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# GCRMN-CARIBBEAN GUIDELINES FOR CORAL REEF BIOPHYSICAL MONITORING

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# GCRMN-CARIBBEAN GUIDELINES FOR CORAL REEF BIOPHYSICAL MONITORING

## INTRODUCTION:

The Global Coral Reef Monitoring Network (GCRMN) was established to support the International Coral Reef Initiative (ICRI)'s Call to Action and Framework for Action in 1994. The GCRMN worked through regional networks, comprising a variety of institutions, with the aim of strengthening the provision of the best available scientific information and communication on the status and trends of coral reef ecosystems, for their conservation and management. Since its inception the Wider Caribbean has been participating in GCRMN through the regional network and sub-regional nodes, coordinated through UNEP's Caribbean Environment Programme (CEP), which also serves as the regional focal point for ICRI.

The current reactivated GCRMN-Caribbean is an open network of coral reef scientists, managers and government expert representatives involved with coral reef monitoring in the region, led by a Steering Committee with the support of UNEP-CEP and the SPAW-RAC[1] as regional coordinator (Table 2). Former participants of the sub-regional nodes also participate in the current network. Following the publication of the "Status and Trends of Caribbean Coral Reefs: 1970-2012"[2] report, UNEP-CEP has taken the initiative in 2014[3] to revitalize and strengthen coral reef monitoring, to ensure the collection of useful and accessible data that can effectively reveal the status and trends of the coral reefs in the region.

To achieve this objective, it is of prime importance to both increase and harmonize the monitoring efforts conducted across the region, starting from the field and the data collection. To serve this purpose, the GCRMN-Caribbean has agreed on regional technical coral reef biophysical monitoring guidelines to guide and support coral reef practitioners and relevant programmes.

Of particular importance, the GCRMN-Caribbean seeks to help reinforce existing national coral reef monitoring programmes and to support the development of new ones where needed. Caribbean Governments are invited to take part in this regional effort, by encouraging their relevant Departments and partners to use the GCRMN-Caribbean biophysical monitoring guidelines, as well as to request assistance and support from this expert network at their convenience.

The GCRMN-Caribbean also recognizes the importance of using an integrated approach to coral reef monitoring and seeks to promote the systematic implementation of a monitoring of social science indicators in conjunction with biophysical monitoring, in order to enhance the ability to make connections and inferences between observed changes in the coral reef ecosystem quality and human and social parameters. While the present guidelines concerns the biophysical monitoring component, the GCRMN-Caribbean monitoring programme also includes Socio

1 Regional Activity Centre aimed at implementing the protocol concerning specially protected areas and wildlife in the Caribbean region (SPAW)

2 Jackson, J. B. C., M. K. Donovan, et al. (2014). Status and Trends of Caribbean Coral Reefs: 1970-2012. Gland, Switzerland, Global Coral Reef Monitoring Network, IUCN.

3 http://www.car-spaw-rac.org/?Caribbean-Coral-reef-monitoring,566

economics monitoring guidelines[4], to complement the biophysical information and to help support integrated analysis of coral reefs conditions and trends.

The GCRMN-Caribbean baseline scientific monitoring guidelines provide a multi-level framework for existing and developing monitoring programmes to contribute data that support a regional understanding of status and trends of Caribbean coral reefs which will help guide management and decision-making as well. The purpose of this collaborative effort is to collect, collate and report reef monitoring data that will be widely available for a variety of purposes including contributing to our understanding of the processes that shape coral reefs and providing actionable advice to policy makers, stakeholders, and communities at a variety of spatial scales from local to Caribbean wide. In order to achieve these goals, the GCRMN-Caribbean partners seek to collect comprehensive and regionally comparable data that build from a modern scientific perspective of reef monitoring. The guidelines are designed for a larger scale objective of detailed regional comparisons for management (particularly the Level 3 - highly recommended protocol), but cognizant of the fact there are many ongoing long-term monitoring efforts that also want to contribute data which will can be included (though minimum standards will apply). The scientific monitoring framework is described herein, and includes several different protocol options based on each monitoring group's operational capacities and provides reference to several well-developed Caribbean monitoring programs with established monitoring protocols available online.

The GCRMN-Caribbean contributes to, and coordinates with the global GCRMN and ICRI efforts, as well as UNEP's coral reefs global partnership and programme (UNEP(DEPI)/CAR WG.36/INF.10). The upcoming ICRI General Meeting will be held in Paris, 2 - 4 November 2016 where UNEP-CEP will be represented through the SPAW-RAC and present on the GCRMN-Caribbean efforts. The ICRI meeting includes within the agenda: The Resolution on sustainable coral reefs management that was adopted at the second session of the United Nations Environment Assembly (UNEA-2) and the Consultation Meeting on Implementation the resolution (Manado, Indonesia, June 2016), as well as Update on the management of the Global Coral Reef Monitoring Network, and a Workshop – Tracking Global Coral Reef Bleaching event and harmonizing methods, which are relevant topics for the Caribbean.

4 http://www.car-spaw-rac.org/?The-GCRMN-Caribbean-guidelines,639

## METHODS

The GCRMN-Caribbean guidelines have been developed to provide a systematic snapshot of the ecosystem health of coral reefs and, when repeated through time, insight into temporal trends in reef condition. Based on the conclusions of a retrospective analysis of trends in reef health over the past decades1, GCRMN-Caribbean partners have agreed that there is great value in coordinating and standardizing future monitoring efforts. To date, Caribbean regional monitoring efforts have often collected non-overlapping types of data about coral reefs, or the efforts have used non-comparable or insufficiently documented methods for describing reef ecosystems. The goal of this document is to define a set of data and data collection techniques that will be used by GCRMN-Caribbean partners. These methods reflect long-standing, vetted scientific protocols and provide a compromise between practical applicability and ease of comparison between existing methods and long-term data sets. Our objective is to provide guidance clarifying the methodological considerations and suggestions for managers needing monitoring information at local (site) level as well as for use at broader geographic levels.

**The GCRMN-Caribbean guidelines describe six elements of the coral reef ecosystem** – (1) abundance and biomass of key reef fish taxa, (2) relative cover of reef-building organisms (corals, coralline algae) and their dominant competitors, (3) assessment of coral health and (4) recruitment of reef-building corals and recruit habitat, (5) abundance of key macro-invertebrate species, and (6) water quality. These elements provide an overview of the current condition of the coral reef ecosystem as well as an indication of likely future trajectories. The GCRMN-Caribbean recognizes that by collecting information about these elements across multiple locations, with regular re-sampling through time, it will be possible to more knowingly describe the status of coral reef health in the Caribbean and to assess the effectiveness of local and regional management efforts.

These methods are designed to provide a basic and regional summary of reef health. Importantly, the elements that are included for GCRMN-Caribbean monitoring are not all-inclusive, and many partner members may be interested in collecting more detailed or spatially expansive data that will be valid at the site level. It is important that any necessary additions or amendments to the sampling protocol (sample sizes, etc.) are noted to assure data are also valid at the site level. In general, these **GCRMN-Caribbean guidelines should be viewed as a minimum set of measurements to provide a reliable regional assessment of reef condition** – data elements should not be selected individually but instead collected in sum. Given the inherent complexity of reef processes, a multi-dimensional description of coral reef health is essential to provide a coherent ‘baseline’ of coral reef condition in a dynamic and changing world.

***Training, standardization, and calibration***

A series of references and support tools are available to assure that the GCRMN-Caribbean methods are well-understood by partners and that the data generated are robust. This document provides an overview of the accepted methodologies along with references to supporting documents. In addition, a number of products are intended for production to supplement this document, including – (i) a species identification guides, providing images and descriptions of taxonomic groups to be used for recording fish and benthic data, (ii) a series of instructional videos, intended to visually 'walk through' the implementation of each set of methods, and (iii) an online portal for discussion and consultation, providing a pathway for partners to troubleshoot methodological or reporting concerns.

Pending resource availability, the GCRMN-Caribbean group will implement (iv) local training workshops, intended to bring partners together to exchange knowledge in the field setting and to perform cross-checks and calibration of data collection protocols. For those using the Level 2 in situ (non-photographic) transect methods, we recommend referring to the well-developed Atlantic and Gulf Rapid Reef assessment training guides and methodology available on www.agrra.org. For those incorporating programs of 'citizen science', we recommend using established methods of ReefCheck (www.reefcheck.org) and/or REEF (www.reef.org), depending on organizational goals and capacities.

***Design of local monitoring***

The GCRMN-Caribbean baseline monitoring guidelines have been developed to enable partners to describe the status and trends of specific locations, frequently including multiple sites, in a manner that is directly comparable across geographies. As such, the design of the monitoring protocols must be founded on consistency within locations and standardization across locations. Operational definitions of the recommended spatial design for GCRMN-Caribbean monitoring are provided here.

A given monitoring effort may partner with the GCRMN-Caribbean if participants provide a reliable description of a coral reef location in the Caribbean region. *A location* is defined as the characteristic reporting unit, and the location has a bounded geographic range, representing somewhere between 5 to 100 km of coastline. For example, an island with a total coastline of 78 km may opt to define their location as the coral reefs spanning the entire coastline of the island or might separate them into windward and leeward components. In contrast, if an island or mainland coast has >100 km of coastline with coral reefs, the partner will define a specific section or sections of the coast as *the location(s)*. The definition of a location is expected to follow from the needs of each partner, for example representing regions of important historical or ecological significance. The partner, however, should begin monitoring only after the specific boundaries of a location have been defined. A GCRMN-Caribbean technical committee is available to assist with site selection, as well as an open GCRMN-Caribbean forum with specific discussions on methods. This platform of exchange between coral reef scientists and members of monitoring agencies will allow GCRMN-Caribbean partners to share experiences, ask for advice, and share and store relevant documents. Please contact the GCRMN-Caribbean coordinator to access the Basecamp forum julie.belmont.carspaw@guadeloupe-parcnational.fr or Steering Committee member Melanie McField mcfield@healthyreefs.org.

A GCRMN-Caribbean partner should complete the minimum sampling noted in these guidelines in order to provide a statistically robust description of *a location*. The unit of replication within *the location* is called the site and is defined as a particular spot on a map where surveyors will get into the water to collect monitoring data. *A site* can be considered operationally as a 'dive site' or 'monitoring station', and will be reported based upon its geographic coordinates (latitude and longitude). Individual sites should be selected randomly from across the location, thereby faithfully (and without bias) representing the variation in the coral reefs across the location. Note that marked permanent sites can be used, but may require modified techniques for data analysis, especially in comparisons with sites using randomized site selection.

The GCRMN-Caribbean recommended minimum level of effort (replication) is 20 sites per location[5]. However, the GCRMN-Caribbean understands of the challenges associated with monitoring, and locations that are described with fewer than 20 sites (due to operational limitations) will be welcomed, as appropriate. Monitoring sites to be used in the collective GCRMN-Caribbean effort will be limited to forereef habitats at depths ranging from 8-18 m, in the zone of most reef development (typically "seaward" or "non-lagoonal" reefs below high-energy reef crest or *A. palmata* zone), in an effort to maximize comparability across the region. Importantly, this constraint disallows contribution of data from backreefs, lagoons, and deep reef habitats. However, wherever GCRMN-Caribbean partners have local interests in monitoring these (or other) coral reef habitats in their region, they are encouraged to apply these same guidelines. By using comparable methods, there will be greater opportunities in the future to consider cross-comparisons within and among regions, as more comparable data become available. A fundamental goal of GCRMN-Caribbean is to increase standardization of data collection for monitoring, thereby increasing the ability of the management and research community to better understand regional patterns of change in coral reef into the future.

The GCRMN-Caribbean recommended frequency of sampling is once every two years under normal conditions, with increased frequency if needed to evaluate, for example, disturbance events or testing of management effects. In order to reduce seasonal variation in reef composition (e.g., algal blooms, fish spawning), sampling should be completed in the same season, and is highly recommended to be completed in the same month of each sampling year.

5 This level of effort is informed by a statistical power analysis considering the ability of the data to detect a 5% change in coral cover between sampling intervals (e.g., a change from 20% to 15% coral cover). Technical assistance can be provided to groups interested in doing power analysis specific to their locations (which is the preferred design). Note that the statistical power increases greatly as the number of sampling intervals increases (i.e., with increased sampling through time). As such, these considerations of statistical power should be viewed as a guide for selection of sampling effort rather than as a strict statement of statistical results that are to be expected from a real, long-term monitoring campaign.

**METHODS OUTLINE**

The methods that follow are organized by individual ecosystem component (fish, benthic, coral health, coral recruitment, key macroinvertebrates, and water quality). Each component has up to three different optional methods - selected by the partner based on the level of detail needed and capacity within their organization. These include: Level 1 (*minimum standard*), Level 2 (*recommended*) and Level 3 (*highly recommended*). The Level 3 method provides the most rigorous and comparable data for current and future applications. In many cases, this method provides higher resolution for archiving reef condition, and thus enables more detailed explorations of reef health today and a permanent archive into the future. The Level 2 method is the basic approach that provides the essential information defined by GCRMN-Caribbean, and uses a common and consistent field approach. The Level 1 method is a collection of viable approaches for collecting the essential information however lacks the detail and resolution provided by Level 2 and Level 3. Level 1 methods provide information that is broadly comparable to the recommended methods, though differ in key aspects that prevent detailed comparisons of the data. The Level 1 and Level 2 methods should be used only in cases where the local GCRMN-Caribbean partner has an established monitoring program, and thus changing methods may compromise the legacy and consistency of the local effort.

**For the partners using the Level 1 minimum standards, we recommend considering and implementing a gradual shift towards Level 2 recommended and Level 3 highly recommended methods, without compromising the continuity of monitoring efforts and data comparability over time. The GCRMN-Caribbean partners and its steering committee are available to assist in this regard**.

**1. Abundance and biomass of key reef fish taxa**

***Core information to collect*** – The goal of data collection for the fish taxa is to characterize the key species of economic and ecological importance. ***In total, the core data to collect are the density and size structure of all species of snappers (Lutjanidae), groupers (Serranidae), parrotfish (Labridae – Scarinae), and surgeonfish (Acanthuridae)***. These species are among the principal food fishes among Caribbean small-scale fisheries that are still relatively intact, as well as being critical species for maintaining reef ecosystem health. Note that collecting information on both density and size structure is required to estimate the biomass of each species by using known length-to-weight relationships published for all fish species. Additionally, it is recommended to record the presence of sensitive species (e.g., sharks, rays) or important invasive species (e.g., lionfish).

Beyond the core information, *it is highly recommended to provide estimates of the density and size structure of all fish species within the survey area.* Such high resolution estimations of the fish assemblage maintain the core information (snappers, groupers, parrotfish, and surgeonfish), while also providing fundamental information about other members of the fish assemblage that may serve important roles in fisheries (e.g., barracuda, grunts and parrotfishes) or ecosystem maintenance (e.g., damselfish, triggerfish) that will be further considered or discovered in the years to come.

*Level 3*– The GCRMN-Caribbean highly recommended method for estimating the density of coral reef fishes builds on the Atlantic and Gulf Rapid Reef Assessment (AGRRA) – http://www.agrra.org/method/methodhome.html. All fish present (of all species, not just the AGRRA fishes) are counted and sized within a belt transect (30m length x 2m width). At each site, 5 transects are surveyed and the data are pooled to provide an average estimate of the density and size structure of all fishes at the site. In cases where local efforts require more ability to track changes at the site-level, it is possible to survey more transects per site, perhaps including more dive time or more divers. In order to standardize the sampling effort per transect, divers should maintain consistency in survey time with a target of 8-12 minutes per transect.

*Level 2*– If the taxonomic expertise is limited among the survey team, it is recommended to follow the same modified AGGRA protocol, but to count and size only the core species (snappers, groupers, parrotfish, and surgeonfish).

Level 1– It is required for contribution to the GCRMN database that the core information about the fish assemblage (including estimates of density and biomass) is collected using a vetted and comparable field method. Acceptable protocols are the stationary point count and belt transects (of different dimensions to the AGGRA protocol). Note that the specifications of these protocols are often variable, and GCRMN-Caribbean members should strive to achieve standardization of methods whenever possible and be sure to document the specifics of the methods employed.

**2. Relative cover of reef-building organisms and their dominant competitors**

**Core information to collect** – The goal of data collection for the assessment of the benthic environment (i.e., organisms attached to the bottom) is to document the relative cover of reef-building, stony corals and their dominant competitors. As such, ***the core data to collect is the percent of the reef bottom that is covered by stony corals, gorgonians, sponges, and various types of algae (turf algae, macroalgae, and crustose coralline algae)***. The stony corals and some of the calcifying algae are the dominant taxa that build the coral reef structure, while the turf, some macroalgae and benthic invertebrates can compete with reef-builders and thereby limit growth of the reef structure.

*Level 3*– The GCRMN-Caribbean highly recommended method for estimating the cover of key taxa on the reef benthos is the photoquadrat method. This approach uses digital photographs of the reef surface in standardized quadrat areas (0.9m x 0.6m). Photographs are taken along each of the 5 transect lines set for counting fish, with 15 images captured per transect line (i.e., one image taken at every other meter marker on the transect tape). In total, 75 benthic photographs will be collected at each site (5 transect lines x 15 photographs per transect).

Prior to collecting image data, users will need to calibrate image collection protocol for the specific underwater camera being used. Because cameras vary in their lens configuration, images taken from two different cameras at the same height above the benthos may include different areas of the reef. Two approaches are used commonly to standardize image area:

(i) Users can construct a quadrat out of PVC or other material. The design is simple, including four lengths of PVC (2 that are 0.9m long, 2 that are 0.6m long) that are coupled together with 90˚ angled couplers. The corner of the quadrat then is placed at alternating meter markers along the transect line, and images are collected that contain the standard frame and the benthic habitat within.

(ii) Users also can construct a 'mono-pod', namely a pole that connects to the camera identifying a height above the benthos which will capture an area of approximately 0.9m x 0.6m. Importantly, the length of this mono-pod will be specific to the camera and housing being used. As such, prior to collecting data, the user will need to calibrate the length underwater (note that due to optical distortion due to the air-to-water transition associated with underwater housings, the calibration *must* be completed underwater). To calibrate, the user can lay a transect tape underwater then hover above the tape until the image contains the correct area. The height can be recorded by a second diver measuring the distance between the camera and the transect tape. The mono-pod is constructed by cutting a length of PVC (or other material) to the defined length and either holding between the camera and that benthos for image collection, or constructing a coupler to mount the pole to the camera base. If using a mono-pod, it is important to include the transect line itself along the edge of the image to provide internal scale within the image, especially for archival value.

Note that there are many approaches for standardizing areas collected using photographic methods. For example, the framed quadrat approach described in (i) can be made more elaborate by constructing a PVC 'quad-pod' that mounts the camera to the frame. The decision of exact field approach will be determined based upon resources available, field operational flexibility (e.g., boat space), and personal preference. The critical constraint is to assure that the area captured in each image is of a standard and consistent size, and that details of the methods used are recorded and archived (e.g., writing quadrat area in metadata file or including transect tape in images for reference).

Data are captured from the images through post-processing by a trained observer using image processing software. On each image, the software randomly places 25 points over the image and the benthic type under each point is classified into a standardized benthic category including key species (and some broader groups) of corals and algae (see Table 1). Image processing software is freely available to support the image post-processing (e.g., Coral Point Count, CoralNet).

If taxonomic expertise is limited in the survey team or time is limited for detailed post-processing, it is recommended to collect the images as above but to follow one of two options for post-processing – (i) identify points in the images to coarse functional groupings (principally stony coral, gorgonian, sponges, turf algae, macroalgae, crustose coralline algae; complete list is available in Table 1), or (ii) solicit support from a GCRMN-Caribbean partner for high-resolution image post-processing.

Image-based benthic data collection is recommended for a number of reasons. First, images can be collected rapidly in the field, providing operational efficiency. Second, image collection is less prone to user bias than some *in situ* approaches (e.g., selecting the exact point for recording using line-point-intercept when the transect tape moves slightly with surge). Third, images provide the ability for discussion and repeated post-processing by multiple observers during image analysis. While such discussion can take time in the short-term, there is great value in error-checking across observers as facilitated by image post-processing. Finally, images provide a raw archival data source. While one group may be interested in only particular levels of taxonomic resolution from the images (e.g., coral composition), future changes in the reef may identify another taxon of particularly large importance. Archiving images provides the raw material for future re-analysis to address novel trends in reef benthic change.

*Level 2* – In order to be included in regional GCRMN-Caribbean comparisons, the core benthic composition data should be collected using a standardized, accepted and reliable method, with adequate replication. Given that some programs have long-standing monitoring using an alternative (but generally comparable) method, or that a potential member may not have access to digital cameras, these alternatives will also be accepted. In particular, *in situ* measurement of benthic cover may be collected using field assessment of quadrats (collected in sufficient quantity) or using line-point-intercept methods (estimated over sufficiently long and replicated transects). Note that the specifications of these protocols are often variable, and GCRMN-Caribbean partners should strive to achieve standardization of methods whenever possible, such as the widely-used AGRRA methodology.

*Level 1* - For partners using volunteer and community stakeholder groups for basic monitoring it is recommended to use the line-point intercept approach, potentially using methods from ReefCheck (www.ReefCheck.org).

**3. Assessment of coral health**

Core information to collect – The goal of data collection for assessing coral health is to document ***the prevalence of disease (not including bleaching) in stony corals (see definition and photos on the AGRRA website [www.agrra.org])***. Disease prevalence is a metric describing the proportion of coral colonies that exhibit signs or pathologies of any disease. Because of the challenges associated with defining the boundaries of individual coral colonies in photographs, the GCRMN-Caribbean core information reports coral disease as the proportion of replicated benthic areas (e.g., photoquadrats) that have diseased corals – herein termed a 'relative prevalence' rate. Note that while this simplified method does not capture many elements of coral disease ecology, like species- or size-specificity of disease incidence, this is a useful approach for collecting standardized and inter-comparable data describing coral health. If, for example, a rapid rise in estimated disease 'relative prevalence' is noted, a survey team could alert the GCRMN-Caribbean partners for advice or connection with specialists.

*Level 3* – The photoquadrat method for estimating disease relative prevalence in corals uses the photoquadrats collected following the Level 3 highly recommended methods for benthic cover assessment. Data will be recorded as the proportion of images collected that contain a coral with any disease pathology. For example, if there are four colonies in a particular photoquadrat and any of these colonies shows signs of disease, this image would be tagged as "*with disease*". The number of images that are "*with disease*" is divided by the total number of images (15 per transect) to generate a proportional estimate of disease prevalence. A benefit of the photoquadrat approach is that archived images can later be used by coral disease experts for more detailed analyses.

*Level 2 option A* – Following on from the Level 2 recommended methods for benthic assessment, the surveyor will record whether or not the quadrat is "*with disease*" and the number of these positive disease quadrats will be divided by the total number of quadrats to generate a proportional estimate of disease relative prevalence.

*Level 2 option B* – Following the AGRRA methodology, surveyors will record the prevalence rate of diseased coral colonies by species along 10m belt transects. This method follows the specifics identified in the 'Coral health' section of the AGRRA methodology (www.agrra.org). This approach

records the proportion of coral colonies, rather than the proportion of benthic quadrats, that contain disease. As such, the units are sufficiently different to limit the ability to compare quantitative 'prevalence' values with Level 3 methods. However, in most cases temporal trends within a location should be comparable using either method. . These data will not be directly comparable to the Level 3 disease prevalence.

*Level 1* – In some cases, GCRMN-Caribbean partners may lack the capacity to collect data on coral disease. Although collection of disease data is encouraged, for GCRMN-Caribbean partners using level 1 protocols, the collection of coral disease data is not required for contribution to the core GCRMN-Caribbean database. Further, if a different method for assessing disease relative prevalence is used, GCRMN-Caribbean partners should accurately document the specific methods used and strive to achieve standardization of methods whenever possible.

**4. Coral recruitment**

Core information to collect – The goal of data collection for coral recruitment is to estimate ***the density of young corals that are likely to contribute to the next generation of adult corals*** on the reef, as well as providing a snapshot of the competitive environment in which young corals live. Documenting the early life stages of corals is notoriously challenging, given that many of the smallest coral settlers (e.g., those that recently settled to the reef substrate) are very small and are found in cryptic habitats, such as in cracks or on the hidden surfaces of rocks. As such, this protocol employs an operational definition of coral recruits as those smallest individuals (0.5-4.0 cm) that are visible to a diver *in situ*.

Importantly, much scientific literature employs the use of standardized substrates (e.g., settlement tiles) for providing precise estimates of relative rates of settlement and recruitment. While such efforts are valuable for experimental studies, they are labor-intensive and prone to methodological bias (e.g., tile type and soaking duration can greatly influence settlement rates). Here, we outline an observational approach that integrates across natural variability in the environment and offers a relative estimate of the density of corals that are likely to contribute to the next generation of coral adults in the region.

*Levels 2 & 3* – The GCRMN-Caribbean highly recommended method for estimating the density of coral recruits follows the AGRRA methodology – http://www.agrra.org/method/methodhome.html – though with some specific differences. Coral recruits are defined operationally for this assessment as any stony coral that is greater than 0.5 cm and up to 4.0 cm in maximum diameter. The lower limit of this range is established based on the minimum size that can be observed reliably by a diver *in situ*, while the upper limit is established as the approximate size at which many species gain capacities typical of adult corals (e.g., increased competitive ability, reproduction). Further, the upper limit also represents the transition from juvenile to adult, following definitions of AGRRA protocols, and thus provides data that when combined with AGRRA adult surveys represent the full range of size class options. The size class (in increments of 0.5 cm) should be noted along with the genus (if possible) of each recruit.

Estimates of coral recruit density are recorded from replicate 25cm x 25cm (625 $cm^2$) quadrats. A total of 5 quadrats will be surveyed along each of the first 3 transects used for benthic surveys. The coral recruit quadrats will be placed at 2-meter intervals along each of the first three transects, i.e., with the lower corner of the quadrat placed at the following meter marks – 2, 4, 6, 8, and 10 m.

Within each quadrat, each coral within the target size range (0.5-4.0 cm) will be recorded to the finest taxonomic level possible (family, genus, or species). Importantly, many of the smaller coral recruits are very difficult to identify to species, even for taxonomic experts, so good judgment must be used to identify to the finest taxonomic level that the observer can confidently assess.

Characteristics of the recruit habitat are also recorded within each 25cm x 25cm quadrat. The height of algae provided a robust estimate of the competitive environment for corals, especially for coral recruits. At each corner of the quadrat, the height of two functional groups of algae will be recorded. For turf algae, the height of the turf filaments will be recorded to the nearest mm; for macroalgae, the height of the macroalgal individual will be recorded to the nearest cm. As such, with the quadrat on the bottom, the surveyor will identify the patch of turf algae closest to each corner of the quadrat and use a small ruler to measure height; similarly, the surveyor will find the nearest macroalgal individual to measure height. Note that if no turf algal patches or no macroalgal individuals are found within a particular quarter of the quadrat, it is critical to record "n/a", identifying that no algae of that type were available to measure. In total, there will be 0-4 measurements of turf algal height and 0-4 measurements of macroalgal height per quadrat.

Note that the area of the quadrat used for coral recruits is smaller than that used for benthic cover assessment. The reason for this is that searching for coral recruits is relatively labor-intensive for the observer, as one needs to explore the focal area within the quadrat extensively. Especially in quadrats covering areas of high topological complexity, the observer needs to explore all surfaces within the quadrat, regardless of orientation (e.g., sides of rocks and under loose fleshy algae).

*Level 1* – It is required for contribution to the GCRMN-Caribbean database that the core information of the density of coral recruits be determined. If the survey team does not have the taxonomic training to identify coral recruits with any taxonomic detail (i.e., only recognizing scleractinian, reef-building corals), then a surveyor will simply record the number of coral colonies within the defined size range (0.5 – 4.0 cm) within the defined quadrats. A comparable sampling protocol will be used (5 quadrats [625 $cm^2$] along each of 3 transect lines; total of 15 quadrats). If capacity of the survey team is limited, omitting collection of data on algal heights will be acceptable under Level 1 standards.

**5. Abundance of key macro-invertebrate species**

Core information to collect – The goal of data collection for key macro-invertebrate species is to provide an estimate of the density of ecologically and economically important species on the reef. **The core data to collect are the densities of the long-spined sea urchin (*Diadema antillarum*), other sea urchins, all sea cucumbers, lobsters, and conch.**

Many species of sea urchin, especially the historically common long-spined sea urchin (*Diadema antillarum*), are important herbivores on Caribbean reefs with a capacity to control the density of many groups of seaweed. As such, sea urchins can play an important role comparable to that of seaweed-consuming herbivorous fishes. The other key groups of invertebrates, the sea cucumbers, lobster, and conch, include important fisheries targets in some locations. Many species of sea cucumber are harvested and sold to export markets. The sea cucumbers thus can contribute to local reef-based economies. Lobsters and conch, although not common in reef environments, are among the most important commercial invertebrates in Caribbean nearshore habitats. Estimates of density for these key macro-invertebrate species are valuable for considerations of ecosystem functioning and potential fisheries value. The GCRMN-Caribbean Levels 3, 2, and 1 all rely counting all urchins, sea cucumbers, lobsters, and conch within 3 of the benthic transect lines. Each belt will cover the first 10m in a 2m wide belt, giving a total area of $60m^2$. If the AGRRA methodology is used then this $60m^2$ sample is achieved using 6 belt transects 10m x 1m wide.

If photoquadrats are used for benthic cover (from **2. Relative cover of reef-building organisms and their dominant competitors**), there will be an additional analysis of the 15 photographs from each of the 5 transect lines (75 photographs total). The number and species identity of each sea urchin, sea cucumber, lobster, and conch will be recorded for each image. The density of these key macro-invertebrate species will be calculated by dividing the total number of sea urchins and sea cucumbers recorded by the product of the number of images (sensu Level 3 highly recommended as 75) and the size of each photoquadrat of 0.54 $m^2$ (i.e., 0.6 m x 0.9m).

**6. Water quality**

Core information to collect – The goal of data collection for water quality is to provide an estimate of the concentration of particulates in the water column. Water quality is influenced by many factors, ranging from oceanographic delivery of nutrients, algal growth in the water column, terrestrial contributions (e.g., mud and silt), and anthropogenic inputs. A standardized and common metric that captures the basic elements of water quality and has a long history of application is the use of Secchi disks. As an estimate of the integrated water quality, ***the core data to collect are the depths at which standardized Secchi disks are visible in the surface waters of the reef.***

*Levels* 3, 2 and 1 – The method for estimating water quality is to deploy regularly a Secchi disk at sites around the study region. The Secchi disk is a black-and-white disk (20 cm in diameter, for the purpose of GCRMN-Caribbean) that is attached to a measured and marked pole, rope, or chain. The disk is lowered into the water from a boat or a diver at the surface until the disk disappears from sight; at this point the measurement on the pole, rope, or chain is recorded. The disk is lowered a bit more, then pulled back up toward the surface slowly. When the disk is visible again, the measurement on the pole, rope, or chain is again recorded. The average of these two

measurements is recorded as the best estimate of the distance at which the Secchi disk is visible through the water.

Note that at many tropical locations, the depth of the forereef site will be less than the vertical Secchi depth (e.g., in cases where one can see the reef from the water's surface). In these cases, horizontal Secchi distances can be substituted and the Secchi disk instead will be placed or held at one location, along with the end of a transect tape. For example, an in-water observer will swim away from the disk, pulling the transect tape and will record the distance at which the Secchi disk is no longer visible. Many operational approaches exist for integrating horizontal Secchi disk measurements into the efforts and responsibilities of members during a survey dive, and teams are encouraged to identify the most efficient approach to record this measurement within the constraints of efficiency and dive safety.

It is Level 3 highly recommended to collect information on water quality at weekly intervals at standardized sites (1-8 total) that are ideally co-located with the monitoring sites. It is Level 2 recommended to collect information on water quality at monthly intervals with a comparable spatial distribution. Notably, the frequency of sampling for water quality is much more frequent than the benthic sampling. As such, it is important to consider complementary on-water efforts (e.g., law enforcement and monitoring, partners in recreational dive industry) to support water quality sampling. Given the relatively low amount of training needed to collect these data reliably, there are a broad set of partners that can be engaged to help gather this information consistently.

The GCRMN-Caribbean community is understanding of the logistical constraints of sampling frequency and will welcome data collected at most frequencies. It is required for contribution to the GCRMN-Caribbean database that the meaningful information of water quality be reported at least annually. In many locations, there are regular programs of water quality monitoring that complement (or often provide higher resolution than) Secchi disk deployments. It is required to report some reliable and consistently-collected form of information about water quality from each GCRMN-Caribbean partner location. Additional types of water quality information include: dissolved oxygen (DO), total dissolved solids (TDS), nutrient concentration analysis, and bacterial sampling.

Importantly, the same type of information must be collected at regular intervals in order for the data to be useful to the GCRMN-Caribbean. If different forms of data are collected in different years, then there is no capacity to document reliably patterns of change in water quality through time. It is fundamental that a consistent methodology be applied through time.

**SITE DATA**

In previous efforts to synthesize monitoring data from across the Caribbean community, a major limitation was in data being recorded with insufficient site data and associated metadata. For example, data may be presented without clear information about where the data were collected, when the data were collected, and what methods were used. As such, it is essential for inclusion to the GCRMN-Caribbean effort that all data be recorded with clear and reliable metadata.

Before each dive record the following on the data sheet. (taken from the AGRRA v5.5 methodology).

**Surveyor**: Name of the person making the survey using 4-letter name code (e.g., John Smith = JOSM).

**Date:** Enter date as: day, month name, year (e.g., 19 Oct 09).

**Site Name**: Name of dive site or description of area (e.g., between Boston Beach & Splash Hotel).

**Site Code**: Sequential site code (e.g., MEX007 = seventh Mexican site).

**How Selected**: Method used to select the site (e.g., stratified random, stratified strategic, strategic MPA site,
etc.).

**Latitude & Longitude:** Latitude and longitude recorded for the site, corrected if necessary from a boat or other fixed position. GPS waypoint may be recorded instead, but at least one datasheet per site should have the actual lat./long. Note which datum the GPS is using (WGS84, etc)

**Reef Type**: Type of reef system (e.g., bank, barrier, fringing, lagoonal, mid-shelf, patch, platform). If different from expected, please describe the reef type surveyed.

**Zone:** Reef zone surveyed (e.g., back, crest, fore). If different from expected, please describe the reef zone surveyed.

**Depth**

**Rel. Exposure:** Relative exposure to waves and wind as: windward, protected windward, leeward.

**Subzone/Habitat** (if Topography & slope/dominant coral type(s): (e.g., rear/brains; breaker/dead palmata; spur known before dive): & groove/Orbicella (i.e., ex-Montastraea); low-relief terrace lobes/small massive;

**Site Comments** (e.g., Describe how latitude and longitude were calculated)

**DATA ENTRY AND REPORTING**

GCRMN-Caribbean partners will use a common database for data entry and archiving. Details of the data entry portal and database platform are currently under development. The Annex F of the report of Curacao workshop contains a proposed concept for the data management platform.

## ANNEX 1 - GCRMN-Caribbean Steering Committee Composition

- **Regional Coordinator/Chair:** Julie Belmont - SPAW-RAC

  Alessandra Vanzella-Khouri - UNEP-CEP & SPAW

- **Co-Chair:** Maria Pena - CERMES,University of the West Indies, Barbados & Regional SocMon Coordinator for the English-speaking Caribbean

  Melanie McField - Healthy Reefs For Healthy People - Meso-American reef

  Peter Edwards - NOAA Coral Reef Conservation Programme & SocMon Global Coordinator

  Paul Hoetjes – Policy Coordinator Nature Conservation for the Caribbean Netherlands

  Ruben Torres – Reef Check - Dominican Republic

  Andy Estep - Director/Science Manager - Waitt Institute

  Mark Vermeij - Director of CARMABI -Curaçao

  Marcia Creary Ford- University of the West Indies – Jamaica

  Jorge Cortés - Universidad Costa Rica& CARICOMP

  Diana Gómez - INVEMAR- Colombia

  Angelique Brathwaite - Independant expert

  Richard Suckoo - Coastal Zone Management Unit, Government of Barbados

  Jean-Philippe Maréchal - IFRECOR - French West Indies

## ANNEX 2- Categories used for benthic surveys

**Table 1** – Categories used for benthic surveys. The GCRMN-Caribbean highly recommended method seeks to record high-resolution taxonomic data, as presented in the detailed categories. If taxonomic expertise is not available (in-house or through collaboration), the recommended and required methods seek to record taxonomic data as presented in the coarse categories.

| Coarse categories | Detailed categories |
|---|---|
| **Stony corals** | *Acropora cervicornis* |
| | *Acropora palmata* |
| | *Acropora prolifera* |
| | *Agaricia agaricites* |
| | *Agaricia humilis* |
| | *Agaricia fragilis* |
| | *Agaricia grahamae* |
| | *Agaricia lamarcki* |
| | *Agaricia tenuifolia* |
| | *Agaricia undata* |
| | *Colpophyllia breviserialis* |
| | *Colpophyllia natans* |
| | *Dendrogyra cylindrus* |
| | *Dichocoenia stellaris* |
| | *Dichocoenia stokesi* |
| | *Diploria clivosa* |
| | *Diploria labyrinthiformis* |
| | *Diploria strigosa* |
| | *Eusmilia fastigiata* |
| | *Favia fragum* |
| | *Isophyllia sinuosa* |
| | *Leptoseris cailleti* |
| | *Leptoseris cucullata* |
| | *Madracis carmabi* |
| | *Madracis decactis* |
| | *Madracis formosa* |
| | *Madracis mirabilis* |
| | *Madracis pharensis/senaria* |
| | *Manicina areolata* |
| | *Meandrina meandrites* |
| | *Orbicella annularis* |
| | *Orbicella cavernosa* |
| | *Orbicella faveolata* |
| | *Orbicella franksi* |
| | *Mussa angulosa* |
| | *Mycetophyllia aliciae* |
| | *Mycetophyllia danaana* |
| | *Mycetophyllia ferox* |
| | *Mycetophyllia lamarckiana* |
| | *Oculina diffusa* |
| | *Porites astreoides* |
| | *Porites branneri* |
| | *Porites divaricata* |
| | *Porites furcata* |
| | *Porites porites* |
| | *Scolymia cubensis* |
| | *Scolymia lacera* |
| | *Siderastrea radians* |
| | *Siderastrea siderea* |
| | *Solenastrea bournoni* |
| | *Solenastrea hyades* |
| | *Stephanocoenia michelinii* |
| | *Tubastraea aurea* |
| | OTHER corals |

| Coarse categories (cont.) | Detailed categories (cont.) |
|---|---|
| **Macroalgae/ plants** | *Dictyota* |
| | *Lobophora* |
| | *Sargassum* |
| | *Stypopodium* |
| | *Caulerpa* |
| | *Halimeda* |
| | Branching and calcareous algae (other than CCA) |
| | *Liagora* |
| | *Padina* |
| | *Seagrass* |
| | *Stypopodium* |
| | *Turbinaria* |
| | *Wrangelia* |
| | OTHER macroalgae |
| **Turf algae** | Grazed or thin turf algae (substrate visible) |
| | Thick turf algae (substrate not visible) |
| | Turf algae overgrowing recently dead coral |
| **Cyanobacteria** | *Schizothrix* |
| | Cyanobacterial mats |
| | OTHER cyanobacteria |
| **Crustose coralline algae (CCA)** | Crustose coralline algae (CCA) |
| **Gorgonians** | *Gorgonia* spp. (FAN) |
| | *Erythropodium* (ENCRUSTING) |
| | *Muricea* (ROD) |
| | *Briareum* (ROD) |
| | *Plexaura* (ROD) |
| | *Plexaurella* (ROD) |
| | *Eunicea* (ROD) |
| | *Pseudoplexaura* (ROD) |
| | *Pterogorgia* (ROD) |
| | *Iciligorgia* (FEATHER) |
| | *Pseudopterogorgia* (FEATHER) |
| | *Muriceopsis* (FEATHER) |
| | OTHER gorgonians |
| **other (invertebrates)** | *Chondrilla* spp. |
| | *Clionid* spp. |
| | Other encrusting sponges |
| | Vase or barrel sponge |
| | Tube or rod sponge |
| | OTHER sponges |
| | Ascidians |
| | *Millepora alcicornis* |
| | *Millepora complanata* |
| | *Millepora squarrosa* |
| | *Stylaster* spp. |
| | OTHER hydrozoans |
| | *Palythoa* sp. |
| | *Trididerunum* sp. |
| | OTHER zoanthids |
| | OTHER (invertebrates) |
| **Sand** | sand |
| **Limestone free of overgrowth** | Limestone free of overgrowth |
| **Rubble (bare)** | Rubble (bare) |