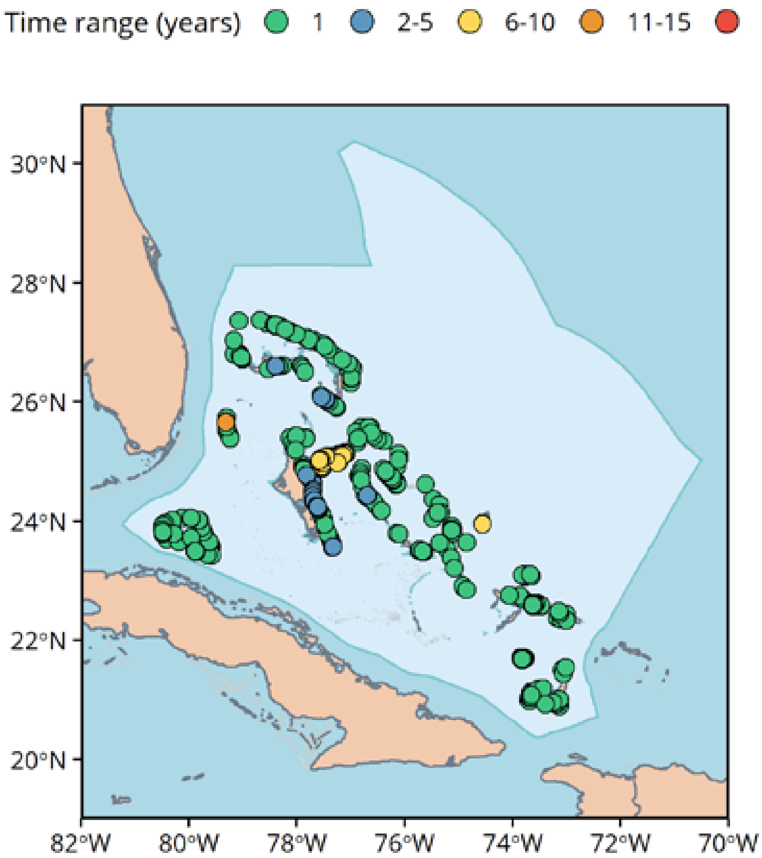


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1999 to 2019. The monitoring effort has been very irregular (Figure 2A).

The data regarding the methods used to survey the site has not been recorded in the database for 93% of the surveys. Point intercept transects were used to conduct the remaining 7% of the surveys (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, as 73% of the observations were recorded at the subgroup level or above. Regarding the precision at which identifications were conducted over time, it slightly increased between the 2000-2009 and the 2010-2019 periods. While the proportion of identifications made to the subgroup level or above remained constant, the proportion of identifications made to the species level increased from 30% in 2000-2009 to 36% in 2010-2019 (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 77% of the observations (Figure 2E).

Only 2 out of the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Further, observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 4% of the observations (Figure 2F).

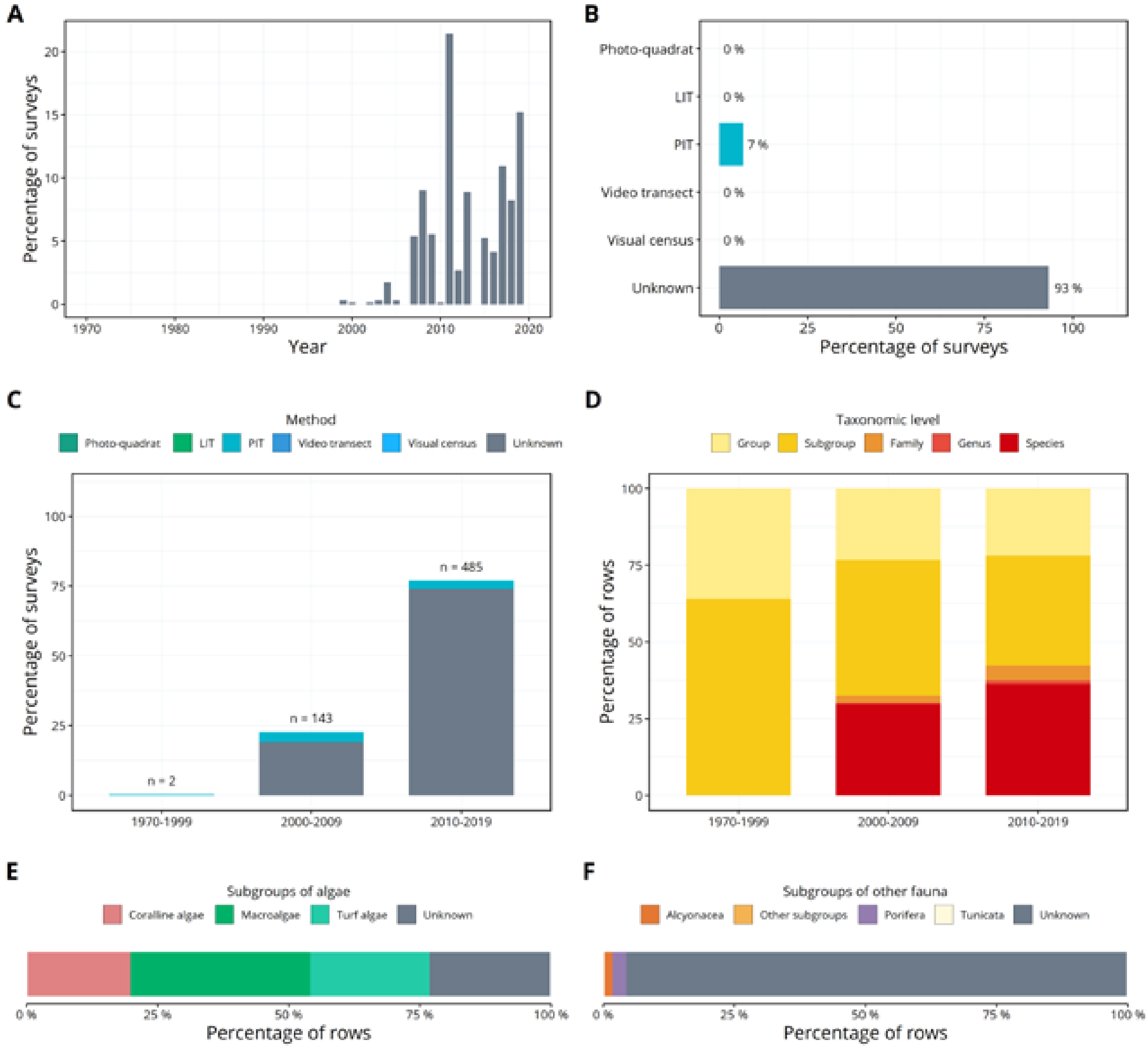


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent. To further increase the coverage, we recommend that additional monitoring sites be established around Ragged Island as well as Acklins Island.

Temporal Extent. The temporal extent of most of monitoring sites is a bit low, except for sites around New Providence and Bimini Islands, which tend to have been surveyed for more than 5 years. Thus, we recommend that more fixed monitoring sites be established, and that monitoring of the existing sites be continued.

Methodology. The information regarding the methods used to conduct most of the surveys is lacking. However, when implementing new monitoring sites, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Around 75% of the identifications made for benthic organisms were made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. Such a high level of precision when identifying benthic organisms is highly valuable and should be pursued. However, for organisms belonging to the group "Other fauna", the subgroup level is unknown for 96% of observations. As such, there is a lack of data on the composition of benthic communities. We thus recommend that these organisms be better included in future monitoring protocols, as part of the monitoring of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 463 sites throughout the Bahamas with data available for 18 different years from 1999 to 2019. Thus, all criteria are met for the indicator "Live Coral Cover" to be considered in use and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** While the cover of algae has been well monitored, the lack of precision when identifying organisms belonging to the group "Other fauna" prevents this indicator from being considered as available.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

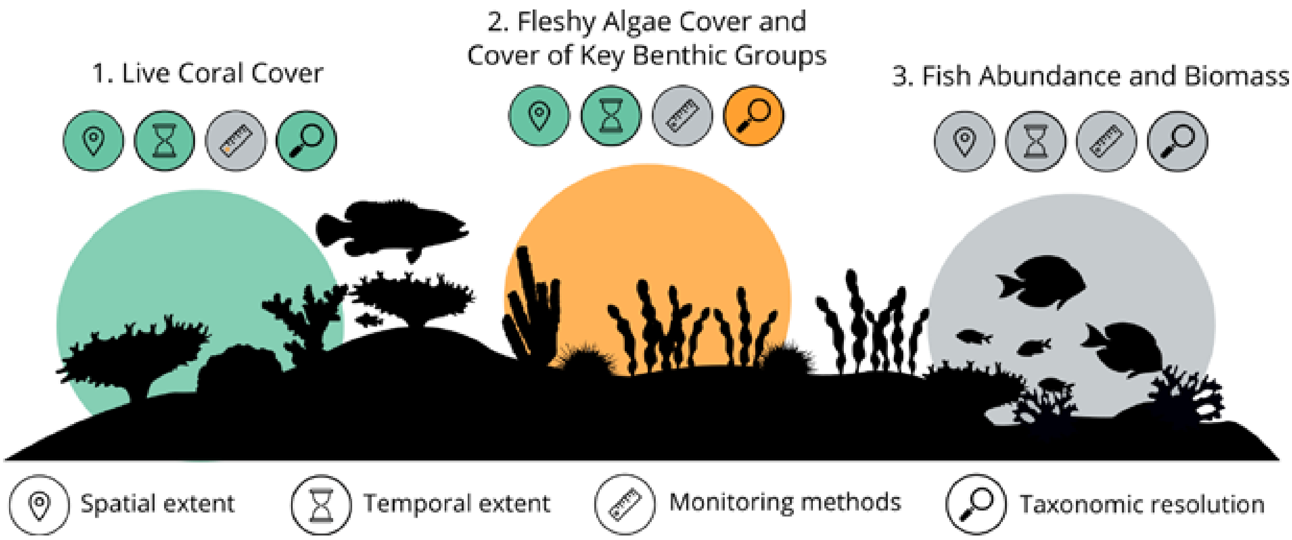


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

To conclude, the ICRI recommended coral reef indicator "Live Coral Cover" presented in Figure 3 is measured and is available on request for most of the existing datasets identified at the country level, while the taxonomic resolution of the data provided is not sufficient for the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" to be considered measured and available at the country level. However, this indicator could quickly be made available, provided that identifications of organisms related to the group "Other fauna" are better included in future monitoring protocols.

3.3 Main contacts

A coral reef monitoring focal point for the Bahamas has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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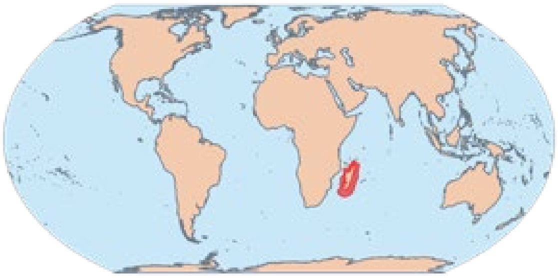

MADAGASCAR

1. Introduction – General context

CORAL REEF CARD

Estimated area: 4,160 km²

Proportion of the world's coral reefs: 1.579%

Ranking based on reef area: 15th

Madagascar is the 4th largest island in the world. Located off the East Coast of Africa in the Western part of the Indian Ocean, it is home to an extraordinary fauna and flora, characterized by a very high level of endemism. Its waters are also home to one of the largest coral reef assemblages in the Western Indian Ocean, which are mainly located on the west coast of the island.

In terms of biodiversity, there are 352 species of hard corals (IUCN, 2021) and 647 species of reef fishes that are known to inhabit the reefs (Froese & Pauly, 2020). Coral reefs around Madagascar can be found forming fringing reefs, barrier reefs, patch reefs, reef flats, submerged coral banks and shoals (Cooke, 2012).

The Malagasy communities are highly dependent on the ecosystem services provided by coral reefs. Small scale fisheries provide one if not the main source of protein and up to 82% of household income for a large part of the population, notably on the West coast (Barnes-Mauthe, Oleson, & Zafindrasilivonona, 2013). Most of the production is for subsistence, as 90% of the catch is sold and consumed locally. Fisheries employ 102,000 fishers, who are mainly located on the West coast of Madagascar and in 2010 they generated US$146 million, which represented nearly 2% of the country's GDP (World Bank, 2003). Coral reefs also attract tourists to Madagascar. A survey conducted in 2000 revealed that 55% of the time spent by tourists in Madagascar was related to ecotourism, and that 19% was related to the sea, sun and sand tourism. Ecotourism regroups the lemurs and birds watching with sport fishing and diving and thus is not solely related to coral reefs (Christie & Crompton, 2003). Reef-based tourism in itself is estimated to account for 0.5% of the country's GDP (Spalding et al., 2017). The ecosystem services provided by coral reefs in terms of coastal protection have yet to be estimated.

In addition to increasing seawater temperatures and cyclones, the coral reefs of Madagascar are threatened by a variety of anthropogenic threats, such as pollution, overfishing, mechanical degradation of the reefs and poorly managed tourism. High levels of sedimentation, caused by deforestation, also represent an important threat to the coral reefs in some regions (Obura et al., 2017).

Marine protected areas in Madagascar span 27,930 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,765 km² of coral reefs within their boundaries, thus placing 42.4% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Madagascar, with data from a total of 169 sites included within the GCRMN dataset. These observations represent 0.4% of the total global dataset compiled by the GCRMN (7,676 rows).

Sites from which data were provided occur mainly from three distinct areas around Madagascar, which are the region of Diana in the North-West, Atsimo-Andefrana in the South-West, and Analanjirofo on the North-Eastern coast. Medium and long-term monitoring sites within Madagascar are common (Figure 1).

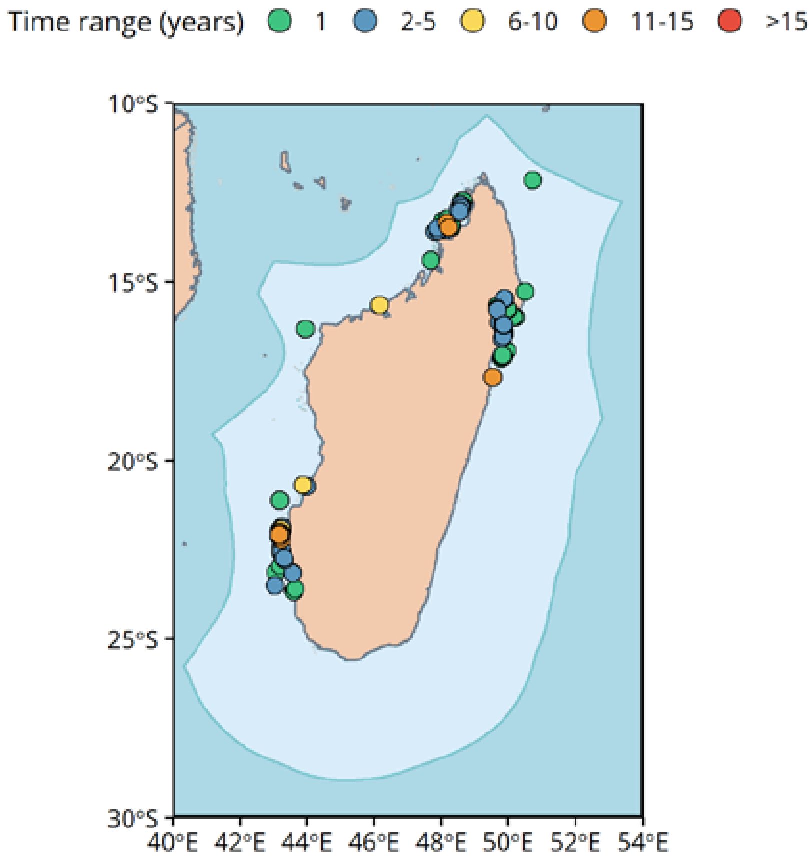

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1998 to 2019. The monitoring effort recorded in the database is not consistent over the years, with an important increase in the recorded data after 2004, punctuated by years characterized by a higher number of sites monitored (Figure 2A).

The majority (89%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects. The method is not specified in the database for 11% of the surveys (Figure 2B).

The percentage of surveys for which there was no information concerning the type of method used decreased over time. While the method used is unknown prior to the 2000s, point intercept transects were the main method used for the next two time periods, as they were used in 126 and 409 surveys between the 2000-2009 and 2010-2019 periods, respectively (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, as 82% of the identifications were made at the subgroup level or above.

Regarding the precision at which identifications were conducted over time, an increase in the precision of the identification happened between the 1979-1999 and the 2000-2009 period as the proportion of observations at the subgroup level or above increased from less than 5% to more than 70% of the observations. While the proportion of identifications made to the subgroup level or above increased slightly between 2000-2009 and 2010-2019, the proportion of identifications made to the genus level also increased from 6% in 2000-2009 to 9% in 2010-2019 (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 68% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 90% of the observations (Figure 2F).

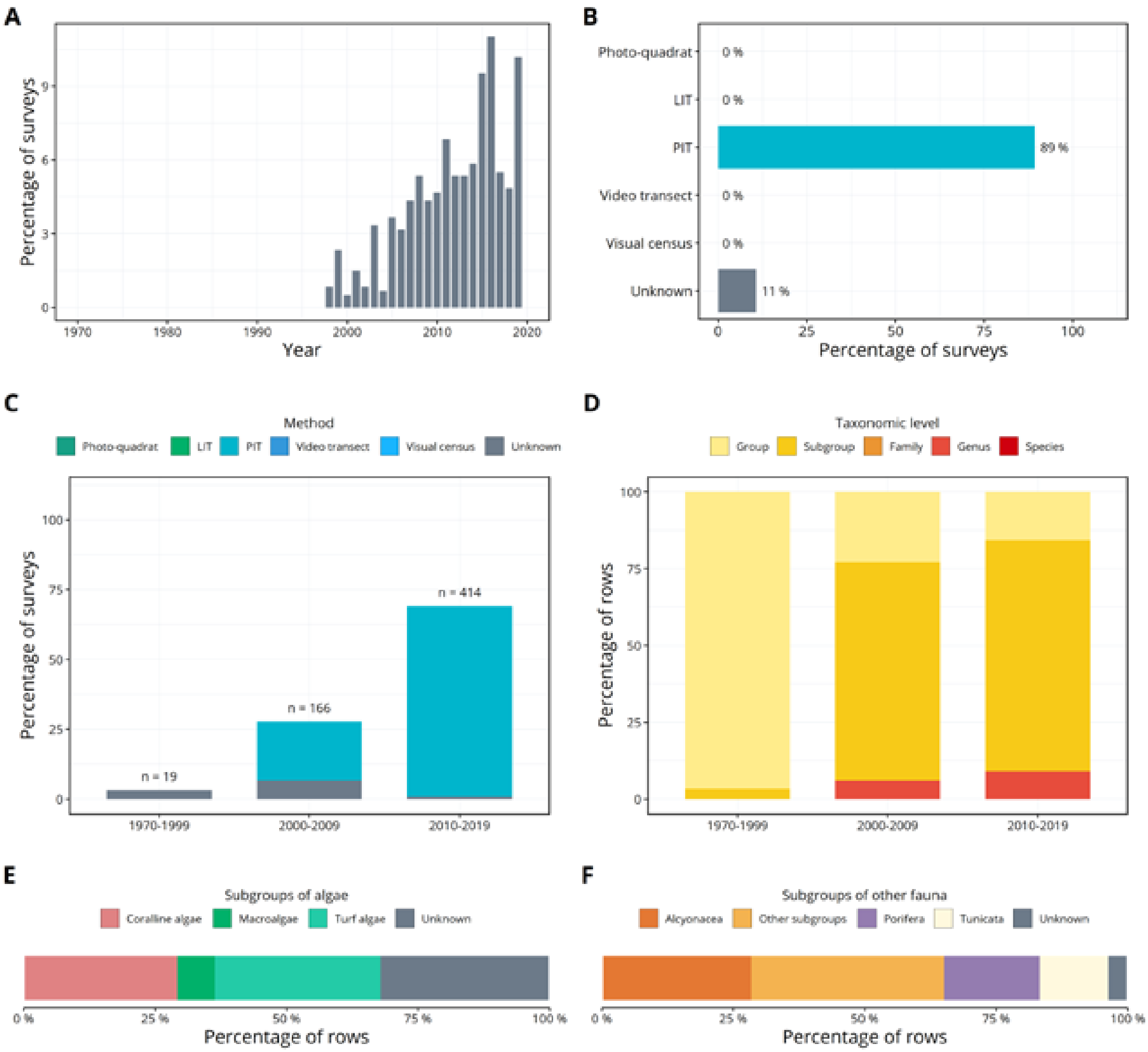

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already good, especially in the regions of Diana, Atsimo-Andefrana, and Analanjirofo. To further increase the spatial coverage of monitoring, we recommend that additional monitoring sites be established in the regions of Sofia, Boeny and Melary, which are located on the West coast, and where most of the reefs are located.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 5 years, representing valuable medium-term records for trends in coral reefs. Such efforts are highly valuable and should be pursued.

Methodology. Most of the monitoring sites are based on point intercept transects, but, when possible, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the available data have a level of taxonomic precision at the subgroup level or above, which is sufficient to assess changes in benthic composition over time. Different subgroups belonging to the groups “Algae” and “Other fauna” were commonly represented indicating that the surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, the proportion of algae identified to at least the subgroup level could still be increased, as 32% of the observations were only identified up to the group level.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 169 sites around Madagascar, which are rather representative of the distribution of coral reefs in the country and data are available every year from 1998 to 2019. Further, all of the other requirements are met, which is enough to consider that this indicator is available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding algae and the other benthic groups is sufficient for this indicator to be considered in use in the country.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

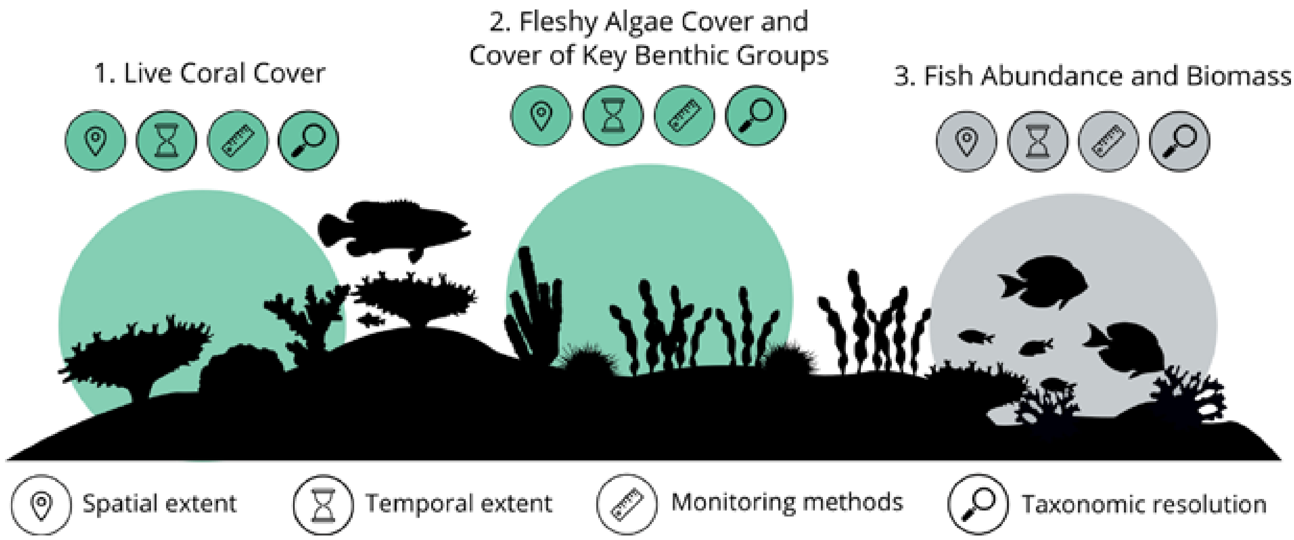

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

A coral reef monitoring focal point for Madagascar has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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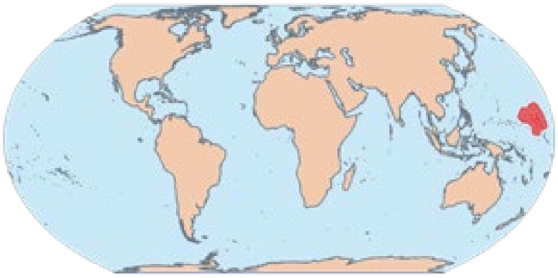
REPUBLIC OF THE MARSHALL ISLANDS



1. Introduction – General context

CORAL REEF CARD

Estimated area: 3,629 km²

Proportion of the world's coral reefs: 1.377%

Ranking based on reef area: 16th

The Republic of the Marshall Islands is an archipelagic nation comprised of 5 single islands and 29 atolls that regroup around 1,225 islands and islets, divided between 2 ancient volcanic chains of atolls, Ratak and Ralik. Two-thirds of the population is concentrated on 2 atolls, Majuro and Kwajalein.

Coral reefs in the Marshall Islands host 342 hard corals species (IUCN, 2021) and are home to 880 fish species (Froese & Pauly, 2020). The only coral geomorphological structures found in the Republic of the Marshall Islands are atolls (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

The people of the Marshall Islands are highly dependent on natural resources for their survival, and as their country is mostly comprised of ocean, marine resources and coral reefs play a critical role in providing food and supporting livelihoods. Thus, fisheries and more specifically reef fisheries are one of the primary pillars of subsistence for local communities. A total of 48.9% of the households interviewed during a national survey reported engaging in fishing activities. Out of these, 64.1% reported fishing for subsistence only, 34.8% reported fishing for both subsistence and income and 1.1% reported fishing solely for income (EPPSO, 2012). In terms of contribution to the national economy, coastal subsistence catches represent two thirds of all coastal fisheries production and have an estimated value of US$6 million, which represented 3.3% of the country's GDP in 2014. This same year, the value of coastal commercial fisheries had an estimated value of US$4.35 million, which represented a contribution of 2.4% to the GDP (Gillett, 2016). While many reefs in the Marshall Islands are still in a very good state and could represent a non-negligible attraction for nature-based tourism, annually, there are few visitors that come to the Marshall Islands. For the past 6 years, around 6,000 tourists have visited the country each year (World Bank, n.d.). The total annual gross revenue for diving and snorkeling was approximately US$242,777, which represented 0.1% of the GDP in 2013 (Gjertsen, Appelbaum, & Barr, 2013). While coastal protection has not been assessed for all inhabited islands, the contribution of coral reefs to protection of local property has been estimated from US$25.4 million to US$44.7 million (Gjertsen et al., 2013), which would represent 13.3-23.6% of the country's GDP at the time of the study.

While the Marshallese coral reefs are prone to COTS outbreaks or cyclones, most of the reefs are in a good state. This is particularly true for the atolls that were evacuated after nuclear testing. On the contrary, coral reefs in the atolls of Majuro and Kwajalein are facing several threats due to uncontrolled coastal development. Over-fishing, poor waste management and aggregate mining represent severe threats to the coral reefs (Office of Environmental Planning Policy Coordination, 2017).

Marine protected areas in the Marshall Islands span 7,200 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 768 km² of coral reefs within their boundaries, thus placing 21.2% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the Marshall Islands, with data from a total of 33 sites included within the GCRMN dataset. These observations represent 0.1% of the total global dataset compiled by the GCRMN (2,590 rows).

Sites from which data were provided occur on the atolls of Majuro, Rongelap, Wotho, Jaluit and Ebon, thus providing data in areas of different population density. Most of the sites tend to have been surveyed only once, but several sites have been surveyed for 2 to 5 years (Figure 1).

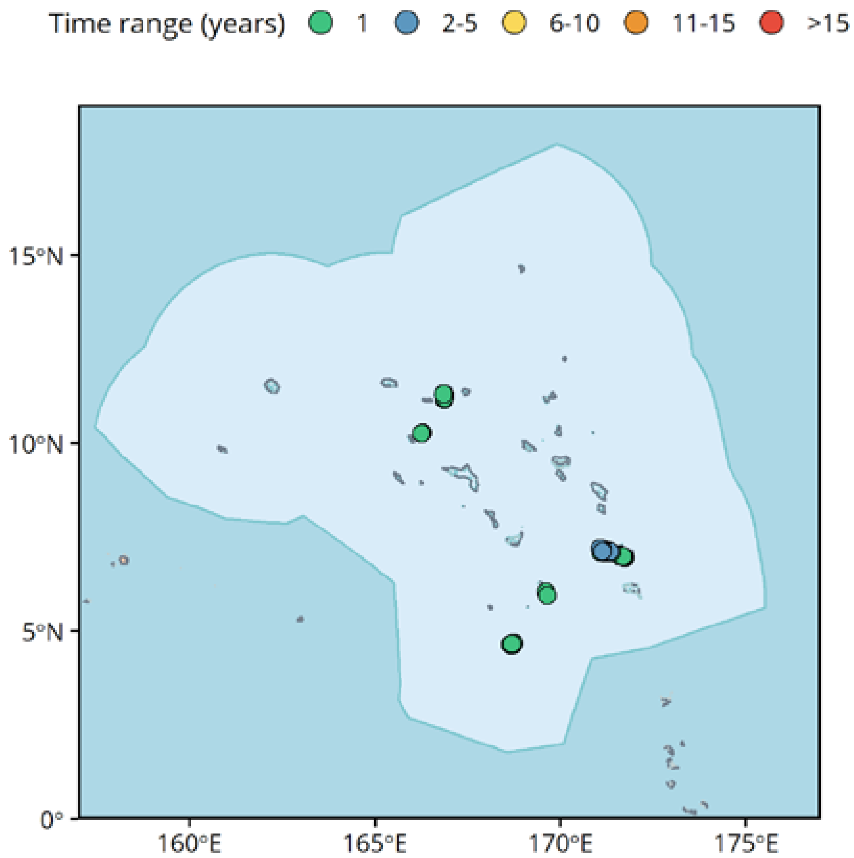


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2001 to 2016. The monitoring effort has been quite irregular and no surveys were recorded from 2002 to 2010 (Figure 2A).

The majority (90%) of surveys contributed to the 2020 GCRMN database were conducted using photo-quadrats, followed by point intercept transects (10%) (Figure 2B).

In 2001, the 2 surveys were conducted using the point intercept transect method. Between 2010 and 2019, 53 surveys were conducted using the photo-quadrat method, while the 4 remaining surveys were conducted using the point intercept method (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”.

Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, as 91% of identifications were made at the subgroup level or above.

Between 2010 and 2019, identifications made at the group level represented only 8% of the data provided, while 45% of identifications were made at the genus level or above (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 85% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 90% of the observations (Figure 2F).

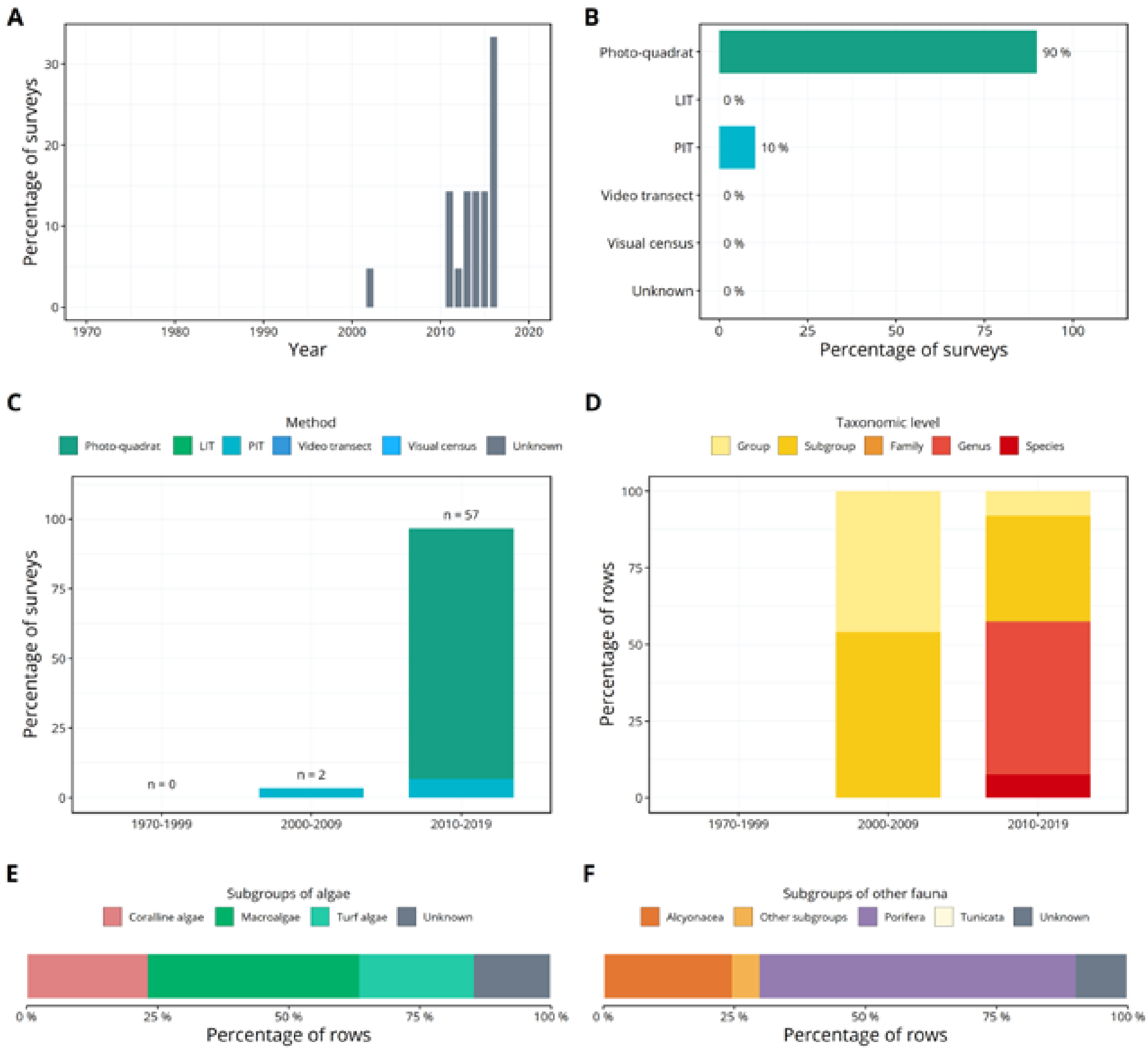


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The current spatial extent of the data is interesting since sites with different levels of urbanisation were monitored. However, the spatial coverage of the monitoring is not sufficient. To increase the spatial coverage of monitoring programs so as to survey the whole archipelago, we recommend that additional monitoring sites be established, in an urbanized atoll such as Kwajalein, in a rural atoll such as Likiep, and in an uninhabited atoll, such as Ujelang.

Temporal Extent. The temporal extent of most of monitoring sites is low. Thus, we recommend that fixed monitoring sites be established and that the monitoring of existing sites be extended.

Methodology. Most of the sites were monitored using photo-quadrats. The use of image-based methods is valuable and recommended, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. More than 90% of the identifications of benthic organisms were made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. Different subgroups belonging to the groups “Algae” and “Other fauna” were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, the subgroup “Tunicata” belonging to the group “Other fauna” is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, we would recommend that these organisms be included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was measured on 33 sites around the Republic of the Marshall Islands for 7 different years between 2011 and 2016. However, the spatial coverage of the monitoring is not sufficient for this indicator to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered measured. However, the spatial extent of the monitoring is too limited for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

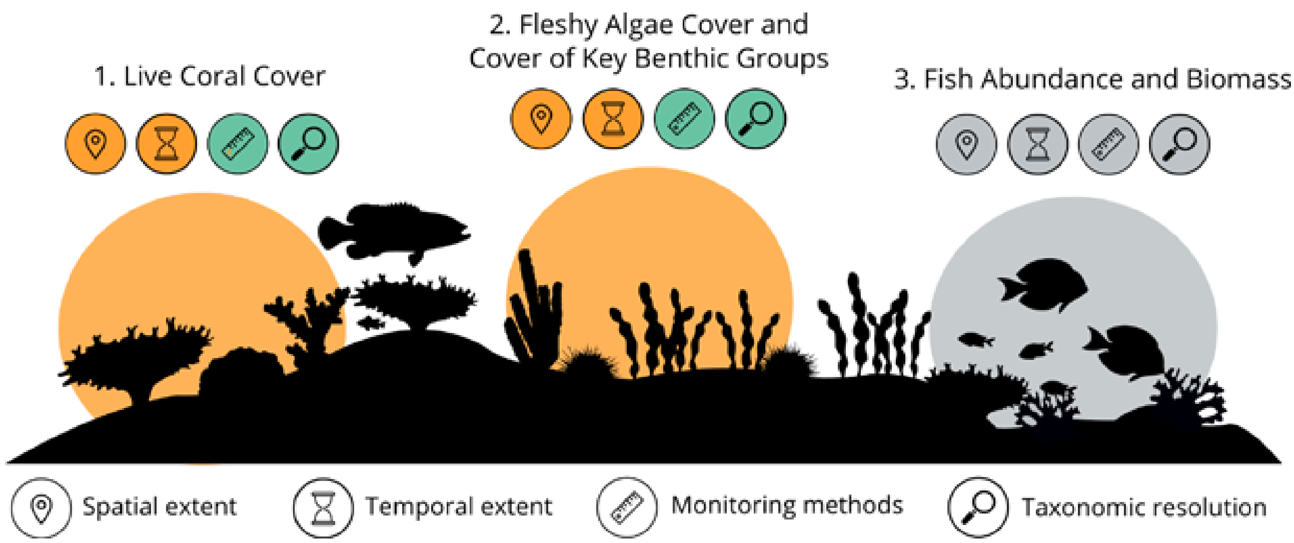


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

The ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured and are available on request for most of the existing datasets identified. However, the spatial coverage of the data is not sufficient yet for these indicators to be considered available and representative of the state of the coral reefs at the country level.

3.3 Main contacts

A coral reef monitoring focal point for the Republic of the Marshall Islands has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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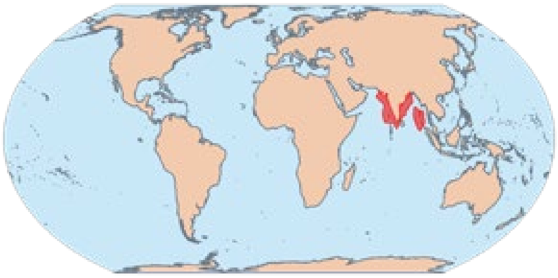
INDIA



1. Introduction – General context

CORAL REEF CARD

Estimated area: 3,583 km²

Proportion of the world's coral reefs: 1.36%

Ranking based on reef area: 17th

India and its islands are home to some of the most extensive coral reef formations in the Indian Ocean. The main coral regions in India are located in the Gulf of Mannar, the Gulf of Kutch (Chachchh), the Lakshadweep Islands as well as the Andaman and Nicobar Islands.

The Indian coral reefs are home to 379 species of hard corals (IUCN, 2021) and 850 species of reef fishes (Froese & Pauly, 2020). Coral reefs in India can be found forming barrier, fringing and patch reefs, as well as atolls, platform reefs and reef flats (Venkataraman, 2011).

Ecosystem services provided by coral reefs in India are crucial for local coastal communities, although this importance has yet to be formally quantified. While national statistics do not take reef fisheries into account, coastal populations are highly dependent on coral reef fisheries for subsistence and as a source of income (Rajasuriya et al., 2000; Venkataraman, 2011). Reef-based tourism is not very developed in India and represents only 0.03% of the country's GDP (Spalding et al., 2017). This can be explained by the remote location of coral reefs in India and the difficulty to access them (Rajasuriya et al., 2000). Though it has yet to be quantified, coastal protection provided by coral reefs is not negligible and its role in mitigating the effects of the 2004 tsunami, thus limiting the human and reconstruction costs, is acknowledged (Baswapoor & Begum Irfan, 2018).

Due to a rapid increase in population growth, coral reefs in India face several anthropogenic threats, in addition to natural threats which include increasing water temperatures and bleaching, COTS outbreaks and an increased level of sedimentation. Unsustainable coastal development, dredging, coral mining, overfishing and destructive fishing practices as well as the pollution generated by urban, industrial and agricultural runoffs are some of the most common anthropogenic pressures that coral reefs are facing (Baswapoor & Begum Irfan, 2018).

Marine protected areas in India span 3,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 217 km² of coral reefs within their boundaries, thus placing 6.1% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around India, with data from a total of 105 sites included within the GCRMN dataset. These observations represent 1.7% of the total global dataset compiled by the GCRMN (35,588 rows).

Sites from which data were provided occur in 3 of the 4 main coral reef regions in India. Sites tend to have been surveyed for more than 11 years in the Gulf of Mannar, for at least 2 years in Lakshadweep Islands, and only once in Andaman and Nicobar Islands (Figure 1).

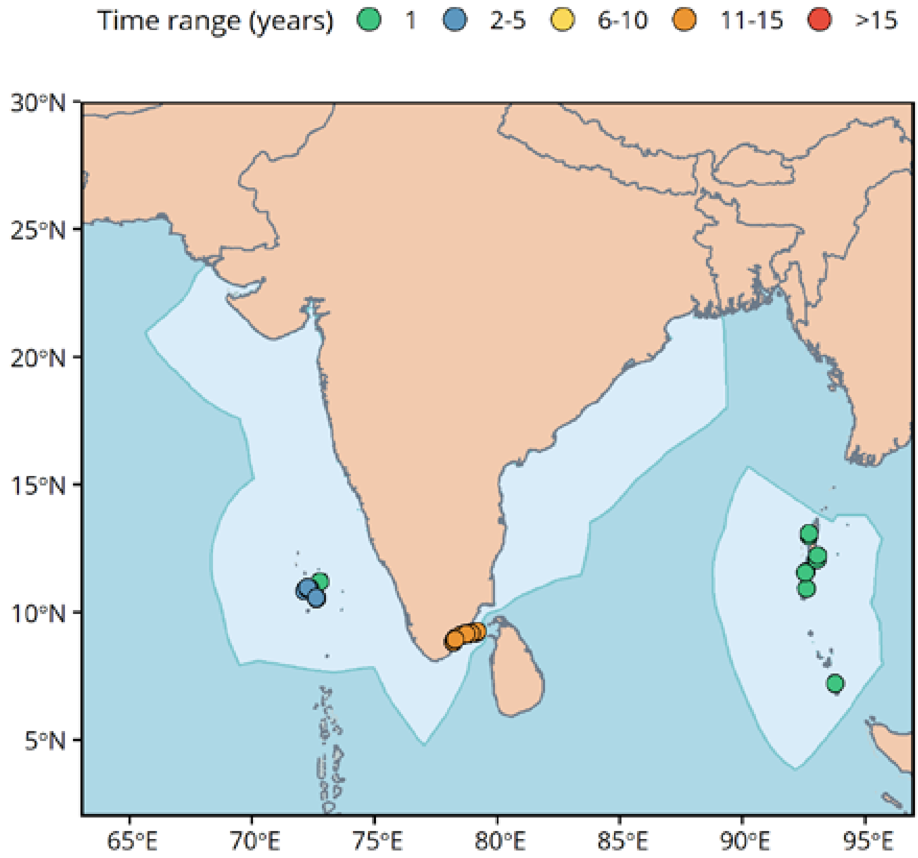


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1998 to 2019. The monitoring effort has been pretty consistent between 2006 and 2016, which marked the beginning of an increase in monitoring effort (Figure 2A).

The majority (93%) of surveys contributed to the 2020 GCRMN database were conducted using line intercept transects, followed by photo-quadrats (7%) (Figure 2B).

Between 2000 and 2009, all sites were surveyed with line intercept transects only (288 surveys) and this method remained the main method used during the 2010-2019 period (656 surveys). Photo-quadrats started to be implemented as the method for surveying benthic communities in coral reefs during the 2010-2019 period and were used for 73 surveys (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, as more than 76% of identifications were made at the subgroup level or above. The precision level at which observations were recorded did not change over the two time periods. Observations that were characterized only at the group level account for 25% of the data. Observations recorded at the subgroup level account for a little less than 50% of the recordings and observations at the family level account for the remaining 25% of observations (Figure 2D).

Only 2 out of the 3 "Algae" subgroups ("Coralline algae", "Macroalgae" and "Turf algae") are represented. Algae were identified to at least the subgroup level for 50% of the observations (Figure 2E).

Organisms belonging to 1 out the 4 "Other fauna" subgroups ("Alcyonacea", "Porifera", "Tunicata" and "Other subgroups") are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 40% of the observations (Figure 2F).

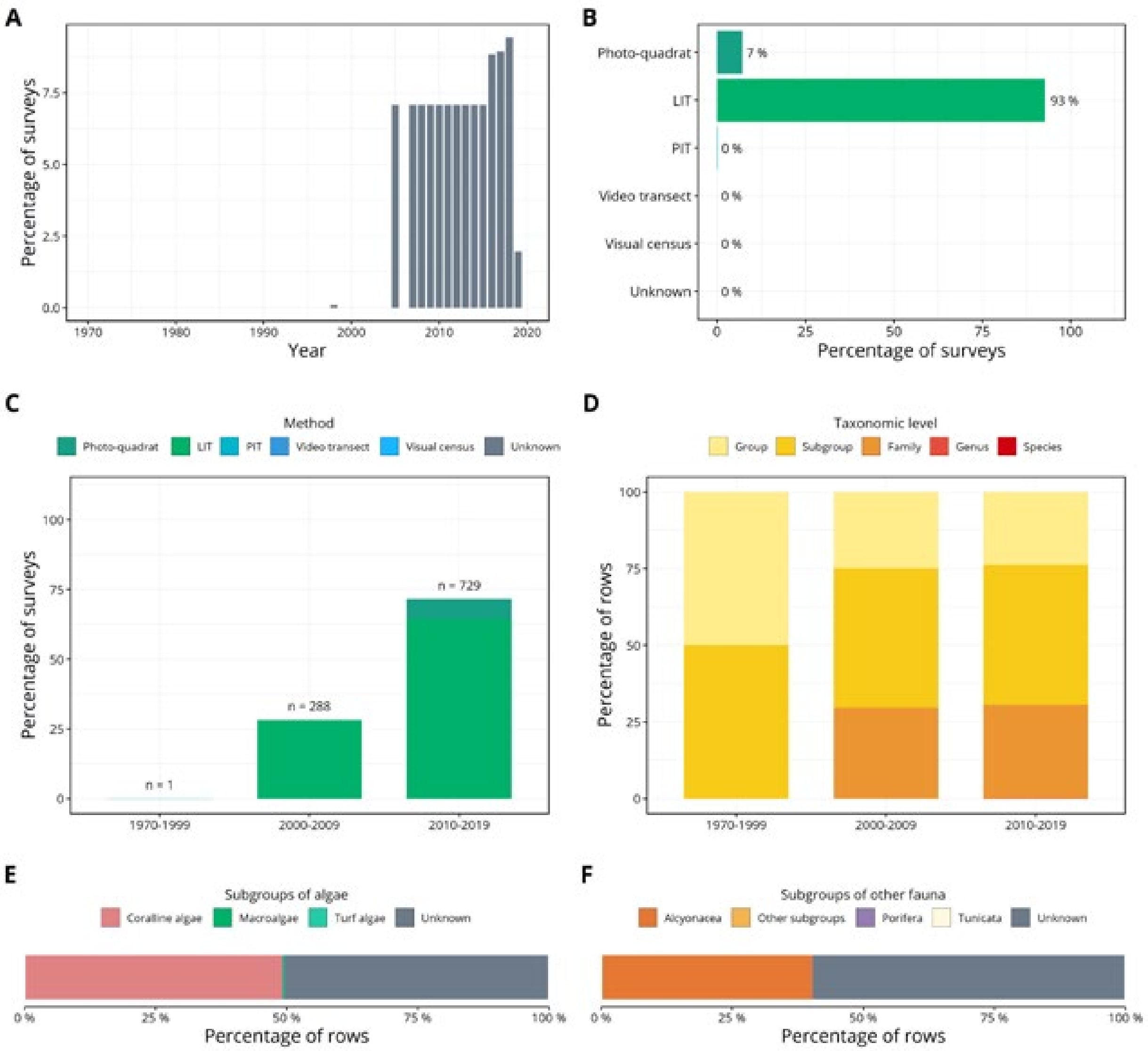


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial extent of the monitoring provides data on 3 out of the 4 main coral reef regions in India, which is valuable. To further increase the spatial coverage of coral reefs monitoring so as to cover the whole country, we recommend that additional monitoring sites be established in the Gulf of Kutch (Chachchh).

Temporal Extent. The temporal extent of most of monitoring sites is low, and we recommend that more fixed monitoring sites be established, and that existing sites be extended. The time series available in the Gulf of Mannar are highly valuable and the monitoring should be pursued.

Methodology. Most of monitoring sites are based on the line intercept transect method. The shift to the use of image-based methods should be continued, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in the taxonomic composition of benthic communities.

Taxonomic resolution. Most of the data provided have a level of taxonomic precision at the subgroup or family levels, which is particularly relevant for assessing changes in benthic communities over time. However, more than 50% of benthic organisms belonging to the subgroups "Algae" and "Other fauna" were identified only to the group level, which is not sufficient to assess changes in these communities. Further, several subgroups belonging either to the groups "Other fauna" or "Algae" are not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were only recorded to the group level or because they were not included in monitoring protocols. If the last two cases were to be true, it would be recommended that they be included in future monitoring protocols. We thus recommend that the current monitoring protocols be updated to include the identification of these organisms in the data collection process as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was measured on 104 sites and there are data available for 14 different years between 2005 and 2019. While one of the main coral reef regions described in the literature is missing, all requirements are met. Thus, this indicator can be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** While the other requirements are met, the taxonomic precision of the identification of benthic organisms belonging to the subgroups of "Algae" and "Other fauna" is not sufficient for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

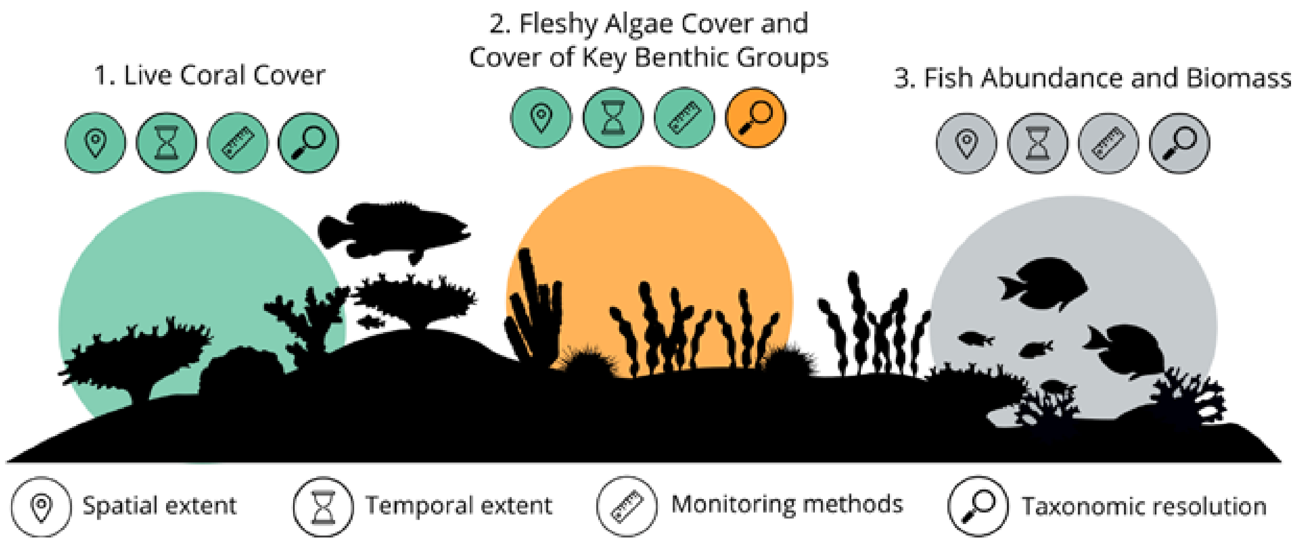


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

To conclude, the ICRI recommended coral reef indicator "Live Coral Cover" presented in Figure 3 is measured and is available on request for most of the existing datasets identified at the country level, while the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is not yet available. However, it could quickly become available, provided that identifications of algae and organisms that are part of the key benthic groups are better included in future monitoring protocols.

3.3 Main contacts

A coral reef monitoring focal point for India has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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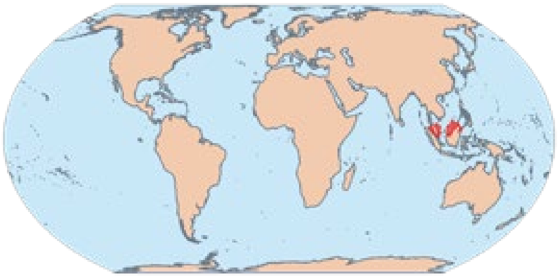
MALAYSIA



1. Introduction – General context

CORAL REEF CARD

Estimated area: 3,383 km²

Proportion of the world's coral reefs: 1.284%

Ranking based on reef area: 18th

Malaysia is divided into two geographically separate regions (Peninsular Malaysia and Borneo) with a total of 904 islands. Coral reefs in Malaysia are mainly found in the Eastern coast of Peninsular Malaysia and Sabah and Sarawak on the island of Borneo.

Located in the Coral Triangle, Malaysia hosts some of the most biodiverse coral reefs, as illustrated by the hundreds of hard coral and fish species observed in its waters. There are 584 species of hard corals (IUCN, 2021) and 826 species of reef fishes that are known to inhabit the reefs (Froese & Pauly, 2020). Coral reefs around Malaysia can be classified into four categories, with fringing reefs as the most abundant, followed by patch reefs, barrier reefs and atolls (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Coral reefs in Malaysia provide extremely valuable services to coastal communities as they act as an important source of food, income and employment. As in every coastal country, fisheries are an important economic sector. Artisanal fisheries in Malaysia represent approximately 20% of total catches and are mainly used for human consumption. Tourism is also an important economic sector and healthy coral reefs are crucial for the economy as tourism promotion in Malaysia is highly focused on marine tourism. Reef-related marine tourism activities include recreational fishing, snorkeling as well as wreck and reef diving (Asian Development Bank, 2014). A 2017 study estimated that reef-tourism in Malaysia represented 0.37% of the country's GDP, with a mean value of US$391,400 per km² of reef (Spalding et al., 2017). While coastal protection by coral reefs is recognized in Malaysia, there are no official estimates of its value at the country scale.

While coral reefs are productive ecosystems, population growth and its concentration on coastal areas creates additional pressure on coral reefs around Malaysia. Although the type and level of anthropogenic pressure vary depending on the location, the main threats identified are overfishing and destructive fishing practices and pollution and increased sedimentation levels due to coastal development. Unsustainable tourism practices also represent serious threats to some areas with a high tourism value (Praveena, Siraj, & Aris, 2012). In addition to these local threats, coral reefs are globally threatened by global warming, leading to bleaching events, and COTS outbreaks (Reef Check Malaysia, 2018).

Marine protected areas in Malaysia span 18,700 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,216 km² of coral reefs within their boundaries, thus placing 35.9% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Malaysia, with data from a total of 585 sites included within the GCRMN dataset. These observations represent 1.8% of the total global dataset compiled by the GCRMN (37,554 rows).

Sites from which data were provided occur in Peninsular Malaysia, Sabah and also in Sarawak. Medium and long-term monitoring sites within Malaysia were provided, with time series at some sites exceeding 10 years (Figure 1).

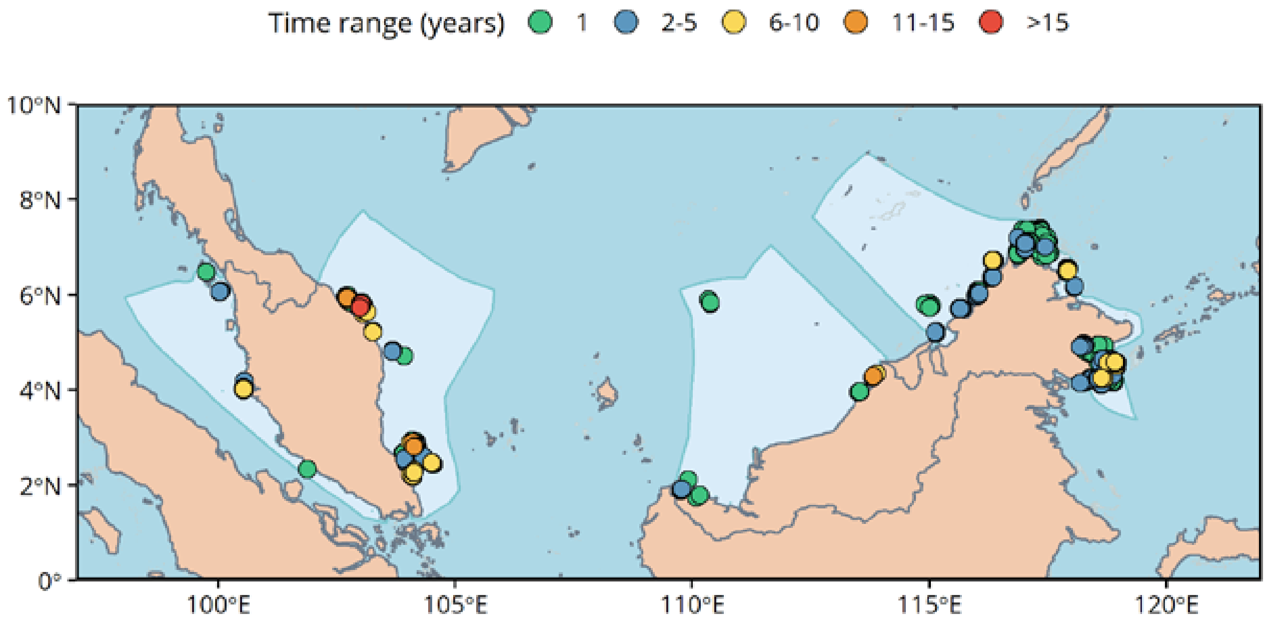


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1987 to 2019. From the data available, monitoring effort was sparse until 2007, at which point monitoring effort started to increase, as 2007 marked the beginning of the Annual Coral Reef Survey[1] (Figure 2A).

The majority (98%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by line intercept transects (2%) (Figure 2B).

Between 1970 and 1999, the sites were mostly surveyed with point intercept transects (44 out of 77 surveys). While line intercept transects were used to conduct 33 surveys during this period, they were not used after this time, and since the 2000s, only line intercept transects were used to monitor coral reefs (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, with 67% of identifications made

1 The Government of Malaysia through its agency, the former Department of Marine Park Malaysia, and now the Department of Fisheries Malaysia, had worked together with the Reef Check Malaysia in conducting the Annual Coral Reef Survey since 2007. Data and information from the annual survey are also used for the country's National reporting to CBD.

at the subgroup level or above. The taxonomic resolution of the data provided is constant over the three time periods. Most of the observations made in Malaysia were recorded at the subgroup level, with around 60% of the observations recorded to this level during each time period (Figure 2D).

The 3 "Algae" subgroups ("Coralline algae", "Macroalgae" and "Turf algae") are represented. Algae were identified to at least the subgroup level for 5% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 "Other fauna" subgroups ("Alcyonacea", "Porifera", "Tunicata" and "Other subgroups") are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 98% of the observations (Figure 2F).

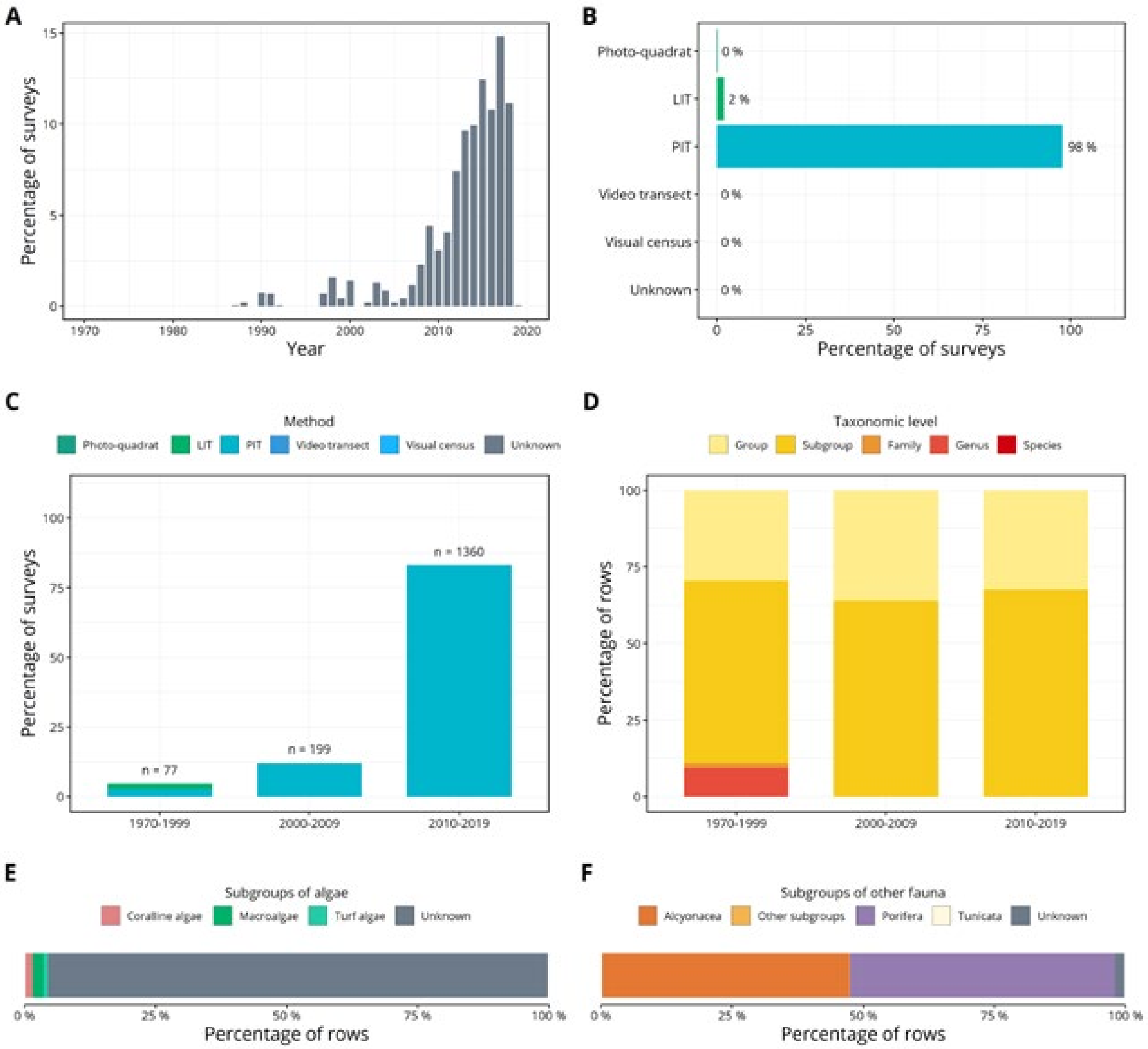


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent[2]. The spatial coverage of the monitoring is good, especially in Peninsular Malaysia and Sabah. To increase the spatial coverage of monitoring programs so as to survey the entire archipelago, we recommend that additional monitoring sites be established in areas such as the Spratly Islands.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 10 years, representing a valuable long-term record for trends in coral reefs. Such efforts are highly valuable and should be pursued.

Methodology[3]. Most of the monitoring sites are surveyed using point intercept transects. However, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Almost 70% of the identifications of benthic organisms were made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. However, 95% of algae observations were recorded only to the group level, which is not sufficient. The subgroup "Tunicata" belonging to the group "Other fauna" is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, we would recommend that Tunicata be included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 585 sites throughout Malaysia, with data available for 26 different years from 1987 to 2019, which is enough to consider that it is implemented and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the algae is not sufficient for this indicator to be considered in use at the country level. Thus, this indicator cannot be considered available at the country level according to the data recorded in the database. Future monitoring protocols should better include the identification of algae in the data collection process as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

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2 Surveys were carried out on several islands off Peninsular Malaysia's East and West coast, covering both established Marine Protected Areas (MPAs) and non-protected areas, and in various parts of East Malaysia, both Sabah and Sarawak.

3 The Annual Coral Reef Monitoring adopted the Reef Check method in the survey, thus explaining the prevalence of the point intercept transect method. An effort was made to ensure that the Reef Check monitoring methodology was compatible with other methods used to monitor substrate cover, fish abundance and invertebrate abundance, particularly those used by Global Coral Reef Monitoring Network (GCRMN). The surveys were carried out by trained government officials from Department of Fisheries and Sabah Parks and as well as trained volunteers.

3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

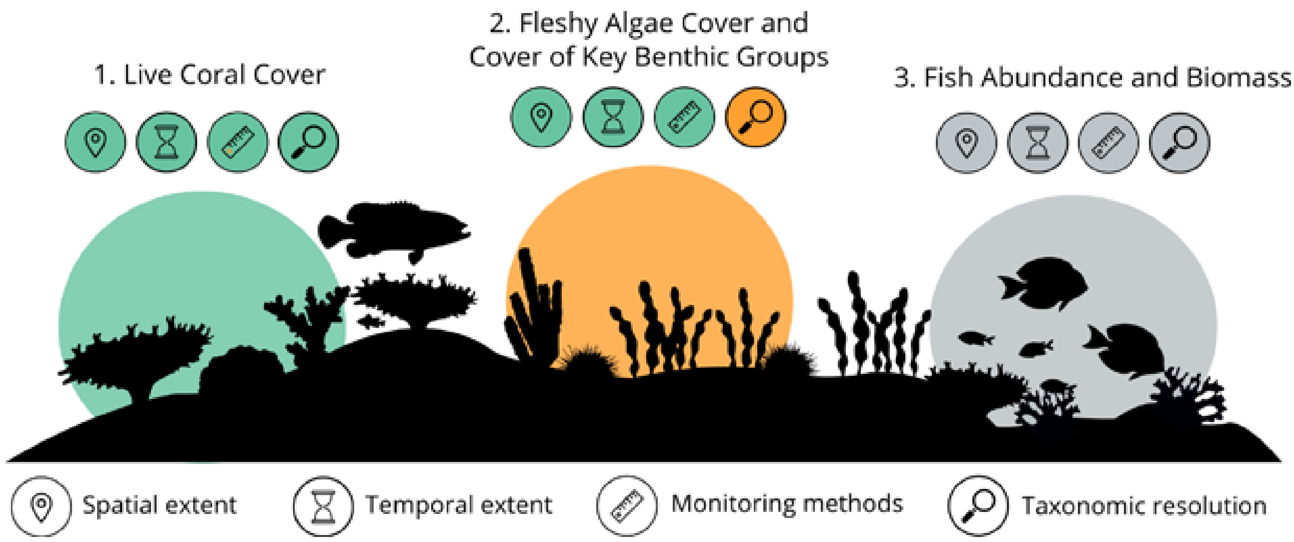

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

To conclude, the ICRI recommended coral reef indicator "Live Coral Cover" presented in Figure 3 is measured and is available on request for most of the existing datasets identified at the country level, while the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is not available. However, it could quickly become available, provided that algae identifications are better included in future monitoring protocols.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Malaysia, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Lim Ai Gaik	aigaik@dof.gov.my	Department of Fisheries Malaysia
Izarenah binti Md. Repin	izarenah@dof.gov.my	Department of Fisheries Malaysia

This summary has been reviewed by the focal points.

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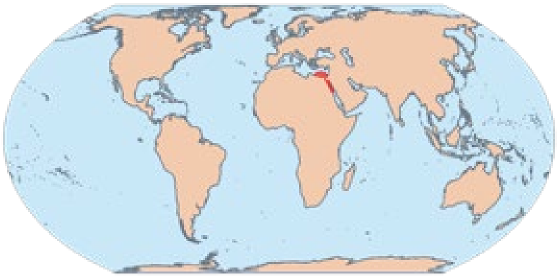
EGYPT



1. Introduction – General context

CORAL REEF CARD

Estimated area: 3,148 km²

Proportion of the world's coral reefs: 1.195%

Ranking based on reef area: 19th

Some of the most beautiful reefs in the Red Sea are found off the coast of Egypt. Their presence has greatly benefited the development of the tourism industry in the area and they also represent a non-negligible asset for fisheries.

The Egyptian waters are home to 310 species of hard corals (IUCN, 2021) and there are 507 species of reef fishes that are known to inhabit its coral reefs (Froese & Pauly, 2020). Reef building corals have built fringing reefs and patch reefs along the coast as well as several submerged offshore reefs (Spalding et al., 2001).

In Egypt, most of the benefits provided by coral reefs come from tourism, as it is one of the main sources of national income and thus one of the major pillars for Egyptian development. Tourism provides 4.5 million jobs, which represents around 13% of the labor force in Egypt (Hilmi et al., 2012). The contribution of reef tourism to the GDP was estimated at 2% in 2017 (Spalding et al., 2017). Fisheries have also been long-established in the region, with a fleet of 1,863 fishing vessels in the Red Sea (Samy-Kamal, 2015) and a long tradition of coral reef-based fisheries for domestic consumption (FAO, 2010). The fisheries industry involves more than 7% of the national workforce. The value of the commercial landing of reef fish is estimated at US$36 million per year, which represented 0.04% of the country's GDP at the time of the study (Cesar, 2003). As beach erosion is not considered a major problem in Egypt, the benefits provided by coral reefs in terms of coastal protection have not yet been estimated (Cesar, 2003).

While they provide numerous services, 61% of Egyptian coral reefs were deemed seriously at risk from human impact (Burke et al., 2011). The main anthropogenic threats are unsustainable coastal development and the pollution it generates, overfishing and negative impacts caused by unsustainable tourism. They are also threatened by increasing seawater temperatures and acidification due to global warming (Cesar, 2003).

Marine protected areas in Egypt span 4,100 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,715 km² of coral reefs within their boundaries, thus placing 54.5% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Egypt, with data from a total of 169 sites included within the GCRMN dataset. These observations represent 0.4% of the total global dataset compiled by the GCRMN (7,666 rows).

Sites from which data were provided occur along all the Egyptian Red Sea coast, including the Gulf of Aqaba, to the exception of the Gulf of Suez. Medium and long-term monitoring sites within Egypt are common, with time series at numerous sites exceeding 6 years (Figure 1).

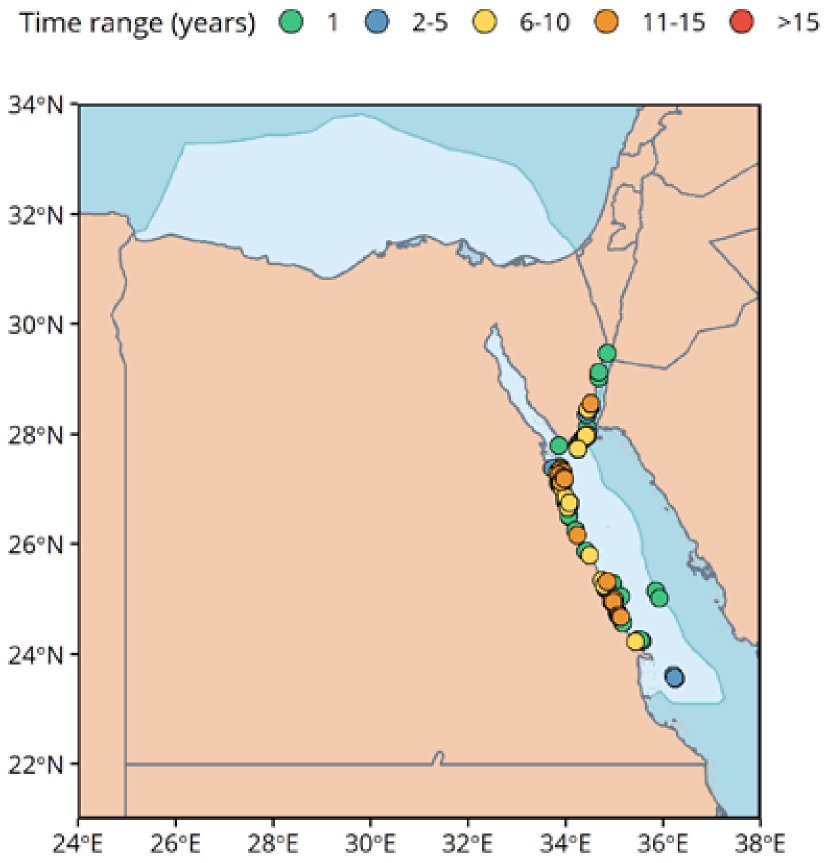


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1996 to 2019. The percentage of sites surveyed per year has fluctuated around 5 % since 2001 (Figure 2A).

The majority (43%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, while the methods used for the remaining 57% of surveys were not recorded in the database[1] (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, with 65% of identifications made at the subgroup level or above. The taxonomic resolution of data provided slightly decreased over the 3 time periods, as the proportion of observations identified to the subgroup level or above decreased from 70% to almost 62% (Figure 2D).

1 Additional information regarding the monitoring methods were provided. All of the sites in the Gulf of Aqaba were surveyed using point intercept transects. All of the sites located at the entrance of the Gulf of Suez and in Northern as well as Southern Red Sea were surveyed using permanent photo-quadrats between 2001 and 2011 and with point intercept transects between 2012 and 2019.

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 12% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented in the database. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

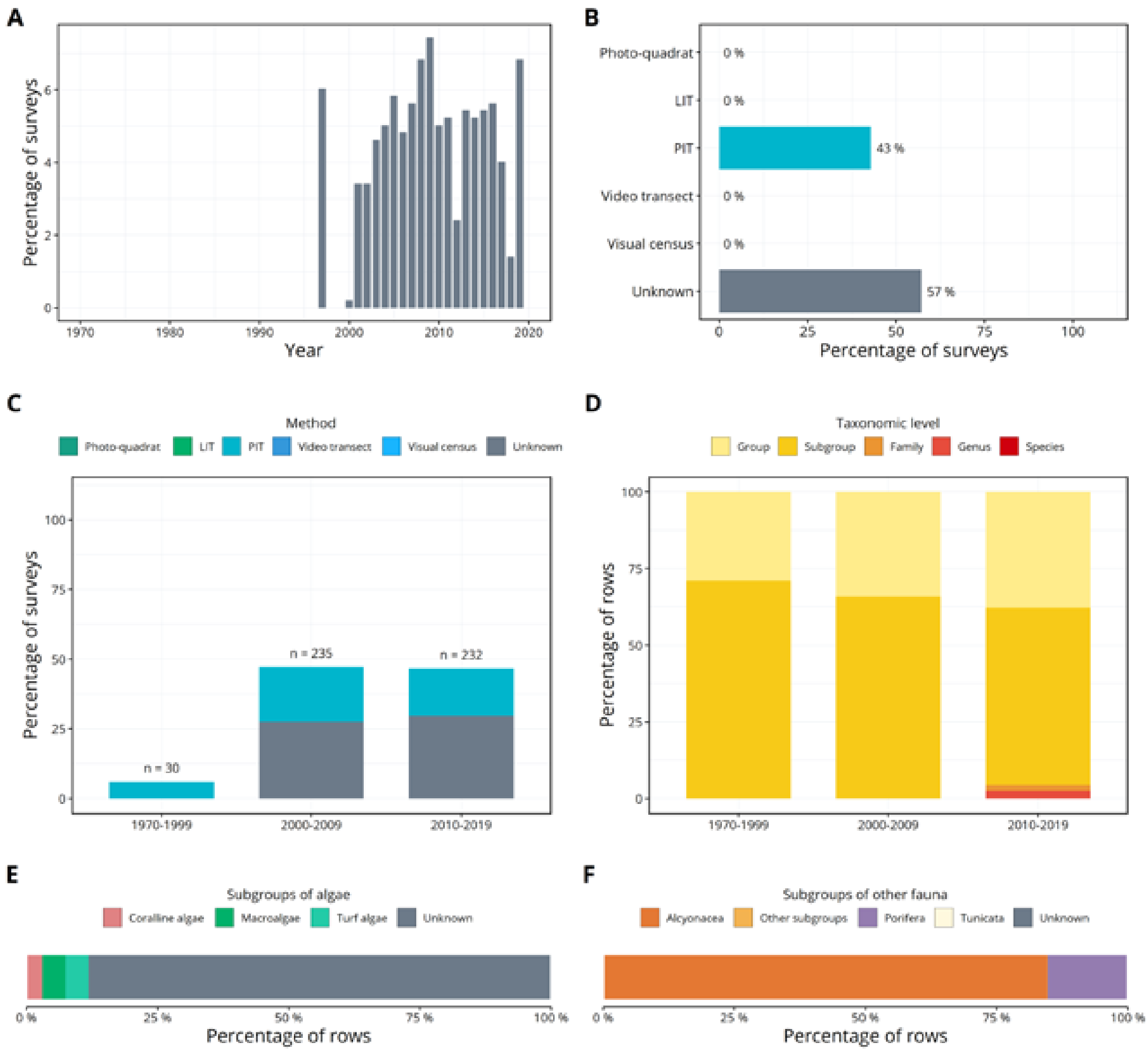


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already very good, especially along the Egyptian Red Sea coast. To further increase the spatial coverage of monitoring programs, we recommend that additional monitoring sites be established in the Gulf of Suez as well as in the southern part of the Egyptian Red Sea coast.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 5 years, representing a valuable medium-term record for trends in coral reefs. Such efforts are highly valuable and should be pursued.

Methodology. Information regarding the methods is lacking for 57% of the surveys conducted. However, when implementing new monitoring sites, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. More than half of the available data have a taxonomic precision at the subgroup level or above, which is enough to assess changes in benthic composition. Further, the subgroup "Tunicata" belonging to the group "Other fauna" is not represented in the database. It might be due to the fact that these organisms were absent from the sites or because they were not included in monitoring protocols. In the second case, we recommend that they be included in future monitoring protocols. While all subgroups of "Algae" are represented, the subgroup level is unknown for 88% of observations. Future monitoring protocols should better include the identification of algae in the data collection process as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 169 sites throughout Egypt for 21 different years between 2001 and 2019, which is enough to consider that this indicator is measured and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** While the cover of key benthic groups has been well monitored, the lack of precision when identifying algae prevents this indicator from being considered as measured. Thus, this indicator fails to accurately represent the cover of algae and the cover of key benthic groups at the country level.
3. **Fish Abundance and Biomass**[2]. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

2 Although it was not included in the 2020 GCRMN world report database, this indicator has been monitored in sites in the North and in the South of the Red Sea. For each site, 4 replicates were conducted using belt transect of 25m length and 5m width and 1m elevation.

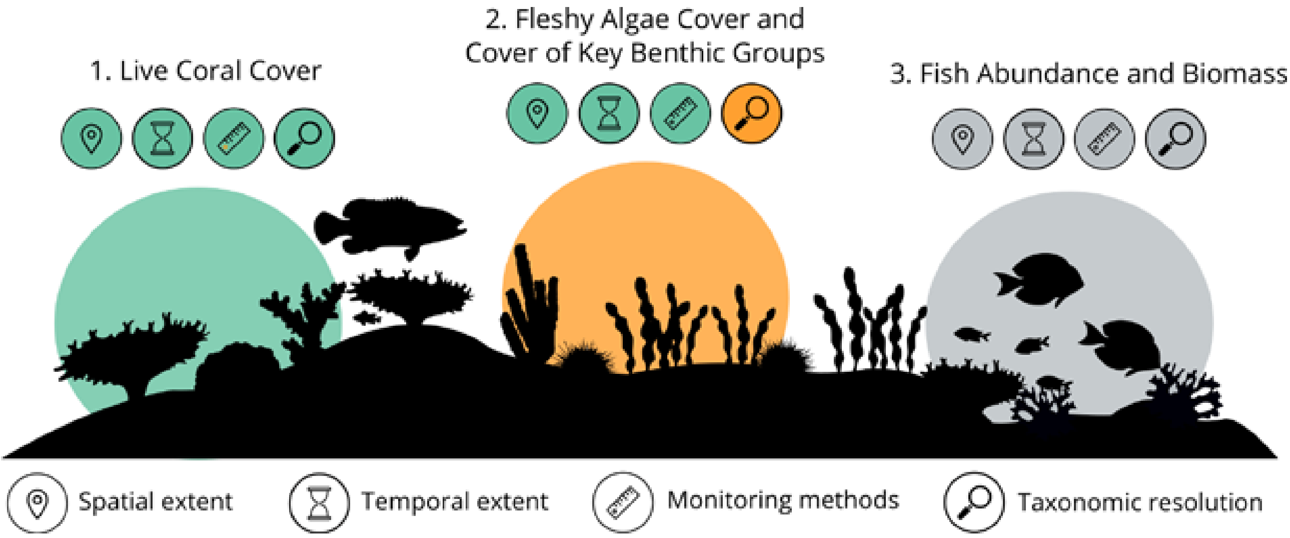


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

To conclude, the ICRI recommended coral reef indicator "Live Coral Cover" presented in Figure 3 is measured and is available on request for most of the existing datasets identified at the country level, while the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is not available. However, it could quickly become available, provided that algae identifications are better included in future monitoring protocols.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Egypt, please contact the focal point, whose contact information is available in the following table.

Name	Contact	Organisation
Tamer Monir Attalla	tamer_m_attalla@yahoo.com 002-01227285839	EEAA-NCS- Red Sea Protectorates

This summary has been reviewed by the focal points.

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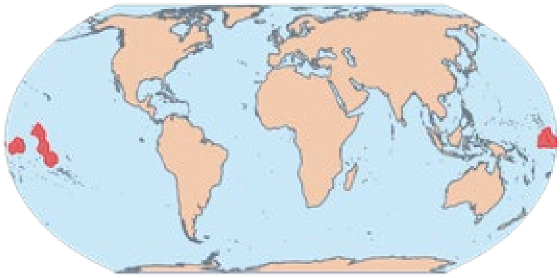

KIRIBATI

1. Introduction – General context

CORAL REEF CARD

Estimated area: 3,064 km²

Proportion of the world's coral reefs: 1.163%

Ranking based on reef area: 20th

Kiribati is an archipelagic nation comprised of 33 low-lying atolls located in the middle of the Pacific Ocean. Out of the 33 atolls, 22 are inhabited. Due to its remote location, the country's coral reefs are almost pristine and support the adjacent marine and land-based ecosystems.

There are 363 species of hard corals (IUCN, 2021) and 459 species of reef fishes that are known to inhabit the local coral reefs (Froese & Pauly, 2020). All types of coral reefs can be found in Kiribati, including fringing reefs, barrier reefs, atolls and patch reefs (Lovell, Kirata, & Tekinaiti, 2003).

Local communities are highly dependent on coral reefs for food, income and for coastal protection. The benefits provided by coral reefs through fisheries have been separated into two categories. The first category comprises the benefits received through subsistence fisheries, which were estimated to be valued between US$8.6 million and US$31 million, which represented 4.7-16.8% of the country's GDP in 2013. The second category comprises the benefits derived from the sale of fish from small-scale fisheries in local markets. The benefits provided by this second category are estimated to range between US$2.5 million and US$9 million, which represented 1.4-4.9% of the GDP (Rouatu et al., 2017). A survey published in 2014 highlighted the fact that all households depend on the nearby coral reefs for fishing for their subsistence (Reddy, Groves, & Nagavarapu, 2014). Coral reefs also play a role in attracting tourists in Kiribati. However, due to their isolated location and a lack of investment in the development of facilities, tourism is relatively limited in the archipelago, with only 5,000 tourists visiting the islands per year. The annual value represented by this industry is estimated at US$3.9 million, which represented 2.1% of the country's GDP. The value of coastal protection by coral reefs has yet to be estimated. However, it is certain that they play an important role in protecting the atolls from storms and coastal erosion. Where coral mining for infrastructure development or construction are common, such as on South Tarawa atoll, significant levels of coastal erosion can be found (Rouatu et al., 2017).

Coral reefs in Kiribati are threatened by rising sea surface temperatures, linked to climate change and global warming. The first broad-scale bleaching events in Tarawa occurred in late 2004 and early 2005 (Donner, Kirata, & Vieux, 2010). Reefs are also threatened by anthropogenic activities, namely over-fishing, destructive fishing practices and over-harvesting of natural resources. Coastal construction, nutrient run-offs from sewage waters and solid waste disposal represent additional threats to the integrity of the reefs bordering the atolls (Mangubhai et al., 2019).

Marine protected areas in Kiribati span 397,600 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 142 km² of coral reefs within their boundaries, thus placing 4.6% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Kiribati, with data from a total of 18 sites included within the GCRMN dataset. These observations represent 0.02% of the total global dataset compiled by the GCRMN (394 rows).

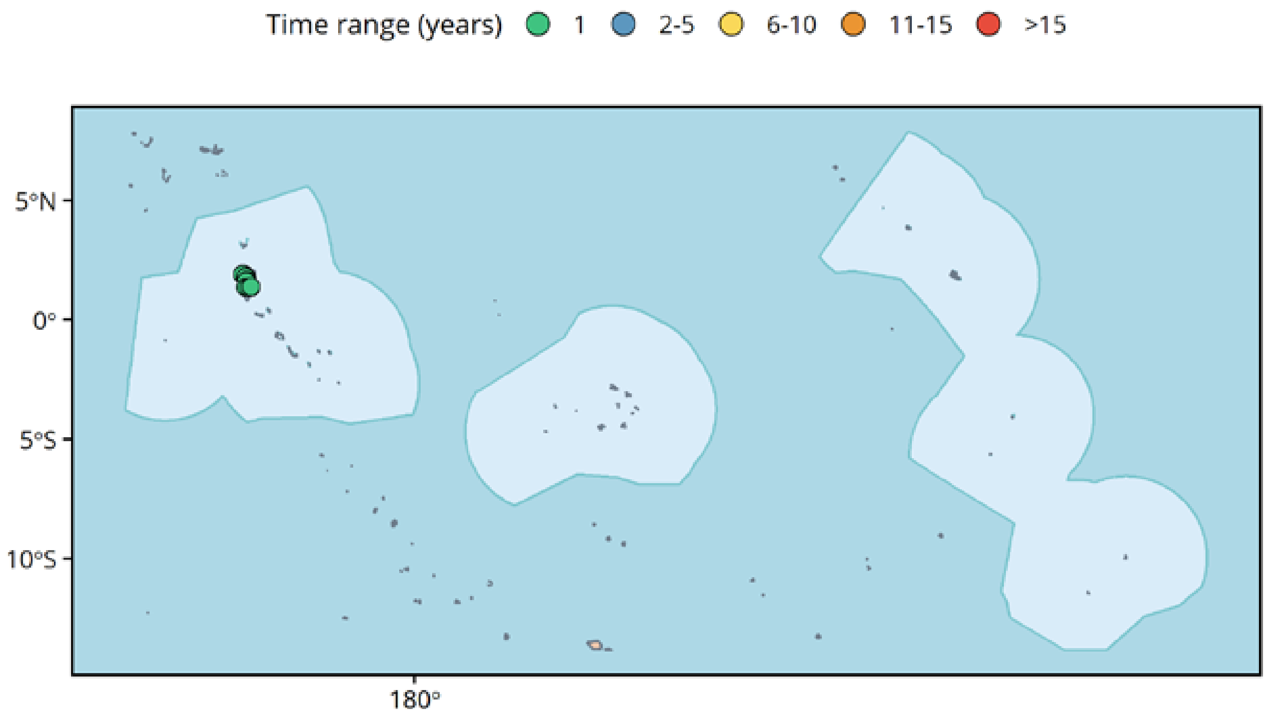

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Sites from which data were provided are concentrated around Tarawa, which is the atoll where the capital is located. The rest of the archipelago is not included in the database. All of the sites were only surveyed for 1 year (Figure 1).

All of the surveys that were contributed to the database were conducted in 2011 and 2018 (Figure 2A).

The majority (89%) of surveys contributed to the 2020 GCRMN database were conducted using photo-quadrats, followed by point intercept transects (11%) (Figure 2B).

Between 2010 and 2019, 16 surveys were conducted using photo-quadrats and 2 surveys with point intercept transects (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: "Abiotic", "Hard living coral cover", "Hard bleached coral", "Hard dead coral", "Algae", "Other fauna" and "Seagrass". Some of these groups are further divided into subgroups, such as the group "Other fauna", which encompasses the subgroups "Alcyonacea", "Porifera" and "Tunicata" in addition to "Other subgroups" (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with 88% of identifications made at the subgroup level or above. Around 60% of identifications were made at the family level or above, the genus level being the most represented in the database, with 51% of organisms identified to this level (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 96% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 89% of the observations (Figure 2F).

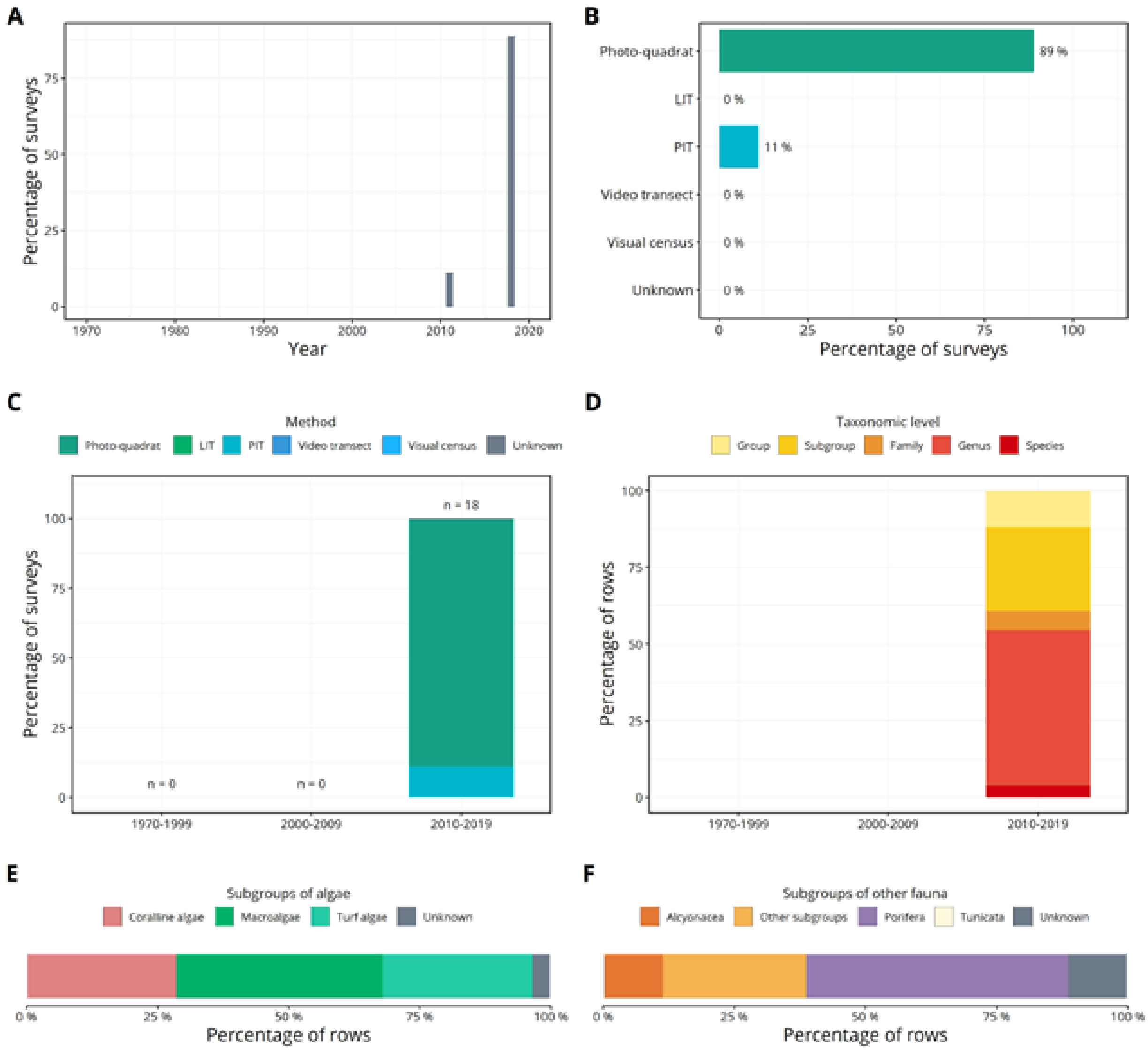

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Anaysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. To increase the spatial coverage of monitoring programs, we recommend that additional monitoring sites be established throughout the archipelago around both inhabited and uninhabited islands.

Temporal Extent. The temporal extent for most of the monitoring sites is limited to only a single year, and we thus recommend that a long-term monitoring program be established and that monitoring on existing sites be extended.

Methodology. Most of the monitoring sites were surveyed with photo-quadrats, which should be continued. The use of image-based methods is valuable, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the data provided have a high level of taxonomic precision, which is particularly relevant to characterise changes in benthic composition over time. Different subgroups belonging to the groups “Algae” and “Other fauna” were commonly represented indicating that the surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, the subgroup “Tunicata” belonging to the group “Other fauna” is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were only recorded to the group level or because they were not included in monitoring protocols. In the last two cases, it would be recommended that these organisms be included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was measured on 18 sites around the main atoll in 2011 and 2018. However, the spatial coverage of the monitoring is not sufficient for this indicator to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered as measured. However, the spatial extent of the monitoring is too limited for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

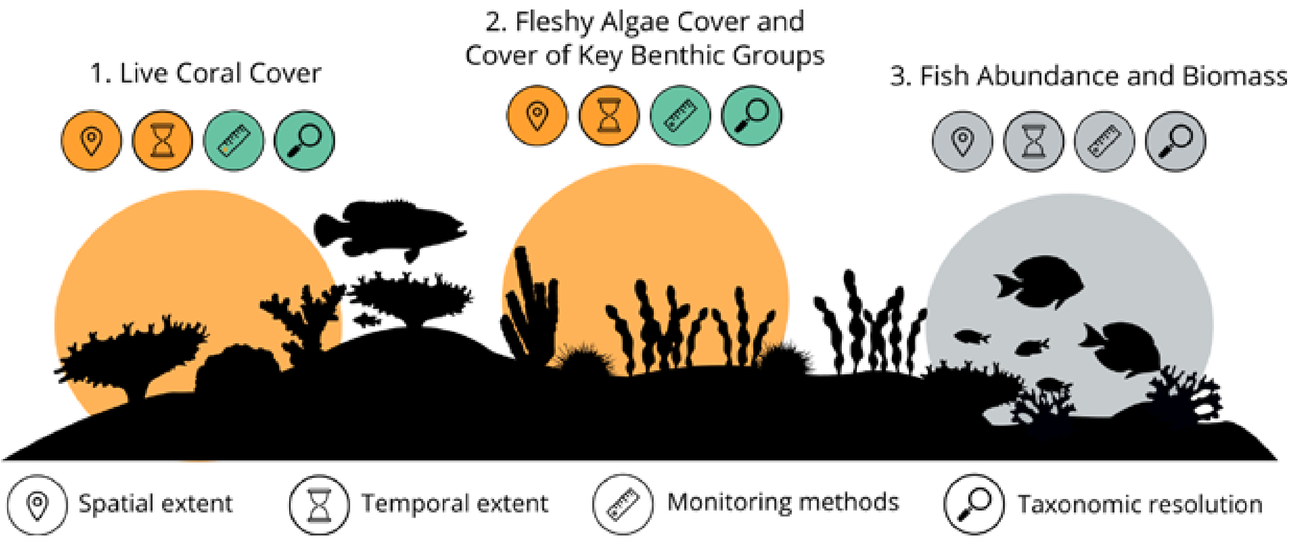

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, two of the four ICRI recommended coral reef indicators presented in Figure 3 are measured but are not yet monitored widely enough to be considered available at the country level. The spatial extent of the monitoring should include the other provinces of the archipelago in order for the monitoring to be representative of the state of the coral reefs in Kiribati.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Kiribati, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Aranteiti Kiareti	aranteitik@fisheries.gov.ki	Senior Fisheries Assistant
Max Peter	maxp@fisheries.gov.ki	Principal Fisheries Officer and the current Officer in Charge of Kiritimati (Christmas Island Fisheries Sub-Division)
Toaea Beiateuea	toaeab@fisheries.gov.ki	Senior Fisheries Assistant
Tooreka Temari	toorekat@fisheries.gov.ki	Coastal Fisheries Director, Ministry of Fisheries and Marine Resources Development, Tarawa, Kiribati

This summary has been reviewed by the focal points.

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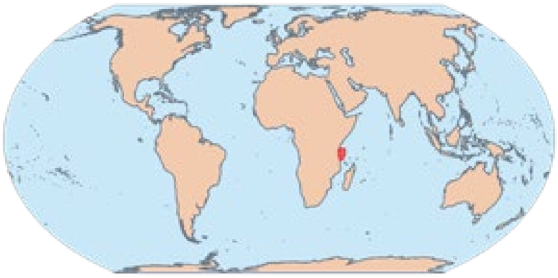
TANZANIA



1. Introduction – General context

CORAL REEF CARD

Estimated area: 3,034 km²

Proportion of the world's coral reefs: 1.151%

Ranking based on reef area: 21st

Tanzania is located on the East Coast of Africa and displays diverse marine biotopes and ecosystems, characteristic of the tropical West Indian Ocean. Two main sets of islands are located off its shores. The first is the Zanzibar archipelago, which encompasses Pemba as well as Unguja Islands, and the second is Mafia Island. Many smaller islands, islets and reefs are also scattered along the coast.

There are 280 species of hard corals (IUCN, 2021) and 678 species of reef fishes that are known to inhabit the reefs (Froese & Pauly, 2020). Coral reefs around Tanzania can be found in the form of fringing reefs, patch reefs and reef flats (Wagner, 2004).

Coral reefs sustain the local communities through different ecosystem services. Artisanal and small-scale fisheries benefit directly from coral reefs, as they represent 98% of total fish production and 1.3% of the country's GDP. This small contribution to the GDP is totally uncorrelated to the importance of fisheries for coastal communities. Fisheries support numerous coastal households that rely on coral reefs for subsistence, income and employment (ASCLME, 2012). The number of artisanal fishermen is estimated at 53,035 in mainland Tanzania (United Republic of Tanzania, 2018) and between 28,000 and 37,000 in Zanzibar (World Bank Group, 2016). Coral reefs also represent an asset for tourism development. Tourism represents around 17.2% of the GDP and is estimated to employ 288,700 people throughout Tanzania (ASCLME, 2012). Although mainland coastal tourism is relatively new and limited due to a lack of facilities and tourism related-activities, Zanzibar and Mafia islands are exceptional destinations with respect to their beaches and cultural tourism. In Zanzibar, tourism is the main source of employment as it sustains between 35,000 and 45,000 jobs and 70% of the local economy depends on it (World Bank Group, 2016). Mainland coastal tourism is a growing industry and the presence of healthy coral reefs will play a great role in its development. Coastal erosion has been observed in several areas but the benefits derived from coastal protection by coral reefs have yet to be evaluated.

The coral reefs in Tanzania face several natural and anthropogenic threats. Bleaching and COTS outbreaks represent the main natural threats (Johnstone, Muhando, & Francis, 1998; Muhando, 2001; Ussi, Mohammed, Muhando, & Yahya, 2019), while pollution and overfishing are the two main anthropogenic threats. These coral reefs are also threatened by direct physical destruction due to unsustainable activities, such as the use of drag-nets or live coral mining (Wagner, 2004). While for many years blast fishing was a major issue (Chevallier, 2017), political and administrative interventions between 2015 and 2018 have worked, and the use of coral blasting as a fishing method has completely stopped.

In order to protect coral reefs, the Marine Parks and Reserves Unit (under the Ministry responsible for Fisheries) established 3 marine Parks and 15 marine Reserves. In addition, there are also several community-managed areas, which together encompass more than 5,100 km² of marine habitat (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020). The Tanzanian MPAs include 811 km² of coral reefs within their boundaries, thus placing 26.7% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Tanzania, with data from a total of 160 sites included within the GCRMN dataset. These observations represent 0.1% of the total global dataset compiled by the GCRMN (2,419 rows).

Sites from which data were provided cover almost all of the coral reefs found in the Tanzanian waters. Some sites are heavily surveyed, such as the areas around Zanzibar and Mafia Islands. Further, the majority of the sites have been surveyed for at least 6 years, providing time series for analysis. The temporal coverage exceeds 15 years for several of the sites (Figure 1).

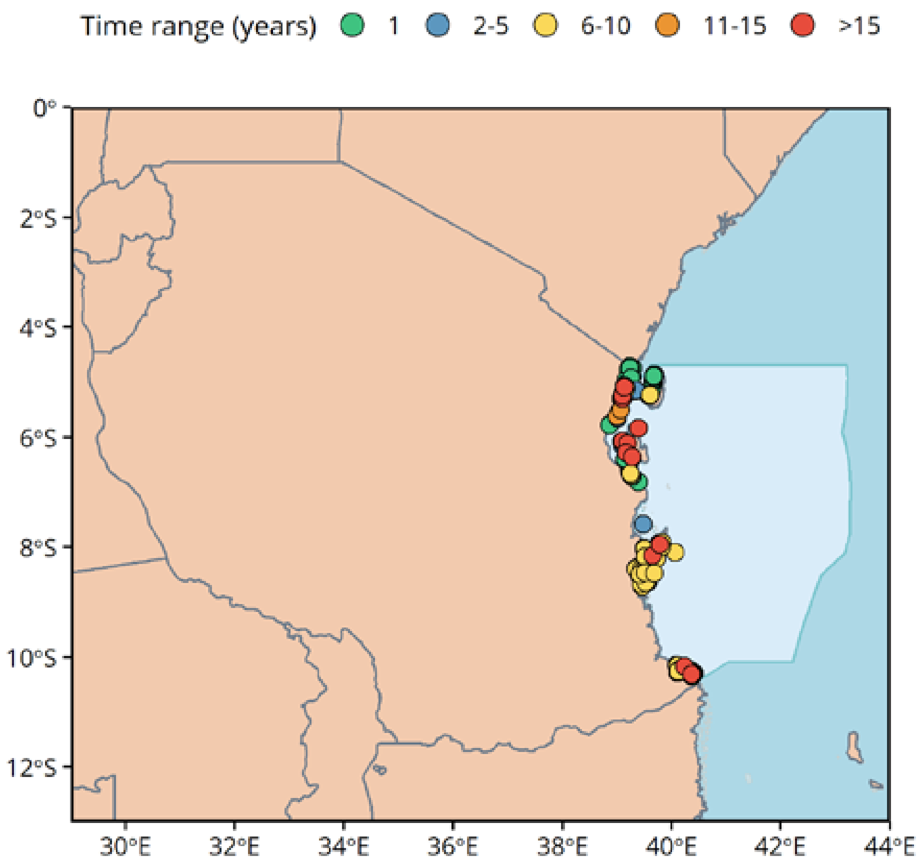


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1987 to 2018. The percentage of surveys conducted per year has not been consistent over the years, however monitoring has been recorded in the database almost every year for the past 20 years (Figure 2A).

The methods used to collect the data contributed to the 2020 GCRMN database is available for only 20% of the surveys. Line intercept transects were used on 12% of the surveys, followed by point intercept transects (5%) and photo-quadrats (3%). The method used during the surveys was not recorded for 80 % of the surveys (Figure 2B).

However, the percentage of monitoring surveys for which the method was not recorded in the database decreased over the three time periods. Between 1970 and 1999, the method used to conduct 94 out of the 100 surveys was not recorded in the database. Photo-quadrats were used in 11 surveys and point intercepts transects in 13 surveys between 2000 and 2009, and the survey method was not recorded for the other 135 surveys. Between 2010 and 2019, 47 surveys were conducted using line intercept transects and 1 with photo-quadrats. The method was not recorded for the remaining 86 surveys (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, with 58% of identifications made at the subgroup level or above. With respect to the identification of organisms, an increase in taxonomic precision occurred during the last time periods. Between 1979 and 2009, around 50% of observations were identified to at least the subgroup level and this increased to more than 70% between 2010-2019, as 29% of observations were recorded to the genus level (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 67% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (Alcyonacea, Porifera, Tunicata and others) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 75% of the observations (Figure 2F).

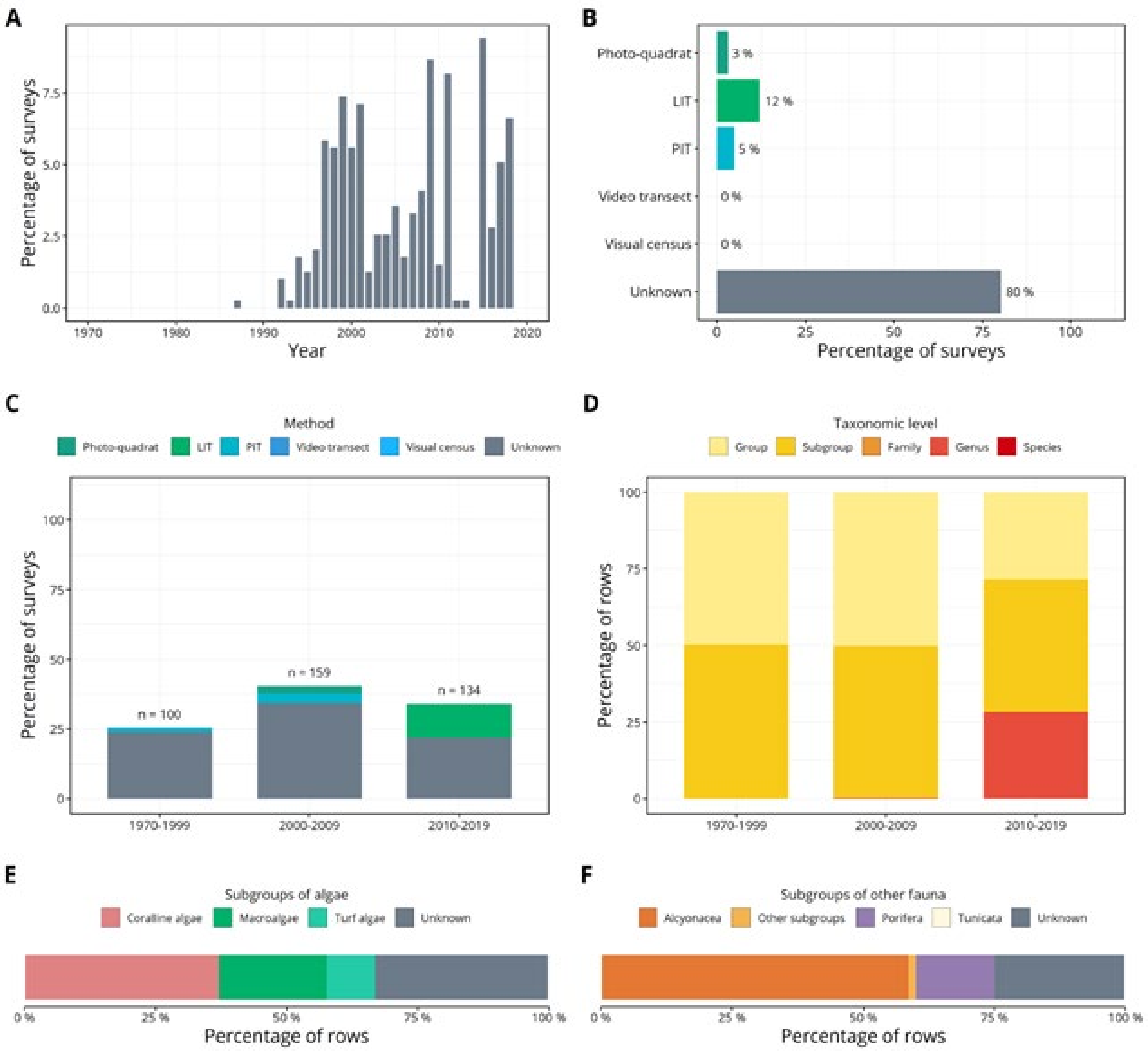


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent[1]. The spatial coverage of the monitoring is excellent, especially around Unguja and Mafia Islands. To further increase the spatial coverage of monitoring programs, we recommend that additional monitoring sites be implemented between Kilwa Bay and Mnazi Bay.

Temporal Extent. For numerous monitoring sites, the temporal extent exceeds 6 years, representing valuable mid and long-term records for trends in coral reefs. These time series are highly valuable to monitor the evolution of coral reef communities and the continuation of these efforts is encouraged.

Methodology[2]. Unfortunately, the methods used in the majority of sites contributed to the GCRMN database were unknown. However, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. More than half of the identifications were made at the subgroup level or above, which is also true for the identifications of organisms belonging to the groups "Algae" and "Other fauna". This level of taxonomic precision is enough to detect changes in benthic communities. However, more than a quarter of observations of the organisms belonging to these two groups were not identified to the subgroup level. Further, the subgroup "Tunicata" belonging to the group "Other fauna" is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but have been recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, we recommend that these organisms be included in future monitoring protocols, and that the identification efforts made during the 2010-2019 period be pursued.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data being contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 160 sites providing data representative of the distribution of coral reefs in Tanzania, with data available for 27 different years from 1987 to 2018. This is enough to consider that this indicator is available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding the other benthic groups is sufficient for this indicator to be considered in use at the country level. However, increasing the taxonomic precision for organisms belonging to the groups "Algae" and "Other fauna" would ensure changes to be better detected in benthic communities.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

1 WWF Tanzania also contributes to the monitoring effort, and monitors the reefs around Songo Songo Island.

2 The survey methods currently used are all based on English et al. (1994). For more details on coral reef monitoring in Tanzania, please refer to (Muhando, 2008, 2009).

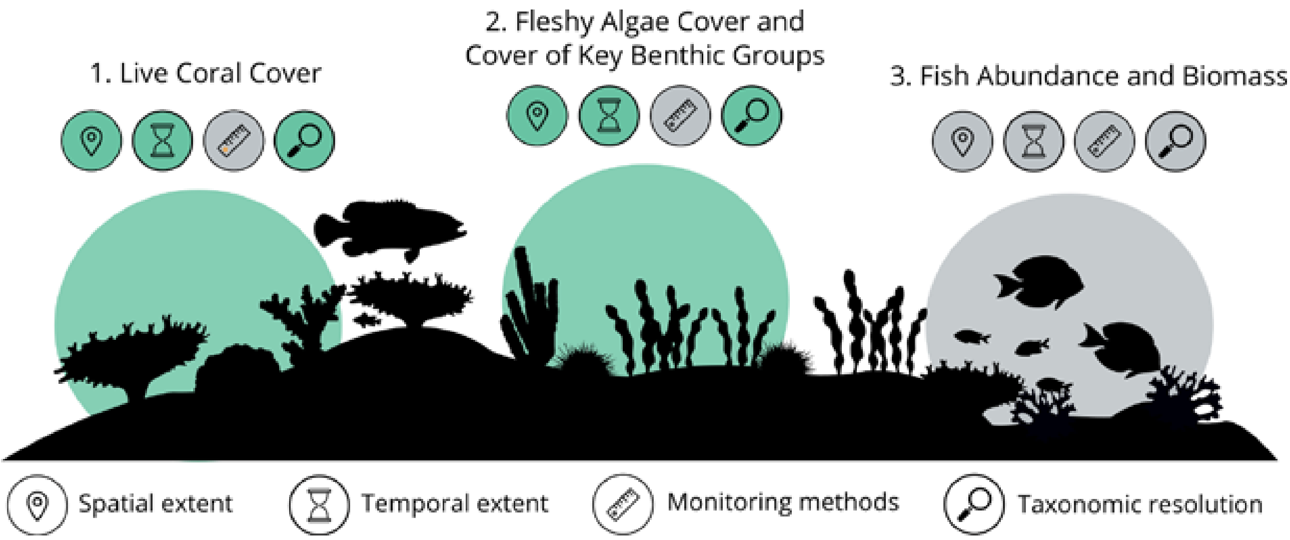


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Tanzania, please contact the focal points, whose contact details are available in the following table.

Name	Contact	Organisation
Dr Christopher A. Muhando	Institute of Marine Sciences (University of Dar es Salaam), cmuhando@gmail.com	Reef benthos
Dr Rose Sallema-Mtui	National Environmental Management Council - nrsallema@yahoo.com	Secretariat for Tanzania Coral Reef Task Force
Dr Saleh Yahya	Institute of Marine Sciences (University of Dar es Salaam) saleh_y@yahoo.com	Reef fish

This summary has been reviewed by the focal points.

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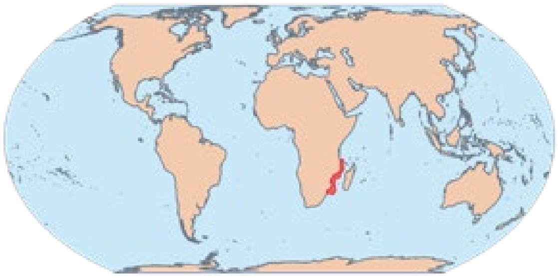
MOZAMBIQUE



1. Introduction – General context

CORAL REEF CARD

Estimated area: 2,536 km²

Proportion of the world's coral reefs: 0.963%

Ranking based on reef area: 22nd

The Republic of Mozambique is located on the South-Eastern coast of Africa, where its coastline runs over 2,700 km, making it the 3rd longest coastline in Africa.

Coral reefs are built by 328 species of hard corals (IUCN, 2021) and are home to 937 fish species (Froese & Pauly, 2020). Fringing coral reefs in the North run almost continuously along the coast for 700 km. The presence of rivers southward disrupts the presence of coral reefs, making their distribution more heterogeneous. Fringing reefs and patch reefs are the most abundant. Coral reefs are also found offshore with their associated islets (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Due to its extended coastline, marine resources and ecosystem services stemming from the presence of coral reefs are of high importance as 60% of the population live in coastal areas (INE, 2007). Tourism represented 6.6% of the country's economy in 2019, with a value of US$954.1 million and provided employment to 667,600 people (World Travel & Tourism Council, 2020). Coral reefs are highly attractive for tourists and there is a healthy dive industry along the coast. In 2012, coastal tourism sustained around 100,000 jobs (ASCLME, 2012) and reef-based tourism represented 0.47% of Mozambique's GDP (Spalding et al., 2017). Coastal communities also depend on coral reefs for subsistence. Most of the fishing is done by artisanal and small-scale fishers. In 2008, their catches represented 84.3% of domestic fish production in Mozambique (ASCLME, 2012; Food and Agriculture Organization of the United Nations, 2019). In 2016, 65,600 people were reported as engaged in fisheries (Food and Agriculture Organization of the United Nations, 2019). Though it has not yet been formally quantified, coastal protection provided by coral reefs has been recognized as highly important as the country is exposed to cyclones, storms and high levels of coastal erosion (Cabral et al., 2017).

Coral reefs in Mozambique are threatened by natural phenomena such as increasing sea temperature, cyclones, flooding and COTS outbreaks. In addition, anthropogenic activities, such as increased sedimentation, overfishing, destructive fishing practices (e.g. beach seining) and trampling pose additional threats to the reefs and have the potential to alter the crucial services they provide (ASCLME, 2012).

Marine protected areas in Mozambique span 24,100 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 346 km² of coral reefs within their boundaries, thus placing 13.7% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2020). Monitoring effort provides good coverage of the coral reefs around Mozambique, with data from a total of 142 sites included within the GCRMN dataset. These observations represent 0.07% of the total global dataset compiled by the GCRMN (1,532 rows).

Sites from which data were provided occur in most of the coral reefs in Mozambique. Sites tend to have been surveyed for one to five years, except for a few in the South, that have been monitored for more than 10 years (Figure 1).

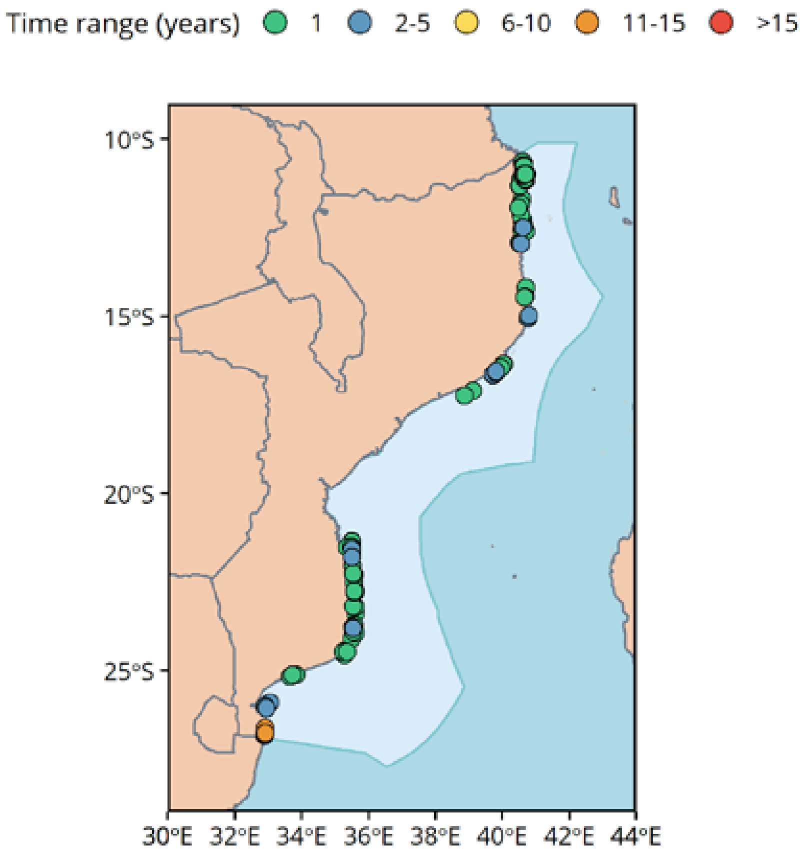


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1997 to 2018. The monitoring effort has been heterogeneous and irregular over the years, with a peak in effort in 2014 (Figure 2A).

The information regarding the method used was not recorded for 71% of the surveys. Photo quadrats and point intercept transects were used on 22% and 7% of the remaining surveys (Figure 2B).

Photo-quadrats were used from 2010 to 2019, which is the period when most sites were surveyed. This method was used in 43 surveys during this period (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, as 75% of identifications were made at the subgroup level or above. Observations made during the 1979-1999 period were identified only up to the subgroup level at most. The precision at which organisms were identified increased between 2000-2009 and 2010-2019, mainly because the proportion of identifications made at the genus level increased from 13% to 23% (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 90% of the observations (Figure 2E).

The 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 84% of the observations (Figure 2F).

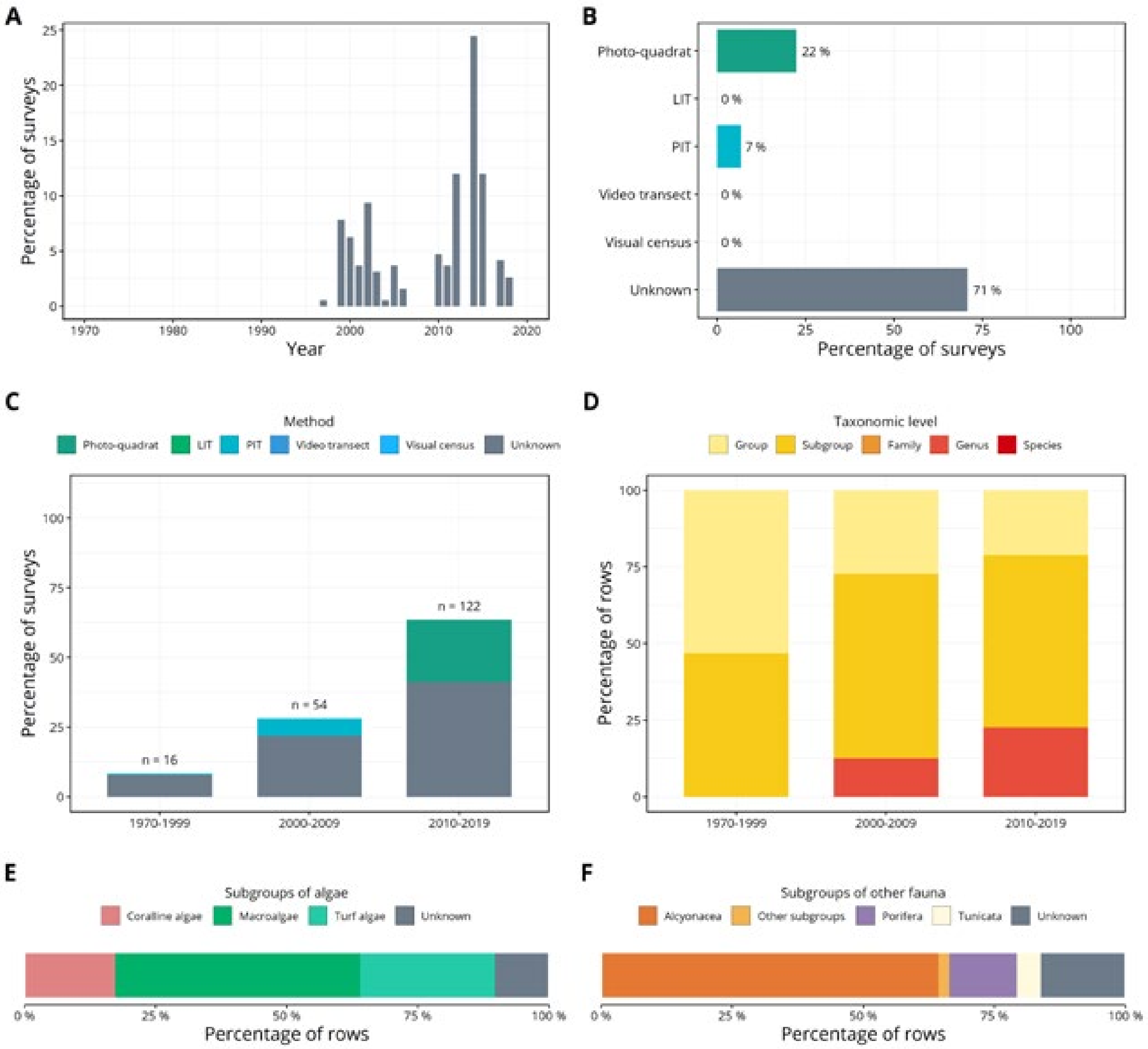


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent, especially in the regions of Cabo Delgado and Inhambane. Such efforts are good and should be continued.

Temporal Extent. The temporal extent of most of monitoring sites is low and does not exceed 5 years. Thus, we recommend that more fixed monitoring sites be established and that existing monitoring sites be extended.

Methodology. The methods used to monitor the sites over the years were not recorded in the database for 71% of the surveys. We recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Around 75% of identifications of benthic organisms were made at the subgroup level or above, which is particularly relevant for assessing changes in benthic communities over time. Different subgroups belonging to the groups "Algae" and "Other fauna" were commonly represented indicating that the surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, around 15% of observations of organisms belonging to the groups "Algae" and "Other fauna" were recorded only to the group level. Although it is still enough to assess changes in the composition of the communities, it would be of interest to better include these groups in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 142 sites with data available for 16 different years from 1997 to 2018, providing data that is representative of the repartition of coral reefs in Mozambique. Further, all major criteria are met for this indicator to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** All major criteria are met and since the taxonomic resolution of the observations regarding the other benthic groups is sufficient, this indicator can be considered in use at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

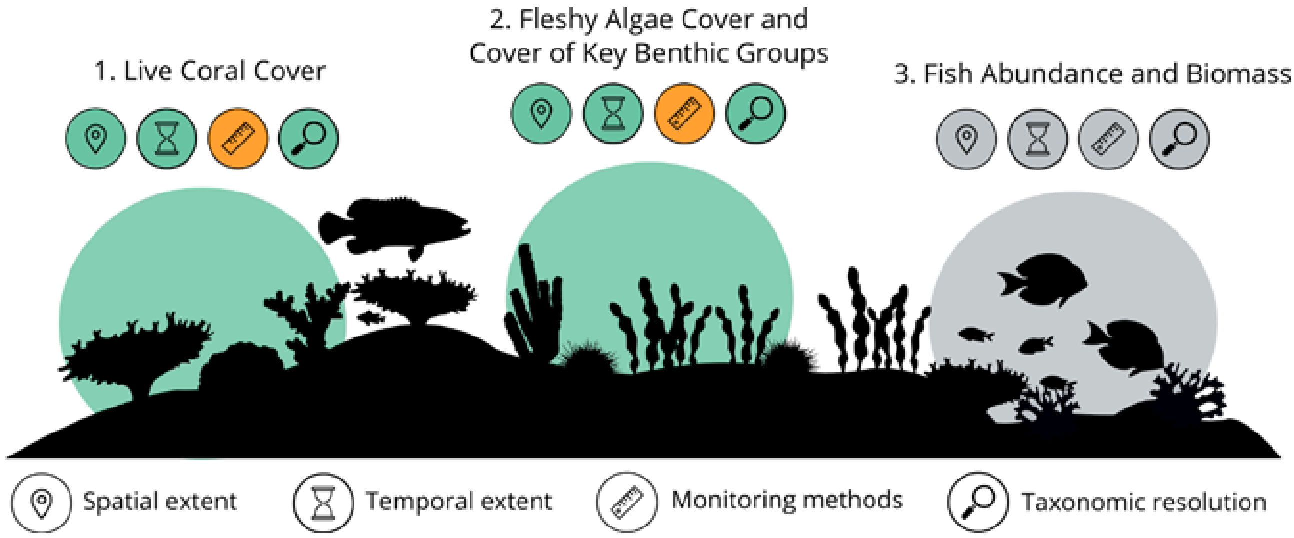


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

A coral reef monitoring focal point for Mozambique has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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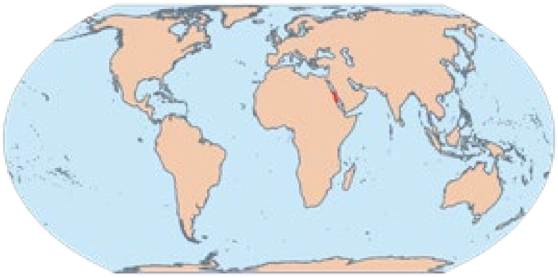
SUDAN



1. Introduction – General context

CORAL REEF CARD

Estimated area: 2,313 km²

Proportion of the world's coral reefs: 0.878%

Ranking based on reef area: 23rd

Sudan is located on the West coast of the Red Sea. Its waters are home to coral reefs which are almost pristine, providing biodiversity-based services to the coastal communities through fisheries, tourism and coastal protection.

There are 303 species of hard corals (IUCN, 2021) and 270 species of reef fishes that are known to inhabit the Sudanese coral reefs (Froese & Pauly, 2020). The coast of Sudan is bordered by a nearly continuous fringing reef. A complex barrier reef can also be found offshore in addition to numerous islands (Klaus et al., 2008).

While fisheries in Sudan contribute marginally to the country's GDP, coastal marine fisheries represent an important source of protein for local communities. In 2018, artisanal fisheries sustained 3,600 jobs (FAO, 2020). Tourism as a whole contributed to 6% of the GDP in 2019 and sustained 586,300 jobs throughout the country. Although the Red Sea is one of the Sudan's tourist destinations, and tourism is growing in the country, it remains limited (World Travel & Tourism Council, 2020) as reef tourism in Sudan represented 0.05% of the country's GDP (Spalding et al., 2017). For instance, in 2008 there were only 8 to 10 dive boats which offered dive excursions in the Sudanese waters. However, the importance of the tourism industry in the area is expected to grow (Klaus et al., 2008). Coastal protection provided by coral reefs in Sudan has yet to be estimated.

The coral reefs of Sudan have long remained untouched due to limited coastal urbanization. However, the sudden increase in coastal development is now threatening the reefs in several urban areas. Harbor development for international shipping and oil export are the main drivers responsible for the destruction of coral reefs, either directly or indirectly due to increased turbidity (Mubarak, Abdalla, & Abdelgadir, 2018). In addition to bleaching, land-based pollution and destructive tourism practices also threaten coral reefs (Nasr, 2015).

Marine protected areas in Sudan span 2,580 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,271 km² of coral reefs within their boundaries, thus placing 55% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Sudan, with data from a total of 47 sites included within the GCRMN dataset. These observations represent 0.04% of the total global dataset compiled by the GCRMN (835 rows).

Sites from which data were provided cover approximately all of the coral reefs off the coast of Sudan. All of the sites have been surveyed only once (Figure 1).

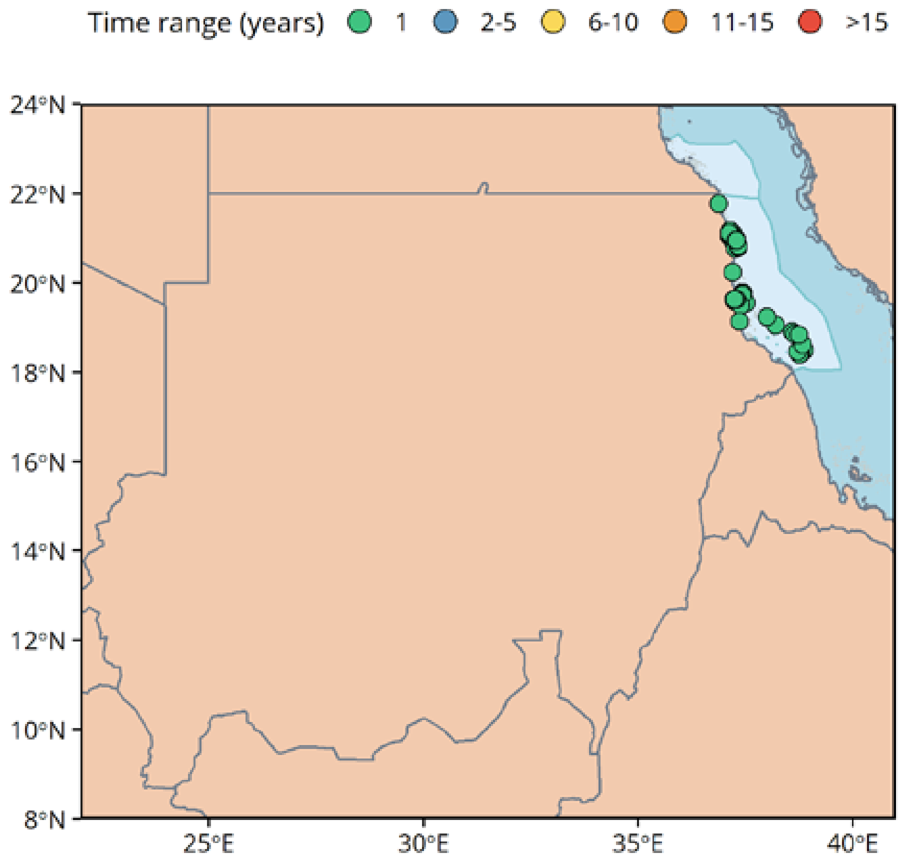


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2002 to 2017. The monitoring effort recorded has been very inconsistent over the years. Monitoring only occurred in 2002, 2004, 2007, 2008, 2016 and 2017 and the percentage of surveys conducted during these 4 years varies (Figure 2A).

The type of methods used to conduct the monitoring was not recorded in the 2020 GCRMN database for 64% of the surveys. Point intercept transects were used for the remaining 36% of the surveys (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is very good, as 73% of the identifications of benthic organisms were made to at least the subgroup level. Further, the precision level of the identifications increased between the 2000-2009 and the 2010-2019 periods. The percentage of observations recorded at the group and the subgroup levels decreased, as the proportion of organisms identified up to the family and genus levels increased during the 2010-2019 period (Figure 2D).

Only 1 out of the 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) is represented. Algae were identified to at least the subgroup level for 53% of the observations (Figure 2E).

Organisms belonging to 2 out the 4 "Other fauna" subgroups ("Alcyonacea", "Porifera", "Tunicata" and "Other subgroups") are represented. All of the observations of benthic fauna other than hard coral species were identified to at least the subgroup level (Figure 2F).

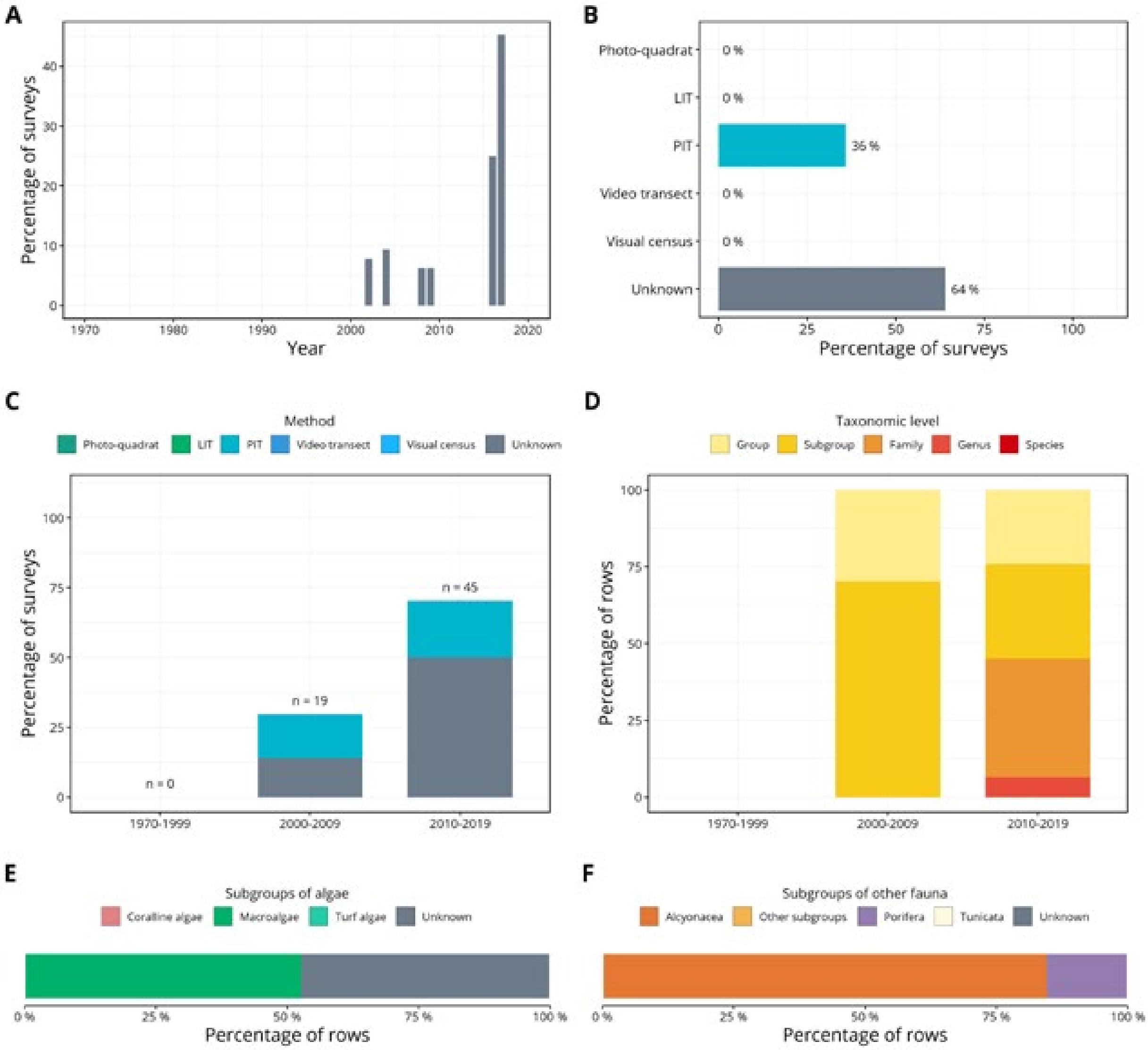


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial covering of the monitoring is good and the monitoring effort should be pursued.

Temporal Extent. The temporal extent of most monitoring sites is low. Thus, we recommend that fixed monitoring sites be implemented in Sudan.

Methodology. The method used is available for less than a quarter of the surveys while 24% of the remaining surveys were conducted using point intercept transects. While this method is useful, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Around 70% of observations have a level of taxonomic precision at the subgroup or family levels, which is enough to assess changes in benthic composition over time. However, the subgroups "Tunicata" and "Other subgroups" belonging to the group "Other fauna" are not represented in the database. Further, the algal subgroups "Coralline algae" and "Turf algae" are also missing. This might be due to the fact that these organisms were absent from the sites, because they were present but have been identified only to the group level or because they were not included in monitoring protocols. In the last two cases, we recommend that these organisms be included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 47 sites throughout Sudan for 6 different years between 2002 and 2017. Although the temporal extent of the data coverage is low, the spatial extent of the monitoring is sufficient for this indicator to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations for algae barely meets the requirement for this indicator to be considered in use in the country. Thus, we recommend that the identification of algae be improved in future monitoring protocols. However, the spatial extent of the monitoring is good. Thus, this indicator can still be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

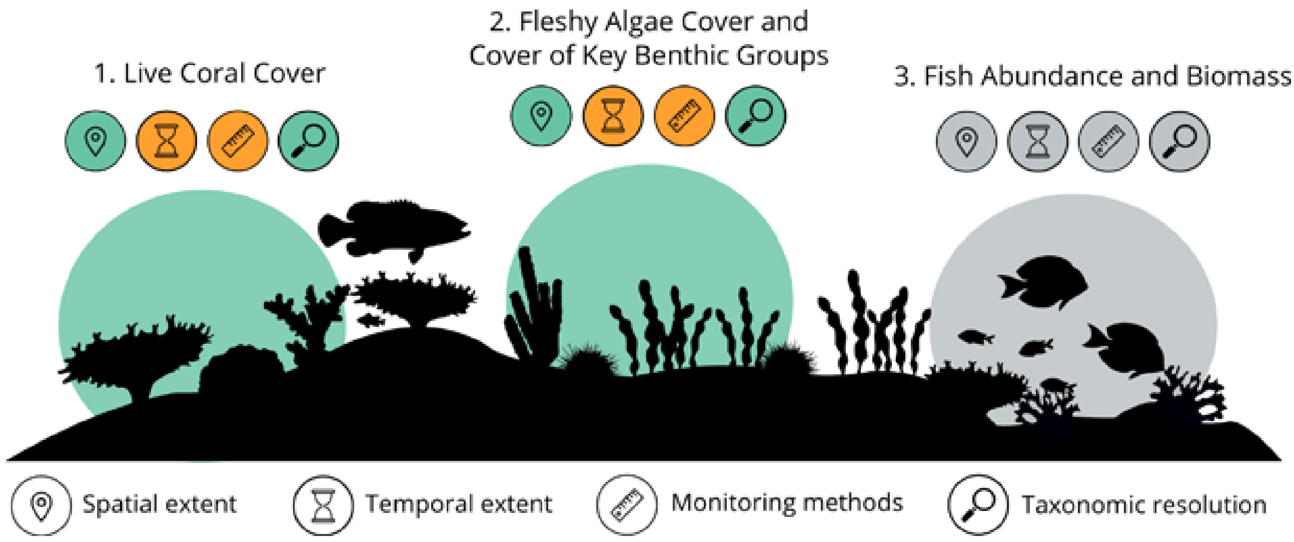


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators “Live Coral Cover” as well as “Fleshy Algae Cover and Cover of Key Benthic Groups” presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Sudan, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Dr. Awatif Abdelgadir Bashir	awatif.sugga@gmail.com	Higher Council for Environment and Natural Resources (HCNER)
Dr. Drar Hassan Nasr	d_nasr47@hotmail.com	Red Sea University. Environmental Balance Establishment – Jeddah, KSA
Dr. Khitma Mohammed Ahmed	khitmamohammed@yahoo.com	Higher Council for Environment and Natural Resources (HCNER)
Dr. Sheikheldein Mohmed Alamin	sheikhelamin@hotmail.com	Red Sea University (RSU)

This summary has been reviewed by the focal points.

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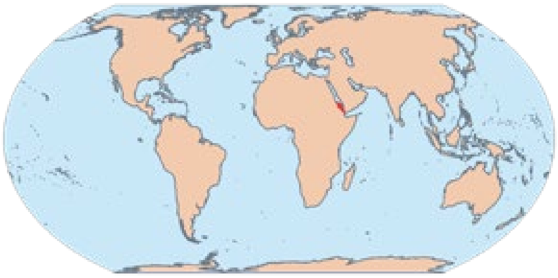

ERITREA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 2,288 km²

Proportion of the world's coral reefs: 0.868%

Ranking based on reef area: 24th

Eritrea has an extensive coastline bordering the Red Sea and more than 350 islands are found off the coast, with 10 of them inhabited. Due to its harsh conditions, the coast is sparsely populated, and hosts approximately 5% of the Eritrean population (Jeudy & Negussie, 2007).

An estimated 324 species of hard corals (IUCN, 2021) and 240 fish species can be found living on the reefs (Froese & Pauly, 2020). The most abundant types of reefs are fringing reefs, developing along the main coastline but also around the numerous islands. Patch reefs are also abundant in Eritrea (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

The war of independence against Ethiopia, that lasted 30 years and ended in 1993, has left some lasting marks on the development of fisheries and tourism in Eritrea. As most of the industrial fishing facilities were destroyed during the war and have yet to be rebuilt, the importance of fisheries in the economy has decreased considerably and represents less than 0.1% of the country's GDP. Further, most of the fishing activity is artisanal. Out of the estimated 3,600 fishermen of Eritrea, 3,500 are thought to be artisanal fishers. There are also an estimated 1,000 foot fishers, who are mainly women and children, who glean the reefs for subsistence. (FAO, 2021). Coastal tourism has also yet to be fully exploited despite the great potential for this industry along the coast and through its natural resources. However, the scenic beauty of the coast, in addition to sandy beaches and an almost pristine marine environment should become real drivers of tourism in the region in the years to come, provided that the necessary infrastructures are built and that the development of tourism is sustainably planned (Alam, 2014). Coastal protection provided by coral reefs in Eritrea has yet to be evaluated.

As the coastal climate is hot and water is scarce, there is little development along the coast. Thus, there is a low level of human threats. The main threats occur at a local scale, and consist of land reclamation, sedimentation and resort development, anchor and diver damage as well as destructive fishing practices and effluents from a desalination station and power plants (Jeudy & Negussie, 2007; Wilkinson, 2008). Further, coral reefs in Eritrea grow in extreme conditions, and are thus are quite resilient to heat stress, as only a few severe bleaching events have been recorded (Wilkinson, 2008).

There is no record of implemented MPA zones in Eritrea in the MPAtlas database (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020).

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides a limited coverage of the coral reefs around Eritrea, with data from a total of 2 sites included within the GCRMN dataset. These observations represent less than 0.01% of the total global dataset compiled by the GCRMN (73 rows).

Sites from which data were provided occur off-shore of the city of Massawa. Both sites were only surveyed once (Figure 1).

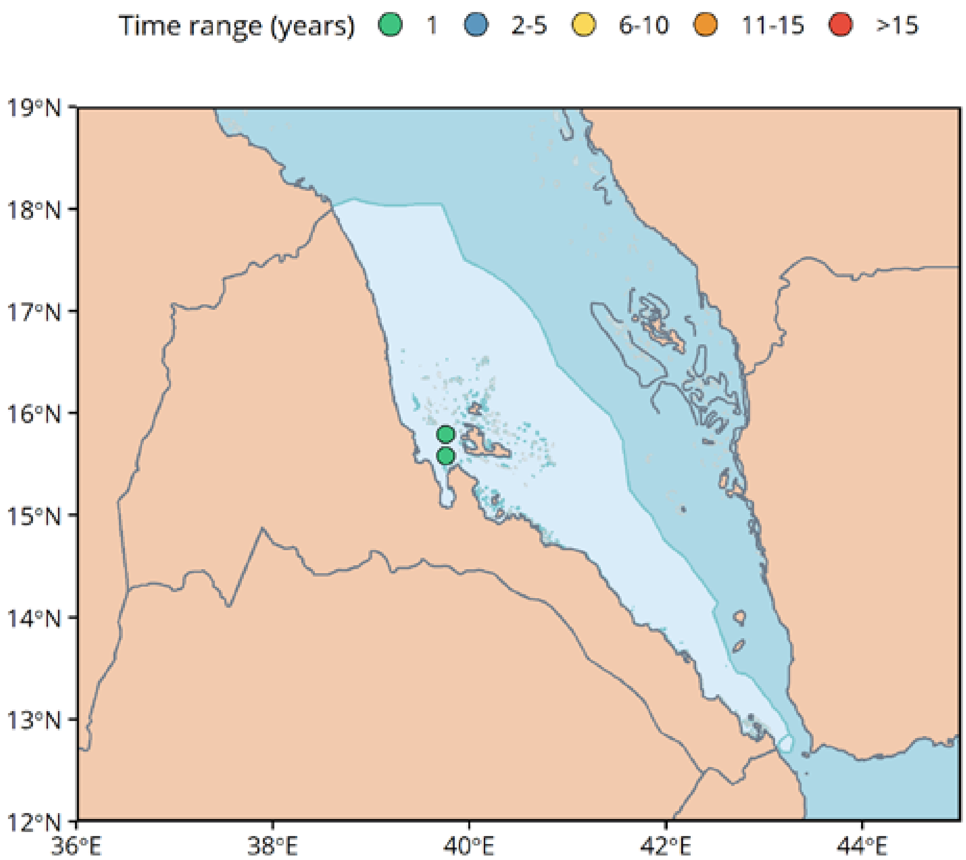

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database was collected in 2000 (Figure 2A).

All of the surveys contributed to the 2020 GCRMN database were conducted using point intercept transects (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The taxonomic resolution of the data provided is good, as 62% of identifications were conducted to the subgroup level (Figure 2D).

Algae observations were recorded to the group level only (Figure 2E).

Organisms belonging to only 2 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Further, observations of benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

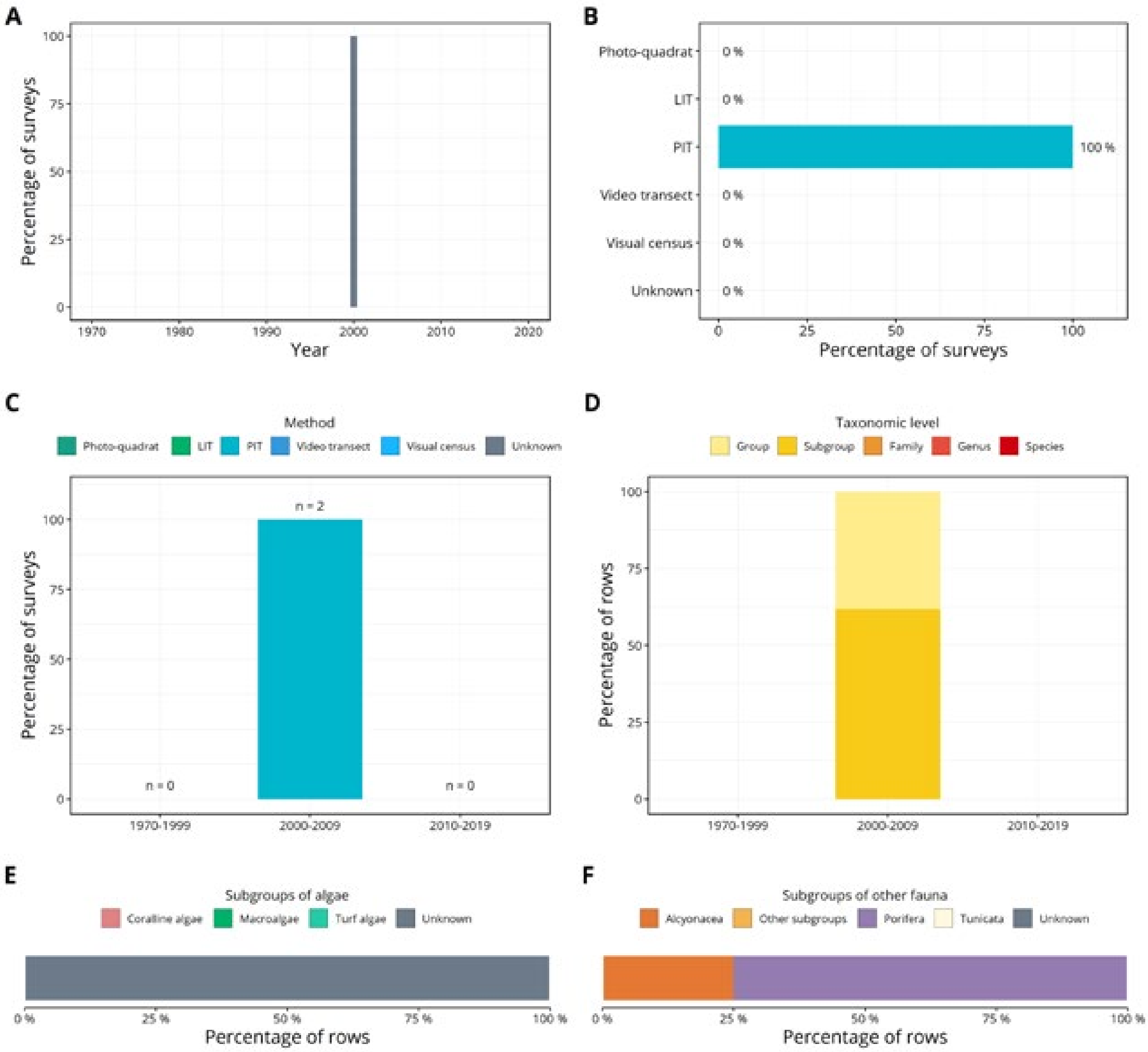

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is too low. Thus, we recommend that additional monitoring sites be established in Eritrea.

Temporal Extent. The temporal coverage of the data provided is low. Thus, we recommend that fixed monitoring sites be established and that the monitoring of existing sites be extended.

Methodology. Both sites were surveyed using the point intercept transect method. However, if monitoring programs were to be continued, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. While the overall taxonomic resolution is good, algae were identified only to the group level, which is not sufficient for the monitoring of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups". Organisms belonging to the subgroups "Tunicata" and "Other subgroups" are not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, monitoring protocols should include the identification of these organisms in the data collection process, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data being contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was only measured once on 2 sites, which is not enough for this indicator to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** Both the spatial coverage and the taxonomic resolution are lacking for this indicator to be considered measured and available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

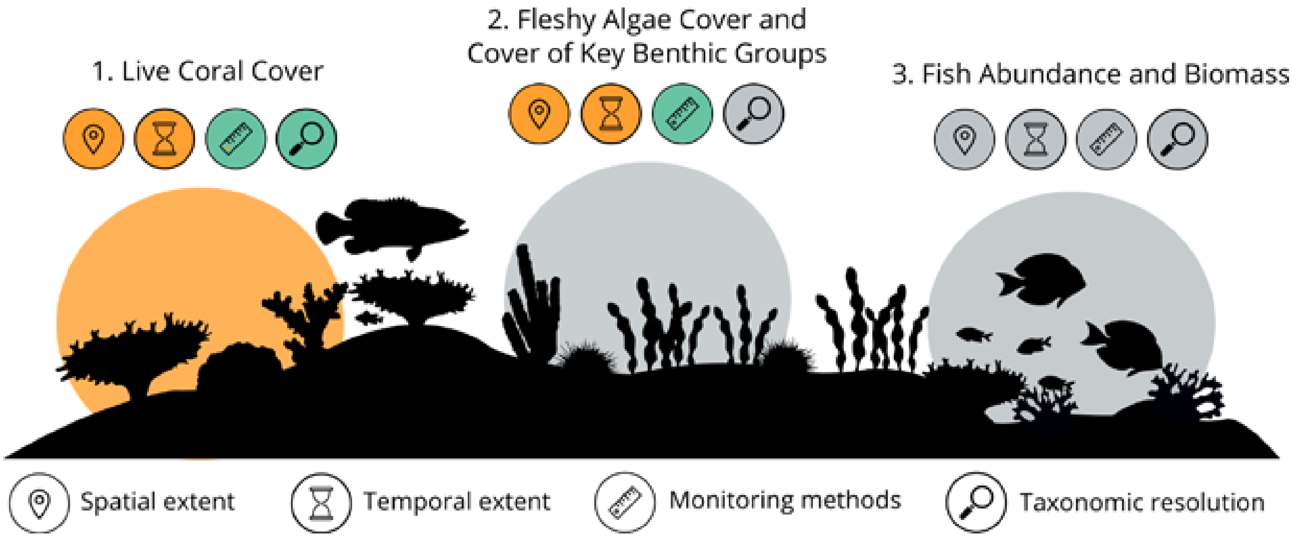

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

The spatial and temporal extent of the monitoring effort recorded in the 2020 GCRMN database is not enough yet for the indicators “Live Coral Cover” as well as “Fleshy Algae Cover and Cover of Key Benthic Groups”, which status is unknown, to be considered available at the country level. Further efforts are needed for these indicators to be considered available in Eritrea, as the spatial coverage and the taxonomic resolution of the data need to be increased.

3.3 Main contacts

A coral reef monitoring focal point for Eritrea has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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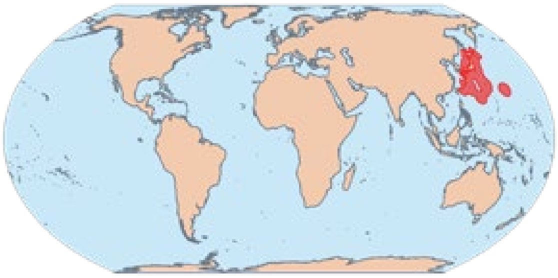

JAPAN

1. Introduction – General context

CORAL REEF CARD

Estimated area: 1.982 km²

Proportion of the world's coral reefs: 0.752%

Ranking based on reef area: 25th

Japan is comprised of several islands, some of which bathe in the warm waters of the Kuroshio current, which explains the presence of coral reefs even up to a latitude of 35°N. Japan's coral reefs are thus mainly located in the Southern part of the Archipelago, where they provide significant benefits to the population.

There are 463 species of hard corals (IUCN, 2021) and 1,690 species of reef fishes that are known to inhabit the reefs of Japan (Froese & Pauly, 2020). Reef building species of corals in Japan form fringing reefs, submerged platforms and mesophotic reefs (Iguchi & Hongo, 2018b) as well as several atolls (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

The Ministry of the Environment (MOE, Japan) tried to estimate the annual economic value of the ecosystem services rendered by coral reefs for the three regions which contain coral reefs in Japan, including the islands of Amami, Ogasawara and Okinawa. In these regions, the value of coral reefs for tourism and recreation was estimated to represent 0.02% of the country's GDP, for an estimated value of US$659,300 per km² of coral reef (Spalding et al., 2017). Tourism is a major industry in these islands, such as in Okinawa, where it represented 17.1% of the incomes (Ministry of the Environment, 2004). Japan is also a big consumer of seafood and coastal fisheries employed 185,130 people in 2006 (Food and Agriculture Organization, n.d.). Coastal fisheries are closely related to the coral reefs, whose annual value in the coral regions has been estimated at minimum at US$123 million (Ministry of the Environment, 2010), which represented 0.002% of the country's GDP in 2010. The benefits of coastal protection provided by coral reefs are estimated to range from US$86.4 million to US$964.4 million (Ministry of the Environment, 2010), which represented 0.002 to 0.02% of the country's GDP in 2010.

Even though they provide highly valuable services, Japan's coral reefs face several environmental and anthropogenic threats. The environmental threats include tropical typhoons, COTS outbreaks, sedimentation, acidification and increasing sea temperatures leading to bleaching events. Among the main anthropogenic threats, overfishing, poorly managed tourism, unsustainable coastal development and sediment runoff from land-based sources have been identified (Burke, Selig, & Spalding, 2002; Iguchi & Hongo, 2018a).

Marine protected areas in Japan span 111,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,416 km² of coral reefs within their boundaries, thus placing 71.4% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Japan, with data from a total of 597 sites included within the GCRMN dataset. These observations represent 0.5% of the total global dataset compiled by the GCRMN (9,567 rows).

Sites from which data were provided are well distributed around the Southern part of the Japanese archipelago, covering each of the different coral regions. Furthermore, at least half of the sites were surveyed for more than 6 years and many of them have been monitored for more than 10 years (Figure 1).

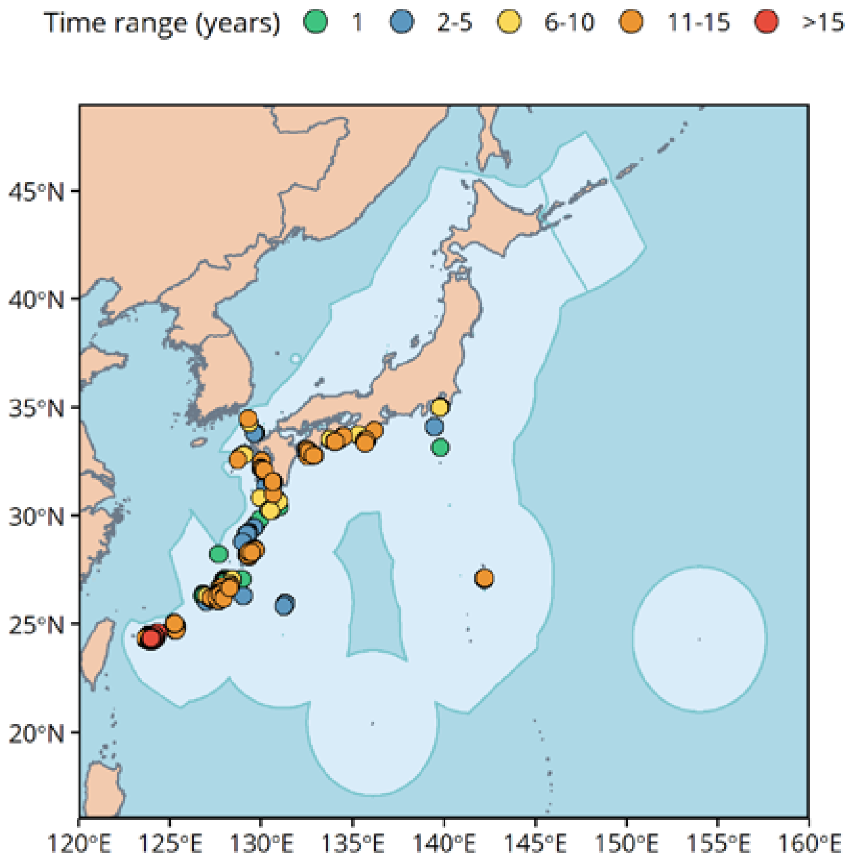

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1983, when a monitoring program around the MPA in Okinawa was first implemented, to 2018. There has been a gradual increase in the monitoring effort through time from 1983 to 2003, which is mainly led by an increase in monitoring effort inside MPAs, with additional efforts from the Reef Check program. From 2004, a sharp increase in effort occurred when a nation-wide monitoring program was established (Figure 2A).

The majority (98%) of surveys contributed to the 2020 GCRMN database were conducted using visual censuses, followed by point intercept transects (2%)[1] (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups[2], which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is low, with only 20% of identifications made at the subgroup level or above. The taxonomic precision was at its maximum between 2000 and 2009, when 30% of identifications were recorded to the subgroup level (Figure 2D).

When recorded, algae observations were recorded only to the group level (Figure 2E).

1 All of the sites contributed to the GCRMN database by the MPA monitoring and the national monitoring programs were surveyed using the visual census method while Reef Check used the point transect method.

2 Originally, percent coral cover observations recorded during MPA monitoring and national monitoring programs in Japan were categorized into 6 groups, which were named as follows: “Branching Acropora dominant”, “Tabulate Acropora dominant”, “Branching and tabulate mixed”, “Specific species dominant”, “Multiple species mixed (with non-dominant species)” and “Soft coral dominant”. In addition to assessing stressors on corals, number of COTS and percent cover of bleached corals were also recorded during the national monitoring program.

Organisms belonging to only 2 out the 4 "Other fauna" subgroups ("Alcyonacea", "Porifera", "Tunicata" and "Other subgroups") are represented[3]. Further, observations of benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

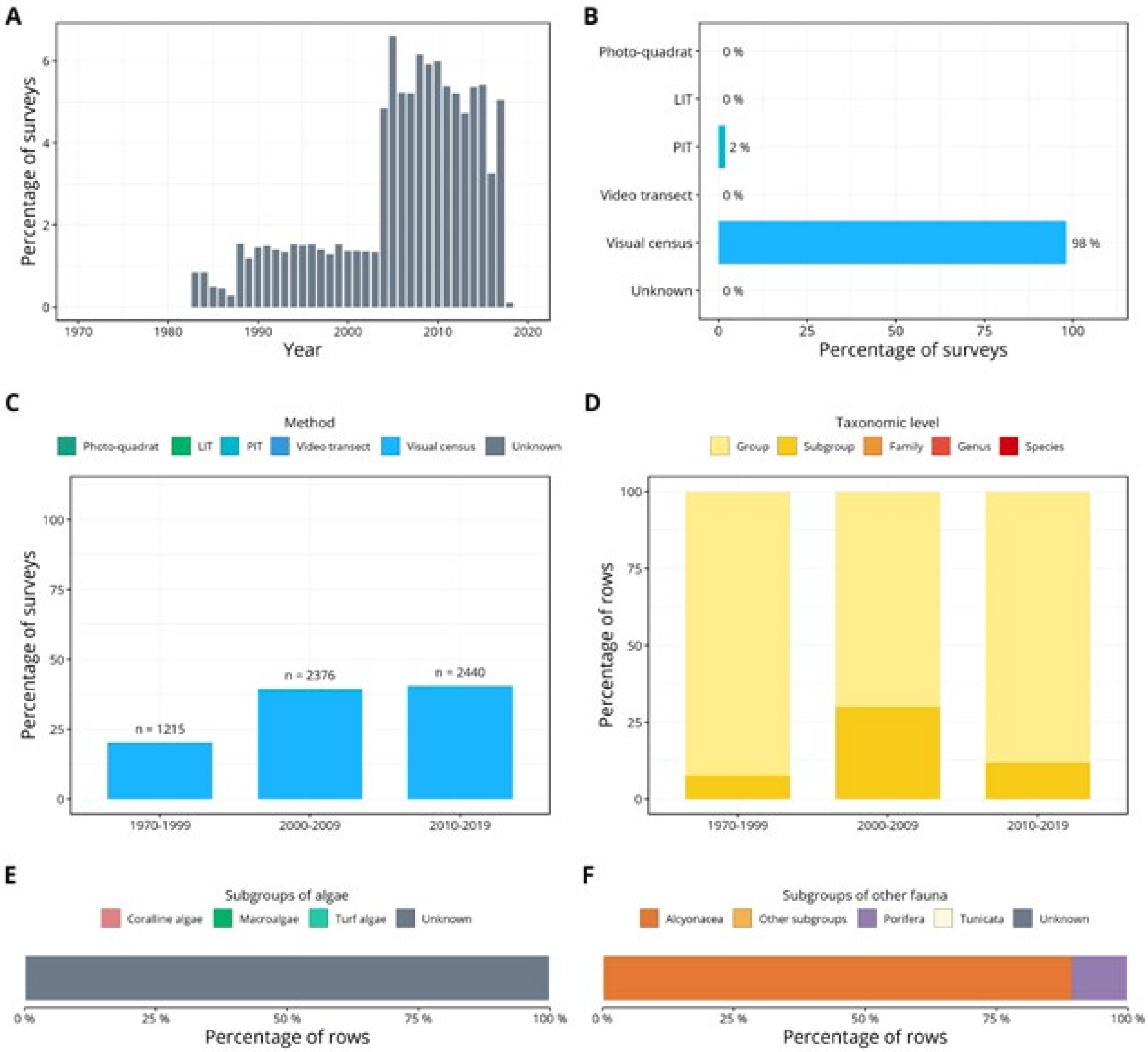

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3 The observations of benthic fauna other than hard coral species were recorded exclusively during Reef Check surveys and were identified to at least the subgroup level for all of the observations.

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of monitoring programs in Japan is good, as it covers pretty much all of the existing reef areas around the archipelago. This extensive coverage of coral reefs is valuable and should be continued.

Temporal Extent. The temporal extent of all the monitoring sites recorded is good and provides time series for analysis, as several sites have been surveyed for more than 10 years. These important efforts should be pursued.

Methodology. The visual census method is useful as it only takes a short amount of time to run a transect, and thus allows for coral reefs to be monitored quickly. However, this method limits our ability to get a precise idea of the composition of benthic communities. Thus, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Almost all of the identifications were made only to the group level and the few that were identified to the subgroup level cannot be considered enough to be representative of the different communities encountered during the monitoring surveys. Organisms belonging to the groups “Algae” and “Other fauna” are also missing, with the exception of the few Reef Check surveys. Thus, in addition to changing the monitoring protocols to include these organisms, we recommend that the level at which organisms are identified be increased, as part of the measurement of the ICRI recommended coral reef indicator “Fleshy Algae Cover and Cover of Key Benthic Groups”.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data being contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 597 sites throughout Japan and is available every single year between 1983 and 2018. Furthermore, all requirements are met. Thus, this indicator can be considered in use at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The organisms targeted by this indicator have not been well included in most of the monitoring protocols in Japan. This might be due to the method used to monitor coral reefs and should be addressed by modifying existing protocols so that they would take both benthic groups into account.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

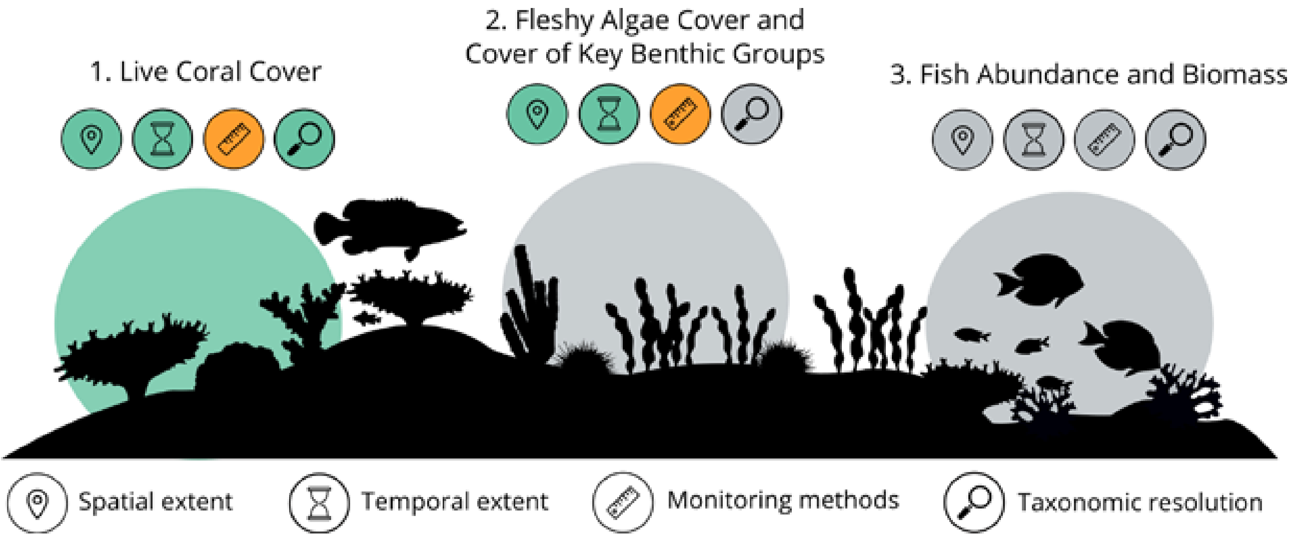

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicator "Live Coral Cover" is measured at the country level and is available on request for most of the existing datasets identified. However, according to the data serials provided during the collection period, we cannot say that the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" is monitored in Japan.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Japan, please contact the focal points, whose contact details are available in the following table.

Name	**Contact**	**Organisation**
Tadashi Kimura	tkimura@jwrc.or.jp	Japan Wildlife Research Center
Eiji Tanaka	EIJI_TANAKA@env.go.jp	Senior Coordinator for Biodiversity Biodiversity Policy Division Nature Conservation Bureau Ministry of the Environment, Government of Japan
Yohei Mori	YOHEI_MORI@env.go.jp	Examiner Biodiversity Policy Division Nature Conservation Bureau Ministry of the Environment, Government of Japan

This summary has been reviewed by the focal points.

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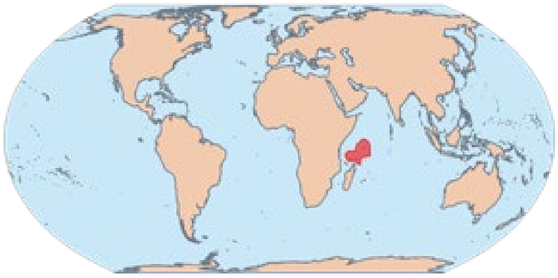
SEYCHELLES



1. Introduction – General context

CORAL REEF CARD

Estimated area: 1.935 km²

Proportion of the world's coral reefs: 0.734%

Ranking based on reef area: 26th

The Seychelles is an archipelagic nation located in the Western Indian Ocean. The nation is comprised of approximately 115 islands, of which 40 are granitic, and the rest are coral. The Seychelles exhibit one of the most extensive coral systems in the Indian Ocean.

Coral reefs in the Seychelles host 323 species of hard corals (IUCN, 2021) and 946 fish species (Froese & Pauly, 2020). Three main types of reefs are present in the Seychelles, including fringing reefs, platform reefs and atolls (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Its coral reefs provide numerous services to the Seychellois people, mainly by supporting the tourism and fishing industries, but also by providing coastal protection against waves and storms. Tourism is one of two pillar industries in the Seychelles and is of crucial importance for the country's economy. It contributes up to 24.4% of the country's GDP and accounts for more than 20% of the national employment (National Bureau of Statistics, 2020, 2021). However, tourism is highly dependent on healthy coral reefs, as a survey published in 2004 revealed that more than 65% of the tourists who visited the islands came to engage in diving or snorkeling (Cesar, van Beukering, Payet, & Grandourt, 2004). The second pillar industry is the fishing industry. Although industrial fisheries represent the main source of income, the catch is mainly for export and contributes very little to food security and employment. On the contrary, artisanal fisheries are the principal provider of protein in the Seychelles, whose people have one of the highest fish consumptions per capita in the world (Cesar et al., 2004). Overall, fisheries accounted for 0.9% of the GDP in 2019 (National Bureau of Statistics, 2020). The benefits of coastal protection, though crucial, have yet to be properly estimated. However, it has been estimated that 90% of the coasts are exposed to waves and storms and that an increase in sea-level or the disappearance of coral reefs would threaten the coastal communities and infrastructures (Jones, Payet, Beaver, & Nalletamby, 2002; Cesar et al., 2004).

Coral reefs in the Seychelles are threatened by overfishing, land-reclamation and land-based pollution. However, coral bleaching due to increasing sea temperatures remains the primary threat (Payet et al., 2007). Several coral diseases, including the "black disease" induced by the invasive sponge *Terpios hoshinota* (GEF, 1999; Friedlander et al., 2015), have also been recorded in the Seychelles, and their prevalence might increase in the future (Harvell et al., 2007; Lamb, True, Piromvaragorn, & Willis, 2014; Nicolet, Chong-Seng, Pratchett, Willis, & Hoogenboom, 2018). Harmful algal blooms were also recorded around the Seychelles (Sanchez, 2015) and they might become an emerging threat to coral reefs in the future (Bauman, Burt, Feary, Marquis, & Usseglio, 2010).

Marine protected areas in the Seychelles span nearly 242,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,725 km² of coral reefs within their boundaries, thus placing 89.1% of the country's coral reefs under protection. The level of site protection has been shown to be an important factor in the recovery of coral reefs (Obura et al., 2017).

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around the Seychelles, with data from a total of 166 sites included within the GCRMN dataset. These observations represent 0.05% of the total global dataset compiled by the GCRMN (1,044 rows).

Sites from which data were provided occur on nearly all of the islands of the Seychelles. Medium and long-term monitoring sites within the Seychelles are available, with time series exceeding 15 years around the islands of Mahe and Praslin. In the outer islands, coral reef monitoring has been done opportunistically (Figure 1).

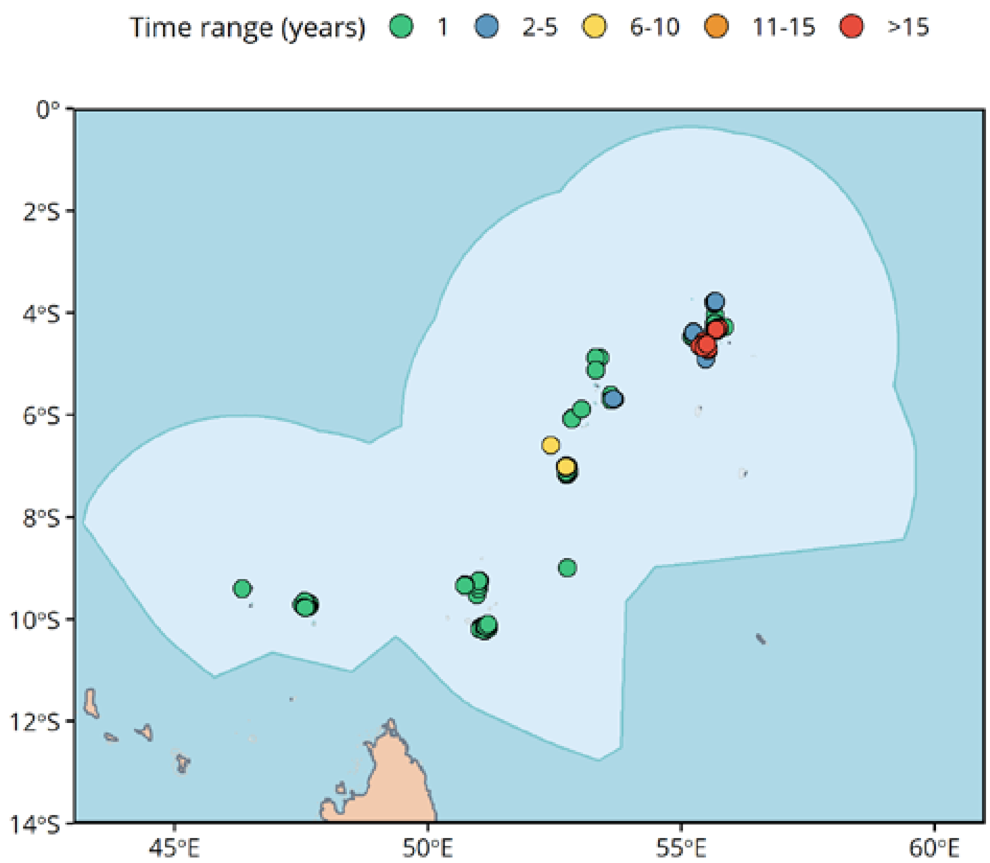


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1994 to 2019. The recorded monitoring effort has been inconsistent over the years, and there are some years where no motoring was conducted, though it has become more consistent since 2011 (Figure 2A).

The methodology used to conduct the monitoring is unknown for 51% of the surveys recorded in the database. Line intercept transects and point intercept transects were used on 45% and 4% of the remaining surveys, respectively (Figure 2B).

While the method used to conduct the surveys is globally unknown, the proportion of surveys for which information is available increased with time, just as the number of surveys performed increased over the three time periods. Between 2000 and 2009, 27 surveys were conducted using the line intercept transect method and this number increased to 96 surveys between 2010 and 2019. During the latter, 6 surveys were conducted using the point intercept transect method (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, with 68% of identifications made at the subgroup level or above. Regarding the evolution of the taxonomic resolution, it steadily increased over the years. Indeed, the proportion of observations recorded only to the group level decreased from almost 40% during the 1979-1999 period to 26% during the 2010-2019 period. Further, this last time period is characterized by the highest level of taxonomic precision of the three, as 39% of observations were made to the subgroup level and 35% to the genus level (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 91% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 93% of the observations (Figure 2F).

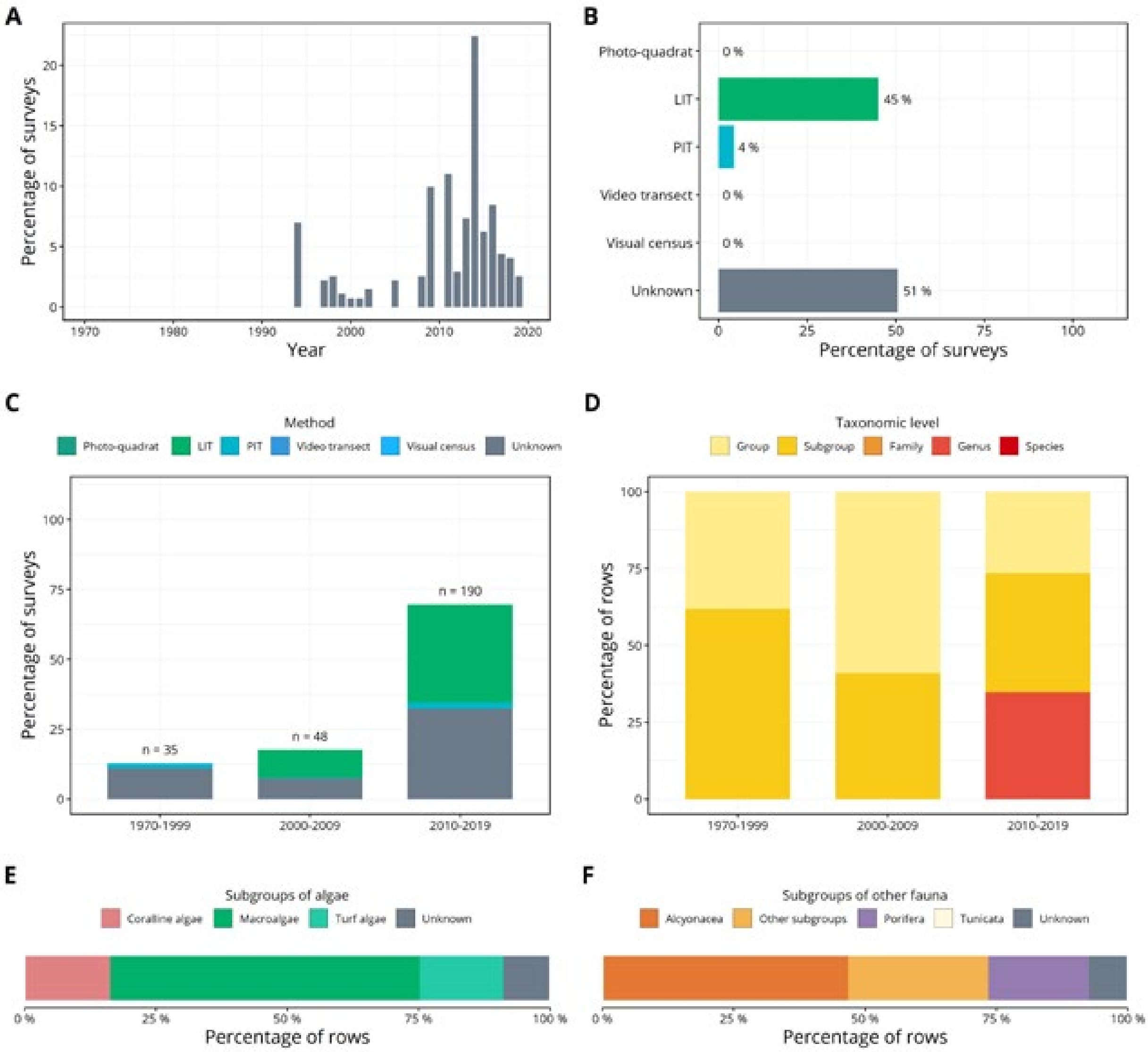


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent and offers a representative description of coral reefs in the Seychelles.

Temporal Extent. While some sites have been monitored for a long time, providing long-term record for trends in coral reefs, the temporal extent of most monitoring sites is low. Thus, we recommend that new fixed monitoring sites be implemented and that monitoring in existing sites be extended.

Methodology. At least half of the sites were monitored using line intercept transects and for 52% of the surveys, no method-related information exists. When implementing new monitoring programs, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Overall, the taxonomic resolution of the data provided is good. Different subgroups belonging to the groups “Algae” and “Other fauna” were commonly represented indicating that surveying of these groups was a standard component of monitoring protocols. Recording the composition of the benthic community with such a high degree of taxonomic resolution is highly valuable. However, the subgroup “Tunicata” belonging to the group “Other fauna” is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but have been recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, we recommend that these organisms be included in future monitoring protocols.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data being contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 160 sites throughout the Seychelles for 19 different years between 1994 and 2019. Furthermore, all requirements necessary for this indicator to be considered available are met. Thus, this indicator can be considered measured and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** Based on the analysis of the four criteria and given the relevant level of taxonomic precision, all of the requirements are met for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**[1]. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

1 There might be data available directly from partners at site level but it would require additional consultations and the datasets might not be complete.

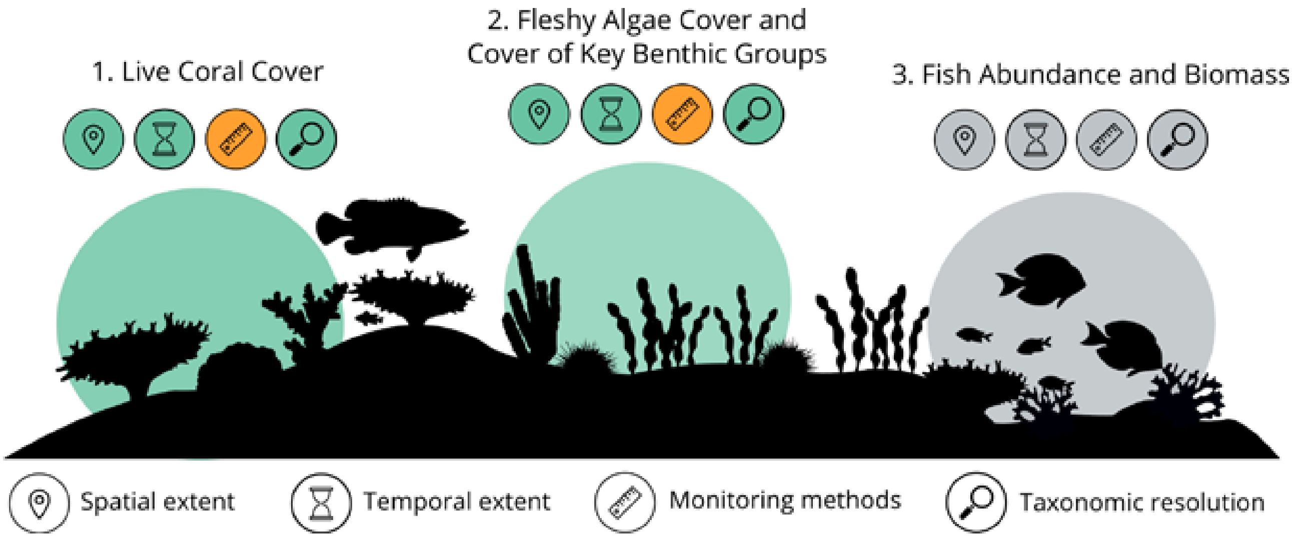


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in the Seychelles, please contact the focal points, whose contact details are available in the following table.

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Nirmal Shah, CEO	nirmal@natureseychelles.org	Nature Seychelles
Norman Weber, CEO	ceo@ics.sc	Island Conservation Society (Seychelles)

This summary has been reviewed by the focal points.

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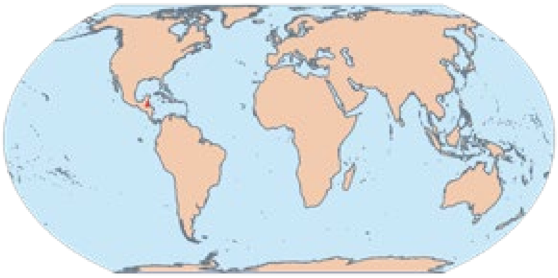
BELIZE



1. Introduction – General context

CORAL REEF CARD

Estimated area: 1.921 km²

Proportion of the world's coral reefs: 0.729%

Ranking based on reef area: 27th

Belize is a small country bordering the Caribbean Sea. It is characterized by a great variety of coral reef ecosystems, including the 260 km long Mesoamerican barrier reef, which is the largest barrier reef after the Great Barrier Reef in Australia.

In addition to its extensive barrier reef, fringing reefs, lagoon patch reefs and three off-shore atolls can be found offshore of Belize (Cooper, Burke, & Bood, 2009). The Belizean coral reefs are home to 58 species of hard corals (IUCN, 2021) and 371 species of reef fishes (Froese & Pauly, 2020).

This diversity of reef ecosystems, tightly linked with the mangrove forests, provides crucial ecosystem services to Belizean communities while supporting a growing tourism industry, artisanal and commercial fishing practices and by providing critical shoreline protection. Coral reef tourism provides 28,800 jobs in Belize. The incomes generated through reef-related tourism and fisheries support the livelihoods of more than half of the population, or about 190,000 people (Dalberg Global Development Advisers, Pironnet, Marsh, & Allan, 2016), accounting for 5.12% of the country's GDP (Spalding et al., 2017). Fisheries not only provide jobs to 3,189 registered fishermen[1] (Government of Belize, 2021) but they also account for 15,000 additional jobs in the processing and export sectors (Foley, 2012). The income generated by reef fisheries was estimated at US$21.3 million in 2019 (UNCTAD, 2020), which represented 1.1% of the country's GDP in 2019. It is estimated that the presence of coral reefs protects up to 40% of Belize's population from storm surges and coastal erosion. Coastal protection is valued at US$120-180 million (Cooper et al., 2009), which represented between 9% and 13.5% of the country's GDP in 2009.

Although they are of great importance to the country, Belize's coral reefs are threatened by the amplification of natural threats associated with climate change, such as increasing sea temperatures and storms, as well as by unsustainable development practices and overfishing (Gibson, Mcfield, & Wells, 1998).

Marine protected areas in Belize span 4,200 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 933 km² of coral reefs within their boundaries, thus placing 48.6% of the country's coral reefs under protection. Furthermore, in 2009, the Belize Barrier Reef reserve system was added to the list of World Heritage Sites in danger but was later removed in 2018 due to progress made towards the conservation goals as listed by the World Heritage committee. Improvements were made, such as (but not limited to) updating existing relevant legislation (fisheries, mangrove, EIA, etc.), updating of conservation/management plans, creation of a moratorium on offshore exploration and exploitation, and the adoption and implementation of the 2016 Integrated Coastal Zone Management Plan (UNESCO, 2021).

The Government of Belize, in partnership with Fragments of Hope, has made efforts in coral restoration along the coast for more than a decade (since 2006). Sites such as the Laughing Bird Caye Marine Reserve have seen live coral cover increase from 6% to 50%. By the end of 2020, there were 23 in-situ coral nurseries and over 274,374 corals transplanted throughout Belize's national waters. Fragments of Hope also uses photomosaics to document coral cover changes on 100-200 m² plots in various sites (UNESCO, 2021).

1 The average number of licensed fishermen during the last few years was around 2,500 (UNCTAD, 2020). The increase in numbers for the year 2020 can be explained by the need to accommodate those displaced by the Covid-19 pandemic.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Belize, with data from a total of 133 sites included within the GCRMN dataset. These observations represent 0.2% of the total global dataset compiled by the GCRMN (5,008 rows).

Sites from which data were provided occur on almost all of the coral reefs, except for some reefs located in the south and for which there are no data available in the database. While some sites were only surveyed for a year, most sites have been surveyed for at least two years. Long-term monitoring sites were also contributed to the GCRMN database (Figure 1).

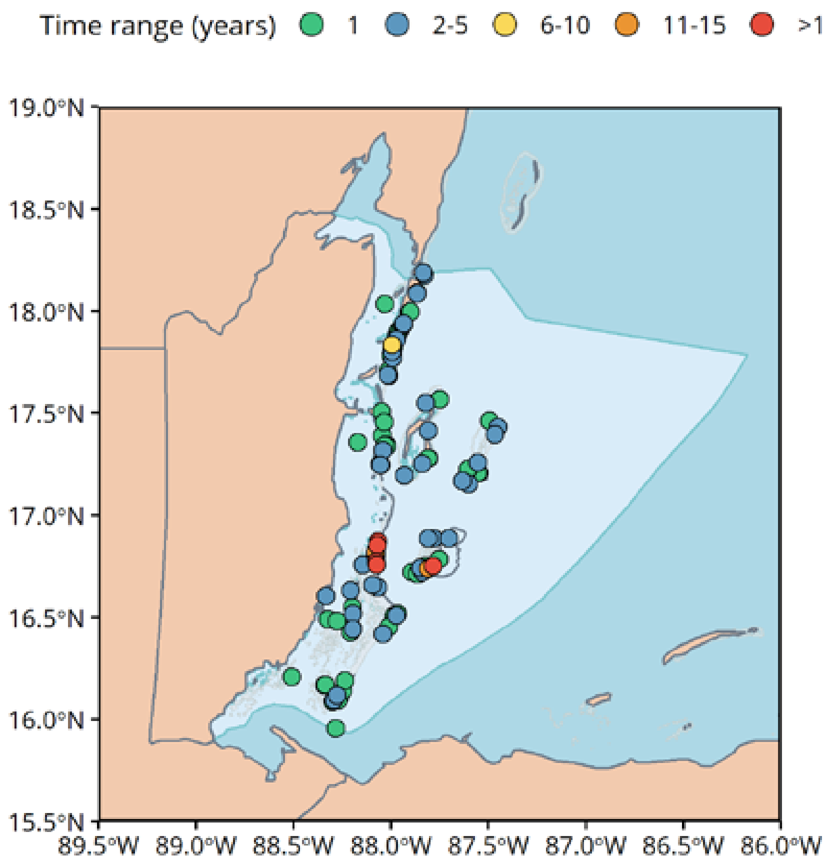


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1997 to 2019. The monitoring effort has been inconsistent other the years, and there are some years with no monitoring effort recorded at all (Figure 2A).

The majority (87%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by line intercept transects (11%) and finally photo-quadrats (2%) (Figure 2B).

The point intercept transect method was the most used during all time periods, and 103 surveys were conducted using this method between 2010 and 2019. The line intercept transect method was used on less than 15 sites during the 2000-2009 and 2010-2019 periods (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows:

“Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, with 64% of identifications made at the subgroup level or above. The taxonomic resolution of the data provided is consistent over the three time periods, with around 60% of the observations recorded to the subgroup level or above during each time period. Observations at the family level account for only a minority of the total observations made (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 76% of the observations (Figure 2E).

Organisms belonging to 2 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented in the database. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 66% of the observations (Figure 2F).

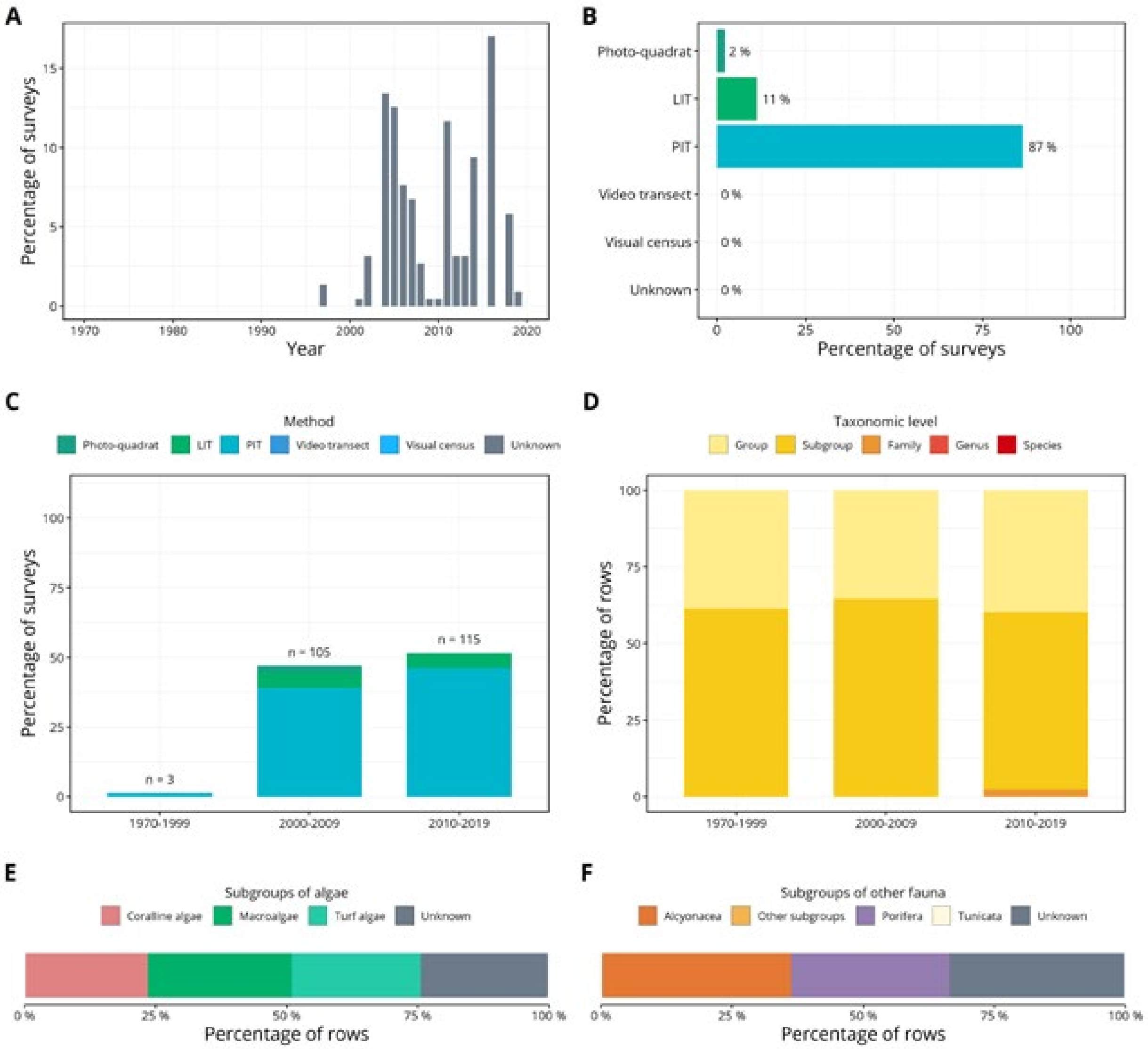


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is already excellent, especially around Ambergris Caye, Glovers Reef and along the Belize Barrier Reef in general. In order to further increase the spatial coverage of monitoring, we recommend that additional monitoring sites be implemented in and out of the Port Honduras Marine Reserve and Laughing Bird Caye National Park.

Temporal Extent. The temporal extent of most of monitoring sites is less than 5 years, thus we recommend that long-term monitoring sites be established and that surveys on existing monitoring sites be extended.

Methodology[2]. Most of the monitoring sites were surveyed using point intercept transects but, when possible, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Most of the available data have a level of taxonomic precision at the subgroup level, which is enough to assess changes in benthic composition through time. However, the subgroup is unknown for 24% of algae and for 34% of the observations for organisms belonging to the group "Other fauna". Organisms belonging to the subgroups "Tunicata" and "Other subgroups" are not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, we would recommend that the identification of these organisms be better included in the monitoring protocols, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data being contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 60 sites throughout Belize for 10 different years between 2002 and 2018. Furthermore, all requirements are met for this indicator to be considered available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** The taxonomic resolution of the observations regarding algae and the other benthic groups is sufficient for this indicator to be considered in use in the country.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

2 While national monitoring programs in Belize were based on the Monitoring Barrier Reef Systems (MBRS) protocol, this protocol is being replaced by the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocols.

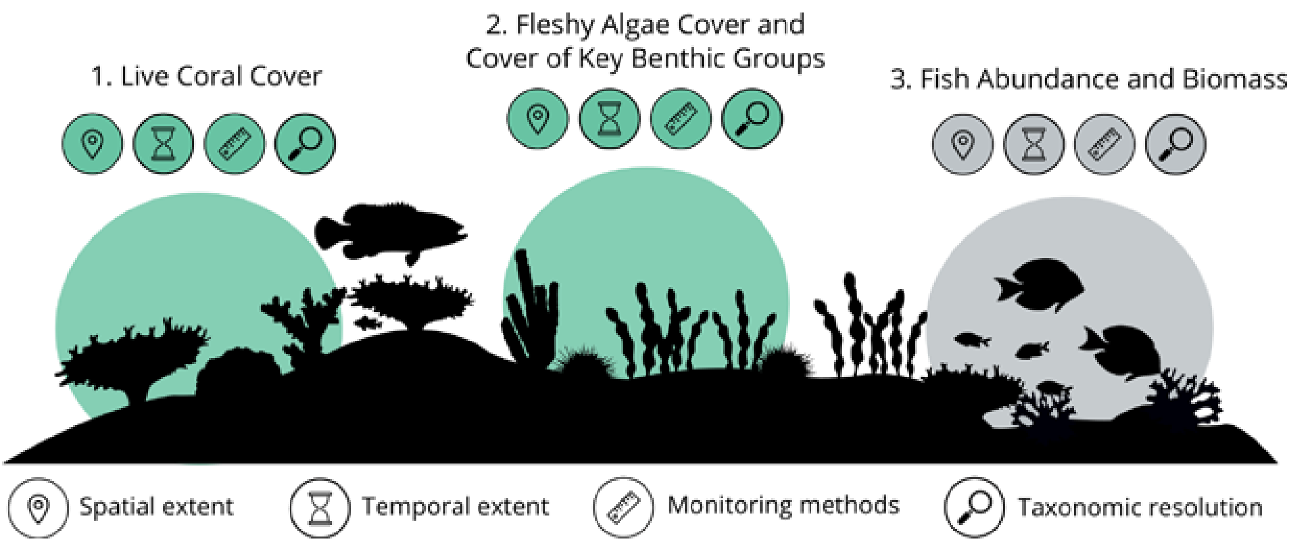


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

Overall, the ICRI recommended coral reef indicators “Live Coral Cover” as well as “Fleshy Algae Cover and Cover of Key Benthic Groups” presented in Figure 3 are measured at the country level and are available on request for most of the existing datasets identified.

3.3 Main contacts

For additional information on the monitoring of coral reefs in Belize, please contact the focal points, whose contact information is available in the following table.

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This summary has been reviewed by the focal points.

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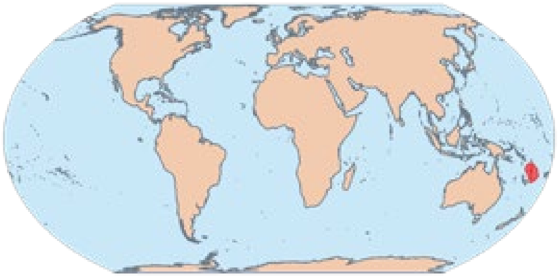

VANUATU

1. Introduction – General context

CORAL REEF CARD

Estimated area: 1,888 km²

Proportion of the world's coral reefs: 0.717%

Ranking based on reef area: 28th

The Republic of Vanuatu is an archipelagic nation located in the South-Western Pacific Ocean. The state is comprised of around 83 islands, of which 12 are major islands. Approximately 65 islands are currently inhabited.

Coral reefs in Vanuatu are home to 384 species of hard corals (IUCN, 2021) and 641 fish species (Froese & Pauly, 2020). Vanuatu displays a variety of reef types. Fringing reefs are the most abundant, but there are also platform reefs, barrier reefs and reef flats (Naviti & Aston, 2000; Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Coral reefs are of high socio-economic importance for Vanuatu as they attract tourists, provide food, employment and income through fisheries, and protect the coast from cyclones and storm surge (Raubani, 2009). Tourism in Vanuatu is vital for the economy, as it represented 34% of the GDP and 36% of total employment in 2019, and sustained 29,000 jobs (World Travel & Tourism Council, 2020). Tourism is highly dependent on healthy coral reefs and reef-tourism has been estimated to account for 6.4% of the GDP (Spalding et al., 2017). The value of coastal commercial fisheries was estimated at US$5.6 million, which represented 0.7% of the GDP. Subsistence fisheries have an estimated value of US$7.4 million (Gillett & Tauati, 2018), representing 0.9% of the GDP. While their economic value is minimal, they are of crucial importance to local communities. Around 60% of rural households rely on fisheries for income and food, and 72% of households engage in fishing activities (Raubani, 2009). Coastal protection provided by coral reefs has been estimated at US$18.4 million (Pascal et al., 2015), which represented 2.3% of the GDP at the time the study was released. However, this value might be underestimated, as sea level rise poses a direct threat to the islands of Vanuatu.

The Vanuatu archipelago is threatened by cyclones and tectonic activity as it is located both in the Ring of Fire region of the Pacific as well as in the cyclone belt. The archipelago is also threatened by increasing water temperatures and COTS outbreaks. In terms of anthropogenic threats, overfishing is the most important threat facing the archipelago as a whole, while threats such as land based pollution, leading to eutrophication and siltation, are more localized (Raubani, 2009).

Marine protected areas in Vanuatu span 44 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 5 km² of coral reefs within their boundaries, thus placing 0.3% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides a limited coverage of the coral reefs around Vanuatu, with data from a total of 32 sites included within the GCRMN dataset. These observations represent 0.05% of the total global dataset compiled by the GCRMN (984 rows).

Sites from which data were provided occur mainly in the south of the archipelago. Most sites were surveyed only once, with the exception of a few sites that were surveyed for 2 to 5 years (Figure 1).

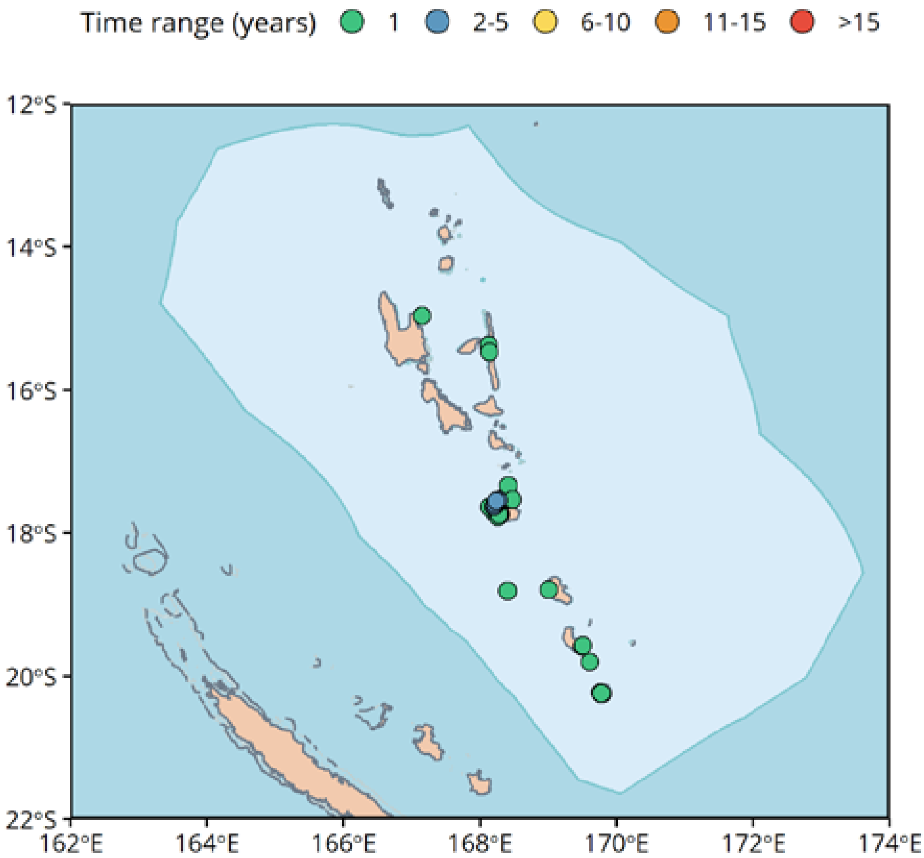

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2014 to 2019. The monitoring effort has been very heterogeneous (Figure 2A).

All of the surveys contributed to the 2020 GCRMN database were conducted using the point intercept transect method (Figure 2B, 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is good, with 59% of identifications made at the subgroup level or above. The taxonomic resolution is consistent, as almost 60% of observations were recorded to the subgroup level for both time periods (Figure 2D).

Only 1 out of the 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) is represented. Algae were identified to at least the subgroup level for 56% of the observations (Figure 2E).

Organisms belonging to 2 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented in the database. The observations of benthic fauna other than hard coral species were identified to at least the subgroup level for all of the observations (Figure 2F).

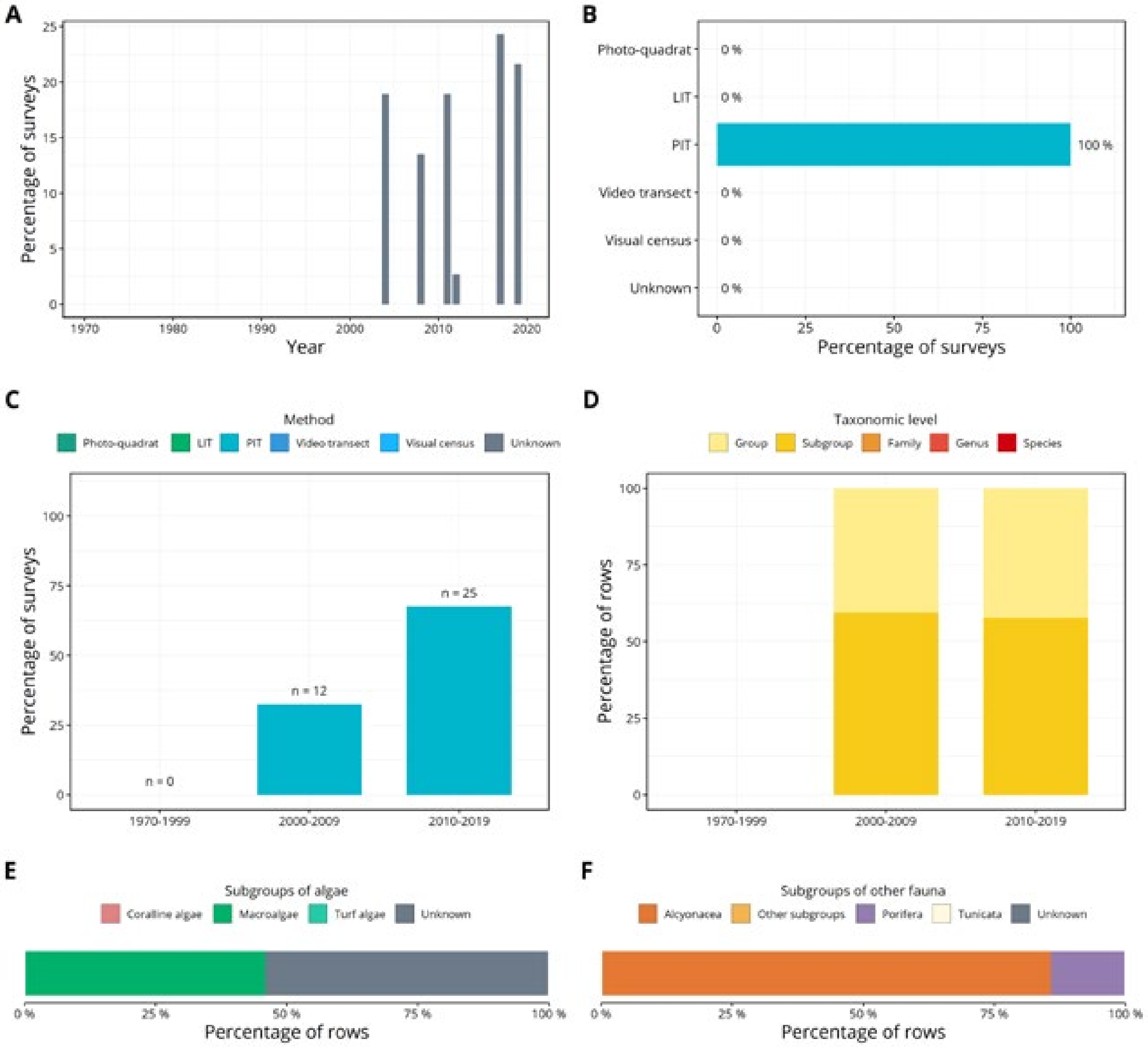

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group "Other fauna".

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring effort recorded in the database is limited and new monitoring sites should be implemented around the northern part of the archipelago, in order to ensure representative coverage of the state of coral reefs in the Republic of Vanuatu.

Temporal Extent. The temporal extent of most of monitoring sites is low. Thus, we recommend that long-term fixed monitoring sites be established and that existing sites be extended.

Methodology. When implementing new monitoring sites, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Almost 60% of the identifications made for benthic organisms were made at the subgroup level or above, which is enough to assess changes in benthic communities over time. Further, algae other than macroalgae are lacking, as well as organisms belonging to the "Tunicata" and "Other subgroups". This might be due to the fact that these organisms were absent from the monitoring site or that their identification was not included in the monitoring protocol. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, monitoring protocols should include the identification of these organisms in the data collection process, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 32 sites throughout Vanuatu for 6 different years between 2004 and 2019. However, the spatial coverage of the monitoring programs is not yet extensive enough to consider this indicator available at the country level. The implementation of new monitoring sites would be necessary for the indicator "Live Coral Cover" to be representative of the state of coral reefs in the Republic of Vanuatu.

2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** While the cover of key benthic groups has been well monitored, the lack of precision when identifying algae prevents this indicator from being considered as measured. Thus, this indicator fails to accurately represent the cover of algae and the cover of key benthic groups at the country level.

3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

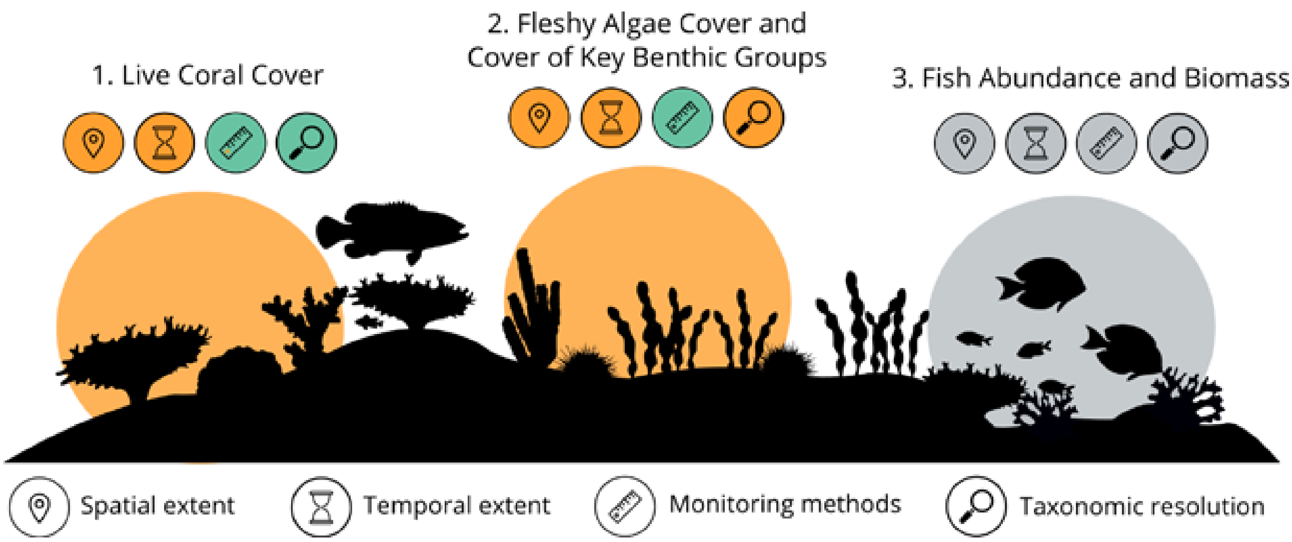

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

The spatial and temporal extent of the monitoring effort recorded in the 2020 GCRMN database is not enough yet for the indicators "Live Coral Cover", as well as "Fleshy Algae Cover and Cover of Key Benthic Groups", to be considered available at the country level. Further efforts are needed for these indicators to be considered available in the Republic of Vanuatu. By increasing the spatial coverage of the monitoring by better including the organisms belonging to the group "Other fauna" in future monitoring protocols, these indicators would easily be available.

3.3 Main contacts

A coral reef monitoring focal point for the Republic of Vanuatu has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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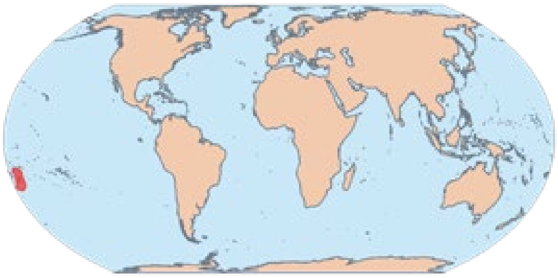

TONGA

1. Introduction – General context

CORAL REEF CARD

Estimated area: 1,775 km²

Proportion of the world's coral reefs: 0.673%

Ranking based on reef area: 29th

The Kingdom of Tonga is an archipelagic nation located in the Southern Pacific Ocean. Its 176 islands are located in an area of high tectonic and volcanic activity, which represents a constraint for the development of coral reefs in the islands that are active. The islands that are less active exhibit well developed reefs, which is particularly true for the Eastern Islands of the archipelago.

Coral reefs in Tonga are made up of 222 species of hard corals (IUCN, 2021) and are home to 1,013 fish species (Froese & Pauly, 2020). Tonga has fringing reefs along most of its coasts, as well as platform and barrier reefs (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Its coral reefs provide numerous services to the Tongan people, by supporting the tourism and fishing industries, but also by providing coastal protection against waves and storms. In 2019, tourism represented 18.5% of the GDP and provided 5,900 jobs (World Travel & Tourism Council, 2020). Coral reefs act as one of the major tourist attractions (Salcone et al., 2015) and reef tourism is estimated to represent 2.9% of the GDP (Spalding et al., 2017). Coral reefs are also important fishing grounds, sustaining both subsistence and commercial inshore fisheries. Even though their contribution to the GDP is less than 1%, which is surely underestimated as most catches are for personal consumption, they represent a major source of animal protein for local communities. The minimum estimate for the net annual value of subsistence fisheries is US$3 million while the minimum estimate for the net annual value of domestic commercial inshore fisheries ranges between US$2 million and US$4.1 million. The benefits of coastal protection are crucial in this region where cyclones and seismic activity are frequent. In 2013, the net value of this service was estimated to range between US$6.5 and 10.9 million, which represents less than 1% of the GDP (Salcone et al., 2015).

The main anthropogenic threat to Tongan coral reefs is overfishing, which is apparent in most inhabited islands. Some additional pressures result from nutrient runoff from land-based development that led to poor water quality and ultimately to the death of the corals, and the collection of organisms for aquarium trade. However, the reefs also exhibit damage from cyclones and coral bleaching (Purkis et al., 2017; Smallhorn-West et al., 2020).

Marine protected areas in Tonga span 382 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 224 km² of coral reefs within their boundaries, thus placing 12.6% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Tonga, with data from a total of 4 sites included within the GCRMN dataset. These observations represent 0.02% of the total global dataset compiled by the GCRMN (451 rows).

Sites from which data were provided occur on Tongatapu, which is the main island of Tonga, as well as on Vava'u, and offshore of Uoleva. Sites tend to have been surveyed only once, with the exception of one site in Tongatapu, which was surveyed for more than 6 years (Figure 1).

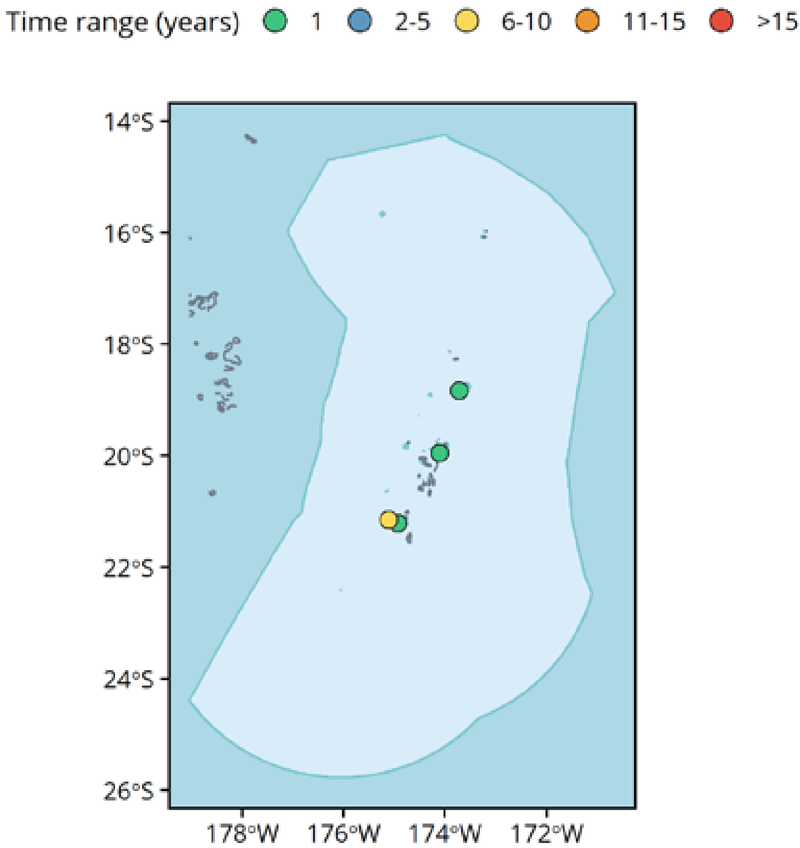

Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 2001 to 2017. The monitoring effort is limited to 6 different years between 2001 to 2017 (Figure 2A).

The majority (62%) of surveys contributed to the 2020 GCRMN database were conducted using photo-quadrats, followed by point intercept transects (38%) (Figure 2B).

Between 2000 and 2009, 2 out of the 3 surveys were conducted using the point intercept transect method, and between 2010 and 2019, when most surveys were conducted, 4 out of the 5 surveys were conducted using the photo-quadrat method (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is excellent, with 92% of identifications made at the subgroup level or above. The level of precision for taxonomic observations increased over the two time periods, as the proportion of observations recorded to the genus level and above increased from 44% to 94% (Figure 2D).

Only 1 out of the 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) is represented. Algae were identified to at least the subgroup level for 13% of the observations (Figure 2E).

Organisms belonging to 2 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other ubgroups”) are represented in the database. When recorded, the observations of benthic fauna other than hard coral species were all identified to at least the subgroup level (Figure 2F).

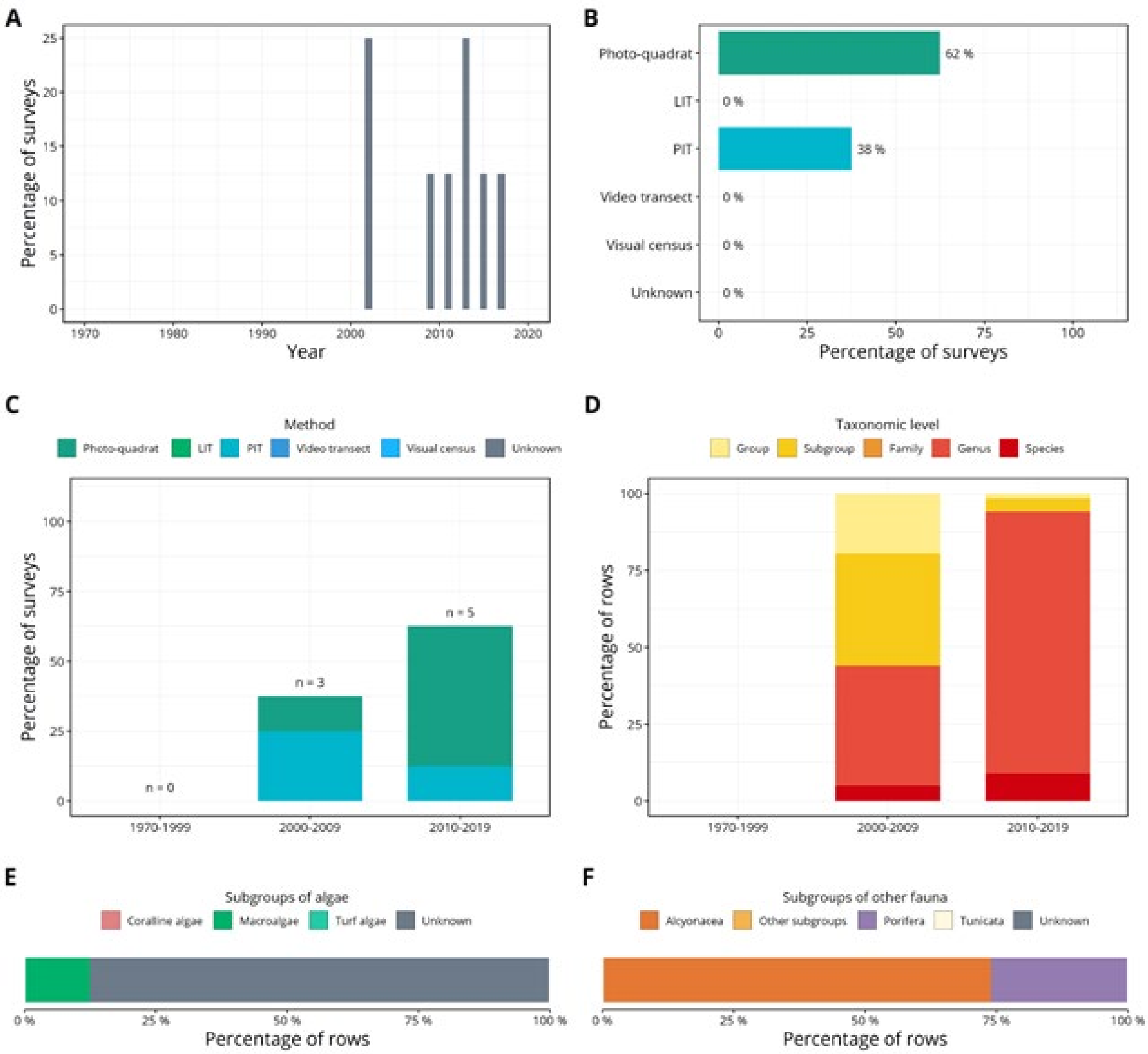

Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is limited to one site. The spatial extent of the monitoring should thus be extended by implementing new monitoring sites around numerous islands within the archipelago.

Temporal Extent. Even though one of the sites included within the database was monitored for 8 years, there is only a single time series available in Tonga. Thus, we recommend that new fixed sites for monitoring be established and that the monitoring on existing sites be extended.

Methodology. The use of photo-quadrats for all surveys is highly valuable, as high-quality photos and videos collected while using image-based methods provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Overall, the taxonomic precision at which observations were recorded is excellent. However, while the general taxonomic precision is excellent, there is a lack of algae other than macroalgae, and the subgroups "Tunicata" and "Other subgroups", belonging to the group "Other fauna" are not represented as well. This might be due to the fact that these organisms were absent from the sites, because they were present but were recorded only to the group level or because they were not included in monitoring protocols. In the last two cases, we would recommend that the identification of these organisms be better included in future monitoring protocols, as part of the measure of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups".

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data being contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 4 sites in Tonga for 6 different years between 2009 and 2017. While two out of the four criteria are verified, this indicator cannot be considered in use at the country level, since the spatial coverage of the monitoring recorded in the GCRMN 2021 database is too limited.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** While the general taxonomic resolution is excellent, algae other than macroalgae are lacking, as well as some of the organisms related to the group "Other fauna". Most importantly, the spatial coverage of the monitoring contributed to the GCRMN database is not sufficient for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

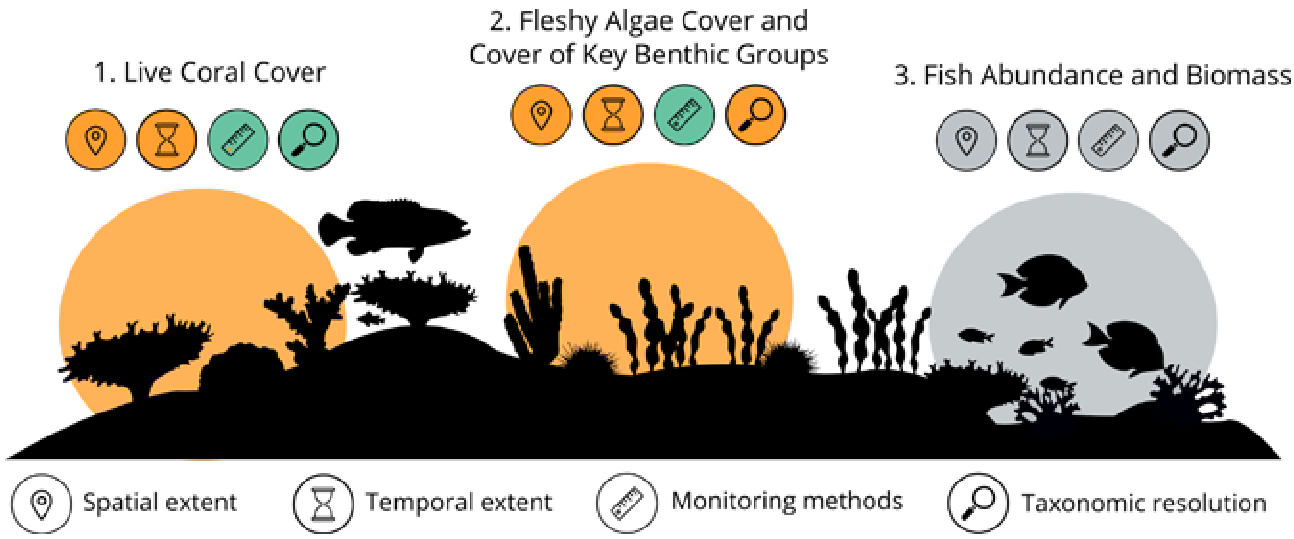

Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

The spatial and temporal extent of the monitoring effort recorded in the 2020 GCRMN database is not yet enough for the indicators "Live Coral Cover" as well as "Fleshy Algae Cover and Cover of Key Benthic Groups" to be considered available at the country level. A little more effort is needed for these indicators to be considered available in Tonga. However, we are aware that extensive surveys of coral reefs in Tonga have been conducted in the past few years. Please, refer to Purkis et al. (2017) and Smallhorn-West et al. (2020) for recent monitoring of coral reefs in Tonga.

3.3 Main contacts

A coral reef monitoring focal point for the Kingdom of Tonga has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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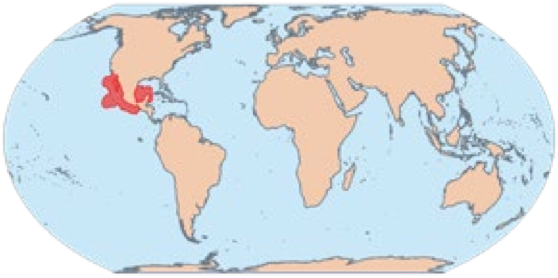
MEXICO



1. Introduction – General context

CORAL REEF CARD

Estimated area: 1,672km²

Proportion of the world's coral reefs: 0.635%

Ranking based on reef area: 30th

Mexico is bordered by the Pacific Ocean and the Gulf of California to the West and by the Gulf of Mexico and the Caribbean Sea to the East. On the West coast, coral reefs can be found in the Pulmo region, the Revillagigedo Archipelago and along Mexico's Pacific coastline (Reyes-Bonilla, 2003). In the Gulf of Mexico, coral reefs are mainly located on Veracruz and Campeche Bank (Gil-Agudelo et al., 2020), while the Northern and most extensive portion of the Mesoamerican barrier reef is located in the Mexican Caribbean (Spalding, Ravilious, Green, & UNEP-WCMC, 2001).

Coral reefs in Mexico are host to 92 species of hard corals (IUCN, 2021) and 637 fish species (Froese & Pauly, 2020). Hard coral species form platform reefs, patch reefs, fringing reefs, atolls and barrier reef (Spalding et al., 2001).

Coral reefs provide numerous services to Mexico's coastal communities, as they support the tourism and fishing industries, and provide coastal protection against waves and storms. In 2019, tourism represented 15% of the GDP, and provided more than 7 million jobs, accounting for 12.8% of the total employment (World Travel & Tourism Council, 2020). However, reef-tourism only represents 0.25% of the GDP (Spalding et al., 2017). In 2019, the total value of diving and snorkeling activities was estimated at US$725 million, and US$455 million if large dive operators and businesses were excluded from the analysis (Arcos-Aguilar et al., 2021). The economic contribution of these activities is comparable to the contribution of artisanal and industrial fisheries, that are estimated at US$700 million (Martínez-Estrada, Melgoza-Rocha, Mascareñas-Osorio, & Cota-Nieto, 2017), which represents less than 0.06% of the GDP. The number of fishermen involved in coral reef fisheries is estimated at 64,700 people (Teh, Teh, & Sumaila, 2013). The benefits of coastal protection are crucial, particularly for the West coast of Mexico, where storms and hurricanes are frequent. The potential cost of sea level rise on the highly touristic state of Quintana Roo alone has been estimated at US$330 million and may go as high as US$2.3 billion, according to sea level rise scenarios of 1 m and 3 m, respectively (Ruiz-Ramírez, Euán-Ávila, & Rivera-Monroy, 2019). However, at most, this estimate accounts for only 0.2% of the country's GDP.

Coral reefs in Mexico face a range of natural threats, such as storms, hurricanes and bleaching events, caused by El Niño and increasing sea surface temperatures due to climate change. In addition to these natural phenomena, coral reefs suffer from anthropogenic threats, such as overfishing, pollution, coastal development and unsustainable tourism practices (Ruiz-Ramírez et al., 2019; Gil-Agudelo et al., 2020).

Marine protected areas in Mexico span 73,000 km² (Marine Conservation Institute, 2020; UNEP-WCMC & IUCN, 2020) and include 1,412 km² of coral reefs within their boundaries, thus placing 84.5% of the country's coral reefs under protection.

2. Description of the available data

The following analysis is based on contributions of data to the GCRMN that were used to prepare the GCRMN *Status of Coral Reefs of the World: 2020* (Souter et al., 2021). Monitoring effort provides good coverage of the coral reefs around Mexico, with data from a total of 541 sites included within the GCRMN dataset. These observations represent 0.8% of the total global dataset compiled by the GCRMN (16,136 rows).

Sites from which data were provided occur on most coral reefs in Mexico. Medium and long-term monitoring sites within Mexico are common, with time series at some sites exceeding 10 years (Figure 1).

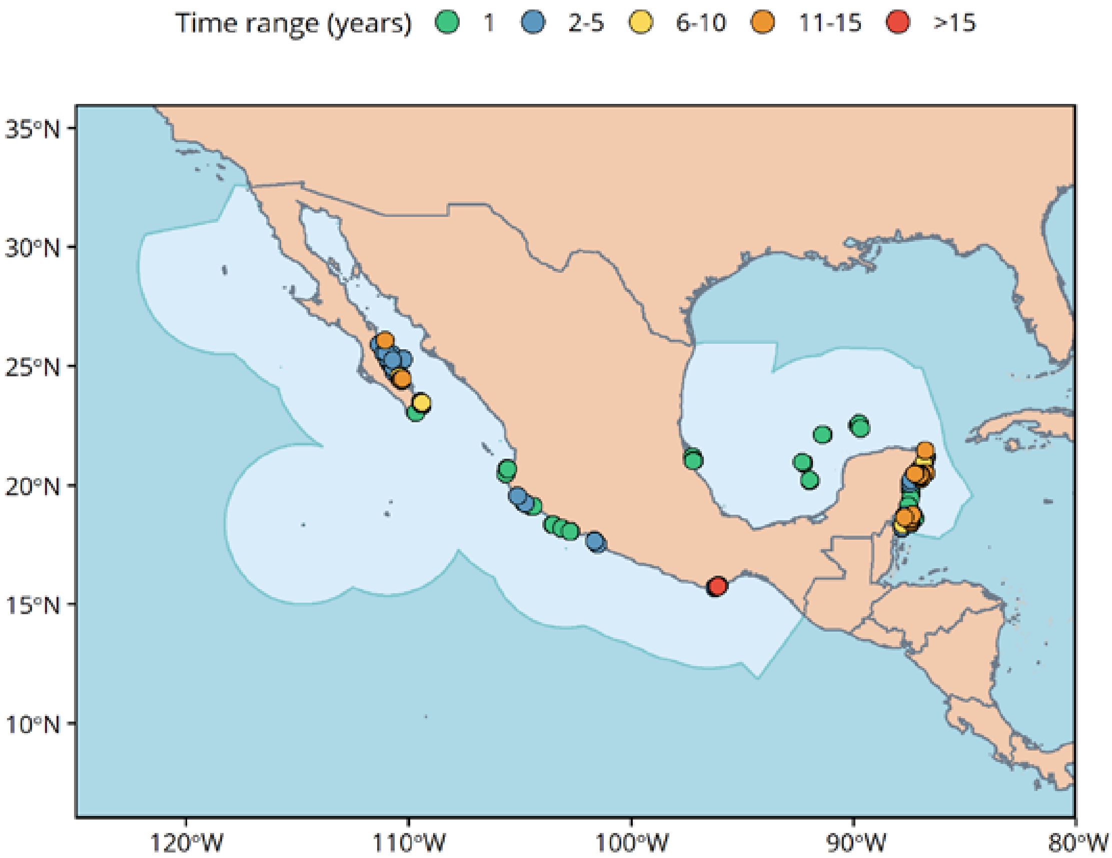


Figure 1. Location and duration of monitoring at each site included in the 2020 GCRMN world report database. The EEZ is represented in light blue while the location of existing coral reefs is represented by grey dots (reef data from Reefs at Risks).

Data contributed to the database spans the period from 1997 to 2019. While the monitoring effort is not consistent over the years, the percentage of surveys conducted per year has greatly increased since 2004 (Figure 2A).

A wide variety of methods were used to survey the coral reefs. The majority (47%) of surveys contributed to the 2020 GCRMN database were conducted using point intercept transects, followed by video-transects (11%), line intercept transects (5%) and photo-quadrats (1%). The method used was not specified for 37% of surveys in the database (Figure 2B).

All of the methods that are listed above were used during the 2000-2009 and 2010-2019 periods, except for photo-quadrats, which were only used during the latter. Although the number of surveys conducted increased during the 2010-2019 period, the proportion of each method used is similar to the 2000-2009 period. During the 2010-2019 period, most surveys were conducted using point intercept transects (501 surveys). Video transects were used to conduct 123 surveys, line intercept transects were used in 36 surveys, and photo-quadrats were used in 17 surveys. The method was not specified for 342 surveys (Figure 2C).

Benthic observations were re-categorized for analytic purposes into 7 groups, which were named as follows: “Abiotic”, “Hard living coral cover”, “Hard bleached coral”, “Hard dead coral”, “Algae”, “Other fauna” and “Seagrass”. Some of these groups are further divided into subgroups, such as the group “Other fauna”, which encompasses the subgroups “Alcyonacea”, “Porifera” and “Tunicata” in addition to “Other subgroups” (see Material and Methods for the full list). The overall taxonomic resolution of the data provided is low, with only 31% of identifications made at the subgroup level or above. The level of precision of taxonomic observations increased over the time periods. During the 1979-1999 period, only 50% of observations were recorded up to the subgroup level. The percentage of observations recorded to the group level decreased between 2000 and 2009, as only 27% of observations were recorded to the subgroup level. The percentage of observations recorded to this level and above then increased slightly between 2010 and 2019, as 32% of observations were recorded at this level (Figure 2D).

The 3 “Algae” subgroups (“Coralline algae”, “Macroalgae” and “Turf algae”) are represented. Algae were identified to at least the subgroup level for 65% of the observations (Figure 2E).

Organisms belonging to 3 out the 4 “Other fauna” subgroups (“Alcyonacea”, “Porifera”, “Tunicata” and “Other subgroups”) are represented in the database. Observations of benthic fauna other than hard coral species were identified to at least the subgroup level for 41% of the observations (Figure 2F).

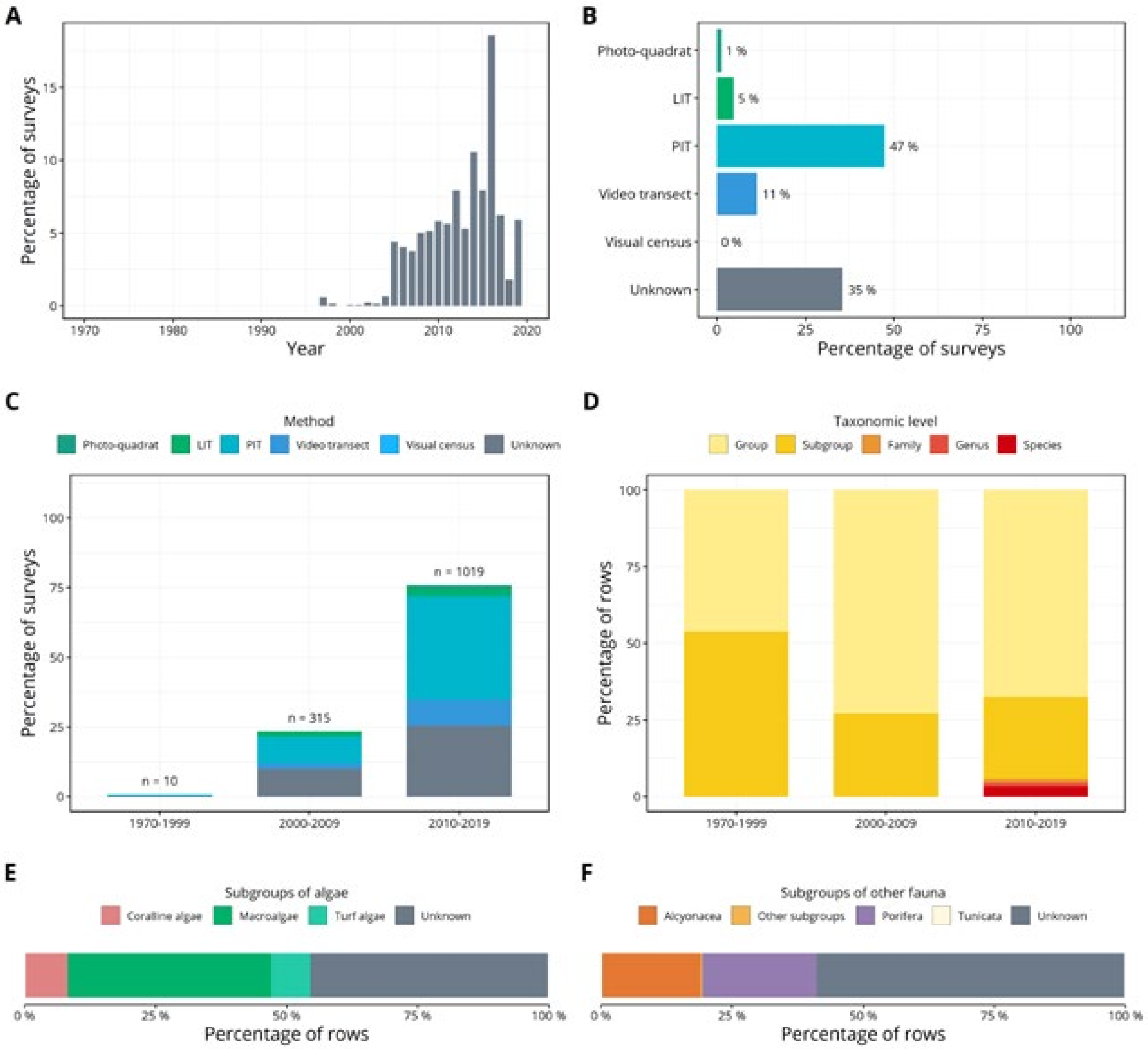


Figure 2. Percentage of the total number of surveys conducted each year (A), percentage of the total number of surveys conducted using each method (PIT: Point Intercept Transect; LIT: Line Intercept Transect) (B), evolution of the use of monitoring methods by time period with the number (n) of surveys conducted during each period displayed on top of each bar (C) and the distribution of taxonomic precision by time period (D). (E) represents the proportion of observations made to at least the subgroup level when describing the algae cover while (F) represents the proportion of observations made to at least the subgroup level when describing the main taxa represented in the group “Other fauna”.

Groups and subgroups were defined to homogenize the biotic and abiotic observations collected during the benthic monitoring of coral reefs (see Methods for full list).

(Figure made using the 2020 GCRMN world report database)

3. Analysis of the data coverage with respect to ICRI coral reef indicators and recommendations

3.1 Potential limitations and recommendations on benthic cover monitoring

Based on the data for the benthic cover presented above (with a strong focus on biotic variables), the following limits and recommendations were developed in order to improve the monitoring of coral reefs at the country level.

Spatial Extent. The spatial coverage of the monitoring is widespread and provides good coverage for coral reefs in Mexico. This coverage is highly valuable as it provides representative results on the state of coral reefs at the country level. However, monitoring is lacking in the Revillagigedo Archipelago, as well as in the state of Guerrero.

Temporal Extent. Several sites were monitored for long periods of time in different reefs around Mexico, providing time series for analysis. This is highly valuable and should be continued.

Methodology. The methods used are very heterogeneous and are even lacking for a significant number of surveys. Thus, when implementing new monitoring sites, we recommend that image-based methods be used, as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in taxonomic composition of benthic communities.

Taxonomic resolution. Overall, the taxonomic precision at which observations were recorded is lacking, though it has increased over the three time periods. The subgroup "Tunicata" belonging to the group "Other fauna" is not represented in the database. This might be due to the fact that these organisms were absent from the sites, because they were present but were only recorded to the group level or because they were not included in monitoring protocols. In the last two cases, it would be recommended that these subgroups be included in future monitoring protocols. It is highly recommended that better identifications of algae and benthic organisms be included in future monitoring protocols, as these organisms are a part of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups". Their inclusion would allow for better detection of changes in the composition of benthic communities on the coral reefs of Mexico.

3.2 Status of ICRI recommended coral reef indicators

The implementation of the ICRI recommended indicators at the country level was evaluated based on 4 criteria: the temporal and spatial extent of the available data, the methods used to monitor coral reefs and the taxonomic resolution of the data contributed to the 2020 GCRMN dataset. The results are presented in Figure 3.

1. **Live Coral Cover.** This indicator was monitored on 541 sites around Mexico for 22 different years between 1997 and 2019. Further, all criteria are met for the indicator "Live Coral Cover" to be considered in use and available at the country level.
2. **Fleshy Algae Cover and Cover of Key Benthic Groups.** All types of algae were recorded during the surveys. However, only 41% of benthic organisms other than hard corals were identified to the subgroup level. Thus, while all three other criteria are met, the taxonomic precision is too low for this indicator to be considered available at the country level.
3. **Fish Abundance and Biomass**. This indicator was not considered for the data acquisition nor for the homogenization process prior to the compilation of the 2020 GCRMN world report database. Thus, based on available data, it is not possible to assess whether this indicator is effectively monitored at the country level.

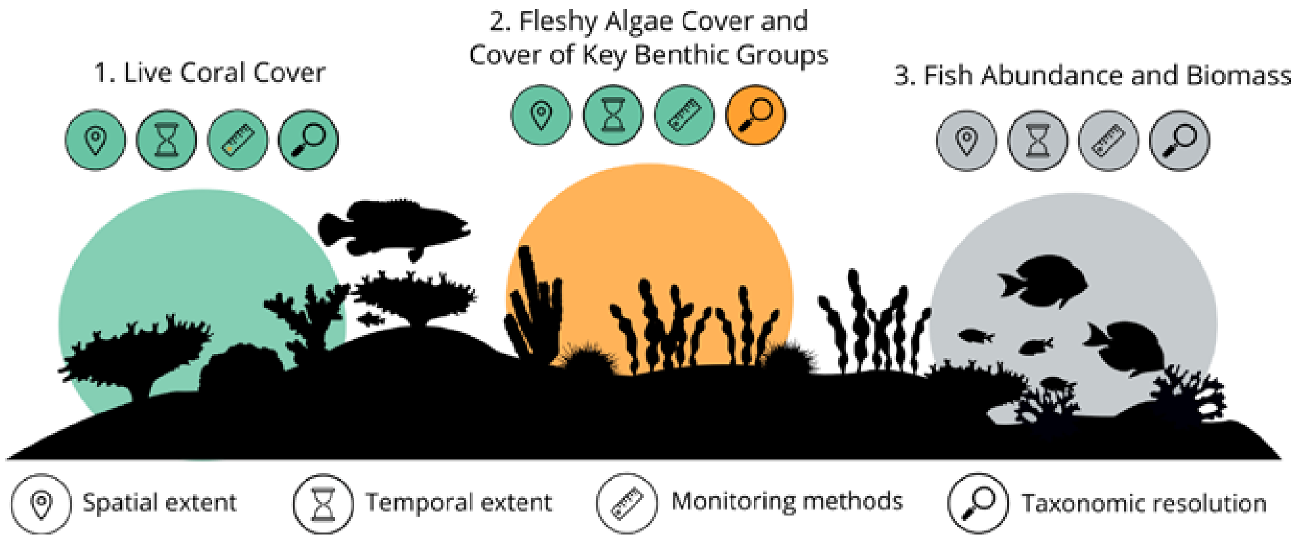


Figure 3. ICRI recommended coral reef indicators and their status of implementation at the country level. The criteria (spatial extent, temporal extent, monitoring methods used, taxonomic precision) are represented in green when the quality of the data is deemed sufficient, in orange when more work is needed and in grey when the data are unavailable. Then, each indicator, which is represented by the large coloured circle, was evaluated based on how it faired regarding the chosen criteria. The status of implementation of the indicators is represented in green when the indicator is considered available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data.

The spatial and temporal extent of the monitoring effort recorded in the 2020 GCRMN database is good enough for the indicator "Live Coral Cover" to be considered available at the country level. However, benthic organisms other than hard coral species need to be better included in future monitoring protocols for the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" to be considered available in Mexico.

3.3 Main contacts

A coral reef monitoring focal point for Mexico has not yet been identified. Please contact Francis Staub from the ICRI secretariat at fstaub@icriforum.org for further information.

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REVIEW OF THE MONITORING EFFORT REPRESENTED BY THE PILOT COUNTRIES TO THE GCRMN DATABASE

This pilot analysis was conducted on 30 countries, representing the 30 countries with the highest coral reef surfaces. Together, these countries represent almost 90% of the world's coral reef surface. A summary of the main monitoring descriptors for each country is presented in Table 1.

Overall, 12,653 sites were contributed to the 2020 GCRMN world report database (Souter et al. 2021) by the 30 pilot countries. The number of sites contributed by each country varied from 2 to 4,790 sites. The number of sites in relation to the coral reef surface in each country, varied from 0.09 to 67.2 sites per 100 km² of coral reefs. A total of 37,012 surveys were contributed to the GCRMN by the pilot countries, with the number of surveys contributed by each country ranging from 2 to 11,775. The density of surveys conducted in relation to the coral reef surface varied from 0.09 to 304.23 surveys per 100 km² of coral reefs. Together, the 30 pilot countries contributed a total of 1,682,943 observations. The number of observations contributed by country ranged from 73 to 982,066 observations, and their density from 3 to 13,777 observations for 100 km² of coral reefs, all years combined. The point intercept transect method was the main method used in 14 countries, followed by unknown methods (8 countries), the photo-quadrat method (6 countries), and finally the line intercept transect method and the visual census method (1 country each). Regarding the taxonomic resolution of the data, 28 out of the 30 pilot countries presented a taxonomic precision at the subgroup level or above for more than 50% of the data provided. Less than 50% of the observations were identified at the subgroup level or above for each of the 2 remaining countries. Finally, the duration of the monitoring was also heterogeneous, as countries provided data ranging from 1 year to 36 different years.

Table 1. Summary of all of the monitoring-related information by country based on the data contributed to the 2020 GCRMN world report database.

Country	Sites	Number of sites per 100 km²	Surveys	Number of surveys per 100 km²	Observations (rows)	Number of observations per 100 km²	Main type of method used	% of observations at the subgroup level and above	Number of years with surveys provided
Australia	758	1.7	4,918	11.06	287,397	646.05	Photo-quadrat	93.66	27
Bahamas	463	10.25	630	13.95	26,637	589.62	Unknown	77.79	18
Belize	133	6.92	223	11.61	5,008	260.65	PIT	62.86	17
Cuba	65	1.22	72	1.35	686	12.9	Unknown	56.71	5
Egypt	169	5.37	497	15.79	7,666	243.52	Unknown	64.56	21
Eritrea	2	0.09	2	0.09	73	3.19	PIT	61.64	1
Fiji	249	3.53	370	5.25	9,221	130.74	PIT	68.57	22
France	386	2.34	2,437	14.77	75,414	457.21	PIT	85.05	34
India	105	2.93	1,018	28.41	35,588	993.22	LIT	75.87	15
Indonesia	1,460	3.63	1,773	4.41	52,474	130.5	PIT	73.04	29
Japan	597	30.12	6,031	304.23	9,567	482.6	Visual census	20.19	36
Kiribati	18	0.59	18	0.59	394	12.86	Photo-quadrat	88.07	2
Madagascar	169	4.06	599	14.4	7,676	184.52	PIT	82.13	22
Malaysia	585	17.29	1,631	48.22	37,554	1,110.19	PIT	67.37	27
Maldives	228	4.28	481	9.02	11,147	209.11	PIT	71.43	23
Marshall Islands	33	0.91	42	1.16	2,590	71.37	Photo-quadrat	90.66	7
Mexico	541	32.35	1,336	79.89	16,136	964.91	PIT	31.18	22
Micronesia	81	1.62	144	2.88	6,895	137.79	Photo-quadrat	91.31	16
Mozambique	142	5.6	192	7.57	1,532	60.4	Unknown	75.26	16
Papua New Guinea	58	0.39	219	1.46	36,745	245.13	PIT	98.2	21
Philippines	568	2.21	764	2.98	24,119	93.93	PIT	67.56	31
Saudi Arabia	106	1.79	112	1.89	4,279	72.2	PIT	77.35	13
Seychelles	166	8.58	272	14.06	1,044	53.95	Unknown	67.82	19
Solomon Islands	111	1.6	260	3.76	21,097	304.94	Unknown	84.79	10
Sudan	47	2.03	64	2.77	835	36.11	Unknown	73.41	6
Tanzania	160	5.27	393	12.95	2,419	79.73	Unknown	58.16	27
Tonga	4	0.23	8	0.45	451	25.41	Photo-quadrat	92.02	6
United Kingdom	427	9.24	694	15.01	15,249	329.88	PIT	89.34	28
United States	4,790	67.2	11,775	165.19	982,066	13,777.26	Photo-quadrat	97.92	29
Vanuatu	32	1.69	37	1.96	984	52.11	PIT	58.94	6

ICRI recommended indicators

While all four criteria (spatial extent, temporal extent, methods used and taxonomic resolution) are important and provide useful insights on the quality of the data contributed to the 2020 GCRMN world report database, only two criteria were selected in order to determine the final status of the indicators: the spatial coverage and the taxonomic resolution of the data contributed. These criteria were selected because they were the most relevant when evaluating whether an indicator is available at the country level.

The indicator “Live Coral Cover” is already available at the country level for more than two thirds of the pilot countries, and it should quickly become available in all of them, provided that the spatial coverage of the monitoring is increased. This indicator is mostly lacking in some provinces[1] of the Central Indo-Pacific and the Eastern Indo-Pacific. In these provinces, most countries have extensive marine territories, or are made of several islands isolated from another, where coral reefs are abundant and widespread. In such places, the existence of structures federated by the NGO Reef Check are highly valuable, as they provide data from sites that are typically located too far from the main research centers to benefit from regular monitoring, and which involve local communities in the monitoring of their reefs.

The availability of the indicator “Fleshy Algae Cover and Cover of Key Benthic Groups” at the country level is more limited. This is mainly due to the combination of an insufficient spatial coverage and the lack of inclusion of the organisms targeted by this indicator in monitoring protocols. This indicator is lacking in some provinces of the Central Indo-Pacific, the Eastern Indo-Pacific, the Western Indo-Pacific the Tropical Eastern Pacific and the Tropical Atlantic.

Methods used to monitor coral reefs

To identify which types of methods were used to collect the benthic data, we used the information that were present in the metadata of each dataset, or asked the data contributors for more details. The identified methods are line intercept transects, point intercept transects, photo-quadrats, video transects and visual censuses. When the information was missing from the metadata, the methods was considered unknown. The use of image-based methods as well as point and line intercept transects was preferred over the use of visual censuses, as the latter is less precise when monitoring the composition of benthic communities a high taxonomic resolution. The methods used were considered to be satisfying for 22 countries (73%). The types of methods or the information regarding the methods were considered insufficient for 6 countries (20%). Not enough information regarding the methods were recorded in the database for 2 countries (7%).

1 As defined in Spalding et al. (2007).

Live Coral Cover

The availability of the indicator "Live Coral Cover" for the 30 pilot countries is represented in Figure 1A, as well as the percentage of countries which met each criterion (Figure 1B).

The spatial extent and the temporal extent were deemed sufficient for 21 countries (70%). The taxonomic precision was always deemed sufficient, as this indicator focuses on the status of hard corals (alive, bleached or dead) and not on the composition of hard coral communities. Thus, we assumed that the indicator "Live Coral Cover" is available at the country level for 21 out of the 30 pilot countries (70%).

The spatial coverage of the monitoring is the major limiting factor that was identified while evaluating the availability of this indicator at the country level. The monitoring effort needs to be sufficiently widespread to be considered representative of the state of coral reefs at the country level. This criterion was considered to be limiting for 9 countries, where the indicator was measured but not available at the country level.

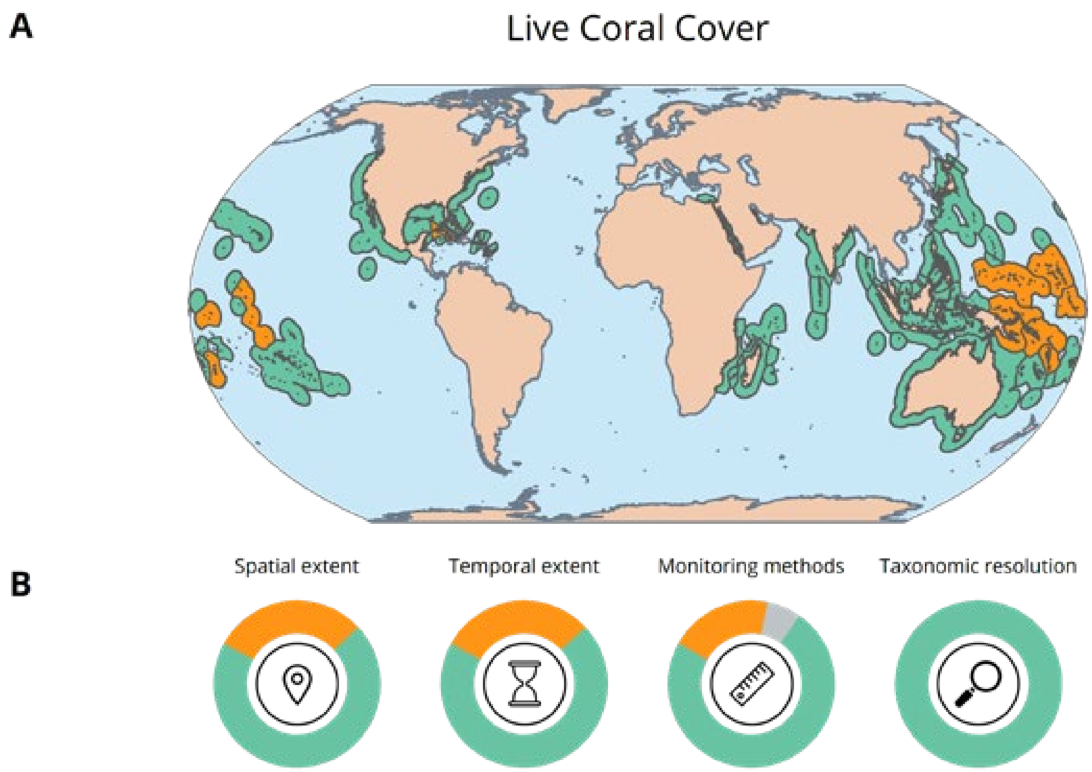

Figure 1. Availability of the ICRI recommended indicator "Live Coral Cover" for the 30 pilot countries, represented by the colour of their EEZ. The EEZ is coloured green when the indicator is available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data (A). The proportion of countries in which each of the four selected criteria are met is represented in green when the criterion is met, in orange when more work is needed and in grey when the data are unavailable (B).

Fleshy Algae Cover and Cover of Key Benthic Groups

The availability of the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" at the global scale is represented in Figure 2A, as well as the percentage of countries that have met each criterion (figure 2B).

The spatial extent and the temporal extent were deemed sufficient for 21 countries (70%). The taxonomic precision was deemed sufficient for 18 countries (60%), insufficient for 10 countries and unknown for 2 countries. We can thus consider that this indicator is available in 13 out of the 30 pilot countries.

Two major limiting criteria were identified while evaluating the availability of this indicator: the spatial coverage (9 countries) and the taxonomic resolution (12 countries). As the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" focuses on the composition of benthic communities other than hard coral species, it requires that the taxonomic precision be at least to the subgroup level. This criterion was limiting in countries where these organisms were recorded, but identified mainly to the group level, or countries where we could not determine whether they were included or not based on the data provided.

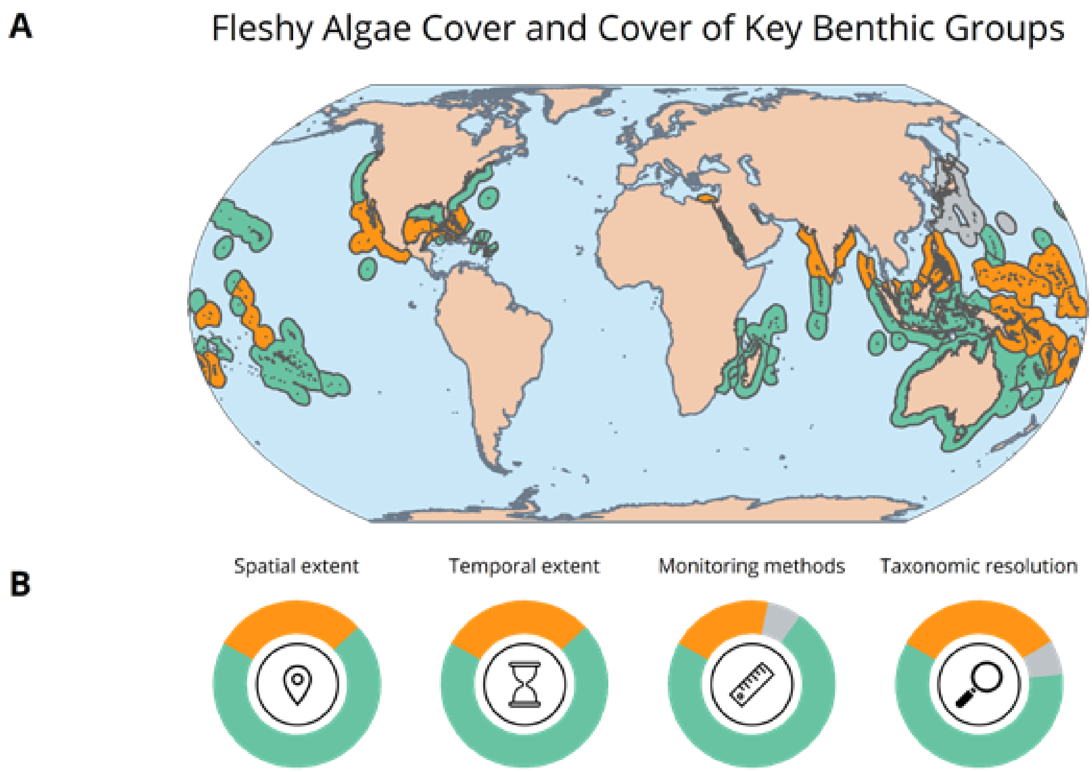

Figure 2. Availability of the ICRI recommended indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" for the 30 pilot countries, represented by the colour of their EEZ. The EEZ is coloured green when the indicator is available at the country level, in orange when it is not yet available and in grey when its availability cannot be determined with the current data (A). The proportion of countries in which each of the four selected criteria are met is represented in green when the criterion is met, in orange when more work is needed and in grey when the data are unavailable (B).

Improving the monitoring of coral reefs worldwide

The 2020 GCRMN world report database was built from contributions provided by numerous individuals involved in the monitoring of coral reefs. However, while extensive, we are aware that this database does not include all of the coral reef data in existence. Thus, a major challenge for future GCRMN reports will be to further **improve the centralization** of the data and to **collect existing data that has yet to be collected**, as these actions would significantly improve the accuracy of the analyses without demanding additional monitoring effort. It would also lead to a re-evaluation of the status of the indicators at the country level, notably by improving the spatial coverage in some areas.

One of the two limiting factors identified when evaluating the availability of the indicator "Fleshy Algae Cover and Cover of Key Benthic Groups" at the country level is the spatial coverage of the monitoring. By analyzing the distribution of the monitoring effort, some **priority areas for the implementation of new monitoring sites** were identified. Thus, we recommend that new sites be implemented in these areas, in order to significantly improve the coverage of coral reef monitoring and its degree of representativeness of the state of coral reefs.

The other limiting factor identified is the taxonomic precision at which the observations were recorded. Identifying organisms up to the genus or species levels can be difficult as it requires a certain degree of expertise, and it can also be time consuming. Thus, we propose a simplified classification to record observations into the groups and subgroups, which is presented in Table 2 (see Material and Methods). We recommend that **identifications be made to at least the subgroup level** rather than the group level, as the subgroup level represents the minimum level of taxonomic precision required to study the evolution of benthic communities.

The taxonomic resolution of observations could be improved by **using image-based monitoring methods**, such as photo-quadrats or video transects. The use of image-based methods is valuable as high-quality photos and videos provide a permanent visual record that can be revisited at a later date to obtain additional information, such as changes in the taxonomic composition of benthic communities.

The lack of homogeneity between monitoring protocols and thus between the resulting datasets is also a major obstacle for the integration of data in global databases. Thus, we recommend that efforts be made to **homogenize monitoring protocols and the data acquisition processes worldwide**, in order to facilitate data aggregation. This is even more challenging for fish monitoring, which could not be included in this report due to extreme heterogeneity. Homogenizing monitoring protocols includes the use of the scientific name when identifying organisms, or the classification used in the GCRMN report *Status of Coral Reefs of the World: 2020* (Souter et al. 2021) when the taxonomic precision is inferior to the family level, but it also includes the use of certified monitoring methods. The way in which a site name is entered and the precise set of associated coordinates is also of great importance, especially when identifying fixed monitoring sites and the associated time series.