Review of Baseline Assessment in Fisheries

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1 Introduction

The Philippines is at the center of global marine diversity (Veron 2000, Alino and Gomez 1995), which places it at a strategic position to demonstrate whether it can overcome the tremendous challenges on its coastal ecosystems. Indeed the tremendous pressures that prevail in the most diverse marine ecosystem such as the coral reefs have placed Philippine reefs among the “hottest of the hotspots” (Roberts *et al*. 2002, Burke *et al*. 2002). Indications of the pressures and states of coastal ecosystems require that improved management actions are done now, and sustained well into the future (GIWA 2001). Adaptive co-management offers an avenue that does not necessarily delay management intervention through the utilization of best knowledge together with the design of management interventions (Walters 1986). Designing the appropriate monitoring and evaluation to gauge the effectiveness of management becomes an inherent part of a monitoring, control and surveillance (MCS) system. Projects and eventual program formulation such as the USAID-Fisheries Improved for Sustainable Harvest (USAID-FISH) requires that improved understanding of the states and pressure trends of the ecosystem are linked to the Fisheries Ecosystem Management (FEM) interventions utilizing a multidimensional array of criteria of effectiveness of management (Done and Reichert 2000 and WCPA 2003). These criteria range from the ecological, social, economic, governance and sustainability (Charles 1994).

The hierarchical integration at various levels of ecosystem management interventions need to be further elucidated so that clear and informed decisions can be undertaken (Perry *et al*. 1999). Thus information from assessments of fisheries stocks (i.e. single or multi species), aggregate yields in a particular area and habitat and ecosystem assessments, should be taken in their appropriate contexts at various phases and interactive components. Some of the key considerations in the fisheries management cycle include:

a) Defining the scale and scope; parameterization need to be spatially and temporally explicit
b) Design and sampling for information inputs to management such as the ecosystem and fisheries resource assessments
c) Deriving information and decisions from the data analyses and feedback to stakeholders
d) Response, adjustments and improvement of management derived from the monitoring and evaluation

Given that the fisheries ecosystems are dynamic and complex in nature, the baseline assessment phase is crucial to fisheries resource management in order to:

a) Assess the conditions, threats and risks of the ecosystem;
b) Derive insights on the bases, strategic target species/ areas, and the likely trajectories of the fisheries resources and its ecosystems;

c) Evaluate the options that can be taken so that management decisions are pursued effectively;

The effectiveness of management is linked to the evaluation of the biophysical and socio-economic baseline conditions of the area. The performance monitoring and financial management plan of the FISH contractors, that are facilitating management interventions for USAID, will come after the initial design of the biophysical assessment of the fisheries ecosystem. The objectives of the third party Baseline contractor are:

a) To validate the assessment of the FISH contractor on the state of the fisheries ecosystem at the four target management areas;
b) To review and evaluate the assessment design of the FISH contractor;
c) To recommend complementary options for the design of adaptive management mechanisms through Monitoring and Evaluation protocols and Performance and Monitoring Financial Planning.

One of the important criteria in resources management is sustainability as espoused by Charles (1994) in his sustainability triangle (Fig.1). In this concept, the long-term ecological sustainability is highlighted as the crucial fulcrum that hinges together the socio-cultural, political and institutional regimes of fisheries ecosystem management.

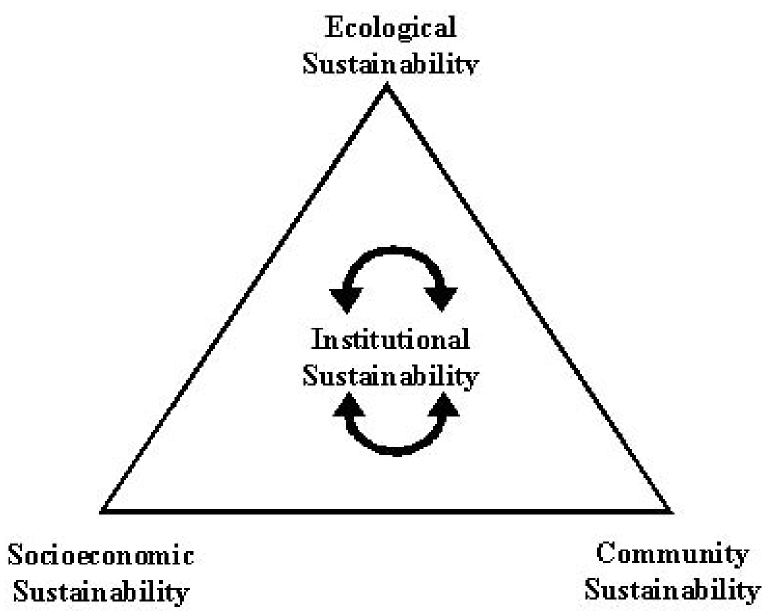

Fig.1. Sustainability Triangle highlighting the interrelated evaluation criteria for the sustainability of fisheries ecosystem management (from Charles 1994).

Thus it is logical that the biophysical assessments have been the priority concern for the FISH baseline contract. Sainsbury *et al*. (2000) provides the general framework referred to as Management Strategy Evaluation (Fig. 2a). Here it is noted that baseline assessment indicators are established followed by performance measures based monitoring and gauge the targets to be achieved or limits to be avoided (Fig.2b).

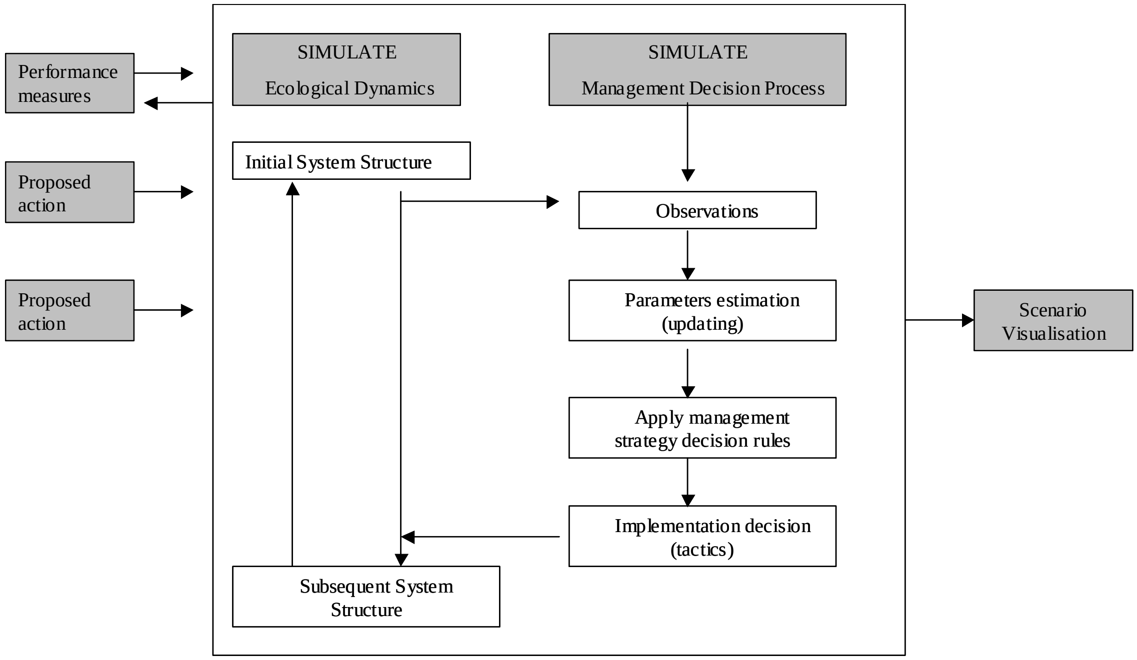

Figure 2a. framework for management-strategy evaluation (MSE) Adapted in K.J. Sainsbury et.al. 2000.

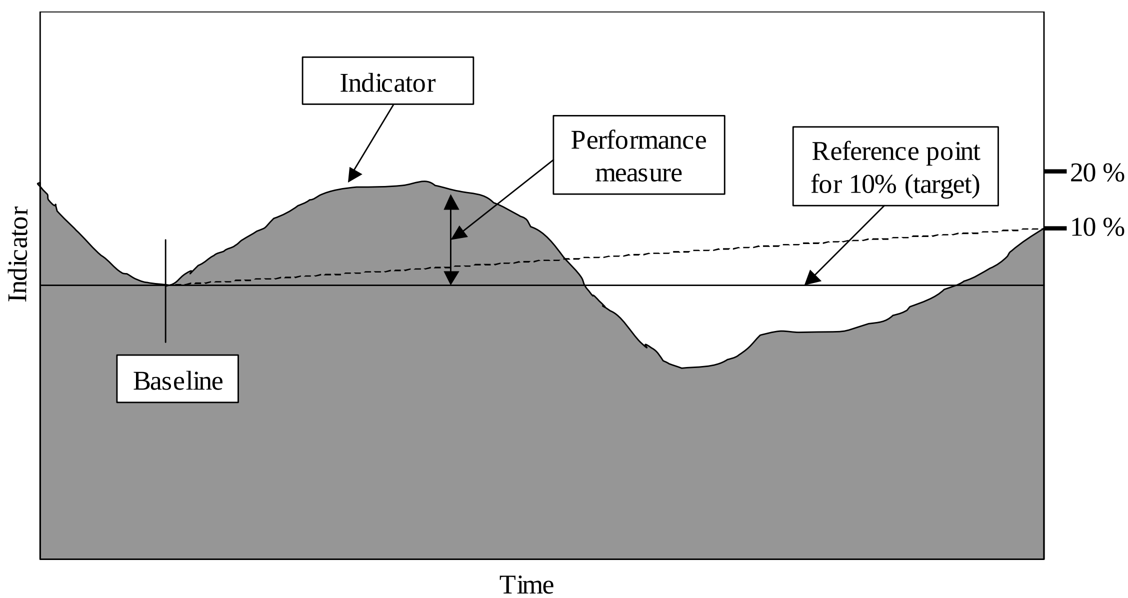

Figure 2b. Example of the use of indicators, performance measures and baseline reference points. An indicator is determined from measurements obtained by monitoring the system. Reference points for the indicators are derived from broader management objectives. They may be targets (to be achieved) or limits (to be avoided).Adapted from Sainsbury et.al. 2000.

This review of best practices in baseline assessments is part of the first month report of the FISH Baseline Contract (No.LAG-I-00-99-00017-00) of the Development Alternatives, Inc. The review as part of the initial phase seeks to:

1. Discuss the theory and practice of baseline assessment approaches and methodologies;
2. Compare the advantages and disadvantages of the various baseline methodologies vis-à-vis the fisheries ecosystem management needs for the FISH target sites;
3. Summarize the best practices in the biophysical fisheries assessment baseline that may be useful for the assessment, standardization and validation with FISH contractor as benchmark indicators to be used for their performance evaluation.

2 The importance of a historical perspective and coastal resources management context

The historical review of global overexploitation by Jackson *et al*. (2001) highlights the shifting baselines through time that needs to be recognized as part of any fisheries management strategy (see also ICES 2000). *Albeit* the Philippines, being in a state of fisheries crisis (White and Cruz-Trinidad 1998, Dalzell *et al*., 1987 and Alino *et al*., in press, Green *et al*. 2003, Silvestre 1989 and Silvestre and Pauly 1997), opportunities abound in the rich experiences and dynamic resilience of the Filipinos. This reservoir of experiences in the Philippines is summarized below to put some context to the needs, gaps and capacity building concerns that have to be overcome, in order to meet the challenges of the FISH project.

2.1 Reviews of fisheries related projects

Flores' (1994) compilation of projects related to coastal resources management indicates that various assessment protocols are being utilized by major projects in the Philippines. The linkage of fisheries management to coastal resources management has been a welcome development in the Philippines. The most extensive of which is the Asian Development Bank funded project Fishery Sector Project that initially started with twelve priority bays. In its second Phase, with additional funding from the Japan Bank for International Cooperation (JBIC), it has expanded its coverage to 18 priority bays. Jacinto et al (2001) also provides some listing of the Coastal Resource Management (CRM) related efforts culling from the work of Aliño (1998) in relation to the transboundary diagnostic analyses of the issues and conditions of the marine resources in the Philippines. Alino (2002a,b,c) provided an overview of Philippine fisheries including some transboundary concerns especially relating to issues in the South China Sea.

2.2 Lessons learned from Philippine USAID projects related to Coastal Resources Management

The USAID resource management projects in the 1980's usually have coastal components (e.g. Central Visayas Resources Project) unfortunately inadequate monitoring has been undertaken. Perhaps the question on the impact of artificial reefs could have been addressed more proactively if improved Monitoring and Evaluation (M&E) was set within an adaptive management framework. Another USAID Funded project led to the establishment of the Lingayen Gulf Coastal Area Management Commission (LGCAMC) in the late 1980's. Baseline information from these projects provided the important baselines on the state of the various coastal ecosystems of Lingayen Gulf. Some complementary work undertaken under the USAID Collaborative Research Support Program involving research institutions from University of the Philippines Marine Science Institute (UPMSI), International Center for Living Aquatic Resources Management (ICLARM) and University of the Philippines-Visayas (UPV) came up with important baseline research and analytical tools that may be useful for fisheries assessment and management. In their efforts (ca. 1987) fisheries assessment has started to recognize the importance of the complementation of ecology, fisheries science and oceanography (McManus and Chua 1990). Their work reaffirms the great difficulties in dealing with malthusian overfishing in the Philippines (Pauly *et al* 1989, Padilla *et al*. 1995, Hilomen and Jimenez 2001; Licuanan *et al*., in prep.). In the mid-1990's USAID's technical assistance in CRM has expanded to areas based in the Visayas through the Coastal Resource Management Program (CRMP), focusing on CRM planning, establishing Marine Protected Areas (MPAs) and public awareness in CRM. Some baseline assessments have been facilitated through participatory coastal resources assessments (PCRA) and a municipal coastal database has been developed for local governments. The Municipal Coastal Database (MCD) is presently being utilized as part of the LGUs self-assessment that is used in complement with the development of CRM certification system. Support for efforts in certification and assessments as tool for certification is also being developed for aquarium trade (Ochavillo 2003). These laudable innovations that are self assessment-based approaches could benefit with third party independent evaluation and performance based instruments. Participatory benchmarking of marine sanctuaries in coral reefs has been undertaken in conjunction with the UPMSI with co-funding from United Nations Development Program (UNDP) (Uychiaoco *et al*. 1999 and Uychiaoco *et al*. 2000). Integration of governance and CRM evaluation are being developed by the Philippine Environmental Governance (EcoGov) project and the utilization of the PCRA has broadened its applications from its pedagogic aspects to the development of heuristic tools for fisheries management. Multi-criteria options and decision support tools in conjunction with simulation modeling and fisheries management scenarios will be powerful next steps to appreciate socio-economic incentives and enhance the adaptive management options (Licuanan *et al*. 2003). It is fortuitous that the FISH project incorporates as an inherent project feature a management evaluation strategy involving a third party independent baseline assessment through the FISH Baseline contract.

3 Review of Methods for Fisheries Baseline Assessment

Baseline information on fisheries and fisheries resources in a given area is always important for establishing reference points for key indicators of the state of ecological health of ecosystems (includes status of exploited stocks and quality of habitats), socio-economic conditions, level of community development and strengths of institutions (*sensu* Charles 1994). It provides a measure from which to determine whether the status of fisheries and fisheries resources has improved or deteriorated after a period of time. Similarly, baseline information is important because it facilitates better understanding of the nature of the fisheries dynamics, response of fish stocks to exploitation, behavior of fishers to levels of stocks and actions of institutions. Moreover, it can serve as bases for refining management objectives, actions and expectations to achieve a 'desired state'. Thus, baseline information (and monitoring and evaluation) becomes essential in fisheries management.

A major purpose of fisheries management is to ensure sustainable production from fish stocks over time through regulatory and enhancement actions that promotes economic and social well-being of fishers and industries that use the production (Hilborn and Walters 1992). This review recognizes the need to develop support for providing scientific advice for fisheries management emphasizing on the principles of precautionary approach (Perry *et al*. 1999). It also considers the framework described by Charles (1994) to achieve fishery sustainability. The framework stresses the simultaneous evaluation of four important components to arrive at sound options for sustainable development in fisheries that considers a multiplicity of objectives. These four components are ecological, socio-economic, community and institutional sustainability. While all of the components above are important in fisheries sustainability this review on methods of assessment of baseline information primarily focuses on the use of important indicators and parameters to determine the status of exploited stocks, quality of habitats and the overall ecological health of ecosystems. The success of any marine fisheries management strategy is largely dependent on a reliable baseline data, particularly on fisheries stock abundance and distribution (Petersen 1992; Helser and Hayes 1995; NRC 1998; NRC 1999; Perry *et al.* 1999; Geromont *et al*. 1999; Walters and Martell 2002; Brodziak and Link 2002; Thompson and Mapstone 2002). It is important to emphasize that the choice of key indicators and parameters for the establishment of baseline information is consistent with the Fishery Ecosystem Management approach. The choice of these indicators and parameters depend on operational management strategies derived from a clear set of management objectives. Sainsbury *et al*. (2000) advocate the use of a management-strategy-evaluation approach, a process that uses operational management objectives, performance measures, and alternative management strategies in a simulation.

This review is divided into two sub-sections. The first is a review of good practices in fishery assessment. This is followed by a discussion of methods used in assessment of important fisheries indicators and parameters. In this section, the advantages and disadvantages of the various methods for a parameter and the importance of the parameter are provided.

3.1 Good Practices in Fishery Assessment

The science-based fishery management-precautionary approach and the integration of traditional/local knowledge through participatory approaches are considered as good practices in fishery assessment. The best scientific evidence and local knowledge available should be used in order to evaluate the current state of fishery resources and the possible impact of proposed measures on the resource. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures. Critical gaps in the existing information should be filled in through time to evaluate alternative management strategies (FAO 1995). In many cases, information from traditional/local knowledge on fisheries resources and fishing practices supplement scientific data when the latter is insufficient. Community-based coastal resources management initiatives in the Philippine have demonstrated that the participation of locals in the coastal resources management process is critical to initiate and sustain management efforts.

3.1.1 Science-based Fishery Management – Precautionary Approach

Whenever a new fishery develops, efforts and catch are likely to increase. Initially, the increase in catch brings in build-up of investment such as increase in number fishing boats or fishing implements, establishment of processing facilities and marketing arrangements. The danger in this scenario is the lack of information on the historical experience with the stock such that the high levels of exploitation are sustained to a point at which the rate of natural replenishment cannot compensate for the rate of harvest (Hilborn and Walters 1992, Perry *et al*. 1999). This is a common scenario (boom and bust) and a reality in the history of many of the overfished areas in the Philippines. Hence, a good practice in fishery assessment is following the guidelines established under the principles of the precautionary approach to fisheries (Garcia 1994, FAO 1996). Perry *et al*. (1999) list the basic biological and fisheries information, ecosystem considerations required for establishing a precautionary management strategy for developing fisheries. In addition, it is also a good practice to evaluate management approaches and determine which worked and which did not.

In the process of investigating problems to fill in critical gaps in fisheries it is important to follow the scientific method. Green (1979) describes a ten-point protocol in the planning of study design and the field execution of a study. Briefly, the ten protocols are:

1. **State questions clearly and concisely**. It is important to ask the right questions. Prioritize what is the important information you need.
2. **Replication**. Take replicate samples at all levels of interests (ex. locations, times). Replication at all levels is important because variation among a factor can only be demonstrated by comparison to variation within a factor. Be aware of pseudoreplication (Hurlbert 1987).
3. **Randomization**. Taking samples from "representative" or "typical" areas is not random sampling. Randomization is ensuring that all possible samples have an equal chance of being sampled. Collect your samples independently (without

bias). Bias from non-independent samples cannot be removed from the data (Underwood 1981).

4. **Use of controls**. The use of replicated samples from a control is important to measure natural variability. It is quite difficult but not impossible to find a control in field studies.
5. **Pilot studies**. Pilot studies are preliminary sampling to refine and fine tune a sampling design, test efficiency of a method and find a range of variation of a parameter. This is the best way to assess efficiency of the sampling method, determine presence of large-scale variability that would make stratification more desirable and determine size of sampling units to maximize precision of sample estimates.
6. **Test efficiency of sampling methods**. A sampling method must be efficient under all relevant conditions. If a sampling method is more efficient in one site than in another then the comparison is biased. If this occurs then a remedy is standardization.
7. **Stratification.** This requires *a priori* information. If there is a large-scale pattern of variation in a factor of interest, then there is a need to break up areas into homogenous sub-areas or strata and allocate sampling effort optimally to the strata.
8. **Size of sampling units.** The size of sample units will depend on the size and shape of the animal, size of the study area, spatial and temporal distribution of the animal, and the cost of sample collection time (time, money, number of personnel, etc.)
9. **Analysis of data.** Data must be subjected to the most appropriate type of analysis. The study design must be matched with the appropriate analysis done *a priori*.
10. **Accept results.** Be objective. Avoid entering into a search for a method that will provide a more palatable answer.

Management measures are refined and fine tuned as new scientific information are generated and evaluated from fishery assessments. This is an adaptive management approach to cope with the 'uncertainty' and complexity in fisheries. Management must be experimental (Larkin 1978).

3.1.2 Gathering information on Traditional/Local Knowledge through participatory approaches

More often than not there is insufficient information about fishery resources and practices in an area that is essential in fishery management. Local ecological knowledge is a major source of information that can be used together with other information (e.g. scientific publications on key fishery species, other studies and surveys in the area) in the assessment of the status of fisheries and the formulation of fisheries management plans.

Tools for rapid appraisal methods for coastal communities are well established (e.g. Townsley 1993). Many of these methods are based on the long and rich experience in rural development on forestry and agriculture. These methods are widely used and are adapted in participatory resource assessments in the Asia Pacific region. It is widely accepted that the active participation of direct resource users and other stakeholders is critical in the sustainability of resource management interventions. Various syntheses and case studies of local CRM initiatives (e.g. Polotan-de la Cruz 1993, Alino & Juinio-Menez 1995, Ferrer *et al*. 1996, Rivera and Newkirk 1997, Alcala 1998, White and Vogt 200, Pollnac *et al*. 2001) invariable conclude that involvement of the local community at various steps in management is crucial (i.e. data gathering, collation and analysis and decision-making). The participatory approach does not serve merely as a means to gather stakeholder knowledge, it is a vital step to engage local stakeholders, develop support and enjoin active participation in the resource management process.

3.2 Indicators and Parameters for Baseline Assessment of Fisheries Ecosystem

The important indicators and parameters for baseline assessment of fisheries ecosystem include stock abundance and distribution of various fisheries resources, gear-fisher history, key parameters of habitat quality and characteristics (coral reef, seagrass, mangrove, soft bottom communities), and some physical and chemical characteristics of water. Key parameters of habitat quality include measures of species composition, richness, diversity and abundances. A summary of the methods is presented in Appendix 1. Other important indicators and parameters essential for fishery ecosystem management are placed under the section on monitoring and evaluation. The indicators and parameters listed under this section (baseline assessment) are included for monitoring and evaluation.

3.2.1 Stock Abundance and Distribution

A stock is self-contained breeding population of fish and is considered as the basic unit in fisheries biology (Russ 1991, Hilborn and Walters 1992). Reliable baseline data on fisheries stock abundance and distribution are paramount source of population parameters that are necessary to create fisheries potential yield models and more complex fisheries ecosystem models (Appeldoorn 1996). These models are an integral part of the processes involved to ensure that the assessment and management goal of increasing and sustaining harvest from marine fisheries resources is achieved (NRC 1998; NRC 1999; Walters and Martell 2002; Brodziak and Link 2002). Projection of future stock sizes in fisheries follows Russell's axiom,

$$S_{y+1} = S_1 + (G+R)-(F+M) \qquad (1)$$

where, S_{y+1} is stock size next year, S_1 is stock size this year, G is growth rate, R is recruitment, F is fishing mortality or catch and M is natural mortality.

The equation underscores the reliability of the estimates of future levels of stocks depends on the accuracy and precision in which stock abundance, growth rates, recruitment rates, and rates of fishing and natural mortality are estimated. Similarly, all other factors that directly and indirectly affect the components of the equation are important in the context of the fishery ecosystem management. Information on how these factors influence each of the components is fundamental in fishery ecosystem management. For example, the patterns and rates of recruitment of fish are influenced by the availability of larval supply (Doherty and Williams 1988, Doherty 1991, Doherty and Fowler 1994), which in turn is affected by the fecundity and reproductive patterns of fish (PDT 1990). The quality of habitats and oceanographic processes are important factors affecting patterns of recruitment and settlement of many commercially important reef fish (Cowen 2002). Similarly, the availability of food supply, space, quality of habitats, health and genetic make-up of stocks influence growth rates, while predation, quality of habitats and health affect natural mortality rates of stocks (e.g. Hixon and Beets 1989, Hixon 1991, Hixon and Beets 1993). Fishing mortality of fish stocks largely depend on fishing pressure and gear dynamics. The nature of fishing pressure and gear dynamics changes with the socio-economic and institutional-political conditions. Prevalent poverty, high population growth in coastal areas and the lack of political will exacerbate the sorry state of a fishery in an area (Polunin and Roberts 1996). Clearly, the fisheries problem is complex. The better understanding of the interplay of factors is essential to achieve sustainable development (Charles 1994).

Initially, for the assessment of the baseline information on fisheries, stock abundance and distribution are two of the most important parameters in fisheries science. The two major sources of fisheries stock abundance and distribution data are fisheries-dependent surveys (e.g., artisanal fisheries landings, commercial fishing vessel landings) and fisheries-independent surveys (i.e., collected by fisheries-research scientists). Methods to estimate stock abundance and determine distribution have long been established (see Hilborn and Walters 1992, Gunderson 1993, King 1995, NRC 1998). The most widely used measures to estimate [relative] stock abundance are catch per unit effort (CPUE) (Richards and Schnutte 1986) and fish density expressed as numbers or biomass per unit area. CPUE is derived using a variety of tools (gears), while fish density is obtained using a variety of census and survey methods (e.g. swept area). A brief review of how CPUE and estimates of fish density are used to collect baseline data on stock abundance is presented below. Other methods are mark-recapture methods, egg production methods and swept area methods (see Appendix 2 for details of these methods). Comments on the advantages and disadvantages of each methodology are included.

3.2.1.1 Catch Per Unit Effort (CPUE)

CPUE is the most commonly used measure of relative abundance of fisheries stocks (King 1995). CPUE can be collected from both fisheries-dependent and fisheries-independent surveys. Records of CPUE include number or weight of fish per trap or gillnet fisher or trawling hour. Conversion of CPUE to stock abundance follows the linear relationship, CPUE = (q x N); where N = stock abundance and q is the catchability coefficient (i.e., the slope of the relationship).

There are a number of problems associated with using CPUE as the basis for estimating stock abundance. The following serious concerns make CPUE an unreliable index for generating baseline data on fisheries stock abundance and distribution:

- A linear relationship between CPUE and abundance does not always exist.
- The catchability coefficient (q) is not always known, making the conversion from CPUE to stock abundance impossible.
- Gulland (1983) claims that in multiple species fisheries, such as those in the tropics, CPUE is not easy to define.
- Variation among fishermen in fishing efficiency, given the same fishing gear, creates statistical sampling problems associated with CPUE.
- Although gear effects can be controlled in fisheries-independent calculation of CPUE, the sampling effort in such surveys is generally low (Appeldoorn 1996). This creates problems associated with precision of abundance estimates, as well as the statistical power of such estimates.
- The inherent assumption that fish are distributed randomly on the fishing ground and have equal vulnerability to the fishing gear is not always met.

As a measure of relative abundance, CPUE is useful in comparing fisheries production between fishing grounds (spatial scale) and between fishing months (temporal scale). For example, one can infer that fishing ground A is twice as productive as fishing ground B from the data indicating that fishermen, on average caught 10 fish per trap in fishing ground A and only five fish per trap in fishing ground B. However, because of the above stated problems associated with this index, CPUE is less useful in estimating abundance and distribution of fisheries stocks, especially for the purpose of establishing baseline data for fisheries management programs.

CPUE indices from fisheries-independent monitoring programs are preferred over those from fisheries-dependent schemes in estimating stock abundance because the former can be derived from sampling units that represent the range of distribution of the entire stock. Furthermore, fisheries scientists can adopt the most appropriate sampling design (e.g., random sampling, stratified or systematic sampling) based on knowledge of the biology and distribution of the target species and can be more consistent in the use of sampling gear across the entire sampling area. These are important considerations in order to reduce sampling bias and maintain precision in the measurement of CPUE. The problems associated with estimating CPUE from commercial fishers are rooted from the facts that fishermen deploy their fishing gears in areas of very high concentration of target species and that variation among fishermen in fishing efficiency typically exist.

Because of the problems associated with CPUE (above), CPUE can vary within a gear at different sites as well as between gears even within the same area. Estimation of CPUE as a measure of relative abundance of stocks is provided in detail for some gears in Appendix 2.

3.2.1.2 Underwater visual census (UVC) methods

UVC techniques (Brock 1954; Sale and Douglas 1981; Green and Alevizon 1989; Thompson and Mapstone 1982) provide direct counts of individuals in portions of the entire stock (i.e., sampling units) that are selected following the principles of random or systematic sampling (Saville 1977; Andrew and Mapstone 1987; Fowler 1987). Counts from these representative samples can then be extrapolated to the total fish stock (King 1995; Gunderson 1993). Gunderson (1993) provides a review of UVC techniques and their use in estimating the abundance of fish in a given area. Some of these UVC survey methods include SCUBA, manned submersibles and remotely operated underwater vehicles. UVC using SCUBA is suitable for reef fish survey where water visibility is high (English *et al.* 1997). The use of submersibles, underwater vehicles and sleds in fisheries survey may be limited to species that inhabit areas of the ocean floor with low topographic relief and species whose behavior is not altered by the lighting equipment necessary to effectively operate these vehicles and the noise they produce during operation. The different UVC techniques used by fisheries biologists follow the same basic principles in converting counts to density (i.e., number or weight per unit area) and extrapolating sample estimates to total stock size or biomass (Gunderson 1993).

An important requirement for a more reliable estimate of total stock abundance or biomass using data from UVC surveys is that the species of interest is visible to the observer. This limits censuses to be conducted only during the day and in less turbid environments. In addition, cryptic species may be completely missed or under-estimated in UVC surveys (Greene and Alevizon 1989; Gunderson 1993; King 1995) and accuracy in counting schooling or migrating fish is often low (Wilkins 1986; Greene and Alevizon 1989; Buerkle and Stevenson 1991). In a study conducted by Brock (1982), UVC surveys gave more accurate counts of diurnal, big, and colorful fishes, but were less accurate in estimating stock size of migratory and less conspicuous fish species. In multi-species and structurally complex ecosystems such as coral reefs, it may be necessary for the observer to form clusters (single species or multiple species) of fish based on similarity in size, behavior, conspicuousness and distribution (Greene and Alevizon 1989; Gunderson 1993). Each cluster can then be assessed at different times, allowing the observer a more focused “search image” and a more accurate count (Greene and Alevizon 1989; Gunderson 1993). UVC surveys can be conducted at night; however, night dives present additional logistical difficulties (e.g., hazards inherent in night diving). Some fish species are also attracted to or shy away from lights, adding to the problems associated with the accuracy of UVC surveys conducted at night. Proper training and re-training of the observer in fish identification and fish-length estimation underwater improves the quality of data obtained using UVC, as well as reduce observer error and statistical bias (Sale and Douglas 1981; Sale and Sharp 1983; Watson *et al*. 1995; Thompson and Mapstone 1997; Mapstone and Ayling 1998). Furthermore, knowledge of the biology, ecology and behavior of the target species is a “must” for the observer (Gladfelter 1979; Helfman 1986; Sale and Steel 1989; Sale 1991; Zeller 1997; Sale 2003).

The following are UVC techniques used by contemporary fisheries biologists.

- **Strip Transects**. In this method, the area and location of strip transect is predetermined. Placement of transects strictly follow the principles of random or systematic sampling and transect width is dependent on the visual acuity of the observer and conspicuousness of fish, especially when conducting the survey using SCUBA (Brock 1982; Helfman 1986; Buckley and Hueckel 1989; Cheal and Thompson 1997). The observer then counts all fishes that fall within the strip transect while moving by the use of a manta board or a diving sled (Uzmann *et al* 1977; Bergstedt and Underson 1990; Butler et al. 1991) or simply by swimming along the transect (Brock 1954; Sale and Douglas 1984; Thresher and Gunn 1986; Greene and Alevizon 1989; Thompson and Mapstone 2002). To minimize bias in fish counts using SCUBA, the observer has to count only those fish that are within fixed area of the transect and to avoid counting an individual fish more than once. Therefore, when using this technique, the observer has to be knowledgeable of the behavior of the target species.
- **Line Transect**. In this method, the observer counts all individuals or schools sighted, regardless of distance from the observer. This eliminates the need for predetermined transect width (as above) and allows the observer to cover a much greater area than with that of strip transect. The sighting distance for each individual fish are then incorporated into a model to define the effective sampling width (Burnham *et al*. 1980; Gunderson 1993).
- **Point Counts**. In this UVC survey, the observer counts all fishes within a circle around the SCUBA diver (Bohnsack and Bannerot 1986).
- **Remotely Operated Vehicles**. Relatively cheaper than manned submersibles, ROVs have to be equipped with high-resolution video cameras, adequate lighting system and a mechanism to produce high quality images. An advantage in using ROV is its ability to sample at depths beyond the normal range of SCUBA divers.
- **Towed Underwater Video Camera**. In this technique, survey is made using a video camera mounted on an underwater vehicle that is towed and controlled along a strip transect at a fixed distance from the sea floor (Richards and Schnute 1986; King 1995). Live counts of fish may be obtained or the recordings are stored for later examination.

3.2.1.3 Remote sensing methods

Estimating fish stocks and productivity from satellite-derived phytoplankton biomass

Phytoplankton forms the base of the aquatic food chain. Through photosynthesis, phytoplankton converts inorganic material into organic compounds (or biomass). Consumers feed on the plant biomass and breaks down the organic compounds into their inorganic forms. In the process, energy is released which is used for movement, reproduction and growth. This nutritional interconnection between organisms (transfer of energy between components in an ecosystem) is trophic dynamics. The primary producers form the first trophic level and consumers form the higher trophic levels.

The process of the transfer of energy between trophic levels (or feeding), however, is not very efficient. Estimates vary but only between 3-23% of the energy in a trophic level are incorporated in the next trophic level (Christensen and Pauly 1993). A significant amount of the energy is lost because it is used up by the organism to move around looking for food and for the manufacture of non-nutritional tissue. This results in a rapid decline in biomass at each successive trophic level with the population size at a trophic level dependent on the food supply or the available biomass in the lower trophic level. It is therefore theoretically possible to estimate fish productivity or biomass of fish stocks using information about the trophic structure (e.g. how many trophic levels between phytoplankton to fish) and energy transfer efficiencies in between trophic levels. The difficulty lies in the fact that in reality, the trophic structure is not linear and unidirectional but more like a web with complex multiple pathways and links between different trophic levels. Software packages, such as ECOPATH, can compute for exchanges between trophic levels based on mass and energy balance.

One consequence of the low transfer efficiencies is that food chains can only afford to be short (few trophic levels) because only a very small percentage of the original phytoplankton biomass is available for the top predators. Members of successive trophic levels are therefore larger in size, fewer in number, and grow and reproduce slower. The size of plankton biomass is often a good indicator of biomass of the remainder of the food web and can be used to estimate potential fisheries production. Fish production can be estimated by calculating the total fish production at a particular trophic level from phytoplankton biomass or production and taking into account the transfer efficiencies at each level. Higher transfer efficiencies and fewer trophic levels lead to greater fish production. Fish populations in upwelling areas for instance, generally belong to lower trophic levels and are smaller in size compared to the large pelagics in the open ocean (Ryther 1969; Chen 2000).

Aside from determining the amount of fish stocks that can be supported by available phytoplankton biomass, it is important to determine fish production since the rate of fish production controls how much fish can be caught. This can be determined by estimating the annual primary production which is the amount of carbon converted into organic material per square meter area of the ocean per year (gm C m^{-2} yr^{-1}). Ryther (1969) estimated the mean annual primary production of the open oceans, coastal zones and upwelling areas to be 50, 100 and 300 gm C m^{-2} yr^{-1}, respectively. The annual primary production is given by

$$\mathrm{APP} = \mathrm{PPR} \times \mathrm{A} \qquad (3)$$

where APP is the annual primary production, PPR is the primary production rate and A is area for which the rate is applicable. The potential production at each trophic level (PP) can then be estimated using

$$PP = APP \times TE \quad (4)$$

where TE is transfer efficiency for each step. For multiple trophic levels, the transfer efficiencies between succeeding trophic levels is multiplied to the right hand side of equation (2).

The primary production rate (PPR) can be estimated in the field using a variety of methods including the ^{14}C method (JGOFS 1994) (measures amount of C fixed), Dark and Light Bottle Method (Parsons *et al*. 1984) (measures difference between gross and net production) or the use of fluorescence. However, these measurements tend to be expensive and time consuming. PPR can also be inferred from chlorophyll, a pigment concentration using phytoplankton production models (Platt & Sathyendranath 1988; Liu *et al*. 2000). The use of phytoplankton production models can provide rough estimates for wide areas as data from satellite remote sensing, vertical distributions of chlorophyll as well as field measurements can be combined and used as inputs. Typical models require information on cloud cover, surface chlorophyll distribution, parameters describing the water-column distribution of biomass and photosynthetic response of phytoplankton to light (Sathyendranath *et al*. 1995)

PPR can vary both in time and space. Nutrients from subsurface or bottom layers can be advected upwards by upwelling or turbulent mixing where it can be utilized by phytoplankton. Production rates can also vary with the type and size of phytoplankton (Chen 2000) and can be classified as either new or old production (Cabrera *et al*. 2002).

Acoustic methods in estimating stock abundance

Thorne (1979) reviewed the application of hydroacoustics in stock assessment for tropical small-scale fisheries. Limited trials of this method have been conducted in some parts of the Philippines (e.g. Hassan *et al*. 2000, Tanay 2002). This method is rapid and cost efficient but requires highly trained, calibration of software to suit target species (e.g. Dalen and Nakken 1983, MacLennan 1990) and advance equipment.

Application of remote sensing in baseline assessment

For rapid assessments, remote sensing provides a cost-effective way of acquiring background information for coastal resource management planning and for detecting changes over time. Studies on a variety of remote sensing platforms have been used and results vary in applicability and accuracy (summary in Green *et al*. 2000) and the type of remote sensing technology applicable to an area depends largely on CRM objectives. The key in any application of remote sensing is the need to integrate field surveys and remote sensing as this is the only way to assess the accuracy of image interpretation. Tools for accuracy assessment include the use of error matrices (Janssen and van der Wel 1994), kappa analysis (Congalton 1991) and Tau coefficient (Ma and Redmond 1995).

The use of remote sensing for habitat mapping is based on the principle that different types of habitats reflect electromagnetic waves differently. Thus the electromagnetic spectrum of the reflected light may be different and if the sensor can discriminate between the different spectra, the different habitats can be distinguished from each other. Of the different platforms available, the Landsat TM is probably the most cost-effective option for coarse-level habitat discrimination of reef and mangrove habitats (Green *et al*. 2000). LANDSAT has been used to map coral reef boundaries and the principal geomorphologic zones of the reef (e.g. reef flat, reef crest, spur and groove, etc) and some of the ecological components. Mapping with LANDSAT often results in >70% accuracy for the geomorphologic zones and less for the ecological components but can be increased using contextual editing and if complemented with broad-scale characterization. Other options are available if higher descriptive resolutions are required.

3.2.2 Gear-fisher history

Understanding the patterns of fishery development is a key source of information about both stock and fisher dynamics (Hilborn and Walters 1992). This parameter provides changes that occur during fishery development. The three important stages are initiation of development, growth and later decline of the fisheries and the later development cycles involving episodes of innovation and consolidation. Different key factors and processes are involved in each of these stages. In the Philippines, however, many of the historical information in the development of fisheries are not documented. In many cases, this type of information is obtained through participatory methods (e.g. FGD and key informant interviews) and gear-fisher inventory.

3.2.2.1 Gear-fisher inventory

For baseline assessment, a gear-fisher inventory is important to obtain current levels of fishing pressure, which is an important input in estimating changes in pressures relative to annual yields (e.g. Silvestre and Palma 1990). Under this method, the distribution of the number and types of gear and fishers are obtained through detailed field surveys.

3.2.2.2 Participatory Methods

Participatory tools and methods in fishery and coastal resources management are well developed and widely used by various development workers particularly in the Asia-Pacific region (e.g. Pacific Islands, India, Philippines). In the Philippines, a compendium of various participatory methods based on field experience of various local CRM practitioners and institutions (IIRR 1998) filled in the need for source books on participatory methods for the growing impetus for community-based coastal resources management. Of these the participatory resource/resource use mapping and coastal habitat assessment methods have became most widely used and modified in various CRM projects primarily as a means to familiarize local stakeholders with semi-quantitative methods used in assessment of seagrass, mangroves and coral reefs and preparation of a coastal profile for the development of CRM plans (e.g. Walters *et al*. 1998). Participatory monitoring and evaluation methods for MPA have also been recently developed by Uychiaoco *et al*. (1999). In comparison, there has been less focus on participatory fisheries assessment and monitoring and evaluation except in the context of coral reef fish sanctuaries. Focused group discussion facilitated by community resource and gear mapping, fishing activity calendars and trendlines provide valuable information of important spatial and temporal parameters associated with fishing and marine resources. In addition species composition and fishery-dependent catch rate estimates for various fishing gears can be derived as well as information on the perception of local communities about the status of their marine resources.

3.2.3 Habitat quality

From the perspective of fisheries ecosystem management, inclusion of key ecosystem indicators is important to baseline assessment studies. In general, key indicators consist of measures of species richness, species composition, diversity and abundance of each ecosystem type. The methods for estimating these indicators vary between types of ecosystem. An entire volume of the Bulletin of Marine Science (see Volume 69(2) 2001) was devoted to cover and review aspects of coral reef assessment, monitoring and restoration. In baseline assessment of habitats, the estimation of aerial cover is essential to provide the extent of study area and determination of sample size for detailed examination. Green *et al*. (2000) provide a review for resource mapping using remote sensing. For baseline assessment of reef communities, the most important parameters to indicate status and quality for coral communities are percentage cover of various benthic categories (e.g. live corals, dead corals, soft corals, abiotic components) (e.g. Gomez *et al*. 1994), and species composition, density and biomass for the associated reef fish (e.g. Hilomen *et al*. 2000). Methods of assessment of these parameters vary and are compiled in Gulko (1999), see Appendix 3. The most widely used method for estimating percentage cover of coral communities are the manta board reconnaissance technique, the line intercept transect (LIT) method and the videographic method. Similarly, fish visual census is used for assessing species composition, density and biomass of associated reef fish. These methods are well described in English *et al*. (1997). A summary of the advantages and disadvantages of these methods is included in Appendix 1.

For seagrass and mangrove communities, the most important parameters are extent of cover, density, frequency of occurrence of species, and composition and abundance of associated fauna, see Appendix 4. The widely used methods are summarized in Appendix 1.

3.2.3.1 Role of hydrodynamics

One of the requirements for the successful management of marine fisheries resources is the understanding of the interaction between fish populations with each other and with the environment in which they live (Bax *et al*. 1999). Each species has a preferred habitat, which is characterized by a set of environmental conditions (Simpson J.J. 1992) which will exhibit some degree of variability. Hydrodynamics can partly influence this variability and as a result can define the boundaries of the fish stocks. For instance, large-scale distribution of organisms are influenced by prevailing physical processes resulting in distinct biogeographic zones. However, within these zones, the variability of the physical environment and its interaction with physiological rate processes produces space-time variable populations (Gargett and Marra 2002). For instance, upwelling areas have high phytoplankton biomass and production utilizing nutrients advected from subsurface layers and the distribution of fish stocks dependent on the high phytoplankton biomass will therefore tend to be distributed within the area where it is available.

The other significance of hydrodynamics is the role it plays in larval dispersal and the effect of this on the spatial extent of adult populations (Largier 2003). Since there is a difference between the area where larvae are dispersed and where adults live, the survival of the species will depend on the compatibility between these two areas (Bhaud 2000). Advective and diffusive processes in the flow field can transport planktonic larvae across vast distances or entrain them locally in eddies and wakes (Wolanski *et al*. 1984). Coastal boundary layers, characterized by strong cross-shore shear can enhance retention close to the coast. However, small changes in cross-shore dispersal or larval behavior can result in significant differences in alongshore dispersal (Largier 2003). The highly variable nature of the ocean coupled with a lack of understanding of larval behavior makes the understanding and quantification of larval dispersal and its effect on recruitment, a continuing challenge.

Advancements in remote sensing and geographic information systems have made it possible to access spatial information and to visualize the consequences of human actions over large spatial and temporal scales of the marine environment. Such tools, if used judiciously can contribute significantly to ensuring wise practices in coastal management. Troost (1999) defines the three main domains of wise practices as knowledgeable manpower, knowledge-based applications and knowledge-based regulations. This means that wise practices involves the availability of knowledgeable manpower, good sources of information and availability of information analysis tools, that there should be wise methods for using the information and to have sufficient regulations to safeguard and ensure sustainability of the resource. In all three domains, geographic information systems play an important role. Geographical Information System (GIS) are powerful analytical tools to describe ecosystem components and to synthesize different types of information. Such systems can also simulate scenarios in response to management interventions as well as detect patterns in the different parameters for monitoring and detecting changes over time. The main drawback is misuse or even abuse of such information if not managed carefully.

3.3 Indicators and Parameters for Monitoring and Evaluation of Fisheries Ecosystem

The indicators and parameters for monitoring and evaluation include size and age structure, size at first maturity, growth rates, mortality rates spawning behavior, recruitment rates of stocks, habitat complexity and integrity, and the social, community and institutional aspects, in addition to those discussed and enumerated under the baseline assessment. Size and age structure of stocks respond to varying levels of fishing effort and can reveal changes in the status of stocks (Jennings *et al*. 2001). Size at first sexual maturity is essential in determining legal size limits if management objective is to allow fish to spawn at least once before they recruit to the fishery. The determination of the size limit is based on the trade off between maintaining a sufficient proportion of spawning stock biomass per recruit while at the same time attempting to maximize yield per recruit (Hill 1990). Age-based techniques estimate growth rates and mortality rates more reliably and accurately than length-based techniques due to the 'pile up' effect (i.e. multiple age classes in single length modes as the animals age) (Beamish and McFarlane 1987, Newman *et al*. 1996) and is often inaccurate due to enormous variations in individual growth rates (Sainsbury 1980). The growth and mortality are key components in analytical models used to predict potential yields of stocks.

4 Existing Baseline Assessment Practices in the Philippines

4.1 Habitats and Ecosystems Assessments: Fisheries Ecological Applications

Coral reef fisheries is perhaps one of the more commonly used example, to understand and illustrate the combination of ecosystem oriented baseline assessment approaches. Fishery dependent and non-fishery based approaches (Miclat *et al*. 1994, Alino *et al*. 1996, Alino and Dantis 1996, Abesamis and Alino 2001, Nanola *et al*. 2002, Alino *et al*., in press), can be used to derive information to guide efforts that complement biodiversity conservation and protection, as well as in the context of fisheries management.

The importance of baseline information to illustrate the correlation of the decline in trends of mangrove conversion and its implications to the decline in shrimp fishery production has been implicated by Camacho and Bagarinao (1986) and Primavera (2000). Seagrass beds and their importance to fisheries have only been implicated by a few studies in the Philippines (Fortes 1995). On the other hand, it remains difficult to isolate the habitat functional boundary delimitation as regards interconnected and interactive fisheries stocks. Thus it is suggested that stock identification techniques needs to be refined in order to better define the management regimes in tropical multispecies fisheries (Ochavillo 2001, Mamauag 2003). Population genetics utilized as tools to assist in stock identification and information from their genetic affinities are used to derive the connectivity of fisheries populations (Ablan 2001). In conjunction with oceanography and remote sensing techniques, the various assessment techniques in relation to fisheries management has increased its potential to improve cross- linking of the various management scales to that of fisheries dynamics and ocean processes.

Estimates of rent dissipation due to fisheries overexploitation have been derived from surplus production models of pelagic and demersal stocks in Philippine fisheries (White and Cruz-Trinidad 2001x), based on Dalzell's work (1987). In addition, the number of fisher density per km of coastline has been suggested by Tandog-Edralin *et al*. 1987 (as cited in White and Cruz-Trinidad 1998). Pauly and Chua (1988) utilized the example of the Samar Sea to suggest the overexploitation and the concomitant shift to deeper fishing areas. Various reviews of catch rates that afford a comparison with that of Philippines reefs have been made by Dalzell (1987).

Recent developments in improvements in fisheries analytical tools (Gayanillo 1996 and Ecopath with Ecosim and EcoSpace, Pauly *et al*. 2000) have been utilized to highlight the importance in understanding the dynamics of single species and multispecies fisheries. Alino *et al*. (1996) utilized Ecopath-Ecosim models to elucidate the susceptibility of the reef system vis-à-vis the pelagic fisheries as potentially affected by pollution. Only a few cases have demonstrated the possible effectiveness of fisheries management interventions in combination with marine sanctuaries (see Arceo *et al*. 2001a and Junio-Meñez *et al*. 2001).

4.2 Dealing with threats and fisheries overexploitation

Natural disturbances such as the El Niño phenomena and catastrophic events such as the Mt. Pinatubo volcanic eruptions have been suggested to have impacts on the fisheries productivity of coral reefs (Ochavillo *et al*. 1994, and Arceo *et al*. 2001b). In these examples the importance of before and after conditions in the assessment of impacts have been crucial. It has been suggested that management interventions may be crucial in the eventually recovery and trajectory of reefs (Arceo *et al*. 2001). It is not well understood how fisheries productivity are affected (Armada 1999, Barut 1999 and Rabanal 1999). Oceanographic examination of important upwelling features in the Northwestern and Southeastern Philippines suggest that they could have profound effects on the productivity in these areas (Salamante and Villanoy 2001).

Gomez *et al*'s (1994) review on Philippine reefs highlight the range of threats they experience and correlative analyses detected siltation as the predominant forcing factor related to coral cover attributes. Experts opinion based modeling with the aid of GIS overlays also indicate the prevalent risks that reefs may experience (Burke *et al*. 2002). Blast fishing and poison fishing (both illegal methods) have been suggested to be some of the major problems in fisheries management as suggested by Pauly *et al*. (1989) that has been labeled as Malthusian overfishing (Russ 1992). In response to these pressures the Philippines has been one of the leaders in good practices in establishing community based marine sanctuaries (Alcala 2002, White *et al*. 200x and Aliño *et al*. 2002). Despite the debate in the merits of a few large versus many small no-take areas, it is recognized that present efforts in marine conservation through no-take areas alone is not a panacea for fisheries management especially in overfished areas like the Philippines. It would urgently need greater impetus to improve management effectiveness, increase efforts in a wider range of options and productivity enhancement measures (Alino *et al*. 2003). Incorporating environmental governance measures in the various CRM initiatives together with the CRMP Municipal Coastal Database (MCD) and the MPA rating system (White, personal communication) are good practices to further develop. Feedback response mechanisms based on simple participatory assessments can also enhance the effectiveness of fisheries management and its adaptive management features (Uychiaoco *et al*. 1999). The simple participatory coral reef monitoring manual developed by Uychiaoco *et al*. (2000) is now being translated through UNEP in Bahasa, Thai, Chinese, Vietnamese and Khmer and the importance of inside and outside no-take areas are important good practices on coral reef monitoring for management effectiveness.

4.3 Local Knowledge and Participatory Approaches

Various syntheses and case studies of local CRM initiatives (e.g. Polotan-de la Cruz 1993, Alino & Juinio-Menez 1995, Ferrer *et al*. 1996, Rivera and Newkirk 1997, Alcala 1998, White and Vogt 200, Pollnac *et al*. 2001) invariably conclude that involvement of the local community at various steps in management is crucial (i.e. data gathering, collation and analysis and decision-making). The participatory approach does not serve merely as a means to gather stakeholder knowledge, it is a vital step to engage local stakeholders, develop support and enjoin active participation in the resource management process.

There are few documented existing traditional fishing management systems in the country such as the *mataw* fishery in Batanes (e.g. Lopez 1985, Mangahas 1993, 2000). Majority of coastal communities that comprise the bulk of artisanal and municipal fishers are comprised of heterogenous migrant communities (CRNRM-Coastal Team 2001). Thus traditional fishery beliefs and management practices may have been overshadowed by community transformations due to migration/immigration, technology modernization and the ever increasing demands of a rapidly growing population. Nonetheless, fishers in a particular locality have acquired knowledge about the biology of the fishery resources they depend on and various ecological aspects that affect their livelihood (e.g. local hydrological and atmospheric factors). Gathering and analysis of this information is vital in the assessment phase of any management project.

5 Proposed Methods for Field Site Assessment

Based on the fisheries ecosystem assessment practices outlined earlier the initial approaches, methods, measures of their specific parameters and variables for baseline field assessment are outlined below. Both science-based and local knowledge-based approaches are utilized together with the relevant methods and analyses. The information derived from the assessments will be inputted in a Geographic Information System database (e.g. Marine Information and Data Analysis System or MIDAS configured to be compatible for Philippine Fisheries Information System or PhilFIS) management. Particular parameter indicators or through overlays will also consider how these may be compatible with decision support tools (e.g. Ecopath, EcoSIM and EcoSpace, Pauly *et al*. 2000, FISH BE model, Licuanan *et al*. 2003).

5.1 Science-based Fisheries Ecosystem Assessments

An orientation and scoping will be undertaken for each site to clarify the objectives and level off expectations at the target sites. This will initially facilitate the definition of a preliminary scale for the fishery baseline and its relevance to the management evaluation strategy and the framework for assessments, monitoring and evaluation and performance effectiveness of fisheries ecosystem management.

5.1.1 Fisheries Assessment

5.1.1.1 Site secondary data review and collection

- Survey availability data from local academic institutions in each of the four study sites for completed reports of relevant fisheries projects
- Obtain initial data on the number and types of fishing for each coastal village from Municipal Agricultural Officers, village leaders or relevant local associations
- Obtain relevant maps to determine type of bottom cover of fishing grounds in each of the study sites. Grid maps at scales of 1 km^2 will be generated for each site and used to determine location of fishing areas.
- Obtain historical data on fisheries production from Bureau of Fisheries and Aquatic Resources (BFAR), Bureau of Agricultural Statistics (BAS), etc.
- Based on initial data, sampling design for experimental fishing, gear-fisher inventory, landing surveys will be formulated. Sampling design for each activity will observe standard protocol (Green 1979). At this stage, the permissibility of experimental fishing in each study site will be explored given the legal constraints on some of the gears for particular waters (e.g. trawl in municipal waters)

5.1.1.2 Rapid fishery assessment

- Remote sensing to estimate fish biomass from estimates of primary productivity. This method will be combined with rapid stock assessment survey to complement and validate results from remote sensing
- Field sampling to execute experimental fishing if appropriate and permissible. Experimental fishing is desired because it will complement and validate fisheries data obtained from remote sensing, participatory methods and habitat data. Choice of gear(s) for experimental fishing will depend on legal considerations and target stocks of interest.
- Choice of sampling area will be made a priori depending on results of remote sensing (e.g. areas of interest such as potential upwelling areas) using grid maps (see above).
- Gear-fisher inventory will be conducted in fishing villages with existing management interventions as well as those with none. The number of fishing villages in each case will be decided after an initial set of information is obtained.
- Survey of landed fish will be conducted at principal and secondary landing areas. This will focus on catch composition, locations of fishing, sizes of catch, catch volume and fishing effort.
- Data encoding and management.

5.1.1.3 Analyses and report generation

- Status of stock abundances will be derived based from a combination of methods (e.g. CPUE, estimates of biomass from remote sensing methods, sizes of catch, catch composition)
- Distribution of stocks will also be derived based on a combination of tools such as grid-map approach
- Formulation of design recommendations for monitoring and evaluation.

5.1.2 Assessment of habitats and their associated resources

5.1.2.1 Site secondary data review and collection

- Background and historical information (including various types of maps and satellite images) on resources assessments, fisheries production and other uses, existing management efforts e.g. zoning plans, practices and institutional arrangements.
- Other attributes to be derived: such as geomorphological and climatological observations and threat indicators – such area of deforestation, other uses and impacts (e.g. including level of fishing) of the area will be endeavored.
- Initial analyses of the major issues and potential drivers of the fisheries will also be gleaned and important sampling design considerations will be elicited.

5.1.2.2 Rapid Area Assessments

- Mapping and Remote Sensing (Habitats and deriving natural and human induced threats) will be utilized to provide the link for location samples to higher level scales (e.g. area of habitats and their distribution)
- Ground Truth and validation of habitat extent and distribution patterns
- E.g. Manta tows, ocular inspections and other triangulation validation techniques.
- Analyses: Inferential and exploratory techniques for classification of habitats and boundary definitions will utilized to discriminate scale and appropriateness consideration in order to scale-up some sample
- Database management (including GIS) and decision support inputs.

5.1.2.3 Associated resources and habitat assessments relevant to fisheries and ecosystem management

These are often referred to as fishery independent methods to gauge the habitat conditions, threats and trends (e.g. distribution and abundance of benthic and fish communities; and when possible to include some indications of important target or endangered or threatened species).

- Coral Reefs – manta tows, lifeform benthos transects in tandem with underwater fish visual census modified from English *et al*., 1997, see also Nañola *et al*. 2002 to include size and patch estimates when necessary derived from RS images and various benthos indicators – e.g. condition indices, successional indices and development indices and fish reproductive sizes, important indicator species abundance and composition.

- Seagrass – Rapid seagrass appraisals; with some retrospective analyses in some areas (Short and Coles 2001)
- Mangroves – Belt transects as described by English *et al*. (1997); Talbot and Wilkinson (2001)
- Other resources associated habitats: other fishery independent assessment methods will be explored if appropriate and doable to link the condition of the fishery with estimates derived from fishery dependent or harvest yields information.
- ANALYSES:
- Classification analyses to gauge distribution and process indicators
- Some inferential statistics to derive developmental and successional stage indicators (ecosystem health condition indicators, see Done and Reichert 1998);
- Database management (including GIS) and decision support to derive an initial site classification and have indicative management regime zones
- These attributes and variables are then related to how these resources and ecological assessment information are relevant to fisheries management.

5.2 *Rapid participatory methods could be employed for exploratory and topical appraisals to get a "good" picture of the area being looked into. The most important tools for rapid fisheries assessment are:*

5.2.1 Habitat, resource and resource use mapping

- Distribution of coastal habitats are gleaned but not the status which will be complemented by the field habitat surveys
- Resource use mapping focuses on the different types of fishing gears and where they are used and major species caught; size of major species caught, relative quantities
- Transect diagram distribution of common fish species with respect to distance from shore/depth

5.2.2 Focused group discussions

a. Fishing and activity calendars

- Derived from discussions on the temporal pattern of fishing activities, major resources exploited, seasonal factors affecting fishing activities (including observations on fry and spawning aggregation observations)

b. Catch Per Unit Effort

- Derived from discussion in relation to major gears identified in seasonal calendar

c. Trend line

- Gauged from total catch per day, species, sizes, causes of changes as gleaned from discussions with "Fishers" who have fished for more than a decade

d. Commodity flow diagram

- Derived from discussions in the marketing and trading system

e. Issues, conflicts, opportunities

- Map facilitated discussions at the village level discussing the threats, issues and concerns and opportunities

5.2.3 Key informant interviews (semi-structured interviews)

a. CPUE is gauged from fishers of different major fishing gears

b. Fishing ground location to be identified on a base map that has grids

c. Profile and analyze the prices of fishery products and their influencing factors such as fishers, traders, buyers etc.

d. Seasonal and other temporal patterns of activities derived from fishers, traders, buyers etc.

e. Characterize the trade and financing systems (e.g. fishers, traders, buyers) and compare with commodity flow diagram in Focus Group Discussion (FGD)

f. Fishery management (institutional characterization of relationships between local government officials, Municipal Agricultural Office/Officer (MAO), Fisheries and Aquatic Resources Management Council (FARMC), bantay dagat) and corroborate with local documents (see also Municipal Coastal Database of CRMP certification criteria and incorporate EcoGov CRM assessment criteria for governance criteria)

5.2.4 Market surveys/vendor interviews

a. Landed catch

- Species composition, size frequency distribution compared with supervised fishing/experimental fishing
- Prices of fishery products and influencing factors compared with household interviews
- Provides validation, of fishery resources for local consumption and results derived from Focus Group Discussions

6 Summary and Implications to the FISH Project Baseline Assessment and Baseline Contractor

As indicated in the earlier sections, fisheries ecosystem management can be pursued in the context of adaptive co-management. It would entail three major phases of science inputs into the management strategy evaluation from the initial phase of baseline assessment indicators, to the design of monitoring and evaluation of performance measures as linked to the effectiveness of management in relation to its goals, objectives and targets.

The various criteria in the review of the FISH contractor relate to the various aspects of the framework of the PROJECT as information is utilized at various phases of a management strategy. Aspects of the criteria would relate to the evaluation of:

a) The framework (e.g. through the management process of planning, implementation and monitoring) and its approaches (e.g. science based and local knowledge and participatory features);
b) The assessment and M&E methods together with their associated indicators and performance measures;
c) The evaluation of the types of information gathered to achieve the management goals and objectives and their analytical procedures;
d) The appropriate scale of the phenomenon that is being measured (e.g. target species or ecosystem functions or trophic groups);
e) The adaptive features (hypotheses and adjustments to alternative scenarios), its mainstreaming and institutionalization of sustainability.

The third party independent baseline and performance evaluation is a good practice that helps improve the elucidation of management effectiveness (e.g. Done and Reichert 2000 and WCPA 2002 on the biophysical, socio-economic and governance) and sustainability (sensu Charles 1994 referring to ecological, socio-economic and community) criteria of the FISH contractor. Since one of the major goals of the FISH project is to increase by 10% the fisheries productivity in the four target sites, much of the crucial evaluation hinges on the biophysical attributes. On the other hand it goes without saying that it is as crucial not to unduly neglect (as often is the gap) and link the ecological with the other criteria related to the social, economic and governance concerns (e.g. using the WCPA 2002 M&E criteria). The challenge then is to sustain the project impacts in the various criteria of effectiveness and sustainability by enhancing the complementation of all the aspects of the fisheries through the synergy of their components as manifested in ecosystem management multiple dimensions.

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Appendix 1. Summary of methods for baseline assessment in fisheries. Methods in bold have been used in various studies in the Philippines

Indicator/Parameters	Importance of Indicator/Parameter	Methods	Advantages	Disadvantages	Reference for Methods
Abundance and distribution of stocks	Important in establishing status and spatial and temporal abundance and distribution of fisheries stocks Key input to numerical analytical models in fisheries	Experimental fishing to obtain CPUE, catch composition • Fish traps • Fish depletion • Mark-recapture • Egg production • Gillnets and trammel net • Purse seine and lampara nets • Swept area (e.g. trawl)	• Scientist can adopt most appropriate sampling design • Applicable to all types of fish using varied fishing methods • Good measure of relative abundance • One of the best ways to directly determine status of stocks particularly when combined with other methods	• Some assumptions inherent in methods are difficult to test • Difficulty in standardization of effort • Comparison across different methods may not be valid • Dependent on fishing skill and efficiency of gear • May further deplete stocks of near collapse species	Saville 1977, Andrew and Mapstone 1987, Recksiek *et al.* 1991, Gunderson 1993, King 1995, Appeldoorn 1996, NRC 1998
		UVC techniques • Strip transects • Line transects • Point counts • Remotely operated vehicles • Towed U/W Video camera	• Non destructive sampling technique • Provides actual estimates of proportion of entire stocks • Can provide estimates of biomass when sizes of fish are included	• Limited to diurnal and non-cryptic species • Dependent on water visibility • Accuracy low in estimating schooling or migrating stocks • Requires highly skilled observers	Uzmann *et al.* 1977, Burnham *et al.* 1980, Sale and Douglas 1981, Brock 1982, Sale and Sharp 1983, Fowler 1987, Buckley and Hueckel 1989, Green and Alevizon 1989, Bergstedt and Anderson 1990, Butler *et al.* 1991, Cheal, and Thompson 1997, Mapstone and Ayling 1998

		Remote sensing methods • Satellite/aerial remote sensing	• Cost effective way of rapid assessments covering large areas • Estimate geoboundaries of habitats • Can detect types of habitat • Can detect changes over time	• Link between producers and fish is confounded by trophic cascade effects • Present technology is limited in resolving components of ecosystem	Thorne 1979, Sathyendranath et al., 1995, Chen 2000, Cabrera *et al*. 2002,
		• Acoustic methods	• Assess stock biomass over large areas using phytoplankton production models or acoustic signals	• Present technology may not be able to distinguish different stocks	Dalen and Nakken 1983, MacLennan 1990, Hassan *et al*. 2000, Tanay 2002
Gear-fisher history	Provides historical patterns in fishery development Provides better understanding to dynamics of gear and behavior of stocks Important inputs to implementation of management options	• Participatory approaches (e.g. FGD, Key informant survey)	• Strengthen participation of locals • Ensure management sustainability	• Perception bias • Variation in background of respondents • Difficulty in sampling respondents • Difficulty in sample design and analyses	Townsley 1993, Polotan-de la Cruz 1993, Alino & Juinio-Menez 1995, Ferrer *et al*. 1996, Rivera and Newkirk 1997, Alcala 1998, Walters *et al.* 1998 White and Vogt 200, Pollnac *et al*. 2001

		• Gear-fisher inventory	• Inventory can be basis for management implementation • Can capture all forms of exploitation in a given area • A good reference data on current levels of exploitation • Data can project total annual production when catch rates are available	• Tedious and time consuming • Requires well trained personnel to conduct inventory • Variants within a gear type can pose a problem	Silvestre and Palma 1990, Hilborn and Walters 1992
Habitat quality • species composition • species richness • diversity • abundance	Provides the ecological condition of each habitat Essential in the evaluation of biological integrity of ecosystems in terms of supporting exploited stocks Provides inputs for suitable management interventions	General • Resource mapping using remote sensing	• Cost effective covering large areas • Estimate geoboundaries of habitats • Can detect types of habitat • Can detect changes over time	• Present technology is limited in resolving components of ecosystem	Green *et al.* 1995, Green *et al.* 2000

		Coral communities • Manta tow • Line Intercept Transect • Videography	• Large areas can be covered in a relatively short time • Relatively simple • Can be conducted with minimum skill requirements • Relatively cheap to operate over time • Little equipment and relatively simple	• Not suitable for areas with poor visibility • Difficulty in standardization of some lifeform categories • Objectives limited to percent cover data and relative abundance • Inappropriate for population studies • Difficulty in detecting temporal changes	English *et al*. 1997, Samways and Hatton 2001, Segal and Castro 2001
		Reef fish communities • Fish visual census	• Rapid and inexpensive assessment • Non-destructive • Repeatability • Minimum use of manpower and equipment • High potential for producing large databases rapidly for management and stock assessment	• Requires well trained and experienced personnel • Repulsion/attraction of fish to divers • Observer error and biases occur in estimating numbers and sizes and fish • Low statistical power to detect changes in rare species • Use of abundance categories reduces power to detect small changes • Depth restrictions	Brock 1982, Andrew and Mapstone 1987, Green and Alevizon 1989, Gunderson 1993, English *et al*. 1997,

		Seagrass • Quadrat method • Productivity • Beam trawl survey	• Simple and can be done with minimum of manpower and facilities • Methods very reliable • Allows below characterization of below ground plant parts • Highly selective for juvenile prawns and fish • Easy to deploy	• Collection of vegetation can be destructive • Counting of shoots can be time consuming • Dependent on the nature and distribution of seagrass meadows • Catchability bias • Difficult to quantify bias	Saito and Atobe 1970, Mellors 1991, English et al. 1997
		Mangrove • Angle count cruising method • Transect line plots method	• Easy to apply and is relatively fast • Simple equipment and relatively cheap • Allows description of forest types and their distribution • Permanent plots allow detection of temporal changes	• Size of plot in method is undefined • Inappropriate to detect temporal changes • Time consuming	English *et al*. 1997

Appendix 2. Details of some methods utilizing measures of CPUE and fish density in estimating relative stock abundance

CPUE-based methods

Fish traps

Fish traps have been used as an effective tool in sampling fishes, especially in "rugose habitats" such as coral reefs (Miller and Hunte 1987; Recksieck *et al*. 1991; Acosta *et al*. 1994; Appeldoorn 1996). Traps are inexpensive, commonly used fishing gear by commercial fishermen, can be deployed over a wide range of habitat types and can capture a wide range of species and sizes of fish. In using trap catch to estimate stock size of abundance, traps have to be "calibrated for catchability or effective area fished (EAF) (Miller 1975; Eggers *et al*. 1982; Recksiek *et al.* 1991; Acosta *et al*. 1994; Appeldoorn 1996). In addition, the confounding effects of habitat type on trap catches have to be eliminated before using them in fisheries stock assessment. EAF can be calculated in two ways. EAF can be determined from trapping experiments where a series of traps are deployed at different between-trap distances (Eggers *et al*. 1982). A reduction in trap catch is observed when traps are set close to one another because of interference effects (EAF can roughly be defined as the area around the trap at which two traps begin to interfere with one another). In this scenario, stock biomass (B) = CPUE * (A / EAF); where CPUE = catch per unit of effort and A = total area of the stock (King 1995). EAF can also be calculated when an independently derived fish density (d) is available (e.g., from UVC methods; see above). In this scenario, EAF = CPUE / d; where d is fish density (fish per m^2) (Appeldoorn 1996). If the fisheries stock is distributed over a heterogeneous habitat, a stratified sampling design is employed in setting up the traps; and EAF of traps deployed at each stratum is obtained (Saville 1977; Green 1979; Andrew and Mapstone 1987; Fowler 1987; Recksiek et al. 1991).

Purse seine nets and lampara nets

Purse seine and lampara nets operate similarly in catching schools of fish such as tuna and mackerel (King 1995). Although, commercial fishermen consider these fishing gears as very effective in catching pelagic, schooling fish species, their use in estimating stock abundance in tropical fisheries is hardly tested.

Gill nets and trammel nets

Gill nets and trammel nets are set on the surface of deep-water or on the bottom of shallow-water fishing grounds, and used to catch pelagic fish such as mackerel and tuna or demersal species such as sharks, scarids and acanthurids (King 1995). Although commonly used by commercial fishers, the efficiency of using gill nets and trammel nets in estimating fisheries stocks is hardly tested in the tropics (Appeldoorn 1996). These fishing gears are highly selective and in the few quantitative studies on the effective use of gill nets and trammel nets as sampling tools for reef fishes and on the size-selectivity nature of these fish-entangling gears revealed that "obtaining an independent estimate of abundance to calculate effective area fished was difficult" (Acosta 1993, 1994; Acosta and Appeldoorn 1995; Appeldoorn 1996).

Fish density-based methods

Swept area methods

Although of limited utility in rugose habitats such as coral reefs, trawl nets have been used as both fishery-dependent and fishery-independent sources of catch data. Stock biomass (B) can be estimated from the mean catch (C) per unit of area swept (a) by the trawl multiplied by the total area of the stock (A) (King 1995). The effective area fished is calculated as a = W * TV * D; where W = effective width of the trawl (i.e., distance between doors at the opening of towed trawl), TV = towing velocity; D = towing duration. Considering that not all fish along the path of the trawl actually end up in the codend, $B = C_w/v * (A/a)$, where v = vulnerability (i.e., the proportion of fish along the path of the trawl that is retained in the codend; C_w.= mean catch (in weight) per tow. It is often difficult to estimate v except for those who use underwater video camera to monitor fish along the path of the trawl. A vulnerability value of 0.5 (i.e., trawl catches 50% of fishes along its path) or a more conservative value of 1.0 (i.e., all fish are vulnerable to capture by the trawl.

Others

Fish depletion methods

In fishing grounds that are considered isolated and discrete and the fisheries stock is considered closed (e.g., deep-water snapper fishery in Western Samoa (King 1990)), fish depletion experiments (e.g., Leslie methods, Ricker 1975) can be used to estimate stock size (King 1995; Appeldoorn 1996). These methods are applicable in estimating abundance of fish in coral reefs because many reef-fish species have site fidelity for at least for a short period of time, have limited home range, and some reefs can be considered restricted (references in Sale 1991 and 2003). In a fish depletion experiment, a fish population is completely removed (i.e., overfished). This is feasible in "bays along a coastline, or on a chain of separated banks or sea mounts" where the fish stock "can be closed off using mesh nets" and then "intensively fished" (King 1995). The number of fish (N_t) at a given time (t) is estimated as $N_t = N_\infty - \Sigma C_t$; where N_∞ = original stock and ΣC_t = accumulated catch up to time t. Likewise, $CPUE_t = qN_\infty - q\Sigma C_t$; where q = catchability coefficient (see King 1995 for further details of this method). The linear relationship between $CPUE_t$ and ΣC_t is then defined to obtain the slope and intercept of such relationship. In doing so, q = absolute value of the slope and N_∞ = intercept divided by the slope (King 1995). The fish depletion method had been used to estimate biomass of fishes on coral reefs (e.g., Appeldoorn and Lindeman 1985; Polovina 1986; King 1990).

Mark-recapture methods

In tagging experiments to estimate fisheries stock biomass (e.g., Petersen method), fish are captured from the population, tagged, and then released back into the stock. The Petersen mark-recapture technique is based on the premise that T / N = R / C; where T = the number of tagged fish, N = fish stock size, R = the number of recaptured tagged fish, and C = the number of fish caught. Thus, N = T*C / R (King 1995). For this estimate of stock size to be valid, the assumptions that fish in the stock are randomly distributed within the habitat and that each fish (tagged or untagged) in the stock has an equal chance of being captured by the fishing gear used (King 1995; Appeldoorn 1996). The latter requires that after the tag and release procedure is conducted, no recruitment, mortality, immigration, emigration and changes in fish behavior had occurred in the fisheries stock of interest. The main problems associated with the mark-recapture technique are the need for large sample size in order to arrive at a reliable estimate of stock size and the fact that the assumptions stated above are difficult to meet (King 1995; Appeldoorn 1996). There are a few studies that utilized mark-recapture techniques to estimate fish stock biomass on coral reefs (e.g., Recksiek *et al*. 1991).

Egg production methods

In fish populations that form spawning aggregations, the mean density of eggs (collected using plankton tows throughout the spawning stock) can be used to estimate stock biomass (Parker 1980; Sale 1991; Samoilys 1997; Zeller 1998; Sale 2003). In this method, stock biomass = daily egg production / (fecundity * proportion spawning (King 1995)). Egg production methods are effective in estimating stock biomass only when the sex ratio and the relationship between fecundity and fish size are known. This method is especially useful in fisheries stocks that are characterized by variable CPUE.

Appendix 3. NCRI Coral Reef Monitoring Methodology Comparison Chart (Compiled by Dave Gulko, Division of Aquatic Resources, State of Hawai'i)

Name of Monitoring Technique	Primary Organism Monitored	Questions Addressed by Method	Measurement Parameters	Impacts Assessed	Method Specifically Addresses: A, D (for A & D: √P, √A, √C), P, S, H, I, D, C	Method Specifically Measures: E, O, S, P, D, R, P, AC, CD, MPA, AS, CH, RA, CRH, DI, V	Monitoring Frequency	Specific Equipment Required	Cost	Specific Require-ments	Statistics & Taxonomy: Field, Stats, Lab, Direct	Personnel: CV, HS, RM, SR	Training # / #	Major Advan-tages	Major Disadvan-tages	Contributor (Classification/ Primary Interest)	Reference for Method
Airborne & Satellite Digital Remote Sensing	Coral, Algae, Active Sediment, Antecedent Fossil Reef[2]	- Can Spectral Imagery be Used to Determine Reef System Bathymetry? - Spatial & Compositional Distribution of Reef Ecosystems? - Threshold Stress for Bleaching?	1). % Coral Cover[1] 2). Geometry of Sedimentary System[2] 3). Composition (# Spp.)[1] 4). Water Color[3] 5). SST[3]	1). Sediment Cycles[2] 2). Global Climate[3] 3). Interaction of Geologic & Biologic Processes 4). Disturbance[6] 5). Coral Reef Health/Recovery[3]	H[3] AD-√P, S, H, C[5] AD-√C, P, H, I, C[6]	E, S, P, CD, PO, RA, CRH, V[3] E, S, R, CD, MPA, CH, RA, DI, V[5] E, S, P, D, R, CD, MPA, CH, RA, V[6]	2+[6] Y[6] S[6] M[5,6] D[3]	- Remote Mapping/Data Acquisition - Diver Mapping Tools - Computer & Software (Data Analysis) - Airplane with Hyperspectral Sensor[5] - Hyperspectroradiometer[5] - GPS[5]	$8,000 + $2,000 + $40,000 + per day $50,000[5] $35,000[6] ?	Boat[3,5,6] Air[5,6] SCUBA[5]	Field[4] Stats[5,6] Lab[5] Direct[3,5,6]	HS[3] RM[3,6] SR[3,5,6]	1-2/10[6] 4+/1[5] 4+/6 months[3]	1) Highly Accessable Visual Imaging.[1,2,6] 2) Bathymetry & Coral Type Classification Analysis. 3) Well Calibrated[3] 4) Global.[3,5] 5) Time-Effective[5]	1) $$$[1,2,6] 2) Rapidly Advancing Technology.[1,2,6] 3) Still Being Developed. 4) Resolution.[3,5] 5) Penetration Through Water Column[5] 6) Cloud Cover.[3]	[1] E. Hochberg (A/V) [2] E. Isoun [3] A. E. Strong (A/I) [4] D. Worthy [5] H. Holden (A/I) [6] D. Potts (B/B)	Clark *et al.* (1996). *Int'l. J. Remote Sensing* 16:237-242[6] Mumby *et al.*(1998). *Coral Reefs* 17:59-69[5,6] Roberts, A.C. & Anderson, J. M. (1999). *Int'l J. Remote Sensing* 20(3): 497-510.[2] Wilkinson *et al.* (1999). *Ambio* 28(2): 188-196.[3]
Aquanaut Survey Method	Coral, Fish, Algae, COTs, Substrate Type, Echinoderms	- Major Community Changes Inter-annually? - Probable Causes of Major Changes?	1). % Live/Dead Coral Cover 2). % Macroalgae 3). % Coral Damaged	1). Local, National, Regional & Global Reef Changes 2). Indicators of Coral Reef Health via Multivariate Analysis	?	?	?	- Coral & Fishing Weights - U/W Paper (Duracopy) - GPS - SCUBA Gear	?Each $2 Each $0.4 $250 + $1,700 +	SCUBA	Field	HS CV RM SR	2/24	1) Optimizes Sample Time by Optimizing Diver Time. 2) Simple to Teach. 3) Objective & Repeatable. 4) Permits Global Reef Comparisons	1) Coverage Area Less Than Manta (but more objective). 2) Requires Learning Coral Growth Forms.	J. McManus	McManus *et al.* (1997). Reefbase Aquanaut Survey Manual. ICLARM. 61pp.
Atlantic & Gulf Rapid Reef Assessment (AGRRA)	Coral Only[1] Coral,Fish & Algae *Diadema*[3,5]	- Spatial & temporal patterns in coral mortality?[1,3,4,5] - Change in algal/herbivore & fish communities?[3,5]	1). % Coral Cover[1,4,5] 2). Mortality[1,2,3,5] 3). % Algal[2,3,4] 4). Bite Marks[3] 5). Key Fish Spp. Sz/Abundance[1,2,4]	1). Scale of Mortality[3] 2). Patterns of Size, Spp., Zones[5] 3). Spp. Declines[2,4] 4). Altered Trophic Webs[5]	A-√C, P, S, H[1] AD-√C, P, S, H, I, D[2] AD-√P, AD-√C, P, S, H[4] AD-√C, P, S, H, I, C[3,5]	E, O, S, D, R, PO, CD, MPA, RA, CRH, DI,V[3] E, O, S, P, D, R, PO, MPA, CRH, DI, V[4] E, O, D, R, PO, MPA, RA CRH, V[1,2,5]	2+[2,3,5] Y[4] S[1,4]	- Transect Lines[1,3,5] - U/W Paper - Video[1] - Water-Sampling Suppl[4] - Quadrats[1,4] - GPS[4]	? $7 -$25 $3000[1] ? ? ?	Boat[2,3,4,5] SCUBA[1,2,3,4,5] PM[1]	Field[1,2,3,4,5] Stats[2,3,4,5] Lab[5] Direct[1,2,3,4,5]	RM[2,3,4,5] SR[1,2,3,4,5]	2/5days[1] 2-4/3-5[2] 2/2days[3] 4+/10[4] 1/2days[5]	1) Rapid[2,3,4,5] 2) Low tech, so suitable in remote areas[3] 3) Effective & Widely Applied[1,2,5]	1) Snapshot Only[2,5] 2) Taxonomic Expertise Required[3] 3) Non-experimental[4] 4) No Visual Record[2,3,5]	[1] A. Bruckner & R. Bruckner (B/I) [2] R. Ginsburg (AB/I) [3] J. Lang (AB/I) [4] P. Peckol (B/I) [5] R. S. Steneck (B/I)	Ginsburg, R. N., Steneck, R. S., Lang, J. & Kramer, P. (1998). Atlantic-Gulf Reef Assessment, *Proc. ISRS, France, Sept. 1998.*[5]
Bioindicators (Butterflyfish)	Coral, Fish	- Changes in Ecological Conditions of Reef?	1). # & Size of Fish Territories 2). Rates of Agonistic & Feeding Behavior 3). % Coral Cover	1). Anthropogenic Effects on Reefs 2). Small, Gradual, Chronic Reef Disturbances 3). "Early Warning"	A, P, H, I, C	E, S, P, D, R, CD, MPA, CRH, DI,V	Y S	- Transect Line - Measuring Tape - U/W Paper (Xerox Never-tear) - Surveyors Tape, Nails	Each $20 Each $40 Each $0.5 $20	SCUBA	Direct	HS CV RM SR	2/4	1) Easy to Learn. 2) Inexpensive. 3) Sensitive to Changing Conditions (Early Warning) 4) High Educational Value	1) Does Not Identify Cause of Changing Conditions 2) Provides Diversity Estimates for Coral & Fish Only.	E. Reese (BA/I), & M. Crosby	Crosby & Reese, (1996). Butterfly-fish Bioindicator Manual for Monitoring Coral Reefs. NOAA, Silver Spring, MD. 45pp. Jameson *et al.*. (1998). *Atoll Res. Bull.* 450:?

Name of Monitoring Technique	Primary Organism Monitored	Questions Addressed by Method	Measurement Parameters	Impacts Assessed	Method Specifically Addresses: A, D (for A & D: -/P, -/A, -/C), P, S, H, I, D, C	Method Specifically Measures: E, O, S, P, D, R, P, AC, CD, MPA, AS, CH, RA, CRH, DI, V	Monitoring Frequency	Specific Equipment Required	Cost	Specific Require-ments	Statistics & Taxonomy: Field, Stats, Lab, Direct	Personnel: CV, HS, RM, SR	Training # / #	Major Advan-tages	Major Disadvan-tages	Contributor or (Classification/ Primary Interest)	Ref-erence for Method
Floating Grid Method	Coral, Fish	- Temporal Shifts in Coral/Fish Assemblages? - Influence of Coral Mortality on Reef Fish Populations?	1). % Coral Cover 2). % Benthic Cover 3). Reef Fish # & Composition	1). Spatio-Temporal Patterns of Coral Colonization 2). Variab. in Reef Fish #/ Assemblages	AD-/P, AD-/C, S, H, I	E, O, S, D, R, MPA, DI, V	Y S	- Floating Nylon Lines (10) - Polyethylene End Ropes - Digit. Camera & Housing - Digit. Video & Housing	Each $20 Each $20 $1000 $6500	Boat Lab SCUBA PM	Stats Direct	HS RM SR	1-2/5	1) High Reso-lution, Archival Imagary	1) Requires Extensive Computer Analysis in Lab.	D. Weaver (B/B)	None
Participatory Coastal Resource Assessment	Coral[1], Fish[2], Algae[1], Inverts[1]	- Significant Economic Resources of Reef? [1] - Resource Use Issues? - Dynamics of Artisanal Fishery[2] - #, Spatial & Seasonal Patterns of Reef Resources?[1]	1). Spatial Substrate Distrib.[1] 2).Value/Revenue of Reef Resources[1] 3). Fish Spp., WL, & Distrib.[2] 4). Harvest Effort /Reef Resource Prod. #s[1]	1). Overfishing[1,2] 2). Destructive Fishing[1] 3). Fishing by Outsiders 4). Other Human Impacts 5). Cultural Factors & Fishery Mgmt.[2]	A-/P, A-/C, S, D[1] AD-/A, S, I, D[2]	E, O, P, AC, MPA, AS, CH, DI, V[1] O, R, AC, CD, MPA, AS, CH, RA, V[2]	2+[1] Y[1] W[2]	- Topo-graphic Maps/Nauti-cal Charts[1] - Field ID Guides[1] - GPS[1] - Aerial Photos, Satellite Imagery[1]	? ? ? ?	None[1,2]	Field[1,2] Stats[2] Direct[1,2]	HS[2] CV[1,2] RM[1,2] SR[1]	1/4[2] 2/1[1]	1) Generates Key Econ. & Ecol. Info. Required for Manage-ment.[1] 2) Involves Local Users & Focuses on Their Experi-ence & Priorities.[1] 3) Applic. by Fisher-men[2]	1) Training Time for Local Volun-teers.[1] 2) Analytical Technical Support Neces-sary.[2] 3) Manage-ment of Volun-teers is Time Consu-ming.[2]	[1] J. Walters (R/I) & J. Maragos (R/I) [2] D. Obura (B/I)	Walters, J. S. *et al.* (1998). Participa-tory Coastal Resource Assess-ment Handbook. Coastal Resources Manage-ment Project.[1]
Recruitment Surveys	Coral, Algae	Distribution & Abund. of Corals & Recruits? Genetic Relationships?	1). Recruit Distribution & Abundance 2). % Adult Coral Cover	1). Are Reefs Self-Seeded	AD-/P, AD-/C, AD-/A, P, S, H, C	E, S, P, D, R, PO, AC, CD, MPA, RA, CRH, DI, V	Y	- Recruitment Plates - Chain (Transect)	? ?	Boat SCUBA PM	Field Stats, Lab Direct	HS	1/2	1) Relatively Simple.	1) Taxonomic Knowledge Needed. 2) Time Consuming	P. W. Sammarco (B/B)	Sammarco, P. W. (1991). *L & O.* Sammarco, P. W. (1982). *JEMBE.*
Reef Check	Coral, Fish, Algae	- Baseline Information?[1] - Annual Change in Reef?[1-3]	1). % Coral Cover[1] 2). Species Distribution[1]	1). Human Impacts[1] 2). Endemic Species[3] 3). Economic Bioindicators[3]	A-/P, A-/C, P, S, H, D, C[3]	E, O, S, P, D, R, PO, AC, CD, MPA, AS, RA, CRH, DI, V[3]	Y[3]	- SCUBA Equipment[3] - Measuring Tape[3] - Transect Lines[1] - Quadrats[1] U/W Video Equipment[3]	$300[1] $15[3] ? ? $3500[3]	Boat[3] SCUBA[3] PM[3]	Field[3] Direct[3]	HS[1,3] CV[3]	4+/1-5[3]	1) Inexpen-sive Equip-ment[1] 2) Easy to Use/Train[1] 3) Can be Used Globally[1] 4) Public Aware-ness[3]	1) Question-able Accu-racy[1,3] 2) Repeat-ability?[1] 3) Lack of Species Info[3]	[1] C. Stepath, [2] G. Hodgson [3] N. Galvis (A/I)	?
Reef Fish Visual Assessment & REEF Roving Diver Technique	Fish[1,2,3,4,5] Spiny Lobster[5]	- Spatial Distribution of Reef Fishes?[2,3,4,5] - Temporal Variation in Reef Fishes?[2,4,5] - Effects of Refuges on Reef Fishes?[1] - Storm Effects?[5]	1). Abundance[1,2,3,4,5] 2). Diversity 3). Biomass 4). Spp. Richness[1,2,5] 5). Frequency of Occurrence[1,3]	1). Habitat & Fish Association[1,2] 2). Design & Assessment of Harvest Refugia[1,2,3] 3). Fishing Effects[1,2,3] 4). Physical Impacts[5]	AD-/P, AD-/A, S, I[3] AD-/C, S, H, I[4] AD-/A, P, H[5]	O, R, AC, MPA, AS, CH, RA[3] E, O, R, AC, MPA, RA, CRH, V[4] E, O, P, R, AC, CD, MPA, AS, RA, DI, V[5]	Y[4,5], M[5]	- SCUBA Gear[1,3,5] - U/W Stopwatch[1] - Fiberglass Measuring Tapes[2,5] - U/W Paper/ Mylar[1,2] - ID Guides[3] - Survey Forms[3] Computers & Software[5]	$1,300 $50 $50 $50 $30 Each $0.2 ?	Boat[4,5] SCUBA[3,5] PM[4]	Field[3,4,5] Stats[3,5] Lab[5] Direct[3,4,5]	HS[3] CV[3] RM[4] SR[4,5]	4/4[3] 2-4/6-10[5]	1) Simple/ Low Cost[1,2,3,4] 2) Monitor Entire Fish Assem-blage[2] 3) High Statistical Power Based on Lg Sample Sizes/ Reduces Many Forms of Bias[1,3,5] 4) Can Use Volun-teers[3]	1) Requires Knowledge of Fish ID[2,5] 2) Limited to SCUBA Depths, Good Visibility[1,2] 3) Misses Cryptic/ Nocturnal Species[2,3] 4) Need Multi Observers[1] 5) Low Precision[4]	[1] J. Bohnsack, (A/B) [2] A. Friedlander [3] C. Pattengill (A/B) [4] A. Thompson (?/V) [5] J. Beets (BA/V)	Brock, V. (1954). *J. Wildl. Mgmt.* 18:298-308.[4] Brock, R. E. (1982). *Bull. Mar. Sci.* 32(1):269-276.[2] Bohnsack & Bannerot. (1986). NOAA. NMFS Tech. Rep. 41:1-15.[1,2,5] Schmitt & Sullivan (1996). *Bull. Mar. Sci.* 59(2):404-416.[3]

2

Name of Monitoring Technique	Primary Organism Monitored	Questions Addressed by Method	Measurement Parameters	Impacts Assessed	Method Specifically Addresses: A, D (for A & D: -/P, -/A, -/C), P, S, H, I, D, C	Method Specifically Measures: E, O, S, P, D, R, P, AC, CD, MPA, AS, CH, RA, CRH, DI, V	Monitoring Frequency	Specific Equipment Required	Cost	Specific Require-ments	Statistics & Taxonomy: Field, Stats, Lab, Direct	Personnel: CV, HS, RM, SR	Training #/#	Major Advan-tages	Major Disadvan-tages	Contributor (Classification/ Primary Interest)	Ref-erence for Method
Sedimentation Monitoring	Sediments	- Change in Depth of Sediments Over Time? - Change in Composition/ Source of Sediments?	1) Sediment Depth 2) Sediment Source 3) Size Distribution	1). Effects of Reforestation on Sedimentation of Kaho'olawe's Reefs			S	- Iron Rebar Rods - Sledge Hammer - Pneumatic Drill - SCUBA Gear	per 10' $6 $25 $125 $1,300	Boat SCUBA	Direct	RM SR	2/2	1) Simple & Cheap 2) Minimizes Exposure to Unexplo-ded Ordnance	?	M. Hodges (R/I)	?
Sea Stewards	Fish Sea Urchins	- Effects of "No-Take" Zones on Density of Target Organisms?	1). Sea Urchin Density & Sz 2). Damselfish Density	1). Overfishing 2). Effectiveness of MPAs	A-/C, P, S, I	D, PO, AS, R, AC, MPA, CH	S	- Quadrat - U/W Compass -U/W Measuring Tape	$10 $40 $50	Boat SCUBA	Field Stats Direct	HS CV	2/8	1) Inexpen-sive 2) Simple & Reproducible Among Observers	1) Problems with Volunteer Partic./Motiv. 2) Target Spp. Must Be Easy to ID & Count	B. Keller (A/I)	None
Stationary Sampling Technique	Fish	- Habitat-Fish Associations?[1] - Long-term Variability?[1]	1). Fish # & Spp.[1] 2). Species Richness[1]	1). Habitat Change[1] 2). Coastal Developm.[1]	AD-/P, AD-/A, P, S, C[1] AD-/A, P, S, H, I, C[2]	E, MPA, CRH, V[1] E, O, P, D, R, AC, CD, MPA, AC, CH, RA, DI, V[2]	Y[2] S[1,2] M[1]	- SCUBA[1] - Boat w/ outboard[1] - Crossbar Meas. Stick[2]	$2500 $6500 ?	Boat[1] SCUBA[1,2]	Field[1,2] Stats[1,2] Direct[1,2]	RM[2] SR[1,2]	2/2days[1] 4+/16+[2]	1) Non-destructive[1] 2) Hi Stat. Power[2] 3) Repro-duceable[1]	1) Requires Trained Observers[1] 2) Needs Low Turbidity[1]	[1] A. Adams (A/V) [2] J. Bohnsack (A/B)	Bohnsack & Bannerot (1986). *NOAA Tech. Rep. NMFS* (41). 15pp.[1,2]
Tissue Monitoring	Coral	- Natural Variation. - Changes in Health of Corals?	1). AFDW 2). Prot., Carbos, Lipids 3). Zoox Density	1). Natural Variation 2). Bleaching 3). Nutrients in SW	?	R, CD, MPA, V	S	?	?	Boat	Field, Stats, Lab, Direct	SR	1/?	1) ? 2) ?	1) Permits to Collect. 2) Destructive Sampling	W. K. Fitt (B/V)	?
Towing Surveys (Manta Tows)	Coral, Algae, Fish, COTs, *Tridacna*, Urchins	- Impact of COTs?[2] - Current Status of Reefs?[1] - Long-term Decline of Reefs?[2]	1). % Coral Cover[1,2] 2). Other Benthos[1,2] 3). % COTs[2] 4). Fish Abundance[1]	1). Destructive Fishing[1] 2). Change in Coral Cover[1,2]	P, H, I, C[1] A, S, H, I[2]	E, O, R, PO, CRH[1] E, R, MPA, PO, CRH, RAV[2]	Y[1] S[2]	- Manta Tow Boards - Data Slate	$500[2] ?	Boat[1,2]	Field[2] Direct[1,2]	HS[1,2] CV[1] RM[1,2] SR[2]	3/20[1] 4+/30[2]	1) Can Cover Large Areas Quickly & Cheap-ly.[1,2]	1) Requires Trained Obser-vers[2] 2) No Species Resolu-tion[1]	[1] C. Wilkinson (A/I) [2] L. Miller (B/I)	English *et al.* (1997). Survey Manual for Tropical Marine Resources. AIMS.[1,2]
Transects: Chain Transects	Coral	- Estimate of Spatial Index of Reef - Change in Abundance of Dominant Coral Spp.	1). % Coral Cover 2). Rugosity 3). Species Diversity	1). Change in Three-Dimensional Cover	S, H, C	E, S, R, AC, CD, MPA, AS, CRH, DI, V	Y	- Measuring Tape - Light-weight Chain -SCUBA Gear	$40 $40 $1,300	SCUBA	Stats Direct	RM SR	2/4	1) Relatively Inexpen-sive. 2) One of the Few Ways to Measure Rugosity.	1) Damages Reef. 2) Cannot Measure Spp. Density or Colony Size. 3) Not for Beginners		S. L. Ohlhorst *et al.* (1988). *Proc. 6th Int'l Coral Reef Symp.* 2: 319-324.
Transects: Line or Point Intercept Transects	Coral, Fish & Algae[5,11] Coral[2,8,10], Fish[3,9] Mobile Invertebrates[5] Sponges[6] Substrate[5] COTs[8]	- Reef Recruitment & Mortality.[2,7] - Dynamics of Community Change.[2,5,6,7,9,11] - Reef Zonation.[4] - E.I.A.[5] - Baseline Surveys.[5,7] - Effects of MPAs[12] - Effects of Man-made vs Natural Disturbances.[6,7]	1). % Coral Cover[1,2,3,4,5,6,7,8,9,10,11,13] 2). Spp. Diversity[1,2,3,5,6,7,11] 3). Colony Size[2,7] 4). Partial Mortality[6,10] 5). % Benthic Cover[9] 6). Fish #[5] 7). Sediment #[5]	1). Pollutants[1,6,7,13] 2). Coral Diseases[1] 3). Dredging[3,7] 4). Overfishing[2,3,9,12] 5). Natural Disturbances[6,9,13] 6). Nutrient Enrich.[6,12] 7). Sewage[7] 8).Sedimentation[2,5,7,10,12] 9). Bleaching[11] 10). Diver Impact[5,8,10]	AD-/A, P, S[2] AD-/A, S, H, I, C[5] P, H, I, C[8] AD-/A, P, S, H, C[10] A,D, P, S, H, I, C[12] A,D, S, H, I[13]	E, D, R, PO, MPA, CH, RA, V[2] E, O, S, R, AC, CD, MPA, AS, CH, RA, V[5] E, O, R, PO, CRH[8] E, O, S, P, D, R, PO, CD, MPA, RA, CRH, DI, V[10] E, O, S, F, R, PO, CD, MPA, AS, CRH, DI, V[12] E, O, P, S, D, R, PO, CD, MPA, CH, V[13]	2+[2] Y[8,10,12,13] M[5]	- 1 m Quadrat[5,8] - Measuring Tape[2,4,6,7,9,10,11] - U/W Paper[2,5] - SCUBA Gear[2,3,5] - Rebar[3,5] - GPS (Garmin)[10] - Permanent markers[13] - Plumb-line[2] - Chain (rugosity)[5] - Transect Line[5] - Sediment Traps[5] - Rock Hammer[2]	$40 $2 - $60 Each $0.5 $1,300 Per 10' $6 $300 ? $10 $55 $60 Each $9 ?	Boat[9,10,12,13] SCUBA[2,5,8,10,11,13] PM[5,9,13]	Field[2,5,10,11,12,13] Stats[10,11,12,13] Lab[11] Direct[2,5,9,10,11,12,13]	HS[2,5,8,11,13] CV[8] RM[2,5,9,10,11,12,13] SR[2,10,11,12]	1/3wks-1month[11] 1/5[10] 2/1[2,9] 2/8[13] 3/10[5]	1) Simple/ Inexpensive[1,3,4,5,6,8,9,10,12,13] 2) Replica-bility.[1] 3) Large Sample Sizes Possible.[2,7] 4) Can Use Volunteers.[6,8,9,13] 5) Detailed ID Knowledge Not Required.[8] 6) Empha-sizes colony size-distribu-tion.[7]	1) Possible Large Variance.[2,5,10] 2) Site Relocation Sometimes Difficult.[3,8] 3) Time-Consu-ming.[3,11,13] 4) Training Time/ID Knowledge.[4,5,7,8,10,11,12] 5) Provides Only Biological Data.[2,6]	[1] S. Al-Moghrabi, [2] C. Birkeland(B, A/V) [3] S. Kolinski, [4] D. Krupp, [5] D. Brown (AB/V) [6] Y. Loya, [7] J. Maragos, [8] S. Russell, [9] C. Wilkinson (A/I) [10] D. Obura (B/I) [11] W. R. Allison(A/V) [12] T.McClanahan(A/I) [13] M. Chiappone (A/I)	Birkeland, C. & Lucas, J. S. (1990). Pp. 50-56.[2] Chiappone *et al.*(1996). *Carib. J. Sci.*[13] Jokiel, P. L. & Tyler, W. (1992). *Proc. 7th Coral Reef Symp.* 2:683-692.[3] Loya, Y. (1978). Coral Reefs: Research Methods. UNESCO 5:197-218[6] Maragos, J. E. & Cook (1995). *Coral Reefs* 14:237-252.[7] Reed, S. A (1980). UNIHI-SEAGRANT-CR-80-01.[5,8]

Name of Monitoring Technique	Primary Organism Monitored	Questions Addressed by Method	Measurement Parameters	Impacts Assessed	Method Specifically Addresses: A, D (for A & D: -/P, -/A, -/C), P, S, H, I, D, C	Method Specifically Measures: E, O, S, P, D, R, P, AC, CD, MPA, AS, CH, RA, CRH, DI, V	Monitoring Frequency	Specific Equipment Required	Cost	Specific Require-ments	Statistics & Taxonomy: Field, Stats, Lab, Direct	Personnel: CV, HS, RM, SR	Training # / #	Major Advan-tages	Major Disadvan-tages	Contribut or (Classific ation/ Primary Interest)	Ref-erence for Method
Transects: Photo Quadrats	Coral, Algae Fish[4]	- Dynamics of Community Change.[1,2,3,4,5] - Baseline Surveys.[1,2,3] - Harvest Refugia.[2]	1). % Coral Cover[1,3,4,5,6] 2). Spp. Diversity[1,2,3,4] 3). Spp. Richness[1]	1). Pollution[1,3] 2). Sedimentation[1,6] 3). Fishing[2] 4). Alien Spp[1] 5). Natural Change[4,5]	AD-/P, AD-/C, P, S, H, I, C[1,4] A-/A, P, S, C[5] AD-/P, AD-/C, AD-/A, S, H, I, C[6]	E, S, D, R, PO, CD, AS, RA, DI, V[1] D, R, CH, RA, V[4] E, P, D, R, CD, RA, V[5] E, S, D, R, PO, CD, MPA, AS, RA, CRH, DI, V[6]	2+[1,6] Y[1,5] S[4] M[4]	- Nikonos RS w/ 12mm Lens 7 Strobe[1] - Nikonos 5 w 15mm Lens & Strobe[1,4,5] - U/W Survey Tapes[1] -U/W Metal Detector[5]	$8,500[1] $3,000[1,4] $150[1] $600[5]	Boat[1,5,6] SCUBA[1,4,5,6] PM[1,5,6]	Field[1,6] Stats[1,4,6] Lab[4,5] Direct[1,4,5,6]	HS[1] CV[1] RM[1,6] SR[1,4,5,6]	2/1[1,4] 1/2[5] 2/40[6]	1) Collects Large # Data Per Unit Time.[1] 2) Archiv-ability[4] 3) Simple, Inexpen-sive[5,6] 4) Allows Expert Review Later.[1,5]	1) Picture Resolution may Limit ID.[1,2,4] 2) Poor in Shallow Water.[3] 3) Need To Do A Lot To Limit Sample Variation[6] 4) Time for Data Analysis/ Interpreta-tion[1]	[1] J. Maragos (R/I) [2] S. Peck [3] F. Te [4] C. Hunter (B/V) [5] P. Edmunds (B/V) [6] R. S. Nemeth (A/I)	Edmunds, P. J., Aronson, R. B., Swanson, D. W., Levitan, D. R. & Precht, W. F. (1998). *Bull. Mar. Sci.* 62:937-946.[5] Nowlis, Roberts, Smith, Siirila (1997). *Ambio* 26(8): 515-521.[6]
Transects: Video Transects	Coral, Algae, & Fish[1,4,7] Fish only[3] Benthos[7]	- Effect of Aquarium Collection.[3] - Nutrient Effects on Coral Communities.[2] - Are Human Effects Changing Reefs?[5,6]	1). % Coral Cover[1,2,3,4,5,6,7] 2). Spp. Diversity[1,7] 3). Spp. Density[1,5] 4).% Algal Cover[4,6] 5). Age Classes[3]	1). Pollution[1] 2). Sedimentation[1] 3). Aquarium Collection[3] 4). Bleaching/Disease[4,5] 5). Vessel Groundings[5] 6). Overfishing[1]	AD-/P, AD-/C, P, S, H, I,C[1,4] A-/C, D-/C, P, H, I, C[3] AD-/P, AD/A, P, S, H, C[5] D-/P, S, H, C[6] AD-/P, AD-/C, S, H, I, C[7]	E, O, R, AC, CD, MPA, AS, CH, RA, DI[1,3] D, R, CH, RA, V[4] E, S, P, D, PO, MPA, RA, CRH, V[5] E, R, MPA, CRH, V[6] E, S, D, R, PO, AC, CD, MPA, AS, RA, CRH, DI, V[7]	2+ Y[1,5,6,7] S[4] M[3]	- U/W Survey Tapes[1] - Permanent Markers[1] - Hi-8 Minicam Videocam w/ U/W Housing[5] or - Digital Videocamera[4] & - U/W Housing[4] - PC w/ Radius Digital Video Card w/ Fireware[7]	$150[1] $100[1] $6,000[5] $3000[4] $2500[4] $4400[7]	Boat[1,3,5,6,7] Lab[3,5] SCUBA[1,3,4,5,6,7] PM[1,3,5,6]	Field[1,3,5,6] Stats[1,3,4,5,6] Lab[3,4,5,6] Direct[1,4,5,6]	HS[1] CV[1,3] RM[1,3,5,7] SR[1,3,4,5,6,7]	1/48[6] 2/1[1,4] 2/20[7] 4+/weeks[3] 4+/20[5]	1) Collects Large # Data Per Unit Time.[1,5,6] 2) Allows Exper Review Later.[1] 3) Archiv-ability[4] 4) Relatively Unbiased[3,5]	1) Picture Resolution may Limit ID.[1,2,4,6] 2) Poor in Shallow Water.[2] 3) Under-estimates Rare/Cryp-tic spp.[3] 4) Time for Data Analysis/Inter pretation[1] 5) Expen-sive[5,6,7]	[1] J. Maragos (R/I) [2] T. Shyka [3] L. Hallacher (B/I) [4] C. Hunter (B/V) [5] J. W. Porter (B/I) [6] P. Tomkins (B/V) [7] T. Murdoch (T/I)	Aronson *et al.* (1993) *Atoll Res. Bull.*[2,7] English *et al.* (1997). Survey Manual for Tropical Marine Resources. AIMS.[6] Sebens & Johnson (1991). *Hydrobiologia* 226:91-101[2]

KEY:

Addresses:
- A (species/organism abundance);
- D (species/organism diversity).
  - For A & D: -/P (presence/absence);
  - -/A (all species – requires taxonomic expertise);
  - -/C (controlled species list).
- P (population size distribution);
- S (species/organism spatial distribution);
- H (habitat condition);
- I (non-coral indicator species);
- D (diurnal/nocturnal effects);
- C (substrate composition)

Statistics & Taxonomy:
- Field (field taxonomic knowledge)
- Stats (high statistical reproducibility)
- Lab (lab/later taxonomic knowledge)
- Direct (directly detect changes over time)

Personnel:
- CV (community-based volunteers)
- HS (can use high school volunteers)
- RM (resource managers)
- SR (scientific researchers)

Training:
- # equipment-trained people required / # hours to train 2 people

Measures:
- E (disturbance events) PO (predation outbreak)
- O (overfishing) S (sedimentation)
- P (pollution) D (diseases)
- R (recovery/restitution) AS (alien species)
- DI (diver impact V (natural variability)
- AC (impact of aquarium collection)
- CD (impact of coastal development
- MPA (effectiveness of Marine Protected Areas)
- CH (all major coastal habitats)
- CRH (only coral reef habitats
- R (remote areas)

Contributor (Classification/Primary Interest)
Note: Superscript number in front of each name identifies that person's specific contribution or comments in other columns of that specific row.

Classification:
- B (research scientist – basic research)
- A (research scientist – applied research)
- R (resource manager)
- T (technician)
- L (layperson)

Primary Interest:
- I (impacts)
- B (scientific biodiversity)
- V (natural variability)

Frequency:
- 2+ (2 or more years) S (seasonally) D (daily)
- Y (yearly) M (monthly) H (hourly)

Results Can Be Used For:
- M (management) P (legislative/political bodies)
- E (educational concerns)

Specific Requirements:
- Air (aircraft) Lab (lab facilities) SCUBA (SCUBA)
- Boat (boat) PM (permanent markers)

Note: A question mark (?) will be used when no information was provided by any of the contributors for a specific technique.

Acknowledgements: This chart is based on one developed for the State of Hawai'i Department of Land & Natural Resources' Coral Reef Monitoring Workshop – A Tool for Management, which was held June 9-11, 1998 in Honolulu, Hawai'i. Additional layout assistance was provided by Ms. Carol Fretwell, NCRI.

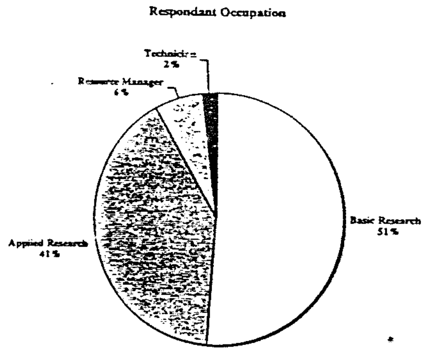
NCRI Coral Reef Monitoring Methodology Comparison Chart

Compiled by Dave Gulko, Division of Aquatic Resources, State of Hawai'i

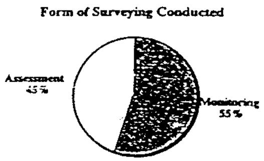
Survey Statistics

1. Number of surveys received: 42

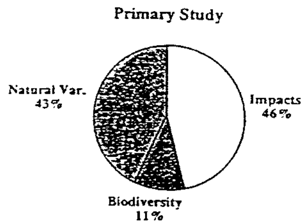
2. Respondent Occupation (49):
   a) Research Scientist (Applied Research)
   b) Research Scientist (Basic Research)
   c) Resource Manager
   d) Technician
   e) Layperson (no responses)



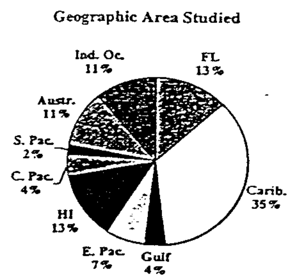
3. Form of Survey (38):



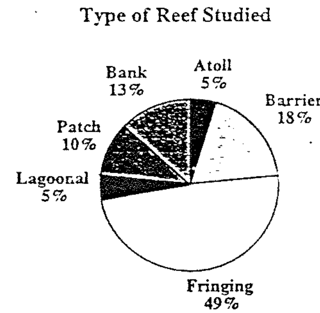
3. Respondent Primarily Assesses/Monitors (46):
   a) Impacts
   b) Biodiversity
   c) Natural Variation



4. Geographic Area Studied (46):
   a) Florida
   b) Caribbean
   c) Gulf of Mexico
   d) Eastern Pacific
   e) Hawai'i
   f) Central Pacific
   g) South Pacific
   h) Australia
   i) Indian Ocean



5. Type of Reef Studied (39):
   a) Atoll
   b) Barrier Reef
   c) Fringing Reef
   d) Lagoonal Area
   e) Patch Reef
   f) Bank/Shoal



6. The most important factors to monitor or assess that are not currently receiving attention (31):

   a) Algae (3)
   b) Diseases
   c) Diver/Snorkelor Damage
   d) Fishing Impacts (3)
   e) Genetics
   f) High Resolution Mapping
   g) Inshore Reefs
   h) Larval Recruitment (2)
   i) Long-Term Monitoring (3)
   j) Measuring Multiple Variables
   k) Mortality Rates
   l) Nutrients
   m) The Planktonic Community
   n) Rapid Assessment (2)
   o) Regional Condition
   p) Seasonal Variation
   q) Sediment
   r) Size Classes
   s) Socio-Economic (2)
   t) Water Quality (3)

Appendix 4. Seagrass and Mangrove Monitoring Methodology Chart

Habitat assessment method	**Primary organism monitored**	**Question addressed by method**	**Measurement parameters**	**Impact assessed**	**Method specifically address**	**Method specifically measured**	**Monitoring frequency**	**Specific equipment required**
1) Method for mapping seagrass distribution using remote assessment	Seagrass, other habitat eg. Coral reef & mangrove		% seagrass cover Extent of seagrass meadows, Water color SST	Seagrasses health & recovery, Disturbance, Sediment cycle	P, S, H, C	E, R, MPA, CH, R, S, V		Computers, Software's, GPS
2) Method for assessing seagrass seed ecology and population genetics	Seagrass,		Annual seed production, recruitment & survival of genets, Proportion of seed samples, germination, Population genetics	Genetics characterization of seagrass production, evolutionary relationship among seagrass	A, P, S, H	E, R, P, AS, V		SCUBA equipment, shovel sieves, transect quadrat, sorting tray, dissecting microscope, seed raising mix
3) Method for the measurement of seagrass abundance and depth distribution eg. Stratified & random	Seagrass, algal and invertebrates communities		%Seagrass leaf cover, Shoot, density, canopy height and biomass, depth pattern	Disturbances, role of seagrass in ecosystem, seagrass health and recovery	A, D, P, S H, C	E, R, CD, MPA, R		SCUBA equipment Ruler plastic bags, Dying oven

Habitat assessment method	Primary organism monitored	Question addressed by method	Measurement parameters	Impact assessed	Method specifically address	Method specifically measured	Monitoring frequency	Specific equipment required
4) Methods for the measurement of seagrass growth and production using leaf and rhizome marking	Seagrass		Seagrass growth, Reconstructive growth estimate, Net production, Growth pattern	Long term cycle methods, Disturbances, Population change, Status of seagrass bed, other human impact	P, S, H, C	E, P, R, CD		Boat, Scuba equipment, Quadrat, Drying oven, weighing scale
5) Measurement of Photosynthetic rates in seagrasses	Seagrass		Gas exchange, photosynthetic rate, respiration rate	Recruitment & survival, seagrass growth from extreme condition	P, S, H	E, P, R, CD, CH, R, S		BOD bottle, SCUBA equipment, Computer, Electrode set up
6) Assessing biomass, assemblage structure and productivity of algal epiphytes on seagrass	Seagrass, algal epiphytes		Assemblages and structure of epiphytes, biomass and diversity		A, P, S, H, C	E, R, CD		Quadrat, scissors,
7) Method to measure macroalgal biomass and abundance in seagrass meadows	Seagrass Macro-algae		Macroalgal biomass, species composition, abundance and distribution		A, P, S, H, C	E, R, CD		Map, tide table, boat GPS, SCUBA, equipment Quadrat, transect line

Habitat assessment method	Primary organism monitored	Question addressed by method	Measurement parameters	Impact assessed	Method specifically address	Method specifically measured	Monitoring frequency	Specific equipment required
8) Techniques for quantitative samplinng of infauna and small epifauna in seagrass	Seagrass, infauna & small epifauna		Species composition, abundance and biomass of infauna and epifauna on seagrass		A, P, S, H, C	E, P, CD		Boat, insulated ice box, sieves
9) Fish crabs, shrimps and other large mobile epibenthos: measurement methods for their biomass and abundance in seagrass	Seagrass, fish, crabs, shrimps, and large epibenthos		Species composition, abundance and biomass of fish, crabs, shrimps, and large epibenthos	Impact on fishing, physical impact, habitat and fish, crabs, shrimp association	A, P, S, H, C	O, V		Boat, GPS, beam trawl, gill net, SCUBA equipment, transect, slates
10) Measuring invertebrate grazing on seagrasses and epiphytes	Seagrass, invertebrates epiphytes		Grazing rate, Grazing preference	Impact of grazing to seagrass	P, S, H, C	E, R		Dying oven, Vials, dissecting microscope, balance
11) Methods for assessing the grazing effects of large herbivores on seagrass	Seagrass, large herbivores eg., Dogong, manatees, turtles, seaurchin, fish		Grazing rate, abundance, feeding habit	Post grazing recovery, grazing impact to seagrass	A, D	E, R		SCUBA Equipment, GPS, Buoys, Dying oven, boat

Habitat assessment method	Primary organism monitored	Question addressed by method	Measurement parameters	Impact assessed	Method specifically address	Method specifically measured	Monitoring frequency	Specific equipment required
12) Seagrass decomposition	Seagrass		Decomposition rate		H, C	E, P		Boat, sieves slates, Dying oven
13) Measurement of seagrass parameters in seagrass habitats	Seagrass		Temperature, salinity, Waves, turbulence	Physical impacts	H	E, P, CD, CH		Thermometer, tide table, refractometer, boat, computer
14) Sediments geology methods for seagrass habitat	Seagrass		Sediment type, characterization of sediments	Sedimentation	H, C	E, P, CD, CH		Stereo-microscope Corer, Hand held counter, Drying oven, Balance, Shaker, Muffle furnace, Dessicator
15) Measurement of light penetration in relation to seagrass using Secchi disc, Seagrass max depth limit, instantaneous PPFD, continuous PPFD and spectral distribution	Seagrass		Light penetration, spectral distribution, photon flux density	Seagrass maximum depth limit, sedimentation, survival, ecology and physiology of seagrass	H.	E, P, CD, CH		Secchi disc, Underwater light sensor

Habitat assessment method	Primary organism monitored	Question addressed by method	Measurement parameters	Impact assessed	Method specifically address	Method specifically measured	Monitoring frequency	Specific equipment required
16) Water quality measurement methods for seagrass habitat	Seagrass		Dissolved and particulate macro-nutrient and photosynthetic pigments	Seagrass growth, abundance, morphology and reproductive capacity of seagrass in respect to availability of the nutrient	A, D, P, S, H,	E, P, R, CD, MPA, R		Spectrometer, High density polyethylene bottle, with screw caps, test tube, flasks, syringe and filter holder
17) Measurement of Mangrove soil	Mangrove		Physical and chemical properties of mangrove soil such as pH, Redox potential, salinity and size particles	Effects of soil factors on mangrove productivity	A, D, H, C	E, P, R, CD, CH, R,		Stainless steel D-section corer, thermometer, pore water squeezer
18) Potential level of Mangrove forest primary productivity	Mangrove		Potential primary production, light absorption, leaf area index, net canopy photosynthetic production		H, S	R, CD, V		Portable light meter, Clinometer, Slates
19) Angle count cruising method	Mangrove		Stem density, basal area per hectare, diameter at breast height (DBH),size and distribution of mangrove	Disturbances, mangrove health and recovery, pattern of size, spp., zone	A, D, P, S, H,	E, R, CD, CH, V		Relescope, transect line, slates
20) Transect line plot	Mangrove		Species composition, community structure and biomass	Disturbances, mangrove health and recovery, pattern of size, spp., zone	A, D, P, S, H,	E, R, CD, CH, V		2 compass. Transect line (50-m), rope (100-m), stainless tag wire, hammer & nail, stakes

Continuation page 1

Cost	Specific requirement	Statistic & taxonomy	Personnel	Training	Major advantages	Major disadvantages	Contributors	References
1)	Landsat and Spot images, Aerial photographs, GIS data base	Field, Stats, Lab, Direct	SR		High spatial resolution, Flexible acquisition, Low technology information extraction	Costly, Scanned analog format must be enhanced, processed or rectify, distortion, need for ground truthing	L.G. Mckenzi, M.A.Finkbeiner & H. Kirkman	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
2)	Plant materials for DNA extraction	Lab	SR				G.J. Inglis & M. Waycott	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
3)	SCUBA Equipment, quadrat, transect line	Field, Stats, Lab, Direct	CV, HS, RS, SR		Method is reliable and can be done with a minimum manpower	Collection for biomass is destructive. Counting shoots can be time consuming	C.M. Duarte, H. Kirkman	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science

Cost	Specific requirement	Statistic & taxonomy	Personnel	Training	Major advantages	Major disadvantages	Contributors	References
4)		Field, Stats, Lab, Direct	CV, HS, RS, SR		Can be repetitive process		F.T. Short C.M. Duarte	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
5)		Lab	SR				S. Beer M. Bjork R. Gademann P. Ralph	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
6)		Field, Stats, Lab, Direct	CV, HS, RS, SR				G.A. Kendrick P.S. Lavery	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
7)		Field, Stats, Lab, Direct	CV, HS, RS, SR				B.J Sidik O.O. Bandeira N.A, Milchakova	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science

Cost	Specific requirement	Statistic & taxonomy	Personnel	Training	Major advantages	Major disadvantages	Contributors	References
8)		Field, Stats, Lab, Direct	CV, HS, RS, SR				A. Raz-Guzman R.E. Grizzle	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
9)	SCUBA, Equipment Beam trawl	Field, Stats, Lab, Direct	SR		FVC-rapid, non-destructive. Inexpensive with minimum manpower Trawl-collect larger epifauna, fast moving animals and demersal nekton	FVC-require knowledge on fish id, limited to SCUBA, good visibility Trawl- the gear is large and required heavy equipment, destructive	G.J. Edgar H. Mukai R. Orth	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
10)	Dissecting microscope Drying oven	Field, Stats, Lab, Direct	CV, HS, RS, SR		Field experiments provide an assessment on grazing impact in natural condition.	In field experiment requires higher number of replicates than in the laboratory experiment	V. Zupo W. Nelson M.C. Gambi	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
11)	SCUBA, Equipment boat	Field, Stats, Lab, Direct	SR				C. Supanwanid J.O Albersen H. Mukai	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science

Cost	Specific requirement	Statistic & taxonomy	Personnel	Training	Major advantages	Major disadvantages	Contributors	References
12)	SCUBA, Equipment Boat	Lab	CV, HS, RS, SR				D.I. Walker G. Pergent S. Fazi	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
13)		Field, Stats, Lab, Direct	CV, HS, RS, SR				E.W. Koch J.J. Verduin	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
14)		Field, Stats, Lab, Direct	CV, HS, RS, SR				P.A. Erftemeijer E.W. Koch	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
15)	Secchi disc, Underwater light sensor	Field, Stats, Lab, Direct	CV, HS, RS, SR				T.J.B. Carruthers B.J. Longstaff W.D. Dennison E.G. Abal K. Aioi	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science

Cost	Specific requirement	Statistic & taxonomy	Personnel	Training	Major advantages	Major disadvantages	Contributors	Referenses
16.	Chemical-reagents	Field, Stats, Lab, Direct	CV, HS, RS, SR				S. Granger H. lizumi	Global Seagrass Methods F.T. Short and R.G. Coles (eds) 2001 Elsevier Science
17.	Stainless steel D-section corer,	Field, Stats, Lab, Direct	CV, HS, RS, SR		Method is simple, inexpensive, quick, repetitive and equipment easy to maintain	Soil fractionation long and tedious task, sedimentation process can be time consuming	S. English, C Wilkinson and V. Baker (eds) (1997)	Survey manual for Tropical Marine Resources ASEAN-Australia Marine Science Project: Living Coastal Resources
18)	Portable light meter, Clinometer, Slates	Field, Stats, Lab, Direct	CV, HS, RS, SR		Method is quick and economical	Potential net productivity by this method and the actual productivity has yet to be elucidated. Method does not estimate primary productivity	S. English, C Wilkinson and V. Baker (eds) (1997)	Survey manual for Tropical Marine Resources ASEAN-Australia Marine Science Project: Living Coastal Resources
19)	Relescope, transect line, slates	Field, Stats, Lab, Direct	CV, HS, RS, SR		Easy and relatively fast, equipment is simple to use and cheap	Size of sampled plot is undefined, cannot be used for temporal measurement of change	S. English, C Wilkinson and V. Baker (eds) (1997)	Survey manual for Tropical Marine Resources ASEAN-Australia Marine Science Project: Living Coastal Resources
20	2 compass. Transect line (50-m), rope (100-m), stainless tag wire, hammer & nail, stakes	Field, Stats, Lab, Direct	CV, HS, RS, SR		Uses simple equipment's and gives accurate results, permanent site allow measurement through time	Very time consuming	S. English, C Wilkinson and V. Baker (eds) (1997)	Survey manual for Tropical Marine Resources ASEAN-Australia Marine Science Project: Living Coastal Resources

Legend:

Addresses:	**Measures**
A (species/organism abundance) D (species/organism diversity) P (population size distribution) S (species/organism) H (Habitat condition) C (Substrate composition)	E (disturbance events) O (overfishing) P (pollution) R (recovery) CD (coastal development) MPA (effective marine protected areas) CH (all major coastal habitat) R (remote areas) S sedimentation) V (natural variability)
Statistics Field (Field taxonomic knowledge) Stats (high statistical reproducibility) Lab (lab/later taxonomic Knowledge) Direct (directly detect changes over time)	**Personnel** CV (community-based volunteers) HS (can use high school volunteers) RM (resource managers) SR (Scientific researchers)