Port Honduras Marine Reserve: Manual for Biological Monitoring, Management Effectiveness Indicators and GIS Applications

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Toledo Institute for Development and Environment
Protecting Toledo's Natural Resources Through Conservation and Sustainable Development.

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I. Introduction

This manual is designed to establish a permanent biological monitoring strategy for Port Honduras Marine Reserve (PHMR) and aid in evaluating management effectiveness. Methods have been chosen based on their use throughout the Caribbean, the Mesoamerican Barrier Reef System (MBRS) protocols, the capacity for annual monitoring and foremost the goals and objectives of the PHMR management plan. In addition to the methods, indicators have been established relating to the management goals and objectives of PHMR. There are many ways to process and analyze data collected from surveys and methods, but indicators allow for evaluation directly related to management objectives.

Biophysical indicators and analysis and were established to gauge management effectiveness for the reserve based upon the WCPA, NOAA &World Conservation Union (IUCN) Management Effectiveness Guidelines in the manual '*How is Your MPA doing?*' (2003). Additionally, some data will be processed for regional comparison and to look at management effectiveness on a broader scale. Organizations such as the MesoAmerican Barrier Reef System (MBRS) have established standardized methods in an effort to gain understanding of regional systems and the health of marine natural resources.

Biophysical indicators are data that should be annually analyzed and compared to previous data. These comparisons will give indication as to whether management is succeeding or if there are any threats, such as over-fishing, development, pollution or bleaching that need investigation and resolution. Indicators should not be looked at as the whether a reserve is 'failing' or' succeeding', but as advisory knowledge that should be used to adapt management policies, goals, and efforts, so the reserve can develop and achieve its' goals. Together with this manual is a GIS database and instructions for incorporating additional data. This database will be used in combination with indicator data to enhance biological understanding and gauge management effectiveness in PHMR. It should also be recognized that the recommended data management and analysis sections could be expanded in relation to project needs and expertise.

The majority of the methods and indicators in the biological monitoring strategy relate directly to Goals 1 and 3 in the PHMR Management Plan:

Goal 1-*To protect the physical and biological resources of Port Honduras.*

Objectives*: Create a zoning plan for the preservation of coastal habitats and ecosystem function*

Goal 3-*To preserve the value of the area for fisheries and other important genetic resources.*

Objectives*: To provide protection to all habitats of commercially important species and o provide areas that will ensure fisheries recruitment*

II. Water Quality

Water Quality (*Biophysical Indicator Seven*)

Water quality is a key determinant of ecosystem health. Water quality is a cumulative concept and multiple factors should be looked into to determine the 'quality' of water.

Why water quality should be monitored

Tropical marine hard bottom and seagrass communities have evolved and thrive in relatively low nutrient (oligotrophic) conditions, while near shore nutrients are generally higher due to river input. Species in the oligotrophic communities efficiently take up nutrients and out-compete other less adapted species in low nutrient environments. They cannot successfully compete with organisms that have evolved to take advantage of elevated nutrient loads. Therefore, nutrients added to oligotrophic systems are very quickly taken up by opportunistic species, out competing the native ones, and therefore disrupting the marine system. Currently, the greatest anthropogenic threats to the water quality of PHMR are agriculture throughout the major watersheds, aquaculture, and coastal and riparian development.

Parameters to be measured for evaluation of Biophysical Indicator

Nitrates and Phosphates- Increasing nitrates and/or phosphates are an indication of pollution (agricultural, development, sewage, etc). These will relate heavily to development upstream and aquaculture development. Nitrate is an essential nutrient for all organisms. Nitrates can be imported into an ecosystem by rain, nitrogen fixation (by bacteria), soil runoff, fertilizers, and organic waste.

Dissolved oxygen (DO)- Dissolved oxygen levels should be inverse of nitrate and phosphates. Fish and other aquatic organisms depend on oxygen, thus depletion of DO causes significant problems, including an increase in macro algae.

Turbidity- Turbidity is a measure of the clarity of water. Increases in turbidity generally stem from coastal and riparian development. Sediment and nutrient loadings can increase turbidity, killing submerged aquatic vegetation. Turbidity is very important to marine organisms requiring light for photosynthesis, but turbidity does not differentiate between inorganic or organic compounds. Turbidity decreases light penetration, which will in turn decrease rates of photosynthesis of primary producers, such as algae seagrasses, and zooxanthellae (coral symbionts). Turbidity may also indicate presence of suspended particles that may precipitate and cover corals and other marine invertebrates, thereby reducing photosynthesis and possibly DO.

pH- pH levels in oceans generally run from 7-9, though the normal for tropical marine environments is 8.0 to 8.4. Pollution can contribute to a change in pH, making water too acidic or basic.

Temperature- Temperature is the key variable controlling water quality, but is relatively insignificant in the deep-water habitats of PHMR, thus consistent measurements should focus on surface waters (Sullivan et al, 1995). Temperature also has a substantial effect on corals and reef environments.

Salinity- Salinity changes in an estuary such as PHMR are influenced by freshwater (river) inflow, winds, and density currents. The salinity of the Snake Cayes will be influenced by local freshwater inputs and the water masses moving south to north in the Gulf of Honduras. In tropical waters salinity changes have the greatest influence on water density and the greater the salinity, the less dense water is.

Monitoring sites in PHMR

Site determination was based on existing monitoring locations established by the Coastal Zone Management Authority and Institute (CZMAI). These sites were revisited and established as PHMR's monitoring sites. Three transects were established starting at Paynes Creek Lagoon, Deep River, and Middle River/Golden Stream extending to the east. Two sites were added at the Northern border of PHMR in order to monitor Monkey River and nearby creeks, and local development impacts (Robinson et al, 2004) (*in draft)*.

Requirements and equipment needed

Schedule-Monthly collections should be made until a full, complete year data set is completed. Also, permanent data loggers are to be installed, which will measure temperature and salinity. Analysis of this data set in connection with permanent data loggers will expectedly allow for a decrease in data gathering. Possibly, quarterly measurements versus monthly may provide TIDE with the necessary data.

Equipment-

- GPS, coordinates
- Datasheet
- Minisonde Hyrdo-lab

- Plastic bottles
- Cooler with ice

Methods for Data Collection

All parameters except nitrates and phosphates are measured using a Minisonde Hyrdo-lab water quality multi-probe and should be done monthly.

1. The probe is to be inserted to the given depth; the values are then recorded once they appear stable on the screen.
2. Samples for nitrates and phosphate are gathered in plastic bottles, labeled, stored on ice, and taken back to the TIDE. Analysis will be done using a HACH DR2010 spectrophotometer. (See manual in TIDE's lab for procedures to analyze nitrates and phosphates with the spectrophotometer.) Monthly collections should be made until a full, complete year data set is completed.

3. **A copy of all data sheets should be kept in the TIDE office for reference**.

GPS Points

Location	GPS position (WGS 84)	
Pt. Ycacos	331255 E	1796465 N
S. of Pt. Negra W. snake	333825 E	1795445 N
N. of Mid. Snake	336429 E	1793635 N
East Snake	338941 E	1792155 N
S. of W. Snake	330680 E	1789373 N
Wilson Caye	328604 E	1792062 N
Man 'o war Caye	327860 E	1794495 N
Deep R. mouth	324855 E	1799120 N
Golden Stream-Middle River	314568 E	1794095 N
Hen & Chicken	316318 E	1790211 N
Moho-Stuart Caye	318890 E	1785783 N
East of Rio Grande	317907 E	1783487 N
Monkey R Mouth	341635 E	1809630 N
North of Monkey R	342302 E	1810630 N

Data Management, Analysis and Interpreting Results

Spreadsheets are set up and attached for data entry in the PHMR Data Management spreadsheet. Also, permanent data loggers are to be installed, which will measure temperature and salinity. Analysis of this data set in connection with permanent data loggers will expectedly allow for a decrease in data gathering. Possibly, quarterly measurements versus monthly may provide TIDE with the necessary data. Once a complete data set for a year has been collected and trends can be looked for and that can be determined. See, Water Quality folder, for 2003 data. The relevance of each parameter to management and possible inferences from data is provided below.

Nitrates and Phosphates- Increasing nitrates and/or phosphates are an indication of pollution (agricultural, development, sewage, etc). In PHMR, these will relate heavily to development upstream and shrimp farm development. Baseline data from the 1993-4 (Sullivan et al, 1995) showed a pattern of lower nitrogen and phosphorus concentrations offshore with slightly higher inshore and upriver levels and Monkey River had the highest inorganic nutrient levels. Special focus of these levels should be noted in the Monkey River samples where recent aquaculture and river development are increasing nearby. Nitrogen in tropical coastal waters are expected to have a range of 0.014 mg/l to 0.7 mg/l and phosphorus is expected to be in the range of 0.0031 – 0.124 mg/l giving a ration of ~10N:1P (Sullivan et al, 1995).

Dissolved oxygen (DO)- Correlations between DO and nitrates and phosphates should be done regularly. In general, the concentration of dissolved oxygen in seawater has a value of 6 mg/L (Sullivan et al, 1995). However, an increase in temperature or salinity will decrease the amount of oxygen dissolved in seawater. Agriculture upstream and sewage effluence (human, aquaculture) are the two main contributors to eutrophication (loss of DO) in PHMR. A continuous decrease in DO should be investigated in correlation with development (river or coastal), local effluence sources, agriculture and Fresh Water Initiative data.

Turbidity- Factors that cause turbidity to increase are; currents, wave action, erosion, construction, mangrove destruction, and boat traffic. Turbidity will fluctuate with rainy seasons and river input and therefore should be watched for an increase over time on a station per station basis versus regionally, because river input greatly effects this parameter.

pH- pH levels in oceans generally run from 7-9, though the normal for tropical marine environments is 8.0 to 8.4. Pollution can contribute to a change in pH, making water too acidic or basic.

Temperature- Temperature will fluctuate between the wet and dry seasons, in correlation with river input. Any rapid, continual increases in temperature should be investigated thoroughly. Also, investigations should be made into the fauna associated with the area. Investigations should be done on a station-to-station basis due to the hydrological complexity of PHMR.

Salinity- Salinity investigations should be done on a station-to-station basis due to the influence of freshwater in PHMR. Baseline data showed lagoon areas of PHMR with salinities of about 20 ppt, with most areas of 30 ppt (Sullivan et al, 1995). 2003 data (Robinson et al, 2004) found a mean high of 35.7 and low of 29 ppt in PHMR. Within coastal areas salinity variability is expected from 2 ppt (low), to 2-5 (medium) and 5-20 (high) and these changes can occur from hours to days to years.

GIS- Water quality can also be analyzed from a watershed perspective by incorporating data from Fresh Water Initiative (FWI) projects. Additionally, water quality data should be entered into the GIS database for comparison to the baseline data collected in 1993-4, 2003. This will aid in noting spatial patterns and possibly highlight areas of optimal health or concern. Some data has already been entered from 2003 studies to allow for some comparison and evaluation.

Evaluation of PHMR's management goals

Based upon the goals to protect the physical and biological resources of Port Honduras and to preserve the value of the area for fisheries and other important genetic resources, maintaining water quality in PHMR is critical. However, due to the long time span of the data from Sullivan et al (1995) and an incomplete recent data set of all parameters, only general criteria can be established.

Preliminary assessment of management effectiveness can be made by categorizing water quality; taking into account available background data and some parameters and the general marine standards discussed in the 'Data management, analysis, and interpreting results' section. Water quality can be categorized as follows, but will be refined, once water quality standards are defined for each parameter. As suggested by the manual '*How is Your MPA doing?*' (IUCN, 2003) the following criteria were determined.

1. Data suggests water quality is **poor**; state across majority of parameters measured has highly degraded compared to those of healthy marine environments or previous data.
2. Data suggests water quality **needs improvement**; state across majority of parameters measured has degraded compared to those of healthy marine and estuary environments or previous data.
3. Water quality is **unchanged** state across majority of parameters measured is consistent with previous data.
4. Data suggests water quality is **improving** state across majority of parameters measured is close to those of healthy marine and estuary environments and previous data.

5. Water quality is **good**; state across majority of parameters measured is desirable for healthy marine and estuary environments and consistent with previous measurements.

A scorecard will then be established, incorporating the measured parameters after a full data set has been collected. (See Appendix 15 for scorecard example.)

Outputs

- Monthly Excel sheet should be kept for **each** parameter of water analysis. Annual analysis should be made for each component and an example graph is provided. Monthly data should be compared and evaluated (See 'Data Management and Analysis' section for aid in interpreting and implications of results for each parameter).

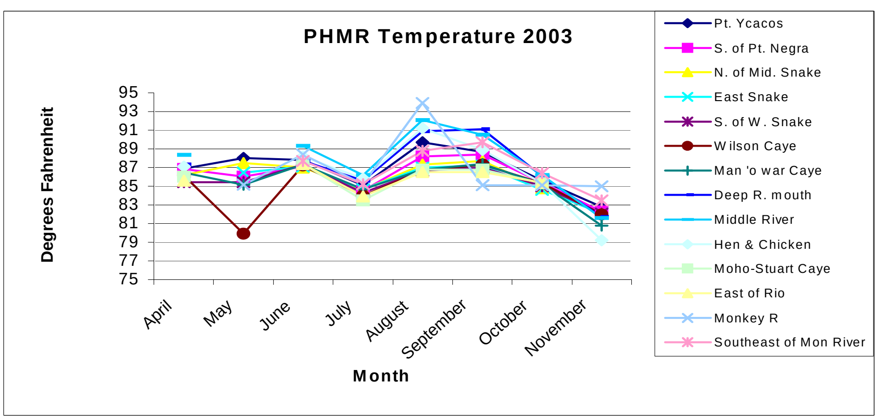
- An indicator scorecard of water quality and establishment of standards at the end of a full year of data collection.

- An annual water quality report should be prepared. Focuses should be on changes throughout the year, trends, and comparisons between rainy season and dry season averages and to previous years.

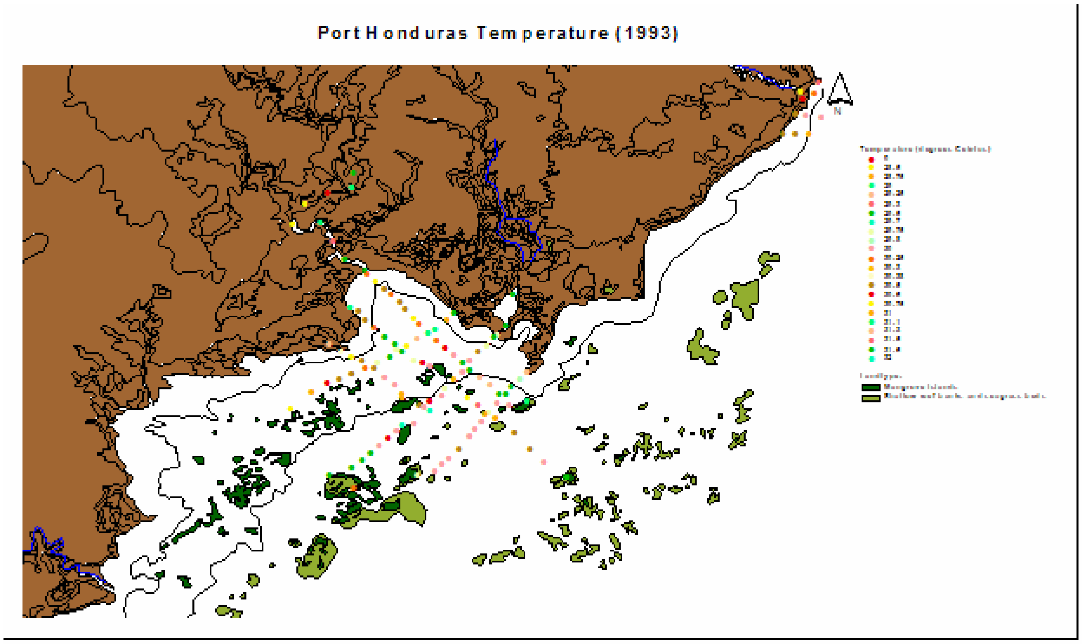
- Annually, the average of each parameter should be added to the GIS database. Measurements should be compared to the previous year and the original data set from 1993-4. These maps can be added to the annual report and will aid in spatial analysis and comparing the sites to one another. Instructions for how to enter data are located in Section IX, GIS Applications.

Examples

Graphs- Graphs are useful for looking at trends, such as differences between the rainy and dry season. Below is an example temperature graph for 2003. One graph should be completed annually for each parameter.



GIS maps- GIS maps can be prepared using Arc View, further instructions for how to enter data is available in Section IX, GIS Applications.



Useful References

- Characterization for Integrated Coastal Management of Port Honduras: Ecology, Oceanography, and Geography of Port Honduras, Belize- a proposed marine protected area (Sullivan et al, 1995). Water quality sample were taken by transects running from Deep River, Punta Ycacos and Monkey River. This data provides a valuable reference of water quality and comparisons to present data and can give valuable insight concerning possible changes in water quality in PHMR. *Please note that some of the parameters were quantified differently and might need conversion for proper comparison.*

- A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve. Robinson et al (2003) (*in draft*)). These data can aid in determining the water quality scorecard.

- Coastal Zone Management Authority and Institute (CZMAI)

- Karl Castillo of the University of South Carolina, had permanent data loggers recording temperature and salinity installed around the Snake Cayes during 2002-3. Some of the data is presented in, Robinson et al (2003) (*in draft*).

- The report in the PHMR biology folder called, Water Quality Concerns in the Florida Keys: Sources, Effects and Solutions (Kruczynski, 1999). This format may be useful for annual water quality reports for PHMR.

Recommendations

- **Vertical profiles should be incorporated into water monitoring.** Due to the heavy influence of freshwater on PHMR, surface waters differ greatly from those at depth and often an abrupt halocline occurs. This layering between water masses (especially near the river mouths), effects circulation patterns, thus the plankton community (fish, shrimp, lobster, etc larvae) and is important for tracking water circulation and recruitment in the area.

III. Seagrass Monitoring

Seagrass Monitoring Biophysical Indicators

Biophysical Indicator 4: Recruitment success-Recruitment success is defined by the manual as, ‘ the degree of juvenile recruitment and survivorship experienced across populations of organisms that exist within a community’ (IUCN) (2003). In reference to seagrass monitoring, recruitment success relates to the essential fish habitat (EFH) that seagrass beds provide for many juvenile and adult finfish and conch species.

Biophysical Indicator 5: Habitat Distribution and Complexity- Habitat distribution is the spatial characterization of a specific community (e.g. seagrass community) based upon the area covered. Complexity relates to the amount of species within the habitat, coupled with abiotic characteristics to define the area. Seagrass habitats are EFH and their health plays an important role in the success of many species.

Why seagrass communities should be monitored

Seagrass meadows are ecologically important habitats in marine environments. Seagrasses and other community components integrate the effects of nutrients in the water column over time. Growth of benthic algae, increased chlorophyll (phytoplankton) in the water column, as well as increased nutrient concentrations have been used to gauge the onset of eutrophication in tropical marine ecosystems. Studies in the Florida Keys have shown how nutrient enrichment affects algal growth on seagrass blades (epiphytes), and the productivity and structure of the shallow water turtle grass *(Thalassia testudinum)* community.

Seagrasses and their associated algae are very productive. As a result of seagrass productivity, the abundances of these creatures are very high, and attractive to larger marine organisms, especially fishes, in search of good feeding areas. In PHMR, seagrass meadows serve as important "nursery grounds" for the juvenile stages of commercially important conch, lobsters, and fishes, and as important feeding sites for adult fishes and birds (Bauer, 2004).

Parameters to be measured for evaluation of Biophysical Indicators

Community Composition- Seagrass communities are often comprised a variety of seagrass species, corals (soft and hard), algae, etc. For PHMR**,** the belt-quadrat method is a continuation of data gathered in 1992-4 (Sullivan et al, 1995) and provides comprehensive picture of the seagrass community, versus just the health of the *Thalassia* populations. The categories are simplified compared to those used in Florida Bay and original studies and can be expanded based upon expertise and time (e.g. identifying algae to species) (see Sullivan et al, 1995 and Fl. Bay site for reference). This is a long-term indicator, which will be compared bi-annually. This parameter may also indicate anthropogenic stresses from boating (blades being damaged by boat propellers), fish traps, or shrimp farming. The percentage of each category should be calculated, to get a 'community picture', which will likely unique to each site. Initial observations will be compared to future to look for community changes. Also, hard coral species present should be listed and notes should be taken on any epiphytic growth on the blades. (See Appendices 1 & 2 for pictures to aid these surveys.)

Seagrass community composition categories:

Macroalgae	Soft coral
Turf algae	Hard coral
Thalassia testudinum seagrass	Sand
Syringodium filiforme seagrass	Mud
Other seagrass	Rubble

Seagrass percentage- for each plot this should be calculated in order to get the site composition and compare it amongst itself bi-annually. A decrease in seagrass percentage will greatly impact juvenile animals that depend on the seagrass community for feeding and refuge.

Biomass- A CARICOMP/MBRS indicator for seagrass is *Thalassia testudinum* biomass. Changes in the structure of the biological community (species abundance and composition) are important signs of nutrient enrichment in oligotrophic systems. Similar to the belt-quadrats, these indicators work together to get a picture of the *Thalassia* health and primary production. Whereas the belt-transect method is concerned with the community structure this is focused on the productivity of the area. *Thalassia testudinum* is the dominant Caribbean seagrass species as it typically contributes more biomass, and thus areal productivity, to total seagrass bed production than *Syringodium filiforme, Halodule wrightii*, and *Halophila* spp., and also because *Thalassia* is the competitively dominant and "climax" species in Caribbean seagrass succession.

Monitoring sites in PHMR

Two monitoring sites were established in 2003, one at Frenchman's Lagoon and the other at Stuart's Caye. Two other monitoring sites are to be established based upon previous work by Heyman, 1996 and the need to monitor a site at the Snake cayes. Further information about these sites can be found in the document, CARICOMP Site Characterization: Port Honduras, Belize (Heyman, 1996).

Requirements and equipment needed

Schedule-Core samples and transects should be done at each site bi-annually in December and June. Appendix 3 is the field data sheet to be used for seagrass community surveys.

Equipment-

- SCUBA equipment
- 20 M Transect tape
- Clipboard and underwater paper
- Waterproof camera (optional, see procedures for further details)
- *Corer- a PVC pipe (beveled and notched) 80 cm long and 15-20 cm diameter with a plug, approx. 5-7.5 cm diameter and a 45 cm long handle
- A 50cm x 50cm quadrat

- 4 ea: Plastic buckets
- 1 ea: Sieve box; 2 mm mesh

  or
- 4 ea: Fine mesh (2-4mm) bags (i.e. diving bag)
- 1 ea: Deep tray
- 2 ea: Plastic kitchen strainers; 6-8" (15-20 cm) diameter
- 10 ea: Plastic basins (for sorting different biomass fractions into)

Miscellaneous:

- Aluminum foil
- Pink flagging tape
- Ziploc plastic freezer bags; quart and gallon size
- Hydrochloric or phosphoric acid (10% v/v; 10% concentrated acid + 90% water)
- Drying oven (45, 60, or 90 oC; see text)
- Analytical balance
- GPS and site coordinates

Corer- The best way to obtain biomass samples in Caribbean seagrass beds is by the use of corers. Corers must be sturdy enough to slice through *Thalassia* rhizomes and dense calcareous sediments. Corers made from PVC pipe are economical and durable. The diameter should be about 15-20 cm and length about 60-80 cm. The cutting end of the corer should be beveled and notched to provide a better slicing edge. The simplest material to use is the blade of a band-saw or hacksaw with coarse teeth. This can be affixed on the inner edge of the corer with pop-rivets, and replaced periodically. A continuous handle should go transversely through the corer and be sealed where it passes through the corer barrel. Handles should be at least 15-20 cm on each side for leverage, and be of sufficiently large diameter to be strong and comfortable. The corer must have a removable plug so that a vacuum can be obtained upon extraction, or else much of the material will be lost.

Methods for Data Collection

Preparation- Before entering the field a few logistics should be considered.

1. Permanent transects should be established, so rebar, a mallet, compass, flagging tape, etc. will be needed for the first outing.
2. Former sites need to be investigated to confirm feasibility.
3. If possible, a digital camera should be used for the seagrass surveys.
4. ID training will be necessary, for the categories to be used in the belt transect portion. The main coral species likely encountered include: *Siderastra siderea*, *Siderastra radians*, Oculina sp., and *Favia fragrum*. A picture guide is provided in Appendices 1 & 2. Additionally, Paul Humann's, Reef Coral book should be consulted for identification assistance.
5. SCUBA equipment is necessary.

Field Procedures- These procedures were adapted from the MBRS and CARICOMP protocols. Appendix 3 is the field data sheet for the procedures. Seagrass community transects and core samples will be performed in December and July.

A. Belt Transect Quadrats

Initially, three 30m permanent transects should be established at each site. Permanent transects can be established by using rebar and marking the positions with a GPS. For further information on establishing permanent transects go to http://www.seagrassnet.org/SeaNetMan.PDF. In the area where core samples are to be taken (see MBRS Category 1) the belt transect method will be completed to gather the percent coverage of the designated categories. See page 16 for current GPS locations and 'reestablishable' sites. Depending on the size and geometry of the community, transect lines should be orientated along the major axis of the community, preferably parallel to the coast. The 30M transect should be run along the major 'community axis' and the quadrats should be placed next to the transect.

1. Using the 50cm x 50cm quadrat, divers will perform visual estimations will performed every 5M down both side for each transect (12 total). The percentage of each category should be recorded and any hard coral species present should be listed. Once an underwater (preferably digital) camera or video camera is available the quadrats should be assessed visually initially and digitally to ensure accuracy. Then percentages from the field can be made to the photo to assure accuracy.
2. **Any 'unusual' or advanced epiphytic microalgae on the seagrass blades should be noted.**

3. Within each quadrat the *percent coverage* of the following categories should be estimated.

Macroalgae	Soft coral
Turf algae	Hard coral
Thalassia testudinum seagrass	Sand
Syringodium filiforme seagrass	Mud
Other seagrass	Rubble

B. Biomass Core Samples (Adapted from MBRS and CARICOMP protocols)

1. The areas previously sampled in 2003 will be used and two more will be established, using the GPS coordinates as a guide.

2. Once in the water, force the corer into the sediment to at least 45-50 cm to obtain over 90% of *Thalassia* rhizomes and roots. If possible, the corer should be sunk up to the handles so that the sample does not slip down in the corer when removed from the sediments. **Important:** do not try to just push the corer into the sediments. It must be rotated rapidly back and forth to cut its way into the sediments as it is pushed. *Cut* - do not just push! Core samples can be placed in individual buckets.

3. At the surface, the sample should be transferred from corer to bucket. **OR** Alternately, as the cores are taken underwater, they can be immediately extruded into fine (2-4mm), pre-labeled mesh bags (e.g. diving bags, laundry bags), while still underwater. With this method, each core can be taken, extruded into its individual bag, and all taken to the surface at the same time, thus eliminating many trips to the surface. There should be a zone at the bottom of the core of 5-10 cm with no roots. This will serve as a guide in the future to just how deep the later cores must be taken.

4. Clean the samples completely of sediment*, and separate them first into species of seagrasses, fleshy macroalgae and green macroalgae of the order *Caulerpales* that grow from the sediment. Separation of macroalgae into species is at the discretion of the team. It is desirable but not required. If the samples are in mesh bags, they can be shaken and massaged while still underwater to remove most of the sediment. If these bags are not available, coarse sorting can be done on a sieve box with a mesh of about 2 mm. Size is not critical but a box about 60 by 40 cm, with sides about 8-10 cm (made of standard 1x3 or 1x4 lumber) is quite satisfactory. The screen must retain small pieces of plant matter and all coarse shell material and fragments must be removed by hand. After coarse sorting, fine sorting can be done on the screen, but is often more conveniently done in a tray of water about 10 cm deep. This greatly aids in sorting the fine fragments. While not a perfect guide, live roots and rhizomes *tend to float*, while dead ones *tend to sink*. Live roots are white or very light gray and crisp when squeezed or

broken, while dead roots are dark and more flaccid. Short shoots and rhizomes can have both live and dead roots intermixed. Likewise live rhizomes have a whiter, crisp interior, while dead rhizomes are darker, both inside and out, and are less crisp when broken.

* *The resulting sample must be all organic matter with no contaminating carbonate fragments.*

* *Uncleaned samples can be held without disintegration for a day in shade submerged or several days if running seawater is provided over the sample. Cleaned samples can be held likewise, or, are best held chilled.*

5. Divide all *Thalassia* plants into the following 5 separate fractions for biomass measurements 1)green leaves, 2) non-green leaves and short shoots, 3) live rhizomes, 4) live roots, and 5) dead below ground material.

   Note- that the green leaves should simply be torn off at the green/white interface (this is usually at the point where the leaves emerge from the bundle sheath, but may be higher up the leaf if the sheath is buried below the sediment).

   Note- also that the “nongreen leaves and short shoots” fraction comprises the non-green portions of the leaves and the sheath bundle, and is simply referred to as “short shoots” in the data sheets. For all other grass species, it is generally possible (and often necessary) to simply sort them into 2 separate categories 1) green and 2) non-green tissue.

Lab Procedures- Data sheets for field and lab analysis are located in the PHMR Data Management spreadsheet titled Seagrass biomass or can be downloaded from the CARICOMP website.

1. After separating the plants into their various biomass fractions, make sure that any remaining sediment is removed from the seagrass rhizome and root biomass fractions by scrubbing with a soft toothbrush. Also, epiphytes on the green leaves must be removed in 10% phosphoric (gentler but expensive) or hydrochloric acid (more commonly used and cheap) unless detailed chemical analysis of the components is contemplated. The leaves should be placed in the kitchen strainer and lowered into the acid until bubbling (evolution of CO2) stops.

Note- acid emersion should be as briefly as possible and certainly should not to exceed 5 minutes. The acid bath must be changed periodically as it becomes less effective.

2. Rinse or soak all biomass fractions thoroughly in freshwater (using the second kitchen strainer) to remove salt and acid. This is greatly helped if the fine sorting is done in a bath of *fresh wate*r.

3. Then place each fraction on pre-weighed and marked, heavy-duty aluminum foil tares and dry them at 60- 90 oC to constant weight (no more than 60 oC if chemical analysis is planned). Some below ground fractions may take several days to dry completely. Until one is familiar with the drying time necessary, it is best to periodically weigh several of the heaviest fractions until they show a constant weight for 12 hours. At this point, all the smaller samples should be thoroughly dry. At this time the samples should be placed in a desiccator to cool before weighing. If no desiccator is available, allow the oven and samples to cool to about 45oC before weighing.

4. When through weighing, store the dried samples in a plastic bag for at least 6 months in case any errors have been made and reweighing is necessary.

5. Divide calcareous macroalgae into above and belowground tissue if desired. Remove all sediment and then decalcify in 20% glacial acetic acid. This may take several days. Fleshy macroalgae need to be rinsed in freshwater, dried, and weighed. Separation into species is generally not required, unless there is a clear dominant macroalgal species in the community.

6. **A copy of all data sheets should be kept in the TIDE office for reference**.

GPS Points

For former sites see, CARICOMP Site Characterization: Port Honduras, Belize (Heyman, 1996).

Seagrass Coordinates

Sites (2003)	UTM E	UTM N
Frenchman's Lagoon		
Stuart's Caye		
Former (1994)	NAD 27	
Monkey River	341994.348	1810415.468
Deep River	322754.725	1799423.275
Snake Caye	To be determined	

Data Management, Analysis and Interpreting Results

Spreadsheets are set up and attached for data entry in the PHMR data analysis Excel file. Analysis, graphs and reports should be compiled annually. The data analysis is labor intensive and TIDE should coordinate interns and/or local schools to aid with the analysis and processing. For comprehensive data analysis, comparison and examination into changes/trends, consult the documents: Site Characterization for Integrated Coastal Management of Port

Honduras (Sullivan et al, 1995); Dr. Wil Heyman's Dissertation (1996) and CARICOMP Site Characterization: Port Honduras, Belize (BCES& Heyman, 1996). MBRS. A MBRS database has been established for data entry and regional comparison to the other MBRS sites and the seagrass biomass protocol is a portion of the MBRS methods.

Community Composition- For the belt-quadrat method, the parameters to evaluate are 'community composition' and percent of seagrass. Each seagrass community will have its' own 'normal' structure and will likely differ from the other sites, thus this composition will provide a baseline for future analysis. An increase in algae should be watched in the long term and seasonally. In the attached file titled 'PHMR data management' there is a worksheet titled 'Seagrass Quadrats'. The percentage of each quadrat per transect can be calculated, then a totals for each site can be determined. Trends between wet and dry seasons should be investigated.

Percent Seagrass- In the attached file titled 'PHMR data management' there is a worksheet titled 'Seagrass Quadrats'. The percentage of seagrass should be pulled from the data for evaluation. Annual comparison of this percentage should be compared. A decrease in seagrass percentage should be investigates with water quality to look for trends. Decrease in seagrass % could indicate stress on the seagrass bed.

Biomass- In the attached file titled 'PHMR data management' there is a Seagrass biomass worksheet for calculation of core samples. The onset of a response to changing conditions (stresses) would likely be realized in loss of below ground biomass. Bi-annual comparisons can be made between high and low productivity times. The *Thalassia* fraction should stay consistent seasonally. If the fraction decreases, this means there is a decrease in productivity for the area, thus effecting juveniles, conch, etc who utilize the area. Also, continuous data from the plots established in 2003 will give determine the productivity of those plots.

GIS- All of these indicators can be evaluated in the context of the GIS database. Reestablishing the former plots will provide very useful insight into changes that may be or have occurred in PHMR since their original measurements.

Evaluation of PHMR's management goals

Based upon the goals to protect the physical and biological resources of Port Honduras and to preserve the value of the area for fisheries and other important genetic resources, maintaining the seagrass beds that provide essential habitat is critical. Once a full year of data for all parameters is available, more precise standards will be established for the following year.

Preliminary assessment of management effectiveness should categorize the seagrass communities; taking into account all recently collected parameters, background data (e.g. Heyman (1996) and Sullivan (1995)) and seagrass measurements from 2003. As suggested by the manual '*How is Your MPA doing?*' (IUCN, 2003) the following criteria were determined.

1. Parameters suggest that seagrass communities are **in notable decline**, largely shifted from healthy, desired and previous states found in background data.
2. Parameters suggest seagrass communities are **in decline**. Slightly shifted from healthy, desired and previous states found in background data.
3. Seagrass communities are **unchanged**. Healthy, normal state across majority of parameters measured.
4. Parameters suggest seagrass communities are **improving**. Slightly better than desired and previous states found in background data.
5. Parameters suggest seagrass communities are **improving notably**. Much healthier than desired and previous states found in background data.

A scorecard will then be established, incorporating the measured parameters after a full data set has been collected. (See Appendix 15 for scorecard example.)

Outputs

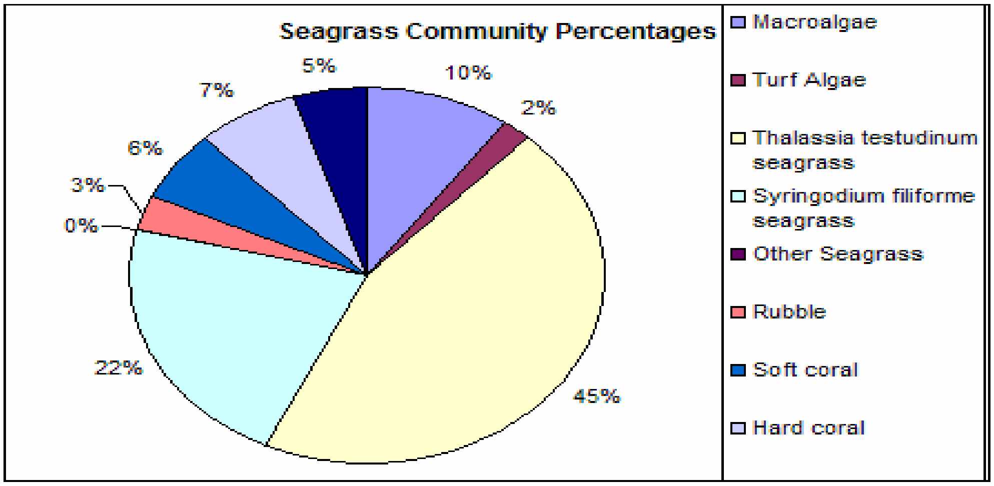
- An Excel sheet should be kept for community composition and biomass parameter. Annual analysis and a report should be made for the community composition percentages, seagrass percentage and biomass. Comparisons should be made between the two seasons. (See 'Data Management and Analysis' section for aid in interpreting and implications of results for each parameter.)

- Entry to CARICOMP and into the MBRS database. A MBRS database has been established for data entry and regional comparison to the other MBRS sites and the seagrass biomass protocols are a portion of the MBRS methods. The MBRS requests that individual persons before data entry, for data quality control, do training prior to receiving a password. For complete, current instructions go to www.mbrs.org.bz or contact them by phone.

- Annually, the average of each parameter should be added to the GIS database. Measurements should be compared to the previous year and the original data set from 1993-4. These maps can be added to the annual report and will aid in spatial analysis and comparing the sites to one another. Instructions for how to enter data are located in Section IX, GIS Applications.

Examples

Graphs- Graphs are useful for looking at trends, such as differences between the rainy and dry seasons. Below is an example community composition graph for displaying community percentage. (e.g. two of these can be made to compare rainy season to dry season to look for trends.)



GIS maps- GIS maps can be prepared using Arc View, further instructions for how to enter data is available in Section IX, GIS Applications.

Useful References

- Characterization for Integrated Coastal Management of Port Honduras: Ecology, Oceanography, and Geography of Port Honduras, Belize- a proposed marine protected area (Sullivan et al, 1995). Seagrass communities were characterized based on composition and biomass/productivity studies were performed. These data can aid in determining the water quality scorecard.

- CARICOMP Site Characterization: Port Honduras, Belize (Heyman, 1996). This can be used to help establish former sites and contains data on productivity and biomass for seven former sites around PHMR. Comparisons to this data will be valuable, especially in noting any increases or decreases from 1996. These data can aid in determining the water quality scorecard.

- A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve. Robinson et al (2003) (*in draft*)). These data can aid in determining the water quality scorecard.

- Previous studies in Florida Bay use a combination of overall distribution patterns of the dominant seagrasses, abundance and biomass of the dominant seagrasses to assess Florida Bay (www.aoml.noaa.gov/flbay/seag95.html).

- Mesoamerican Barrier Reef Systems Project (2003). Manual of Methods for the MBRS Synoptic Monitoring Program. P.C. Almada-Villela, P.F. Sale, G. Gold-Bouchot and B. Kjerfve. This manual and organization provides valuable assistance pertaining to methods and data management.

- CARICOMP website. This website and organization provides valuable assistance pertaining to methods, data management and comparisons of PHMR to the rest of the Caribbean.

IV. Mangrove Monitoring

Mangrove Monitoring Biophysical Indicators

Biophysical Indicator 4: Recruitment success-Recruitment success is defined by the manual as, ‘ the degree of juvenile recruitment and survivorship experienced across populations of organisms that exist within a community’ (IUCN, 2003). In reference to mangrove monitoring, recruitment success relates to the habitat that mangroves provide for many juvenile fish.

Biophysical Indicator 5: Habitat Distribution and Complexity- Habitat distribution is the spatial characterization of a specific community (e.g. mangrove community) based upon the area covered. Complexity relates to the amount and type of species within the habitat, coupled with abiotic characteristics (soil type, salinity, etc) to define the area. Mangrove communities are EFH and their health plays an important role in the success of many species.

Why mangrove communities should be monitored

Mangroves perform a vital ecological role by providing habitat for a wide variety of species and the dominant vegetation type within PHMR is the mangrove, red mangrove (*Rhizophora mangle*) being the most abundant. The importance of these communities to the ecological functioning of PHMR cannot be stressed enough, especially in terms of habitat for commercially valuable species (e.g. permit, snook, lobster, snappers, jewfish, etc). Many species, though not permanent mangrove inhabitants, make use of mangrove areas for juvenile habitat, foraging, breeding, and other activities. Additionally, mangrove roots are particularly suitable for juvenile fishes. A study in the Florida Everglades showed that comparatively more fishes were sampled from mangrove areas than from adjacent seagrass beds (Thayer et al, 1987). When fish densities in each habitat were examined, fish density in mangroves was 35 times higher than in adjacent seagrass beds.

In terms of productivity, mangrove litter contributes greatly to local fisheries in terms of nutrition. The cyclical process of mangrove leaf litter falling, being decomposed and utilized as food is commonly known as the “detrital food web” and serves as a fundamental link between primary producers and higher consumers (e.g. shrimp and fish). Mangrove productivity is affected by both direct impacts, such as clearing, and indirect impacts such as pollution and hydrological interference. Baffling by mangrove root systems provides a physical trap for fine sediment with loads of heavy metals and other toxicants. Changes in pH, dissolved oxygen and salinity lead to inhibition of photosynthesis and respiration in mangroves, causing dieback and less productivity. Current threats to mangroves in PHMR include upstream development, encroachments (fishing camps, housing, squatting on the coast and cayes), and possibly boat exhaust, especially in fly-fishing areas. Through the maintenance of an appropriate level of mangrove productivity, it will be possible to maintain the ecological integrity of the mangrove ecosystem.

Parameters to be measured for evaluation of Biophysical Indicators

Visual examination of threats- The main damage to mangrove forests comes from anthropogenic activities such as deforestation for timber, charcoal, firewood, boating, fish traps, coastal fish or shrimp farming. Qualitative data on these threats is valuable in detecting long-term impacts to mangrove forests. A list is provided to assess these threats to the mangrove sites at the sites and should be incorporated into Lighthawk flights.

Community composition- Mangrove communities are diverse, especially those of PHMR. Differing characteristics relate to location in relation to river input, water circulation and anthropogenic impacts. To be able to analyze and detect trends, impacts, growth, etc, a community must be categorized due to each having unique characteristics and productivity levels.

Leaf litter fall- Leaf litter fall provides an indication of the quantity of detritus that enters the marine food chain at the lower trophic levels (a.k.a. productivity). The difference between total litter fall and standing crop of litter, estimated by surface litter collection (although only at one time of year), is an indication of the rate of the litter in the particular habitat. A high standing crop indicates accumulation, while low standing crop indicates removal. Removal can be interpreted as how much is being recycled back into the marine system as nutrients and the amount of organic material available to other components of the ecosystem

Monitoring sites in PHMR

In 2003, one mangrove site was established at East Snake and two others will be reestablished based upon findings from Dr. Wil Heyman's Dissertation (1996) and CARICOMP Site Characterization: Port Honduras, Belize (BCES& Heyman, 1996). These reestablished sites should be in the vicinity of Monkey River and Deep River. Also great amount of mangrove data exists in the GIS database and the document; Site Characterization for Integrated Coastal Management of Port Honduras (Sullivan et al, 1995). *Hurricane events have likely altered some of the sights, so evaluation of a few before establishment will be necessary.*

Requirements and equipment needed

Schedule- Visual examination will take place twice a year, once in the field and once during Lighthawk flights. Community composition will take place once a year and productivity will take place twice a year, during peak and low productivity months. Appendices 4 & 5 contain the field data sheets for mangrove surveys.

Equipment-

- Clipboard, data sheets, pencils
- Camera for visual assessment and Lighthawk flights
- Calculator
- 10 m tape measures
- Sighting Compass, or 4 light, 10 m lines
- Nylon twine
- PVC stakes for plot corner
- Paint or paint pens for permanent tree marks
- Flagging tape
- Vinyl-coated wire
- Large number of weatherproof numbered tags (preferably aluminum)
- 1 m cloth tape measure, or dbh tape
- 6 m telescopic measuring rod
- Clinometer (if possible)
- Hammer
- Litter fall traps, 10 per plot. Construct traps in the form of a basket from a 1 m**2** of nylon netting (mesh size 1.5 mm) sewn onto a PVC, wood, or metal frame, 0.5 x 0.5 m (0.25 m2)
- Sample bags, 10 per plot (c. 30 x 20 cm)
- Sandwich-size paper bags for drying litter
- Drying oven
- Balance
- Wire or string to tie traps
- Forceps and white sample trays for sorting
- GPS and site coordinates

Methods for Data Collection

Preparation- Before entering the field a few logistics should be considered.

1. Permanent sites need to be established/reestablished and the proper equipment will be required (see methods).
2. Knowledge of mangrove species will be necessary.

Field Procedures- These procedures were adapted from the MBRS and CARICOMP protocols. Appendices 4 & 5 are the field data sheets for the procedures.

A. Visual Examination of Threats (Adapted from MBRS and protocols)

1. In the field

The main damage to mangrove forests comes from anthropogenic activities such as deforestation for timber, charcoal, firewood, scaffolding, fish traps, coastal fish or shrimp farming. Very often, damage to mangroves is obvious (e.g. areas cleared for development, damage by storms). Use the field sheet (Appendix 4) as a guide to recognize stresses in the mangrove community. Make careful examinations over time of these characters to show whether a mangrove is recovering or being damaged further.

2. In the air

Visual examination of mangroves should will be incorporated into Lighthawk flights and not be limited to the three ground plots. These flights offer excellent opportunity to monitor community changes and along with qualitative data and watch for human impacts (deforestation from fishing camps, removal of mangroves for building and/or fires) along the coast and amongst the cayes in the reserve. During flights, special attention should be paid to areas of greatest threat, such as inhabited cayes, coastal areas with development and the Monkey River area in relation to the shrimp farms. Regular photos and GPS points should be taken documenting changes in the mangrove communities, encroachments, etc, and a PHMR mangrove community photo portfolio should be kept. A visual examination data sheet is provided for field/plot excursion and can be utilized during aerial flights. This data should also be entered into the GIS database.

3. A **copy of all data sheets should be kept in the TIDE office for reference**.

B. Community Composition (Once a year) (Adapted from MBRS and CARICOMP protocols)

The East Snake site will be visited, using the GPS coordinates as a guide, and the other sites will be reestablished.

1. Once at the site, establish three 10 x 10 m plots within the two former sites (or nearby) (see GPS points on page 28). These plots will be designated A, B, C. Leave 3 – 5 m between each plot.

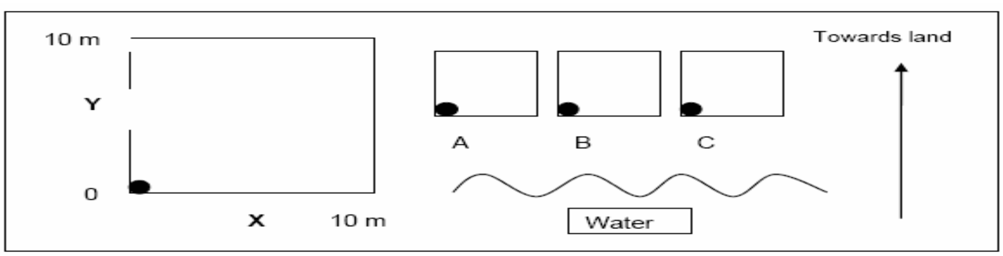
2. To begin each plot, mark a tree at the first corner (left side corner, closest to the sea; see below) with flagging tape or paint. Measure a 10M side parallel to the shore, marking the second corner with flagging tape. Use the compass to set the second side (from the second corner to the third) at right angles to the first, and then completing the square in a similar way. To facilitate the effectiveness of the measurements, you could subdivide the plots into smaller sections. However, you should avoid walking inside the plots as much as possible to prevent damage to the seedlings and saplings.

3. Use flagging tape to mark all the trees to be measured (dbh >2.5 cm) at the beginning of the survey. As each tree is measured, the flagging tape can be removed, making it easier to spot those trees still to be measured. (Use data sheet on page 46). See CARICOMP study by Heyman (1996) for figures and additional data.

   Use these species codes for identification:

   Rhi – *Rhizophora mangle*
   Lag – *Laguncularia racemosa*
   Avi – *Avicennia germinans*
   Con – *Conocarpus erectus*

Mangrove community set up (CARICOMP (2001).



4. *Sub-plots.* Within each plot, establish and mark five randomly placed 1 x 1 m sub-plots. Mark the corners of each subplot with PVC stakes and delineated the plots with flagging tape. In each sub-plot, all live saplings (< 2.5 cm dbh) and rooted seedlings should be tagged, identified, mapped, and measured, as above. Label each plant with an aluminum (Al) tag attached loosely with a vinyl-coated wire. Measure the total height of each plant within each subplot. (Use Appendix 5 data sheet).

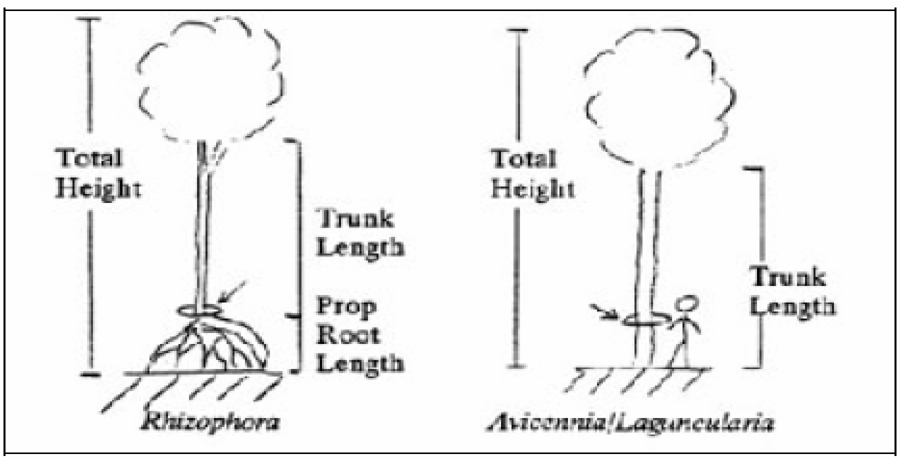
5. Map these plants using X Y plotting techniques. Record coordinates. The 0 point in each subplot should be at the left side corner closest to the water. The X-axis should be parallel to the water and the Y-axis should be perpendicular to the water.

Note: *It is recommended that these sub-plots be established and marked before making the tree measurements, then carefully avoid walking in them, to prevent damaged seedlings/saplings from being included in the initial sample.*

Note: *Some scrub/dwarf mangrove stands may have mature trees with dbh < 2.5 cm. These differ from saplings in fringe and estuarine mangroves by the presence of aerial roots arising from branches (in addition to normal prop-roots). For scrub mangroves take the mean dbh of all major stems and record height as above.*

6. *Label Trees.* For the two reestablished plots mark all mangrove trees with trunk diameter greater than 2.5 cm should be (a) numbered with a permanent marker such as Al tags, plastic ring-tags, or paint, (b) their position mapped (Figure 5.1), (c) identified, and (d) measured as follows:

Measuring tree height and diameter. (CARICOMP (2001).



7. *Diameter.* Measure the circumference (c) of the tree in order to obtain the diameter of the trunk (diameter at breast height or dbh). With *R. mangle,* the circumference is measured immediately above the uppermost buttressing prop root, using a flexible tape marked in centimeters.

   Diameter is then calculated as: **dbh = c/π**

   Note: *Specialized tapes that measure dbh directly are also available through forestry suppliers.*

8. For the reestablished plots, paint a ring around the trunk to mark the point where the dbh measurement was made. One year later, the measuring tape can be placed on top of this marker when re-measuring the circumference or dbh. Red mangrove trees sometimes have more than one trunk arising from common buttress or "prop-roots." In these cases, each trunk is measured as a separate tree. Where

prop-roots grow down from high branches, these should be ignored when deciding where to measure the circumference.

9. *Height*. Height should be measured for all marked red mangrove trees in the plot using three parameters: (a) height above sediment surface of the highest prop root, (b) length of trunk, from prop roots to main area of branching and (c) total height, from ground to highest leaves (Figure 5.2). For black and white mangroves, measure: a) total height from sediment to highest leaves; and b) the length of the trunk from sediment surface to area of main branching.

10. *Mapping*- Use X Y plotting techniques to map all the trees within each plot and record coordinates. The 0 point in each subplot should be at the left side corner closest to the water. The X-axis should be parallel to the water and the Y-axis should be perpendicular to the water (Figure 5.1).

11. **A copy of all data sheets should be kept in the TIDE office for reference**.

C. Productivity (Twice a year)

For the two reestablished plots, surface litter will be collected only once, at the start of the survey (see Initial Surface Litter Data Sheet in MBRS manual p.72). Simultaneously with the first period of litter collection, loose surface litter on the forest floor should be collected from ten 0.25 m^2 quadrats per plot. Bag separately, and label as surface litter from near an identified litter trap. Floor litter samples should be washed carefully to remove sediment and salt and then dried, sorted, and weighed like the trap litter samples.

1. Within each sample plot, deploy 10 litter fall traps at peak and low productivity, five parallel to the shore, and five perpendicular to it. The traps should be tied to prop roots of *R. mangle* approximately 1 m above the highest high tide. Plot the location of each trap using the X Y plotting technique (see Figure 5.1). (For East Snake Caye, thirty 0.5 m^2 leaf litter traps were constructed from pvc pipes and fiberglass 0.5mm mesh screen. Ten traps were placed in each plot following the CARICOMP methodology. However, the branches were too high for traps to be suspended from, so 4ft. lengths of rebar were used to make stands on which the traps could rest. So, modifications may need to be made at the other sites.)

2. In addition, number each litter trap so that the code for any litter trap will include a letter (for the plot) and a number. For each litter collection, place litter from each plot (10 traps) into labeled bags and oven dry it at 70º C for 48 hours. Sort the litter into leaves, flowers, fruits, bracts, and wood/twigs. Each fraction should then be weighed.

Note- For the litter fall traps, since plots that were once established are being continued, it is not necessary to do a full year data collection to determine peak and low productivity. However, to be precise, it is recommended (personal communication E.Garcia, University of Belize) that leaf litter traps should be set a month before and after the peak and low determined by the previous data, since there has been a substantial lapse in data collection. Using data from Heyman (1996) the Monkey River site had a productivity peak in August and low in February. The Deep River site had a productivity peak in June and low in January. The average peak litter fall for Monkey River and Deep River sites to be June and the low peak to be in February. For East Snake this is not necessary and only two collections need to take place, at periods of maximum and minimum production. Currently data is being processed and the low litter fall month has yet to be determined. However, data from April to August revealed July to be the peak productivity. Likely, the peak and low productivity months may not coincide for the sites**. Feasibility, timing and capacity may necessitate the average of these sites be the bi-annual collection times.**

3. **A copy of all data sheets should be kept in the TIDE office for reference.**

GPS Points

The site at East Snake Caye and the coordinates for the three plots. Datum is WGS 84.

East Snake (2003)

	UTM E	*UTM N*	*Lat/Long*	*Bearing*
Plot A	338800	1792712	N 16 12.54	X-228
			W 08830.486	Y-153
Plot B	338781	1792695	N 16 12.576	X-230
			W 08830.497	Y-150
Plot C	338807	1792655	N 16 12.545	X-020
			W 08830.482	Y-290

The plots that the need to be reestablished will be in/near the following locations. One will be from Monkey River, one from Deep River. All sites should be investigated, due to the time lapse and events such Hurricane Mitch that have altered the coast. The most suitable should then be reestablished. See *CARICOMP Site Characterization: Port Honduras, Belize* (BCES& Heyman, 1996) for further information and figures. Datum is in NAD 27.

Sites (1995)	*UTM E*	*UTM N*
Monkey River	341994.438	1810279.092
Monkey River	341965.552	1810214.636
Monkey River	341965.552	1810214.636
Deep River	323441.121	1800949.70
Deep River	323412.196	1800988.976

Data Management, Analysis and Interpreting Results

Attached in the PHMR data analysis spreadsheet is the mangrove community structure and litter fall spreadsheet. The litter fall sheet has been downloaded from the CARICOMP website.

Visual examination of threats- A visual threat data sheet should be filled out during field excursions and LightHawk flights. These threats can be ranked and areas of concern can be highlighted for mediation. Regular photos and GPS points should be taken documenting the mangrove communities, encroachments, etc, and a PHMR mangrove community photo portfolio should be kept.

Community Composition- Community composition gives you community description (within plot), the unique forest characterization/zonation, trunk diameter at breast height (dbh), and the height range for trees within the plot. In the PHMR Data Management spreadsheet there is a worksheet titled, Mangrove forest structure, to calculate these parameters. For East Snake they should be compared to 2003-4 data. Future inferences can be made between the differing sites in relation to the unique make-up of each and factors effecting the communities and their growth. Also, comparisons should be made to Sullivan et al (1995) and Heyman (1996).

Leaf litter fall- provides an indication of the quantity of detritus that enters the marine food chain at the lower trophic levels. The difference between total litter fall and standing crop of litter, estimated by surface litter collection (although only at one time of year), is an indication of the rate of the litter in the particular habitat. . For East Snake they should be compared to 2003-4 data. Future inferences can be made between the differing sites in relation to 1994-5 productivity levels and recent measurements. TIDE Baseline Studies 2003 (*in draft*) compared 2003 East Snake Caye mangrove productivity to Deep River and Monkey River (1996). Comparison showed East Snake had a higher density of mangroves (23.7 trees/plot) but, the trees had the lowest height and DBH. A lack of phosphorus could be responsible for this difference and highlights the need to coordinate indicators (e.g. mangrove productivity and water quality) for the most effective means of gauging management effectiveness.

GIS- Extensive spatial and quantitative data and a complete classification of the mangroves of PHMR is located in the GIS database. Consult the document titled, Site Characterization for Integrated Coastal Management of Port Honduras (Sullivan et al, 1995), for complete information. Current parameters and findings should be incorporated for trend and spatial analysis. Encroachments (e.g. fishing camps) have also been documented in the database and the visual threat data should be a continuation of this.

Evaluation of PHMR's management goals

Based upon the goals to protect the physical and biological resources of Port Honduras and to preserve the value of the area for fisheries and other important genetic resources, maintaining the mangrove communities that provide essential habitat is critical. Once a full year of data for all parameters and more than one site is available, more precise standards will be established for the following year. Preliminary assessment of management effectiveness can categorize the mangrove communities; taking into account all recently collected parameters, background data (e.g. Heyman (1996) and Sullivan (1995)) and mangrove measurements from 2003. As suggested by the manual '*How is Your MPA doing?*' (IUCN, 2003) the following criteria were determined.

1. Parameters suggest that mangrove communities are **in notable decline**, largely shifted from healthy, desired and previous states found in background data and at East Snake, 2003.
2. Parameters suggest mangrove communities are **in decline**. Slightly shifted from healthy, desired and previous states found in background data and at East Snake, 2003.
3. Mangrove communities are **unchanged**. Healthy, normal state across majority of parameters measured.
4. Parameters suggest mangrove communities are **improving**. Slightly better than desired and previous states found in background data and at East Snake, 2003.
5. Parameters suggest mangrove communities are **improving notably**. Much healthier than desired and previous states found in background data and at East Snake, 2003.

A scorecard will then be established, incorporating the measured parameters after a full data set has been collected. (See Appendix 15 for scorecard example.)

Outputs

- An Excel sheet should be kept for community composition and leaf litter fall. Annual analysis and a report should be made for the all parameters. Comparisons should be made between the two seasons for leaf litter fall. (See 'Data Management and Analysis' section for aid in interpreting and implications of results for each parameter.) All comparisons should be made to previous available data.

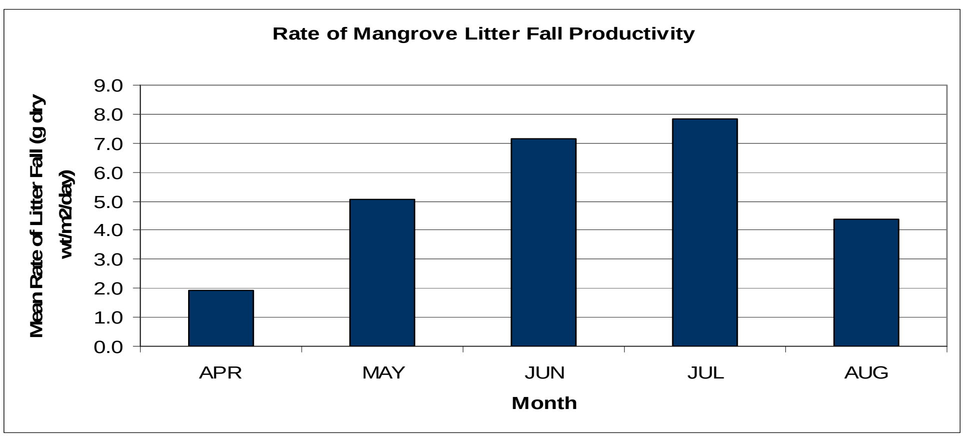
- A 'threat' analysis should be done for any areas with major threats. This should be incorporated into the annual report. Pictures and mapping these spots and a possible ranking system for these threats is an option for this.

- Submission of data to CARICOMP and the MBRS database. A MBRS database has been established for data entry and regional comparison to the other MBRS sites and the community composition and leaf litter fall data should be entered. The MBRS requests that individual persons before data entry, for data quality control, do training prior to receiving a password. For complete, current instructions go to www.mbrs.org.bz or contact them by phone.

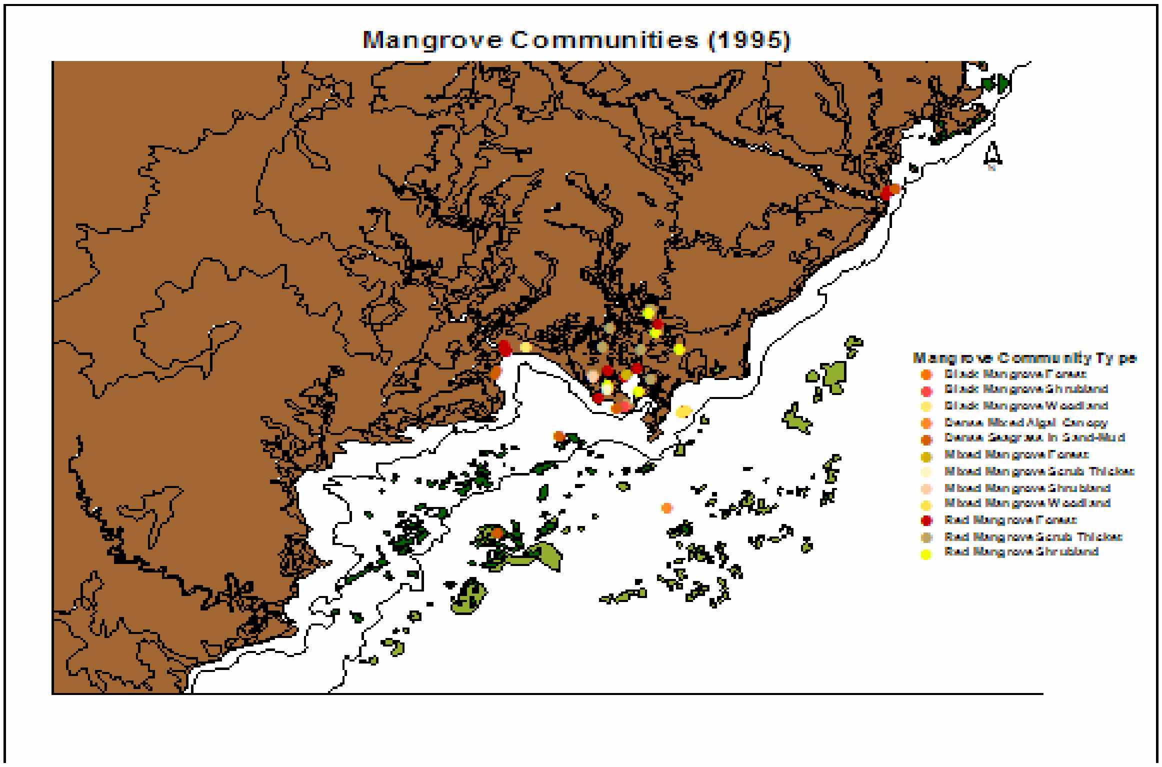
- Annually, any visual threats and the leaf litter data should be entered into the database. Encroachments (e.g. fishing camps) have also been documented in the database and the visual threat data should be a continuation of this. Measurements should be compared to the previous year and the original data set from 1993-4. These maps can be added to the annual report and will aid in spatial analysis and comparing the sites to one another. Instructions for how to enter data are located in Section IX, GIS Applications.

Examples

Graphs- Graphs are useful for looking at trends, such as differences between the rainy and dry seasons. Below is an example graph from Robinson et al (2004) is below looking at monthly productivity (leaf litter fall) to determine the peak and low months for the East snake site.



GIS maps- GIS maps can be prepared using Arc View, further instructions for how to enter data is available in Section IX, GIS Applications. Extensive data exists in the original database on community vegetation throughout PHMR. Below is a map of the communities defined by Sullivan et al (1995).



Useful References

- Characterization for Integrated Coastal Management of Port Honduras: Ecology, Oceanography, and Geography of Port Honduras, Belize- a proposed marine protected area (Sullivan et al, 1995). Seagrass communities were characterized based on composition and biomass/productivity studies were performed.

- CARICOMP Site Characterization: Port Honduras, Belize (Heyman, 1996). This can be used to help establish former sites and contains data on productivity and biomass for seven former sites around PHMR. Comparisons to this data will be valuable, especially in noting any increases or decreases from 1996.

- Mesoamerican Barrier Reef Systems Project (2003). Manual of Methods for the MBRS Synoptic Monitoring Program. P.C. Almada-Villela, P.F. Sale, G. Gold-Bouchot and B. Kjerfve. This manual and organization provides valuable assistance pertaining to methods and data management.

- CARICOMP website. This website and organization provides valuable assistance pertaining to methods, data management and comparisons of PHMR to the rest of the Caribbean.

V. Reef Benthic Monitoring

Reef Benthic Monitoring Biophysical Indicators

Biophysical Indicator 3: Composition and Structure of Community- A community is a collection of interacting organism found interacting in a defined geographic area. For the reef areas of PHMR this indicator can aid in determining whether the ecosystem is maintaining and if there is healthy Essential Fish Habitat (EFH) for species to thrive and detect anthropogenic threats.

Biophysical Indicator 5: Habitat Distribution and Complexity- Habitat distribution is the spatial characterization of a specific community (e.g. reef or mangrove) based upon the area covered. Complexity relates to the amount of species within the habitat, coupled with abiotic characteristics to define the area. For the reef areas of PHMR this indicator can aid in determining whether the ecosystem is maintaining and if there is healthy EFH for species to thrive and detect anthropogenic threats.

Why reef benthos should be monitored

Reef benthic environments and their composition make up what is known as Essential Fish Habitat (EFH). The Snake cayes and surrounding banks are spatially complex with unique hard and soft bottom communities and holds a diverse assemblage of coral species. The Snake cayes and many of the mangrove islands of PHMR are described as coral rampart islands with thick accumulations of finger coral rubble (Sullivan et al, 1995). Along with these habitats, a variety of commercial species thrive (reef fish, conch, lobster, etc). Baseline research in PHMR in 2003 was used to set up permanent monitoring sites and revealed each site had a distinct make-up, especially between the cayes and banks.

Parameters to be measured for evaluation of Biophysical Indicators

Area Coverage- Using the totals and percentages from linear point intercepts (LPI) totals, the area coverage of coral and sessile organisms can be determined. Because each site is unique in composition it is important to establish what is ‘normal’ for each location to base future analysis upon. These site compositions should stay relatively constant in healthy environments.

% Hard live coral- Hard coral is considered a key indicator of coral reef health. There is no definite % a site should be, thus comparisons should be made annually based upon the findings of the Baseline Survey (2003).

% Hard Dead coral-Percent dead coral should be observed in terms of 'recently dead'. Coral death results from pathogens in the water (diseases), faltering water quality, increased turbidity, etc. In the Caribbean a major source of coral death is bleaching, which is attributed to increased water temperatures.

% Disease- Hard coral diseases stem from many sources and causation of most is yet to be determined. Bleaching is indicative of elevated water temperatures, while other diseases stem from pathogens in the sea and could be related to sewage or effluence from polluted sources.

% Macro algae- % Macro algae should be comparatively inverse to hard coral percentage and carefully monitored, though seasonal fluctuations are common. An increase in macro algae may indicate over-fishing, lack of *Diadema*, or outside pollution and should be compared with water quality and fish abundance diversity to look for any overall declines, etc. In PHMR monitoring sites (2003) a trend was found where macro algae generally decreases with distance from river sources.

% Crustose Coralline Algae (CCA)- CCA is related to coral recruitment and is considered the 'cement' of reefs and is necessary for reef health and stability.

Coral diversity (species richness)- Relative should be consistent annually. Coral diversity indicates a healthy ecosystem and is individual to each site/region. Annual comparisons amongst sites should be made. Any large decreases in diversity likely indicates pollution, increase water temperature, extra sedimentation or turbidity, etc.

Diadema antillarium- Throughout the Caribbean there has been a major die-off of *Diadema antillarium*. These are major algae consumers and help control macroalgae on the reefs. In 2003, Middle Snake had the greatest number (28) and density of *D.antillarium* and Bank 2 had the second greatest out of the monitoring sites.

Recruitment- Coral recruitment is key to reef stability, as well as, the species 'recruiting'. Abundance and species diversity should be compared annually amongst sites. In 2003, South Snake had the greatest density of recruits and East Snake had the greatest species richness. *Porites asteroids* (Mustard Hill) was found most abundant and accounted for 42% of the recruits.

Regional Comparisons- It is important to look at a reserve's resources and success regionally. Thus submission of certain data to the MBRS and AGRRA will define PHMR's resources in relation to other reserves and protected areas in the Caribbean.

Monitoring sites in PHMR

Eight permanent reef (benthic and fish) monitoring sites were established in 2003. See Robinson et al (2004) (*in draft).* Their locality was based upon the need to measure management effectiveness in the Conservation and Preservation areas, as well as to assess the commercial fisheries.

Requirements and equipment needed

Schedule- Data collection should be performed annually between May and July, taking advantage of the dry season visibility. For comparison purposes the data should tried to be gathered the same time each year.

Equipment- The following equipment is required for each diver in addition to basic snorkeling gear and SCUBA gear (including depth gauge):

- Underwater data sheets
- Underwater ID books/cards to aid species identification
- A 30 m long transect line
- A 1m long measuring device (PVC pipe with holes drilled in)
- Plastic slates or writing cylinder
- A small plastic ruler tied to the slate or writing cylinder

Underwater data sheets -Attach a data sheet for benthic coverage onto a clipboard, underwater slate or writing cylinder. An example of the datasheet template designed for the benthic surveys can be found in Appendices 6 & 7. You can photocopy the data template onto white underwater paper to provide a permanent paper record of the data collected. Use rubber bands, clips or cable ties to attach the template to the slate. Use each template only once and keep in a safe place as a future records.

A 30m PVC measuring tape- This can be the same tape used for visual transects of fish. It will help to use a brightly colored PVC electrical tape or with a permanent marker, boldly mark this tape every 25cm. These marks will be used when measuring percentage cover of the benthos.

A 1 m measuring device- A 1m long PVC stick (~1/2" diameter) marked in 10-cm intervals or metric measuring tape can be used.

A small plastic ruler tied to the slate or writing cylinder-Trim the ruler to have a narrow, tapered point, but still be legible, at the basal 5 cm.

Methods for Data Collection

Preparation- At each monitoring site (see coordinates and number of transects below) fish surveys will be performed in the same area as the benthic transects. These transects have already been established with rebar, flagging tape and GPS points and should be easy to locate with the GPS. Before going to the site considerations and preparations are:

1. Data collection should be done once a year between May-July.

2. Knowledge of coral species, diseases and benthos and methods is necessary. Thus multiple training sessions featuring identification and procedures should be planned before data gathering. Good training resources for reef benthos is, Reef Creatures and Reef Coral by Paul Humann.

3. All team members should perform a complete and thorough read through of the protocols before any data gathering.

4. Check the GPS to confirm the points are in or enter them as waypoints. Also, a copy of all data sheets should be kept in the TIDE office for reference. Field data sheets are in Appendices 5 and 6.

5. SCUBA equipment is necessary.

Field Procedures- These procedures were adapted from the MBRS and AGRRA protocols. Using the GPS points on page 18, locations and transects will be located for surveying. Field data sheets are located in Appendices 6 & 7.

A. Linear Point Intercept

1. Once the GPS point is located, lay the 30-m transect line just above the reef surface and swim in the direction of the corresponding transect point.

2. Approximate the percentage cover of sessile organisms by swimming the transect, recording the nature of the organism directly below at every 25cm point along the transect. Do your best to avoid being selective (especially in places where the tape is held above the substratum providing

ample opportunity for parallax error to play a role). Recording every 25cm will yield 120 records per transect from which it is possible to compute percentage cover of each substratum type (as (# records/120) * 100%). On the data sheet put a tally mark for each 25cm point into the correct category. Classify organisms as:

a) Coralline algae: crusts or finely branched algae that are hard (calcareous) and
   extend no more than 2cm above the substratum
b) Turf algae: may look fleshy and/or filamentous but do not rise more than 1 cm
   above the substrate.
c) Macro algae: include fleshy algae whose fronds are projected more than 1 cm
   above the substrate.
d) Sponges
e) Gorgonians
f) Specific genera of stony corals.
g) Bare rock or sand, or dead coral, record that fact also. Do not record mobile organisms such as urchins or conchs. Encourage these to move out of the way if necessary in order to record the substratum underneath them.

Particularly with gorgonians and macro algae, avoid recording presence under a point when the tape has held down the organism horizontally. This will exaggerate the actual abundance of these species. Instead, focus on points that overlie points of attachment of the organism to the substratum.

B. Diadema antillarium counts and Presence/Absence Diversity Sampling

1. On completion of LPI swim back along the tape, using 1m pvc pipe count all the *Diadema antillarium* on both sides of the transect, 1m on each side. Carefully inspect the substratum, including under overhangs, within this belt, and record the number of Diadema urchins seen. Since these can be cryptic, especially when young, swim slowly and explore crevices carefully.

2. Then swim and record all hard corals to species within a 1m belt on either side of the transect line (presence/absence). Again, the 1-meter PVC pipe should be used as visual reference. If time permits, a tally of each time species is seen on transect should be done. Species were recorded by using the first letter of the genus followed by the first three letters of the species name.

C. Coral Recruitment

1. With a 50cm x 50cm quadrat, marked in 2cm increments, a diver recorded coral recruitment. Quadrats were placed along the transect line at 5m intervals and all recruits <2cm were recorded to genus level. This was done on both sides of transect, tallying on the data sheet the number of each found.

2. Where possible, the species should be recorded.

With team coordination, one member can start the step below, while Diadema, absence/presence and coral recruitment is done by another team member.

D. Characterization of the Coral Community (Coral Health)

1. After completing the point-intercept swim, swim back along the transect and stop at the first coral head, cluster, or thicket (or a portion) that is located directly beneath the transect line, is at least 10 cm average diameter, and which is in original growth position. For a colony that has fallen or been knocked over, only assess it if it has become reattached to the substratum or is too large to move. If the colony is loose and rolling around, then skip it. For each coral surveyed, record each of the following:

   a) Name (species).

   b) Record the water depth at the top of the corals at the beginning and end of each transect. In cases where bottom topography is very irregular, or the size of the individual corals is very variable, record the water depth at the top of each coral beneath the transect line at any major change in depth (>1m).

   c) Identify the colony's boundaries based on connective or common skeleton, connective living tissue, polyp size, and polyp color. Using a measuring device, measure to the nearest cm, its maximum projected diameter (live + dead areas) in plan view and maximum height (live +dead areas) from the base of the colony's substratum (not from the base of the reef). The diameter should be measured perpendicular to the axis of growth. The height should be measured parallel to the axis of growth. Plan view is assessed from an angle that is parallel to the axis of growth.

   d) Estimate the percent (%) of the coral that is "recently dead" and the % of the coral that is "long dead" as viewed from above in "plan" view. Plan view is assessed from an angle that is parallel to the axis of growth (be prepared to tilt your head to find the axis of growth and establish the proper plan view).

• "Recently dead" is defined as any non-living parts of the coral in which the corallite structures are white and either still intact or covered over by a layer of algae or fine mud. For recent mortality, there are several “stages” of recent:

Very recent = white intact skeleton is still visible (dead w/in 1 month or less)
Recent = corallite may be covered by thin turf algae or sediment (up to 6 months)
Older recent = corallite structure may be slightly eroded or covered but can still be identified to genus (< 1-2 yrs), unless covered by clionid sponge (see Note below).

Combine all of these recent mortality categories into RECENT. In some cases circular or oblong lesions or excavations caused by fish biting may result in destruction of the corallite. If fish bites are identifiable and constitute part of the mortality, consider it as recent mortality.

• "Long dead" is defined as any non-living parts of the coral in which the corallite
structures are either gone or covered over by organisms that are not easily removed (certain algae and invertebrates). If it is entirely “long dead”, indicate this on your data sheet as 100% “long dead”, as long as you can identify it to generic level based on morphology (e.g., *Acropora* palmata) or skeleton (e.g., Diploria sp.).

Note: In some cases, a coral may be partially or completely overgrown by the brown encrusting sponge, Cliona sp. At a quick glance, it may look like live coral tissue, but if you look closely you may observe the in/ex-current holes of the sponge and sponge tissue and will not observe live coral polyps. If you can see the coral skeletal structure underneath and are able to identify it to genus (e.g., Diploria and Montastraea), this should be considered old mortality and you should note Cliona overgrowth in comments.

Note: If a coral like columnar M. annularis or Dendrogyra has been knocked over, has either reattached to the substrate or is too large to move, has started to regrow towards the water’s surface, it now has a different diameter and height because of its new growth direction. You should measure diameter, height, and mortality in the correct plan view along the new axis of growth. Only measure the recently “live” part of the M. annularis when estimating mortality and not the old “base” because this will skew old mortality.

e) Scan over the surviving portions of the ENTIRE coral colony and note if there are any DISEASES and/or BLEACHED tissues present. Characterize any DISEASES using the following nine categories taken from CARICOMP, 2001. Underline any of these sources of disease (not bleaching) that are visible in plan view and which contributed to your estimate of "% recently dead". For more information about coral diseases see the disease cards (Bruckner & Bruckner, 1998) or visit the following web site: www.uwimona.edu.jm/centres/cms/caricomp/methods_manual.html

Characterize BLEACHED tissue as approximate severity of discoloration:

P = Pale (discoloration of coral tissues)
PB = Partly Bleached (patches of fully bleached or white tissue)
BL = Bleached (tissue is totally white, no zooxanthellae visible)

Coral Disease Categories:

- Black-Band Disease (BBD) Multispecific
- White-Band Disease (WBD) Types I and II (only in acroporids so far as known)
- White Plague-II (WP-II) Multispecific
- Yellow-Blotch Disease (YBD) Only described in species of Montastraea but also reported in many other species.
- Dark Spots Disease I (DS-I) Small, dark areas with no apparent tissue mortality. This disease is common in Siderastrea spp.
- Dark Spots Disease II (DS-II) Large dark areas, larger than DS-I, common in M. annularis and S. intersepta.
- Red Band Disease (RBD) Careful here since BBD can be seen as red bands too. RBD has been reported for Gorgonia spp and Agaricids in the Caribbean.
- Aspergillosis (ASP) In *Gorgonia ventalina, G. flabellum, P. americana* and other octocoral species as well (*Plexaura flexuosa*).
- Other - This category includes all other "unconfirmedpathogen-produced" diseases (tumors, hyperplasia, white pox, and all the "blotches"). Severely bleached coral tissues in many species are translucent, but you can still see the polyp tissue above the skeleton. Bleached tissues should not be included with the "recently dead" estimates. We are only interested in large scale bleaching events due to elevated sea surface temperatures, not bleaching due to algal overgrowth etc. Several months after a mass bleaching event, you may notice some corals (especially massive mound corals) still have pale or partly bleached tissues due to a previous bleaching event. Often these corals are still recovering.

Note: It is important to differentiate between tissue/skeleton with fish bites (=recently dead), recovering tissue from fish bites (=live tissue), bleaching and bleached tissue (=live tissue), and recent or old dead skeleton.

f) Whenever possible, record any other sources of recent mortality that can still be unambiguously identified: possibilities include sediments, storm damage, parrotfish bites, damselfish bites and/or algal gardens, predation on the soft tissues by snails like Corallophilia abbreviata or the bristle worm *Hermodice carunculata*, various effects of adjacent benthic algae, and any other spatial competitors (e.g., Erythropodium caribaeorum, other stony corals). Underline any of these sources that contributed to your estimate of "% recently dead".

2. Go to the next appropriate coral and repeat the measurements above. Continue evaluating each coral head (>10 cm) until you reach the other end of the transect. At least 50 coral colonies from *each site* should be sampled, though this may not be possible for Frenchman and Wilson. At the completion of your first transect tally the number of colonies evaluated. Repeat this process for each successive transect. In most sites you will reach 50 colonies after 2-3 transects. Always sample all appropriate colonies on a transect, but once you have exceeded 50 colonies, subsequent transects can be run for point intercept estimates of percent cover only. In cases where more than one person is running transects, you should compare notes after your first 1-2 transects.

3. **A copy of all data sheets should be kept in the TIDE office for reference**.

GPS Points

Originally ten transects per site were established (2003), but based upon investigations the number of transects has been set at six for most sites (the MBRS recommends a minimum of five). These transects allow for the collection of the necessary data to characterize the reef communities by the Linear Point Intercept portion and evaluate the suggested 50 hard corals > 10cm in the coral health portion of the methodology. Researchers need to be cautious when collecting data and make sure the correct transects are being surveyed. The transects are numbered and should correspond to the numbers below. GPS points are in WGS 84.

Beginning Points: **End Points:**

West Snake

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*
5	WS5B	332190	1790658	WS5E	332209	1790674

6	WS6B	332193	1790877	WS6E	332186	1790911
7	WS7B	332181	1790881	WS7E	332182	1790910
8	WS8B	332177	1790878	WS8E	332176	1790909
9	WS9B	332168	1790678	WS9E	332170	1790910
10	WS10B	332167	1790880	WS10E	332164	1790910

East Snake

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*
1	ESNA1	338803	1792511	ES1E	338838	1792520
2	ESNA2	338792	1792515	ES2E	338827	1792527
3	ESNA3	338785	1792515	ES3E	338819	1792519
4	ESNA4	338851	1792536	ES4E	338875	1792559
5	ESNA5	338846	1792544	ES5E	338872	1792562
6	ESNA6	338839	1792549	ES6E	338864	1792569

South Snake

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*
5	SS5	332756	1789590	SS5E	332764	1789610
6	SS6	332754	1789599	SS6E	332764	1789619
7	SS7	332756	1789666	SS7E	332730	1789677
8	SS8	332747	1789675	SS8E	332723	1789675
9	SS9	332274	1789656	SS9E	332719	1789669
10	SS10	332744	1789649	SS10E	332716	1789664

Middle Snake

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*
1	MSNAK1	334199	1792057	MSA1E	334213	1792026
2	MSNAK2	334208	1792055	MSA2E	334220	1792026
3	MSNAK3	334217	1792057	MSA3E	334228	1792028
4	MSNAK4	334225	1792065	MSA4E	334240	1792034
5	MSNAK5	334240	1792058	MSA5E	334260	1792032
6	MSNAK6	334318	1791997	MSA6E	334301	1792021

Wilson

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*
1	WN1B	330277	1794254	WN1E	330303	1794287
2	WN2B	330277	1794270	WN2E	330295	1794292
3	WN3B	330272	1794274	WN3E	330285	1794301
4	WN4B	330309	1794292	WN4E	330329	1794315
5	WN5B	330303	1794295	WN5E	330326	1794317
6	WN6B	330298	1794300	WN6E	330312	1794325

Frenchman

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*

1	FR1B	325061	1789663	FR!E	325044	1789640
2	FR2B	325055	1789666	FR2E	325038	1789643
8	FR8B	325048	1789678	FR8E	325043	1789708
9	FR9B	325066	1789670	FR9E	325096	1789659
10	FR10B	325070	1789680	FR10E	325098	1789665

Bank 2

Transect	*Code*	*East*	*North*	*Code*	*East*	*North*
1	B2A	333569	1789609	B2a	333597	1789638
2	B2B	333601	1789603	B2b	333607	1789636
7	B2G	333563	1789630	B2g	333547	1789607
8	B2H	333557	1789635	B2h	333563	1789665
9	B2I	333551	1789641	B2i	333557	1789670
10	B2J	333550	1789646	B2j	333554	1789674

Bank 3

Transect	*Code*	*East*	*North*			
1	B3A	329837	1786772	B3a	329841	1786773
2	B3B	329845	1786773	B3b	329819	1786789
3	B3C	329852	1786775	B3c	329828	1786744
4	B3D	329814	1786795	B3d	329789	1786790
5	B3E	329821	1786806	B3e	329788	1786805
6	B3F	329823	1786811	B3f	329792	1786810

Data Management, Analysis and Interpreting Results

Spreadsheets are set up and attached for data entry in the Excel file ‘PHMR data management’. Though all the data can be utilized to gather a complete benthic ‘picture’ of each site and coral health; certain parameters are related directly to PHMR management goals and evaluation of the Biophysical indicators. The parameters chosen relate to the health of the benthic communities and EFH. Investigations into the benthic communities of the monitoring sites revealed each site had a distinct make-up, especially between the cayes and banks. Also, only one General Use Zone (GUZ) site (Bank 2) had a comparative site make up to those of the Conservation and Preservation areas, the no take zones (NTZ’s). Due to this, primarily site-to-site and zone-in-zone comparisons and evaluations are suggested, versus an overall comparison of the GUZ’s to the NTZ’s. Once an outside site/s is established further investigations can be made.

Area coverage- Using the totals and percentages from linear point intercepts (LPI) totals in the Excel spreadsheet the area coverage of coral and sessile organisms can be determined. Pie graphs can display this data well and allow for simple annual comparison and characterization of the reef communities.

The categories are slightly different from those used in 2003, but comparisons and trends can still be investigated.

% Hard live coral- Percent live coral should be calculated for each site. Any decrease in coral > than %5 should be looked into carefully and compared with water quality and fish abundance and diversity to look for any patterns. This percentage should be calculated from the 'point intercept' portion of data collection. This data should also be compared to the data collected in 2003 (see 2003 AGRRA Benthic folder).

% Hard dead coral- If this percentage increases, correlating investigations should be made into water quality, coral disease presence and macro algae to aid in determining the causation. This percentage should be calculated from the 'coral health' portion of data collection, which stems from AGRRA protocols. This data should also be compared to the data collected in 2003 (see 2003 AGRRA Benthic folder).

% Disease- Hard coral diseases should be watch and noted carefully. Disease is measured during the 'coral health' portion of the benthic surveys and percentages should be analyzed annually. Additionally, if there is a high percentage of any one disease or many, AGRRA and the MBRS should be contacted for consultation. Using the spreadsheet for coral health, add up the total percentages for each disease to get a site total. (See 2003 AGRRA Benthic folder for previous values.)

% Live coral- In the attached file titled 'PHMR data management' there is a LPI worksheet for the number of tally marks per transect in the related categories. For each transect, enter the number of tally marks for each category, the last column will calculate a percent for each category per site.

% Macro algae- There is no definite % a site should be, thus comparisons should be made annually based upon the findings of the Baseline Survey (2003). In the attached file titled 'PHMR data management' there is a LPI worksheet for the number of tally marks per transect in the related categories. For each transect, enter the number of tally marks for each category, the last column will calculate a percent for each category per site. Sum up the three macroalgae categories for a complete macroalgal abundance.

Crustose Coralline Algae (CCA)- In the attached file titled 'PHMR data management' there is a LPI worksheet for the number of tally marks per transect in the related categories. For each transect, enter the number of tally marks for each category, the last column will calculate a percent for each category per site. There is no definite % a site should be, thus comparisons should be made annually based upon the findings of the Baseline Survey (2003). Comparison between CCA and coral recruits should be made after data collection.

Diadema antillarium- In the attached spreadsheet is a *Diadema* worksheet. Enter the # per transect. This will yield a total, the total should then be put in terms of density (each transect equals $60m^2$). For example if 10 transects are done at East Snake and 15 *Diadema* found it will equal 10*60= $600m^2$, thus 15/600= 0.025/m2. Site comparisons should be made annually, looking for abundance increase or decrease. Correlations should be made between abundance and macroalgae.

Recruitment- For recruitment, follow the procedures as *Diadema*. In addition, abundance graphs should be formulated depicting the number of species. An example is provided.

Coral diversity (species richness)- In the attached spreadsheet, enter a '1' for every species found a transect. The row totals will give the number of species per transect, the column total will give a relative abundance- the # of transects the species was found on. If the number of times the species was found per transect was tallied, this number should be entered in a separate sheet, giving a more precise species abundance.

Evaluation of PHMR's management goals

Based upon the goals to protect the physical and biological resources of Port Honduras and to preserve the value of the area for fisheries and other important genetic resources, maintaining the habitat in which these species thrive is foremost.

Comparison of the values determined in the baseline studies of the aforementioned parameters can indicate if the habitat distribution and complexity is maintaining, successional, degrading or recovering/improving. Based upon the values for each parameter found in Robinson et al (2004) a scorecard can be evaluated (Appendix 15). Using the data, criteria were developed and a scorecard, using guidelines established in the manual, *How is my MPA doing?,* (IUCN, 2003).

Outputs

- Analysis, graphs and reports should be compiled annually in the form of an annual report, along with the reef fish data. In the 'Data Management and Analysis' section, recommendations for this are made related to each parameter. Also, following the document, A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve, (Robinson et al, 2004), comparisons can be made.

- Entry into the MBRS database. Data should be filled out and submitted to the MBRS and AGRRA for regional analysis. A MBRS database has been established for data entry and regional comparison to the other MBRS sites. The MBRS requests that individual persons before data entry, for data quality control, do training prior to receiving a password. For complete, current instructions go to www.mbrs.org.bz or contact them by phone.

- Parameters and indicators should be incorporated into the GIS database. These maps can be added to the annual report and will aid in spatial analysis and comparing the parameters and indicators from year to year. Also, trends between the monitoring sites can be evaluated. Instructions for how to enter data and example maps are located in Section IX, GIS Applications.

- An indicator scorecard for habitat complexity and distribution (Appendix 15)

Examples

The document, A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve (Robinson et al, 2004) (*in draft*)), contains many examples of how to display data using these methods.

Useful References

- A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve. (Robinson et al, 2004 (*in draft*)). This can be used to establish annual comparisons amongst the reef monitoring sites.

- Characterization for Integrated Coastal Management of Port Honduras: Ecology, Oceanography, and Geography of Port Honduras, Belize- a proposed marine protected area. (Sullivan et al, 1995). This contains benthic classification of many areas in PHMR, including aerial photo interpretation around the Snake cayes.

- Mesoamerican Barrier Reef Systems Project (2003). Manual of Methods for the MBRS Synoptic Monitoring Program. P.C. Almada-Villela, P.F. Sale, G. Gold-Bouchot and B. Kjerfve. This manual and organization provides valuable assistance pertaining to methods and data management.

- AGRRA website

Recommendations

- **An outside reserve monitoring site should be established to compare to the General Use Zones and No-Take Zones in PHMR.** A possible location would be a bank East of South Snake, which would have similar characteristics to the reef monitoring sites within PHMR. A basic approach to measure reserve effectiveness is to compare flora and fauna outside the boundaries to those within, as suggested by the WCPA &World Conservation Union (IUCN) Management Effectiveness Guidelines. Effectiveness need not only be gauged by increasing species/biodiversity within a reserve, but moreover by comparison as to what is occurring outside the reserves boundaries.

VI. Fish Monitoring

A. Reef Fish

Fish Biophysical Indicators

Biophysical Indicator 1: Focal Species Abundance- Focal species abundance is both how common a species is in relation to the population present (species abundance) and the number of individuals of a population of a particular species (IUCN) (2003). A key part of the PHMR management plan is to stabilize and increase fish populations to sustain the local fishing economy.

Biophysical Indicator 2: Focal Species Population Structure- Population structure is defined by the manual as, ' the frequency with which specific sizes of individuals are likely to be encountered within a population' (WCPA, NOAA &World Conservation Union (IUCN) (2003). Demonstration of a stable size class structure is an important, sought out benefit of MPA's.

Why reef fish populations should be monitored

A major goal of the PHMR management plan is to stabilize and increase fish populations to sustain the local fishing economy (Goal 3, PHMR Management Plan). Much research has been done on the fish populations within Port Honduras and the reserve itself.

In 2003, eight reef monitoring sites were established to survey fish and the benthic populations; six were adjacent to cayes and two were on banks. Results of these studies can be found in Robinson et al (2004) (*in draft*). The monitoring of these sites should continue and indicators will be used to gauge management effectiveness in sustaining the reef commercial fish populations of PHMR. Further, investigations into the effectiveness of the No-Take Zones (NTZ's) around the Snake Cays needs to be continued and will be aided with the establishment of a monitoring site outside of the reserve.

These NTZ's are to serve as harvest refuge for the biota within, with the expected purpose of sustaining populations within the zones, conserving biodiversity and providing fish 'spillover' into the adjacent areas. Spillover effects from these harvest refugia are becoming more frequently documented as a benefit of marine reserves. For example, in the Philippines, evidence of fish spillover from the Apo Island Reserve was found with increasing fish densities in close proximity to the reserve's boundaries Russ and Alcala (1996). Fishing directly outside reserve boundaries has become more commonly known as 'fishing-the-line' and has also been well documented in the Florida Keys National Marine Sanctuary (FKNMS) (Bohnsack, 1996). Thus, the success of the NTZ's is expectantly critical to sustaining fish stocks in PHMR and conserving biodiversity within.

Parameters to be measured for evaluation of Biophysical Indicators

Abundance of commercial fish- Abundance (the number of individuals at a site) is a key indicator in the success of PHMR. An increase or stability in the abundance of commercial fish species will infer management success. Both the RDT and Belt-transect technique will be used to assess this. Research of the RDT has noted its' 'ability' to 'picking up' rare and commercial, cryptic species such as some groupers.

Density of commercial fish- Density is the number of individuals/ a defined area. Abundance and density can be directly related, but density becomes very significant when determining the locality of specific species. Further, techniques that quantify in terms of area generally incorporate the measurement of the lengths of fish species, allowing for analysis into juveniles and adults of species Additionally, density is more statistically sound, due to the area quantification it requires and more comparable for evaluation of management effectiveness.

Family Density- Fish family density should be thought of in terms of community composition and structure. In terms of management effectiveness an increase in top-level commercial fish families such as Lutjanidae (snappers) and Serranidae (groupers) is ideal.

Size structure of commercial fish- Population structure is listed a key Biophysical Indicator and defined the distribution of adults, juveniles and recruitment. Size structure is a useful indicator and simple to analyze and compare. It addresses important management questions such as:

1. …Is the population structure one that would be considered normal of naturally occurring?
2. …How many juveniles (recruitment) and reproductive adults are there in the population?

Species diversity/richness- Species richness is often recognized as a component of the 'integrity' of an area (IUCN, 2003). The maintenance of the naturally occurring species composition of an area indicates the area is 'healthy' and stable. Fish species richness can indicate effective or ineffective management from increasing (or consistent) or decreasing measurements. Research on the RDT has noted its' 'ability' to accurately measure this parameter.

Seasonal fish recruitment- This indicator will specifically be measured by belt-transect swims, looking for certain species within a defined, juvenile size classes (see Reef Fish Protocols for details). Additionally, this data will be submitted to the MBRS for regional comparison.

Regional Comparisons- It is important to look at a reserve's resources and success regionally. Thus submission of certain data to the MBRS and REEF will define PHMR's resources in relation to other reserves and protected areas in the Caribbean. Certain, significant species may be noted or prevalent in PHMR in comparison, species diversity can be compared, and effectiveness can be gauged in relation to other reserves.

Monitoring sites in PHMR

Eight permanent reef (benthic and fish) monitoring sites were established in 2003. See Robinson et al (2004) (*in draft)* for a map of their location. Their locality was based upon the need to measure management effectiveness in the Conservation and Preservation areas, as well as, to assess the commercial fisheries.

Requirements and equipment needed

Schedule- Data collection should be performed annually between May and July, taking advantage of the dry season visibility. For comparison purposes the data should tried to be gathered the same time each year.

Equipment- The following equipment is required for each diver in addition to basic snorkeling gear and SCUBA gear (including depth gauge):

- Underwater data templates for fish and urchins
- Underwater cards or books to aid species identification
- Plastic underwater slates
- 2 x 30 m fiberglass surveying tapes OR 30 m nylon cord attached to a reel
- 2 x 3 lb weights
- Graduated T-bar

An underwater slate-Since the diver will need a new page for each transect, we suggest the following design for an underwater slate: 5 mm plastic slate, 21.6 cm x 28 cm (8.5 x 11") with two "picture frames" cut from ~3 mm (1/8") plastic, also 21.6 cm x 28 cm in outer dimensions with the frame ~12 mm (1/2") wide. In the simplest case, frames are held tight to each side of the slate using bulldog clips top and bottom (4 in all), and frames hold the datasheets in place. To facilitate working underwater, the slate can be attached to the T-bar (see below).

Note*- The slate would be set up with one side containing the juvenile recruitment form and the other the adult fish data entry form. In addition, a diver should have a large ziplock bag with a fishing weight sewed to it in which to keep completed datasheets. Once a datasheet is completed, remove from the slate and store in the plastic bag. The form can be folded and carried in a BC pocket, or left beside the* *tape reel. The diver will swim the remaining transects, picks up the reel (and data bag) and rewinds the tape ready for the next transect. These steps are continued for the eight transects. Divers are cautioned to avoid rubbing their fingers against the data sheet underneath the slate, especially towards the end of the dive, when the paper starts to get saturated.*

Two PVC or fiberglass tapes- At least two 30m fiberglass transect lines with a 3 lb weight attached at one end of each line. Commercially available PVC surveying tapes are suitable for the transect line, or a 30 m nylon cord attached to a home-made reel will work. A clip can be attached to the reel and suspended from the diver's belt, which allows for the tape to deploy freely as the diver swims.

A graduated T-bar or other measuring device-Construct a T-bar using 1/2" diameter PVC pipe and a T connector available at hardware stores. It has a 60 cm long handle and two equal length arms providing a total width across the top of 1 m. Use PVC electrical tape or paint to create a scale along both arms showing divisions at each 5 cm.

Methods for Data Collection

Preparation- At each monitoring site (see coordinates and number of transects below), 30m line transects will be surveyed. These transects have already been established with rebar, flagging tape and GPS points and should be easy to locate with the GPS. Before going to the site considerations and preparations are:

1. Data collection should be done once a year between May-July.

2. Knowledge of fish species and method training will be necessary. Thus multiple training sessions featuring identification and procedures should be planned before data gathering. Good training resources for reef benthos is, Reef Creatures and Reef Coral by Paul Humann.

3. Prior to surveying, the members of the survey team should calibrate both identification of species and size estimations by land exercises and snorkels.

4. A complete and thorough read through of the protocols should be performed before any data gathering by all team members.

5. Check the GPS to confirm the points are in or enter them as waypoints. Also, a copy of all data sheets should be kept in the TIDE office for reference.

6. SCUBA equipment is necessary.

Field Procedures- These procedures were adapted from the MBRS and AGRRA protocols. Appendices 8. 9, &10 are the field data sheets for these procedures. Using the GPS points on page 42, locations and transects will be located for surveying.

A. Roving Diver Technique (RDT) (Once a year) (Adapted from REEF and the MBRS)

The Roving Diver Technique (RDT) is a methodology managed by Reef Environmental Education Foundation (REEF) (http://www.reef.org/). The Rover Diver census is conducted in the same general area as the benthic and belt transects.

1. Using a clipboard and data sheet the divers are to swim slow, but deliberate around the reef site for 30 minutes and record **ALL** fish species observed. The idea is to search all fish habits; under overhangs, in caves, and so on. The objective is to find the maximum number of species that you can during your search time at the site. Do not extend your search even if you anticipate there may be additional species to see, and remain within the approximately 200m diameter within the site throughout your survey.

2. Approximate the density of each species by using logarithmic categories: Single (1 fish), Few (2-10 fishes), Many (11-100 fishes), or Abundant (>100 fishes). Record your observations on the standardized data entry sheet (see page 57). For each survey, each diver should fill out one form per dive per site and should be submitted to REEF. Data sheets are located at TIDE and more can be requested www.reef.org.

3. Two of these should be performed at each site. Additionally, to get a REEF ID, an online form will need to be filled out for all those who plan to perform the counts.

B. Belt transect counts for defined species list and recruitment

1. Fish transects should placed in the same area as the permanent benthic transects.

2. Using a weighted 30, transect tape, a diver will drop the weighted end of the 30m transect and swim in a straight line while the transect tape is released from the reel. As the diver swims along the transect and every species of fish in the designated families* should be counted and size estimated within a 2m belt (see Appendix 9 for the data sheet).

3. Estimate the size of fish and assign them to the following size categories (<5 cm, 5-10, 10-20, 20-30, 30-40, >40cm, ACTUAL) using the T-bar to assist in estimating sizes. Large groups of individuals of a species will be classified by attempting to put them into one or more size categories as necessary. By remembering to keep effort equivalent on all segments of the transect, you can limit the tendency to count all members of a school crossing the transect, instead of just those members which happen to be within the transect as counting of that segment takes place. A speed that covers the transect in about 6-8 minutes should be attempted

4. Once the first transect is complete, the diver will reel in the transect tape and move to the next transect, while avoiding other divers and repeat the steps again.

   Note: *The decision on the species to target depends on the time of year for the annual monitoring survey. A number of distinctive, moderately conspicuous species that can be reliably surveyed are available. The proposed set of suitable, summer-recruiting species and their size limits are listed in on the data sheet (Appendix 9).*

5. When you reach the end of the transect line (only if surveys are completed during the summer) position the tape reel on the substratum, wait 2 min, and begin the survey for recruits. This will be a 1m wide belt transect back down the tape, recording presence of newly settled fish of target species. It is important to count only individuals of each species that are smaller than the target size, to ensure that only recruitment from the current season is being counted.

6. **A copy of all data sheets should be kept in the TIDE office for reference**.

* A few modifications have been made to accommodate the monitoring needs of PHMR.

   1. Include **ANY** commercial fish in counts not listed (e.g. Permit, tarpon). See list below.
   2. For all commercial species that are greater than 40cm give exact measurements if possible. E.g. barracuda and tarpon are rarely <40cm.

   <u>Commercial Reef Fish of PHMR</u>

   All Snapper
   All Grouper including:
   Grasby, Coney, Red Hind, Rock Hind
   Permit
   Tarpon
   White and Blue Grunt

Hogfish
Crevalle, Horse-eye, Yellow, Bar Jacks
Spanish and Cero Mackerel
Snook

GPS Points

The fish surveys will be performed in the same locations as the Reef Benthic surveys. The GPS points for those transects are on page 42.

Data Management, Analysis and Interpreting Results

Baseline investigations into the benthic communities of the monitoring sites revealed each site had a distinct make-up, especially between the cayes and banks. Also, only one General Use Zone (GUZ) site (Bank 2) had a comparative site make up to those of the Conservation and Preservation areas; no take zones (NTZ's). Due to this, primarily site-to-site (within refuge) and zone-in-zone comparisons and evaluations are suggested, versus an overall comparison of the GUZ's to the NTZ's. Once an outside site/s is established further investigations can be made. Worksheets for the parameters below are in the Excel file, PHMR data management. Additionally, investigations can be made into commercial fish biomass, guild structure, correlations between species and habitat, etc if time and capacity allow. A biomass worksheet is included in the PHMR Data Management Excel file with length/weight relationships from Bohnsack and Harper (1998) if further analysis is sought. All parameters will be evaluated in relation to data collected in 2003.

Abundance of commercial fish- Focal species (commercial) fish abundance is a key indicator in the success of PHMR. In the PHMR Data Management Excel file there is a worksheet titled, 'Commercial fish abundance and density'. One of these should be completed for each monitoring site. Along with the individuals, the average abundance for 'snapper' and 'grouper' families will automatically be calculated in the summary table. Commercial fish being more abundant in the NTZ's can gauge effectiveness.

Density of commercial fish- In the PHMR Data Management Excel file there is a worksheet titled, 'Commercial fish abundance and density'. One of these should be completed for each monitoring site.

Family Density- Fish family density should be thought of in terms of community composition and structure. In the PHMR Data Management Excel file there is a worksheet titled, 'Belt Transect Fish'. One of these should be completed for each

monitoring site. Once the numbers are entered, the family density will be calculated.
Also key commercial families (snapper and grouper) should be reviewed and compared.

Size structure of commercial fish- In the PHMR Data Management Excel file there is a worksheet titled, 'Commercial Size Distribution'. Preliminary analysis can be made to see the general sizes and determine the distribution of juveniles and adults and abundance of each. Also in the 'Commercial fish abundance and density' worksheet, the average size of commercial fish can be calculated. First, the average size of each fish from each transect count must be calculated, then this average size should be entered for each transect. The site total will then be calculated in the summary table. Management effectiveness can be evaluated in terms of increasing or decreasing abundance in adult and/or juvenile sizes and the 'normal-ness' of the size distribution.

Species diversity/richness- Species diversity will be calculated from the REEF RDT counts. In the PHMR Data Management Excel file there is a worksheet titled, 'REEF and Diversity'. An example is shown of how to calculate diversity. Look at the abundance data and make another species column next to those columns. Put a '1' next to a species if it was found in either of the REEF counts at the site. Sum the column and that will be the species diversity for the site. Further investigations should then be made between sites, comparing diversity, commercial fish found, what species might be unique to the site, etc.

Seasonal fish recruitment- This data will be submitted to the MBRS for regional comparison. In the PHMR Data Management Excel file there is a worksheet titled, 'Fish Recruits'. Fill in the number of designated fish recruits found during each transect swim, the 'Total' column will give you total per site. One of these should be completed for each site. Additional investigations can be made into the density, if necessary.

Regional Comparisons- It is important to look at a reserve's resources and success regionally. Thus submission of certain data to the MBRS and REEF will define PHMR's resources in relation to other reserves and protected areas in the Caribbean. REEF data sheets are located at TIDE and more can be ordered for free by contacting REEF. www.reef.org. A sheet should be filled out for each count done, being careful note the exact site and GPS coordinates.

GIS- Data from the plankton tows and otter trawls in 1994 is already included in the database. Recently, files have been completed incorporating data from the 2003 surveys. Current data should be continually added for spatial and site investigations. A list of current data that has been incorporated and instructions for continuation are in the GIS (Section IX) section of this document.

Evaluation of PHMR's management goals

Based upon the goals to protect the physical and biological resources of Port Honduras and to preserve the value of the area for fisheries and other important genetic resources, the evaluation of fishery resources is foremost for evaluating management success.

Comparison of the values determined in the baseline studies of the aforementioned parameters can indicate if the fish populations are maintaining, successional, degrading or recovering/improving. Based upon the values for each parameter found in Robinson et al (2004) criteria and a scorecard were developed using guideline established in the manual (IUCN, 2003) (Appendix 15).

Outputs

- Analysis, graphs and reports should be compiled annually in the form of an annual report, along with the reef benthic and conch and lobster data. Also, following the document, A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve, (Robinson et al, 2004), comparisons can be made.

- Entry into the MBRS, AGRRA and REEF database. Data should be filled out and submitted to the MBRS and AGRRA for regional analysis. A MBRS database has been established for data entry and regional comparison to the other MBRS sites. The MBRS requests that individual persons before data entry, for data quality control, do training prior to receiving a password. For complete, current instructions go to www.mbrs.org.bz or contact them by phone.

- Parameters and indicators should be incorporated into the GIS database. These maps can be added to the annual report and will aid in spatial analysis and comparing the parameters and indicators from year to year. Also, trends between the monitoring sites can be evaluated. Instructions for how to enter data and example maps are located in Section IX, GIS Applications.

- Criteria and a scorecard for indicators (Appendix 15)

Examples

The document, A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve (Robinson et al, 2004 (*in draft*)), contains many examples of how to display data using these methods.

Useful References

- A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve. (Robinson et al, 2004 (*in draft*)). This can be used to establish annual comparisons amongst the reef monitoring sites.

- Characterization for Integrated Coastal Management of Port Honduras: Ecology, Oceanography, and Geography of Port Honduras, Belize- a proposed marine protected area. (Sullivan et al, 1995). This contains benthic classification of many areas in PHMR, including aerial photo interpretation around the Snake cayes.

- Mesoamerican Barrier Reef Systems Project (2003). Manual of Methods for the MBRS Synoptic Monitoring Program. P.C. Almada-Villela, P.F. Sale, G. Gold-Bouchot and B. Kjerfve. This manual and organization provides valuable assistance pertaining to methods and data management.

- REEF and AGRRA websites offer some scientific papers to aid in further investigations.

Recommendations

- **An outside reserve monitoring site should be established to compare to the General Use Zones and No-Take Zones in PHMR.** A possible location would be a bank East of South Snake, which would have similar characteristics to the reef monitoring sites within PHMR. A basic approach to measure reserve effectiveness is to compare flora and fauna outside the boundaries to those within, as suggested by the WCPA &World Conservation Union (IUCN) Management Effectiveness Guidelines. Effectiveness need not only be gauged by increasing species/biodiversity within a reserve, but moreover by comparison as to what is occurring outside the reserves boundaries.

B. Commercial Fish Creel Survey

Why creel surveys should be used to measured commercial species

Many commercially valuable fish in PHMR are located in the General Use Zone in estuary, turbid waters and do not lend themselves to visual census techniques for monitoring. Also, many of the species are highly migratory, thus different types of monitoring technique must be utilized. In gauging management effectiveness in PHMR, there is a critical need to monitor the type of fishing and gear, primary locations for fishing and the species, amount and size composition of the species being harvested in PHMR. In terms of indicators (WCPA &World Conservation Union (IUCN) Management Effectiveness Guidelines), there is a clear intersection between the biophysical and socioeconomic in terms of commercial fishing, effort and monetary gain by the fishermen.

Creel surveys (surveys based upon fishermen volunteering their data) have long been used to guide fishery management bodies for estimating fishery populations, to know the export and commercial values of fish, to set catch and size limits and for determining the characteristic habitats and localities of species in an area. Admittedly, they are not technologically advanced or sophisticated scientifically, but nonetheless offer valuable data and a sound monitoring option. The objectives of creel studies and monitoring in parks are to estimate catch per unit effort (cpue), relative abundance, age structure, total harvest, and boating and fishing activities.

Compiling creel data, combined with fish life history data, PHMR can determine effectiveness, decide if size/catch limits need to be set, if certain fishing techniques or areas should be banned, and overall determine if its' fishery resources are being used sustainably. The protocols and survey provided are preliminary in nature and logistics of implementation will be the greatest challenge in conducting a continual, creel monitoring survey. These surveys can be used directly to track trends in fishery yields, technological uses, and livelihood status and are not meant to be as in depth as those conducted for previous studies in PHMR. The main intention is to gather fishery data related to the indicators listed. Also, in gauging management effectiveness, it is recommended that surveys or data be gathered outside of the reserve to compare to PHMR.

Parameters to be measured for evaluation of Biophysical Indicators

Type, Level and Return of Fishing Effort – this is Biophysical Indicator 8 in the MPA guidelines. The level of fishing effort (hours/number of days/type of fishing) is often compared to the catch (species, size, and amount) of the fishermen to estimate the Catch Per Unit Effort (CPUE).

Catch Per Unit Effort (CPUE)- Catch per unit effort should remain stable is fish populations are sustaining. Increase in hours/days spent fishing and an increase in fishing technology needed to catch fish can indicate that fisheries may be declining. This will guide if catch limits need to be established. A simple example formula is: Catch Per Unit Effort (CPUE) = Fish Kept- Fish Released/ fisherman* hours fished.

Catch Abundance- Comparing catch data from previously mentioned PHMR resources to current data will be done to determine species-specific catch trends. If a species is being caught significantly less, then catch limits should likely be established.

Size composition- Comparing catch data from previously mentioned PHMR resources to current data will be done to determine species-specific size-trends. Individual species size inquiries and analysis should be made and then the data paired with life history information. This will be used to determine if species are being fished unsustainable, mainly in terms of reproductive maturity.

Methods for Data Collection

Protocols for creel surveys depend upon the implementation logistics necessary for a given area. These will be determined for PHMR and will likely include survey liaisons that will collect surveys in the buffering communities and local markets and submission to the rangers at Abalone Caye and TIDE. It is understood, for accurate and honest data, that these liaisons are prudently chosen. Additionally, a reward system for local, cooperating fisherman is a consideration. PHMR is based on community management and the management body will rely heavily on this factor for successful implementation of these surveys. It is recommended that surveys be collected monthly to aid data management and avoid lag or loss of data. Provided is an example survey adapted from one used in the Parque Nacional del Este in the Dominican Republic (*Fishery Investigations and Management Implications in Marine Protected Areas of the Caribbean*, 2001) (Appendix 11). Data management and analysis will be determined once implementation and survey design has been established. The *How is Your MPA Doing?,* manual should be consulted for support and guidance in this area, as well as, the below contacts.

Useful References

- TIDE has recently conducted a resource value assessment of PHMR and in early 2004 further commercial and sport fisherman surveys were conducted in relation to socioeconomic indicators (data is still in analysis stage).

- *The Voice of the Fishermen of Southern Belize* (Heyman and Graham, 2000) and, *An analysis of Commercial and Sport Fishing in the Proposed Port Honduras Marine Reserve* (Heyman, and Hyatt, 1996) offers additional baseline, comparative information on the commercial fisheries of PHMR.

- In Everglade National Park (ENP) fishing activity and harvest of sport fish from have been monitored nearly continuously since 1958. The data set is used for generating park annual fishing reports, fishery status and trends reports and publications, local and regional stock assessments. (Contact Tom Schmidt, tom_schmidt@nps.gov, for further information).

- NOAA has a comprehensive database estuary fish and their life history, collected and compiled through its' Estuary Living Marine Resources (ELMR) program (contact David Nelson at david.moe.nelson@noaa.gov for further information). Using this as a reference, TIDE's current data and other fishery sources from the Caribbean, determinations can be made if the size/amount of species being caught is sustainable, critical habitat areas that might need further protection, and contribute to the knowledge of species.

VII. Conch and Lobster

Biophysical Indicator 1: Focal Species Abundance- Focal species abundance is both how common a species is in relation to the population present (species abundance) and the number of individuals of a population of a particular species (WCPA, NOAA &World Conservation Union (IUCN) (2003). A key part of the PHMR management plan is to stabilize and increase fish populations to sustain the local fishing economy (Goal 3, PHMR Management Plan).

Biophysical Indicator 2: Focal Species Population Structure- Population structure is defined by the manual as, ‘ the frequency with which specific sizes of individuals are likely to be encountered within a population’ (WCPA, NOAA &World Conservation Union (IUCN) (2003). Demonstration of a stable size class structure is an important sought out benefit of MPA’s.

Why conch and lobster should be monitored

Lobster and conch are two of PHMR’s most valuable resources. Queen conch grow relatively slowly, and do not reach sexual maturity until 3.5 years of age, when their shells reach 180-270 mm in length and develop the characteristic flared lip (Appeldorn, 1988). In terms of recruitment, conch are generally thought to have localized recruitment and self-sustaining populations, which is important for target conservation areas. In a recent resource value assessment of PHMR, queen conch brought in an estimated BZ$51,420.00 in revenue to the local fishermen and baseline studies found West Snake Caye to have the greatest abundance (Robinson et al (2004) (*in draft*)).

The resource value assessment of PHMR also found that spiny (*Panulirus argus)* and spotted lobster (*Panulirus guttatus*) were the most profitable fishery in the reserve. Lobster catch accounted for 57% of the total value of fish caught within PHMR with an estimated value of BZ$506,638.80. Thus the livelihood of many fisherman, depend upon the sustainability of this crustacean. In Belize (and PHMR), divers generally use hook-sticks to catch lobster within the extensive inshore reef habitats or others use wooden traps and "casitas". The traps used are rectangular "palmetto" traps normally un-baited (or with coconut) with a funnel entrance on one side.

Studies have been conducted on lobster at certain areas such as Glovers Reef Marine Reserve where densities of different size classes of spiny lobster was determined to be linked to the area size distribution of primary benthos habitats (Acosta and Butler, 1997), thus the monitoring of benthic habitats in combination with lobster populations is important. Lobster larvae are widely dispersing, spending much time in the open ocean, thus making it more difficult to set priority conservation areas. Sexual maturity of the spiny lobster is ~ 76 mm CL (Florida Fish and Wildlife Conservation Commission, FMRI 2003).

In 2003, preliminary lobster and conch surveys were conducted in PHMR. They were preliminary in the sense that there are numerous places and habitats fished in PHMR for lobster and conch and these investigations need to be further expanded.

Parameters to be measured for evaluation of Biophysical Indicators

Abundance of conch and lobster- Focal species (commercial) fish abundance is a key indicator in the success of PHMR. An increase or stability in the abundance of conch and lobster will infer success of this indicator. Also, these commercial fish being more abundant in the NTZ's can gauge effectiveness.

Density of conch- Density is the number of a species per defined area unit. Due to the cryptic nature of lobster and the method used to monitor them, density is measured from a general site perspective.

Lobster Timed Effort- The methodology to assess and monitor lobster relies on a timed swim, thus time being the parameter of comparison for analysis. If more lobster and counted in the same time frame as previous surveys, then possibly populations are sustaining or increasing. Due to the migratory nature of lobster, these counts and evaluations should be gauged in terms of 3-4 years.

Size structure of lobster and conch- Physical, visual counts combined with the creel surveys, lobster and conch catches will be quantified. Similar to finfish, population numbers and average catch sized can be determined. This data can then be used in conjunction with life history data to determine if size and/or catch limits need to be established.

Monitoring sites in PHMR

Using the knowledge of local fishermen and PHMR Rangers, four areas of high productivity for spiny lobster and queen conch were selected as monitoring sites during these surveys. These areas were mainly in the NTZ's and future establishment of monitoring sites in the GUZ and outside the reserve's boundaries are necessary to gauge management effectiveness and determine if the populations are being fished sustainably.

Requirements and equipment needed

Schedule- Annual counts should take place, prior to the opening of each season.

Equipment-

- Clipboard/underwater slate/pencils
- Underwater paper and data sheets
- Measuring rod with cm increments
- Calipers (can be purchased in Belize City)
- Watch
- Transect tape (30M)
- 1M pvc pipe
- Carapace measuring device
- GPS and points
- SCUBA gear

Methods for Data Collection

Preparations- Before entering the field a few things should be considered:

1. Both milk and queen conch will be counted and measured, so prior to data gathering, a brief identification training should take place.

2. Smaller conch tend to bury during the day and a practice run should be done with divers, to 'train the eye' in finding them and lobsters are cryptic species and practice searching suitable habitat should be done with divers, to 'train the eye' in finding juvenile and adult.

3. Scuba is required

A. Conch

1. Four transects will be run per site (unless the habitat is extensive and allows for more), using a 30M, weighted transect tape and a 1M pvc pipe.

2. In the areas of most copious seagrass cover, divers will be dropped and the GPS location recorded by the boat captain. Once down, the divers will space themselves apart and take a directional, so they are running approximately parallel in view of one another, but more than 2M apart. They will run the transect tape and then slowly swim back down the transect, counting and measuring (cm) all the milk and queen conch within 2M of the tape (see data sheet, Appendix 12). This will be done on both sides of the tape.

3. For **queen conch**, lip thickness will be measured with a caliper. If calipers are unavailable, the length measurement of the conch can be taken with a ruler or by carefully marking cm increments along the edge of the clipboard.

B. Spiny and Spotted Lobster

1. A timed dive/snorkel 1hour total (e.g. 1 hour with 1 diver or ½ with 2 divers) should be minimally conducted at each site. If the site is large or dispersed enough, additional counts should be done.

2. In the areas of suitable lobster habitat, divers will be dropped and the GPS location recorded by the boat captain. Counts should be performed in these locations annually. Once down, the divers will space themselves apart and swim parallel to the reef, in view of one another, but taking care not to survey the same area more than once in a single dive/snorkel.

3. During the dive, all crevices should be carefully searched for all lobsters including juveniles that may hide amongst algae. Once lobsters are found, they are to be identified to species level and the carapace length estimated by used a small rod marked with 1cm increments. The rod should be carefully used as you would a "hook stick" in order to determine length. Any egg mass seen should also be noted.

4. A copy of all data sheets should be kept in the TIDE office for reference.

GPS Points

These are approximate locations where surveys should begin for already established sites.

Lobster	UTM E	UTM N
South Snake	332761	1789578
East Snake	338938	1792815
West Snake	332229	1790744
Middle Snake	334229	1791877
Conch		
South Snake	332719	1789126
East Snake	338938	1792815
West Snake	332044	1790304
Middle Snake	334229	1791877

Data Management, Analysis and Interpreting Results

Abundance of conch and lobster- Focal species (commercial) fish abundance is a key indicator in the success of PHMR. In the PHMR Data Management Excel file there are worksheets titled, 'Lobster' and 'Conch'. These should be completed for each monitoring site. The totals and average size will be automatically calculated. Analysis and comparisons should be made to 2003 data.

Density of conch- In the PHMR Data Management Excel file there are worksheets titled, 'Lobster' and 'Conch'. These should be completed for each monitoring site. By taking the abundance and dividing by the area surveyed, then multiplying by 100, you can get the density/100m2 per site of conch. For conch a more in depth analysis might look into which specific locations have the greatest density of conch and the average size in certain areas. This is especially important for areas of conservation target and reproduction. Also, greater density of conch in the NTZ's can gauge effectiveness. Baseline data from 2003, will provide a basis for comparison and management evaluation.

Lobster Timed Effort- The methodology to assess and monitor lobster relies on a timed swim, thus time being the parameter of comparison for analysis. If more lobster and counted in the same time frame as previous surveys, then possibly populations are sustaining. Due to the migratory nature of lobster, these counts and evaluations should be gauged in terms of 3-4 years. In the PHMR Data Management Excel file there are worksheets titled, 'Lobster' to calculate this data.

GIS- Density and abundances for each species and site should be entered into the database, annually.

Evaluation of PHMR's management goals

Based upon the goals to protect the physical and biological resources of Port Honduras and to preserve the value of the area for fisheries and other important genetic resources, the evaluation of fishery resources is foremost for evaluating management success.

Comparison of the values determined in the baseline studies of the aforementioned parameters can indicate if the fish populations are maintaining, successional, degrading or recovering/improving. Based upon the values for each parameter found in Robinson et al (2004) criteria and a scorecard were developed using guidelines established in the manual, *How is Your MPA doing?,* (IUCN, 2003) (Appendix 15). Though the Appendix 15 focuses on reef fish, the parameters for conch and lobster are similar and criteria and scorecards can be prepared in the same manner.

Outputs

- Analysis, graphs and reports should be compiled annually in the form of an annual report, along with the reef fish and benthic data. Also, following the document and the data from, A Biological Baseline Study and Resource Value

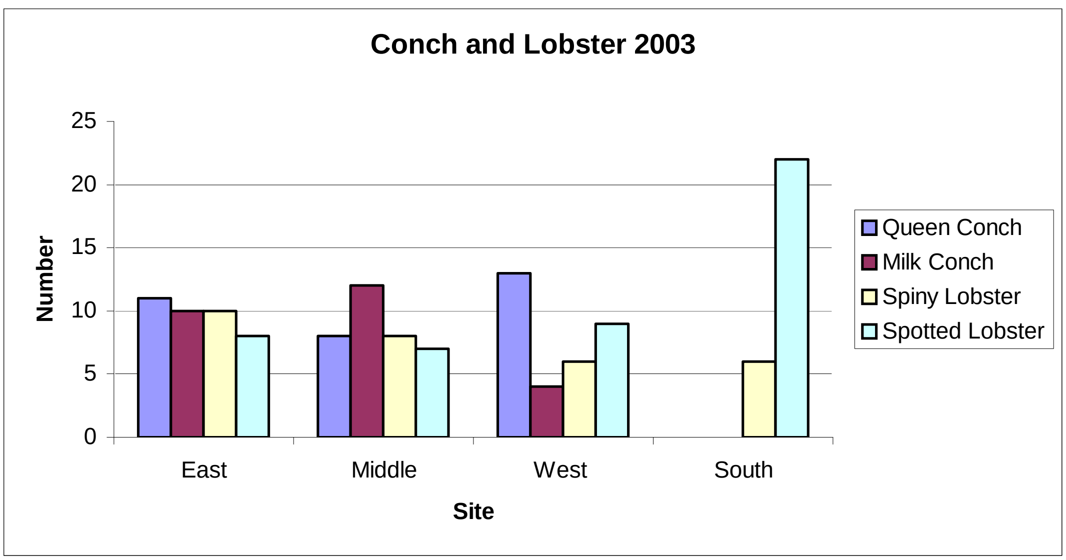
Assessment for Port Honduras Marine Reserve, (Robinson et al, 2004), comparisons can be made.

- Parameters and indicators should be incorporated into the GIS database. These maps can be added to the annual report and will aid in spatial analysis and comparing the parameters and indicators from year to year. Also, trends between the monitoring sites can be evaluated. Instructions for how to enter data and example maps are located in Section IX, GIS Applications.

- Criteria and a scorecard for indicators (Appendix 15)

Examples

Graphs- Graphs are useful for looking at trends, such as differences between the rainy and dry season. Below is an example of the abundance of conch and lobster found in 2003.



Useful References

- A Biological Baseline Study and Resource Value Assessment for Port Honduras Marine Reserve. Robinson et al (2003) (*in draft*)). These data can aid in determining the water quality scorecard.

- Also, as data collection expands, the study, Effects of natural barriers on the spillover of a marine mollusk: implications for fisheries reserves, by Tewfik and Bene (2003) should be consulted for analysis aid. This study used density gradient maps for juvenile and adult conch populations that were constructed using underwater visual survey data from within a reserve and from the surrounding the protected area. The study can be found in pdf in the PHMR biology folder.

- Dr. Charles Acosta, Glover's Reef

Recommendations

- **Establish more monitoring sites for conch and lobster.** Another future site suggested in the GUZ is Abalone Caye and outside the reserve's boundaries there are many banks that can be established.

VIII. Manatees, Dolphin and Sea turtle Monitoring

Biophysical Indicator 1: Focal Species Abundance- Focal species both how common a species is in relation to the population present (species abundance) and the number of individuals of a population of a particular species (IUCN, 2003). A goal of the PHMR management plan is to preserve the rare, endangered species within the reserve

Why manatees, dolphins and sea turtles should be monitored

PHMR is home to many endangered and threatened species. Examples in PHMR include the West Indian Manatee (*Trichechus manatus*) which is listed by IUCN as an endangered species; bottled nosed dolphins (*Tursiops truncates)* which are threatened in many areas, and three marine sea turtles: Loggerhead turtle (*Carretta carretta*), Green turtle (*Chelonia mydas*) and Hawksbill turtle (*Eretmochyles imbricata*), which are all generally threatened worldwide. The beaches south of Punta Negra Village and several cayes are nesting grounds for the Hawksbill turtle, while the numerous lagoons in PHMR provide sanctuary for manatees. The surveys are done by a low altitude flight provided by Lighthawk. In 2003, 16 manatees were spotted.

Parameters to be measured for evaluation of Biophysical Indicator

Manatee abundance- A major goal of PHMR is to stop the illegal poaching of manatees. Thus, management success can be evaluated as an increase in the abundance of these species.

Dolphin abundance- Wild dolphin populations in PHMR are spotted regularly and detailing their typical locations and abundance will provide valuable information, especially from a conservation perspective. Thus, management success can be evaluated as an increase in the abundance of these species.

Sea turtle abundance and nests- Sea turtles are seen regularly and their nesting sites and timing areas are known approximately. Further investigations of the 'Punta Ycacos and Punta Negra coastline area' and noted cayes will lead to a more comprehensive understanding of their status, populations and nesting sites. Thus, abundance and nesting sites will be key indicators for priority monitoring sites.

Requirements and equipment needed

Equipment-

- GPS
- Data Sheet
- Flashlight

Methods for Data Collection

A. Aerial Surveys and Ranger Patrols

The data for manatee and dolphin populations will be qualitative in nature, but combined with GIS, spatial and population knowledge will be gained. The monitoring will involve a combination of aerial surveys and ranger patrol coordination. As established, manatee and dolphin populations will continue to be monitored during Lighthawk flights. During the flights a GPS and data sheet is should be brought. All manatee and dolphins spotted should be marked with a GPS point. Also, these surveys should be conducted as early in the day as possible or early evening to take advantage of 'prime' spotting time.

In addition to the Lighthawk flights, manatee and dolphin data gathering will be incorporated into the PHMR ranger patrols. The rangers will be trained, and equipped with GPS and data sheets, which will be carried out on all patrols. If a manatee or dolphin is spotted, the GPS point should be marked, then transferred onto a data sheet. Also, any additional information such as the sex, size, etc should be recorded if possible.

These sheets should be handed in monthly to TIDE.

B. Beach Sea Turtle Patrols

These surveys will be preliminary in nature and hopefully lead to a more comprehensive nesting monitoring program. However, baseline data must confirm sites, peak months, and nesting species to elucidate feasibility of such a project. Similar to manatee and dolphin surveys, nesting surveys will be incorporated into the PHMR ranger patrols. Additionally, the community members of Punta Negra should aid these surveys. With proper training and equipment, regular, nightly surveys can be conducted by a few of the community members. For the rangers, nesting occurs primarily at night and thus these surveys should be incorporated into night or early morning patrols.

Using a flashlight, data sheet and GPS, the rangers and/or community members will patrol 'known sea turtle nesting areas' as often as possible between the months of July through September. When patrolling for sea turtle nests, some steps should be taken to aid in locating nests, as they are not always in the open beach.

1. Look for crawl tracks in the sand
2. Look for emergence from the water
3. Listen for rustling in the bush

4. ‘Smell’ for fresh dirt or look for fresh holes

Since these investigations are baseline, it is important not to disturb the nests, just document their location with the GPS along with any other information that is readily available, such as the species of the turtle. Appendix 14 is a sea turtle ID guide from www.reef.org. Sheets should be handed in monthly to TIDE.

GPS Points

Preliminary site surveys were done with the aid of local rangers to establish some probable nesting areas. No nests were found, but these areas were recommended for future nesting monitoring. GPS points in WGS 84.

Turtle Investigation Sites	UTM E	UTM N
S. of Punta Negra	332356	1799390
S. of Punta Negra	332271	1799247

Data Management, Analysis and Interpreting Results

Manatee abundance- The abundance of manatee and any additionally data should be kept in an Excel spreadsheet. Annually, population abundance should be compared and evaluated.

Dolphin abundance- The abundance of dolphins and any additional data should be kept in an Excel spreadsheet. Annually, population abundance should be compared and evaluated.

Sea turtle abundance and nests- Once these baseline investigations are made, monthly investigations should be made to note any peak nesting periods. Site specific investigations should be made to determine which sites hosts the most nests and the specific species nesting in which areas.

GIS- GIS will play an important role in managing and analyzing the manatee, dolphin and sea turtle data. Once data sheets are handed in from the aerial and field surveys, they should be incorporated into the GIS database. (Instructions for how to do this are in the GIS section of this document.) Species abundance and preferred habitat can be tracked monthly and annually.

Outputs

- Monthly report from the rangers about nesting sites and dolphin and manatee sightings.

- GIS map of mammal sightings from Lighthawk flights. Also, an annual map with all sightings plotted to look for trends related to habitat.

- A report about the nesting findings and map of locality of nests found.

Examples

GIS- See Robinson et al (2004) (*in draft*) for a GIS map of manatee sightings.

IX. Geographic Information Systems: Introduction and how to apply GIS to monitoring and evaluation of Port Honduras Marine Reserve

Why GIS should be incorporated into the monitoring of PMHR

Geographic Information Systems also known as G.I.S. is a way to visually display data for comparison and assessment. The Marine Reserve project created in ArcView has been incorporated data from 2003 into a database prepared after the

1994 Site Characterization of Port Honduras (Sealey et al, 1995)[1]. For further information about the database and all of its' original contents, see the document titled, Site Characterization For Integrated Coastal Management: Ecology, Oceanography, and Geography of Port Honduras Belize- a proposed marine protected area (Sullivan et al, 1995). In terms of data management, analysis and evaluation; GIS provides spatial analysis, coupled with quantitative data to provide a more complete 'picture'. Building upon this database, current data has been incorporated to aid spatial analysis and incorporate indicator data to enhance biological understanding and gauge management effectiveness in Port Honduras Marine Reserve. Provided are detailed instructions for the future incorporation of data to aid management. Additionally, maps of 2003 data have been included.

GIS Terms and Applications

Project: Includes Views, Tables, Charts, Layouts and Scripts. A Project can have multiple Views, Tables, Charts etc. For example in the marine reserve project it has 12 Views, each of these Views were created to show specific data. Although any and all of the information displayed can be put into one View.

Views are tabular data displayed on a map.
Tables are numerical data in a dbf file that can be input into Arc View.
Charts are the tabular data displayed in a chart form.

1. Opening a Project in GIS

Open Arc View GIS 3.2
It will prompt you to either create a new project or opening an existing project.
Click on open an existing project
It will then prompt you to identify which project to open.
We will open marine reserve, which is in file folder marine reserve arc view.
Once you have double clicked on the project it will open in Arc View automatically.
If this does not occur, click on the Views Icon in the Project Menu, and then click open, this should bring up all the views available for that project.
To open each View in the project double click on the View.

2. Opening a Table

Tables are originally formatted in Excel and contain information such as the coordinates, titles, quantitative data, etc. How to create them is explained on page 78.

To open a table in a View, click on the Table Icon in the Project Menu

[1] The GIS project and instructions were prepared by Laura Kukich (2004), Nova Southeastern University

Click 'add'
Find the table that you wish to add
Double click on the table name.
It will then be added to your table menu
If your table is not available make sure you have saved it as a dbf file.

3. Opening/Creating a Chart

Click on the Charts Icon in the Project Menu
Click in New
Your chart will automatically be displayed.

4. Using Tools in the Toolbar

For each Project Icon, different tools are available to you.
When a View is active, more tools are available to you than when a table is active.

The 'i' with the dark circle around it is the first tool icon on your toolbar – this is the identify tool. To use this tool, make sure the data you wish to know about is highlighted. For example, if you wish to identify points on a map, make sure that the points shape file in the view is active (indented)

The arrow, is the pointer

The outlined arrow is the vertex edit tool.

The square with the star in the corner is the select feature tool

The magnifying glass with the plus sign is the zoom in, the magnifying glass with the minus sign is the zoom out tool.

The hand is the pan tool. You can move the map in the View using this tool.

The ruler with the arrows on top is the measuring tool, you can use this to measure any distance on the map.

The lightning Bolt is the Hot Link Tool

The next tool is the area of interest tool

The label is the label tool

The T is the text tool

The dot is the drawing tool

If you every need to know what a tool does, click on the pointer with the question mark icon on the right hand side of the toolbar. And then click on any tool, it will tell you what that tool is and what it does.

5. Creating a Viewable Table for Arc View in Excel

In Arc View there are several ways of entering data, the main way to enter quantitative data is to do so by first creating an excel document. This example uses Water Quality Data that was collected in 2003.

Sites	Temp (C)	Turbidity (NTU)	DO (mg/l)	Salinity (‰)	pH	Nitrates (mg/l)	Phosphates (mg/l)
N. Monkey River	30.7	0.6	5.10	34.9	8.39	0.20	0.20
Monkey River	32.1	29.1	5.73	29.0	8.42	0.43	0.86
Pt. Ycacos	30.8	23.9	5.42	35.4	8.40	0.30	0.53
S. Pt. Negra	30.3	21.8	5.22	35.7	8.41	0.23	0.60
N. Mid. Snake	30.3	21.3	5.04	35.5	8.44	0.73	0.82
East Snake	30.2	14.1	5.36	35.4	8.44	0.43	0.64
Deep River	31.0	14.7	5.24	30.5	8.43	0.33	0.37
Man 'o war Caye	30.0	25.4	5.04	35.1	8.41	0.50	2.81
Wilson Caye	29.9	24.5	5.01	35.0	8.42	0.30	0.72
S. of W. Snake	29.9	22.1	5.07	35.0	8.43	0.38	1.07
Middle River	31.7	17.2	5.20	27.8	8.39	0.55	0.39
Hen & Chicken	31.2	14.6	5.28	31.6	8.43	0.25	0.61
Moho-Stuart Caye	30.0	16.7	5.07	32.4	8.41	0.28	0.36
E. Rio Grande	29.9	12.2	5.01	31.4	8.41	0.53	2.91

This data will be reformatted into Excel so that is can be viewed in Arc View. To do this we need to first format the cells of Excel, otherwise data that we enter will not be shown in Arc View.

- In excel enter all of the information needed such as Location, Q-value (WGS 84 datum) etc. Not the numerical data. ***Next, format all of the cells that are to contain numerical data by changing the number category from general to number so that it shows all numbers entered and the desired decimal points.***
- Set up the Data as shown below, this depicts all of the above information as well as the location via GPS of each data point.

Location	Q-Value	North	UTM	West	Temp	Turbidity	DO	Salinity	pH	Nitrates	Phosphates
Pt Ycacos	16Q	331255	UTM	1796465	30.8	23.9	5.42	35.4	8.4	0.3	0.53
S of Pt Negra	16Q	333825	UTM	1795445	30.3	21.8	5.22	35.7	8.4	0.23	0.6
N of Mid Snake	16Q	336429	UTM	1793635	30.3	21.3	5.04	35.5	8.4	0.73	0.82

When saving your work you will save it as a .dbf 4 file. When the Save As window appears, title your work in the File Name window as you wish to find it and, scroll through the Save as type window until you see DBF 4 (dbase IV) and then click on the save button. It is advised to cut and paste and save one spreadsheet as an Excel and another in the dbf format*.

You cannot transfer dbf information to another dbf spreadsheet. If you wish to compile 2 dbf data sheets you will need to use a new spreadsheet and save it as a new document.

Saving it as a dbf file will allow you use and view this information in Arc View.

6. Adding dbf files to Arc View

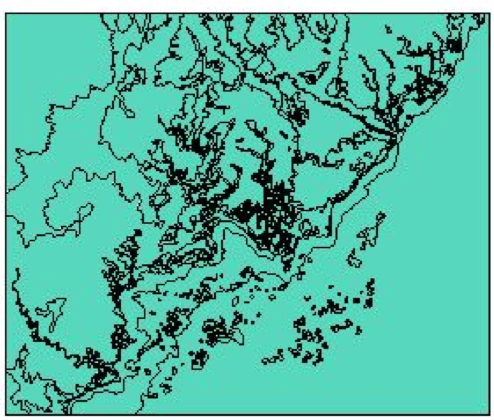
After you have saved your information as a dbf file you can then open ArcView. It will prompt you if you would like to:

a. Create a new project with
b. A new View
c. As a blank project
d. Open an existing project

This time we will Create a new project with a new View. A new prompt appears asking if you would like to add to the view now. Click Yes

It will bring up your directory. For this project find where you have saved the original database data, which should be under a PHMR folder, a sub folder appears noting Port Honduras GIS. After double clicking on that subfolder, many shape files or views will appear in the data source type window on the left.

For this project we will need to use the view named landtype.shp. After selecting the landtype shape file it will appear in View 1. In order to see the file you will have to click on the check box in the left hand corner. This is the map that we will be adding our water quality data to.



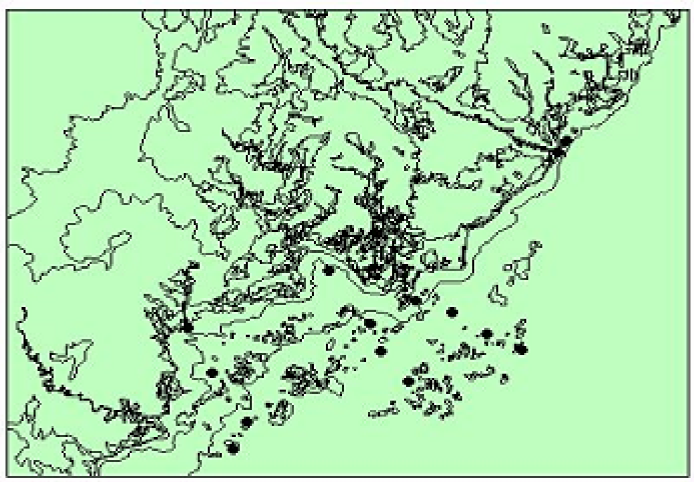
Currently the View is open in the Project Menu to the left. In order to add our data we will have to select Tables, which is located below View in the Menu order. When the Table Menu is opened we can see that there are no other tables available. We will have to add our table to this project. Click on Add in the Project Menu.

This will then ask you which table you wish to add. Select the table and it will automatically show up in the project as a table, it has not yet been entered into the Map.

In order to plot this data onto the map of Port Honduras we will have to make it a theme.

7. Making a Table A Theme

Currently in your project the table of water quality data is open. Make the View active. After making the View active, go to View on the Toolbar, find and select Add Event Theme. It will prompt you to choose a table, X component and Y component. You will choose Water Quality Data 2003.dbf. Your X component will be North and your Y component with be West. Click OK



Your table is now available in the View. In order to make these data points appear click on the empty check box. To view information about each data point, click on the i encompassed by a black circle on the toolbar. Make sure that Water Quality data 2003 is the active theme, i.e. it is the View, which is “indented”. If not, you can make it the active theme by clicking in the general area of the box.

Click on one of the data points for Water Quality Data 2003. An identify results box will pop up denoting all the information about that particular point.

8. Making the Theme a Shapefile

After you have made your table a theme you will want to convert it into a shapefile so that you will not have to complete the above every time you want to view this data.

In order to convert the theme into a shapefile, make the View active and choose Theme from your Toolbar. Scroll down the Theme menu and choose Convert to Shapefile. It will prompt you to choose where you will save the shapefile. Otherwise it will save it under your temp file. This will be named Water Quality data.shp

Arc View will them prompt you to either add the shapefile as a theme to the View. Choose Yes.

Now Click on Water Quality data.shp in your View. These points now cover your existing Water Quality data. So we will delete the dbf file from the View.

Deleting a dbf from a View:
Make the dbf file that exists in the View active (indented). Then from the Edit option on the toolbar select delete themes. It will them prompt you asking if you want delete the file. Select Yes or Yes to All. The dbf file is now removed from the View.

The dbf file will still be a usable file in your Project; you will use this for tabular information in the database.

9. Querying Information

So now that you have Water Quality data available to you in Arc View, we need to know what each point means. A typical question may be, what was the pH value for the Deep River Mouth in 2003? In order to answer that we need to use the table Water Quality Data 2003, which we already have available to us since we just added our dbf file.

To open the table, click on the Tables Icon in the Project View. It should have a list of tables available to you and show Water Quality Data 2003. If it is not open, click on the open button after you have highlighted the file. This shows a considerable amount of data, so to easily identify what we want to know we will query the information.

Make sure the Table is active, then click on the button on the Tool bar that looks like a hammer and has a question mark in it. The Query box shows the names of your data fields, mathematic tools in the center and a blank column on the right of values.

In order to obtain the information we need we will need to query information about the River first. Begin by double clicking Location in the left column. Then double click on the equals sign in the middle and finish by double clicking on Deep R Mouth in the right hand column. As your double click on information, the box at the bottom creates your equation.

You have three options when performing a query:

New Set - Makes a new selected set containing the features or records selected in your query. Features or records not in this set are deselected.

Add To Set - Adds the features or records selected in your query to the existing selected set. If there is no existing selected set, the features or records specified in the query become a new set. Use this option to widen your selection.

Select From Set - Selects the features or records in your query from the existing selected set. Only those features or records in this existing set that are selected in your query will remain in the selected set. Use this option to narrow down your selection.

Since this is our first query we will choose New Set

The query builder has selected Deep River from the data set by highlighting the data. To bring this data to the top of our data sheet select the promote button, which looks like a bunch of arrows pointing upwards on your Toolbar. This brings your data to the top.

We can then scroll to the field that shows pH and read that Deep River Mouth has a pH of 8.43

10. Adding Existing Shape files to your Project

After viewing your Water Quality data you decide that you also want to view mangrove data that was completed previously.

You can leave everything as is, just make sure that the view is active. Click on the button that is second from the left on the toolbar and has a plus sign on it, this is the add themes button. A screen will pop up and prompt you to identify which file you would like to add. Go to the original database and select mangrove.shp. The shape file will then appear at the top of your view. Make the theme active by clicking on the checkbox. The mangroves are now seen in your project view.

11. Shape file Order in your Project

The order in which your shape files or themes are displayed is the same order that Arc View layers the data. To show you this, move the water quality data from the middle of the legend to the bottom, the water quality data is no longer visible because it is now the bottom layer of data, with the land and mangrove data on top of it.

To make everything visible in this project, have the Water Quality data at the top of the legend followed by the mangroves and the land shape files.

12. Accessing Tables for shape files

Now that you have opened the shape file for the mangroves you want to access the information. To do this you must open the corresponding table in Arc View. In the Project Toolbar, click on Tables. The only available table is the Water Quality Table we created. We need to add the Mangrove table. Click Add. In original database, click on mangrove.dbf. We now have access to the mangrove data and will be able to query this information if we need to in the future.

PHMR Maps

Some example maps have been provided for data gathered in 2003 (TIDE Baseline Studies, 2003 (*in draft*)). These maps correlate directly with Biophysical Indicators discussed throughout the manual. It should be recognized that socioeconomic data can also be incorporated, along with Fresh Water Initiative data to aid comprehensive analysis. These are located in Appendix 14.

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Appendix 1. Common Seagrasses. *Drawings by Mark D. Moffler.*

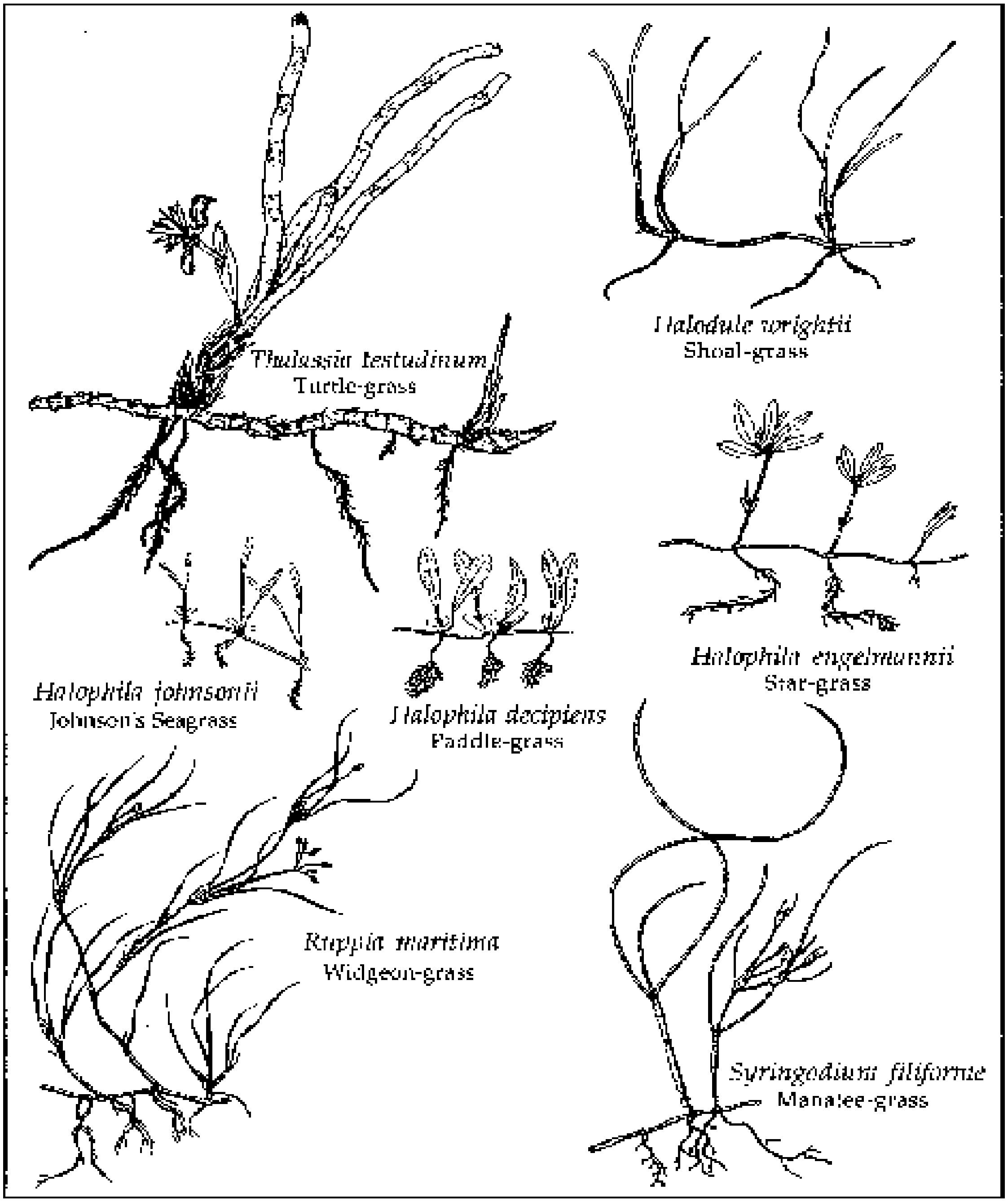
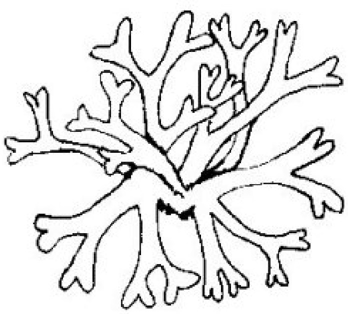
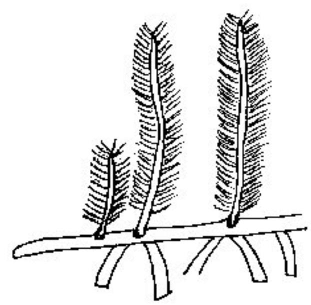
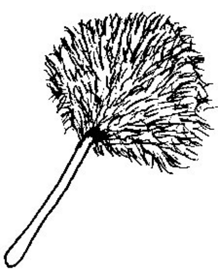
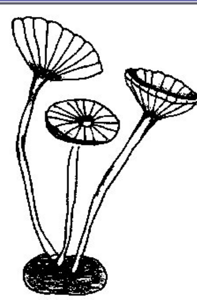
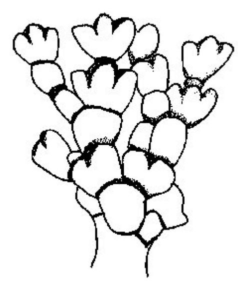


Figure 1. Seagrass species occurring in the shallow coastal waters of Florida (based on drawings by Mark D. Moffler).

Appendix 2. Seagrass Community Pictures

Manicina areolata	*Oculina diffusa*
	

Common algae

		
Dictyota	Sargassum	Caulerpa
		
Penicillus	Acetabularia	Halimeda

(Algae pictures from AGRRA website.)

Appendix 3. PHMR Seagrass Field Data Sheet

Date Surveyor Time Location Water Depth start/end

Community Percentages	Quad1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6	Quad 7	Quad 8	Quad 9	Quad 10	Quad 11	Quad 12
Macroalgae												
Turf Algae												
Thalassia testudinum seagrass												
Syringodium filiforme seagrass												
Other seagrass												
Soft coral												
Hard coral												
Sand												
Mud												
Other												
Hard Corals Present (Specify Genera)												
Notes (eg. epiphytic growth on blades)												

Appendix 4. Mangrove Field/LightHawk Observation Data Sheet (Adapted from MBRS, 2003)

Site:

Lat. North :
Long. West:

Date:

Mangrove threats:	**NOTES (Please mark or note any threats and location)**	**GPS points (aerial examination)**
• There may be large or small areas where trees have been removed		
• Trees may have branches cut off		
• Branches and trunks may have bark with cracks or crevices		
• The uppermost branches in the sun may be dying at their tips		
• Leaves may be fewer, smaller, show twisting and curling, and have dead parts or spotting; the distance between leaf parts on shoots may be very much shorter than in a healthy tree		
• There may be no flowers		
• Fruits may fall off before they have matured		
• The seeds may be deformed – have abnormal growth		
• Established seedlings may begin to grow abnormally		
• Seedlings may die		
• The small upright aerial roots (pneumatophores) coming up from the mud may be branched, Twisted or curled, and aerial roots may develop on the tree's trunk		
• Young trees may grow at an angle		
• Other		

Appendix 5. Mangrove Forest Data Sheet (MBRS, 2003).

MBRS MANGROVE FOREST STRUCTURE DATA ENTRY FORM

Plot ID:______

MSMP_4B

Location:		Recorder:			Time:		Latitude:		
Site ID:		Plot ID:			Date:		Longitude:		
Position		Tree No.	Species	Circumference dbh (cm)	Diameter dbh (cm)	Basal Area (sq. cm)	Height		
X	Y						Prop roots	Trunk length	Tree height

Appendix 6. Field Coral Health Data Sheet

Loc:	Recorder:	Water depth (start):	Time:	Latitude:	Longitude:	Notes:	
Site ID	Date	Water (end):		%Dead		Condition	
Trans #	Coral Species	Max diameter	Max Height	%old	% recent	Disease: BB, WB, WP-II, YB, DS-I, DS-II, RB, ASP	Bleached P, PB, BL

Appendix 7. Field Linear Point Intercept Benthic Data Sheet

Date Surveyor Time Start/End Location Water Depth start/end

Benthic Categories	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 5**	**Comments**
Bare rock						
Sand						
Coralline Algae						
Turf Algae						
Macro Algae						
Sponges						
Gorgonians						
Coral (Specify Genera)						
Other (seagrass,etc)						

Diadema tally : 1 2 3 4 5

Coral Diversity: 1 2 3 4 5
(species and tally)

Appendices 8, 9, & 10. Fish recruitment, Belt transect and Roving Diver Field data sheets (from MBRS, 2003).

Location: Site ID: Date:
Time: Name: Lat: Long:

	Transect 1			Transect 2		
	Max Length(cm)	Tally	Total	Max Length(cm)	Tally	Total
Acanthurus bahianus Ocean surgeon	5			5		
A. coeruleus Blue Tang	5			5		
Chaetodon striatus Banded butterfly	2			2		
C. capistratus Four-eye butterfly	2			2		
Gramma loreto Fairy basslet	3			3		
Bodianus rufus Spanish hogfish	3.5			3.5		
Halichoeres bivittatus Slippery dick	3			3		
Halic. Garnoti Yellowhead wras.	3			3		
Halic. maculipina Clown wrasse	3			3		
Halic. Pictus Rainbow wrasse	3			3		
Thalassoma bifasciatus Bluehead wrasse	3			3		
Chromis cyanea Blue chromis	3.5			3.5		
Stegastes diencaeus Longfin damsel.	2.5			2.5		
Steg. dorsopun. Dusky damselfish	2.5			2.5		
Steg. leucost. Beaugregory	2.5			2.5		
Steg. partitus Bicolor damselfish	2.5			2.5		
Steg. planifrons Threespot damsel.	2.5			2.5		
Steg. variabilis Cocoa damselfish	2.5			2.5		
Scarus iserti Striped parrotfish	3.5			3.5		
Sc. taeniopterus Princess parrot.	3.5			3.5		
Spararisoma atomarium Greenblotch parrot.	3.5			3.5		
Spar. aurofren. Redband parrotfish	3.5			3.5		
Spar. viride Stoplight parrotfish	3.5			3.5		

Site ID: Date:

Time: Lat: Long:

		Trns1	0-5	6-10	11-20	21-30	31-40	>40	actual	Trns2	0-5	6-10	11-20	21-30	31-40	>40	actual
French Angel	*Pomacanthus paru*																
Gray Angel	*Pomacanthus arcuatus*																
Rock Beauty	*Holocanthus tricolor*																
Queen Angel	*Holocanthus ciliarus*																
Foureye Butter	*Chaetodon capistratus*																
Banded Butter	*Chaetodon striatus*																
Spotfin Butter	*Chaetodon ocellatus*																
Reef Butter	*Chaetodon sedentarius*																
LongSnout																	
Porkfish	*Anisotremus virginicus*																
White Grnt	*Haemulon plumieri*																
Bluestriped Grnt	*Haemulon sciurus*																
French Grnt	*Haemulon flavolineatum*																
Tomtate Grnt	*Haemulon aurolineatum*																
Smallmouth Grnt	*Haemulon chrysargyreum*																
Caesar Grnt	*Haemulon carbonarium*																
Spanish Grnt	*Haemulon mactostomum*																
Sailors Choice	*Haemulon parra*																
Stoplight Parrot	*Sparisoma viride*																
Redfin Parrot	*Sparisoma rubripinne*																
Redband Parrot	*Sparisoma aurofrenatum*																
Princess Parrot	*Scarus taeniopterus*																
Striped Parrot	*Scarus croicensis*																
Queen Parrot	*Scarus vetula*																
Redtail Parrot	*Sparisoma chrysopterum*																
Midnight Parrot	*Scarus coelestinus*																
Rainbow Parrot	*Scarus guacamaia*																
YT parrot	*Sparisoma rubripinne*																
Blue Parrot																	
Tiger Grouper	*Mycteroperca tigris*																
Red Hind	*Epinephelus guttatus*																
Graysby	*Epinephelus cruentatus*																
Nassau GRP	*Epinephelus striatus*																
Black Grouper	*Mycteroperca bonaci*																
Rock Hind	*E.adscensio*																
Coney	*Epinephelus fulvus*																
Yellowfin GRP	*Mycteroperca venenosa*																
Yellowmouth GRP	*M. interstitialis*																
Schoolmaster Snp	*Lutjanus apodus*																
Gray Snapper	*Lutjanus griseus*																
Mahogany Snp	*Lutjanus mahogany*																
Yellowtail Snp	*Ocyurus chrysurus*																
Lane Snapper	*Lutjanus synagris*																
Cubera Snapper	*Lutjanus cyanopterus*																
Mutton Snapper																	
Dog Snapper	*Lutjanus jocu*																
Ocean Surgeonfish	*Acanthurus bahianus*																
Doctorfish	*Acanthurus chirurgus*																
Blue Tang	*Acanthurus coeruleus*																
Queen Triggerfish	*Balistes vetula*																
Black Durgon	*Melichthys niger*																
Orangespotted F	*Cantherines pullus*																
YT Damselfish	*M chrysurus*																
Spanish Hogfish	*Bodianthus rufus*																
Great Barracuda	*Sphyraena barracuda*																
Bar Jack	*Caranx rubber*																
Blue Runner	*Caranx chrysos*																

Other commercial fish

Hamlet/Seabass	Squirrelfish
_ S F M A Barred *Hypoplectrus puella*	_ S F M A Blackbar Soldier *Myripristis jacobus.*
_ S F M A Butter *H. unicolor*	_ S F M A Dusky *Holocentrus vexillarius*
_ S F M A Black *H. nigricans*	_ S F M A Longjaw *H. marianus*
_ S F M A Blue *H. gemma*	_ S F M A Longspine *H. rufus*
_ S F M A Indigo *H. indigo*	_ S F M A Reef *H. coruscum*
Hogfish/Wrasse	_ S F M A Squirrel *H. adscensionis*
_ S F M A Hogfish *Lachnolaimus maximus*	Surgeonfish
_ S F M A Spanish *Bodianus rufus*	_ S F M A Blue Tang *Acanthurus coeruleus*
Jacks	_ S F M A Doctorfish *A. chirurgus*
_ S F M A Bar *Caranx rubber*	_ S F M A Ocean *A. bahianus*
_ S F M A Horse-eye *C. latus*	Triggerfish
Parrotfish	_ S F M A Black Durgon *Melichthys niger*
_ S F M A Blue *Scarus coeruleus*	_ S F M A Ocean *Canthidermis sufflamen*
_ S F M A Greenblotch *Sparisoma atomarium*	_ S F M A Queen *Balistes vetula*
_ S F M A Midnight *Scarus coelestinus*	Wrasses
_ S F M A Princess *Sc. taeniopterus*	_ S F M A Bluehead *Thalassoma bifasciatum*
_ S F M A Queen *Sc. vetula*	_ S F M A Clown *Halichoeres maculipinna*
_ S F M A Rainbow *Sc. guacamaia*	_ S F M A Creole *Clepticus parrae*
_ S F M A Redband *Sp. aurofrenatum*	_ S F M A Puddingwife *H. radiatus*
_ S F M A Redfin *Sp. rubripinne*	_ S F M A Slippery Dick *H. bivittatus*
_ S F M A Redtail *Sp. chrysopterum*	_ S F M A Yellowhead *H. garnoti*
_ S F M A Stoplight *Sp. viride*	Others
_ S F M A Striped *Sc. croicensis*	_ S F M A Great Barracuda *Sphyraena barracuda*
Puffers	_ S F M A Chub, Ber/Yel *Kyphosus sectatrix /incisor*
_ S F M A Balloonfish *Diodon holocan.*	_ S F M A Glasseye Snap. *Heteropriacanthus cruentatus*
_ S F M A Porcupinefish *D. hystrix*	_ S F M A Redspotted Hawkfish *Amblycirrhitus pinos*
_ S F M A Sharpnose *Canthigaster rostrata*	_ S F M A Yellowhead Jawfish *Opistognathus aurifrons*
Rays	_ S F M A Saucereye Porgy *Calamus calamus*
_ S F M A Southern Sting *Dasyatis Americana*	_ S F M A Cero *Scomberomorus regalis*
_ S F M A Spotted Eagle *Aetobatus narinari*	_ S F M A Yellowfin Mojarra *Gerres cinereus*
_ S F M A Yellow Sting *Urolophus jamaicensis*	_ S F M A Sand Diver *Synodus intermedius*
Seabass	_ S F M A Sharksucker *Echeneis naucrates*
_ S F M A Creole Fish *Paranthias furcifer*	_ S F M A Silversides
_ S F M A Harlequin Bass *Serranus tigrinus*	_ S F M A Greater Soapfish *Rypticus saponaceus*
_ S F M A Tobaccofish *Serranus tabacarius*	_ S F M A Glassy Sweeper *Pempheris schomburgki*
Snappers	_ S F M A Tarpon *Megalops atlanticus*
_ S F M A Dog *Lutjanus jocu*	_ S F M A Sand Tilefish *Malacanthus plumieri*
_ S F M A Gray *L. griseus*	_ S F M A Trumpetfish *Aulostomus maculatus*
_ S F M A Lane *L. synagris*	
_ S F M A Mahogany *L. mahogoni*	

Angelfish	Eels
_ S F M A French *Pomacanthus paru*	_ S F M A Brown Garden *Heteroconger halis*
_ S F M A Grey *P. arcuatus*	_ S F M A Goldentail Moray *Gymnothorax miliaris*
_ S F M A Queen *Holacanthus ciliaris*	_ S F M A Green Moray *G. funebris*
_ S F M A Rock Beauty *H. tricolor*	_ S F M A Spotted Moray *G. moringa*
Basslets	Filefish
_ S F M A Blackcap *Gramma melacara*	_ S F M A Orangespotted *Cantherhines pullus*
_ S F M A Fairy *G. loreto*	_ S F M A Scrawled *Aluterus scriptus*
Blennies	_ S F M A Whitespotted *C. macrocerus*
_ S F M A Redlip *Ophioblennius atlanticus*	Goatfish
_ S F M A Saddled *Malacoctenus triangulatus*	_ S F M A Spotted *Pseudupeneus maculatus*
Boxfish	_ S F M A Yellow *Mulloidichthys martinicus*
_ S F M A Honeycomb Cowfish *Lactophrys polygonia*	Gobies
_ S F M A Scrawled Cowfish *L. quadricornis*	_ S F M A Bridled *Coryphopterus glaucofraenum*
_ S F M A Smooth Trunkfish *L. triqueter*	_ S F M A Colon *C. dicrus*
_ S F M A Spotted Trunkfish *L. bicaudalis*	_ S F M A Goldspot *Gnatholepis thompsoni*
Butterflyfish	_ S F M A Masked *C. personatus*
_ S F M A Banded *Chaetodon striatus*	_ S F M A Neon *Gobiosoma oceanops*
_ S F M A Foureye *C. capistratus*	_ S F M A Pallid *C. eidolon*
_ S F M A Longsnout *C. aculeatus*	_ S F M A Peppermint *C. lipernes*
_ S F M A Reef *C. sedentarius*	Groupers/Seabasses
_ S F M A Spotfin *C. ocellatus*	_ S F M A Black *Mycteroperca bonaci*
Chromis/Damselfish	_ S F M A Coney *Epinephelus fulvus*
_ S F M A Blue *Chromis cyanea*	_ S F M A Graysby *E. cruentatus*
_ S F M A Brown *C. multilineata*	_ S F M A Nassau *E. striatus*
_ S F M A Sunshinefish *C. insolata*	_ S F M A Red Hind *E. guttatus*
Damselfish	_ S F M A Rock Hind *E. adscensionis.*
_ S F M A Beaugregory *Stegastes leucostictus*	_ S F M A Tiger *M. tigris*
_ S F M A Bicolor *S. partitus*	Grunts
_ S F M A Cocoa *S. variabilis*	_ S F M A Bluestrip. *Haemulon sciurus*
_ S F M A Dusky *S. fuscus*	_ S F M A Caesar *H. carbonarium*
_ S F M A Longfin *S. diencaeus*	_ S F M A French *H. flavolineatum*
_ S F M A Sergeant Major *Abudefduf saxatilis*	_ S F M A Black Margate *Anisotremus surinamensis*
_ S F M A Threespot *S. planifrons*	_ S F M A White Margate *H. album*
_ S F M A Yellowtail *Microspathodon chrysurus*	_ S F M A Porkfish *A. virginicus*
Drums	_ S F M A Sailors Choice *H. parra*
_ S F M A Highhat *Equetus acuminatus*	_ S F M A Smallmouth *H. chrysargyreum*

Appendix 11. Example Creel Survey. (Page 1)

How do you fish?

Dory [ ]
Boat with engine [ ]
Coast [ ]

What type of fishing?

Fish Traps [ ]
Gill Nets [ ]
Spear [ ]
Long Lines
Hard Lines [ ]
[ ]
Diving [ ]
Other [ ]

Purpose of fishing? Food [ ] Recreation [ ] For Sale [ ]

For the month about how much did you sell? Where did you sell?
All [ ] Half [ ] Less than Half [ ]

Please keep a log of each day you fish for the month and return to TIDE area representative.

Date	Time Start	Time Stop	Location	

Please keep a log of what you catch for the month and return to TIDE or area representative. If you have more than one sheet, please keep them together.
(Page 2)

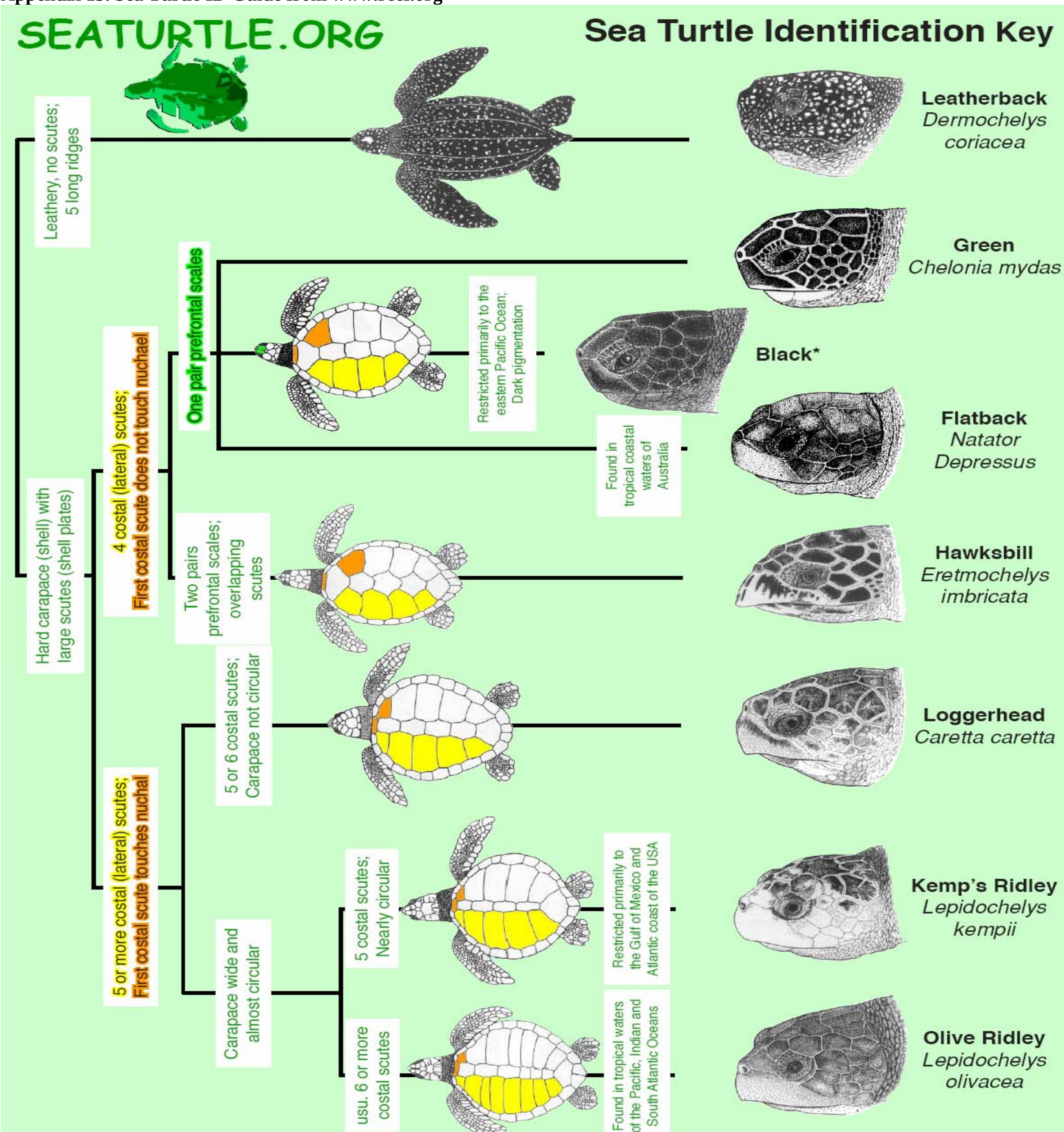
Date	Species	Average Length	Weight	Price

Appendix 12. Field Form for Lobster and Conch Surveys.

Surveyor: Date: Time start: end: Site:

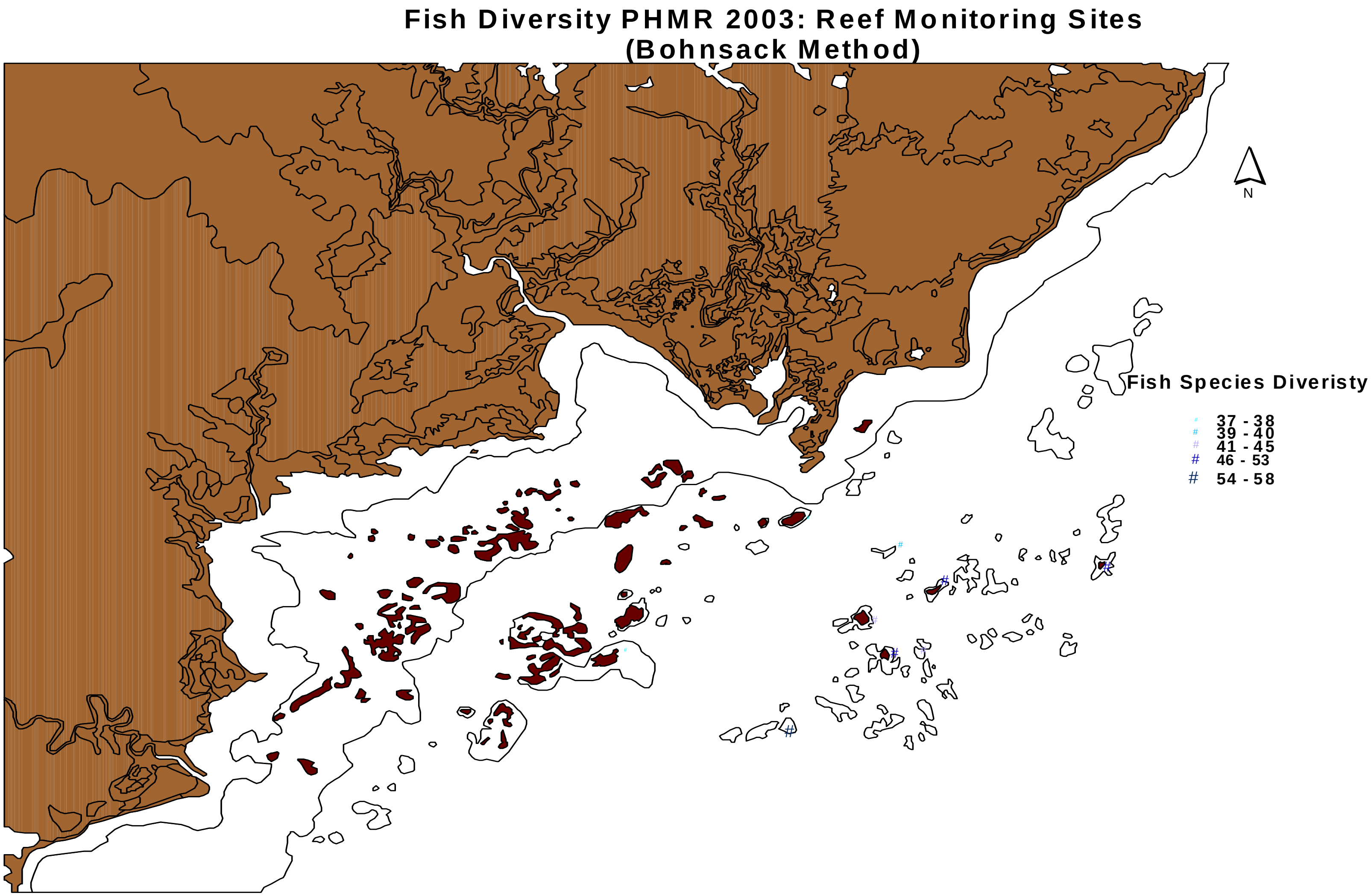
Survey – Lobster or Conch	GPS pt	Species	Adult/Juvenile	Total length (cm)	Lip thickness (Queen Conch)

Appendix 13. Sea Turtle ID Guide from www.reef.org

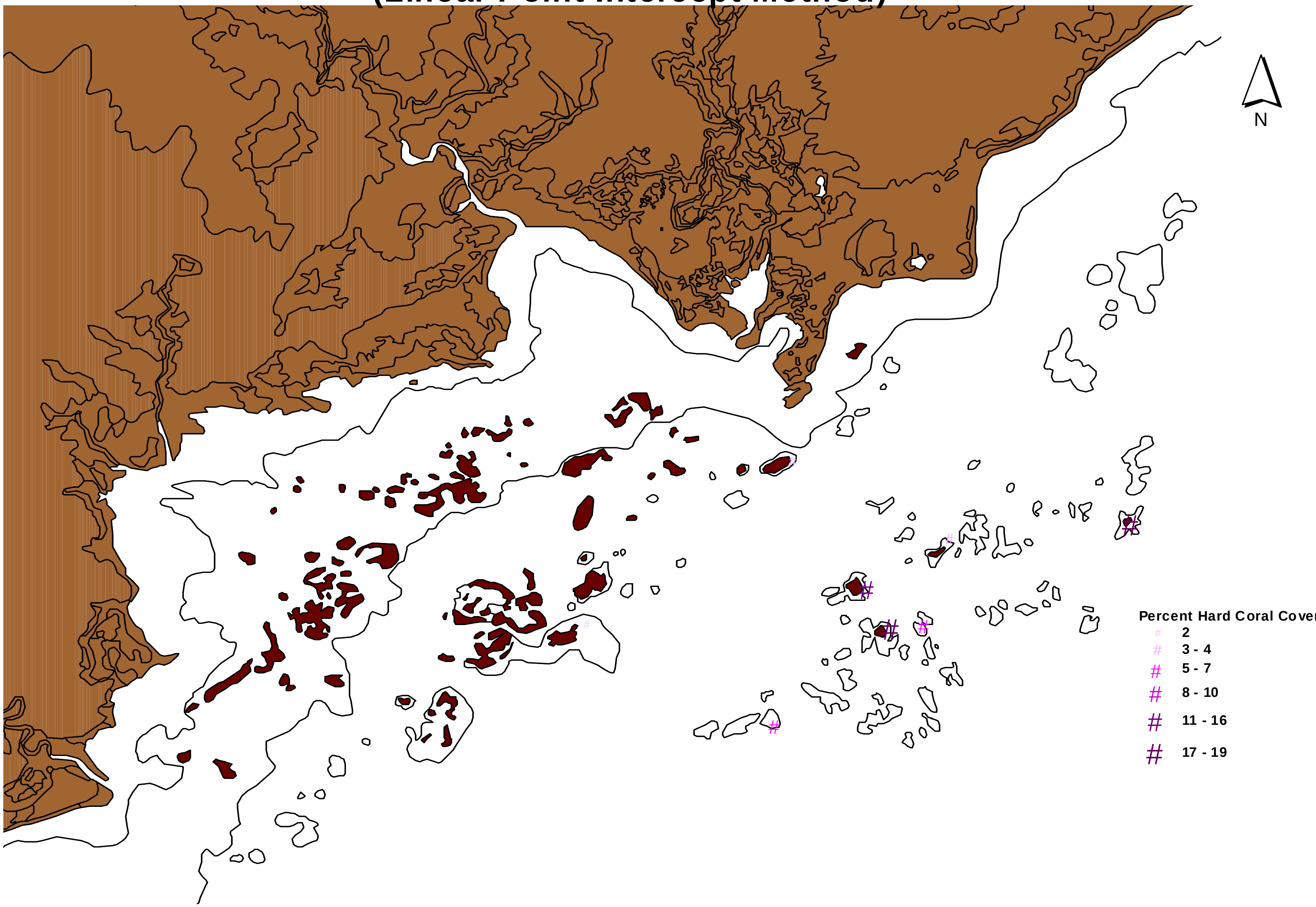


Sea turtle figures used by permission of the Marine Turtle Specialist Group (lucn-mtsg.org)
Source: Pritchard, P. C. H. and Mortimer, J. A. (1999) Taxonomy, External Morphology, and Species Identification. pp. 21-38. *In:* Eckert, K.L., K.A. Bjorndal, F.A. Abreu-Grobois, and M. Donnelly (Editors). 1999. *Research and Management Techniques for the Conservation of Sea Turtles.* IUCN/SSC Marine Turtle Specialist Group Publication No. 4. (for further details see http://www.iucn-mtsg.org/publications.htm) Illustrations by Tom McFarland

Appendix 14. GIS Example indicator maps from 2003 data.



PHMR 2003: Percent Hard Coral Cover at Monitoring Sites (Linear Point Intercept Method)



Appendix 15. Reef benthic and fish criteria and scorecard examples.

1. A scorecard* will be evaluated for each sight based upon the parameters and Biophysical Indicators being assessed. Scores will be based upon the % change from the previous year using the % criteria for given parameters.
2. A cumulative score for the site will be determined. Cumulative scores will be slightly subjective, as certain parameters 'weigh' more in terms of management priorities.
3. Management actions will be determined based upon score.

Site: West Snake Measurement: Reef Communities
Parameters: % live coral, dead coral, disease, macro algae, CCA, # of *D. antillarium*, recruits, and species.
Biophysical Indicator/s: Habitat Complexity and Structure

Parameters	2003 value	2004 value	Change	Score (1-5)
% Hard live coral	15			
*% Hard dead coral** *	3			
*% Disease** *	4.3			
*% Macro algae** *	13.9			
%Crustose Coralline Algae (CCA)	1.8			
Diadema antillarium #	15			
Recruitment #	21			
Coral diversity (# sp)	20			

Cumulative Site Score (1-5) ______
**An increase in all values, accept for % dead coral, % disease and % macro algae is positive.

Cumulative Score Criteria for Reef Benthic Communities:

1. Data suggests that the complexity and distribution of the reef habitats is in **notable decline** (reductions $\geq$ 20% for majority of parameters).
2. Data suggests that the complexity and distribution of the reef habitats is in **decline** (reductions of 5- 20% for majority of parameters).
3. Data suggests that the complexity and distribution of the reef habitats is **unchanged** (reductions $\leq$5% for majority of parameters).
4. Data suggests that the complexity and distribution of the reef habitats is **improving** (increase between 5- 20% for majority of parameters).
5. Data suggests that the complexity and distribution of the reef habitats is **notably improving** (increase >20% for majority of parameters).

Site: East Snake   Measurement: Reef Fish
Parameters: abundance and density of commercial fish and species diversity
Biophysical Indicator/s: Focal Species Abundance (and Density)

Scorecard for Abundance and Density of Commercial Fish					
Parameter	Species	2003 value	2004 value	% Change	Score (1-5)
Abundance of commercial fish (#) (Belt Transect Method)					
	Lane Snapper	0			
	Yellowtail Snapper	24			
	Gray Snapper	0			
	Dog Snapper	0			
	Schoolmaster	10			
	Blue Grunt	10			
	White Grunt	18			
	Hogfish	0			
	Barracuda	0			
	Etc.				
Density of commercial fish (#/100M^2) (Belt Transect Method)					
	Lane Snapper	0			
	Yellowtail Snapper	1.67			
	Gray Snapper	0			
	Dog Snapper	0			
	Schoolmaster	4.00			
	Blue Grunt	1.67			
	White Grunt	3.00			
	Hogfish	0			
	Barracuda	0			
	Etc.				
Species diversity/ richness (# sp) (Roving Diver Method)	**Total Species**	57			

Cumulative Site Score (1-5) ______

Site: East Snake Measurement: Reef Fish
Parameters: Size structure of commercial fish
Biophysical Indicator/s: Focal Species Population Structure

Scorecard for Population Structure of Commercial Fish																				
Size (cm)	**<5**	**<5**	**5-10**	**5-10**	**11-15**	**11-15**	**16-20**	**16-20**	21-25	**21-25**	**26-30**	**26-30**	**31-35**	**31-35**	**36-40**	**36-40**	**actual**	**actual**	**% Change**	**Score (1-5)**
year	**03**	**04**	**03**	**04**	**03**	**04**	**03**	**04**	**03**	**04**	**03**	**04**	**03**	**04**	**03**	**04**	**03**	**04**		
Snapper Totals																				
Lane Snapper																				
Yellowtail Snapper																				
Gray Snapper																				
Dog Snapper																				
Schoolmaster																				
Grouper Totals																				
Red Hind																				
Graysby																				
Nassau Grouper																				
Yellowmouth Grouper																				
Permit																				
Barracuda																				
Etc.																				

Cumulative Site Score (1-5) ______

Site: East Snake Measurement: Reef Fish
Parameters: Family density
Biophysical Indicator: Community Composition

Family:	*Surgeon*	*Parrotfish*	*Grunt*	*Snapper*	*Grouper*	*Angelfish*	*Butterflyfish*	*Leatherjacket*	*Other*
Density (#/100m2) 2003	11.00	31.00	12.50	5.67	1.00	2.83	3.17	0.00	6.83
Density (#/100m2) 2004									
% Change									
Score (1-5)									

Cumulative Score (1-5)________

Cumulative Score Criteria for Focal Species and Focal Species Population Structure:

1. Parameters suggest that the focal species abundance and focal species population structure is experiencing **notable decline/shift** (reductions $\geq$ 20% for majority of parameters).
2. Parameters suggest that the focal species abundance and focal species population structure is experiencing **decline/shift** (reductions of 5- 20% for majority of parameters).
3. Parameters suggest that the focal species abundance and focal species population structure is **unchanged** (change $\leq$5% for majority of parameters).
4. Parameters suggest that the focal species abundance and focal species population structure is **experiencing growth** (>5% increase in majority of parameters).
5. Parameters suggest that the focal species abundance and focal species population structure is **experiencing notable growth** (>20% increase in majority of parameters).

Cumulative Score Criteria for Community Composition of Fish:

1. Parameter suggests that key fish families are in **notable decline** (reduction $\geq$ 20% in the density commercial families (snapper and grouper)).
2. Parameter suggests that key fish families are experiencing a **decline** (reduction of 5- 20% in the density commercial families (snapper and grouper)).
3. Parameter suggests that the key fish families have remained **unchanged** (change of $\leq$5% in the density commercial families (snapper and grouper)).
4. Parameter suggests that key fish families are experiencing **growth** (growth of 5- 20% in the density commercial families (snapper and grouper)).
5. Parameter suggests that key fish families are experiencing **notable growth** (>20% increase in the density commercial families (snapper and grouper)).