

Coral Demographics Survey Protocol for the U.S. Caribbean and Flower Garden Banks National Marine Sanctuary

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Introduction

NCRMP is a broad-spatial snapshot for reef condition (*i.e.* fish species composition/density/size, benthic cover, and coral density/size/condition) to provide context for local-scale studies of tropical reef ecosystems. Data collection will occur at stratified random sites where the sampling domain for each region (*e.g.* Puerto Rico, USVI, Flower Garden Banks and Florida) is partitioned by habitat type and depth, sub-regional location (*e.g.* along-shelf position) and management zone. NCRMP is intended to supplement local monitoring efforts by providing large-scale data on reef fishes and the benthos.

This coral demographics protocol was devised to provide additional, species-specific insight (and ‘signal magnitude’) for corals than is provided by percent cover. Specifics of the protocol are based closely on other long-established monitoring programs in the Atlantic region, including AGRR (Caribbean-wide), SCREAM (Florida), and FRRP (Florida). However, the sampling resolution may not capture the population structure of rare or uncommon corals, including currently-listed or candidate ESA species.

Precise designations of coral condition (*e.g.* attributed disease, minor bleaching/paling conditions) are NOT included due to the low temporal resolution of the NCRMP sampling (biennial and potentially not seasonally consistent) and the wide array of surveyors involved, which is why the survey protocol is designed to capture the least ambiguous colony conditions likely to be encountered, specifically recent mortality (*i.e.* dead white skeleton) and bright-white bleaching on a partial or an entire coral colony.

Goal of Coral Demographics Surveys

The goal of the coral demographic surveys is to collect and report information on species composition, density, size, abundance, and specific parameters of condition (% live vs. dead and bleaching) of non-juvenile scleractinian corals (> 4 cm maximum diameter), and of overall species diversity (all corals) using 10m x 1m belt transects in a stratified random sampling design in hard-bottom and coral reef habitats in the U.S. Atlantic and Caribbean.

Likely task allocation scenarios

- 1 Demographic diver:
 - Demographic diver collects all coral demographic data in a single 10m x 1m belt transect area per site.
- 1 Demographic + 1 LPI diver:
 - When the LPI diver completes the LPI transect, s/he will coordinate with the coral demographic diver to assist with completing the demographic transect (if LPI benthic ID skills allow).
 - It is a higher priority for the demographic transect to be completed than for the LPI diver to complete the key species survey (*i.e.* macro-invertebrate [spiny lobster, queen conch, *Diadema* urchin] counts and coral ESA presence-absence). However, every effort should be made, in cases where LPI and coral demographic surveys are concurrently conducted at a site, to complete both surveys completely.
- 2 Demographic divers:
 - The 10m x 1m belt transect area should be subdivided, with the two divers starting at opposite ends of the transect tape.
 - This is preferable at deeper sites with shorter bottom time.
 - At sites where only coral demographic surveys are conducted, randomized grid cells (*e.g.* 50m x 50m in the USVI and Puerto Rico, 250m x 250m in the Florida Keys) will be selected and GPS waypoints generated for the center (centroid) of the grid cell. The survey team will navigate on the boat to the GPS waypoint, deploy a surface buoy or dive flag to mark the site, descend to the marker buoy, and then, using a random compass heading, deploy a 10m transect tape.

Coral Demographic Transect Information

1. Coral demographic transects will usually occur at a subset of the fish/LPI sample sites (Appendix I), as the demographic surveys will usually take longer to complete, particularly within dense coral habitats.
 - a. Where fish transects (not RVC cylinders) are used, the LPI and Demographic divers may use the same transect as the fish diver (Appendix I).
 - Benthic divers will follow along behind the fish diver at a distance to avoid influencing swimming behavior of fishes (*i.e.* the LPI diver should start when the fish diver is near the 5m mark, then the Demographic diver will start).
 - The fish diver will strive to keep the transect tape relatively taut throughout survey.

- The fish diver may use weights to secure the transect tape along the bottom.
 - At Fish + LPI + Demographic sites, LPI diver may assist demo diver to finish demo transect within depth/time limits of dive. Demographic data completion has higher priority than key species (macro-invertebrates and ESA-proposed corals species) data collection, but if possible, key species surveys should be completed at all LPI sites.
 1. If LPI diver assists Demographic diver in survey completion, LPI diver starts her/his survey at 10 m and works until s/he finishes a complete meter and meets Demographic diver. LPI and Demographic divers will coordinate to avoid duplicating counts.
 2. To ensure that all space is surveyed, there should be no surveys of partial meters.
- b. Where RVC fish cylinders are used (*e.g.* Florida), the LPI and Demographic divers will establish the transect using a random compass heading and in close proximity (*i.e.* safe diver distance) to the fish surveyor.
- Details are in development and will be added to this protocol when they are complete.
- c. Where the coral demographic surveys occur independently of fish/LPI surveys, they may not use the exact same transect location or bearing, but will represent the same grid space (*e.g.* 50m x 50m map grid cell in the USVI and Puerto Rico, 250m x 250m map grid cell in the Florida Keys).

2. Locating the sample site(s) and survey area(s).

Divers are deployed together and maintain contact with each other throughout the entire census.

- a. Prior to entering the water, one of the benthic divers obtains a random compass heading for the transect and records the compass bearing (0-360°) on the datasheet.
- b. Navigate to previously selected sites using a handheld GPS unit.
- c. Where appropriate, the boat can drop a weighted float that will mark the start of the transect.
 1. Dropping a float in the VINP and VICR is not an option so divers are dropped as close to the GPS position as possible.
- d. Divers will descend as rapidly but safely as possible to maintain relative proximity to the centroid position.
- e. The only instance where the transect should deviate from the designated path is to stay above 99 ft.

- f. Do not alter the predetermined course if the centroid is not on hardbottom or the bearing does not cover hardbottom.
 1. If it becomes apparent that no hardbottom is in the vision of the dive team (*i.e.*, continuous sand, seagrass or limited visibility), then the dive will be terminated and an alternate site selected.
 2. If hardbottom is observed in the vicinity of the site, then the dive continues as planned- starting on the centroid, or close approximation, and on the predetermined random bearing.
 3. On-site, do not avoid structural features within a habitat such as a sand patch or an anchor as these are "real" features of the habitats.

3. The demographics transect area will be 10m long by 1m wide (Figure 1, Appendix I).
 - a. This is less than the size of the LPI and fish transects.
 - b. Demographics transects will begin at/near the meter marker zero (0) on the transect.
 - c. The transect tape should be secured so that it moves as little as possible.
 - d. The transect line will be surveyed along the **left** edge of the transect area starting at meter marker zero (0) and proceeding to meter marker 10. This means the area of the transect is to the left side of the tape.
 - Do not split the transect area ½ on either side of the tape.
 - e. This transect area is consistent with existing demographic monitoring programs including AGRRA, CREMP, SCREAM, and FRRP.

4. Every possible effort will be made to complete the entire 10m x 1m belt transect.
 - a. If the whole belt transect area cannot be completed:
 - Finish at a whole meter and note the meters of completion on the datasheet.
 - (optional, and ONLY if this can be accomplished immediately) Mark the transect and survey the end-points carefully, and send another team to complete the remaining transect area using the original datasheets.
 - Data may be discarded, or may be retained for density, size, condition for that site, but not used for species richness or any sort of species/area, or any sort of stratum-level analyses.

5. When a coral demographic transect is split between two demographic surveyors:
 - a. A transect will only be split by opposite ends (horizontally). Surveyors will work opposite ends (0m and 10m marks, respectively), and will converge somewhere between meter markers 0 and 10. They will coordinate to avoid duplicating counts upon convergence.
 - b. A transect will NOT be split width-wise (vertically) between surveyors. This minimizes the potential for double-counting colonies.
6. Bottom time may be highly variable between sites, depending on the density of corals at a site and the number of coral demographic surveyors.

Field equipment

1. Boat folder and documentation (maps, site lists, DEAP, boat logs, etc).
2. Demographics datasheets, clipboard, pencil (& backup pencil)
 - Extra datasheets should be on the clipboard in the event extra space is needed for a survey.
3. Transect tape
4. Small rigid measuring instrument, marked in cm.
 - Because the transect tape will be more or less taut across the substratum, the coral demographic surveyor will either need a ruler or scale bar to measure colony dimensions.
5. Measuring instrument, marked in cm increments for measuring coral colony dimensions AND/OR for measuring 1m out from the transect tape.
 - e.g. 0.5 or 1m PVC marked measurements or with measuring tape securely attached.
6. Camera (battery, housing)
7. Optional: CREMP 4cm measuring tool
8. Optional: ankle weights or some other means of weighing down the transect tape.

Notes for field equipment for transect deployment divers (*i.e.* for demo-demo team):

1. Each transect deployment diver may need a few weights (ankle, soft) to periodically place along the transect tape to hold it down to the substrate.
2. Each transect deployment diver must securely tie off the beginning and end of the transect tape.

Coral demographic survey protocols

1. Complete datasheet header (Figure 1) before beginning survey.

Demo diver		Site ID		Habitat type					
Fish diver		Date		Bed	SCR	Patch	Linear	Pave	Other
LPI Diver		Time		Transect completion (1-10 meter)					

Figure 1. NCRMP demographic datasheet header.

Photographs of the site

1. If the Demographic diver is working a transect independently of the LPI/Fish diver, s/he should take photos of the site. Otherwise, the LPI diver will take photos of the site.
 - a. Prior to taking any photographs of the site, one photograph should be taken of the slate to include the site name and date.
 - b. Photographs should be oriented just left, forward, and just right of transect.
 - c. Photographs may also be taken of anything unusual (*e.g.* rare fish, bleached or rare corals) and for species identification clarification.
 - d. The process for downloading and storing site photographs is detailed in a separate document titled “Photo Documentation Manual”.

Species/colony identification

2. Each individual scleractinian coral colony *with all or any part of the living colony or skeletal unit within the transect area* will be identified and measured (Figure 2).
 - a. Record each individual on datasheet (Figure 3).
 - b. Thickets/clumps. If the skeletal unit is connected, identify as one individual. If not, then they are considered multiple individuals (Appendix II).
 - i. Species such as *Acropora cervicornis*, *A. palmata*, *Eusmilia fastigiata*, *Porites porites*, *Madracis* spp. or *M. annularis* may have large colony areas by these criteria.

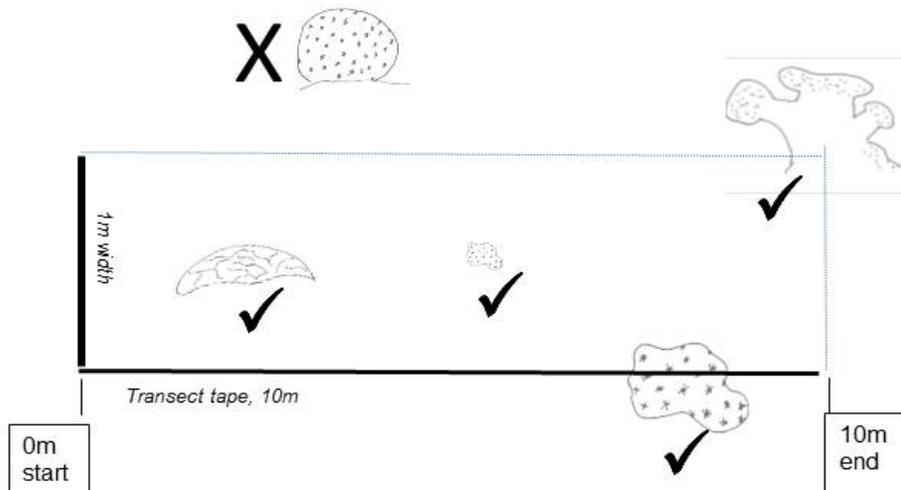


Figure 2. Schematic of example 10m x 1m transect area.
Corals with all or part of colony within transect area are included (✓).
Corals outside of the transect area are not included (X).

- A. All visible corals of any size will be identified to the species level (Figure 3).
- a. If species-level identification is not possible, take photo for later analysis.
 - b. ID *Montastraea* spp. to species; do NOT lump as species complex if possible (*i.e.* identify as *annularis*, *faveolata*, or *franksi*).

Coral ID	Coral Dimensions			Old mortality (% old dead)	Recent mortality (% new dead)	Bleached Total, Partial, None (T, P, N)
	Max Diam (cm)	Perp Diam (cm)	Height (cm)			

Figure 3. Datasheet section showing coral identification, dimension, and condition headers and data entry.

- B. When a scleractinian colony **smaller than 4 cm maximum dimension** (< 4cm) of a species that is not present as a larger, measured colony is encountered in the transect area (Figure 2):
- a. Identify the coral to lowest possible taxonomic resolution (Figure 3).
 - b. Then draw a line through the rest of the column, and continue to the next coral.

- c. Data will be used for species richness calculations only, not density, so any juveniles of a species only need to be recorded once per transect, regardless of the number of times encountered.
 - This methodology is consistent with CREMP. This allows an estimate of richness concurrent with the coral demographic surveys, which are biased due to the > 4cm cut-off, but the present funding of NCRMP does not allow time for juvenile coral surveys.
- C. When a scleractinian colony **with a maximum skeletal dimension of greater than 4 cm** (>4 cm) is encountered in the transect area, continue with ALL of the following measurements.

Coral colony size measurements

Measure entire coral (skeleton + live tissue) on a planar dimension to three (3) exact dimensions (cm).

- Measurements should be made to the nearest centimeter (1 cm).
- Do not bin, estimate, or aggregate measurements. For example, measurements of length, width, and height of a colony might be 5cm x 3cm x 2cm, respectively.

1. Measure the **maximum diameter** (cm) of identifiable skeletal unit.

(Figures 4, 5, Appendix II)

- location where diameter of skeletal unit is widest
- make sure to measure skeletal unit, not just live tissue

2. Measure the **perpendicular diameter** of skeletal unit (Figure 4).

- perpendicular to maximum diameter

3. Measure the **height** (cm) of the skeletal unit (Figure 5).

- Height is measured from the base of the skeletal unit perpendicular to plane of growth.
 - If the colony is growing on a slope, measure perpendicular to the slope
- Measure linearly (*i.e.* do not drape tape across the colony)
 - If the colony has an encrusting morphology, the height of the colony should still be measured to the nearest 1 cm.

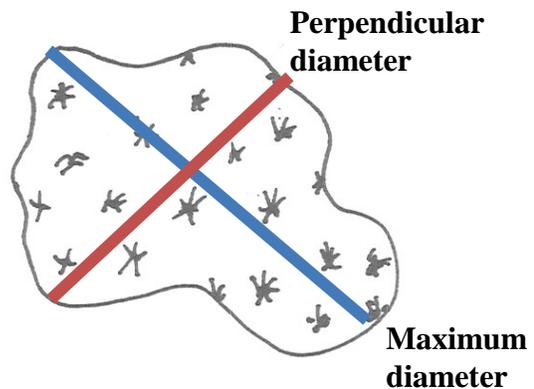


Figure 4. Example of measurements of perpendicular diameter and maximum diameter.

- This methodology is consistent with AGRRA, SCREAM, and FRRP methodologies.

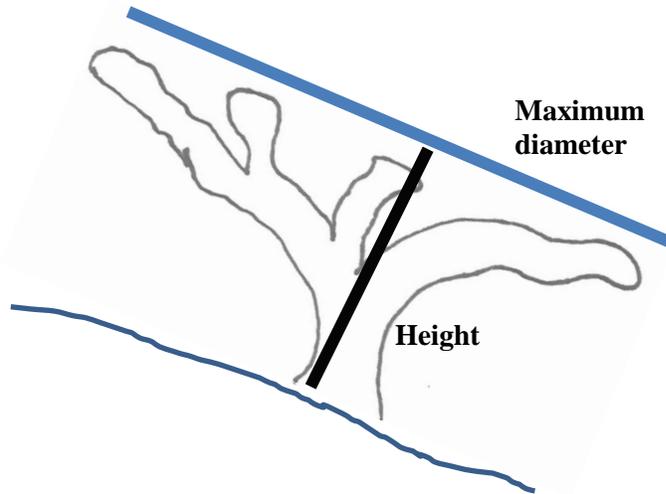


Figure 5. Height and width measurements perpendicular to plane of growth. Colony is shown on a sloped reef.

Coral condition measurements

4. Old mortality (%)

- a. Estimate the percent dead skeletal cover (partial mortality estimate for each colony) based on skeletal structure. Skeletal structure = (old or recent) mortality + live tissue (Figure 6).
 - Consider where tissue is supposed to be on the colony, depending on species and morphology (not on columnar colonies such as *Eusmilia fastigiata* and *Montastraea annularis*)
 - This methodology is consistent with AGRRA, SCREAM, and FRRP

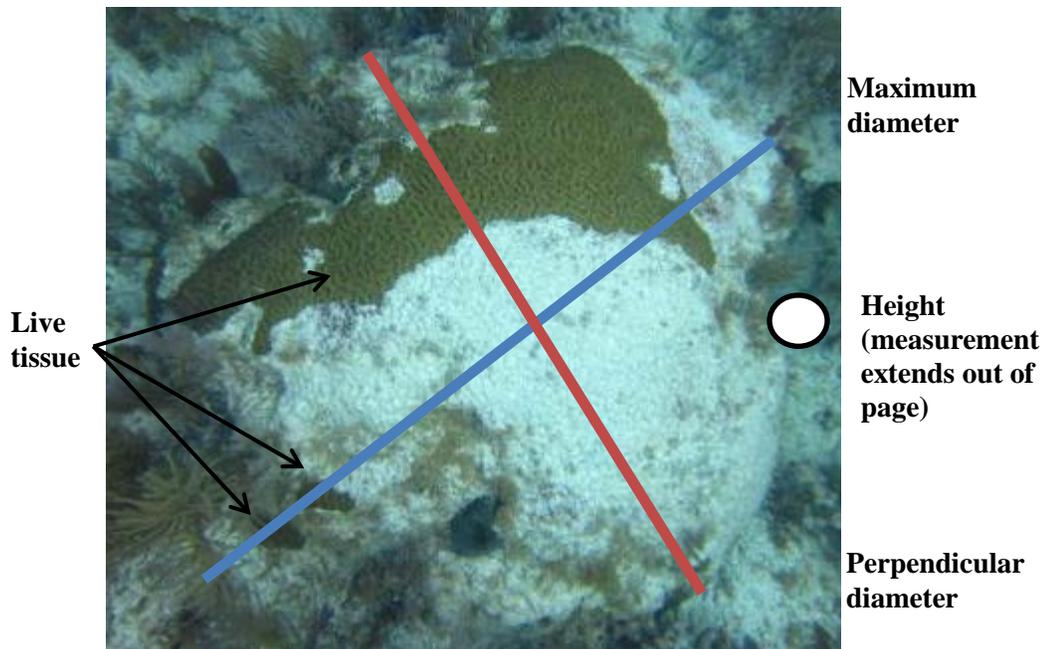


Figure 6. (example) Entire skeletal unit is measured for dimensions (max diameter, perpendicular diameter, height). Estimate % old mortality (~70%).

5. Recent Mortality (%)

- a. Estimate the recent mortality as a percentage of the total colony size (**NOT** as a percentage of total mortality).
 - For example, a theoretical colony with an encrusting morphology with dimensions of 10cm x 10cm with one-quarter of the colony recently dead would be scored as 25% recent mortality.
 - Recent mortality is defined as **exposed white bare skeleton** un-colonized by algae or other organisms. Examine carefully to be sure that bleached tissue is not present.
- This methodology is consistent with AGRRA, TCRMP, FRRP, and SCREAM

6. Bleaching (T/P/N)

- a. Note if any coral bleaching is present or absent
 - **T** = Total bleaching: **bright-white** bleaching over the entire colony¹
 - Bleaching is defined as bright white tissue.
 - Other conditions such as various shades of paling or disease are *not* included.
 - **P** = Partially bleached: **bright-white** bleaching over a part of the colony
 - **N** = No bleaching: no bleaching present.
 - Use this code to indicate **no bleaching**. If a colony is exhibiting any apparent “discoloration” of tissue, unless it is partially or completely white, this condition should be scored as “No bleaching”.
 - Do not leave this item blank.



Figure 7. Partially bleached *Montastraea* coral colony. Because pigment is still visible around the lower right and upper left margins of the colony, this bleaching condition would be scored as *partially bleached*.

¹ NOTE: *Siderastrea siderea* and *S. radians* may appear bright blue rather than white when bleached.

Notes

- a. Notes may be added into the bottom of the datasheet.
 - o Notes can be used to indicate any field observation that may be important, such as presence of an ecological incident (*e.g.* disease).
 - o Notes are for reference only and do NOT get included in the database.

Data Entry into Database

- a. Enter data into the database (see example in Figure 8) as soon as possible, preferably the same day as underwater data collection.
 - o More detailed data entry information will be provided on site.
 - o Refer to QA/QC protocol and photo storage protocol.

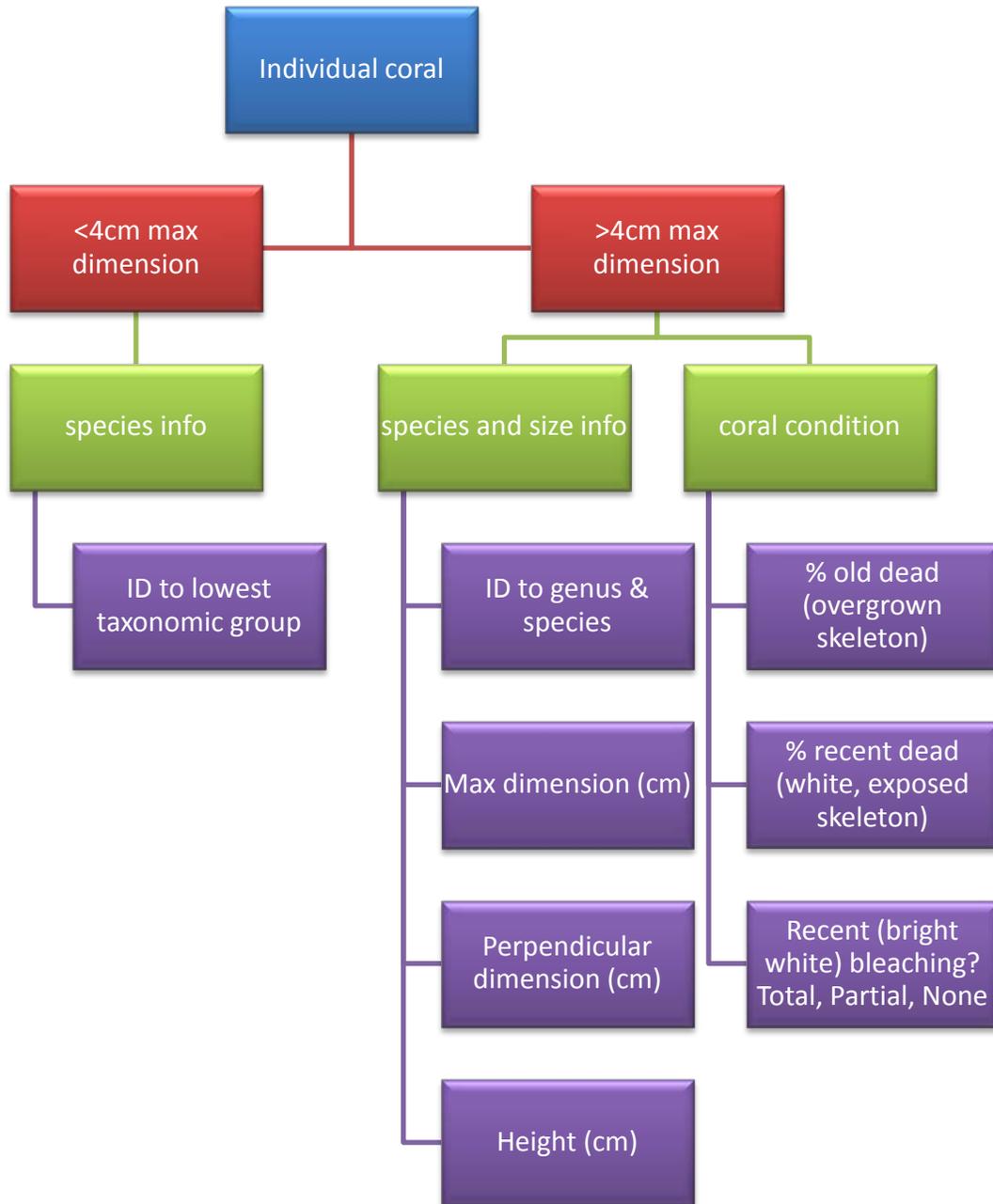
Figure 8. Coral demographic database with data entry example. Each coral colony is entered sequentially. Note the check box for juvenile corals (< 4 cm max. diameter). In this example, AGAHUM is a juvenile, while the MONFAV colony is not.

The screenshot shows the BenthicDemographci database interface. At the top, there are input fields for 'Demo Diver' (Richard.Nemeth), 'Date' (5/8/2013), 'Time', 'Site ID' (HBI2p), 'Habitat' (Linear), and 'Trans completion (0-10)' (10). Below these is a 'Coral Dimensions' section with a table for data entry. The table has columns for Coral ID, Colony ID, Juvenile? (checkbox), Max Diam (cm), Perp Diam (cm), Height (cm), Old mortality (% old dead), Recent mortality (% new dead), and Bleached Total (Parital, None (T, P, N)). An 'Add Item' button is to the right of the table. Below the main table is a scrollable list of existing coral colonies.

Coral ID	Colony ID	Juvenile? Colony < 4cm	Max Diam (cm)	Perp Diam (cm)	Height (cm)	Old mortality (% old dead)	Recent mortality (% new dead)	Bleached Total Parital None (T, P, N)
MONFAV	3	<input type="checkbox"/>						

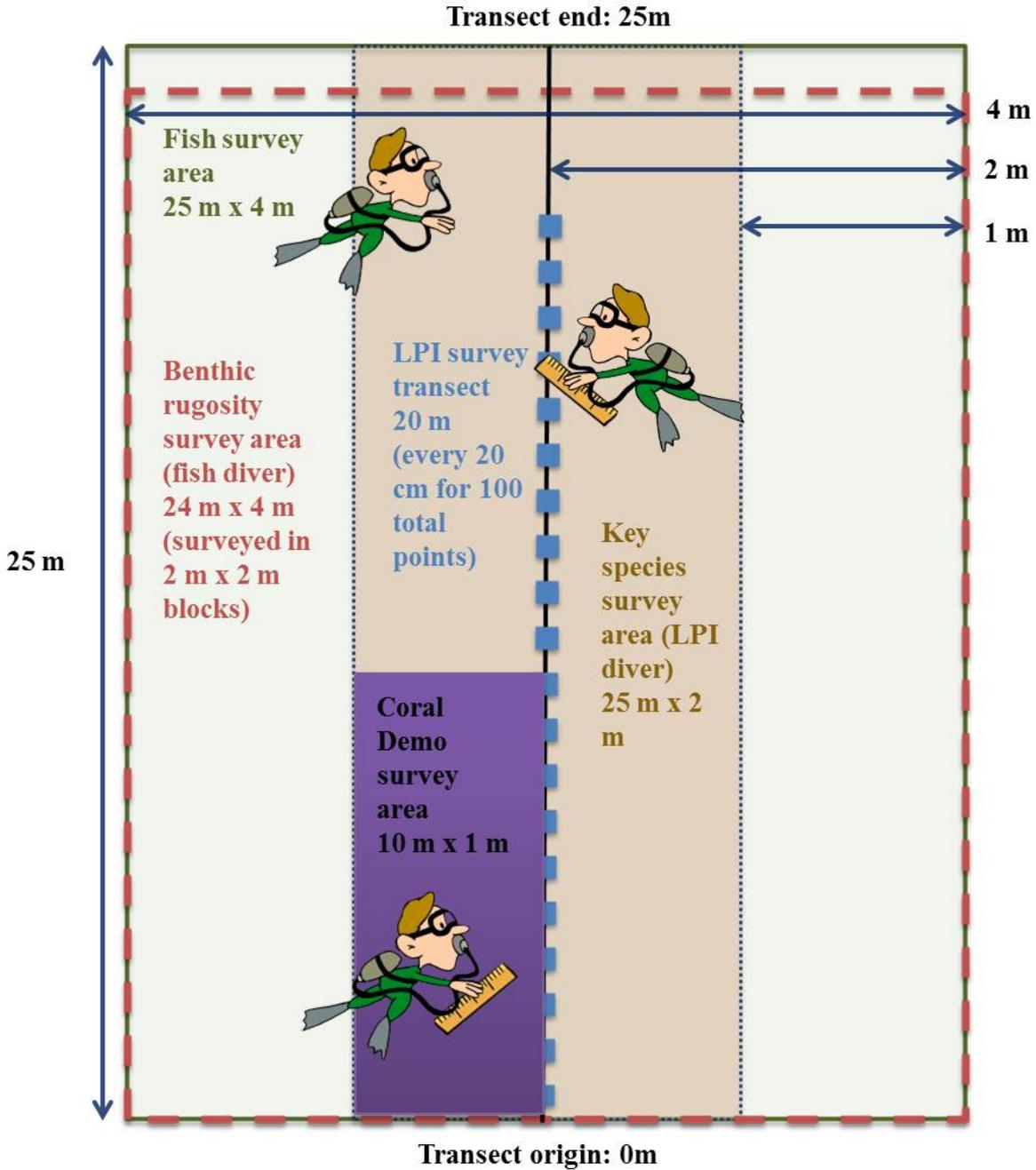
CoralID	ColonyID	Max Diam	Perp Diam	Height	Old Dead	New Dead	Bleached
AGAHUM	1	-1	-1	-1	-1	-1	N
MONFAV	2	100.0	200.0	10.0	1	1	N

Figure 9. Summary of NCRMP coral demographic sampling.



Appendix I.

Diagram of all surveys. Size of each respective survey area is also indicated. Fish, LPI, and Coral Demographics will be surveyed as the divers move out away from the transect origin. Other invertebrates (e.g. spiny lobster, queen conch, *Diadema* urchins) and topographic complexity will be surveyed as the divers return to the transect origin.



Appendix II.

Categories and definitions

- **Skeletal unit:** A coral colony is identified as a ‘skeletal unit’, which could contain one or more live patches of tissue.
- **Individual:** Thickets/clumps of corals, *e.g.* thickets of branching scleractinian coral species such as *Acropora*, *Madracis*, and *Porites* that are connected by skeletal units (or indistinguishable) are counted and measured as a single individual (see example images on next page (*protocol source*: AGRRA)).

Small *Acropora cervicornis* thicket



Small *Acropora palmata* thicket



Skeletal unit of *Eusmilia fastigiata*



Skeletal unit of *Montastraea annularis*



Skeletal unit of *Madracis mirabilis*



Skeletal unit of *Porites porites porites*



